OPERATIVE DENTAL SURGERY

Second Edition

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and
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Operative Dental Surgery

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SECOND EDITION

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This book is dedicated to the Dental School of University College, London, and to the memory of Alan Shefford, O.B.E.

Those of us who remember him best will never forget his stock phrases of which the following are examples:

'... The foundations of surgery are based on anatomy, physiology and pathology.'

'... Always look for the sparrows, not the Golden Crested Eagle.'

'... The most important instrument in the conservation kit is the sharpening stone.'

Contents

Preface to the First Edition

The authors of this text have nearly thirty years of academic and general practice experience to guide them, and with this in mind it was thought that they could contribute a work of value to practitioners for reference, and for students, to supplement both lectures and practical studies. In order to achieve this goal much has been treated in note form, and particular sections such as materials, bridgework and precision attachments require reference to specialist texts. On the other hand more space has been devoted to techniques of restorative treatment, and to endodontia, in order to highlight some of the changes brought about through the introduction of new materials and instruments, and to emphasise the importance of looking repeatedly and objectively at our work in the light of the latest research.

As a departure from the conventional layout, the chapter on cavity preparation has been written to include all types of intra-coronal work, thus enabling students to make ready comparisons between the variations in procedure for each class of cavity.

Restorative procedures are then followed separately under appropriate headings in relation to the materials considered. Many erstwhile popular materials, such as cohesive gold, copper amalgam and inlay porcelain, have been omitted or only briefly mentioned, partly because there are already many sources available, and partly because of their dwindling popularity within the United Kingdom.

The bulk of the procedures described are taught at University College Hospital Dental School, but allowance has been made for the natural differences of opinion which inevitably arise, but such differences are on the whole slight and do not invalidate the basic principles underlying the work.

A few of the techniques mentioned are original, but the majority are not, and the authors wish to acknowledge their indebtedness to their teachers and colleagues from whom the subject matter contained in this book has been gleaned, though it would probably be right to acknowledge that we owe an even greater debt to those members of the public who have so trustingly looked to us for help over the years.

We also wish to acknowledge the generous assistance provided by the following: Miss Frances Ross, for typing the manuscript; Mr C. R. Day, for the photographic reproductions; Mr J. M. Perkins, for the illustrations; and Mr R. Sherman and the staff of his laboratory for the production of models to be used in making the photographic illustrations.

We wish also to thank the editors of the *British Dental Journal, The Dental Practitioner* and the *Journal of the British Endodontic Society* for permission to reproduce photographs and drawings, used previously in these journals, and also the Amalgamated Dental Company, Engelhard Industries Ltd, Dental & Surgical Supplies and L. Porro Ltd for their invaluable help in supplying photographs and line drawings of their apparatus and instruments. Also the 3M Company for their permission to reproduce the tables of comparative physical properties, in the chapter on Composite Restorative Materials, and Mr J. W. McLean for the drawing and photographs of his alumina tube post crown technique.

In particular we owe our grateful thanks to Professor Prophet for his generous help in placing the facilities of the School at our disposal during the writing of this book.

London, 1972

J. J. M.
G. E. R.

Preface to the Second Edition

Since 1972 when the first edition of this book was published, there have been immense strides in the technology and science of operative dental surgery. These developments and the great volume of research behind them have rendered obsolete much previously accepted dogma.

Thus the weeding out of some of the obsolescent techniques and their replacement has engendered considerable soul searching and I apologise to all who feel that their own invaluable contributions to dentistry have been overlooked or dealt with in a superficial manner.

Two problems that had to be faced were that the original publishers, due to circumstances beyond their control, were unable to publish a new edition along the lines of the first, and that George Ray, for personal reasons, felt unable to co-operate fully in the new venture.

Happily, the Macmillan Press, with the agreement of Kimptons, decided to publish a second edition, and George Ray kindly offered to rewrite completely his chapter on the occlusion.

As a result the remainder of the book has been revised by me and I accept full responsibility for any omissions or errors. That is not to say that I have altered everything. The format remains virtually as before, having been favourably received by many students and practitioners who have expressed their views to me.

George Ray has rewritten Chapter 2, on the occlusion, bringing to this difficult subject a breath of commonsense, which should help students of all ages to comprehend the fundamentals of what has become over-complicated through an excess of misplaced zeal and theorisation. It was Leonardo da Vinci who advocated simplicity as the basic tenet of scientific investigation and mechanical development. It is still true today in many spheres of activity, not the least of which is dentistry.

In Chapter 3, the section on pulp capping has been enlarged, while the chapter dealing with physical considerations has been removed, although certain highly relevant aspects have been included in the chapter on restoration form. A new section on the physical considerations of castings and investments is now included at the end of the chapter on impression techniques.

Four-handed dentistry, now an accepted and widely practised procedure, is dealt with in Chapter 7.

Calcium hydroxide cements, liners and high copper alloys are covered and, thanks to the Editor of the *British Dental Journal*, the excellent guidelines for handling mercury, prepared by Professor G. S. Nixon and Dr Christine Helsby, have been reproduced.

Composite resins and the acid etching technique have been brought up to date, but many of the older techniques have been eliminated or modified, whilst the glass ionomer cements, which are of fairly recent origin, are described.

The section on porcelain contains reference to the bonded alumina crown, and pin-retention for plastic materials has been dealt with more critically than in the first edition. The latest types of pin have been described and illustrated.

Impression materials, such as the putty and wash silicones, the polyethers and the new addition-curing silicones are covered and there is a summary of factors which influence the success or failure of impression procedures. Methods for detecting the reasons why a cast restoration fails to seat are described.

The chapter on advanced restorative dentistry has been enlarged by the addition of 'Diagnosis and Treatment Planning', and operative procedures are described in greater detail. Some attention has been devoted to the problems of fractured facings and the removal of crowns and bridges.

There is a section, in the chapter on the three-quarter crown, dealing with alternative types and modifications, in which the techniques for preparation are described.

The pin-ledge preparation is unjustly neglected and frequently ill-prepared. However, space has been devoted to the indications for its use and the method for its preparation and impression-taking.

The chapter on post crown preparation has been augmented by adding the technique for constructing a cobalt–chromium wrought post and building a core pattern in acrylic resin burn-out material in the mouth.

Finally, the greatest increase in factual content has gone into the chapter on Endodontics, related especially to the use of calcium hydroxide as a canal medicament, the treatment of the 'Endo-Perio' lesions and the author's own solutions to a number of endodontic problems.

Throughout the book, numerous research papers have been quoted and there has been a great increase in the number of references. This relates to the greater awareness among teachers that the student or dental surgeon must spend a good part of his time finding out the latest developments in thought, materials and techniques by reading current literature.

There have also been changes in many of the photographs and illustrations, and helpful criticisms of the first edition have been of inestimable value in preparing the manuscript.

I would like to express my thanks to Charles Day for his help with the photography; to Marcus Woods for a few of the illustrations; to Suzanne Messing for typing the manuscript; and to my wife for putting up with the long anti-social evenings while I struggled with what turned out to be a more difficult task than the first edition.

London, 1982

J. J. M.
G. E. R.

1

History Taking, Examination and Diagnosis

History Taking

History taking should be systematic, confined to relevant findings, and should always include negative general medical findings. During the history taking the surgeon should note any general signs such as, cyaesis, race, manner (confident or not), colour (pallor, plethora, etc.), clinical age, appearance (state of health), tremors, spasms, herpes, rhinophyma, finger clubbing, scarring, etc., and exophthalmos or proptosis.

Personal history

The personal history should include the patient's surname, christian names (in full), marital status, address, telephone number, date of birth and occupation. Some patients object to direct enquiries relative to their age, and a tactful enquiry as to the approximate year of birth usually elicits an exact response. The nature of occupation serves three objects; it may reveal the resources of the individual, or draw attention to certain occupational hazards, and it will often provide a source of communication which will permit the operator to distract the patient's attention from treatment.

In many cases a note of the patient's general medical practitioner is also helpful, though any communication with him should only be conducted with the patient's consent.

Reason for attendance

The reason for attendance should always be noted in writing, and the patient's complaint (if any) set in inverted commas, in the patient's own words where possible. Surgeons should refrain from asking leading questions, thus 'does anything bring on the pain?' not 'is the pain caused by eating or drinking hot food?'

Complaints should be listed in order of importance, e.g. pain, swelling, headache, etc. Common complaints are; numbness, swelling, trismus, halitosis, aesthetics, clicking joints, or bleeding gums.

History of present complaint

The history of the present complaint should indicate its nature, site, duration, frequency, initiating factors, relieving factors, and any associated phenomena. The patient should be asked to indicate any details on his person (pointing sign).

Social history

Enquiries may be necessary with regard to tobacco and drinking habits, anxiety, oral hygiene and home nursing facilities. The patient's attitude to treatment, and the possible economic effects of any treatment should be estimated, and his reliability as a witness assessed.

With regard to the matter of oral hygiene, only very superficial information can be gleaned by verbal examination, and it is often necessary to ask the patient to bring his toothbrush with him on his next visit. A convenient short-hand notation for this purpose is TB^2 (to bring toothbrush). Patients are often inclined to treat this as a bad joke, and to emphasise the point a note should be made on the appointment card.

While, for his own protection, the surgeon should try to estimate the patient's solvency, it is a bad mistake to attempt to decide for the patient what he can or cannot afford. Most patients can afford expensive courses of treatment if they desire them sufficiently, and the surgeon's liability in this respect is confined to indicating what can and cannot be done, its desirability, and cost.

General medical history

The patient should be asked whether he is currently receiving any medical attention, whether he has been hospitalised and why? Any serious illness remembered by the patient should be noted, and specific enquiries should be made on the subject of drugs (hypotensive drugs, tranquillisers, steroids, etc.), rheumatic fever, scarlet fever, or any heart or lung trouble. He should be asked if he is subject to post-extraction haemorrhage, or whether he suffers from any fits (chorea), allergies, epistaxis or alimentary disease.

Family history

If a history of bleeding, allergy, diabetes, congenital or hereditary defects has been forthcoming (e.g. supernumary teeth), details of the patient's family history may reveal valuable information.

Examination

Once the history has been recorded the examination will follow. General observations should be followed up and, where necessary, the temperature, pulse, and respiration rate recorded. Any irregularity of rate or rhythm of the pulse should be noted, bearing in the possibility of one or more of the following conditions:

auricular fibrillation,
rheumatic mitral disease,
high blood pressure,
thyrotoxicosis,
myxoedema.

The examination should be systematic and should always include comparative observations of both sides. Extra- and intra-oral examinations are conducted by inspection, PALPATION (direct and bi-manual), percussion or auscultation and if necessary may have to be extended by other special methods.

Extra-oral examination

The eyes should be examined for exophthalmos or proptosis, and the pupils for size, irregularity and light reaction. The absence of the corneal reflex is indicative of a fifth nerve lesion. When eliciting the corneal reflex the cotton-wool wisp should be kept out of sight until it touches the cornea. The size of pupil may indicate drug addiction and a washed out iris may be indicative of Adie's syndrome. Pallor of the conjunctivae may also indicate anaemia.

The face should be examined for abnormal markings, expression, asymmetry and pathology (e.g. herpes, lupus erythematosus, etc.). The lips should be examined for competence, indentations, cracks, swellings, ulcers, and changes in colour, and the size of the lips and mouth noted. The amount of plaque and the area of its distribution should be ascertained. If there is a heavy deposit, the patient should watch in a mirror while the operator scrapes it from the teeth with a straight probe. A more dramatic indication of its presence is obtained by staining it with a plaque disclosing solution, such as erythrosin, which the patient flushes around the teeth for one minute. Following this disclosure, instruction in oral hygiene may be given.

The neck should be inspected for mid-line or lateral swellings, scars or any inflammatory lesions. The sublingual, submaxillary and cervical lymph glands should be palpated bilaterally with the patient's head relaxed and slightly proclined.

In those cases where the patient complains of trismus or clicking joints, auscultation of the joints may be helpful in determining the cause of trouble. An early click during opening from closure to the rest position may be indicative of overclosure and excessive distal displacement of the disc, while a late click, i.e. one occurring beyond the rest position, is indicative of protrusion of the disc. In cases of condylar fracture, intra-aural palpation may be useful in determining the position of the head of the condyle. (See chapter 2.)

Intra-oral examination

An intra-oral examination should begin with observations of opening movements of the mouth for extent or deviation. The extent of opening is usually described in terms of the width of the patient's fingers, e.g. two, three or four finger opening.

The condition of the vestibule and the floor of the mouth should be noted and the openings of the salivary ducts examined for enlargement, redness and discharge. The ventral, lateral and dorsal aspects of the tongue should be examined and the presence or absence of the papillae noted. Lateral fissures are usually congenital in origin, whereas longitudinal fissures are usually pathological in origin and, when present, should be examined for ulceration or induration at the base of the fissure.

The pharynx and tonsils should be examined for congestion or ulceration, and the size of the tonsils noted, bearing in mind the age of the patient. The hard and soft palates and sulci should be examined for swellings, ulcers, sinuses and perforations. Perforations of the palate may be due to specific disease and their discovery should be routinely followed by an examination of the pupils for the Argyll-Robertson sign of tabes. Mucosal changes may be observed in association with leukoplakia or tobacco irritation.

The gingivae should be examined for the health line and stippling. The colour, size, and appearance of the interdental papillae should be noted and any local cause of cratering, ulceration or food stagnation sought. The gingival crevices should be explored for pocketing with a periodontal marker. Periodontal markers are marked in 2 mm divisions, and should be used to explore all around each individual tooth, and the depth and location of any pockets recorded. Where calculus is present its location and type, i.e. supra- or sub-gingival, noted.

The presence, absence, appearance, mobility, position, sensitivity and hardness of the teeth should be noted. Absent teeth should be accounted for and any mobility classified as nil, marked or gross.

The sensitivity of the teeth to heat, cold, electrical stimulation, percussion, lateral pressure, osmosis and probing should be investigated, and the arch alignment and any tooth movement recorded.

Many of these recordings can be made on a dental chart such as the one shown in figure 1.1. Permanent teeth are referred to by number and deciduous teeth by capital letters, starting in the mid-line at the front of the mouth and continuing backwards in each quadrant. The following symbols are commonly understood in this country:

.	tooth present no treatment required.
–	tooth missing.
/	tooth to be extracted.
+	a retained root.
X	a recently extraced tooth.
o	a simple cavity.
U	a cavity extending onto another surface.
●	a simple restoration.
U	a defective restoration.
C	a crowned tooth.
A	a pontic.
→	a tooth movement.
#	a fracture.

In order to facilitate examination of the teeth, they should be cleaned with a polishing paste, after removing gross deposits of calculus, and then dried. If an excessive flow of saliva makes examination difficult, a saliva ejector and cotton rolls may be required. The area under examination should be well illuminated and inspected preferably through a lens. Sound areas will appear hard and translucent, whereas cariously defective areas will appear chalky and opaque, and will disintegrate under pressure from a fine probe.

The presence of hyperaemic gingivae, when due to local causes, may be a sign of overhanging or deficient margins of restorations; poor contact relationships; the impaction of food particles or a foreign body; or plaque stagnation in a carious cavity or around calculus.

Pits and fissures can best be examined with the aid of a sharp probe. Disintegration or stickiness on withdrawal is a sign of defective tissue, and catching at the margins between sound tooth and the restorative medium a sign of marginal imperfection.

Proximal areas should be examined for the presence or absence of shadows. The search for proximal shading in the anterior region can be easily assisted by the use of transillumination, while non-accessible areas in the posterior region can best be examined with the aid of bite-wing X-rays.

In some cases defective restorations or the presence of proximal caries can be disclosed with the aid of dental floss. By passing floss through the contact areas, the adequacy or otherwise of the contact areas can be determined, and breaches of the enamel surfaces or defects in restorations will reveal themselves by catching and fraying of the fibres.

The occlusion should be examined both in the closed and the rest position, in centric and in excursive movements. The presence of an open bite should be noted and related to the tongue position during swallowing movements. The type of occlusion, i.e. whether pre-normal, post-normal or normal, should be noted using Angle's classification.

Class I Neutrocclusion: the mesio-buccal cusp of the upper first molar lies in the buccal groove of the lower first molar.

Class II Distocclusion: the mesio-buccal cusp of the upper first molar occludes distally to the buccal groove of the lower first molar.
Division 1. When the labial segment is proclined.
Division 2. When the labial segment is retroclined.

Class III Mesiocclusion: the mesio-buccal cusp of the upper first molar occludes mesially to the buccal cal groove of the lower first molar.

The degree of overjet or overbite is noted and the occlusal surfaces of the teeth examined for mutilation or facetting. Any sign of bruxism, bite of accommodation, or cuspal interference should be sought for, and the presence of a locked occlusion or premature contact noted.

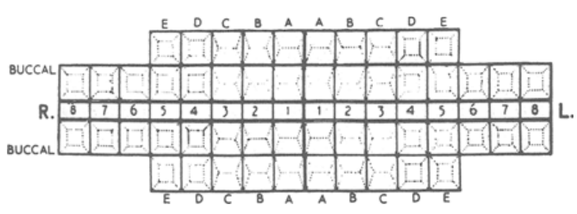

Fig. 1.1

Special examinations

Vitality testing

Normally teeth will withstand temperatures of from 20°C to 50°C without pain, but an inflamed pulp may react violently to such temperatures. A source of heat, such as a cotton pledget laden with water and heated in a flame, or a heated ball of gutta percha may be used to compare the reaction of a tooth with that of other equivalent normal teeth. The reaction to cold may be elicited by soaking a pledget of cotton-wool with ethyl chloride and blasting it with air, so that the rapid evaporation will cause icing of the pledget. The cold pledget can then be applied to the tooth and comparative reactions to cold investigated.

Electrical tests are in many cases preferable to thermal tests, because they can be more carefully graded and in many other instances provide useful supplementary evidence (figures 1.2 and 1.3). When making electrical tests, care must be taken to ensure good electrical contacts with the tooth and tissues, and ensuring that any other contacts are secure. The tooth must be dried carefully, except in the area of application of the electrode, which must not be placed near the gum or on a metal restoration terminating near the gum or in contact with a metal restoration in an adjoining tooth. The readings should be compared with other similar readings of equivalent sound teeth, and the voltage gradually raised until a response is elicited.

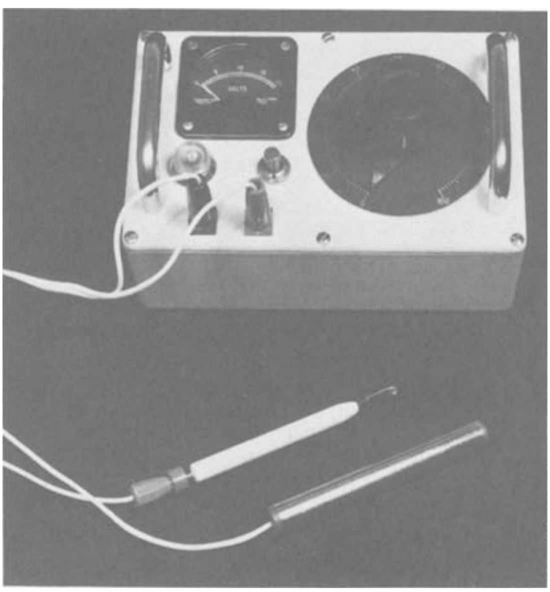

Fig. 1.2 Electronic vitality tester with hand electrode and spiral of wire into which damp cotton-wool is inserted.

Fig. 1.3 An electronic vitality tester in use. The indifferent electrode is held by the patient, whilst the active electrode loop, carrying a small moistened pledget of cotton, is applied to the dried surface of the tooth. The assistant moves the pointer around the dial slowly until the patient experiences a tingling sensation in the tooth.

The indicator lamp, which indicates that the current is flowing, glows when the current control button is depressed.

The nature of the expected response to pulp stimulation should first be explained, in order to avoid a false response from a nervous patient. It is often preferable to test a normal tooth first, in order to allay the patient's apprehension regarding a painful tooth. A lowered threshold is a fair indication of pulpal response, but a raised threshold is of less significance. It may well indicate a degenerate or moribund pulp, but may also indicate a well-insulated pulp, especially in the presence of heavy restorations. A positive response does not always indicate normality (especially in a multirooted tooth), as vital tissue may co-exist with some necrotic tissue. In doubtful cases comparative readings over two or three days may well indicate a progressive pathology.

It cannot be stressed too strongly that vitality tests give only an indication of the status of the pulp and must be interpreted in conjunction with other clinical and radiographic findings and the history of the condition.

Radiography

Radiographs are principally used in restorative dentistry for the location of interstitial caries (figure 1.4) in order to ascertain the shape and size of the pulp chamber and the anatomy of the root canals, and for the examination of the periradicular tissues.

The part to be examined should be placed in the area of most critical focus, i.e. in the central part of the X-ray beam. Excessive foreshortening or elongation should be avoided by the careful angulation of the beam at right-angles to an imaginary line bisecting the angle formed between the long axis of the tooth and the plane of the film. Difficulty may also be experienced in preventing the overlapping of proximal areas when examining the coronal tissues, and more than one X-ray may be required when teeth are malaligned. Two divergent views may also be helpful when examining multiple canals, and in differentiating between osseous foramina and periapical lesions.

The examination of a radiograph should be conducted with the aid of a hand lens, and the film should be masked so that only the area under examination is transilluminated. The area under examination should be compared with the normal, bearing age changes in mind. When a radiolucent area is divorced from but superimposed on a tooth root, it will change its relative position to the root when viewed in a second film taken at a divergent angle.

Points of special significance are the condition of the lamina dura (intact or otherwise), the thickness of the periodontal ligament, the presence of fracture lines and the integrity of the enamel or dentine.

Where teeth overlie bony cavities such as the antrum or the inferior dental canal, translucent areas appear larger, and where radiopaque areas overlie translucent areas (as in the proximal regions of the molar teeth), they appear smaller.

Canals should be examined for deposits of secondary dentine, cornual extensions, pulp stones, curvatures, hour-glass constriction, swallow-tail termination and simple openings, or a periapical delta.

Biopsy

When pathological tissue is removed, such as an ulcerous lesion, a lump, or a soft tissue mass from the bone, it is essential that its nature be verified by a competent pathologist after sectioning, staining and microscopic examination. After removal, it should be placed in a pot containing formol-saline and labelled, then dispatched with full relevant clinical details to the laboratory.

When taking specimens for pathological examination, the following points should be noted.

1. The specimen should be of reasonable size.
2. The specimen should include the edge of the lesion.
3. The proportion of abnormal tissue should be about twice as large as that of normal tissue, so that an adequate comparison can be made of one to the other.

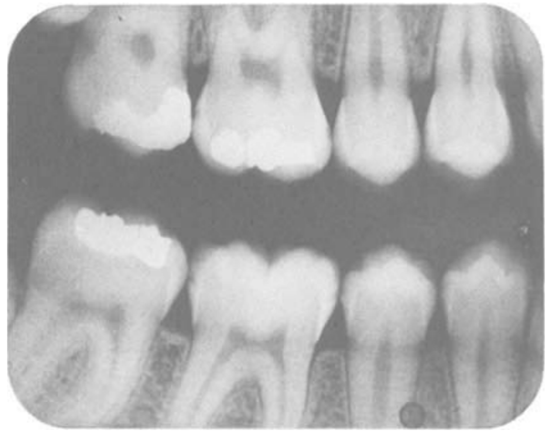

Fig. 1.4 Bitewing radiograph showing incipient enamel caries in the proximal surfaces of the first molars.

Bacteriological examination

Bacteriological samples should be made with a slightly moistened absorbent point, and should be conveyed directly to a culture bottle by the shortest route, with sterile tweezers. The mouth of the bottle should be flamed, and the cap removed for the shortest time possible, while the bottle is held at an angle so as to expose the minimum aperture to falling airborne particles.

Haematological examination

The approximate average systolic pressure in millimetres of mercury is calculated by adding the patient's age to 100, and depends upon the cardiac output (e.g. the average systolic pressure of a patient of twenty-five is about 125). The diastolic pressure varies from about 80 mm in the young adult to about 90 mm in later life when taken under resting conditions and is dependent on the peripheral resistance of the vascular system.

The blood count should be estimated in relation to normal findings, viz.:

R.B.C.	4.5–5.5 x 10 per mm^3.
W.B.C.	5000–7000 per mm^3.
Neutrophils	60–70%, 3000–4500 per mm^3.
Eosinophils	1–3%, 100–300 per mm^3.
Basophils	0–1%, 50–80 per mm^3.
Lymphocytes	20–35%, 1000–2000 per mm^3.
Monocytes	2–6%, 200–600 per mm^3.

Clotting time	1–5 minutes.
Bleeding time (Duke)	up to three minutes.
Haemoglobin	14.5–15.5 g/100 ml.

Serum-calcium	9–11 mg/100 ml.
Cholesterol	180–250 mg/100 ml.
Serum phosphorus	2.5–4.5 mg/100 ml.
Sugar	80–110 mg/100 ml.
Urea	18–30 mg/100 ml.
Serum proteins	6–8 g/100 ml.
Alkaline phosphatase	5–15 King-Armstrong units.
E.S.R. (Westergren)	0–10 ± 5 mm/hour.
Basal metabolic rate	± 15 of 100%.

Diagnosis

The art of diagnosis is the art of determining the nature and cause of disease. Therefore, by definition it presupposes that the patient exhibits some definite abnormality of health. The practice of restorative dentistry also includes the intelligent anticipation of disease, a factor which is complicated by the fact that an abnormality may result in disease in some cases and not in others. In circumstances of this kind, improvements should be effected in those cases where essential treatment can be extended to include the affected issue; in other cases there is much to be said for keeping the condition under careful observation, and following a policy of 'masterly inactivity'.

Many diseases have a background of multiple causology, and diagnosis may be confused by the existence of a dual pathology. The procedure of diagnosis consists of the systematic consideration of the various possibilities and of the gradual narrowing of the field by careful analysis of the signs and symptoms, bearing in mind that the most probable diagnosis is also likely to be the commonest. In order to do this the available data is passed through a diagnostic sieve such as that summarised below.

Diagnostic sieve

Is the condition:

- Congenital or hereditary?
- Infective, specific or non-specific, acute or chronic?
- Neoplastic, benign or malignant, primary or secondary?
- Traumatic?
- Chemical?
- Nutritional?
- Metabolic?
- Allergic?
- Idiopathic?
- Psychological?
- or one of the blood dyscrasias?

Pain

The commonest presenting symptom is pain; it may be provoked by touch, cold, heat, acid, salt, bending, jolting, exertion or lying down. When it is unprovoked it may be interrupted or episodic, may occur during the day or at night, or may be continuous. It may be described as mild or severe and, in turn, as burning, lancinating, throbbing or searing, and may be relieved by grinding, temperature change or the use of analgesics.

The differential diagnosis of pain may be extremely difficult. In restorative dentistry the commonest causes of pain are pulpal or periodontal in origin, though both may co-exist simultaneously. The classic description of pulpal pain is that of a severe, episodic, lancinating (stabbing) or sharp nature, responsive to thermal stimuli and frequently brought on or exacerbated when lying down. In contradistinction, periodontal pain is usually chronic, continuous, dull, aching or throbbing in character, and well localised, and may be relieved by clenching the teeth, in the early stages and by analgesics. As the intensity of the periodontitis increases, the affected tooth becomes hypersensitive to the minutest pressure.

Pulpal pain is commonly referred to other sites. When pulpal and periodontal symptoms occur simultaneously it is usually evidence of the extension of a severe pulpitis, but may also be caused by the slight overbuilding of a recent restoration. When solely pulpal symptoms are present, the lesion will always be found on the same side of the face as the area of pain. Where pain first appears in one site and then moves to another, it is usually the initial site that reveals the location of the lesion. In an unpublished pilot survey of twenty cases of referred pain (Ray), the lesion was found to occur immediately above or below the site of the pain in the opposing jaw in 50% of the cases investigated, and in the same jaw in the remaining 50%.

Thus if pain of a pulpal nature is complained of in an upper first premolar, the cause is likely to be found either in that tooth, the lower first premolar, or some other upper tooth.

Ulcers and swellings

The points to look for in the differential diagnosis of ulcers or swellings are the site, size, shape, consistency (fluctuant or non-fluctuant, soft, firm, hard), the edge, base, attachment (superficial or deep), any discharge, and whether sessile or pedunculated. Examinations of ulcers and swellings must be followed up by an examination for lymph node enlargement.

Spots

Spots should be described as macules, papules, pustules, vesicles or bullae. Macules are non-elevated spots of any size or colour, papules are elevated spots not containing pus, and pustiles are elevated spots containing pus. Vesicles are small round fluid-filled lesions of about 0.2 to 3 mm in diameter, which are frequently found orally in the burst condition, and bullae are similar but larger lesions.

Once a diagnosis has been arrived at, a treatment plan may be formulated in the following general sequence:

1. The relief of pain.
2. The control or elimination of any acute infective condition.
3. Preliminary periodontal therapy and instruction in oral hygiene.
4. The restoration of the teeth.
5. If periodontal surgery is to be undertaken it should follow restorative procedures except in those cases where extensive coronal restorations are envisaged when it should precede these by not less than six weeks or more than three months.
6. Surgery.
7. Prosthetics or orthodontics, bearing in mind that orthodontic treatment should take precedence if the two are both to be undertaken.

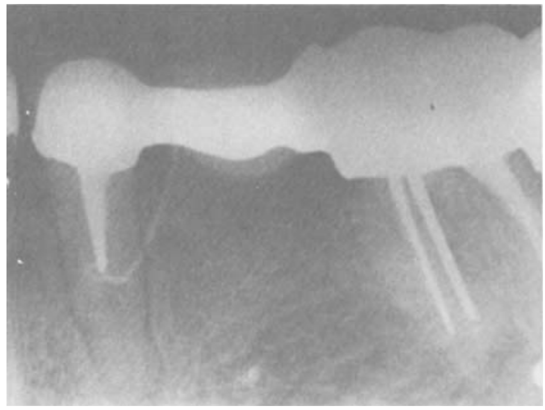

Fig. 1.5 Gutta percha cone in a sinus. The radiograph showed the lesion to be originating from the end of the post crown in the premolar, and aroused suspicion that there might be buccal or lingual perforation of the root. When a flap was reflected a vertical fracture of the root was found.

Relation of a sinus to underlying pathosis

Frequently a sinus is found without any obvious pathological origin. In the absence of symptoms, there may be a chronic infective focus either near to or distant from the point of discharge. In order to ascertain the exact position of the lesion, a fine gutta percha cone should be insinuated gently into the sinus and pressed in until resistance is encountered. A radiograph will show the relationship of the tip of the cone to the lesion (figure 1.5).

2

The Occlusion

Occlusion (from the Latin ob- against, and claudere- to shut) is defined as the act of closing or shutting the teeth. The method of closure is governed by the neuro-musculature, but the final position of the mandible, vis a vis the maxilla, is governed by the cuspal articulation of the teeth. In practice it is convenient to recognise three separate components of occlusion, namely that of posture, of reflexive closure, and articulation.

Posture

Thompson and Brodie (1942, 1946) said that all functional movements of the mandible end in the rest position, i.e. a position in which the mandible is suspended with all its relevant muscles in equilibrium. A position which should coincide with a centric position, namely one in which the condyles of the mandible are in a balanced and unstrained position within the fossae.

It was further postulated by Posselt (1962), and confirmed by many others, that, in closing from the rest position to the centric position the mandible can close about a true hinge axis.

The present view is somewhat different, because it has been found that the rest position varies with general posture, with the effect of small quantities of chemicals which may be a normal concomitant of the diet, with nervous tension, with changes within the dentition, and so on. The whole complex controlled by reflex neural activity stemming from the temporo-mandibular joint, the stretch receptors of the ligaments, and the proprioceptors of the head and neck.

In its most simple form occlusion is controlled by the reflex action of the muscles of mastication acting about the joint and its associated ligaments, in response to periodontal stimulation, or inhibition. The initiation of such movements depends on the presence or absence of tactile sensation, the act of swallowing (which, according to Kerr, Lea and Moody (1960) occurs about every two minutes) and on cognitive direction via the cortex. That the act of closure is part of a complex synergism is clear from the finding of Thiländer (1961) that local anaesthesia of the joints makes no perceptible difference to the ability of a patient to close normally.

Conjecture

Clearly any closing movement must start from the position adopted by the mandible in response to posture etc., and it is not unreasonable to think that such a position might be one of least strain, from which the patient can close his teeth with minimum effort. If the observations of Posselt and others are correct, then it is also not unreasonable to think that beyond a certain point of closure (in the absence of any specific inhibiting factor), the final stage of reaching centric occlusion (i.e. that of maximal cuspal interdigitation) is that of a conditioned reflex. Further, that between the open and closed positions reflexive closure is modified by postural reflexes which correct for variations between them.

Observation of closure in infancy, before the eruption of the deciduous dentition, shows that the mandible is postured forward so that the final position is one in which the gum pads approximate. Whereas, after eruption, the relationship of the jaws is governed by the presence of the teeth and the need to bring them safely into centric occlusion during deglutition. However, during mastication, the orientation of the mandible in preparation for initial contact is also governed by cognition, the selection of the site for contact with the food bolus and the initiating pressure depending on the quality of the selected item.

In modern man the amount of cuspal wear which is observed varies considerably depending on his choice of diet, and this has led to speculation on the role of his cusps. One school of thought maintains that the form of the teeth protects the temporomandibular articulation, and also adds to the efficiency with which he can masticate his food. Others believe that the retention of cusps in the adult dentition is an anomaly resulting from the adoption of easily digestible foodstuffs, which only require minimal masticatory effort. This view, which appears to be the more rational of the two, would suggest that there should be a progressive reduction of the cusps with aging, and that their persistence beyond a given point is likely to lead to occlusally induced traumatic effects.

Whether or not a potentially traumatogenic occlusion produces deleterious effects depends in turn on other considerations. For example, if a patient suffers from psychological disturbance, and an overall increase in neural activity, a small prematurity which he would otherwise adapt to, may provoke bruxism, i.e. the grinding or gnashing of teeth. In fact the ability of a patient to adapt to changes of articulation often conceals potentially harmful situations, and in such circumstances signs of disease, such as recession, attrition, erosion, or increased mobility may be the first indication that treatment is required. How the tissues react depends on a number of constitutional factors which remain obscure. Some patients exhibit a greater degree of tolerance than others, and some tend to react hypoplastically to conditions which in others produce a hyperplastic reaction. Certainly a clue to the importance of constitutional factors is given by the evidence that periodontal breakdown often accompanies advanced malignancy.

Ray (1980) has pointed out that even if patients can normally stage their final arc of closure about a condylar hinge axis, the practice of obtaining centric records with the teeth apart is invalidated by the finding that in four-fifths of the population the occlusal plane is obliquely inclined to the condylar axis. Moreover, while it is said that during deglutition the teeth meet in centric occlusion, i.e. in a position of maximum intercuspation, this is not always true, because in a case of malocclusion, there may be more than one position which would fit such a description. Hence it would probably be better to describe the position of adaptive occlusion as one of maximum comfort, though the two may coincide. The point is important, because not all cases of malocclusion are susceptible to treatment, and in many instances where there is a crossbite, or where the teeth are in pre- or post-occlusion a compromise has to be accepted.

The partially edentuluous state

One of the most perplexing problems which faces the dental practitioner is the direct result of the efficiency with which a patient is capable of adapting his occlusion to changed circumstances, and the persistence with which he will retain a conditioned occlusion during the process of restoration. Not only this, but the work of Watson (1977), and Ray and Greenfield (1977), has made it clear that mastication in an intact dentition, varies markedly from a partially restored condition.

Watson says that in an intact dentition there is a common pattern of behaviour in which a bolus is restricted mainly to the cheek teeth during the first twenty chewing strokes. Unilateral chewing is atypical even in patients who believe that they use only one side, but in patients with a deep overbite there is an increased use of the incisor teeth in conjunction with the cheek teeth.

With tooth loss in the posterior region there is intermittent extrusion of the bolus beyond the incisor teeth. With minor tooth loss the premolars are used more frequently, and less use is made of the defective side when chewing soft food. There is also an increased use of the incisor teeth, particularly in cases of gross tooth loss, where they demonstrated the most skilful use of their incisors in the management of the bolus.

After the restoration of minor deficiencies patients tended to revert to a more normal pattern of activity, though still tending to guard areas in which the natural teeth were missing. Following the restoration of major deficiencies more chewing strokes were observed in the premolar and incisor regions, than upon the artificial molars. Greater use was made of the entire arch than of the cheek teeth, and unilateral chewing exceeded bilateral activity.

Watt and his co-workers at Edinburgh (1958) were the first, to the author's knowledge, to comment on the decrease of pressure which accompanied the use of partial denture restorations, and this was dramatically confirmed by the electromyographic monitoring of muscle activity with and without removable precision attachment appliances reported by Ray (1977). Of particular note was the overall reduction of applied effort noted with prostheses in place, which may have been accentuated by the possible effect of leverage on essentially tooth-borne appliances.

None of the above workers commented on the effect of restorations on lateral excursive movements, though Liddelow, who conducted the initial work of cineradiography on mastication in full denture cases, stressed the absence of lateral excursive movements, and this would seem to be a feature of major reconstructions in the molar region, once the bolus reaches the posterior segment. However it is difficult to be certain, because of the change of position of the mandible which accompanies the transfer of the bolus to the working side.

Occlusal Records

It has already been pointed out that any change in the occlusion is accompanied by re-adaptation of the neuro-musculature, which will persist to an extent even after restoration. The operator is therefore faced with deciding whether the adaptation which exists will remain after completion of the work, and whether his task is simply one of constructing the proposed work in harmony with existing conditions or whether, after restoration, the patient will change his occlusion, and, if so, to what.

With the teeth present, some adaptation of the occlusion to the dentition is inevitable, and unless the patient has a malocclusion, i.e. one in which he is inhibited from biting comfortably, he will automatically use the position of most comfort whenever possible. Even assuming, as many operators claim, it were possible by the administration of a sufficiency of relaxative soothing syrup, to register the relation of the teeth in the ligamentous position (i.e. in the most retrusive position that the condyles can assume within the fossae with the teeth slightly apart), this would not help, because hinge closure from such a position will only rarely result in the teeth meeting in the patient's habitual centric relationship.

The position is complicated even further by the fact that once a registration medium is introduced into the mouth, of a sufficient hardness to arouse tactile responses, it is automatically treated as a piece of food, and the mandible and muscles respond immediately to the position and hardness of the material. Nor can this be readily overcome, because such a response is in essence involuntary and cannot be completely over-ridden by voluntary action. If in contrast a medium, such as plaster, is used, in which the tactile response is so slight that it offers virtually no resistance, then the position which the patient will adopt will automatically be the one which he normally adopts with whatever occlusion he has left.

Suppose for example the patient has lost his teeth in the lower left posterior quadrant, as far forward as the canine, then he will posture his mandible forward and to the right or working side, and inhibit his muscles on the left-hand side. If a stable base is inserted carrying a wax rim on the defective side it either will meet the upper teeth prematurely, or it will fail to make contact (if we ignore the rare possibility that it could meet in exactly the right position). In the former case the moment he makes initial contact he will re-orientate his mandible to respond to the obstruction, or try to crush it out of the way. Either way he will not register the desired occlusion, and in the latter case, he will automatically go directly to his habitual relationship. However, if one modifies the wax rim until he is just making contact simultaneously with his other teeth, he will then begin to register feed-back signals which will activate the muscles of his left side. Clearly, he cannot immediately register the best position in which he can use both his existing teeth and the artificial replacement because there has been no time for him to re-adapt his neuromusculature. In fact it is unlikely that he will be able to do so properly until he has worn the finished appliance for a little while. Partly because his feed-back signals will alter as a result of changes in shape, and differences in weight which influence his stretch receptors.

In practice one is likely to meet with one of three conditions. A defect in a relatively intact situation in which sufficient stops will remain after preparation, for one to find the occlusion by opposing the casts to one another in the same relationship as obtains in the mouth. For these, accurate full mouth impressions are essential, but whether one chooses to mount them on a simple hinge articulator, or something more elaborate, is merely a question of convenience. Sometimes, more than one space has to be restored, and in these, it may be possible to use similar methods provided one works systematically, item by item always retaining a sufficiency of natural stops with which to orientate the working models.

The second situation one may meet is one in which the existing occlusion is acceptable and can be located before treatment, but which may change during treatment as a result of the loss of essential stops during the work of preparation. A situation in which it is desirable to obtain full initial records and models before commencing the preparations, but where one must recognise the possibility that after preparing the teeth it may be impossible to match the working model to the original registrations.

Thirdly there may be so few teeth that one is forced to reconstruct the dentition to conform to border registrations because no other relevant relationship exists. In either case the work of obtaining accurate occlusal records cannot be undertaken at the time of preparation, because any local analgesic used to obliterate the discomfort of the work will also block other essential neural information.

Most single crown restorations or small span bridges will fall into the first of these categories, and only present problems if insufficient clearance is obtained during preparation to allow for subsequent adjustment, or if in an effort to reproduce exactly the previous condition, the technician over-emphasises the cuspal formation and introduces some lateral obstruction. The primary cause of the first error is to fail to examine the relationship of the prepared tooth in excursive positions. Very often with the teeth closed in habitual centric, there seems to be more than enough room, but the amount of room always looks a little larger than it is because of the optical illusion created by the reflection of the white teeth against a dark background. Again, during excursive movement with the teeth in contact, a space which may have appeared more than adequate may disappear, because the reduction in cusp height has not been matched by an adequate reduction of buccal or lingual tissue.

The second, of the three possibilities, is most frequently met in those cases where a large bounded restoration is required either anteriorly or laterally, and in these cases the work may be simplified if pre-constructed artificial stops can be prepared which do not require stabilisation on the abutment teeth, and do not impinge on the soft tissues. Obviously if the artificial aid is related to the abutments it cannot fit once they have been prepared, and equally, since soft tissues distort differently depending on the magnitude and direction of any applied force, soft tissue-related appliances cannot be transferred from a model made in one way, to another made from a different impression. Clearly the opportunities in which the use of such a jig is possible are very limited, though in anterior restorative work, if adequate posterior stops remain, a simple wax up may give useful antero-posterior information.

An alternative solution, given sufficient suitably placed abutments, is to construct two acrylic bridges from the original master model made from a post-preparative impression. Both bridges should be able to slide on and off the abutments easily without being unstable, hence it is helpful to process them on duplicate foiled models. At a second visit the existing temporaries are removed and the margins checked. One of the bridges is selected and placed over the abutments, making sure that it does not over extend on to the soft tissues, the occlusion is examined, and if necessary, amended using articulating paper, until both the natural and the artificial teeth appear to meet evenly. The bridge is then used to take a final impression, using an adhesive and a thin mix of a silicone elastomer, and when set, a final check of the occlusion is made without removing the bridge from the prepared abutments. Then, after any remaining small adjustment has been made, it is removed within an overall impression of the whole mouth, and the other temporary bridge substituted as a provisional restoration while carrying out the remaining work.

If a unilateral or bilateral free-ended extension is contemplated it cannot be overstressed that any tooth-borne fitting must be placed as near the cervix of the retainer as is compatible with constructing an access for cleaning. Not only are attachments usually placed too near the occlusion to allow for necessary adjustment in many cases, but with natural aging and the forward tilt and movement of the teeth, posteriorly placed metal work will assume an increasing obstructive position. What makes occlusal good sense coincides in this case with what is most desirable from a periodontal standpoint, but for this to be possible the retainers must be of a sufficient height, and most troubles stem from the use of teeth which are too short, particularly in the lower jaw. Regretfully in many of these cases there seems to be no satisfactory substitute at present for the use of simple wax rims to register the occlusion, and a high degree of clinical judgement is needed, though the use of solid state electronics is now reaching a point where a time might be envisaged in which electromyographic monitoring could be used to check the accuracy of occlusal registrations.

Border Registrations

Where so few teeth remain that ligamentous limits have to be established, border records should be taken for transfer to an adjustable or semi-adjustable articulator. Essentially a face-bow registration and a centric record taken at the correct vertical height. Much depends on the view taken, but in the face of the evidence described when comparing natural and artificially restored dentitions, it would seem to be irrational to spend too much time on over-elaborate procedures, and the only other recommended record is a protrusive registration with which to set the condylar angles of an adjustable articulator if one is to be used.

Figure 2.1 shows a face-bow mounting of an upper model on a Dentatus articulator, and figure 2.2 shows the Dentatus articulator with both models mounted, and figure 2.3 the way in which the face-bow and its orbital indicator would appear in use. Originally the simple face-bow shown was designed by Snow and if we accept the work of L'Estrange (1969) it should be possible to make external facial markings relative to known anatomical features which correspond to a hinge axis and then, by using the bow to transfer them to the articulator. The anatomical points usually used for this purpose lie twelve millimetres in front

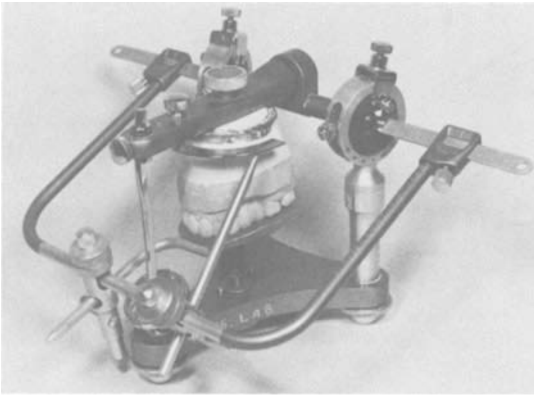

Fig 2.1 Face-bow mounting of upper model on a dentatus articulator.

Fig. 2.2 Dentatus articulator with mounted models.

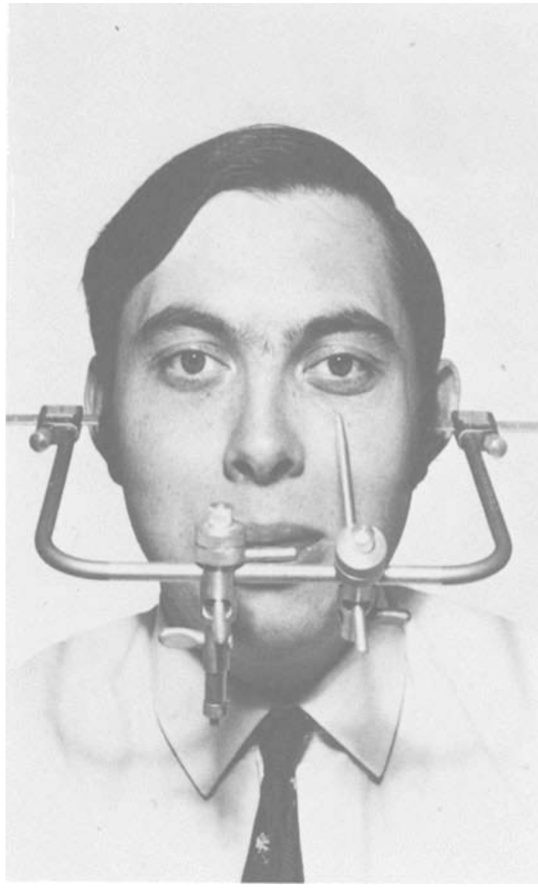

Fig. 2.3 Face-box with orbital indicator.

of the auditory meatus on a line drawn between the middle of the tragus and the external corner of the eye.

The technique is as follows:

1. Wax a bite-fork, mould it to the upper teeth and chill.
2. Arrange for the patient to hold the bite-fork firmly in position against the upper teeth.
3. Fit one of the universal joints of the bow over the bite-fork and manipulate the bow until the condylar arms lie over the axis markings, then lock the joint.
4. If desired use the other joint to position the tip of an orbital indicator over the inferior margin of the orbit.

The Intra-Oral Gothic-Arch Tracer

This consists of a light rigid plate which can be mounted either on a wax rim or processed to a small cribbed acrylic plate with a central bearing pin which can be raised or lowered by rotation about its thread. In use this pin must be positioned as nearly as possible to a central position between the retromolar pads and the proximal space between the lower incisors. A similar flat plate is also required for mounting in a like manner within the upper jaw, and both items must be transferable from the working models to the mouth and back again. A tracer of this type can be used to determine the vertical height of the occlusion, to separate the teeth slightly thus allowing controlled free movement, and to register a centric position of the mandible relative to the maxilla.

The basis on which it works depends primarily upon the fact that in lateral excursion, without protrusion, the mandible rotates about one condylar centre, while the other condyle slides forwards and downwards. If the upper part of the tracer is smoked or painted with graphite and the bearing pin is kept in contact during the movement an arc is described concentric with the arc of movement of the mandible.

A similar movement on the other side will trace another arc, and where the two intersect the bearing pin will bear its most distal position in relation to the two fossae. In order to locate this position in the mouth, a small transparent disc, through which has been punched a small hole, is stuck, so that the hole and the point of intersection coincide.

The patient is then coaxed into making small excursive movements until he can locate the bearing pin within the hole. Keeping this position the two mountings are then related to each other by the addition of some quick setting plaster, or by moulding some silicone putty between them.

A similar system using an extra-oral tracer with intra-oral plates is the basis of the pantograph, but once one introduces gadgets which project between the lips they must necessarily invoke undesirable additional neural stimuli. If the tracer is to be used to determine the vertical then the method described by Timmer is advocated.

The plates are mounted as heretofore, but the bearing pin is lowered until the patient is obviously over-closed, taking care to see that there is no interference in the tuberosity area. The screw is then gradually raised step by step until the patient reaches his most comfortable position. The method should work equally well from an open position, but it has been found that if one starts from an open position one arrives at a slightly raised vertical by comparison to the converse method, a vertical relation, which Nairn has aptly described as the *height of folly*.

Traumatic Occlusion

It is clear from the varying descriptions of traumatic occlusion that we are not dealing with a single disease entity. Traumatic occlusion implies trauma resulting from the occlusion, and for this reason some authorities prefer the expression traumatogenic occlusion, but it should be made clear that the injuries that occur are associated with the occlusal system, not necessarily with the act of occluding. The common characteristics of traumatic occlusion are:

1. That the dentition suffers traumatic injury.
2. That the injury is sustained as a result of activity within the occlusal system itself.
3. That the disease is essentially intrinsic in origin, i.e. arising either within the occlusal system, or through the occlusal system from the central nervous system.
4. That in many cases the presence of a traumatic occlusion is masked by adaptive behaviour, and only becomes apparent with the appearance of signs of injury.

The presence per se of an occlusal anomaly does not necessarily result in traumatic occlusion, though the presence of an anomaly always suggests the possibility that potential instability of the occlusion may develop.

It follows from the complexity of the problem, that it includes many varying syndromes of which the following are typical examples.

The 'cherry-stone' syndrome

The cherry-stone syndrome arises from perceptive failure, when a hard object becomes part of a bolus without recognition. Normally we suit our attack to the nature of the problem, for instance we use lighter finger grips to pick up an empty eggshell than we do to pick up an intact egg, and we change from a pen-grip to a palm-grasp according to whether we use a dental turbine, or a straight chisel. Similarly in mastication we may incise an apple, but we will usually transfer a slab of chocolate to the canine region, and we grip an apple more slowly and firmly than, for example, a spoonful of cooked vegetables.

The process is entirely involuntary, though in the case of the mouth it is possible to over-ride a situation voluntarily within limits. In this instance if in the process of occluding the teeth the progress of the dentition is suddenly arrested by a hard foreign body, we have no means of arresting the action before receiving a nasty jar, and we will suffer an unpleasant experience at the least if nothing worse. A possible variation which illustrates another aspect of the same condition occurs when we suspect that a food morsel may contain a harder object. Under these circumstances we attack the food rather more tentatively in the first instance, reverting to normal function in the absence of any indication of anything untoward, or if we encounter a more concrete particle we may test its hardness before rejecting or continuing the process of comminution.

The overbalancing contact

In this situation the teeth engage prematurely on the balancing side before the working side makes contact, and in an attempt to make maximal contact may then slide along one or other slope of the interference, or we may arrest the movement before making another tentative approach in a different manner. In either case we normally inhibit our actions until a satisfactory compromise is reached, given that this is possible. Alternatively, no satisfactory stable position can be found, or a semi-precarious relationship is established. In the former case seeking movements are likely to continue, and though the mastication will still be influenced by protective inhibition, the general level of neural activity will be raised. If this happens it often develops into bruxist activity and does not cease until the offending obstruction is removed. Whereas in the latter instance a sort of uneasy truce may be established, in which the occasional return to the position of normal first contact may result in gingival recession, or tooth mobility etc., but not necessarily to symptoms of pain.

Labial stripping

This condition is normally seen where there is imbrication of the lower incisor teeth, in which premature contact is made on part of a tooth which is locked in a prominent position. In this case both adaptive and protective neural responses may be expected, but neither can be fully effective, and in this case the protruding tooth is likely to be subject to repeated jars which eventually lead to tissue stripping.

This type of situation is the one instance in which occlusal trauma may cause periodontal breakdown. It has repeatedly been asserted that there is no evidence to show that an artificially produced prematurity will produce periodontal symptoms in experimental animals. On the other hand there is a small percentage of cases in which idiopathic spontaneous deep periodontal abscesses develop which result in residual deep intra-bony pockets. Where such a condition has been observed once, the likelihood is that it will recur, such patients are said to be suffering from a periodontosis, and the prognosis is not good. Tooth-borne restorations are apt to fail in these cases, and the initial breakdown is often associated with a restored tooth, which suggests that in a very small number of cases a traumatic occlusion coupled with constitutionally hypoplastic tissue, does result in periodontal injury.

Lateral prematurity

This condition is similar to that of labial stripping. A condition which occurs commonly following extraction and over-eruption of an opposing tooth which then becomes obstructive in excursive movement (figure 2.4). In most cases the situation may be aggravated by food-packing and the usual periodontal sequelae, but in some cases the forward drift of the teeth maintains the contact relationship and the tooth with its periodontal tissues responds. Increased mobility may not occur and buccal stripping often associated with osteo-sclerosis may then be the presenting sign of occlusal imperfection.

Fig. 2.4 Over-eruption of maxillary first molar with consequent gingival stripping and interference with the occlusion in lateral excursion. (Courtesy of Dr. Ian Waite, Department of Periodontology, Dental School of University College London.)

Thieleman's law

In some cases symptoms arise remotely from the site of the problem. For example, an over-erupted third molar, or a peri-coronitis may cause a patient to shift his initial occlusal contact to the diagonally opposite side. This is known as Thieleman's law, and is the most common cause of increased mobility, gingival recession, and hypersensitivity. A condition most commonly observed in the premolar region.

Locking

An extension of the problem of lateral or anterior prematurity occurs when a deep overbite prevents normal occlusion. A situation which occurs most commonly in Angle Class II division II type malocclusions. In such cases the upper central incisors are retroclined while the lateral incisors tend to overlap and rotate, and a deep anterior overbite is evident, which may be so severe that the tips of the upper incisors may traumatise the gingivae buccally, or the lower incisors may injure the palate. As the teeth close initial incisor contact forces the mandible into a retrusive position, often with depression of the posterior segments and sometimes with muscle strain or injury to the joints.

In these cases the neural input is accentuated and often signs of attrition indicate the extent to which a patient may attempt to free himself from the obstruction. Such cases should always be treated with care, food trapping between the upper incisors is common, and restorations are difficult. Pulpal exposure is not uncommon, and the stresses applied to post-retained restorations may result in bending or fracture of either a post, or the root, and in some cases splinting is indicated.

Vertical Prematurities

With some exceptions, notably where a tooth has been lost and the resultant forward tipping of a distal tooth causes elevation of its posterior surface, the majority of such prematurities are iatrogenic. In many cases patients are unaware of their presence, but in others they may give rise to a mild pulpitis, squeaking resulting from tooth movement and rubbing in contact areas, or a feeling of insecurity or tooth mobility.

More extensive prematurities associated with larger restorations such as bridge-work may give rise to features such as mucosal soreness, mobility, prolonged sub-acute pulpitis, and luxation or fracture of the restoration. Where there is an element of mobility, these prematurities can be most difficult to resolve, because the mobility of the teeth increases the difficulty of locating the site of initial contact.

Bruxism

Bruxism has been defined by the nomenclature committee of the *Journal of Periodontology* as the gnashing or grinding of teeth in other than functional movement. It principally occurs during sleep and the subject is either unaware or only dimly aware of the activity, which usually involves severe destructive force, and is characterised by attrition or erosion.

Erosion is thought to arise from a combination of abrasion and chemical destruction of the tooth surface, and the areas affected often occur in sites that are difficult to interpret. It is possible that they are due to tooth clenching associated with soft tissue movement caused by spasm of the facial muscles, and possibly regurgitation of the acidic stomach contents.

In most cases it is found in patients with psychic disorders or suffering from stress, and it is usually triggered by some quite small occlusal obstruction, but it can be found in other conditions. Thus it may arise in association with:

1. *Local inflammatory disturbances* such as pericoronitis, periodontitis, teething, stomatitis, etc.
2. *General medical disorders* such as tuberculosis, meningitis, ascariasis (round worms), etc.
3. *Disturbances of the central nervous system* such as displacement activity, neurosis, or psychosis (figure 2.5).

Fig. 2.5 Attrition of the lower incisors associated with bruxism.

Diagnosis

When symptoms are present, by far the most common complaint is pain, which may be facial, or dental, and sometimes of tenderness of the joint which is often associated with what patients call 'clicking'. The procedures of diagnosis are common to those dealt with in the first chapter, but should also include measures specifically concerned with occlusion.

Common conditions which must be eliminated before consideration of purely occlusal problems, include conditions of joint pathology, such as fracture, luxation, osteo-arthritis, or osteophytic deposition associated with gout; all of which may be accompanied by muscle spasm which must be interpreted as protective in an effort to guard the joint, but which may also be associated with locking, or more rarely with gross dental deficiencies. Other conditions may cause facial pain due to sinusitis, neuritis, tumour formation, inflammatory conditions such as parotitis, and dental pain which may spread from an inflamed pulp, pericoronitis, etc.

The examination should be systematic and bilateral. The joints must be examined directly by palpation for tenderness, and by palpation within the auditory meatus for irregularity of movement during opening and closing, by visual examination for mandibular deviational movement, by auscultation, and by radiography.

Auscultation is carried out with a stereo-stethoscope, the bells being placed on either side of the face about 2 cm in front of the joints to avoid confusion from sounds created by movement of the connective tissues, avoiding undue pressure, but with the edges of the bells sealed against the soft tissue. *Negative* *findings by auscultation are an almost certain feature of trouble arising without the joints.*

Muscles are examined by palpation, by strained movement, by stretch, and by the use of local analgesia. In the absence of positive findings the oral cavity and the dentition are then examined along the lines previously described.

Special Examination

The most sensitive simple examination of the occlusion is by auscultation with a stereo-stethoscope. In this case the bells are placed about 2 cm below the infraorbital borders with light pressure to ensure that the edges of the bells are sealed by the soft tissues, with the patient seated erectly in the dental chair. The examination is then conducted by listening to the sounds of snap closure and separation.

Watt (1969) described the findings as follows:

Class A patients, i.e. those who could close crisply into positions of stable contact on ten or more occasions. These sounds are crisp and rapidly damped lasting no more than 25 milliseconds, and may be divided into two groups, namely those who can close without muscle strain, and those who develop muscle strain during the activity.

Class B, classically patients with Angle Class II division I type malocclusions, who make random stable and unstable contacts depending on whether they close posteriorly or incisally.

Class C, patients who make unstable contacts of prolonged duration, 89% of which also display separation noises indicative of sliding contacts.

There is however, another group who are so inhibited that they find it difficult to make snap contacts at all. This group, and those in the third class C category, may be assumed to have some occlusal instability, given the absence of other positive findings of dental or facial abnormalities. A useful ancillary aid to auscultation is muscle palpation of the temporalis. This is based on the fact that, of all the muscles of mastication, the temporalis is the most sensitive. This muscle takes its origin on the lateral side of the skull, the most posterior fibres running forward to be inserted on the coronoid process, and its most anterior fibres running almost vertically downwards to be inserted on the anterior aspect of the ramus as far down as the retromolar pad.

If the patient is asked to close lightly into the position of maximum intercuspation and then clench his teeth, bunching of the muscle can be felt. In the presence of a prematurity, guarding of the affected region occurs and the inhibition of the affected fibres is indicated by a failure to bunch in the same manner as the corresponding fibres of the other side. Obviously it is necessary to phrase the approach to the patient so that he can understand what he is expected to do, without providing so much information that he uses his voluntary over-ride to confuse the situation. The method takes a little practice, only light pressure should be applied to the fibres under investigation, and the operator should stand behind the patient using his first three fingers of both hands on either side to equate the sensation. The method is remarkably sensitive and indicates clearly the quadrant in which the initial contact is occurring (Ray 1980).

Other methods of special examination are as follows:

1. The use of articulating paper.
2. The use of articulating wax, i.e. a soft inlay wax lacquered on one side. This is applied to the dried teeth lacquer side to tooth and moulded firmly into place. The patient is then asked to wet the wax with his tongue and then make light tapping movements. Initial contacts are shown by deep penetration through which the teeth can be marked with a chinagraph pencil.
3. The use of celluloid strips on which the patient is asked to bite firmly. The differential force then needed to withdraw the strip can be used to indicate individual teeth making premature contact.
4. Palpation during occlusion and excursion. Motion observed during such activities must be reviewed with extreme caution because all such movements are relative. Hence they must be accompanied by a careful assessment of the occlusal conformation. The point is probably best exemplified by comparing the sensation of a traveller sitting in a train about to pull away from a station alongside another train. The moment of departure may be very smooth and it is sometimes easy to imagine that one's own train is moving when in fact it is the neighbouring train which moves out first, or vice versa.

Adjustment of the occlusion

Adjustment of the occlusion should be carried out with caution. Prematurities located on restorations should be eliminated first, and should proceed until full tooth to tooth contact is readily audible. Whether this is done by reduction of a restoration or by the reduction of its opposing cusp is a matter of judgement. If too much of the restoration is taken away the surface may be breached and a new and deeper restoration may be needed, there is also the point that the retention of deep cusps is in many ways an undesirable feature in an adult dentition. On the other hand a massacre of dental tissue is equally unwarranted.

Once it has been ascertained that it is the teeth which are meeting rather than any restoration, the eradication of occlusal instability becomes more complex. In some cases, such as extreme locking, the situation has to be explained and accepted, but in others, careful examination of the general pattern will reveal obvious anomalies, and by careful analysis a considerable improvement can often be effected with minimum surgery. The most difficult cases are those in which the teeth are obviously arranged in a haphazard fashion, vertically, horizontally, or both. With most horizontal anomalies some improvement can be effected, and with an isolated over-erupted tooth, or an obvious segmental anomaly, one can also make a reasonable assessment of the best course to follow, but in other cases more damage may be inflicted by trying to correct the situation than by leaving it alone

The complexity of the problem should be clear, and though the use of articulated casts and records may assist inspection, at best one can only transfer the existing condition to the machine. There is therefore no substitute for careful clinical judgement, which is why after all, the practice of dentistry is, and for the present must remain, an *art* rather than a *science*, though the sooner the one becomes the other the better.

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3

Biological Considerations and Treatment of the Pulp

Biological Considerations

Restorative denistry may be considered as a form of bio-engineering, in which fundamental biological features must predominate, and set the limits within which operative procedures can be conducted. The art is primarily concerned with the treatment of caries or traumatic injuries to the teeth, and with the replacement and maintenance of the dentition.

The tooth is a sensitive living structure, consisting of a relatively inert cap of enamel covering a core of dentine, through which ramify prolongations of the odontoblasts, a lymph circulation and possibly nerve fibres. Any invasion of the dentine results in inflammatory changes within the pulp, which may either resolve or lead to degeneration.

Where minor damage occurs, for instance as a result of exposure of the dentine by attrition or erosion, the damaged cells undergo fatty degeneration and calcification leading to the formation of dead tracts and a translucent zone (figure 3.1). Beneath this zone the neighbouring cells and any cells which recover are stimulated into laying down secondary dentine (figure 3.2). The greater the degree of damage the more disorganised the secondary dentine deposited.

Where massive damage occurs, as for instance during tooth preparation, the reaction is considerably more violent, often exceeding the damage found beneath chronic carious lesions. This may constitute a hazard, particularly in young patients, and in those cases where the normal recession of the pulp has been slow to occur.

The violence of bacterial attack varies likewise, and if the progress of the lesion exceeds the reparative ability of the pulp, necrosis may follow. Pulp damage may also result from excessive thermal stimuli, or from the irritant action of restorative materials, and pulp changes can be shown to follow generalised systemic conditions including age changes.

Unfortunately the symptoms of pulp damage are not specifically related to tissue changes. A mild pulpitis may be symptomless, or may show varying symptoms ranging from a lowered threshold tolerance to stimuli to severe pain. This condition may resolve, lead to the formation of a chronic pulp abscess or proceed to acute suppurative degeneration of the pulp. A chronic pulp abscess may become acute, or more rarely resolve, with the formation of fibrous or calcific nodules; or may lead to degenerative changes and an apical abscess, or the entire canal may become filled with fibrous or fatty tissue

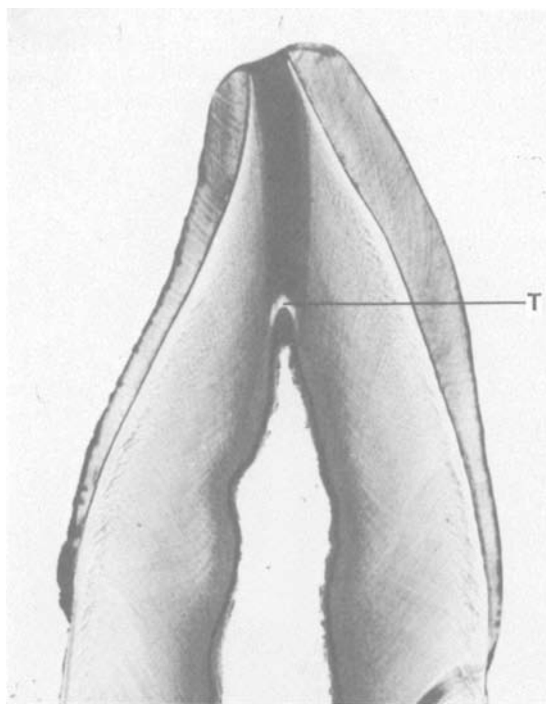

Fig. 3.1 The 'dead tracts of Fish' in the dentine resulting from attrition and showing the translucent zone (T).

Fig. 3.2 Secondary dentine in relation to carious cavities.

leading to calcification and the total obliteration of the pulp chamber and the root canal.

These changes are essentially similar to those found elsewhere in other parts of the body, viz.:

Cellular degeneration.
Circulatory changes.
An endothelial cellular reaction.
Fibrosis.
Calcification.

Similarly when abscess formation occurs (whether periapically or in the pulp) a histological section will reveal comparative tissue changes common to all abscess formation in comparable situations of the body. These are namely:

A necrotic zone.
A lymphocytic barrier.
A fibrous area if the lesion is sufficiently chronic.
Hyperaemic tissue.
An area of resorption of calcific tissue and an area of calcific deposition in more remote areas.

In very acute cases, local barriers are insufficient to contain the infection and a diffuse spreading cellulitis may occur, The extent and rate of the histological picture depending on the balance existing between the degree of injury and virulence of invading organisms, and the resistance and reparative ability of the individual. In acute conditions signs of repair are minimal and the tissues exhibit hyperaemia which, in the pulp, may lead to stasis, thrombosis and the rapid, progressive degeneration of the pulpal tissues, whereas in chronic inflammatory states the condition is well localised and reparative changes predominate.

When the entire tooth has been traumatised, the shock of the blow may be absorbed by fracture of the tooth, or the tooth may be luxated, with the resulting rupture of the delicate apical venules or by the total disruption of the apical vessels. Thus it is of paramount importance to check the vitality of neighbouring teeth when a tooth is fractured and to keep them under close observation. If only the venous vessels have suffered injury the tooth may undergo violent discolouration, but the circulation may not be totally disrupted and a secondary circulation may be established. Subsequently the tooth may suffer from internal resorption or chronic degenerative changes.

Apart from the considerations mentioned above, the restorative operator may find his work complicated by the presence of an excessively large pulp chamber, the presence of cornual extensions, which may persist into late life, and developmental anomalies, such as invagination and evagination.

Invagination consists of an infolding of the enamel organ which protrudes into the dentinal papilla. As a result, a cavity may exist within the dentine communicating directly to the exterior by a narrow passage lined in part with enamel. In such circumstances the dentine between the floor of the invaginatory pit is often poorly developed and pulp death frequently ensues. The condition may vary from a simple cingulum pit to specimens of great complexity; the radiographic evaluation and early occlusion of cingulum pit defects are therefore of paramount importance (figures 14.16 and 14.17).

Evagination is relatively rarer, and is characterised by the presence of a raised enamel nodule. The nodule contains a fine extension of the dental pulp which may interfere with the occlusion and the normal alignment of these teeth, and if fractured or rapidly worn down may lead to exposure of the pulp and subsequent pulp death.

It follows that in any operative procedure it is of vital importance to assess the condition of the tissues, their precise anatomy, and to avoid excessive injury to them either by overzealous instrumentation or by subjecting them to thermal or chemical injury.

Treatment of the Pulp

Pulpal inflammation may result from caries, as a reaction to restorative procedures, or from seepage beneath a temporary restoration. In addition, the pulp may be exposed or nearly exposed following traumatic injury, during the preparation of a cavity or during the excavation of caries. In all these cases the operator must decide whether the pulp can be preserved and whether it is desirable to do so, bearing in mind that, with certain specific objections (e.g. teeth with fused roots), an elective root treatment usually has an excellent prognosis.

When a carious cavity is opened up and all the caries and stain eliminated from the perimeter, the care with which residual caries overlying the pulp is removed will determine the likelihood of an exposure. If there was a history of severe and possibly spontaneous pain, it is probable that the caries has already involved the pulp and the presence of soft moist caries at a great depth will be a further indication. In such a case, pulpectomy will offer the greater hope of success. In the absence of symptoms, it is widely accepted that some softened dentine may be left over the pulp, in preference to exposing the pulp by its removal. Dorfman, Stephen & Muntz (1943) demonstrated the invariable presence of micro-organisms in superficial caries; the greatly diminished numbers present in the deeper layers and the virtual absence of organisms in the deepest layers. Earlier, Canby and Bernier (1936) found that the deep carious zone had a pH 5.5–4.7. This, they concluded, was probably due to the activity of Lactobacilli preventing the entry of organisms into the pulp.

Jolly & Sullivan (1960) showed that in the deep layers of caries, overlying the pulp, no organisms could be demonstrated.

Pulp capping

In the earlier decades of the century, it was customary to cover an exposed pulp with a zinc eugenolate cement, over which was placed a tiny aluminium or tin cone. This was used in order to prevent the exertion of pressure on the cement overlying the exposure, when inserting the restoration. Subsequent research has shown that the effect of zinc eugenolate cement on the exposed pulp is to maintain a chronic inflammation but not to aid healing of the pulp.

However, provided that no overt exposure of the pulp is present, zinc eugenolate cement may be used as a sedative base under the restoration. This treatment is currently referred to as *Indirect Pulp Capping* and a calcium hydroxide based cement has been shown to stimulate the formation of secondary dentine by the odontoblasts and simultaneously produce remineralisation of the intervening layer of softened dentine. Similarly, calcium hydroxide cement appears to be the best material for direct pulp capping, producing the least clinical reaction coupled with the greatest stimulation of odontoblastic activity to date. The goal to be achieved is the formation of a dentine bridge to heal the exposure and this may be visible radiographically or clinically.

The criteria for direct pulp capping are as follows. Firstly, the area of the exposure must be free from caries; secondly, the pulp should not have been traumatised, e.g. by probing; thirdly, the exposure should be uncontaminated by saliva; fourthly, the pulp must be vital, and fifthly, there should be no history of a painful pulpitis.

In the early stages of pulpitis, when the pulp is still vital, it is possible, after eliminating every vestige of caries, to dress a bleeding exposure with a corticosteroid and antibiotic preparation. This, as a result of the anti-inflammatory action of the corticosteroid (glucocorticoid) alleviates the symptoms, while the wide spectrum antibiotic destroys the bacteria.

After approximately four days, if the tooth becomes comfortable, the dressing is replaced by a calcium hydroxide cement (e.g. 'Dycal' or 'Procal') and restored with Amalgam or Composite resin. Electrical vitality tests are carried out after all such treatments for a period of one year at intervals of three months, and subsequently annually.

Schroeder (1972) considered that healing of a pulp wound under calcium hydroxide is due, firstly, to a coagulation necrosis, the alkali forming alkaline albuminates with tissue proteins. The sub-necrotic layer heals through stages of a transient inflammation. The necrotic tissue may become calcified or be partially resorbed. New connective tissue may become mineralised and organised as osteodentine and covered with tubular dentine, the pulpal fibroblasts or histiocytes being responsible for this calcific change.

Failure of these procedures indicates irreversible pulp damage and the alternatives are root treatment or extraction. In those cases of frank exposure or near exposure of the pulp following trauma, root treatment may be complicated by the incomplete formation of the root, and in these instances the technique of partial pulpectomy should be considered.

Partial pulpectomy

The technique of partial pulpectomy consists of the excision of the pulp at the neck of the pulp chamber (under aseptic conditions) with a sharp sterile excavator. The cut surface is then covered with a thick paste of calcium hydroxide and sterile water which is sealed into place with zinc oxide/eugenol cement (avoiding pressure on the injured pulp), and finally protected with a layer of amalgam.

Teeth subjected to this form of treatment should be kept under routine observation until root-filled or extracted.

Corticosteroids

The pain associated with pulpal inflammation is principally due to pressure, caused by local oedema within the restraining limits of the pulp chamber. Topical steroids, by virtue of their anti-inflammatory action, are particularly effective in suppressing these changes and when used with a broad spectrum antibiotic in a hard inert cement liner can be safely used over sound dentine. In other cases the suppression of inflammation may conceal irreversible tissue changes.

After being in use for well over a decade the indications for the use of corticosteroids are becoming clearer. The term corticosteroid is used to distinguish cortisone and its derivates from numerous steroids. The principal actions of corticosteroids are on carbohydrate metabolism, and to a lesser degree on water and mineral metabolism and androgenic function.

Associated with the glucocorticoid activity is an anti-inflammatory and anti-allergic factor which is of major interest when the drugs are used empirically.

Triamcinolone, Fluocinolone and Betamethasone, because of their topical anti-inflammatory action, are of particular interest to the dental surgeon. The action of the topical steroids appears to depend on their prolonged ischaemic action, a measure of which is used to determine the efficacy of the drug.

The quantities of these drugs used for dental treatment is too small to have any significant systemic action. They can, however, by reducing the circulatory changes which accompany acute inflammatory reactions minimise the undesirable effect of pressure within the tooth and the periodontium, and when used in conjunction with an antibiotic they obviously have considerable benefits to offer in root canal treatment.

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4

The Problem of Pain in Conservative Dentistry

The greatest deterrent to people requiring conservative dentistry is the fear of pain. An anxiety state following previous unpleasant experience or listening to the larger-than-life experiences of others, can produce a psychogenic overlay which increases apprehension and magnifies the intensity of the slightest discomfort until it becomes synonymous with pain. Simultaneously we must take into account the pain threshold, which not only varies markedly from person to person but varies in the individual from year to year and even at different times of the day, depending on their mental and physical condition; for example, it is well documented that soldiers may be severely wounded in the heat of battle and yet be unaware of pain, while some people may faint from the pain if they prick their finger.

Bearing in mind the variety of personalities encountered in dental practice it is incumbent on the dental surgeon to develop a sympathetic approach to the patient's problems, thus putting them at their ease and allaying their fears.

The problems of pain in dental surgery are twofold. Firstly, the prevention of pain and secondly, its alleviation.

Prevention of pain

The saying 'familiarity breeds contempt' may be applied also to the practice of dental surgery. The dental surgeon must always be on his guard against becoming oblivious to the sufferings of his patients. The best way of acquainting himself anew with the discomfort experienced in the chair, is to be a patient himself from time to time.

Even in small ways, unnecessary discomfort may be caused. If fingernails are too long, they may dig into the soft tissues; pens in the top pocket may be pressed into the patient's face, as may the patient's spectacles, which should be removed before starting treatment, and replaced with close-fitting protective plastic goggles if the patient is supine.

Pain may be caused by careless handling of the soft tissues. Lips and cheeks should not be pulled back sharply, because excessive tension on frena and muscle bands can be very painful.

Care should be exercised when removing a cotton-wool roll which has become adherent to the oral mucosa. If it is pulled away sharply, it may tear off a large area of mucous membrane and leave a painful ulcer. This is similar to the ulcer which may be produced on the lip, should a cigarette stick in similar manner and be pulled away. The correct method of removal is to saturate the roll with water spray, when it will be found to disengage easily.

Instruments must be maintained in perfect order because they too may be potent causes of pain. Blunt burs applied to dentine under pressure, or burs operated at high speed without adequate coolant spray, are apt to cause severe pain, and even if a local anaesthetic is used, a severe pulpitis can develop subsequently.

Hand pieces, especially contra-angled, undergo wear under normal conditions of working, which is accelerated by contamination with abrasives, such as polishing paste, and by lack of cleaning and lubrication. When this occurs, eccentricity of the bearings sets up unpleasant vibrations which, for many patients, is synonymous with pain. Similarly, the use of eccentric stones or large burs is accompanied by wellnigh unbearable noise and vibration.

When dentine is cut with rotary instruments, it is preferable that the cutting instrument be operated under a coolant spray or jet, in order to reduce or eliminate thermal damage to the pulp. This is essential at speeds higher than 6000 rpm, but when cutting without spray at lower speeds, the bur should be operated with light pressure and applied intermittently to minimise frictional heat and the discomfort engendered by heavy pressure. For the same reasons only sharp burs should be used, because there is a temptation to increase speed and pressure when a bur does not appear to be cutting.

If chisels and excavators are not sharpened, they require the application of considerable pressure to achieve a modicum of effect. Such pressure is extremely unpleasant and should there be an inadequate digital rest on the teeth, the chisel could slip. The resulting injury could involve the dental surgeon in litigation, and would certainly cause the patient great distress.

A blunt excavator will glide over caries instead of curetting it away. If caries is left *in situ* and continues to spread, the pulp can be involved subsequently, but should the operator exert undue force with a blunt excavator in close proximity to the pulp, the involvement could be immediate.

Pain is often experienced in the temporo-mandibular joints because the mouth is kept open for a long period, or because it is stretched open too wide. Discomfort resulting from such causes may be unavoidable, but another factor, not always suspected, can be the exertion of sustained pressure on the mandible while drilling or using chisels. The obvious and simple remedy is to support the mandible by placing one or two fingers along the inferior border to counteract any undue pressure.

There are some patients who prefer to undergo conservative treatment without local anaesthesia and there are times when the operator suggests that there is no need for an anaesthetic. Under these circumstances pain may be avoided by irrigating cavities with water jet or spray, which is close to body temperature, also by providing a warm mouth wash and by drying the cavity with cotton-wool pledgets and using only a short, sharp blast of warm air. Dessication of dentine should be avoided because, apart from being painful, it can cause injury to the pulp.

When packing styptic cord around teeth to produce gingival retraction, discomfort may be alleviated by the prior application of a 1% solution of cocaine. This may also be applied to the gingivae prior to the removal of subgingival calculus or overhanging margins of restorations.

Pain after placement of the restoration may be avoided by careful inspection of every deep cavity for evidence of pulpal exposure. Moreover, a deep cavity should have a base of sedative cement, separating the dentine from the phosphate cement lining, if it be used, or from the restoration itself.

Acidic cement, especially if improperly mixed, or irritant materials such as silicate, acrylic or composite restorative materials are potent causes of post-operative pain when they are placed close to the pulp.

Pain is frequently severe when a patient is dismissed with a high spot on a restoration. The use of local anaesthesia may prevent the patient from sensing the prematurity, and the traumatogenic occlusion soon produces an actue periodontitis. This may also result from the careless use of matrix bands, wedges and copper bands, and the sole remedy is the avoidance of unnecessary trauma.

High spots may be found and corrected at the time of inserting the restoration by the use of articulating paper or, with newly inserted amalgam, by looking for burnish marks where premature cuspal contact has occurred.

The treatment of periodontitis consists of removing the cause and applying a counter-irritant to the gingivae, such as tincture of aconite and iodine, to give symptomatic relief. If the pain is severe a systemic analgesic, such as aspirin or codeine, may be prescribed.

Local anaesthesia

The techniques used in obtaining local anaesthesia, while outside the province of this book, must be mentioned in relation to the avoidance of pain in cavity preparation. Many patients' fear of dental treatment is matched only by their fear of 'the needle'. Much has been done in recent years to produce sharper, finer needles and the recent availability of disposable needles has done much to reduce the pain associated with injections.

To give a painless injection, the following routine should be followed. The sulcus is dried and painted with a solution of lignocaine (5%), or cocaine hydrochloride (10%), which is left *in situ* for one minute. Meanwhile the cartridge of local anaesthetic solution and the needle are assembled in the syringe and the solution is warmed over a bunsen flame until it is close to body temperature. The lip or cheek is pulled back gently to tense the areolar mucosa and the needle is inserted at the line of reflection with a swift, deft thrust, just below the surface with the bevel facing the bone. Anaesthetic should be injected so slowly that the movement of the plunger in the cartridge is barely perceptible. Meanwhile the needle is advanced to lie above the apex of the tooth. When approximately 1.0 ml of anaesthetic solution has been deposited, the needle is withdrawn and the submucous bleb of fluid is massaged gently to aid diffusion of the anaesthetic into the periapical bone.

It is rarely necessary to give a palatal injection for conservative treatment, but should the anaesthetic prove to be incomplete after a few minutes delay a few drops of anaesthetic may be injected subperiosteally over the apex, or at the base of the interdental papilla (intrapapillary injection).

Although it is usually necessary to give an inferior dental block in the mandible, a mental block will often suffice for the treatment of mandibular premolars and incisors, boosted, when necessary, with an intrapapillary injection into the appropriate papilla.

Sedation

When a patient is extremely nervous, the work may be carried out under intravenous diazepam (Valium). This is especially valuable when difficulty is experienced in obtaining anaesthesia to extirpate an inflamed pulp under local anaesthesia. For allaying apprehension, tablets of diazepam (Valium, 2–5 mg) may be prescribed, one to be taken about thirty minutes prior to the treatment. Alternative relaxants which may prove safisfactory are Librium (10 mg) and meprobamate (400 mg T.I.D.). Ideally the patient should take the drug on the day before treatment, in addition to the pre-treatment dose, in order to achieve the optimum effect.

Treatment of pain

It is axiomatic that the relief of pain may be accomplished by removing the cause and then dealing with the effect. The chief causes of dental pain are inflammation of the pulp and periodontal ligament. The causes of these conditions include caries, mechanical trauma, infection, chemical irritation, and many other factors, which will be considered in the appropriate sections of the book. There is, however, one painful condition which develops in certain individuals as an accompaniment to gingival recession but not necessarily associated with caries. This is exposed cementum which, being a connective tissue and having no nerve supply, may be deficient in quantity or may have been worn away. This exposes the root dentine in close proximity to the pulp canal, hence thermal and osmotic stimuli may be transmitted to the pulp, which becomes hyperaemic and responds unpleasantly when the patient eats and drinks or even breathes cold air.

Treatment consists of precipitating the protein in the mouths of the dentinal tubules by the use of caustics, such as zinc chloride (40%), reduced by potassium ferrocyanide (20%), Howe's ammoniacal silver nitrate solution, reduced by formaldehyde or eugenol, and sodium fluoride paste (Lukomski's paste).

Silver nitrate, when reduced, leaves a black layer of colloidal silver on the tooth which does not disappear until subsequently worn or polished away, hence its use should be confined to areas not normally visible.

Lukomski's paste, which consists of equal parts of sodium fluoride and kaolin, made into a paste with glycerin, is applied to the dried and isolated area. This is immediately painful, but the pain soon passes. Desensitisation is accomplished either by burnishing the paste on the surface of the dentine with a ball-ended burnisher, or by operating a rubber porte-polisher cup, loaded with paste, at low speed.

The treatment may need to be repeated at weekly intervals until desensitisation is complete or, alternatively, the patient may purchase a toothpaste containing strontium chloride or formaldehyde and use it daily to combat the condition.

Treatment of after-pain

Patients occasionally suffer pain, of varying degree, following conservative treatment. This can result from physical or chemical trauma to pulp or periodontal structures, or may be a reaction to local anaesthetic or due to trauma from the needle. Whatever the cause may be, the majority of such bouts of pain will disappear within 24 hours, but the discomfort may be mitigated by prescribing an analgesic, such as aspirin (0.3–1.0 g) or paracetamol (0.5–1.0 g), the dose to be repeated every 3–4 hours if required.

If the patient should insist on being seen, any obvious cause of pain should be ruled out, such as a premature contact, or an exposed pulp. The contact area also should be checked by pulling thin nylon thread through the interspace, because food impaction is a potent cause of pain, which may become excruciating if not eradicated.

Should the pain prove to be due to residual inflammation of the soft tissues, the patient should be reassured and given a suitable analgesic. Symptomatic relief may be obtained by painting the area with tincture of aconite and iodine, which should be left on the isolated area for one minute before being rinsed away. Aconite and iodine is a counter-irritant and, although it is effective in allaying discomfort, it is of a toxic nature, so the patient should be warned against swallowing the tincture.

5

Restoration Form

Restoration form is to a large extent dependent on the anatomy of the individual, and the aim of the operator or his assistants should be to restore each dentition in such a way that the subsequent shape harmonises with the remainder of the dentition. Further, in considering the individual restoration it should be regarded as part of a larger whole formed by the two articulating dental arches. Thus cusp height, inclination and morphology cannot be determined by the acceptance of a standard shape.

In defining restoration form it is advisable to think of the dentition as a whole, and then in specific detail, subject to the above proviso. Each tooth should be in tight contact with its neighbour, the occlusal plane should be arranged at right-angles to the sagittal plane, and any curvature that may be present should be in harmony with the condylar path and the cuspal facets. In general it may be observed that small deviations from these requirements are both usual and tolerable, always provided that such modifications do not encroach on the functional pathways. Thus, for instance, the lower anterior arch may be slightly imbricated and collapsed, without severe repercussions, whereas in the upper anterior segment any encroachment on the overjet can be extremely damaging.

Contact relationships

The importance of contact relationships is related partly to the purely mechanical function of maintaining the relative positions of the teeth, and partly to the need to prevent food stagnation between the teeth. The contact point or area should be as small as possible, as is consistent with the contours of the teeth, in order to reduce food stagnation to a minimum, and in the posterior region should lie immediately beneath the sluiceway formed by the marginal ridges on their occlusal surfaces. In the anterior region they are slightly larger (and triangular in shape) and lie close to the incisal edges, the transitional boundary occurring in the canine region, which accounts for differing levels of the mesial and distal contact sites on these teeth. In the healthy condition the interproximal space below the contact site is filled with the interdental papilla, but after the onset of caries or some periodontal disturbance this tissue is often lost, and it is essential that any resultant embrasure is modified as far as possible to allow easy access with interdental sticks.

The occlusal surfaces

The healthy, newly-erupted tooth is surmounted by cusps which terminate in sharp chisel-shaped ridges confluent with the marginal ridges (in the posterior regions), which are traversed buccally or lingually on the proximal aspects by spillways, which allow food to overflow from the valleys between the cusps out on to the sluiceways between the teeth. Similar but less pronounced characteristics can be found anteriorly running along the proximal lingual boundaries, leading into a palatal pit or on to a rudimentary cusp.

The valleys between the cusps and in the cingulum area are often distinguished by fissures or crevices which act as potential food stagnation areas, and which are therefore eliminated in restorative work. Further, in some cases the valleys may have to be modified to strengthen a restoration and/or for the purpose of rendering them easier to clean, and in such instances the tips of the opposing cusps may have to be slightly reduced.

In those cases where teeth have rotated or tilted, both upper and lower teeth are usually affected, though in general such abnormalities in the upper arch are less likely to influence the lower arch than vice versa. Once such abnormalities occur both proximal and marginal ridge relationships are affected, and it is often essential to recontour the occlusal surfaces by grinding before completing the tooth preparation.

Attention should also be paid to variation in cuspal inclination and height mesio-distally, and in this respect it should be noted that cusp height will vary antero-posteriorly with the inclinations of the condylar path and the incisal plane, and only when these two are inclined at equal angles can cuspal inclination coincide throughout the dentition.

The labio-lingual surfaces

The buccal and lingual surfaces are curved so as to deflect food from the occlusal table (to protect the gingival attachment) and the arches are arranged so that the upper buccal cusps overhang the lower, thus preventing enmeshment of the lips and cheeks during mastication. The lower lingual cusps are smaller than the corresponding cusps of the upper, which enables the tongue to reach the lingual areas of both arches.

Over-building of the labio-lingual curvatures restricts access of the lips, cheeks and tongue to the cervical areas, whereas conversely, if the curvatures are too slight, then the labio-lingual shunt mechanism is inactivated.

Horizontal abnormalities affect self-cleansing in a similar manner, thus tilting may eliminate a natural overhang on one side, and accentuate it on the other; and buccal or lingual displacement will prevent access into the recess formed between the teeth on the one aspect, while the bulge will interfere with the close apposition of the tissues on the other.

The relationship between functional anatomy and restoration form

When restoring a carious or traumatised tooth, the principal aim is to bring about a return to normal anatomy, function and aesthetics and, if necessary, to effect an improvement on the original condition.

The operator must be ever mindful of the periodontal aspects of restorative procedures.

Bulbosity is related to the marginal gingivae, deflecting food away from the gingival crevice, yet allowing frictional stimulation of the crest and alveolar surface of the gingivae.

Exaggeration of the degree of bulbosity prevents this stimulation, so that the gingivae become soft and inflamed and this condition is aggravated by the stagnation of food and accumulation of bacterial plaque which also occurs. On the other hand, underdevelopment of the bulbosity may allow continual impingement of food onto the gingival crest and into the gingival crevice. This may cause gingivitis leading to gingival detachment and subsequent pocketing and osteoclasia.

The occlusal contour of the restoration must be modified to eliminate deep pits and fissures which would allow stagnation of food and resultant metallic tarnish and corrosion. The normal marginal ridges and spillways should be reproduced, as should the normal cusp to fossa relationship. Hypofunction renders the tooth ineffectual, whilst hyperfunction, i.e. premature contact, induces a traumatogenic occlusion which produces acute periodontitis in many cases and, if untreated, may result in periodontoclasia, osteoclasia and joint dysfunction, developing from a 'bite of comfort'.

The contact area should be firm enough to allow dental floss to snap through, solely when pressure is exerted. It must be close to the marginal ridge in posterior teeth and situated well to the buccal side of the mid-line (figure 5.1). Any defect in contact between the bucco-proximal areas of cheek teeth will allow food to be forced against the interdental papilla and gingivitis will develop.

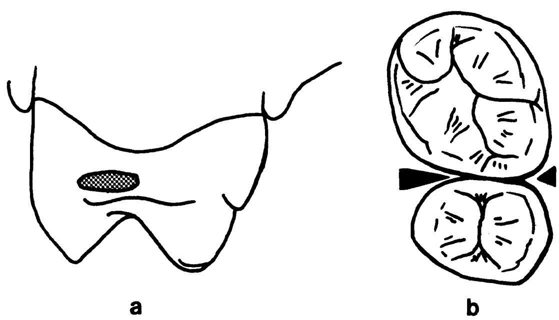


Fig. 5.1 (a) Position of contact area towards the bucco-occlusal aspect in a maxillary molar. (b) When restoring normal morphology, it is essential to consider the occlusal outline of the embrasures as two triangles; palatally-long and thin, and buccally-short and wide.

Unless otherwise dictated by the spread of caries, the margins of restorations should be extended just into the gingival crevice or kept well clear. This will minimise gingival irritation. In all cases the edge of the restoration should fit well, to prevent lodgement of debris in deficiencies or under excess with consequent recurrence of caries (figure 5.2). The edge should be impalpable and this implies that it be in line with the surface contour at all points.

A polished restoration is less apt to harbour debris and therefore is less subject to tarnish and corrosion. Moreover it feels more comfortable and is aesthetically more acceptable.

The temptation to overcut a cavity, when operating a high-speed turbine drill, must be resisted. The drill should be used solely to prepare the rough outline form, as conservatively as possible, and the final

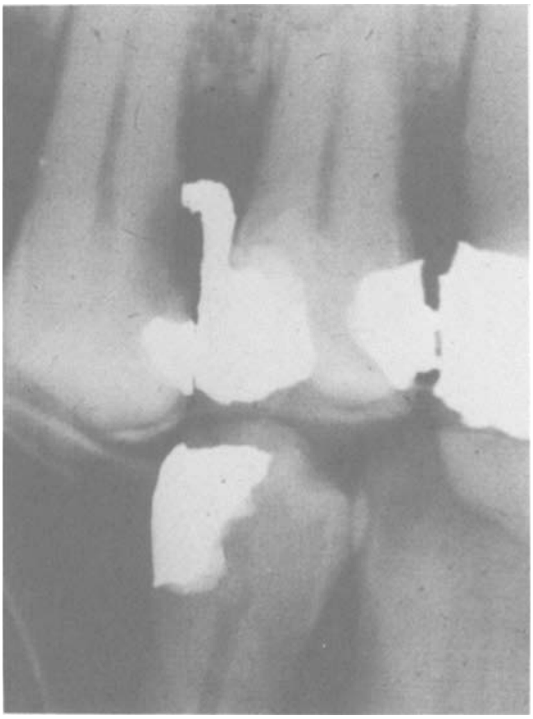


Fig. 5.2 Gross over-spill of proximal amalgam which has caused caries to develop in the adjacent premolar.

cavity should be completed with hand instruments and slow-running burs and stones, to keep the final restoration as small as possible, bearing in mind Black's dictum of extension into cleansible areas. Overcutting will weaken the residual tooth structure and encourage stress concentrations which sooner or later may lead to fracture of the enamel.

Similarly, the topography of the restoration should exhibit a sinuous, smoothly curved outline involving all potentially carious pits and fissures. When, however, the tooth is worn and the fissural pattern is modified or non-existent, considerably less extension is indicated. Care should be exercised not to undermine the marginal ridges in amalgam cavities. When preparing buccal and lingual walls of a Class I occlusal cavity the undercuts are automatically produced when the cavo-surface angles are cut at an angle of 90° to a tangent to the surface, but the mesial and distal aspects should be prepared with a 5–10° flare to avoid undermining of the enamel.

Retention

If we exclude the vexed question of full denture retention, the physical factors used in restorative dentistry are dependent on the use of adhesion, friction and interlocking systems. The first two factors are of relatively minor importance in comparison with the third.

Consider a section through a simple Class I (Black's) occlusal amalgam restoration. A thrust applied to the biting surface will be transmitted uniformly over the floor of the cavity, and will be resisted by the floor of the preparation. Additionally, the applied load will tend to cause deformation of both the amalgam and the tooth.

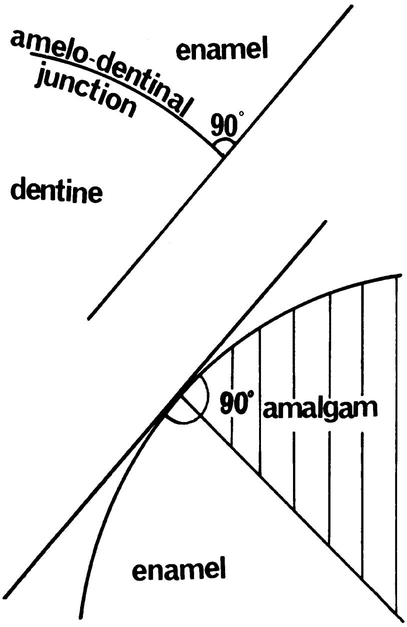
Conversely, a tractional force applied at the same place will be resisted by the overhanging sections, and the amalgam and tooth will tend to distort. Further, the retention in both cases will be affected by the slight setting expansion which occurs in the amalgam during crystallisation, which tends to drive the corners of the crystals into the small irregularities on the prepared surface.

In addition we have to remember that the character of the tooth substance is far from homogenous. The outer layer of hard crystalline enamel consists of a series of columns composed of offset rhomboidal crystals; these columns twist around one another in a regular pattern except at the cervical border and over the cusps, and the spaces between them are filled with a principally inorganic substrate containing a series of smaller tricalcium phosphate crystals. It has been shown that such a complex fractures along an irregular path corresponding to the weakest (or most highly stressed) sections beneath the applied load.

The dentine consists of a fibrous collagenous substrate into which a semi-inorganic filling has been consolidated, the whole ramified by a series of parallel tubules running from the pulp to the amelodentinal junction, and interconnected one with another. These tubules are filled with a fluid system largely consisting of gels and sols. Thus the system resembles a reinforced concrete mass through which courses a complex hydraulic buffering system and the enamel is almost 10 times more rigid than the underlying dentine.

Under these circumstances we would expect to see the enamel fracture far more commonly than it does, were it not for the fact that the fibres of the dentine run up and into the enamel forming a tie between the two substances, giving support to one section from the other throughout the bell-like conformation of the enamel cap. If the integrity of the cap is interrupted the whole structure is weakened, though if the replacing medium has similar structural properties to the enamel it will at least convey compressive stresses evenly.

It can be concluded from these comments and



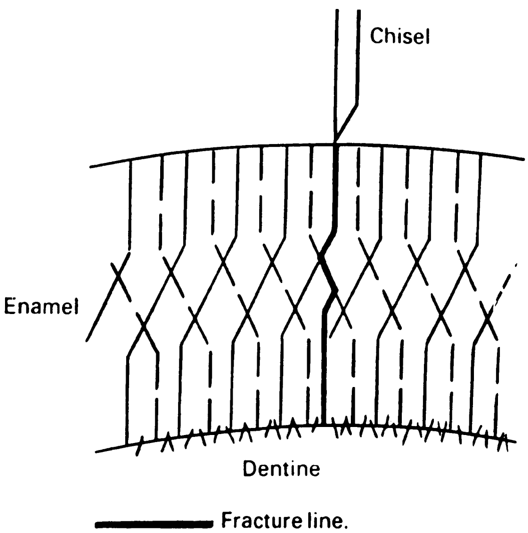


Fig. 5.3 The decussation of enamel prisms.

such experimental work as has been done that the enamel should always lie on a firm foundation of dentine, and further that for maximum strength the angle formed between the amelo-dentinal junction and the enamel wall should never exceed 90° (figure 5.3).

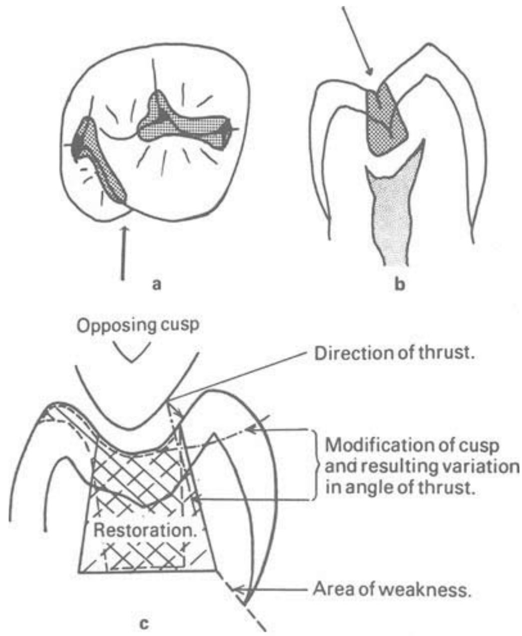


Fig. 5.4 (a) Preparation of palato-occlusal fissure towards the palatal cusp in order to strengthen the weak disto-palatal cusp. (b) Direction of occlusal fissure in order to protect weak lingual wall of lower premolar. (c) Extension of restoration by cusp coverage, or simple cusp reduction to minimise the load.

Similarly any brittle substance like enamel should terminate at the surface in an angle of not less than 90°.

Once the tooth has been injured it is obviously weakened and it becomes imperative to ensure that the remaining sections which support the restoration are not subjected to damaging stresses. This can be done either by preparing the cavity in such a manner that weak sections are strengthened, or by altering the angle at which the applied load is presented to the tooth. Examples of the first of these are shown in figure 5.4. In the third case (5.4c) alteration of the occlusal surface may not be acceptable and it may be necessary to strengthen the whole by enveloping it in a veneer casting.

Alternatively, if a cast restoration is to be used with a reasonably high tensile strength the application of the load can be modified by the use of cusp coverage.

6

Instruments and Their Use

Instruments

Hand instruments

It is customary to refer to instruments by names which indicate their function, e.g. chisels, plastics, excavators, etc. (figure 6.1). They are also referred to by the angulation of the head of the instrument to the shaft (straight, mon-, bin-, contra-angled, hatchet, or full-face) and by the shape of the head (spoon, disc, pear, etc.).

A description of probes, chisels and excavators has been laid down by the British Standards Institution (B.S. 2965:1958), which includes details of materials, tolerances, etc. The basis of the classification is that devised by G. V. Black, with the exception that the term bin-angle has been omitted, bin- and contra-angled instruments being classified together; and the term tetragrade has been substituted for centigrade. The term centigrade has been discontinued because it is now a generally accepted measure of temperature. A grade is an accepted metric term meaning one-hundredth of a right-angle, and hence a tetragrade is one-hundredth of 360°, which is the equivalent of Black's original measure.

In this classification, instruments (with the exception of cervical margin trimmers) are referred to by three numbers:

1. The width of the blade in 0.1 mm.
2. The length of the blade in mm.
3. The angle of the blade to the axis of the handle in tetragrades.

Cervical margin trimmers have a fourth number inserted between the first two, specifying the angle of the cutting edge to the blade in tetragrades, and the letters R and L are used to denote right- and left-hand cutters.

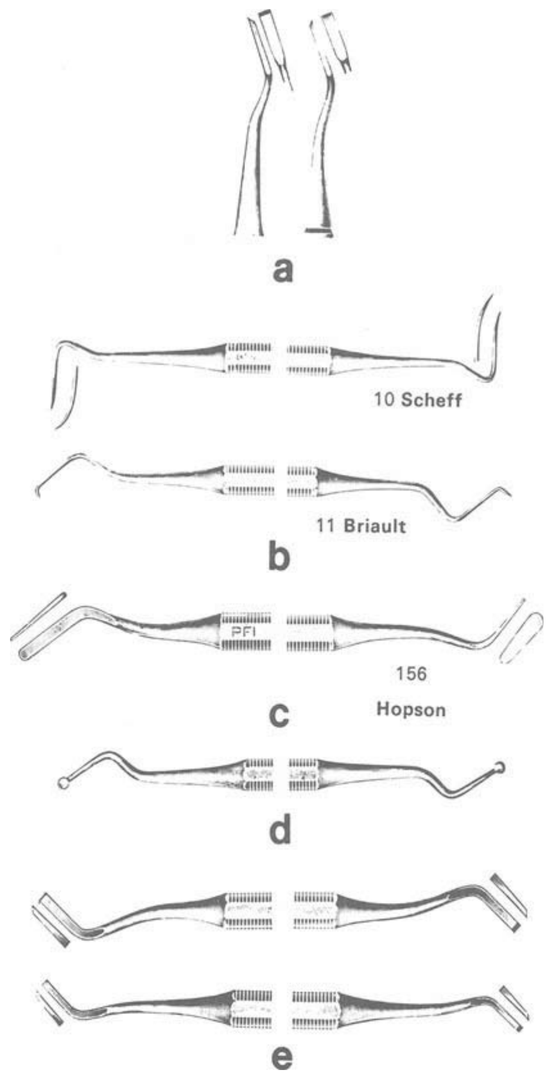


Fig. 6.1 (a) 'Bin-angled chisels'; (b) Scheff probe (top); Briault probe (bottom); (c) Hopson 156 plastic; (d) excavator; (e) Black's enamel hatchets.

Rotary instruments

Rotary instruments cut by milling, grinding or drilling. Milling instruments are available in tempered steel and tungsten carbide, grinding instruments in diamond or corundum, and drills in tempered steel (figure 6.2).

Tempered steel cutters can be made in sizes as small as 0.025 in. diameter. Instruments of these dimensions should be run at low speed, i.e. 150–5000 rpm. At higher speeds they rapidly lose their cutting edges, and are subject to local overheating.

Tungsten carbide instruments reach their optimum cutting efficiency at speeds of about 1500 feet per minute, i.e. at about 150,000 rpm for a tool 1 mm in diameter. Further increases of speed do not improve their performance, and at about 3000 feet per minute their performance rapidly falls off as a result of wear (Henry and Peyton, 1954).

In contradistinction to tungsten carbide, diamond instruments improve their cutting efficiency with speed to well above 5000 feet per second, always provided that satisfactory swarf clearance can be effected. The difficulty of obtaining adequate swarf clearance in a small cavity handicaps their use to a certain extent, so that they are best used for crown preparations and for finishing the walls of cavities.

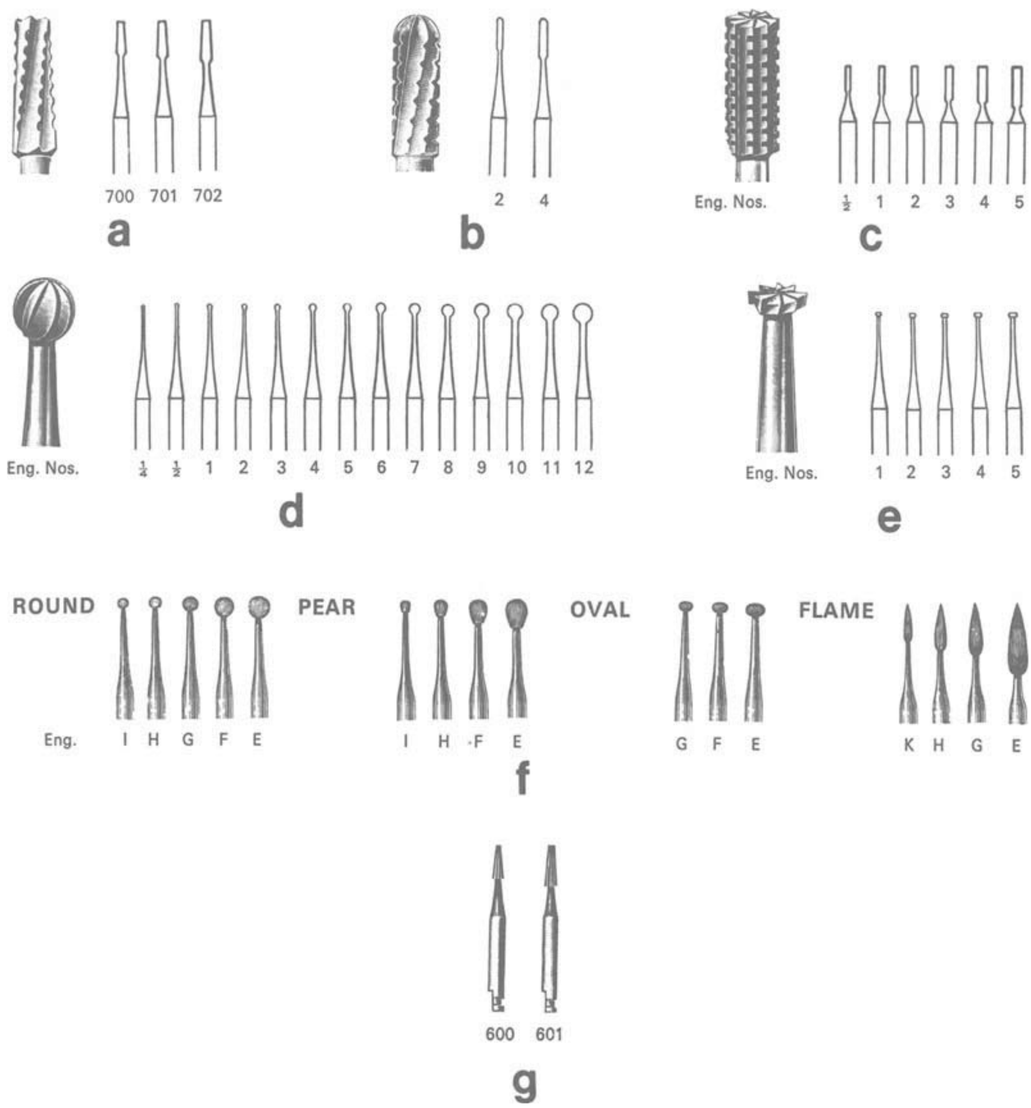


Fig. 6.2 Ash Burs. (a) Tapered fissure (cross cut); (b) domed fissure (cross cut) . . . both tungsten carbide; (c) steel flat fissure; (d) steel round plain-cut; (e) steel wheel plain-cut; (f) finishing burs; (g) inlay burs.

The cutting action of a dental bur corresponds to the industrial action of milling. The blade of the tool is fed into the face of the tooth compressing the surface, and leading rapidly to rupture and shear, the resultant chip being conducted away from the work face via the swarf channels which separate the blades. In dental practice the blades are set with a negative rake angle which, while it is less efficient, reduces the wear of the tool (figure 6.3).

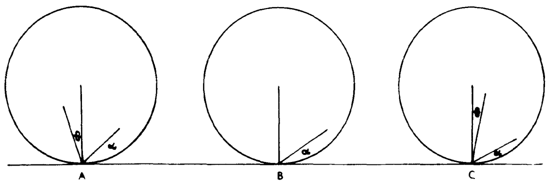


Fig. 6.3 (A) Negative rake. (B) Radial rake. (C) Positive rake. The rake angle is the angle formed between the surface of the cutting blade and the radius normal to the working surface (θ). The clearance angle is the angle between the back of the tool and the working surface (α). When the blade surface and normal radius coincide the rake angle is zero and the rake angle is said to be radial.

Apart from the efficiency of cut, the residual surface finish of the work face is of considerable importance, especially in crown and inlay work. For precision work the surface finish left by a bur is too rough, and the work face should be roughly polished with pumice, or lightly ground with the fine grit instruments.

A list of general factors common to the use of rotary instruments is as follows:

1. The blades of most milling tools including rose-head burs meet at top dead centre, so that to engage the cutting edges the bur must initially be held at a slight angle to the work face.
2. The internal diameter of a hole is always slightly larger than the tool that cuts it.
3. Swarf clearance is more easily effected with milling than grinding tools.
4. In order to avoid damage to the neighbouring tooth the line of cut should always be slightly more than the radial width of the tool from the periphery of the preparation.
5. Pinholes should be approximately 4 mm deep in order to give adequate retention.
6. When following out a fissure, care should be taken not to weaken unduly the tooth structure. Thus, when preparing the palatal-occlusal fissure of an upper molar the tool should be trained towards the larger mesio-palatal cusp: and in lower premolars the excision should be kept towards the stronger buccal cusp and should be inclined at an angle of 45° to the axial alignment at the tooth.
7. Soft bonded abrasives should be used on hard materials and vice-versa.
8. If an abrasive will not attack the tooth surface (i.e. bite into it) reduce the circumferential speed.
9. If an abrasive wears too quickly increase the circumferential speed.
10. Always grind wet.

The use of high speed tungsten carbide blanks

Baker and Curson (1974) described the use of smooth, friction-grip, tungsten-carbide (TC) burs, operated at high speed in a turbine handpiece, for the smoothing of walls and bevelling of margins. These burs may be made by grinding a used TC bur against a diamond bur so that the blades are eliminated and the required shape is produced, otherwise a set of four burs is obtainable (figure 6.4).

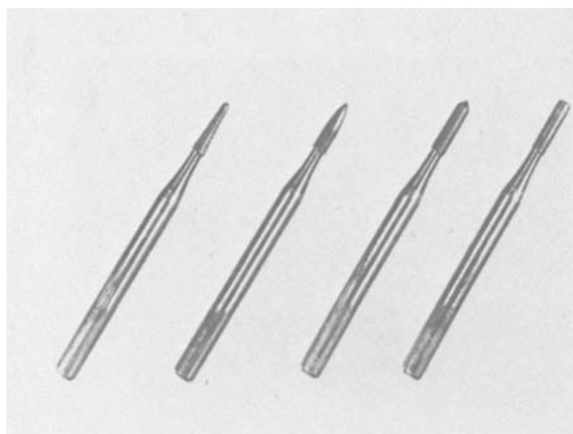


Fig. 6.4 A set of tungsten-carbide finishing blanks. (Ash)

Barnes (1974) compared the use of a TC blank with various finishing burs and hand instruments for producing a gingival bevel. Scanning electron microscopy demonstrated the superior finish obtained when a TC blank is used. It may also be employed for the elimination of subgingival marginal excess of amalgam, composite or silicate, which it effects with minimum trauma to the soft tissues.

Maintenance of instruments

Apart from sterilisation after use, conservation instruments require to be maintained in good working condition. All set cements and debris should be cleaned off thoroughly before sterilisation. Most cutting instruments are made with tungsten carbide tips on stainless steel shanks or entirely of chrome-plated carbon steel. In the former case, the need for sharpening is reduced due to the fact that tungsten carbide keeps a cutting edge for a lengthy period, whereas carbon steel instruments require to be sharpened each time they are used. Stainless steel instruments, by and large, do not maintain a cutting edge for a sufficient time to be worth using. There is also a special problem relating to carbon steel instruments. They are subject to tarnish and corrosion if they are allowed to remain wet after sterilisation in boiling water or in an autoclave. Consequently, they should be dried, sharpened and put away immediately after they have cooled.

Manufacturers of tungsten carbide chisels and scalers recommend that they be returned to the factory for sharpening when they are blunt, but the author has found that they may be made serviceable by holding them, at the correct angulation, against a rotating diamond disc for a few seconds.

The criteria for bluntness are: (1) The instrument does not cut, (2) there is a shine along the cutting edge and (3) the cutting edge does not catch, when placed against the thumbnail, but slides when pressure is applied.

Chisels should be sharpened at an angle of 45°, and care must be exercised, when angulating the chisel on the Arkansas oilstone, to ensure that the end of the blade subtends this angle, even though some handles may be offset at an angle of approximately 15° to the cutting blade (e.g. bin-angled chisels) (figure 6.5).

In order to maintain the correct angle throughout sharpening, the tips of the third and fourth fingers should slide along the stone as a guide (figure 6.6).

Excavators should be rotated around their axes while moving the spoon end to and fro, in order to produce a continuous edge and maintain their shape after continual sharpening (figure 6.7).

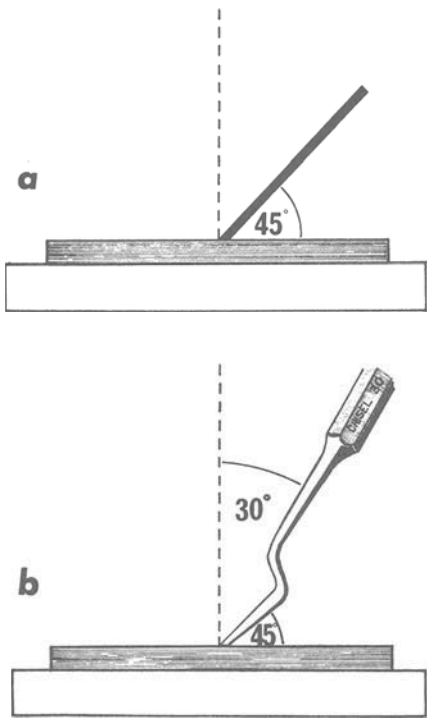


Fig. 6.5 (a) Correct angle for sharpening a straight chisel. (b) Correct angle for sharpening a bin-angle chisel (Ash 30). Note the modification in the angulation of the handle to the sharpening stone.

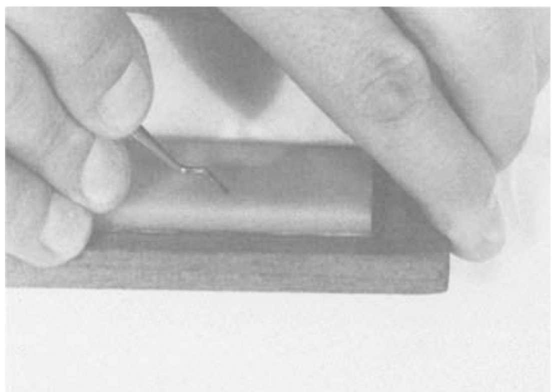


Fig. 6.6 Fingers acting as a guide in maintaining the correct angulation.

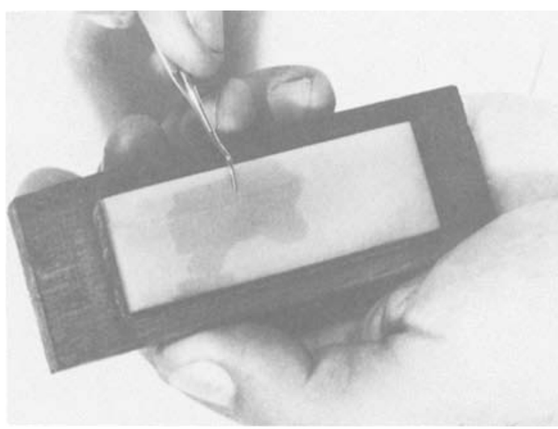


Fig. 6.7 Sharpening an excavator. Position at start of stroke. As the instrument is drawn to and fro along the length of the stone, it, and the stone are rotated one toward the other, so that the entire edge of the excavator is sharpened without producing a series of facets.

After use, all metal fillings should be cleaned off the stone by wiping it with a cloth moistened with clean oil, otherwise the efficiency of the stone would be impaired.

All cutting instruments used for cavity preparation must be sharpened after sterilisation, with the sole exception of tungsten carbide tipped instruments, and the operator should keep a number of duplicates of those he uses most frequently, so that delays will not occur because instruments which require sharpening have not yet been put away.

The role of the chairside assistant

In the last decade a great change in operating conditions has been brought about by the advent of what is termed 'four-handed dentistry'. This refers to the use of a dental chairside assistant, seated behind and to the left of the patient's head, whose task it is to act as another pair of hands to increase the efficiency of the operator. In the traditional surgery, with the unit and spittoon sited on the left of the chair and plumbed into the floor as a fixture, this was not a feasible procedure, hence a new concept in operating positions has been developed around a low, couch-like chair and a split unit which brings the drills and syringes to the right hand side. The dental chairside assistant (DSA) now has a more intrinsic function in each part of the work, as she aspirates fluids, retracts soft tissues, places cotton rolls and, in general, helps to make life easier for both patient and operator.

The dental chair

The modern dental chair is electrically operated and descends to a short distance from the floor. It is adjustable to provide a flat, couch-like position for the patient to lie supine, or it can be used with the patient at any other angle up to the upright position commonly adopted for prosthetic work. Having the patient supine introduces a host of new problems which must be considered and overcome.

Firstly, when spray from the handpiece enters the mouth, in order to prevent gagging and choking when it flows around the soft palate, the nurse must keep a high speed aspirator tip close to the tooth that is being drilled and thus eliminate any tendency for fluids to pool.

Secondly, the patient's eyes must be protected in case any object is dropped onto them. If spectacles are not already being worn, a pair of plastic goggles should be used. If they have dark lenses, they shelter the eyes also from the spotlight.

For many operations, the use of rubber dam will be found advantageous and increase the patient's comfort. Some patients, due to spinal problems, neurosis or cardio-pulmonary insufficiency, may object to the supine position and should be treated at an angle which they find comfortable.

The operator is seated either directly behind the patient's head (12 o'clock), or to his right (9.00 o'clock) and his work area lies between these two points, while the DSA's work area occupies the corresponding zone on the left hand side (figure 6.8A, B).

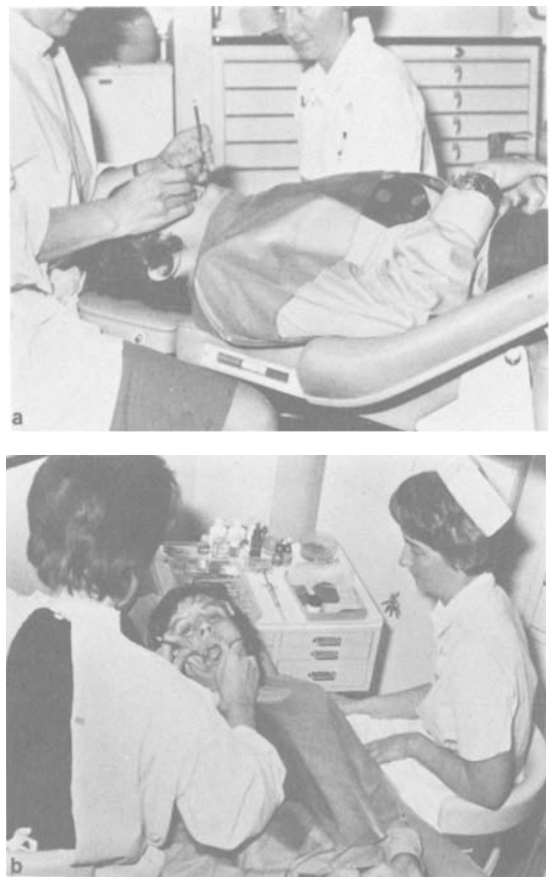


Fig. 6.8 Four-handed dentistry. (a) Patient supine with operator at the 12 o'clock position (b) Operator at the 9 o'clock position . . . this position is usually adopted when operating on the lower anterior teeth or those on the lower right side.

The operator's stool is adjusted so that his feet are flat on the floor with the thighs parallel to the floor. The back should be straight and supported where possible by the backrest. The head should be bent forward slightly and the elbows should hang naturally at the side. The DSA should be positioned at a level about 6 inches higher than the operator and as close to the chair as possible in order to see clearly the field of operation.

The patient's head should be as close as possible to the top of the chair, with the maxillary plane approximately 90° to the floor. The chair is positioned so that there is sufficient room beneath it for the operator's knees.

The light, which is adjusted by the nurse to provide clear illumination, should be high and, for the best effect, this is usually almost above the operator's head.

The patient's clothes should be protected with a large plastic bib, preferably with a flap along the lower border which traps fluids which inadvertently escape from the mouth.

The DSA and operator must develop a routine technique for the transfer of instruments and it is important to remember that all such transfers must be carried out over the patient's chest and not over the face, onto which they could be dropped. Also the DSA should position the aspirator tip so that it does not interfere with the operator's line of vision. Selection of instruments is carried out by the DSA, so they are located within easy reach, and she should have a work top on which restorative materials may be mixed or prepared for use.

A considerable amount has been written about the techniques and minutae of assisted operating and the reader is recommended to study the writings of Paul (1972).

Despite the advent of seated dentistry, there are still dental surgeons who prefer to work standing. This is especially the case with those who were thus trained or who have the older style of equipment.

When operating in a standing position, much of the associated fatigue can be avoided by adopting a relaxed, semi-upright position, the legs slightly apart and the weight of the body evenly distributed between them. The patient should be placed in such a position that his mouth is approximately level with the operator's elbow. The question whether a dentist should stand behind or in front of the patient is determined, in the final analysis, by his training and also by the access and manoeuvrability inherent in either position. Generally he will work from behind when operating on the upper molars and premolars, lower left molars and premolars and certain aspects of the upper incisors. Elsewhere he will tend to favour a frontal approach. It is essential when choosing an operating position that no excessive lateral or vertical curvatures of the spine be allowed to develop as a result of faulty posture. A compromise should be developed between the standing and sitting positions so that, for example, the operator may cut a cavity while standing, but will sit down to fill it. This will tend to diminish fatigue.

Before describing the various methods available for cutting teeth, it is worth considering briefly the fundamentals of instrument control. In essence, an instrument is operated securely only when the operator rests one or more fingers on the teeth of the same jaw as the tooth which he is cutting. The closer his rest to that tooth, the less danger there is that his fingers will slip when pressure is applied with the cutting end of the instrument.

In addition, when exerting pressure on the lower teeth, considerable discomfort to the patient can be avoided if the operator supports the mandible along the inferior border, thus cushioning the pressure (figure 6.9).

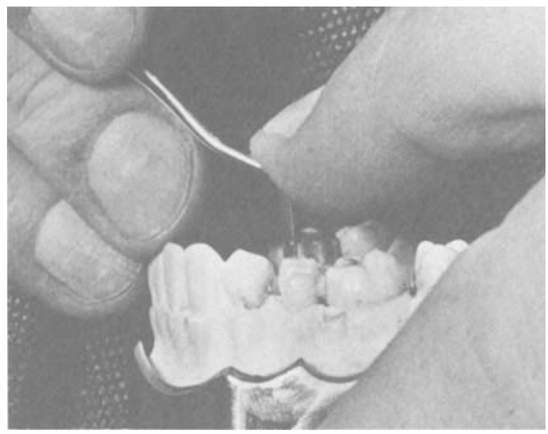


Fig. 6.9 Use of thumb to guide and increase pressure on an enamel chisel when used in the mandible, the remaining fingers being used to support the mandible.

There are two methods commonly used by dentists to hold instruments. These are the 'pen' and the 'palm' grasp (figures 6.10, 7.11). Of the two, the palm grasp will engender a sensation of greater security, and is invaluable for the subgingival scaling of the palatal aspect of maxillary incisors or for using straight chisels in the maxilla. Although it is used less often in the mandible, experience teaches the operator on which occasions it can be best employed.

When operating in the standing position the patient's mouth should be sited approximately opposite the operator's elbow with the patient's head slightly extended. For work carried out in the maxilla or the left mandible, the chair should be tilted back. Improved access may be obtained by asking the patient to turn his head towards the

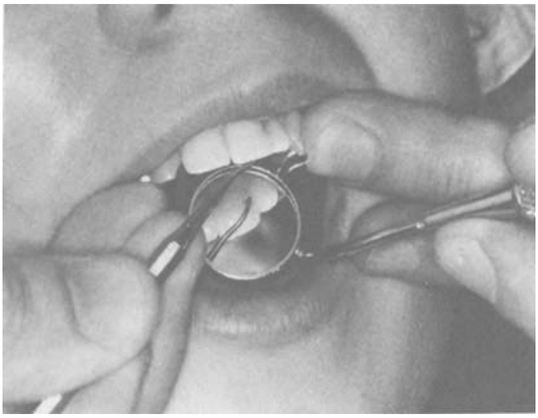


Fig 6.10 The pen grasp.

Fig. 6.11 The palm grasp.

operator when operating on the patient's left teeth, or away from him when working on the right teeth. In this way the operator may place himself in such a position that the instruments may be applied with a good rest on the side of the jaw on which he is working.

Special Aspects of the Use of Turbine Drills

Operative dental surgery is in the process of a dramatic upheaval, generated by the advent of more sophisticated cutting instruments, improved restorative materials and more accurate impression materials and techniques. The operator, having been trained to use both high and low speed drills and to manipulate a variety of hand instruments, is in a position to select the most appropriate tool to carry out each operative procedure. The chief danger in possessing an air-turbine handpiece lies in the temptation to use it for aspects of cavity preparation for which its use is not applicable.

Firstly, it should never be used for Class III and Class IV cavities, apart from the removal of composite resin, or for the removal of caries, because at speeds in the region of 300 000 rpm there is a tendency to cut away more tooth tissue than necessary and to damage the adjacent tooth. Secondly, it should not be used to prepare cavities in inaccessible areas, such as the lingual cervical of lower molars or the distal of upper second and third molars. The need, at ultrahigh speeds, for an adequate coolant spray or jet of water, plus the necessity to work by indirect vision, results in a diminution of visibility as the water droplets obscure the surface of the mirror. There are various measures available to counter this problem, such as dipping the mirror into a weak solution of detergent or having the assistant aim a continuous jet of air across the mirror, or using a mirror which is made to revolve at high speed, powered by compressed air.

Despite these precautions there are areas in the mouth in which it is safer to carry out the bulk of the preparation using slow-running burs. The operator must bear in mind that the special function of the turbine handpiece is to cut away large areas of enamel. This function is performed less efficiently at lower speeds, even with the use of tungsten-carbide and diamond burs, and high speeds in the range of 50 000–500 000 are especially effective for full and partial veneer preparations.

Although visibility is improved to some extent if the bur is run dry, heat generated by friction may injure the pulp and, even though the surface of the dentine may be cooled by a jet of air, the resultant dessication of the dentinal tubules and Tomes processes would cause damage to the pulp. This is made evident by the aspiration of nuclei of odontoblasts into the dentinal tubules and disorganisation of the layer of odontoblasts underlying the affected area, plus an infiltration of inflammatory cells into the zone.

It is imperative that the water spray or jets be allowed to impinge on the end of the bur while it is cutting. They may be prevented from doing so because of an intervening cusp or cavity wall and the operator will become conscious of this fact through the odour of burning dentine. Kramer (1960) demonstrated that burning of the dentine occurred when a bur is operated at ultra-high speed without coolant spray. He also noted that when this occurred close to the amelo-dentinal junction, the enamel became more fragile and apt to fracture.

Cavity preparation must, in consequence, be modified in order to overcome this problem. When opening up a cavity with conventional burs at low speeds, an access hole is drilled to the amelo-dentinal junction and then extended by the use of fissure burs which are carried down to the depth of the access cavity. Were this to be done at ultra-high speed, the coolant would not reach the tip of the bur and the dentine would be burned on contact. Thus the technique should be modified by 'painting away' the enamel, producing a shallow trough corresponding to the outline form and deepening it evenly to the desired depth. In this way the whole bur is bathed continuously with coolant.

Torque

The majority of turbine drills operate with considerably lower torque than is found with cord-driven drills. Consequently, if a pressure greater than 2–3 ounces is applied the drill will stall. This is accompanied by a modulation of the high-pitched whine. Thus, if the operator finds that the pitch fluctuates while he is drilling, it is an indication that excessive pressure is being applied and that, in consequence, the drill is cutting with decreased efficiency.

The operator must develop a delicate touch when drilling with the turbine handpiece and use it as though it were a paintbrush. The use of a pulling rather than a pushing stroke is found to be more effective.

Damage to adjacent teeth

The use of any side-cutting bur between two teeth is to be condemned, unless there is sufficient space to operate it without damage to the adjacent enamel, or if the preparation of the adjacent tooth is contemplated. In order to avoid trauma to the adjacent enamel surface, it is recommended that the bulk of the preparation of proximal walls be carried out with hand instruments, after thinning down the proximal enamel with a fissure bur in the turbine handpiece. A brief lapse in concentration while undermining the proximal enamel may result in damage to the neighbouring tooth, hence the exercise of firm control over the bur is mandatory. Alternatively, a safe-sided diamond disc may be used without risk of trauma to the next tooth.

Some operators place a steel matrix strip between the teeth in the hope that it will prevent trauma. However, there is no certainty that the strip will not be breached before the operator is aware of the fact and furthermore, when the bur makes contact with the strip, it is apt to displace it violently against the gingivae and produce a laceration. Because of these drawbacks, the use of a strip is not advised.

Damage to soft tissues

The ease with which a turbine handpiece may be made to cut enamel can lead to a feeling of false security, and it must never be forgotten that it is a rapid and powerful cutting instrument. The drill should not be left running in the mouth unless it is in contact with the tooth. It should never be used unless a clear view of its position in relation to the tooth can be obtained. Cheek and tongue must be protected by the use of a flanged saliva ejector and a mirror. After releasing the foot control, the drill should be allowed to come to rest before taking it out of the mouth, so that accidental contact with the soft tissues may be prevented. Finally, the patient's head should be restrained from making excessive movements by a firm but gentle hold with the free arm and hand, whilst a firm rest on the teeth is maintained by, at least, the tips of two fingers, which is as essential as the rest required for conventional drills and hand instruments.

The operator must be on his guard against sudden movements by the patient and be ready at all times to restrain any movement. Efficient aspiration by the assistant will reduce the risk of lingual damage due to reflex swallowing movements, but patients with large muscular tongues will benefit from the interposition of a mirror between the drill and their tongue.

Noise

Although there have been many improvements in the design of turbine drills, many models emit a piercing shrill, high-pitched whine, which has been inculpated as the cause of high tone deafness in some dental surgeons (Skurr and Bulteau, 1970). Because of this, some operators wear earplugs while they are drilling. The patient is unlikely to suffer auditory damage because the exposure is of short duration, but the bulk of the noise may be eliminated and replaced by music, if the patient is supplied with padded earphones into which taped music is relayed.

Inhalation

In order that the ball-races of the turbine may function at ultra-high speeds, they are bombarded with an oil mist which is partly returned to the oil mist chamber and partly exhausted into the mouth through the rear of the head of the handpiece. This oil is prepared from a vegetable source and is apparently non-toxic if inhaled.

There is a greater danger to the operator from the cloud of water droplets, mixed with saliva and finely divided particles of caries, enamel and dentine, which tends to spray and splash back in the form of a mist. If this is inhaled constantly throughout the day, there is a great risk of transference of respiratory infections from patient to operator. The author carried out an experiment in which blood agar plates were exposed at varying distances from the mouth in the course of drilling with a turbine handpiece. The inoculated plates were then incubated aerobically and anaerobically for several days and it was noted that heavy growths of organisms were found in all instances, the growth being vastly increased when the plate was held only six inches from the mouth. Bearing this in mind, for his own protection the operator should wear a mask while using the turbine drill.

Protection of the eyes

From time to time when cutting through restorations, particles of gold or amalgam, or even a fractured bur tip, may fly out of the mouth and enter the eye. If the cornea were to be traumatised, it could lead to the formation of an opacity or, at least, would cause severe discomfort. Spectacles should always be worn, even when no refraction is necessary, when plain glass lenses can be prescribed. Anyone who normally wears spectacles can vouch for the fact that there is usually a film of debris on the lenses after using a turbine handpiece. This debris, in the absence of protection, would almost certainly enter the eyes and could be the cause, on occasion, of conjunctivitis.

Maintenance of turbine drills

A strictly followed scheme of maintenance is required if the turbine is to function efficiently over a long period. Firstly, the oil level in the reservoir and the rate of drips per minute of the oil drip feed should be checked monthly against the manufacturers' specifications. Each day the chairside assistant should operate the handpiece with the water spray turned off and the finger pressed hard against the bur, to overcome the torque and prevent it from rotating. This will bring the oil mist to the bearings and, after approximately one minute, a film of oil can be discerned on the thumbnail when it is held close to the exhaust orifice. If the handpiece is run before this warm-up period, there will be excessive wear on the bearings and the turbine will soon cease to operate. The air pressure should also be checked daily before starting in order to ensure that sufficient motive force is available.

When a polythene chuck, which is used in a large percentage of turbine handpieces, fails to grip the bur it should be replaced. Otherwise there is a possibility that the bur might be expelled into the mouth while drilling. Moreover, the bur will tend to run eccentrically, producing unpleasant vibrations and causing damage to enamel margins. These sequelae will also follow any bending of a bur, most likely to occur when a diamond bur is pressed home into a tight polythene chuck in a careless manner. Eccentricity may be checked by running the bur and holding it up to a good light. If the bur is not running true, a 'ghosting' effect will develop as the turbine gathers speed.

Short burs should always be used in preference to long burs, because there is a tendency to 'whip' and eccentric cutting in the longer burs. Furthermore, for each 1/32 inch that a bur is extruded, there is a loss of 10 000 rpm.

If the handpiece has, for any reason, been used without coolant spray, dust may get into the bearings. If this happens, the handpiece should be operated for about one minute with its head immersed in cleansing fluid (if this is not supplied already by the manufacturers, carbon tetrachloride may be used, but only in a well-ventilated room). Immediately afterwards the turbine should be oiled once again.

Air-bearing handpiece

In recent years, a much quieter version of the turbine handpiece has been developed, namely the air-bearing handpiece, in which the turbine spins on a cushion of air. There is no need for an oil mist or solenoid, but a small quantity of liquid paraffin is introduced into the turbine chamber to avoid wear when the turbine comes to rest. The foot control consists of an air valve and a higher air pressure (60 lb/in^2) is required for efficient running. The supply of coolant is regulated by a needle valve close to the handpiece.

The noise level has been reduced to a mere hissing sound, and tests with a Dawe high frequency stroboscope show that the speed unloaded is in the region of 528 000 rpm and loaded, 500 000 rpm. The cutting load is reduced from 2 ounces, with a conventional turbine drill, to 1½ ounces.

Undoubtedly, this handpiece shows a marked improvement on previous designs, and slow-running turbine handpieces have similarly been developed, which have largely replaced the cord driven motor in the modern split unit. Both air motors and electric micro-motors are at present available for low speed cutting.

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7

The Control of Moisture in the Mouth

One of the problems encountered in conservative dentistry is the need to use materials which must be kept dry in a naturally wet environment. Saliva is not only essential to enable the masticatory machine to create a manageable bolus, but it is needed to cleanse the mouth after eating. Nevertheless, the wrong types of food tend to be eaten and their adhesive nature necessitates the use of a toothbrush. Without saliva the oral condition deteriorates, as may be seen in patients suffering from xerostomia (dry mouth), which develops in certain pathological conditions of the salivary glands. Gingivitis and caries often develop to an alarming degree in the absence of saliva. The quantity of saliva secreted varies considerably and its nature is altered by the mucin content, being viscous and difficult to control when rich in mucin. Salivary flow is also increased under stress, e.g. as a result of painful procedures or when the mouth is full of dental equipment, such as saliva ejector, mirror and handpiece.

Saliva must be controlled during dental operations for two reasons: firstly, to obtain a dry field and secondly, in root canal therapy, to procure an aseptic field of operation. Endodontic treatment requires complete exclusion of saliva and this means that a rubber dam is essential, whereas for many types of restoration it may be possible to exclude saliva completely for a short period by other means.

Apart from the need to control saliva, many dental drilling operations are carried out under a water spray and consequently efficient evacuation is essential to prevent the water running into the throat or out of the mouth.

Antisialagogues

Hypersecretion of saliva during dental treatment may be such that special measures are indicated to control it. The patient may be given a tablet of atropine sulphate (0.25–1.0 mg) or Probanthine (propantheline bromide 15–30 mg), to be taken thirty minutes before the appointment. The dosage should be adjusted subsequently in relation to the result obtained, but it is essential that a history of glaucoma be excluded before either drug is prescribed, because antisialogogues are apt to precipitate an acute attack. Should symptoms of dry throat and diplopia (double vision) develop in a susceptible individual, the continued use of atropine would be contraindicated.

These drugs are especially useful when taking elastomeric impressions or restoring lower posterior teeth, with special reference to Class V cavities.

Saliva ejectors

The majority of dental units are equipped with a saliva ejector which works on the Venturi principle. At the end of a flexible tube, attached to the unit, is a rubber connection containing a wire mesh filter, which should be removed for cleaning each day. Various mouthpieces are available to fit into the connector. There are two main types. The first is a simple J-shaped tube, perforated at its tip, around which there may be a guard to prevent the sublingual mucosa from being aspirated into the holes, which could be painful and would certainly interfere with the evacuation of saliva. The other type possesses a flange, which is used as a tongue retractor and thus facilitates working on lower teeth.

After a time, the mouthpieces tend to become blocked and are difficult to clean out. To overcome this problem, disposable plastic mouthpieces are now obtainable.

With the advent of ultra-high speed drills, which require the continuous use of a jet or spray of water, the Venturi type of saliva ejector has proved inadequate in coping with the increased volume of water and has been supplanted largely by an electrically-operated, low vacuum, high volume aspirator (figure 7.1). This is used with saliva tubes of markedly greater bore and it should aspirate a pint of water in

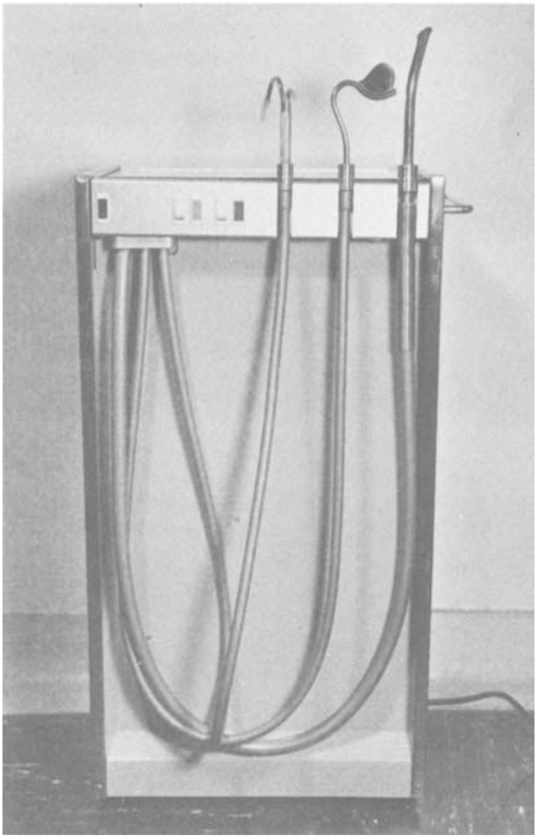

Fig. 7.1 A high volume aspirator.

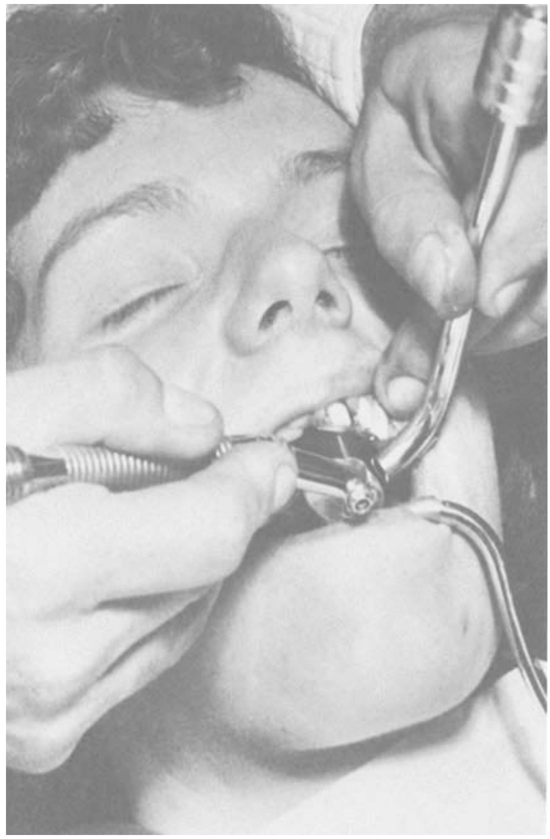

Fig. 7.2 Preparation of |1 as bridge abutment. The aspirator tip has a mirror soldered to the undersurface so that water spray may be removed as it hits the mirror, thus improving visibility.

approximately three seconds. The types of mouthpiece are similar to those described, but in addition there are bifid metal tubes, tipped with interchangeable perforated plastic tips, which are placed in the buccal and lingual sulci, thus increasing the efficiency of the evacuation. There is no tendency for the mucosa to be aspirated.

When using a single mouthpiece, it is easier to evacuate the water spray coming from the handpiece by tilting the patient's head to one side and placing the ejector in the buccal sulcus at that side. However, if a chairside assistant is available, she can hold a wide-bore aspirator tip close to the tooth, which will deal with the spray before it can flow into the mouth, while a simple sublingual ejector will remove the saliva.

There is also available a wide-bore aspirator tube to which a mirror is attached. This may be held by the operator and in certain instances it will obviate the need for ancillary aid (figure 7.2).

In recent years, the practice has developed of performing dental operations with the patient in the supine position. Hence, efficient evacuation by an assistant is mandatory and consequently the use of a high volume aspirator is essential.

Cotton-wool rolls

Apart from the aspiration of saliva which flows from the orifices of the parotid, submandibular and sublingual ducts, there is also a mucinous secretion coming from mucous glands in the palate, buccal mucosa and elsewhere in the mouth. Therefore, it is necessary to have absorbent pads close to the teeth when inserting a restoration, so that fluid secretions may be prevented from contaminating the cavity or the restoration. Cotton-wool rolls are available for this purpose in a variety of diameters and lengths for use in various locations. They should be placed in the buccal and lingual sulci in the mandible and in the maxillary buccal sulcus opposite the parotid duct orifice, when working on lower teeth. For upper teeth, they are placed solely in the buccal sulcus.

When inserting the roll into the sulcus, its retention is made more secure by giving it a twist about its axis, from sulcus to cheek, before releasing the cheek or lip.

In some mouths, due to lack of depth of the sulcus or to excessive muscular activity on the part of tongue and cheek, it proves impossible to keep cotton-rolls in place. Special clamps have been designed (figure 7.3) which have buccal and lingual curved flanges to hold cotton-rolls in place. They are supplied in two sizes, for molars and premolars, and are placed over the tooth, or its neighbour if a matrix band is to be used, with rubber dam clamp forceps.

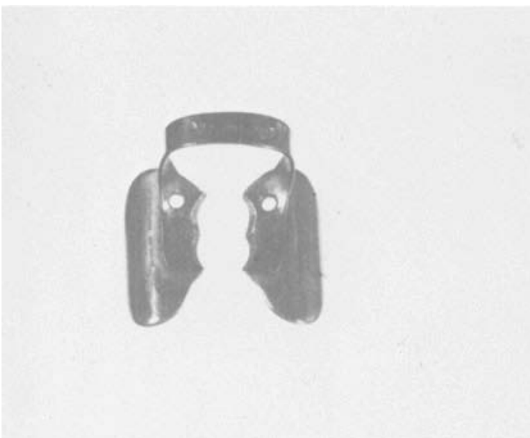

Fig. 7.3 Ash cotton-roll clamp for a lower molar.

A simple apparatus may be made to hold cotton-rolls in the molar region, by bending up a length of 0.8 stainless steel orthodontic wire and sharpening the ends so that the rolls may be speared easily (figure 7.4). This will solve the problem of holding the roll in the upper sulcus when working on the lower jaw.

When operating on maxillary central incisors, a single cotton-roll may be placed across the mid-line, by cutting a V-shaped wedge out of the centre to accommodate the fraenum, so that it does not displace the roll (figure 7.5). This is better retained than two rolls, one on either side of the fraenum, which are apt, when moist, to slide out distally.

Rubber Dam

The only certain way of isolating teeth from moisture is to apply the rubber dam. Not every tooth is suitable for rubber dam and the subgingival extension of many Class V cavities precludes its use, although it

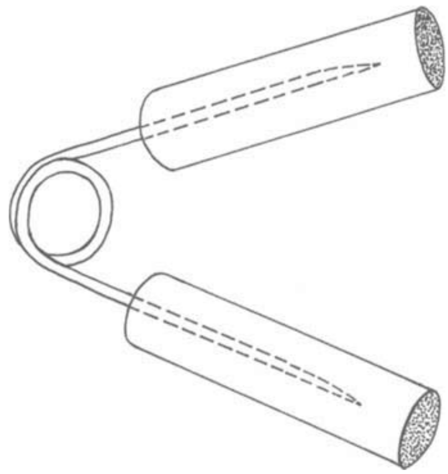

Fig. 7.4 Cotton-rolls speared onto wire retainer for use in the buccal sulci.

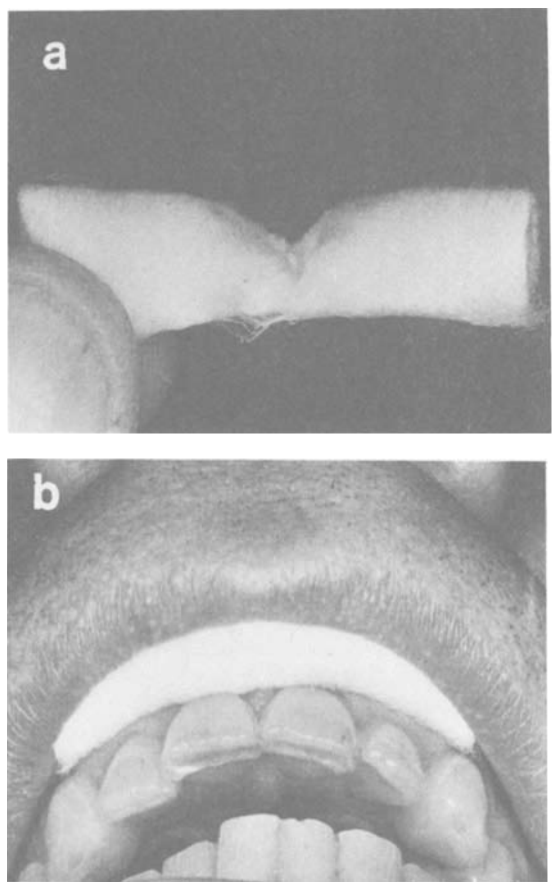

Fig. 7.5 (a) Wedge-shaped piece cut from cotton-roll. (b) Roll located on either side of fraenum is less apt to be displaced by muscular action.

has been suggested that, in order to facilitate its application, a muco-periosteal flap may be reflected, the flap being sutured back into place following the restoration of the tooth.

Such a method, although advocated and used by some practitioners, is not standard practice. Should a cavity extend far beyond the gingival margin, its restoration may be preceded by gingival surgery, so that the subsequent use of rubber dam would then be feasible.

The chief indications for the use of rubber dam are:

1. Root canal therapy and pulp capping.
2. Restoration with silicate cement, composite or acrylic resin.
3. Cohesive gold restorations.
4. Bleaching.
5. Amalgam restorations in patients with ptyalism.
6. Cementation of gold inlays.
7. Compulsive rinsers and talkers.

The application of rubber dam should be simplified in order to save time and to minimise discomfort for the patient. Whenever possible, only one tooth should be isolated, if thereby good access can be obtained, but the operator should not hesitate to include several teeth if, by so doing, improved access can be achieved.

Armamentarium

The following instruments and materials are required:

1. A roll of dark, heavy duty, rubber dam material.
2. A rubber dam punch, for making holes in the rubber.
3. Rubber dam clamp forceps.
4. An assortment of clamps, with or without wings.
5. A frame to retract and hold the rubber dam away from the mouth at its perimeter.
6. A container of dental floss.
7. A double-ended plastic instrument (Ash 156).
8. A saliva ejector.
9. Vaseline or brushless shaving soap, to lubricate the dam and facilitate its placement.

1. Rubber dam

The rubber is supplied in rolls, of varying lengths, and usually 15.0 cm in width. Heavy duty rubber is easier to manipulate, but some operators prefer a thinner gauge; Although the rubber is available in many colours, such as ivory, fawn and black, the black dam has the advantage of contrasting in colour with the teeth, which reduces eyestrain and gives improved visibility. To cut the rubber, the operator should stretch the end of the roll while approximately 10.0 cm of dam is cut off with scissors by the assistant. Through the use of this method the rubber can be cut in a straight line, a difficult operation if performed by the assistant alone. Two other forms of dam are available. It may be purchased in pre-cut squares of heavy duty rubber or in an ingenious form with an inflatable surround (Steri Dam) which makes marginal retraction unnecessary. The air is introduced into a valve using the air syringe (figure 7.6).

Fig. 7.6 A sheet of rubber dam with an inflatable retractor. (SteriDam . . . AB SteriScan, Stockholm, Sweden.)

2. Rubber dam punch

The punch (figure 7.7), which has a circular plate with a series of holes of ascending diameter, ranging from 0.5 mm to 2.0 mm, must be capable of cutting perfectly circular holes in the dam, without leaving the punched-out portion attached. Failure to ensure this may lead to tearing of the dam when it is stretched over the tooth or clamp. If the punch is faulty, it should be returned to the manufacturer for renewal of worn parts.

The size of the holes punched in the dam should be related to the size of the teeth to be isolated; thus the largest hole is for large molars and the smallest hole for lower incisors and upper lateral incisors. In order to produce a leak-proof seal around the neck of the tooth, the smallest hole that will pass over the crown, without tearing the rubber, should be punched. Some teeth are of such a size that a larger hole is required than may be cut with the punch, therefore two holes, almost superimposed, should be punched

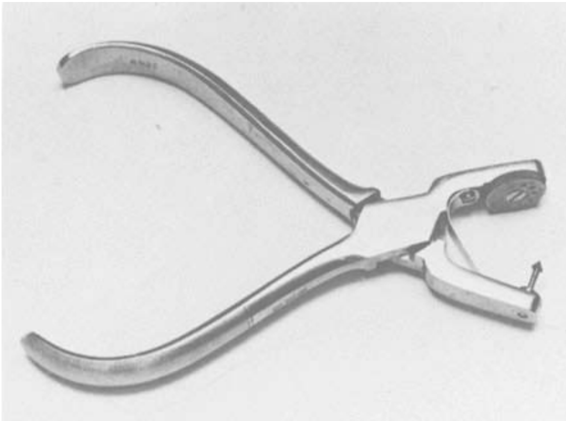

Fig. 7.7 Ash rubber dam punch (Ainsworth).

to produce a large oval shape which will accommodate the crown or clamp without incurring the risk of splitting the dam.

The moving parts of the punch should be oiled from time to time, but the punch should never be sterilised by boiling or autoclaving because of the tendency of the punch-plate orifices to rust and thereby become inefficient. After use, the punch may be rubbed down with a solution of a quaternary ammonium compound, e.g. chlorhexidine (Hibitane).

3. Rubber dam clamp forceps

The clamp forceps (figure 7.8) are designed for transferring the clamp to and from the tooth. The beaks have small bulbous ends for location into holes on the jaws of the clamp, so that the clamp may be sprung open and placed over the crown. Many of the forceps available have a sharp groove on the outer surface of the beak where the bulbosity ends, and this tends to prevent withdrawal of the forceps after the clamp has been settled into position. In consequence, the clamp may be pulled off inadvertently or pushed into the gingivae. To overcome this problem, the bulbosities should be ground to the minimum size required to hold the clamp and then smoothed and rounded, so that no further difficulty will be experienced in detaching the forceps from the clamp.

The forceps may be sterilised by routine methods.

Fig. 7.8 Ash rubber dam clamp forceps (Stokes). Three examples of rubber dam retractors: Left, Fernald frame, Top right, Östby frame, Bottom right, Starlite Visi-frame.

4. Rubber dam clamps

Many different makes of clamp are available, but the majority of teeth can be clamped by the use of six different patterns of the Ivory and Ash ranges. Nos 00, 1, 2, 9, 10 and 11 (figure 7.9).

Other useful clamps are 7, 14, 14A, 15, 26, 27. The last two are wingless clamps. The main point to be

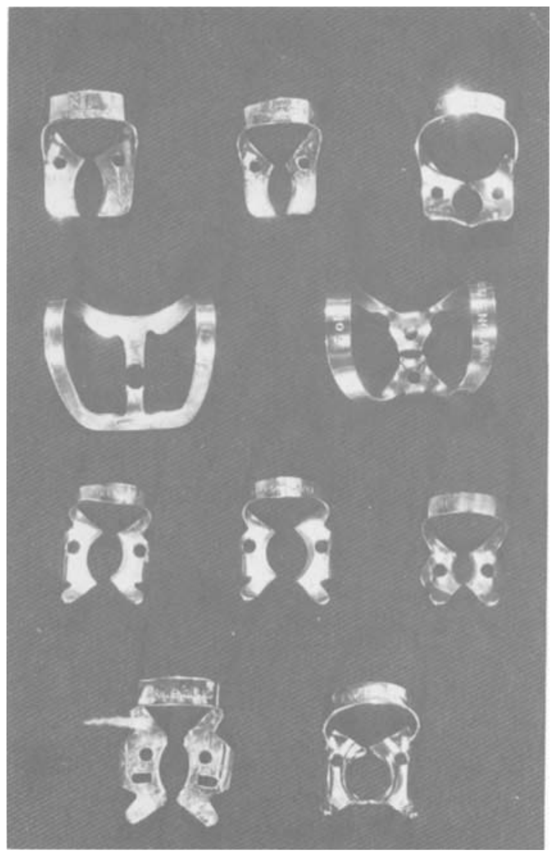

Fig. 7.9 Rubber dam clamps. (To satisfy most requirements.)
Top (left to right) numbers, 26, 27a, 8a,
Second row .... Ferrier, 9 (Butterfly)
Third row .... 10, 11, 1.
Bottom row .... 7a, 14a.

borne in mind, when choosing a clamp, is that bulbous and partly erupted teeth require clamps which have jaws in the shape of a large arc of a small circle. Jaws with flatter arcs will tend to pivot on the more bulbous surface and the clamp will be easily dislodged (figure 7.10).

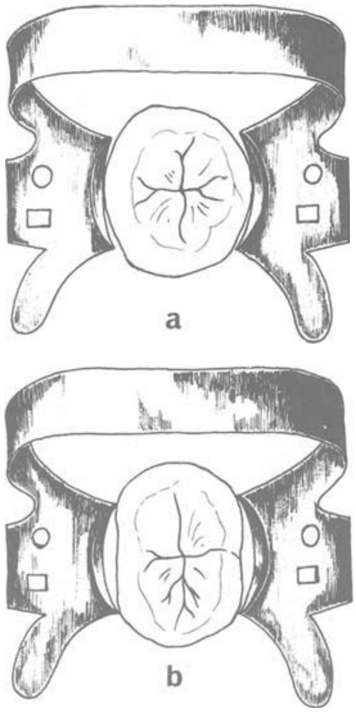

Fig. 7.10 (a) The clamp in this illustration will tend to pivot and fly off the tooth. This may be corrected by using a clamp with more convex jaws or by grinding out the jaws to the required shape. (b) The correct relationship of the jaws of the clamp to the tooth.

Broken-down crowns or those with insufficiently retentive walls (e.g. under-erupted teeth) may be clamped with the Ferrier Clamp, which resembles a butterfly clamp (Ash 9 or 15) and may be used on anterior teeth, premolars and small molars. It is designed to exert pressure in a gingival direction and thus produce some degree of retraction of the gingivae. This is of benefit for the isolation of Class V cavities.

In addition to the patterns mentioned, the Hatch cervical clamp is invaluable for Class V restorations (figure 7.11).

5. Rubber dam frame

The Fernald metal frame (figure 7.8) or the Östby plastic frame have been devised to retract the peri-

Fig. 7.11 Hatch cervical clamp.

meter of the rubber sheet and hold it away from the area of operation. The Fernald frame is to be preferred when working on posterior teeth, although it is perfectly satisfactory for anterior teeth, whereas use of the Östby frame should be reserved for anterior teeth because, when used in the posterior regions, it tends to impede access to the teeth.

Techniques for the application of rubber dam

Rubber dam may be applied to one or more teeth, depending on the nature of the operation and the degree of access required. One or more clamps may be used to hold the dam in place and ligatures can be tied to keep the rubber margins tucked into the gingival crevices. There are numerous ways of applying rubber dam and some of those most frequently used will be described.

1. Application of rubber dam to a single tooth

The rubber dam should be placed on a single tooth when the presence of the clamp will not hinder access to a cavity or a root canal. This will be feasible for the majority of Class I restorations and for many endodontic treatments.

(i) the rubber dam sheet should measure 15.0 cm x 10.0 cm and the hole should be punched in a position which will allow the dam to extend beyond the lips in such a way that a frame can be attached without getting in the way of the operator's hands. For an upper incisor, the hole is punched 3.5–4.0 cm from the upper border of the dam and close to the mid-line. For an upper molar, a larger hole is punched at the same height and about 4.0–5.0 cm from the lateral border. Experience will dictate the ideal position for perforating the dam for each tooth, but when there is any doubt, the rubber should be placed across the mouth and then pressed on to the tooth to be isolated and a mark made with a pen at that point.

(ii) A suitable clamp is selected and placed on the tooth. If it sits firmly, close to the neck of the tooth, without causing discomfort, it is removed. The undersurface of the dam, in the region of the hole, is smeared with vaseline or brushless shaving-soap to aid its passage over the tooth.

(iii) The rubber is stretched to enlarge the hole and pulled over the tooth and, using a length of dental floss, is pulled past the contact areas. If there are rough restorations in the proximal surfaces which prevent the rubber from passing the contact area, they should be smoothed with sandpaper discs and strips.

(iv) The clamp is picked up in the forceps and, while pressing the rubber up to the cervical region of the tooth with thumb and forefinger, the clamp is placed gently onto the tooth. The forceps are not removed until it is seen that the clamp is firm and is not impinging on the gingivae and causing pain. It is advantageous to seat the palatal jaw first and then bring the labial jaw into position, pivoting about the palatal point of contact.

(v) The frame is placed in such a way that the rubber is held back, without occluding the nostrils or occasioning the patient any discomfort, and a cotton napkin or sheet of absorbent paper is placed between the lower lip and the rubber to soak up any saliva which might collect at the corners of the mouth. A saliva ejector is placed in the floor of the mouth.

Modifications of technique

Instead of placing the rubber prior to clamping the tooth, the clamp may be attached to the rubber by stretching the rubber so that the clamp may be slipped into the hole, thus spearing the rubber onto the wings. The clamp is placed on the tooth and the rubber is dislodged from the wings on to the tooth, with a probe or a plastic instrument (Ash 156). When using a wingless clamp, it is placed on the tooth and the hole in the rubber is pulled over the bow and then over the jaws of the clamp. This clamp is the easiest to apply and is less bulky than a clamp with wings.

2. Application of rubber dam to several teeth

When proximal cavities are to be restored, or a tooth is partially erupted or of such a shape that a clamp will not hold, the dam should be clamped to an adjacent tooth.

Furthermore, the presence of a clamp too close to the tooth being treated might interfere with access or with the manipulation of endodontic instruments. In such cases, the clamp is placed on a tooth distant from the tooth under treatment, while the rubber is perforated and tucked into the gingival crevices. If necessary, another clamp is attached at the other side, to prevent the rubber slipping off the teeth, Alternatively, the rubber may be carried up past the contact areas with dental floss, which is pulled tight around the necks of the teeth and tucked into the gingival crevices with a flat plastic instrument and a knot is secured with a half-hitch. The two knots most frequently used are the surgeon's twist and the clove-hitch (figure 7.12), the latter being used on teeth with inadequate retention, because it pulls back the rubber and holds it more securely.

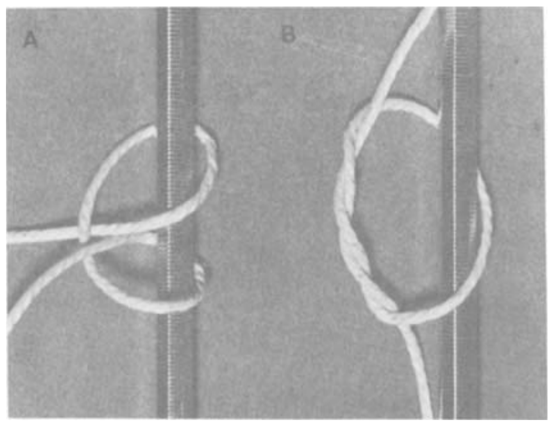

Fig. 7.12 Types of knot used for securing ligatures: (A) clove-hitch; (B) surgeon's twist. Both knots are finally locked by means of a half-hitch.

When placing the dam over a number of teeth, the sheet of rubber is held just below the nostrils and stretched lightly over the teeth to be included. Then the centre of each crown is marked with a ball-point pen, and holes of the appropriate size are punched. The rubber is then stretched to spear the wings of the terminal clamp, which is then placed on the tooth and the rubber is detached from the wings. The inside of the rubber is given a light coating of lubricant and pulled over the teeth so that each crown protrudes through its hole, starting with the tooth most distant from the clamp. Dental floss is used to pull the rubber past the contact areas with a gentle sawing motion and the rubber is tucked into the gingival crevices with a flat plastic instrument. If the holes are small enough, this is accomplished with ease, and frequently it is unnecessary to apply ligatures. When the cavity margin is at or below the neck of the tooth, improved retraction of the dam will be obtained with a ligature. When tying a surgeon's twist, the floss is pulled through the two contacts so that the free ends lie buccally. A double-hitch is then tied and, as the knot is tightened, it is pulled in a gingival direction, while the lingual loop is pressed into the gingival crevice with a flat plastic instrument. When the knot has been tightened to carry the whole circumference of rubber subgingivally, a further half-hitch is tied. The free ends may then be cut off or wound around the frame as a reminder to remove the ligature. A clove-hitch is usually made outside the mouth, slipped over the tooth and, when in place, is similarly secured by means of a half-hitch.

Should it be necessary to include all the incisors and canines, plus the first premolar, an additional clamp may be placed on the contralateral premolar to stabilise the dam (figure 7.13).

Fig. 7.13 Rubber dam held in position by premolar clamps. A restoration is to be inserted in |2 and the rubber is maintained cervically by means of a ligature.

In order to facilitate the passage of the dam between the teeth, the interproximal strip of rubber should be inserted edgeways on and tensed slightly in a bucco-lingual direction, in order to present the minimum bulk to the interspace. If, despite this precaution and the use of dental floss to exert pressure on the rubber, it should prove impossible to negotiate a very tight contact, the teeth may be separated temporarily by inserting a silver wedge or forcing a thumbnail between the teeth. The separation is terminated instantly when the rubber has passed the contact.

When removing the dam, the frame is taken away first, then the ligatures are cut and slipped out and the rubber is pulled away from the teeth so that the interdental strips can be cut through and the dam and clamps removed.

Some operators then massage the circulation back into the gingivae for a short while to remedy the temporary pressure-induced ischaemia which may accompany the use of rubber dam.

When the rubber dam is placed on the last-standing tooth, access to the distal surface tends to be obstructed by the posterior part of the dam, pulled forward by the tension from the retractor. B. E. Greenfield suggested a simple, but elegant, modification to a lower molar clamp. A piece of 1.2 mm stainless steel (orthodontic) wire is intertwined through the holes in the clamp and bent backwards to make a flange (figures 7.14 and 7.15).

The flange effectively displaces the dam and improves access.

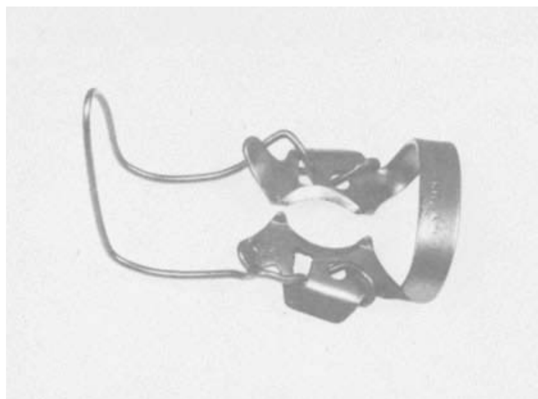

Fig. 7.14 Modified rubber dam clamp for retraction of the rubber posterior to a last-standing molar. Note the enlargement of the two holes occupied by the wire, to make room for the clamp forceps. (Courtesy of B. E. Greenfield.)

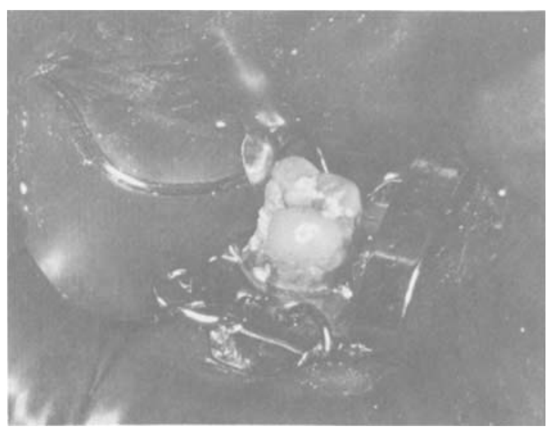

Fig. 7.15 Modified clamp in use, showing vastly improved access to the distal surface. (Courtesy of B. E. Greenfield.)

Hints and precautions

1. Do not use rubber dam when a patient is unable to breathe through the nose.
2. Avoid damage to the soft tissues when applying clamps.
3. Do not place a clamp on a newly-cemented copper band, otherwise it will break down the cement and the band will come loose.
4. Always try the clamp on the tooth before engaging the wings of the clamp in the hole in the rubber dam. It is easier to apply the lingual aspect first.
5. Never place a small clamp on a large tooth. It may fracture and fly off in the middle of treatment.
6. When no local anaesthetic is used, the gingival margin should be painted with topical anaesthetic prior to the application of ligatures.
7. If a ligature will not hold, owing to an underdeveloped cingulum or a large cavity, the rubber may be held away by twisting up the ends of a length of soft brass wire, or 15 amp fuse wire, which has been looped around the cervical margin.
8. Always remove the frame before taking off the rubber dam, because the tension of the frame on the rubber could make it fly off the teeth and propel a shower of debris into the operator's face.
9. Gingival retraction can be improved by the introduction of an interproximal wedge after placement of the dam. For this purpose Interdens gingival massagers are admirably suited.
10. Figures 7.14 and 7.15 show an ingenious modification of a lower molar clamp, by Greenfield, which improves access to distal cavities.

8

Temporary Restorations and Lining Materials

Temporary Restorations

After caries has been removed from a tooth or there has been loss of tooth structure as a result of trauma, form and function must be restored to normal. Roughly speaking there are two main groups of materials, namely those primarily concerned with the restoration of aesthetics and those, the chief object of which is to restore normal contour and function.

In general there is a sharp division between the groups, but continual research is in progress to develop a restorative material which will fulfil all the stated criteria.

At the present time, the immense backlog of caries demands the use of simple materials, such as amalgam and composite resin, which can be inserted into cavities immediately following their preparation and which do not require the exacting technique required for cast gold.

Nevertheless, irrespective of the material used, a careful technique must be followed if the final restoration is to last for a reasonable time. The cavity preparation plays as important a part as the restorative material, but as this is dealt with elsewhere, in this chapter the emphasis will be placed on the correct handling of the materials, in order to achieve ideal results.

The majority of restorations consist of a base or lining for the protection of the underlying pulp and an outer cover of an insoluble, impermeable nature to restore the contour of the tooth. The need for a lining stems from the harmful effects of many restorations, e.g. thermal conduction by metallic restorations and chemical irritation from silicate, acrylic and composites. A lining will also mitigate the effect on the pulp of osmotic and bacterial irritation resulting from micro-leakage.

The function of the temporary restoration is to protect the dentine until the tooth may be restored permanently and being of vital importance it deserves separate consideration.

Zinc eugenolate cement

The most commonly used temporary restorative material is zinc eugenolate cement. This is formed by spatulating, to a firm consistency, a mixture of zinc oxide, B.P. and eugenol or oil of cloves. The resulting product sets slowly in contact with saliva to form a moderately hard but brittle cement which has a low compressive strength and consequently is of no value in very large cavities. Copeland *et al.* (1955) showed that the set mass consists of zinc oxide embedded in a matrix of long, sheath-like crystals of zinc eugenolate.

In order to increase the speed of setting, small quantities of various additives are used, such as zinc acetate, zinc stearate and acetic acid. By the incorporation of 0.5–2% of one of these chemicals, the setting time is reduced to a few minutes, thus minimising the danger of premature disintegration of the temporary restoration.

Continuing research has led to an increase in compressive and transverse strength by the addition of polystyrene (10% by weight) to the eugenol (Messing, 1961). Also by combining 67% of ortho-ethoxy benzoic acid with 33% of eugenol in the liquid, and adding hydrogenated rosin and heat-treated fused quartz (5 μm particle size) to the zinc oxide, a similarly improved cement has been produced which may be used for linings, for sealing coronal access cavities during endodontic treatment, and for the cementation of crowns, inlays and bridges. It has been demonstrated that ortho-ethoxy benzoic acid will chelate with zinc, probably by forming an ionic complex with divalent metallic ions. The cement is easier to carve when hard, due to the incorporation of fused quartz, and appears to have markedly better physical properties than zinc oxide and eugenol cement, showing compressive, tensile and shear strengths close to those of zinc phosphate cement (Civjan and Brauer, 1964).

Uses of zinc oxide cement

It is possible to mix a quantity of zinc oxide/eugenol cement at the start of an operating session and to store it in the hollow of the glass stopper of a jar containing calcium chloride or silica gel to abstract the moisture from the air in the jar. This prevents hardening of the cement, keeping it plastic until required. The chief drawback to this measure is the prolonged setting time of the cement in the tooth, the set being accelerated solely by the saliva. Moreover, the patient is subjected to the highly aromatic flavour of eugenol until setting has occurred.

At present various proprietary cements are available which contain zinc acetate or zinc stearate. Their setting times have been reduced to a few minutes with consequent ease of insertion and increase in comfort.

Manipulation of zinc eugenolate cement

The cement should be mixed to a heavy paste, the consistency of putty, incorporating the maximum amount of powder so that it may be manipulated lightly between thumb and forefinger without sticking to the skin. Thus it can be rolled into a ball and impaled on a probe, carried to the cavity and deposited there. Packing is best effected by the use of a tightly bound small pledget of cotton-wool, damped with water. Alternatively, plastic instruments may be used after dipping them in dry zinc oxide powder to prevent their adhesion to the cement.

When zinc oxide cement has been placed in a completed cavity as a temporary restoration, some of it may be left later as a sedative base under the restoration. If, however, it is used in a cavity prepared for a cast gold restoration, its subsequent removal may be facilitated by coating the cavity with a film of vaseline and incorporating a few wisps of cotton-wool in the cement, which should be mixed with a high powder:liquid ratio, which also decreases its adhesion to the cavity.

Phosphate cement

Phosphate cement may be used as a temporary restoration provided firstly, that the cavity is not too large and secondly, that there is no heavy masticatory force concentrated on it. Otherwise a better temporary restoration may be produced if a copper band, cut free from the opposing teeth, is contoured and cemented around the tooth. This measure is used frequently in endodontia and will be dealt with in chapter 25.

Gutta percha

Gutta percha has long been used as a temporary restoration. It is easy to insert and remove and, being tasteless, does not produce any aversion. However, if left more than a few days it tends to absorb fats from the diet and become foul. Moreover it does not seal the cavity well and, probably as a result of leakage of fluids, the dentine tends to become exquisitely hypersensitive. Its use should be confined to fully-lined cavities or those in pulpless teeth. It is soluble in chloroform and eucalyptus, therefore use may be made of this fact to aid its adhesion to the cavity walls by swabbing the cavity with either liquid and, by the same token, sponging the surface of the gutta percha will leave a smooth finish. Pulpal and axial dentine, unless covered by cement, should not be swabbed with chloroform, which acts, in a deep cavity, as a pulpal irritant. Nor should chloroform contact a calcium hydroxide base as it would dissolve it. Gutta percha should never be overheated because the more volatile constituents are lost and the residue becomes brittle and unworkable. After warming it over a flame it should be pressed between thumb and forefinger to ascertain the degree of softening, and finally, before placement in the cavity, it is advisable to test the temperature on the back of the hand. If it is placed in an anaesthetised cavity when overheated, there is every possibility that irreparable pulpal damage may ensue. The sign denoting overheating of gutta percha is bubbling of the surface.

Lining Materials

Calcium hydroxide

A large amount of evidence has been built up in the past three decades to show that, of all the materials at present in use as pulp protectives, the most consistently beneficial to the pulp is calcium hydroxide. Slaked lime, formula $Ca\ (OH)_2$, has a pH of 9.0 and is mildly caustic when applied to the living pulp. However, it has been shown to stimulate the odontoblasts to form secondary dentine when placed on the dentine close to the pulp and, in addition, to stimulate recalcification of softened dentine between the caries and the pulp (Massler, 1962).

It may be used in two distinct forms. Firstly, as a suspension in carboxymethyl-cellulose, e.g. Calcipulpe (Septodont) and Pulpdent (Rower), which does not set hard and consequently must be covered with a cement which hardens; and secondly, as one of the proprietary brand formulae consisting of a two-paste system, basically calcium hydroxide, which when spatulated sets quickly to form a solid of low compressive strength. Examples of this two paste system are Dycal (Caulk), Life (Kerr) and Procal (3M). The formulation of Dycal is reproduced below from the 1975 edition of accepted Dental Therapeutics:

Dycal
Catalyst
Calcium hydroxide 51.0
Zinc oxide 9.23
Zinc stearate 0.29
Ethyl toluene sulphonamide 39.48

Base
Titanium dioxide 45.1
Calcium tungstate 15.2
Calcium hydroxide 0.6
Glycol salicylate 39.1

The effect on the pulp of the three cements, mentioned above, is similar, but the setting times of Procal and Life are longer, thus making their placement easier in cavities with limited access.

These cements may be used under silicate, composite and amalgam and they are effective as barriers to thermal and chemical irritation in fine layers. However, Fisher and McCabe (1978) showed that Dycal, Procal and Reocap (a capsulated cement) were bactericidal against Streptococcus Mutans and Lactobacillus Casei; both isolated from carious dentine, whereas Hydrex showed no antibacterial properties. Hydrex was modified subsequently, the new formulation being marketed as Life.

The antibacterial properties of these cements stem from the calcium hydroxide which is in excess of that needed to chelate with the salicylate of the base. There is a greater residual hydroxide content in the set Dycal than in Hydrex, thus producing a higher final pH under clinical conditions. Fisher and McCabe postulate that the hydrophobic matrix of Hydrex (paraffin) as opposed to the hydrophilic base of Dycal (Ethyl Toluene Sulphonamide) does not allow diffusion of water into the mass and consequent egress of hydroxide.

When using these cements which set on contact with water, cavities must be dried thoroughly, all excess material must be removed from the cavo-surface angles and the material allowed to set completely before placement of the appropriate restoration.

Cavity liners

In 1950, Zander *et al.* described a lining varnish for coating the walls of cavities. This consisted of a suspension of calcium hydroxide in a solution of polystyrene and chloroform. This was for use as a barrier to chemical irritation from silicate and phosphate cements.

Brannström & Nyborg, in 1968, described 'Tubulitec' (Dental Therapeutics A. B., Sweden), a liner similar to the above, but incorporating di-iodo-dithymol, a bacteriostatic agent, and calcium fluorophosphate, a cariostatic fluoride.

Tubulitec was shown to inhibit bacterial growth between the cavity walls and the restoration and to reduce the solubility of the dentine composing those walls.

Grieve (1973) found that Tubulitec gave no greater protection against caries than did a plain copal-ether varnish. However, his study suggested that the extent of spread of caries around amalgam restorations is markedly reduced when a liner is used, although its occurrence is not prevented entirely.

Phillips *et al.* (1969) stated that films of liner become porous and thus allow percolation of fluids around permanent restorations, and Wilson and Smith (1978), investigating the behaviour of a liner under several types of amalgam, concluded that the resistance and retention form in a cavity may be reduced, while marginal leakage may be increased. Such defects relate to the thickness of the liner and whether sufficient time has been allowed for it to set.

The author has used Copal-ether varnish under amalgam for many years and is not convinced, on clinical evidence, that it is either harmful or beneficial. In the final analysis, the care with which the restoration is condensed and finished and the cavity walls prepared and finished, is the paramount factor. No varnish will protect against poor technique.

Zinc eugenolate cement

Zinc oxide/eugenol cement has a time-honoured association with conservative dentistry because of its anodyne action on an inflamed pulp, after it has been substituted for caries or an irritant restoration. It takes too long to set, however, for the immediate placement of a restoration, but this problem may be overcome by the addition of accelerators. This nevertheless produces a lining of poor compressive strength (approximately 2000 lb/in^2 after 5 minutes).

By the addition of 10% by weight of polystyrene to the eugenol, this five-minute figure may be raised to 5000 lb/in^2, an increase in compressive strength sufficient to withstand direct condensation of amalgam (Messing, 1961).

Similarly, the addition of ortho-ethoxybenzoic acid and quartz has brought the zinc eugenolate cements into the category of direct lining materials. It is difficult, however, to manipulate minute quantities of the cement in shallow Class II cavities where, in fact, phosphate cement would be adequate, but in deep cavities, where the base may be given adequate bulk, it is ideal.

It should be inserted in the manner described for zinc eugenolate temporary cement. Mixed to a putty-like consistency, the pellet of cement is carried to the cavity on a probe, care being taken to avoid depositing any on the walls, and packed home with a tightly-rolled cotton-wool pledget, slightly damped with water. After one minute, any excess cement may be removed with a few strokes using a cleoid excavator.

Zinc oxyphosphate cement

The first oxyphosphate cement was introduced by S. S. White in America in 1879, having been developed by a Dr. Weston. Since then it has enjoyed, and still enjoys, great popularity as a lining material and cementing medium. An average cement consists of zinc oxide, modified by the addition of magnesium oxide, with a liquid composed of phosphoric acid modified with zinc and aluminium phosphates.

It makes an excellent base in shallow cavities because of its thermal insulation property, but it tends to have a high pH at the time of insertion which could cause pulpitis in a deep cavity where the pulpal dentine is thin.

If the material is manipulated correctly it attains neutrality within 24 hours, hence it may be used in those deep cavities which have been filled previously and in which the pulpal dentine is sclerosed.

Being radiopaque, it is easily visible on a radiograph and its absence under a silicate or radiolucent composite restoration is obvious. It has been recommended for many years as a base under silicate, but recent research has cast doubts on its adequacy to prevent chemical irritation of underlying pulp tissues in deep cavities. It is recommended that, if it is to be thus used, a sub-base of calcium hydroxide be inserted.

Manipulation of zinc oxyphosphate cement

A clean polished glass slab and a stainless steel spatula are required. In hot weather the slab should be cooled, but not below the dew point of the room. The phosphoric acid should be dispensed immediately before mixing, because it is hydroscopic and, depending on the temperature and humidity, would gain or lose water if exposed to the air for any length of time. This would produce a corresponding speeding-up or slowing-down of the setting reaction. Similarly the liquid bottle must be kept tightly stoppered.

The reaction which occurs when the powder and liquid are mixed is exothermic. Any rise in temperature of the mix speeds up the reaction, so that setting is advanced before sufficient powder has been incorporated. This results in a mix with higher residual acidity which is more irritant to the pulp.

By slaking the drop of liquid with a few particles of powder for about 30 seconds prior to mixing, the setting time is prolonged. This gives a longer working time, which may be further increased by incorporating small increments of powder over a large area of the slab, thus dissipating the heat of reaction. The average mixing time is 1–1½ min, depending on the manufacturers' instructions, which should be followed if the best results are to be obtained.

The consistency required for use as a cavity lining is that of sticky putty. A small quantity of cement is picked up on the point of a right-angled probe (Ash No. 6), lightly rolled into a ball between thumb and forefinger, replaced on the tip of the probe and deposited on the floor of the cavity. It is tapped home with instruments which have been dipped in methylated spirit, to prevent adhesion of cement to metal. Before picking up the cement, all excess spirit is shaken off the instrument. Pluggers, such as the Porro Special A plastic or Ash G plastic, are now used to tap the cement home into the cavity. In the Class II cavity, the cement is pressed against the axial wall with a double-ended flat plastic instrument (Ash No. 156), the axio-pulpal line angle is moulded to a rounded angle with the same instrument and a probe or small excavator is used to remove any excess from the cavo-surface angles and from the retention grooves or pits.

Removal of excess cement from the cavity, especially in hot weather, means unnecessary work plus the added risk of loosening the whole mass by manipulation of partially set cement. Consequently, the minimum quantity should be inserted. The cavity must be dry, otherwise the cement will not adhere. However, the dentine must not be dessicated by the use of absolute alcohol with or without a blast of hot air. This will cause injury to the odontoblasts, which will be further intensified by the irritancy of phosphoric acid absorbed from the cement by the dessicated dentine. Any trimming with burs should be delayed for at least ten minutes after insertion, to avoid dislodgement, and should be carried out with sharp burs operated at moderate speed (approximately 6000 rpm) and exerting minimum pressure.

Once the lining has been inserted, it should be protected from moisture for at least 2 min, otherwise a weak brittle cement is produced as a result of water contamination and washing out of phosphoric acid.

It is imperative that the depth of the lining be as small as is consistent with its function. In most cases, a depth of 0.5–1.00 mm will suffice. If inadequate space is left for the restorative material, it will be weak and apt to fracture under stress.

The practice of including a small quantity of silver/tin alloy, when mixing zinc phosphate cement, has long been carried out by clinicians in order to strengthen a base used to build up the contour of a preparation for a full or partial veneer crown.

Mahler and Arnem, in 1962, demonstrated that whereas this had no apparent influence on compressive strength, it resulted in a 100% increase in transverse strength, so that where the cement was subjected to bending stresses or combined shear and tension, it was of distinct value.

Polycarboxylate cement

In 1968 a new cement was developed by D. C. Smith, which consisted of a concentrated aqueous solution of polyacrylic acid which reacted with zinc oxide to form a hard set cement. The main advantages of this cement lie firstly, in the reactivity between polyacrylic acid and the calcium of enamel and dentine producing a chemical bonding. Secondly, there is a complexing between polyacrylic acid and proteins which may play a part in increasing adhesion. There is also an adherence to some metals, but it is essential that both the tooth and the metal be free from saliva and oily contaminants, otherwise the adhesion is nullified.

The powder to liquid ratio recommended is 1.5: 2.0 by weight. When used for a lining, the cement is mixed to a putty-like consistency, whereas, when used for cementing an inlay, it may be mixed to a thicker consistency than would be permissible for phosphate cement. This is due to the excellent flow properties which allow the excess cement to escape without hindrance during seating of the restoration.

The cement should be mixed on a chilled slab, to increase the working time, and all the powder should be incorporated into the liquid within 25–30 s. The cement is deposited in the cavity from the point of a probe and, as with phosphate cement, instruments used for shaping it are dipped in alcohol, excess of which is shaken off.

Prolonged manipulation beyond the point of early polymerisation results in lack of adhesion. This point is observed as the formation of fine filaments (cobwebbing), and subsequent trimming should be resumed only after the material has hardened.

The cement also appears to be non-irritant, showing pulpal reactions comparable to those obtained from the use of zinc oxide/eugenol controls (Smith 1968), which is apparent clinically when one compares the pain associated with cementation using phosphate cement with the absence of pain when polycarboxylate cement is used.

The compressive strength of the cementing material is somewhat lower than that of phosphate cement but the tensile strength is slightly higher. Adhesion has been shown to be superior to all previous materials and Mizrahi and Smith (1971) have even used the cement successfully to attach orthodontic brackets to enamel, and have found no harmful effect on either enamel or soft tissues.

Richter *et al.* (1970) showed that, under compressive forces, zinc phosphate cement possessed higher strength than either zinc oxide/eugenol/E.B.A. or polycarboxylate cements, whereas all three cements had equivalent tensile strength.

The retentive property of the zinc oxide/eugenol/E.B.A. cement was only half that of the other cements, and it failed consistently under test conditions at the interface between cement and dentine.

From a consideration of these findings it may be concluded that it is unwise to use an E.B.A. cement for the cementation of bridges and crowns and gold inlays.

There is at present some divergence of opinion concerning the efficiency of polycarboxylate cement as a cementing medium for gold inlays.

It has been found that adhesion is greater to enamel and dentine surfaces which have been well smoothed and polished (Mizrahi and Smith, 1971). There is also greater adhesion to stainless steel than to gold, with which the degree of adhesion depends on the same interlocking effect as is found with phosphate cement.

Undoubtedly the retentivity of the preparation and the fit of the casting play a major part in the longevity of the cement bond. Subsequent experience and research should cast more light on this controversial matter.

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9

Amalgam

For many years, until the last decade, only two types of amalgam were available for the restoration of teeth. These were silver and copper amalgam. Now, a new type of high copper amalgam which exhibits superior clinical properties is becoming established and improved and may ultimately replace completely the older amalgams.

The original copper amalgam was used almost exclusively for the restoration of deciduous teeth. It causes severe discolouration of the dentine, but it is less sensitive to contamination by moisture, thus it is especially useful when dealing with very young or troublesome children. Silver amalgam, however, is employed universally as the standard restorative material, except in those areas of the mouth where aesthetics is the prime consideration.

Silver amalgam is a solid solution, consisting of silver/mercury and tin/mercury phases, surrounding particles of the original alloy. The lower the content of these phases in the final amalgam, the greater will be its strength, given that there is sufficient quantity of mercury and that the trituration time is adequate.

The American and Australian Bureaux of Standards have laid down specifications relating to formulation, compressive strength, expansion and flow, and the majority of manufacturers have ensured that their products comply with such specifications. The American Dental Association's specification No. 1 for amalgam, published in 1958, indicates the following general formulation as coming closest in the achievement of the A.B.S. specifications:

Silver – minimum of 65%
Copper – maximum of 6%
Zinc – maximum of 2%
Tin – minimum of 25%

The early amalgams were compounded only of silver and mercury. In fact, in many instances, the silver was obtained by filing a silver dollar. It was found however, that silver produces a high expansion of the restoration, so this problem was overcome by the addition of tin which produces a contraction and, having a great affinity for mercury, speeds up the amalgamation. However, it reduces the compressive strength and increases the flow of the amalgam.

Copper is included because it minimises the flow and increases the crushing strength and setting expansion, whilst zinc acts as a scavenger for oxides formed during manufacture. If the zinc is omitted, the amalgam tends to be dirty and difficult to manipulate, although modern methods of manufacture have largely overcome this problem, especially with regard to the manufacture of a spherical particle alloy.

Alloys with zinc have slightly higher compressive strength and the resultant restoration is less apt to tarnish and corrode and will take a better polish.

Conventional alloy is filed from blocks to produce particles of varied shapes and sizes. The fine grain alloys produce an amalgam possessing superior carving properties and which adapts more easily to the margins. The conventional alloy, however, requires considerable packing force to achieve a satisfactory degree of homogeneity and adaptation.

The content of mercury in the final restoration is of great importance. If it is high, the compressive strength of the amalgam will be decreased and the setting time increased, which will result in a greater risk of fracture of the restoration in the early stages of setting. The majority of correctly proportioned and manipulated amalgams attain close to 90% of their ultimate strength after one hour.

To achieve the best results, only triple distilled mercury should be used.

Spherical alloys

In recent years a new type of alloy, composed of spherical particles, has been developed in Japan and the U.S.A.; its special advantages lie in the lower condensation pressure required and the early achievement of a high compressive strength. The condensation force needed is between one-third and one-half of that which must be applied to a conventional amalgam. Furthermore, a smaller quantity of mercury is required to produce a homogeneous amalgam (e.g. 45 parts of mercury to 50 parts of alloy).

The modulus of elasticity and the tensile strength are higher than those of conventional amalgams after one hour, although measurements made subsequently show little difference, the conventional amalgams tend to be slightly stronger.

Trituration is carried out in the same way as with conventional alloys, but larger condensers must be used with light packing pressures when condensing spherical amalgam.

The width of the condenser should be such that it will just fit the cavity. Carving tends to be more difficult and there is also increased difficulty in obtaining good contact areas with Class II restorations. These problems, however, may be overcome with adequate practice in the technique.

The author has found spherical alloy of great value for certain tasks. It can be condensed more easily around pins and screws. It is easier to condense in cavities where access is limited, e.g. buccal and lingual cavities in second and third molars. It is also useful for retrograde obturation of root apices where visibility is reduced by anatomical factors. Its chief disadvantages are the short working time and slight initial contraction (24 hours) with consequent slight micro-leakage. It has also proved invaluable for the restoration of hemi-circumferential Class V cavities, frequently seen in lower incisors, under the cover of an inadequately cleaned partial denture. In such cases, the ability to insert amalgam with minimum pressure is essential.

One of the chief drawbacks to the use of spherical alloy is the greatly accelerated setting time which drastically reduces the working time. This is not fully counterbalanced by the lower condensation pressure required, because almost the same number of thrusts is necessary to ensure perfect condensation.

If packing is continued after hardening has commenced, a weak restoration will be produced.

High copper alloys

In 1974, a new type of alloy was marketed under the trade name of Dispersalloy (Johnson & Johnson). The alloy was improved by the inclusion of spheres of silver–copper eutectic. Part of the tin was replaced by copper, thus enabling the copper to react with the remaining tin with consequent reduction of the amount of gamma 2 phase in the set amalgam. Duperion *et al.* (1971) showed that the decreased gamma 2 phase resulted in a decrease in corrosion.

The dispersed phase alloys have been demonstrated to undergo lower dimensional change, lower flow at 3 hours and lower static creep at 7 days. At the end of 1 hour, 24 hours and 7 days, their compressive strength is higher, but of even greater clinical significance are the increased early tensile strength and the resistance to corrosion and tarnish.

There are now numerous binary or ternary alloys available and research is continuing to ascertain the best combination. The greater time that Dispersalloy has been in use has shown that it has greater resistance to marginal fracture. Other materials such as Indiloy, which embodies a quaternary spheroidal particle composed of silver–tin–copper–indium, have shown great promise, but only after prolonged clinical evaluation can a final assessment be made.

The high copper amalgams contain, in place of gamma 2 ($Sn_{7-8}Hg$), a reaction product of copper and tin (Cu_6Sn_5). Although they are more resistant to corrosion than conventional amalgams, there is ultimately a formation of solid corrosion products to seal any space which develops due to creep, between the restoration and the walls of the cavity. These corrosion products appear to be relatively resistant to organic acids elaborated in plaque.

Properties of amalgam

Amalgam cannot be considered aesthetic, even when highly polished, hence its use should be confined to those areas where its presence is unobtrusive. It exhibits low tensile strength, a feature often referred to as 'poor edge strength', which indicates that fine edges will tend to fracture under stress. Consequently, it should be used only in cavities with cavo-surface angles of 90° in order to allow the production of a butt-joint.

Amalgam is considerably softer than enamel, has a coefficient of thermal expansion twice that of the tooth and a thermal conductivity five hundred times greater. Under constant stress it tends to cold flow or creep and, because of its electrolytic properties, it is subject to tarnish and corrosion. Porosity in amalgam has a vastly greater influence on its strength than the residual mercury content, but both factors are directly related to the degree of creep. The strength of amalgam is furthermore related to the bond strength between the core (i.e. the 'γ' phase) and the matrix (i.e. $\gamma_1 + \gamma_2$ phases) and the degree of condensation which ensures a high proportion of γ phase in the final restoration. The commonest cause of failure of amalgam restorations is faulty cavity preparation, but faulty manipulation is responsible also for a very large proportion of failures.

The American Dental Association specifies that the flow of amalgam should not exceed 4%. A greater degree of flow indicates a weaker amalgam, the flow potential being related directly to the mercury content and affected by the type and composition of the alloy and the methods of manipulation by chairside assistant and operator.

When cold flow has continued over a lengthy period and amalgam margins have crept away from the walls, metallic disintegration products of amalgam and food particles block the space which develops and cause staining of the adjacent enamel and dentine (Lyell *et al.*, 1964). This staining may be prevented by coating the cavity walls with copal-ether varnish prior to condensing the restoration (Barber *et al.*, 1964).

It has been established that a recently inserted amalgam does not seal the cavity margins completely, although the seal is ultimately improved by the blocking effect of corrosion products in the absence of a copal-ether varnish liner.

Proportioning

Strict adherence to fundamental principles in the use of amalgam is mandatory if satisfactory, enduring restorations are to be produced.

Proportioning of the alloy and mercury may be effected by the use of volumetric proportioners (figure 9.1). Provided the mercury is kept free from supernatant oxides the same volume may be dispensed each time, but the quantity of alloy which enters the well of the dispenser, when it is inverted, will depend on the particle size and the degree of agitation employed. The finer alloys tend to be dispensed more accurately in this way; however, it is more accurate to weigh the corresponding quantities of mercury and alloy in a special balance (figure 9.2).

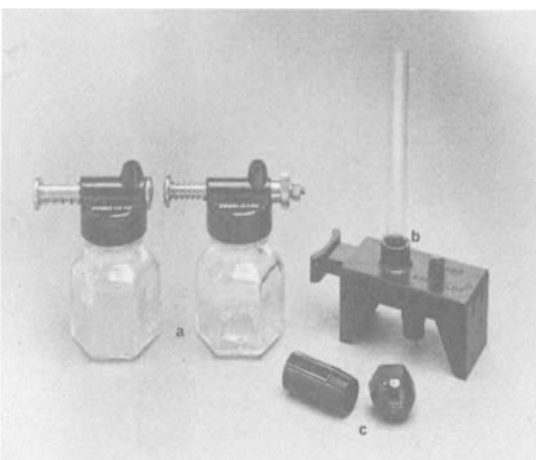

Fig. 9.1 (a) Alloy and mercury volumetric dispensers for Aristalloy amalgam. (b) Pelletted alloy dispenser. (c) Capsule for automatic amalgamator. Photograph reproduced by kind permission of Engelhard Industries Ltd.

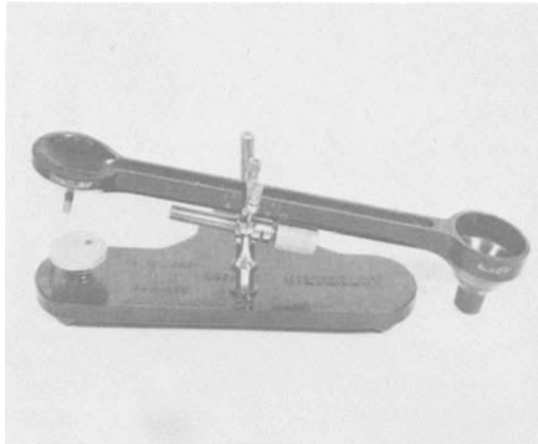

Fig. 9.2 Mercury/alloy balance for use with Wig-L-Bug amalgamator.

Many of the manufacturers now supply their alloy in the form of a tablet, which avoids the time-consuming operation of weighing. Adjustable dispensers are now available which deliver a tablet plus a drop of mercury, the weight of which may be regulated according to the dentist's requirements.

Preparation of the amalgam may be carried out by hand trituration, using a ground glass pestle and mortar, or by the use of an electrically operated mechanical amalgamator (figure 9.3).

Hand trituration takes more time (30–45 s) and

Fig. 9.3 Dentomat mechanical dispenser/amalgamator. This amalgamator has the added advantage that trituration is done under cover. Thus, spillage of mercury and contamination of the environment are prevented.

is subject to individual variations of technique, whereas mechanical mixing produces, in 8–12 s, a standard mix of amalgam ready for use.

Hand trituration

The pestle and mortar must be clean and dry and free from any residue of old set amalgam which would contaminate a new mix. The inner ground-glass surface should be rough, in order to aid the wetting of the alloy particles by the mercury. If in time the surface becomes smooth, it may be reconstituted by triturating some carborundum powder for 20–30 s, then wiping the pestle and mortar clean with absolute alcohol.

Having placed the correct proportions of mercury and alloy in the mortar, the pestle is held with a pen grasp and the mixture is stirred with light pressure until no unamalgamated particles of alloy are visible. A palm grasp should never be employed, because greater pressure is apt to be exerted and this results in comminution of the alloy grains and subsequent contraction of the amalgam. The amalgam is picked up in a cotton napkin with a sweeping action and is mulled gently to complete the amalgamation process. Then it is placed back in the mortar for transference to the cavity. When ready for use, the amalgam should exhibit a homogeneous shiny appearance.

The proportions of alloy and mercury depend on the operator's technique. The majority of dentists use a 5:7 ratio of alloy to mercury, but Eames (1959) recommends the use of equal parts of alloy and mercury which are triturated in a mechanical amalgamator, giving a greatly increased mixing time. This amalgam requires minimum expression of excess mercury and has a higher initial compressive strength. Heavy condensation pressure is necessary with the Eames technique, using small condensers.

It is important to remember that low mercury mixes set more quickly than conventional amalgams, hence speed is essential when packing.

Amalgam must never be handled because it may be contaminated with sweat, and, if it contains zinc, the water is hydrolysed by the zinc with the production of hydrogen bubbles. This causes porosity in the amalgam, plus delayed expansion of a high order, which may be sufficient to cause pain or even fracture a cusp, and which ultimately will produce corrosion and weakening of the restoration (figure 9.4).

Apart from the harmful effect of sweat on amalgam, any handling of unset amalgam with consequent absorption of mercury may lead ultimately to mercury intoxication or poisoning. Deaths have been reported following long term misuse (Cook and Yates, 1969). Any mercury which is expressed from amalgam should be collected in a water-filled container. It should never be dropped onto the floor because of the danger of inhaling mercury vapour from droplets which tend to lodge in carpets, between floorboards and under cabinets.

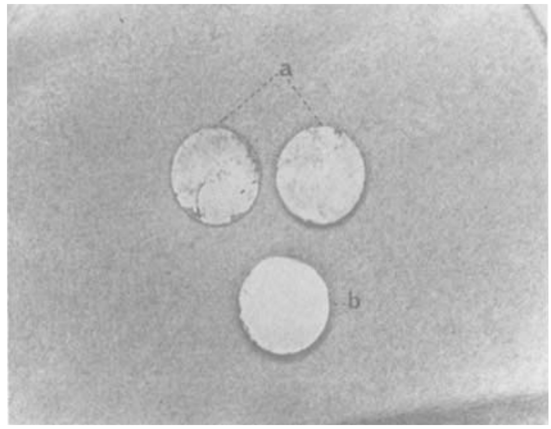

Fig. 9.4 Specimens of a zinc-containing silver amalgam. polished and etched to show: (a) corrosion of amalgam contaminated with saliva during condensation; (b) amalgam condensed in the uncontaminated state. Note the absence of corrosion.

Guidelines For Handling Mercury

The recently-published report, Environmental Mercury and Man (Central Unit on Environmental Pollution, Paper No. 10, HMSO, 1976) has revived public interest in mercury poisoning hazards, particularly in high risk occupations such as dentistry.

The following guidelines were prepared by Professor G. S. Nixon and Dr Christine Helsby of the Turner Dental School in Manchester and are reproduced here by kind permission of the British Dental Association.

All personnel concerned with the handling of mercury in any form should be acquainted with the potential hazards of this metal. Personnel should also receive instruction in the safe handling procedures needed to deal with any mercury spillages together with suitable methods for the disposal of contaminated materials. The need for routine personal hygiene should be appreciated to minimise the possibility of skin absorption of mercury.

1. Personal hygiene

(a) Since mercury can be absorbed through the skin, it is essential for hands to be washed immediately after any handling of metallic mercury or contaminated equipment. Hand contamination can be minimised by the use of disposable plastic gloves or by the application of barrier cream. Hand washing facilities should be readily accessible and include hot and cold water, soap, towels and nailbrushes. Ideally, a liquid soap dispenser, disposable paper towels and elbow operated taps are recommended.

(b) Mercury vaporises readily even at room temperature and can be absorbed by inhalation. Eating, smoking, drinking and the application of cosmetics should not take place in the dental surgery and personnel who are working with mercury should not undertake any of these actions until the hands have been washed.

(c) Cuts in the skin must be protected before any work involving metallic mercury or amalgam is commenced.

2. Working environment

(a) All dental surgeries should be efficiently ventilated, preferably by means of a mechanical exhaust ventilation system. Filters in air-conditioning systems should be checked on a regular basis and changed as necessary. The ventilation system should be well maintained.

(b) Floor coverings in dental surgeries should be of the linoleum or polyvinyl chloride type with the minimum of cracking and there should be the minimum number of joins. If possible the edges of the floor covering should extend a short distance up the wall to eliminate crevices and in addition any joints should be filled. Tiled floors should be avoided and carpets should never be used.

(c) Dust traps should be avoided, e.g. open shelving should be replaced by closed cupboards.

(d) All operations involving the use of mercury should be confined to a single designated area in the surgery. This area should be kept free from any other equipment, away from direct heat, and also be well ventilated. The work surface itself should be of a smooth impervious material such as formica. A wooden or metal bench should be avoided or, if used, covered with plastic sheeting. The wall to bench junction should be sealed and covered to prevent mercury accumulating in inaccessible areas at the back of the bench. As an additional precaution, the working surface should be cleaned on a weekly basis with a mercury suppressant such as 1% polysulphide solution.

(e) Cleaning equipment used in the dental surgery itself should not be used in any other area. The preferable cleaning technique is to use a damp mop. A conventional vacuum cleaner should *NEVER* be used as this will increase the atmospheric concentration of mercury vapour. Additionally, once a week a mercury suppressant such as 1% polysulphide solution can be used to reduce any contamination of the floor covering to a negligible level.

3. Procedure for operations involving the use of mercury

(a) Operations involving mercury such as in the preparation of amalgam should be done over a suitable drip tray. Triturators or other equipment used in conjunction with mercury can be placed on a shallow tray large enough to catch any stray droplets.

(b) The use of funnels and dispensers is recommended to reduce the possibility of mercury spillage. Such equipment must be maintained in good working condition. Similarly, the use of encapsulated material with predetermined amounts of mercury will help to reduce the possibility of mercury spillage.

(c) To reduce hand contamination disposable plastic bags may be used for enclosing squeeze cloths when expressing excess mercury from a mix of amalgam.

4. Storage of metallic mercury and waste mercury material

(a) All mercury, including waste and amalgam residues, should be stored in a cool place in a well-sealed clearly labelled container. Waste mercury should not be poured down the sink, placed in open waste bins, nor kept in beakers or other open containers. Suitable containers include plastic, glass and ceramics; metal containers should be avoided. Plastic containers are preferable due to their greater durability.

5. Procedure to deal with mercury spillage

(a) Any mercury spillage must be cleaned up immediately.

(b) In no circumstances should a vacuum cleaner be used for cleaning up mercury spillages.

(c) All the required equipment for dealing with a spillage should be readily available and checked routinely. Such equipment should include disposable plastic gloves, paper towels, a bulb aspirator for the collection of large drops of mercury, a suitable container fitted with a seal, and a mercury absorbent paste (equal parts of hydrated calcium oxide, flowers of sulphur and water). Or alternatively a commercial mercury spillage kit can be used.

6. Disposal of waste mercury and contaminated materials

(a) All waste mercury, including pieces of amalgam and the results of spillages, should be kept in a labelled sealed container preferably under water until sufficient has accumulated for return to the supplier for the purpose of recovery.

(b) Articles contaminated with mercury, e.g. squeeze-cloths, paper tissues and paper towels should be kept in a labelled sealed container until disposal is possible. Polyethylene bags are suitable for this purpose. Prior to disposal the container should be stored in a safe cool place.

7. Monitoring for mercury exposure

If there is any reason to suspect a serious mercury spillage or atmospheric contamination by mercury, the concentration of mercury vapour in the air should be measured and compared with the threshold limit value for the eight hour working day (presently 0.05 mg Hg per cm). Additionally, the personnel should undergo urine or other forms of biological monitoring. It is recommended that personnel who are routinely exposed to mercury should undergo some form of monitoring at regular intervals.

Exclusion of moisture

Amalgam may be protected from contamination by saliva by the use of cotton-rolls and an efficient saliva ejector. However, in some mouths and in certain situations these measures are inadequate, so the use of rubber dam, when feasible, is indicated. When all methods of isolation are impossible, as may be the case in dealing with subnormal children or when restoring buccal subgingival cavities in maxillary third molars, a zinc-free alloy should be used.

Removal of excess mercury

Excess mercury should not be expressed before inserting the first portion of amalgam into the cavity, because, being too dry, the mercury is not brought to the surface and layering of the amalgam results, with consequent reduction of compressive strength. When the first layer is rich in mercury, condensation of further increments brings the mercury to the surface making a homogeneous restoration. It is essential to remove the supernatant mercury-rich layer from time to time, otherwise it may be trapped in the depths of the amalgam and constitute a weakness, the surface being subject to tarnish and corrosion in juxtaposition to the mercury-rich layer. Excess mercury may be expressed from amalgam with a chamois leather squeeze cloth or a four-fold napkin. Partially set amalgam must be discarded. If it is reworked with added mercury, a weak restoration will be produced which shows marked contraction.

Burnishing

Conflicting views have been expressed concerning the advantage of burnishing the surface of a restoration. Sweeney (1944) condemned burnishing because weak amalgam is pushed ahead of the burnisher up to the margins of the cavity. Phillips (1953) states that burnishing draws excess mercury to the margins, weakening them and rendering them subject to tarnish and corrosion. On the other hand, Kanai (1966) has demonstrated that, with light burnishing, marginal adaptation is markedly improved. He showed that burnishing tends to increase the relative content of residual alloy grains, thus improving the properties of the amalgam margins.

Polishing

After the restoration has been in the tooth for 24–48 h, it should be polished. The reasons for polishing are, (1) the restoration presents a more acceptable surface to the tongue; (2) if left rough, it would tend to harbour food debris; (3) small feather edges of excess amalgam, left beyond the margins, would finally fracture away under stress, leaving rough, jagged edges; and (4) a rough unfinished surface undergoes electrolytic breakdown because of the different phases in the amalgam with the saliva acting as the electrolyte, allowing the formation of corrosion cells (figure 9.5). The production of a highly polished homogeneous surface, known as a 'Beilby layer', endows the restoration with a measure of resistance to corrosion and tarnish, the effectiveness being governed largely by the state of oral hygiene and by the quality of the completed restoration (figures 9.6, 9.7). It is thought that the increased resistance to corrosion after polishing may be due to the preponderance of the silver/tin

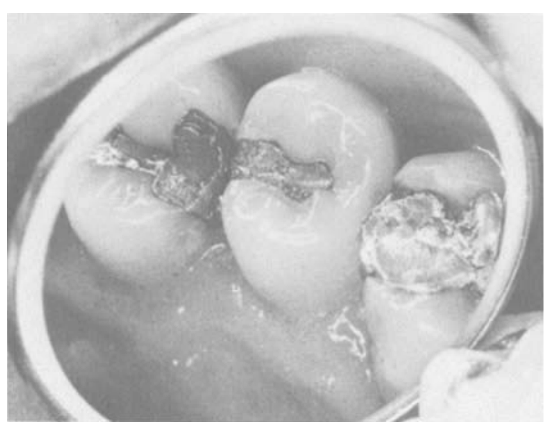

Fig. 9.5 Amalgam restorations showing pitting and corrosion.

Fig. 9.6 6| unpolished amalgam – note granular appearance of surface.

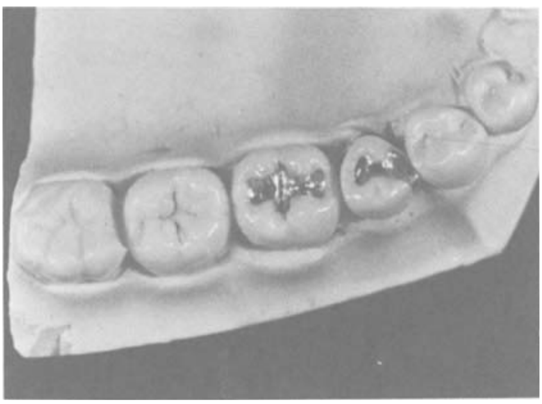

Fig. 9.7 6| restoration polished – note production of 'Beilby layer'.

phase over the mercury/silver and mercury/tin phases. Care should be taken to avoid overheating the amalgam when polishing, which would cause damage to the surface.

Galvanic action

Galvanic shock is apt to occur in some patients following the insertion of an amalgam restoration, especially when it is biting against a restoration of a different metal, such as gold. The chief symptom is a sharp pain elicited on closure of the teeth, bringing the dissimilar metals into contact.

Intermittent contact of dissimilar metals in a conducting fluid (electrolyte) sets up a galvanic cell and one of the metals, i.e. the lower in the electromotive series, goes into solution while an electric current is set up. The metal thus undergoes electrolytic corrosion.

A more chronic manifestation may arise in some patients as a galvanic burn on the tongue or cheek, usually opposite the occlusal line. The restorations in association with this finding are usually tarnished or corroded.

Galvanic shock may be encountered in association with an inadequately-lined restoration, although symptoms tend to vanish as the restoration ages. It is possible that pulpal irritability, following cavity preparation, is increased to a level at which it responds to what normally would be subliminal galvanic currents. Relief is obtained, when such pain occurs following insertion of an amalgam, by painting the surface with a layer of copal-ether varnish. If this does not result in eradication of symptoms, it may be necessary to replace the restoration with one of a different metal and to increase the depth of the cement base.

Pain of galvanic origin, caused by the insertion of a new amalgam restoration can be relieved by the application of a silver nitrate solution to its surface, followed by the precipitation of colloidal silver when eugenol is applied. This technique, recommended by Watson and Wolcott (1975), is supported by evidence of unfailing success in 150 teeth. The mechanism for this treatment is unknown.

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10

Aesthetic Plastic Restorative Materials

There are four main groups of tooth-coloured plastic restorative material. Firstly, there is silicate cement and, in the same group, silicophosphate cement. Secondly, there are the self-polymerising resin restorative materials, thirdly the composite resin materials and, fourthly, alumino-silicate-polyacrylic acid cement (ASPA).

Silicate Cement

Silicate cement is prepared from a powder which consists principally of metallic oxides, and a liquid composed of orthophosphoric acid and buffering salts. On mixing, some of the particles react with the liquid to form an irreversible silicic gel which embodies the remaining particles as a core. The reaction is affected by time, concentration and temperature and the composition of the liquid is balanced by the presence of a critical volume of water in order to control the setting time. Moreover, the water content of the gel is critical and care must be taken to avoid moisture contamination when the silicate cement is soft and also for several hours after it has hardened. On setting there is a small contraction, compensated later by an expansion when water is imbibed.

Silicate may be used only in those situations where an aesthetic result is desired but where, in view of its brittle character, no edge strength is needed. Hence it is indicated for Class III and Class V cavities, but it is of little value in the teeth of mouth-breathers because it tends to become dehydrated and washes out quickly.

Dehydration causes shrinkage and fissuring of the surface and the translucency is destroyed. The restoration becomes opaque and stains readily. Only partial rehydration may occur, but once the gel has lost water, the fissures remain and dissolution is accelerated.

Silicate is of value in mouths subject to recurrent caries because of its fluoride content which renders contiguous enamel immune to decay. It has two main disadvantages, namely its solubility in saliva (figure 10.1) and its high toxicity to the pulp when no adequate protective cement is interposed between restoration and pulpal dentine. It was considered until recently that, even in a deep cavity, a layer of phosphate cement would give adequate protection to the pulp from the irritant effect of fluoride and the continuous leaching of acid. It has been shown as a result of recent research in Japan that a calcium hydroxide base is essential, because the phosphate cement is not impervious to the irritant constituents of silicate cement.

Attempts have been made to improve the tensile strength of silicate by the incorporation of glass fibres, but subsequent experimental evidence has shown that they are of little value.

Despite the deficiencies of silicate as a permanent restorative material, it will give reasonable service if it is mixed and manipulated correctly, although it tends to waste quickly in mouths subject to acid plaque formation.

The liquid is hydroscopic and, if exposed to the atmosphere, it will tend to absorb or lose moisture depending on the relative humidity. There is a critical water content which has a profound effect on setting

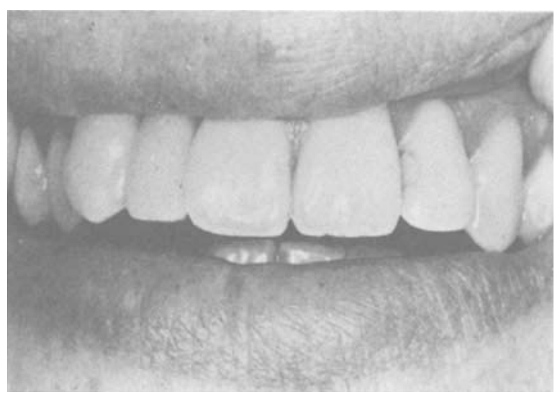

Fig. 10.1 Washing out of silicate restoration in |2.

time, so that any gain or loss will increase or decrease the speed of setting of the silicate. The visible effect of loss of water will be cloudiness due to precipitation and the liquid should be discarded. In order to avoid precipitation, the bottle should never remain unstoppered and the liquid should be dispensed onto the slab immediately before use. Mixing should be carried out over a small area of the slab and completed in as short a time as possible, not exceeding one minute. The gel formation is an irreversible chemical reaction and the mixing time must be limited to the time of reaction, otherwise the gel is broken up and a weak restoration is produced. Silicate may also be supplied in premeasured quantities of powder and liquid in compartmented capsules. When required, a capsule of the appropriate shade is selected and compressed in a small handpress. This pierces the seal, bringing the powder and liquid into contact. The capsule is then placed in a mechanical mixer and agitated for the recommended time. The ball of silicate cement thus formed is ready for use in a short time and a constant, standardised ideal mix is produced.

When powder and liquid are dispensed for manual spatulation, the maximum quantity of powder should be incorporated into the liquid, ensuring that all particles of powder are wetted to produce a homogeneous gel. A cooled slab will alow a greater powder/liquid ratio, but it should not be cooled below the dew point of the room, otherwise there will be condensation of moisture. A thick mix will give a restoration possessing higher compressive strength and diminished solubility, but if the mix should become too dry it must be discarded, and never remoistened with liquid. To test the consistency of the mix, it should not follow a spatula and droop over when the spatula is raised in contact with the cement, but should break leaving a jagged surface. Moreover, on tapping the mixed cement with the spatula, the surface should present a shiny appearance.

When silicate has been prepared it must be inserted into the cavity and pressed home with the minimum number of strokes, after which a suitable matrix is applied and held without movement until the material has hardened.

As previously stated, the water content of silicate liquid is critical, hence it is imperative that the silicate be protected from moisture contamination initially while soft, and subsequently after setting, for a period of several hours whilst the setting reaction progresses to completion.

In the first instance, protection is afforded by the use of rubber dam whenever possible, plus the application of a celluloid or cellulose acetate matrix which also prevents loss of water by evaporation.

After removal of the matrix, the restoration should be coated with a layer of copal-ether varnish which prevents contamination by saliva.

Other than the removal of any excess which interferes with mastication or causes discomfort, no finishing should be attempted until a later visit. Gross excess should be removed with a coarse sandpaper disc or a white Alpine abrasive stone coated liberally with vaseline and used at low speed and with minimum pressure. Following such adjustment, the restoration must be re-coated with varnish before the patient is dismissed.

Finishing

Although it is ideal to leave unblemished the smooth lustrous surface produced by contact with a metal or celluloid strip, in practice this is rarely possible if contour and marginal excess are to receive due attention. Thus whenever possible the surface should be left untouched, but margins may be reduced by planing with a sharp chisel or scaling instrument and finishing off with sandpaper discs or white Alpine stones coated with vaseline until the restoration is flush with the enamel. A fine finish may be produced by the use of a rubber porte-polisher cup with a fine abrasive paste, but once the original gloss has been removed, it can never be restored.

Mixing technique

A thick glass slab, clean and dry, must be used in conjunction with an agate or tantalum spatula. Stainless steel is too soft and the silicate particles would tend to abrade the metal and thus discolour the restoration.

One or two drops of liquid are placed near a heap of powder which is divided into a few smaller heaps. Each increment is incorporated swiftly into the liquid to produce, in less than one minute, a mix of putty-like consistency which glistens when tapped. Ideally, a measured quantity of powder should be dispensed for mixing with a given quantity of liquid.

The advantages of mechanical mixing of a capsulated silicate are:

1. Slight decrease in solubility.
2. Slight increase in compressive strength.
3. Consistency of result.
4. Less waste.
5. No moisture contamination when mixing.
6. Rapidity of mix.
7. Increase in setting time.
8. No time-wasting cleansing of slab and spatula.

Insertion of the restoration

For maintaining the contour of a Class III restoration and compressing the material into the cavity, a celluloid, cellulose acetate, mylar or anodysed aluminium strip may be used. It should not be coated with any lubricant, a time-honoured but worthless practice, because of the risk of incorporating the lubricant into the restoration when it is introduced into the cavity.

When the silicate is ready for insertion, the strip is held against the lingual aspect of the tooth with the index finger and the soft silicate is pressed home into the cavity and against the lingual wall with the minimum number of strokes using a flat plastic instrument (Ash 156). When the cavity has been filled to excess, the labial end of the strip is brought over the labial surface of the tooth and directed incisally. This forces excess silicate away from the gingival margin and makes the final finishing much easier. The strip is then held in place with the thumb and index finger for approximately 3 min until the silicate has set. If the cavity is of minimal extent, pressure may be exerted also towards the centre of the tooth, but if this is done where a large labial or lingual extension exists, the proximal contour will become concave instead of convex and a deficient restoration will be produced. In such a case, the pressure exerted should be minimal, and directed towards the contact point, in order to maintain the proximal contour.

The techniques available for the insertion of Class V restorations necessitate the use of a preformed cervical matrix of celluloid or cellulose acetate, which is trimmed to follow the contour of the gingival margin. Alternatively a steel pen-nib haft may be ground to contour, or a Hawes cervical matrix, consisting of a preformed, plastic-coated metal slip, may be pressed onto the over-packed cement, the excess teased away immediately, and the slip, which adheres to the cement and protects it, left until the next visit, or picked off by the patient after 24 h. The margins are varnished.

When placing a cervical matrix, it should make contact with the tooth beyond the gingival cavity margin before it is lowered into place on the tooth, thus ensuring the filling of the cervical portion and directing excess material away from it.

The author has found that a more constant result may be obtained when the matrix is thus adjusted and held at an angle to the tooth, pivoted out from the subgingival position. The silicate is introduced from the undersurface of the matrix which is then lowered into position and held until the restoration has hardened (figure 10.2).

It is important to avoid movement of the matrix until the gel has formed, which otherwise would be broken up and would never re-form. If the matrix breaks cleanly away from the surface of the restoration, it is a sign that the initial set of the silicate is complete.

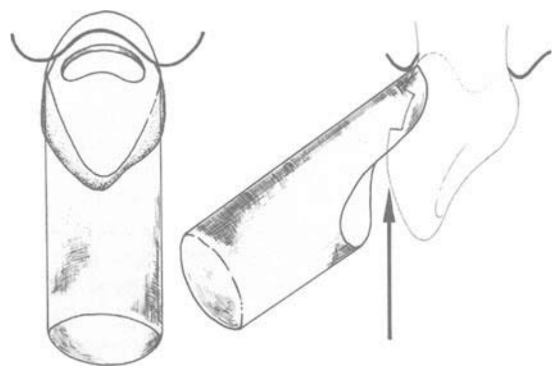

Fig. 10.2 (Left) Cellulose acetate matrix adjusted over a Class V cavity. (Right) Matrix held out from the tooth, pivoted at a point above the cavity margin to allow insertion of restorative material from below so that, when the matrix is positioned, gross subgingival excess is avoided.

Gingival seepage or haemorrhage may best be avoided by the use of rubber dam and a Ferrier or Hatch cervical clamp, but frequently it is not possible to use rubber dam. In such cases it is better to avoid trauma during preparation and to pack the gum back with a string incorporating alum solution and 8% racemic epinephrine, which will dry and retract the marginal gingivae.

If the cavity extends into a deep pocket, it is preferable to resect the gum or to reflect a flap, apply rubber dam, insert the restoration and then suture the flap back into place.

Small areas of haemorrhage may be treated by applying a pledget of cotton-wool soaked in hydrogen peroxide (20 volumes) until the bleeding ceases.

As an indication of the consistency of the silicate the excess may be held between thumb and forefinger and tested periodically with a fingernail. When no further indentation can be made, the silicate is hard enough for removal of the matrix.

When this has been done, the restoration is covered immediately with copal-ether varnish and the rubber dam is removed. The bite is checked with articulating paper and any excess preventing closure, or likely to cause irritation of the soft tissues, is removed by grinding with a vaseline-coated abrasive stone. Once again the restoration is coated with varnish and the patient is dismissed.

At the next visit, the margins are made flush with the enamel, the contour is corrected and the surface is polished with fine abrasive discs, and finally rendered as smooth as possible with an abrasive prophylaxis paste applied on a brush or porte-polisher cup. Once the surface has been ground, a superficial high polish is unobtainable but provided that the restoration is smooth, it will be imperceptible to the patient.

To sum up, silicate cement requires strict attention to detail with regard to manipulation and finishing. It must be used only in mouths in which it has the right environment, i.e. where drying out will not occur and where it is not apt to be affected by acid plaque. It stands up extremely well in some mouths, having a high resistance to abrasion, but there is a tendency to staining in the mouths of smokers. The techniques for mixing, insertion and finishing are too exacting to make silicate a foolproof material and the reason that there are so many failures lies in the ease with which it may be mixed and inserted to give an apparently satisfactory result, at least for a short time.

Silicophosphate Cement

Silicate-phosphate cement, otherwise known as zinc silicate, is a combination of zinc phosphate cement and silicate.

The main uses for silicophosphate cement are as a die material and for aesthetic restorations. It may be used also as a cementing material, particularly for porcelain jacket crowns because of its translucency. The film thickness is greater than that of phosphate cement, which renders it useless for cementing gold inlays, but the removal of a platinum matrix from a jacket crown creates sufficient space for the lute of zinc silicate cement.

Being less translucent than silicate, silicophosphate possesses inferior aesthetic properties, but some operators prefer to use it in Class II and Class V cavities in premolars and molars, in situations where a metallic restoration would be unsightly.

The solubility in saliva is considerably less than that of phosphate cement.

Autopolymerising Acrylic Resin

Chemistry

Autopolymerising acrylic resin consists of a methyl methacrylate monomer and a polymer of the same material which incorporates suitable fillers, to provide the requisite degree of colour and opacity. In addition there is an activator system capable of accelerating the polymerisation at body temperature. The reaction is exothermic and the rise in temperature assists in accelerating the interaction. The two chief activator systems in general use are the peroxide-amine or peroxide-mercaptan system and the paratoluene sulphinic acid system.

Moisture contamination

Apart from increasing the reaction time and temperature, the presence of traces of moisture has negligible effect on the peroxide/amine systems, but the presence of moisture interferes with the sulphinic acid system leading to failure in setting.

Colour

Although recently developed acrylic resins are more colour-stable than the earlier resins, there is still a tendency for the restoration to become yellow or brown with age. This staining is due partly to the coloured products of decomposition resulting from the reaction between the benzoyl peroxide and the tertiary amine and partly, in anterior restorations, to the effect of ultra-violet light.

Although the sulphinic acid-activated resins theoretically are less apt to discolour, because sulphinic acid tends to be used up in the polymerisation reaction, there is still a tendency for the restorations to darken after a time.

Shrinkage

The calculated volumetric shrinkage of acrylic resin restorative material is between 7% and 9%. The effects of this shrinkage may be overcome by one or more of the following methods:

1. The application of a suitable catalyst (e.g. Sevriton adhesive cavity seal) to accelerate the set of the deeper layer of resin, thus directing the shrinkage towards the cavity.
2. The bulk/pressure technique, in which the cavity is packed to excess and pressure exerted through a suitable matrix.
3. The Nealon technique, in which the restoration is built up layer by layer.
4. A combination of layer and bulk/pressure techniques.

Coefficient of thermal expansion

Acrylic resin has a coefficient of thermal expansion more than seven times that of enamel and this means that in the face of intra-oral temperature changes, fluids will tend to percolate between the cavity and the mouth, bringing stains and bacteria into the cavity. This is evinced as staining around the margins and the offensive odour which is apparent when acrylic restorations are drilled out.

Abrasion resistance

The surface hardness of acrylic is only one-quarter of that of silicate, hence it will wear severely under the stress of mastication and toothbrushing.

Mixing technique

Mixing is carried out either on a slab or in a pot. In the latter technique, a given number of drops of monomer are covered to excess with polymer and the dry powder is shaken off. A further 1–2 drops of monomer are added and the mass is stirred and covered until ready for insertion (Sevriton).

For the slab mix, monomer and polymer, and with one product (Orthofil) a crushed tablet of activator, are incorporated with a stainless steel spatula on a cool clean glass slab, using a patting and puddling action in order to minimise the inclusion of air bubbles. The avoidance of vigorous spatulation will help to prevent some of the porosity which would result from the incorporation of air.

Bulk/pressure technique

1. Mix the resin according to the manufacturer's instruction.
2. Press a small quantity of the fresh mix into the undercuts.
3. Fill the cavity to excess.
4. Apply a metal or cellulose acetate matrix and maintain it without movement and with light pressure until the resin has hardened.
5. Remove gross excess, trim the margins flush with enamel and polish. This should be deferred for at least 15 min after the initial set, in order to avoid dislodgement of the restoration.

Nealon (brush) technique

1. Moisten the cavity with monomer.
2. Moisten a 00 sable brush with monomer; pick up a few particles of polymer and convey them to the cavity.
3. Continue to apply monomer and polymer to the cavity in this way until the surface of the restoration is overbuilt.
4. Cover the restoration with vaseline until polymerisation is complete (approximately 10–15 min), to prevent evaporation of monomer.
5. Trim and polish the restoration.

Combination technique

In this technique the deeper layers of the restoration are built up by the brush technique and then it is completed by the bulk/pressure technique.

There is a tendency for restorations made by the brush technique to discolour, due to the accumulation of excess monomer. On the other hand, the brush technique avoids gross excess and ensures better adaptation to the cavity walls.

Finishing

Because of the great difference in hardness between acrylic resin and enamel, it is preferable to trim gross excess away with steel finishing burs of suitable shapes. Projections of resin may be eradicated efficiently with coarse sandpaper discs.

Fine finishing is carried out with small, fine-grit sandpaper discs run at moderate speed and used with light pressure on the dry restoration. Subgingival excess is best removed with a Swann-Morton scalpel blade No. 12, employing a gentle pulling action against the margin of the restoration.

The final polishing is done with a small cup brush or porte-polisher cup, using firstly a prophylaxis paste and finishing with a suspension of whiting in water in order to produce a high lustre. Great care must be exercised to avoid over-heating during polishing, otherwise the acrylic will be burned. This will happen if excessive pressure is applied or if the engine is run at too high a speed.

Whiting should not be used with alcohol as a vehicle because it would cause crazing of the acrylic.

Matrices

Acrylic may be used with steel or cellulose acetate matrices but never with celluloid, because there is a chemical reaction between them which produces a greenish discolouration.

Linings

Acrylic may be placed over phosphate or polycarboxylate cement or over calcium hydroxide cement without deleterious effect, but it should never be left to set in contact with any cement containing an essential oil, such as eugenol. This would act as a plasticiser and prevent setting.

Although there is evidence that acrylic is less irritant to the pulp than silicate, nevertheless it can, in deep cavities, cause severe irritation, hence it should always be used with a suitable lining in vital teeth.

Indications for the use of acrylic resin

Because of its toughness, acrylic resin may be used, in addition to Classes III and V cavities, for Class IV cavities, the incisal angle being retained by the use of pins and grooves in the dentine. Acrylic may be used as a temporary or as a semi-permanent restoration for a tooth which does not merit the use of porcelain or gold.

Despite the wear which is bound to occur, it is a simple task to remove part of the surface, when indicated, and to bring the restoration up to normal contour with an addition of new acrylic, which bonds to the acrylic base.

Acrylic tends to be better tolerated than silicate for Class V restorations because, unlike the latter, it does not 'ditch' gingivally, with consequent buildup of plaque and debris in contact with the gingiva. Provided that it is well polymerised with good marginal adaption and has a well-polished surface, it should not cause any gingival irritation in the presence of good oral hygiene.

Acrylic resin may be used to face areas of gold on the labial aspect of Class IV inlays and on the buccal aspect of Class II inlays.

A window is cut out of the wax pattern, when it has been carved, allowing a depth of at least 1.5 mm. The consequent weakening of the gold necessitates the use of a hard gold to avoid distortion of the inlay under masticatory stress.

The window may be cut out of the wax pattern with a slow-running inverted cone bur or with a small excavator or dentine hatchet. The final undercut is made in the gold with a size 1 wheel bur. The proximal margin of the window should be placed at the contact point.

After insertion of the inlay, some of the cement should be teased over the base of the window to mask the gold colour. The facing is inserted and held under a matrix until set, after which it is polished as described. Alternatively the facing may be built up by means of the brush technique.

Acrylic resin may be used in Class III and Class V cavities, especially in mouthbreathers, in preference to silicate which would otherwise tend to disintegrate.

Repair of Crowns in the Mouth

When a porcelain or acrylic facing fractures off a crown or bridge, in order to avoid removing the restoration, an acrylic facing may be purchased or made and cemented in its place.

Some of the recently developed plastic teeth are much denser and harder than cold-cured resin and will give longer service.

The technique is as follows:

(1) An impression is taken of the backing and the adjacent teeth after all remnants of facing and cement have been removed.

(2) A suitable tooth is selected and the back is hollowed out and 'touch-ground' to the gold backing.

(3) At the next visit, the facing is checked on the backing and any correction made. Retentive undercuts are made in the backing and facing, after which it is cemented with autopolymerising resin. The excess of resin is removed with a probe while still soft and the facing is held pressed home with a finger until the acrylic cement is hard.

(4) Final trimming is carried out with a flame-finishing bur and No. 12 scalpel blade subgingivally and discs at the margins. The facing is polished.

Temporary Restorations in Acrylic

Three alternative methods are in common use:
1. Stock tooth; 2. Crown form; 3. Impression matrix.

Stock tooth

1. Select a suitable stock tooth.
2. Hollow grind the interior to fit loosely over the stump or temporary post.
3. Fill the tooth with autopolymerising resin and insert it over the post or lubricated preparation.
4. Remove the restoration when hard, trim, polish and cement it with a temporary luting cement.

Crown form

1. Select a suitable crown form.
2. Trim into position and make small holes in the incisal corner or tip of the cusp to allow the escape of air.
3. Fill with resin and place over the post or lubricated preparation.
4. Remove when set, trim, polish and temporarily cement into position. The crown form may be left in place when there is insufficient bulk of resin.

Impression matrix

1. Before starting the preparation of the teeth, any cavities or defects are built up in inlay wax and an overall impression is recorded in silicone or alginate. If the latter material is used it should be covered with a damp napkin and placed in a polythene self-sealing bag.

2. When the preparation has been completed the impression is dried and the teeth are lubricated with a film of vaseline. The impression of the prepared tooth is filled with resin (or an epimine plastic–Scutan) exercising care that no air bubbles are trapped, and the impression is carried to place and held there until the resin has set.

3. The impression is removed and the temporary crown teased out; it is then trimmed to the margins of the preparation, polished and temporarily cemented.

In recent years, to replace methyl methacrylate resin which contracts on polymerisation, new tempor-butyl methacrylates have become available, e.g. 'Trim' (Bosworth). Although their setting is slightly prolonged, their lack of dimensional change makes them better suited to the impression matrix technique.
the impression matrix technique.

For the purpose of cementation of temporary crowns, a zinc oxide and eugenol cement is adequate, but TempBond (Kerr) sets quickly, holds the crown efficiently and sticks to the crown when it is removed, thus obviating removal from the tender dentine.

Temporary post crowns may be attached adequately with hot gutta percha, which is easier to remove subsequently from the root canal.

In conclusion it must be emphasised that acrylic resin is inferior in many respects to silicate and in all respects to the composite restorative materials (Chapter 11). However it is a useful material, especially in geriatric dentistry for 'permanent-temporary' restorations and also for temporary crowns.

11

Composite Restorative Materials

From the foregoing consideration of silicate and autopolymerising acrylic resin, it can be seen that they fall far short of the ideal permanent restorative material. Chemists and dental research workers have given considerable thought to the problem of replacing these restorative materials with something more permanent. The criteria for the ideal replacement are as follows; it should

1. Match the tooth in hue and translucency.
2. Remain effective after prolonged storage.
3. Be easy to mix, insert and polish.
4. Be non-irritant to the pulp.
5. Have a coefficient of thermal expansion similar to that of enamel.
6. Be resistant to abrasion.
7. Be insoluble in oral fluids, with low water absorption.
8. Be colour-stable.
9. Have high compressive, flexural and shear strengths.
10. Have high tensile strength.
11. Have a low modulus of elasticity.
12. Have low thermal conductivity.
13. Have high surface hardness.
14. Possess minimum flow properties.
15. Have minimal setting contraction.

Continuous assessment of newly developed products soon brings to light their relative deficiencies and further research is then inaugurated to develop materials which come closer to the ideal.

Attempts have been made to develop a material which combines the best features of silicate with those of acrylic resin.

By reinforcing a resin with ideally orientated ceramic filaments an exceptionally strong composite would be obtained, but this would not be practical for a dental composite, owing to the difficulty in orientating the fibres or filaments and the impossibility of using long filaments, which would be essential to impart a requisite degree of toughness to the material.

Composite materials have been developed however which combine an *inorganic phase*, which imparts stiffness to the material (using e.g. 70% by weight of one of the following: glass rods, soda glass beads, ceramic oxides, alumino-silicate glass, pure silica, quartz or synthetic minerals), with an *organic phase*, a resin, to provide ductility and tensile strength. The resin, which forms the matrix for the inorganic particles, must be bonded to these particles so that a strong, insoluble union is developed to minimise abrasion in the mouth.

Polyesters and epoxides have proved to be inferior to acrylic resin for this purpose, because of their high water sorption and colour instability. In 1957 McLean investigated the use of glass and ceramic fillers to improve the marginal seal and abrasion resistance in acrylic resin restorations. His findings led to the further development of a ceramic and resin composite which appeared to be superior, both clinically and in laboratory tests, to acrylic resin.

There are now four main groups of composite restorative materials.

- Group 1. Acrylic polymer/inorganic filler composites, e.g. TB71
- Group 2. Liquid resin/inorganic filler composites, e.g. P-Cadurit, Addent 35, 12.
- Group 3. Polymer coated ceramic composites, e.g. TD71
- Group 4. 2 paste polyacrylate with inorganic filler, e.g. Concise, Adaptic.

History of Development

Group 1

An experimental powder and 40% dry weight of acrylic polymer and bonded with modified methyl methacrylate monomer. Polymerisation is initiated through the action of lauryl mercaptan and benzoyl peroxide. Resulting from inadequate bonding at the glass/resin interface, wear occurred after three years and it was felt that by improving the bonding of the constituents,

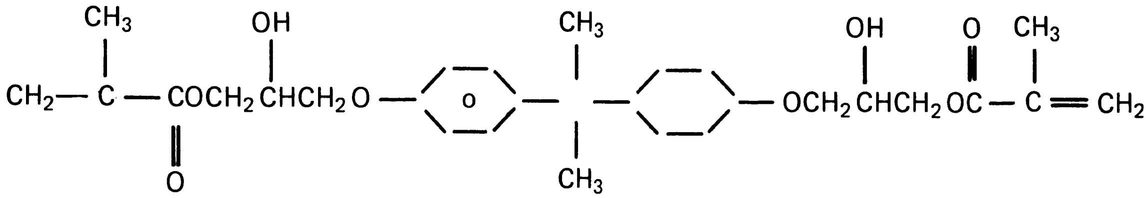

Fig. 11.1 The formula of polymethylacrylate, known as Bowen's resin and used in the majority of composite resins.

an alternative might be found for silicates where an acid environment was encountered, in which wasting of silicate would be accelerated.

Group 2

P-Cadurit, which belonged to this group, was introduced in 1962 by ESPE Pharmaceutical Preparations of West Germany. It consisted of a glass bead dispersion in liquid resin, an aziridino polyester, and catalysed by sulphonic acid. The glass beads were present in the ratio of 40 parts by weight to 100 parts of resin and 40 parts of silane–primed glass fibres. The material was not found to be colour-stable (McLean and Hargreaves, 1963) and suffered from loss of contour due to hydrolytic instability with penetration of moisture through the resin/glass interfaces.

Addent 35 was developed by the 3M Company, following the original work of Bowen (1962) (figure 11.1) and contains 70% of inorganic filler, in the form of soda glass beads which have been treated with vinyl silane primer (figure 11.2) in order to make them water-repellent and increase their bonding with the resin. The liquid catalyst is benzoyl peroxide in methacrylic acid and the system is an amine/peroxide redox system, with the amine in the resin paste. A cavity liner is supplied which is a synthetic vinyl copolymer dissolved in acetone.

The resin is supplied in sachets, the contents of which are squeezed out onto a mixing pad, flattened and cross-hatched. One drop of catalyst is added and the paste is spatulated with a folding action for 30 seconds and then transferred to the cavity and held there, under a matrix, until set.

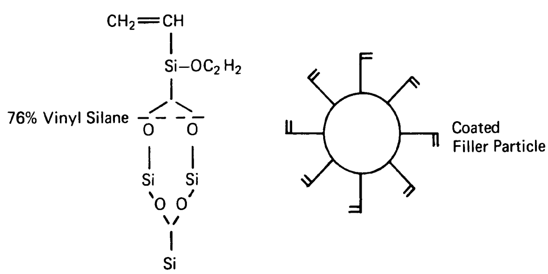

Fig. 11.2 Bonding of glass and silicates – a vinyl treatment.

Group 3

Resistance to wear was increased greatly in this group by bonding the resin to the filler particles of alumino-silicate (2–75 microns) by coating the particles with a silane primer, over which a uniform layer of polymer was bonded. Thus the experimental material TB 71 was superseded by a material for clinical use, TD 71.

The liquid monomer which bonds the resin-coated ceramic consists of a mixture of methyl methacrylate and methacrylic acid, and the catalyst system is based on an aliphatic peroxide and a long chain mercaptan (lauryl mercaptan).

The material is supplied in three phases: a capsule of polymer-coated ceramic (numbered in relation to a shade guide), a small capsule of catalyst powder, and a dropper bottle of liquid monomer.

Method of use

A capsule of the correct shade having been chosen, the contents of the phial of catalyst are emptied into it, plus six drops of monomer. The capsule is then closed with the plastic top and placed in an automatic amalgamator in which it is agitated for 10 s, after which it is ready for insertion in the cavity. Alternatively, the contents of the capsules may be incorporated with the monomer on a slab and, using a tantalum spatula, a satisfactory mix may be produced in approximately 1 min. The mechanical mixing technique is preferable however, because there is less likelihood of incorporating air bubbles in the mix.

Group 4

The most usual contemporary form of composite is the two paste system, and numerous manufacturers have produced almost identical kits for mixing and manipulation. The pastes are supplied in two jars, each of which is basically a ceramic filler with a polyacrylate binder; one jar contains the accelerator whilst the other contains the initiator. Also available are coloured pastes in basic hues for modifying the hue of the restoration. Equal portions of each paste are placed on a mixing pad and are mixed together thoroughly, inserted in the cavity and allowed to set undisturbed under a matrix.

The rationale behind this mode of use is the prevention of waste, which tends to occur when a prepackaged amount of material is dispensed. The amount required may be judged fairly accurately by an experienced operator.

The restorative paste may be polymerised by combining a benzoyl peroxide catalyst and a sulphinic acid accelerator in the monomer, although one manufacturer uses lauryl mercaptan and an aliphatic peroxide as the catalyst system.

The aesthetic properties of the composite materials vary from one to the other, but in general they are excellent to fair. At first they were supplied in a universal shade, because it was thought that the inclusion of glass rods and beads would produce a chameleon effect, taking up the colour of the adjacent enamel. It was found later however that such was not invariably the case, and various shaders were made available to modify the basic colour.

Properties of composite materials

In many respects the composite resins tend to behave better clinically than silicate and acrylic. Their setting reaction is basically similar to autopolymerising acrylic resin, but composites contain approximately 70–75% of a vitreous inorganic filler. This inclusion reduces polymerisation shrinkage and coefficient of thermal expansion. Bowen's resin has many advantages over methyl methacrylate. It has a lower exotherm and less polymerisation shrinkage and is less toxic. There is no tendency for residual monomer to leach out and it is not volatile.

Although composites are more resistant to abrasion than acrylic, they still tend to wear far more than amalgam. With the exception of the new microfine-filled composites, surface finish tends to be poor, due to the coarse particles (10–16 μm) of filler at the surface and the under-polymerised superficial resin. The inhibitory effect of oxygen and water is responsible for poor polymerisation.

The micro-fine composites have a silica particle size of 0.6 μm and the particles are incorporated into a cured resin matrix. Having a lower ratio of inorganic particles to matrix, there is a low polymerisation shrinkage, but the modulus of elasticity is reduced while the coefficient of thermal expansion is closer to that of acrylic. Clinically, however, the material takes a good polish and when used correctly, does not undergo marginal discoloration. Braden (personal communication) believes this to be due to its low thermal diffusivity, which nullifies the effect of the higher thermal coefficient.

Abou-Tabl *et al.* (1979), investigating the radiopacity of eighteen composite restorative materials, noted that the majority were less radiopaque then dentine. Obviously, in order to ensure recognition of radiographic evidence of underlying caries, radiopacity is a desirable feature and it is hoped that all composites will be modified to fulfill this requirement.

Colour stability

There is a tendency for the colour of composite resins to deteriorate after placement. They appear to pick up extrinsic stains from tobacco smoke, coffee and tea, especially when rough, and in this connection the micro-fine filled variety appears to stain less. The other factors encouraging colour change are water absorption and chemical breakdown of unreacted components. Nunn *et al.* investigated the degrees of colour change in several composites over a six-month period and found that most of them changed colour, the greater degree of change occurring within the two weeks after placement. Clinical observation of standard and micro-fine composites appears to show less colour change in the latter over a 12 month period. Careful manipulation and finishing of composite restorations are undoubtedly important factors in producing colour stability.

Indications for use

Composite materials are indicated for those cavities for which silicate and acrylic have been proposed. In addition, they may be used for small Class II cavities, especially in maxillary premolars in which any show of metal would be unaesthetic. The writer has used them successfully to restore, as a temporary measure, very large cavities in molars and premolars for which any other form of restoration would have been a practical impossibility. However, composites do not appear to stand up to stress as well as amalgam, and surface wear becomes obvious with consequent loss of contour after 1–2 years.

They should be reserved entirely for restoring teeth where aesthetic considerations are paramount (figure 11.3) and for large scale restorations in elderly patients, for whose teeth an extended life is not foreseen.

Normally they would be used in all cases for which silicate had hitherto been advised and, in addition, as a semi-permanent restoration for Class IV cavities and to restore horizontally and obliquely fractured incisors.

Fig. 11.3 Replacement of worn and discoloured silicate, acrylic and amalgam restorations in

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| 3

by composite restorative materials.

Adhesion and retention

The accepted method of retaining composite resin in a cavity, until the present decade, was by means of undercuts or pins. Buonacore (1955), used 85% phosphoric acid solution to etch enamel and improve the marginal adaptation of methyl methacrylate resin. Subsequent work (Silverstone, 1974) with buffered 50%, and unbuffered 30%, phosphoric acid solutions, showed that the latter produced the most favourable surface for bonding to acrylic or composite.

With the advent of acid-etching and the possibility of retaining composite resin on hitherto unretentive areas, a new phase in the sphere of adhesive dentistry has opened up which is in the process of revolutionising conservative dentistry.

Acid-etch retention

Because of its high mineral content, the use of a phosphoric acid etchant, or conditioner, will demineralise the surface of enamel and render it porous. Into this porous zone, resin is able to penetrate and bond with the enamel. The tags of resin, so formed, have been shown to measure between 20 μm and 60 μm in length, when viewed under the scanning electron microscope. Adhesive bond strength arises from physical-chemical adsorption, and for this to be made operative there must be intimate contact between the molecules of the adhesive and those of the substrate, so that secondary inter-molecular and adsorption bonds can be set up. Then the adhesive sets to a solid state with low shrinkage so that no further disruption of the bonds can occur.

The ability of the composite to wet the surface of the enamel is directly related to the ability to bond to it, and the use of an etchant increases the wettability of the surface. After etching, the enamel presents a dull, matt surface with a greatly reduced contact angle. The etching of enamel with strong mineral acids results in extensive superficial dissolution, offering less retention than the differentially attacked prisms produced by the use of unbuffered phosphoric acid.

Prior to the application of an etchant, all pellicle and plaque should be polished away with a slurry of pumice and water. This is essential for the production of a good etch. Proprietary polishing pastes should never be used because they may contain resins or gums which would interfere with etching.

After the recommended time that the etchant is in contact with enamel (1.0–1.5 min), the tooth should be washed for an equivalent time. The reason for so prolonged a period of washing is that, following etching, there are present primary and secondary calcium orthophosphates. If these are not washed away, the composite is bonded to them rather than the enamel and the bond strength is greatly reduced. If care is exercised in the preparation of the enamel and handling of the composite resin, bond strengths in the region of 200 kg/cm^2 are obtainable.

Trimming and polishing the restoration

Ideally the matrix should be so adjusted and held that only marginal trimming and finishing are necessary, because the strip or matrix imparts a gloss to the surface (figure 11.4). However, such factors as the shape of the tooth, the shape and size of the cavity and the position of the adjacent tooth do not always allow the insertion of a restoration without the forma-

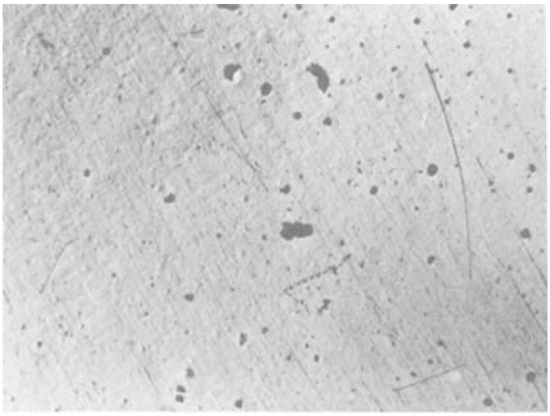

Fig. 11.4 Scanning electron microscope picture of Adaptic composite (Johnson & Johnson) as set in contact with a mylar strip. Note the large number of porosities.

tion of some excess (figure 11.5). Any attempt to finish a composite restoration before it has had time to harden may dislodge it. At least 15 min should elapse after it has been inserted and, apart from the removal of gross excess, it is preferable to leave final finishing until a subsequent visit.

Removal of gross excess may be carried out with coarse sandpaper discs and diamond burs (figures 11.6, 11.7), or by the use of specially-made tungsten carbide finishing burs for use in the turbine handpiece. Care

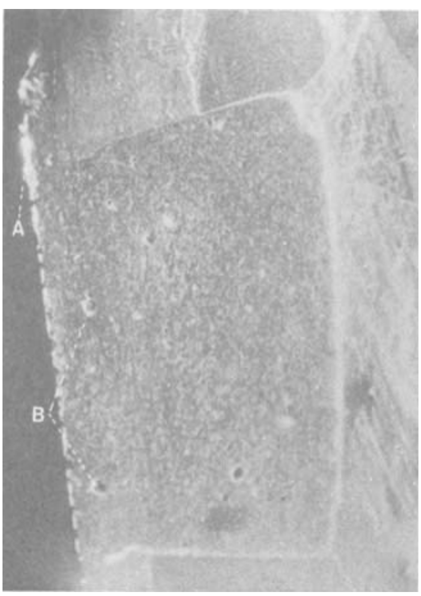

Fig. 11.5 Section through a composite resin restoration (Adaptic . . . Johnson & Johnson) in a class V cavity, under the scanning electron microscope. The restoration was allowed to cure under a cellulose acetate strip. Note the gingival overhang at (A), voids at (B), and the poor surface finish.

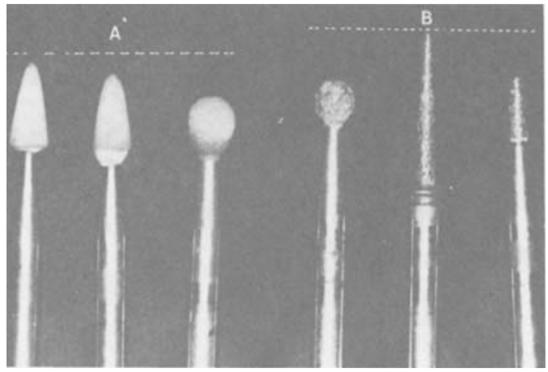

Fig. 11.6 (A), white stones to smooth the surface of composite resin after the use of diamond instruments (B). These instruments should be run at low speeds.

must be exercised however, when the latter are used, to avoid contact with the enamel which would be traumatised. A No. 12 Swann Morton scalpel blade is ideal for removal of subgingival excess, as recommended for acrylic margins. The excess should be pared away layer by layer until no further margin is palpable with a probe. Any attempt to cut away a thick margin in one piece could result in the application of a dislodging force which could loosen or totally luxate the whole restoration.

When the restoration has been contoured to perfection, it should be smoothed over with fine cuttle strips and discs and finally polished with a special black rubber abrasive cup or wheel (AABA) used, for preference, under water spray. It is not advisable to polish with an abrasive paste because the resin component of the surface will tend to be abraded more than the filler, thus leaving the particles of filler standing proud and producing a rough surface.

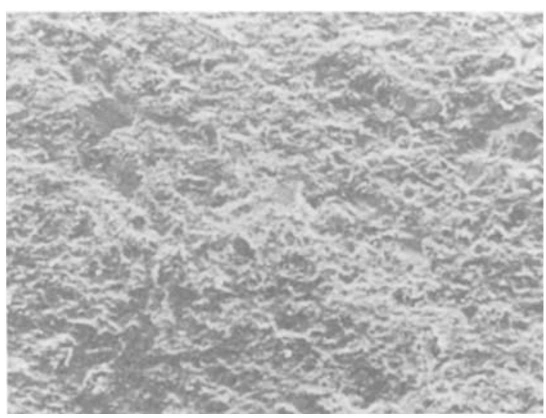

Fig. 11.7 The surface of a composite resin restoration (Concise . . . 3M), finished with a medium grit abrasive disc. Note the particles of inorganic filler projecting through the resin material.

Final finishing of conventional and micro-fine composite resin is best carried out with aluminium oxide discs and strips (SOFLEX, 3M). These are available in three grades: medium, fine and extra-fine and are used in that order.

Pearson and Messing (1979), investigating the differing abrasivity of a variety of finishing agents, found that considerable heat was generated at the surface when discs were used. The appearance under the scanning electron microscope indicated that smearing of the resin had occurred, the smear layer covering the particles of filler due to thermal softening of the resin. The smoothest surface was that obtained by the use of Soflex discs.

Special aspects

Although composites may be retained by internal undercuts or pins, a less noticeable margin may be obtained by bevelling the cavo-surface enamel at 45° and etching the bevelled margin. This has been shown to minimise marginal staining by a reduction in microleakage, and at the same time, give excellent retention.

It is possible, by the use of thin stainless steel matrices, carefully wedged and burnished, to restore normal interdental contacts. However, irrespective of the type of matrix used and especially when restoring large proximal cavities, there may be difficulty in obtaining a good contact. If this is encountered, following removal of the matrix, a further mix of composite resin should be applied and moulded, with a 156 plastic or Hollenback instrument, directly on the dry surface of the restoration. Any addition of new material will adhere fully to a recently inserted restoration, but if a period greater than 30 minutes has elapsed, the surface of the composite resin should be thoroughly roughened and coated with bonding resin. Instruments used for shaping soft composite should be dipped into alcohol and all excess spirit shaken off. This prevents adhesion of composite to the metal.

Some composite resins are supplied with unfilled liquid resin, in the form of catalyst and universal liquids, which are mixed and applied to the conditioned enamel immediately before the filled resin. There is some difference of opinion regarding the advantage of an intermediary bonding resin and some authorities claim that the adhesion is weaker when it is used. Clinically, the results of applying liquid resin to etched enamel seem to be indistinguishable from those obtained when it is omitted. However, when adding new composite resin to an existing restoration, a thin layer of unfilled intermediary resin appears to be beneficial.

Class IV restorations

Until the advent of acid-etch techniques, a Class IV cavity or fractured incisal tip could be repaired only by the use of retention pins and composite as an alternative to a gold inlay or an artificial crown. Now, by cutting a simple cavity, without a lingual dovetail, and bevelling the margins at an angle of approximately 45°, the etched margins give good retention for composite. Additional retention, when considered necessary, may be obtained in a Class IV cavity by cutting a gingival groove in the dentine or by the use of a pin gingivally.

Linings

It is essential to line the dentine under all composite resins if the risk of acute pulpal inflammation is to be avoided. When etching, care should be exercised to prevent acid coming into contact with dentine, especially when close to the pulp. This is best avoided by the application of a cement base to cover the dentine. Calcium hydroxide cement appears to be the best lining material at present and Brown (1979) has demonstrated that Procal (3M) and Dycal (Caulk) provide complete barriers to acid, when etching, if used in a layer at least 1.3 mm in thickness. These cements also serve as excellent linings because they set quickly, are easy to apply and prevent pulpal irritation. If, during etching, some dissolution of the cement should occur, a further layer should be applied. The cement must be fully set before the composite is applied, otherwise there is a risk that it may be squeezed out to the margins or block the under-cuts.

Other uses for composite resins

Composite resin is a versatile material and has proved to be of value in the solution of many hitherto insoluble problems. When anterior teeth have been rendered unsightly by stained restorations, erosion, attrition, hypoplasia, tetracycline staining or have discoloured after death of the pulp, the sole means of improving aesthetics used to be by crowning. Now it is possible to coat them with a composite resin and achieve acceptable results. In order to avoid excessive thickening of the labial surface, a layer of enamel may be ground off, but the dentine should not be exposed. The enamel is etched, washed and built up with composite (figure 11.8). No matrix is needed. The composite is moulded with a plastic instrument and finished to a peripheral feather-edge margin. Areas of deep staining may first be masked with a film of

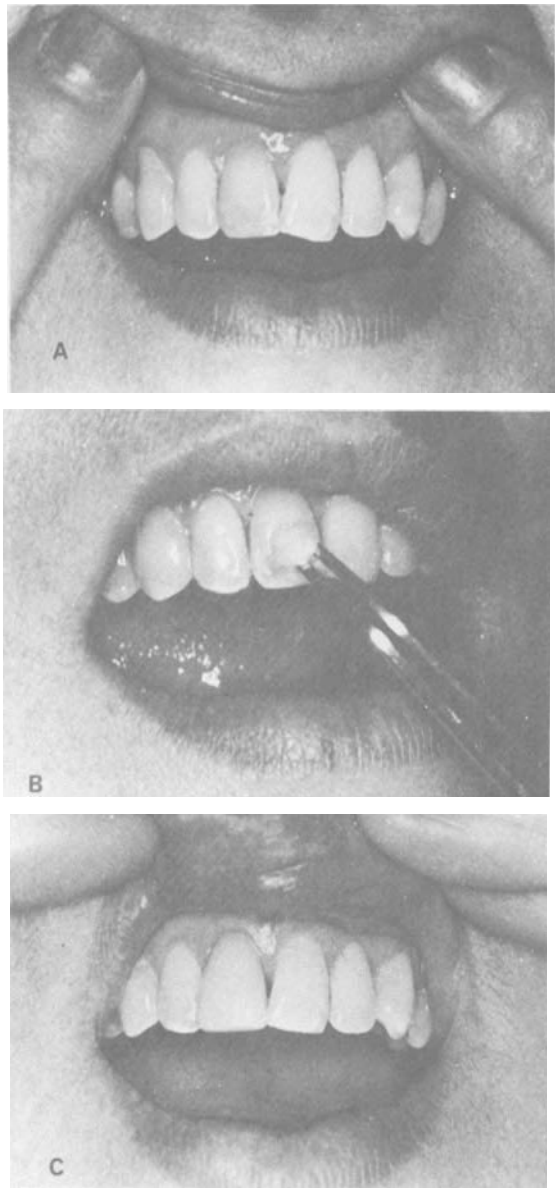

Fig. 11.8 **Upper central incisor re-surfaced with (acid-etch) composite resin. Discoloration was due to death of the pulp. (A) Discolored incisor. (B) Application of etchant (note protective strip to keep acid away from adjacent teeth). (C) Improvement in appearance.**

composite, tinted with an opaque resin before applying the restorative to rebuild the contour (figure 11.9). Any areas of exposed dentine should be covered with a lining cement. There is a tendency for the material to discolour superficially after a time, but discolouration may be removed when the patient attends for his regular check-up, by discing with aluminium oxide (Soflex) discs.

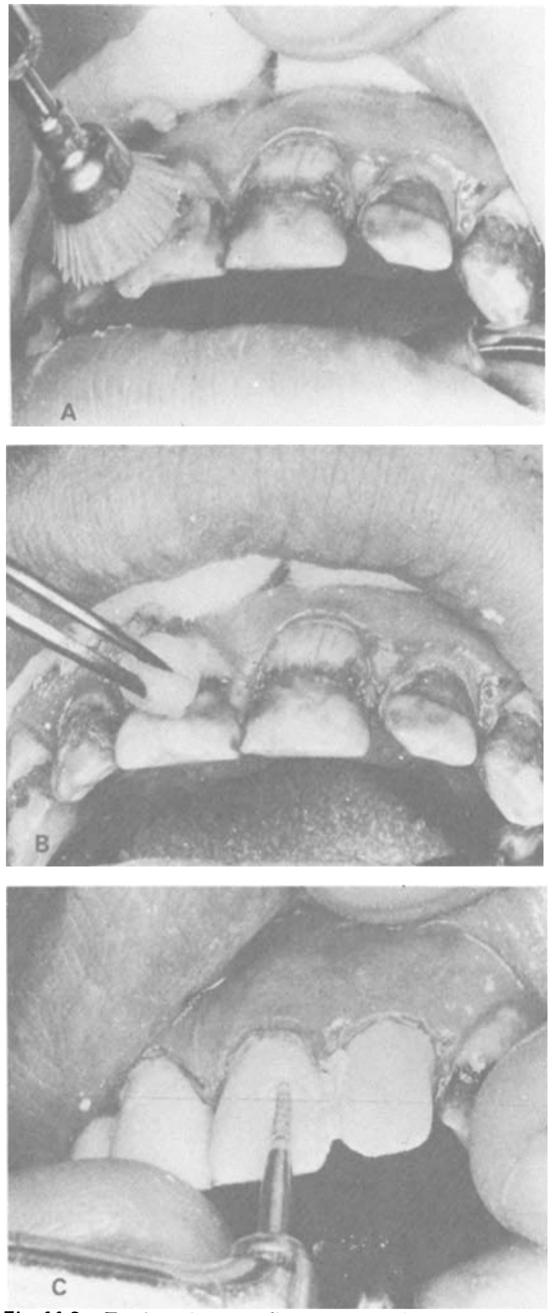

Fig. 11.9 **Teeth with severe fluorosis coated with composite resin. (A) Enamel cleaned with a pumice slurry. (B) Etchant applied. (C) Surface of composite being trimmed with a tapered cylinder diamond but at low speed. A masking layer of opacified resin was interposed between the enamel and the surface resin.**

A conical lateral incisor may be etched and, by filling a suitable cellulose acetate crown form with composite and adjusting it over the conical crown, a more acceptable aesthetic result can be obtained.

Careful trimming to eliminate marginal excess is necessary to prevent gingivitis due to plaque entrapment (figure 11.14 (A and B)).

It is often convenient to modify the shape of a tooth by etching the enamel and adding composite resin, in order to avoid the need for a crown. In the case illustrated (figure 11.10) a bridge had just been made, where previously the teeth had been spaced. The left lateral incisor was a perfect tooth with a large pulp so, in order to avoid risking the vitality of the pulp, the projecting mesial incisal angle was reduced and the crown was extended mesially with composite resin (figure 11.11).

In another case (figure 11.12), in which a fixed bridge had come loose at one end, the crown was almost totally destroyed by caries. Following removal of the caries, without exposure of the pulp, three Stabilok pins were placed and the pulpal dentine was protected with a coating of calcium hydroxide cement. The fitting surfaces of the retainers were made retentive by cutting a series of horizontal grooves, and the bridge was re-cemented, using phosphate cement for the central incisors and composite resin, made less viscous by an addition of bonding resin, for the pinned abutment (figure 11.13).

Temporary splinting of loose teeth with acid-etch-retained composite, with or without the use of reinforcing wires, has been known to last for months or years and is easily repaired if it should break down.

When restoring badly broken down teeth as a prelude to crowning, composite resin may be locked to the root by means of pins, screws or canal-retained devices. Special hard composites, usually of a different colour, e.g. white or black, are available for this purpose and the technique should be confined to the rebuilding of posterior teeth where adequate strength and rigidity are obtained through bulk.

Fig. 11.10 Abnormally wide space remaining after cementation of fixed bridge.

Fig. 11.11 Lateral incisor built out with composite resin to close the space.

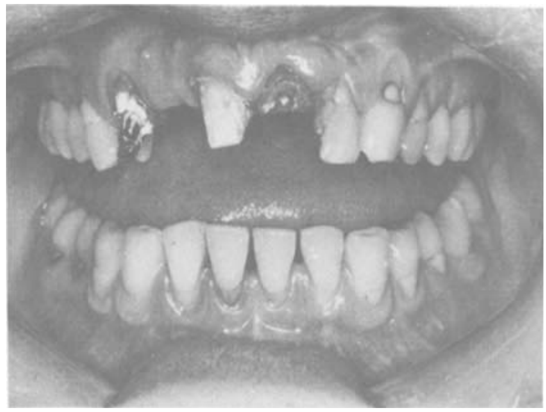

Fig. 11.12 Repair of a carious abutment, using pins and composite resin.

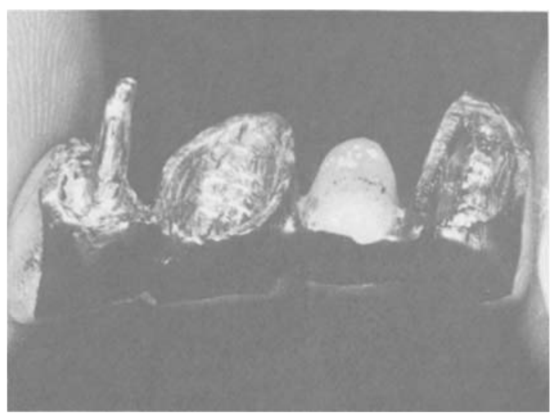

Fig. 11.13 Grooving of internal surfaces of retainers to obtain retention.

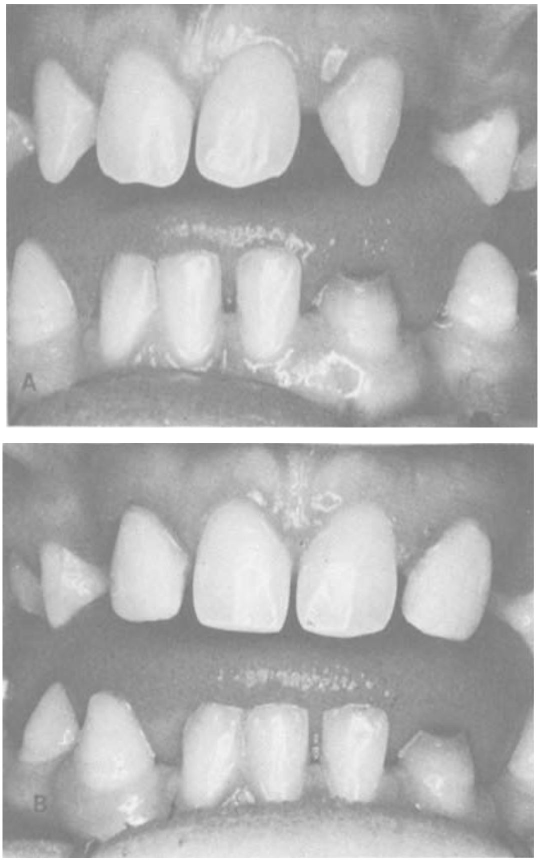

Fig. 11.14 Partial anodontia. The appearance was made worse by the presence of conical lateral incisors. (A) Conical lateral incisors. (B) Incisors built up with composite resin after conditioning with phosphoric acid.

Immediate temporary bridges can be made, after extraction of a tooth, by cutting off the root, undercutting the pulp chamber and making a composite or acrylic dome to contact the labial gingiva. The tooth and its erstwhile neighbours are polished, etched and washed. Rubber dam is applied and the tooth is reattached with composite resin. This is more comfortable than a temporary denture and the author has found that they will last 4–6 months. It is essential that they be ground clear of the bite but, should a fracture occur, re-attachment is simple. As an alternative to the use of a natural crown, an acrylic denture tooth may be used. The proximal and lingual surfaces are prepared to produce a wide undercut groove which is filled with composite at the time of fixing the tooth to its neighbours.

Fissure sealing

Composite resin has also been incorporated with methyl 2-cyanoacrylate to prevent caries by sealing pits and fissures (Cueto and Buonocore, 1967; Buonocore, 1970). The investigators claimed a reduction of 86% in caries in one year. Another experiment in Japan (Takeuchi *et al.*, 1966) showed that, using alkylcyanoacrylate and polymethyl methacrylate, after nine months there was no caries, as compared with caries in 15% of the control teeth. The authors recommend reinforcement of the effect by replacement of sealer every six months.

Investigation still continues into the effectiveness of various techniques for the sealing of pits and fissures. Composites of three main types are being used for this purpose. These are: (1) Two paste materials, used with or without a liquid resin (e.g. Concise – 3M), (2) ultra-violet light-activated composite resin (e.g. Nuva-seal – D. Caulk Co.) and (3) a visible light-cured composite restorative (Fotofil – Johnson & Johnson).

The basic technique employed entails, firstly, an assessment of the presence of caries. (If this is present, a conventional cavity is cut and filled.) Secondly, the enamel is polished with a pumice slurry to eliminate all adherent film and debris. Thirdly, the defect is sealed with the chosen material and, when set, the occlusion is checked and adjusted where indicated. Finally, the sealant is inspected at regular intervals and, if lost, is replaced. In order to aid inspection, some manufacturers incorporate a colourless fluorescent dye which becomes visible under UV light, while others colour the composite to contrast with the adjacent enamel.

Fissure sealing has also been carried out using a glass ionomer cement, and McLean and Wilson (1974) reported a 90% success rate, after two years, in pits and fissures in which the orifice measured at least 100 μm. Narrower fissures were widened prior to sealing. The disadvantage of this cement is its sensitivity to moisture contamination which, combined with its prolonged setting time, renders its use more difficult, especially in small children for whom it is especially needed.

Recent Developments in Composite Restorative Materials

Microfine composites

These materials, e.g. Isosite (Vivadent), Silar (3M), can be polished to a high gloss which lasts for a considerable time. Isosite is composed of a filler and resin, the filler differing from the coarser composite materials in that it consists of pulverised polymer incorporating silica of a particle size in the region of 0.05 μm.

Particle size of conventional composites is usually 15–60 μm. The content of filler is also reduced to 30% from the usual 60–70%. Despite their higher coefficient of thermal expansion, clinically the microfine composites appear to be standing up well with regard to marginal seal, especially when used against etched enamel (Glyn-Jones *et al.*, 1978).

Composites polymerised by exposure to ultra-violet light

In order to control the polymerisation of composite and thus allow sufficient time for manipulation of the soft material, Buoncore modified Bis-GMA sealant by the incorporation of an ultra-violet light-sensitive catalyst, benzoin methyl ether. This resin is supplied in two forms: (a) for fissure sealing (e.g. Nuva-seal) and (b) for restorations (e.g. Nuva-fil) by Caulk Co. and polymerisation is effected by exposure to a UV source, using the Nuva-lite lamp. A preliminary warm-up period for the lamp is necessary.

Composites polymerised by exposure to visible light

Fotofil, first marketed in 1978 by Johnson & Johnson, is a single paste composite resin, cured by a visible light beam from a filtered quartz halogen lamp transmitted through a quartz rod. The resin consists of Urethane Dimethacylate and Ethylene glycol dimethacrylate co-monomer and the filler is a silane-coated radiopaque glass. The time of exposure needed to effect polymerisation is in the region of 60 s, the exposure depending on the depth of the restoration.

Bassiouny and Grant (1978), in a clinical assessment of Fotofil, reported that it was easy to handle and the light source was more reliable than UV light. They found that the pulpal reaction was favourable and the material showed up well in radiographs due to the radiopacity of the filler, which was close to that of enamel. Restorations up to 3.0 mm in depth were fully cured by a 60 s exposure. Deeper restorations, it was recommended, could be cured in layers, because there was a satisfactory bonding between the layers. Over a 12 month period, colour stability was good.

In a subsequent report by Smith & Wilson (1979), in which a comparison was made between Fotofil and Adaptic (Johnson and Johnson), no significant differences were noted, although they found that the surface finish of Fotofil was superior. They commented on the difficulty encountered when attempting polymerisation on the material under a finger-held strip.

Both UV and visible-light cured restorative materials are most useful when building up extensive areas, such as labial coatings, temporary bridges and splints, although they may be used in all cases for which conventional composites are applicable.

Bonding of a Composite Resin to Dentine

Until recently this objective had not been attained because the structure of dentine does not lend itself to the development of a pitted surface similar to that produced in enamel after a limited exposure to phosphoric acid.

Work carried out by Iwaku *et al.* (1981) showed that conventional resin tags in dentine underwent marked contraction during polymerisation, thus separating from the tubules and minimising retention. However, they have developed a new resin which exhibits a firm adhesion to the walls of the tubules after polymerisation.

Fusayama (1981), through the development of this new adhesive resin, has demonstrated a revolutionary approach to the restoration of carious teeth. He has shown that carious dentine is composed of two layers. The superficial layer is infected and, being necrotic, can not be remineralised. The deeper layer is uninfected and vital and can be remineralised.

An experimental caries detector was used in animal and human subjects to stain the superficial layer of caries. A solution of 0.5% basic fuchsin in propylene glycol was found to stain only the superficial caries, but was without effect on the deeper layer. Fear of the potential carcinogenicity of basic fuchsin led to its replacement for clinical use by a 1% solution of acid red ($C_{27}H_{29}O_7N_2S_2Na$) in propylene glycol ($CH_3CHOHCH_2OH$).

The clinical technique entails exposure of the carious dentine and an application of the dye for 10 s. After washing off the dye, the stained (red) caries is excavated by hand or with a round steel bur at low speed. A further application of dye will reveal any residue of superficial caries and when no further staining of the dentine occurs, it is safe to place the definitive restoration of amalgam or resin. It is stressed that the removal of the stain-impregnated layer can be accomplished without pain and, when the resin is used, no retention need be cut in the majority of cavities.

The bonding resin system

The 'Clearfil Bond System' appears to achieve a chemical adhesion to both enamel and dentine, in contradistinction to conventional resins which bond only to etched enamel.

However, Clearfil shows a four-fold increase in bond strength when bonded to etched enamel and dentine. Furthermore, the bond tends to increase with time, suggesting the possibility of chemical adhesion to the tooth. Examination of specimens under the scanning electron microscope failed to reveal any space between tooth and resin, whereas conventional resins showed a gap of 10 μm at the dentine interface and a similar gap against the enamel.

A lining of calcium hydroxide cement is advocated solely for very deep cavities where the pulp is close to the cavity floor (less than 150 μm). Otherwise, there is no need to line the cavity because pulpal response to etchant and resin is negligible. It is postulated that this stems from the blockage of the etched dentinal pits with plugs of polymerised resin, which prevents subsequent percolation of fluid resulting from microleakage due to thermal and mechanical stresses.

Apart from bonding to etched normal dentine, the resin will bond to the deeper, non-staining layer of caries. From human and animal experiments, Fusayama showed that when the deeper layer of carious dentine is remineralised through the pulp, it recovers its normal degree of hardness in time. Following elimination of the stained superficial caries, bacteria are not found in the deeper layer.

The black dentine found under old amalgam restorations in the inner carious layer may be left unless its colour, transmitted through the adjacent enamel, presents a cosmetic problem.

A further advantage stemming from the use of the caries detector is the indication of the extent of undermined enamel when the dye seeps laterally into the superficial caries below the surface of the enamel. Thus a guide to the extent of the cavity may be obtained.

Clinical application of Clearfil resin

After removal of 'Cavex' – (the caries detector) stained caries, the cavity is isolated from saliva and etched for 60 s. Then it is washed and blown dry with water spray and warm air jet respectively.

Equal quantities of catalyst and Universal liquid resins are mixed and applied to the dentine and enamel surfaces to be covered. Ethanol in the resin is evaporated by the brief application of a jet of warm air.

As soon as possible thereafter, equal quantities of Clearfil, catalyst and Universal, pastes are mixed on a pad and applied over the dried bonding agent, thus allowing it to polymerise, on the exclusion of air, so that it bonds to both the tooth and composite resin forthwith.

The resin contains 75% α-quartz particles as a filler and is polymerised by means of a conventional peroxide-amine system.

Clearfil is not recommended for use in posterior occlusal restorations because of its poor resistance to abrasion. It should be used for cervical erosions and carious cavities and, where these are flat, a small stabilising groove is cut with a small round bur just internal to the margins. This will avoid lateral slippage of the polymerising resin with consequent damage to the resin tags and loss of retention. In Class IV cavities, the same function is served by the cutting of labial and lingual bevels.

Clearfil may be used to obliterate dentinal defects found on completion of a crown preparation. The bonding ensures their continued retention during impression procedures.

When building up a restoration, the final contour may be obtained by addition of two or more layers of resin. However, saliva must be excluded, otherwise a failure to bond may occur. If contaminated, the surface should be washed and dried thoroughly but the surface of the resin should not be drilled, otherwise the adhesion of the added resin would be reduced.

Trimming should be carried out as soon as the resin is hard (after about 5 min) using diamond and carbide burs, in bud and flame shapes, at low speed.

Tungsten carbide burs, used under water spray in the turbine handpiece, are effective for the removal of subgingival excess of resin. Final finishing and polishing are best effected after a few days, using white stones, abrasive strips and Soflex discs (3M). When rubber and silicone polishers are used, a water spray coolant will avoid over-heating the resin, which could burn the surface.

This new concept in dental restorative materials and cavity preparation may revolutionise operative dental surgery. Time and experience will be needed to evaluate this innovation and doubtless it will undergo improvements, but at last the long awaited truly adhesive dental system appears to be within our grasp.

Glass Ionomer Cement

The search for a material with the adhesive property of polycarboxylate cement and the abrasion-resistance of silicate, but without the inherent disadvantages of either material, led to the development of a new translucent cement, the glass ionomer or alumino silicate-polyacrylate cement (Wilson and Kent, 1972). The cement is based on an alumino-silicate glass powder, prepared by crushing to a fine powder a glass fused by heating silicon dioxide and aluminium oxide with sodium, calcium and aluminium fluorides and aluminium phosphate at 1050–1350°C. The liquid in ASPA (Amalgamated Dental Co.) is composed of polyalkenoic acids which contain chelating monomers. The reaction between these two components produces a rapid hardening as the acid decomposes the alumino-silicate powder, in the presence of water, and cations are liberated to form a cement. The setting reaction is analogous to that of silicate cement, in that it is an acid–base reaction. Wilson and Kent presume that . . . 'in the freshly mixed mass, hydrated protons from the liquid penetrate the surface regions of the particles of powder and displace cations ($Al^3 + Ca^{2+}$), and degrade the alumino-silicate network to a hydrated siliceous gel. Cations, either simple or as fluoride complexes, migrate into the aqueous phase of the cement paste, where metallic salt bridges are formed between the long chains of charged polycarboxylate ions, cross-linking them and causing the aqueous phase to gel and the cement to set to an amorphous mass'.

They offer, in support of this hypothesis, evidence from IR spectroscopy, which showed progressive conversion of carboxylic acid groups, along the polymer chain, to carboxylate ions and the formation of a siliceous hydrogel.

Properties of a glass ionomer cement (ASPA)

Because of its property of bonding to enamel and dentine, ASPA is a truly adhesive cement. The bond depends on the ionic interaction between the carboxyl groups of the cement and the calcium ions of the tooth, in the same way that polycarboxylate is bonded, and the attachment to enamel, due to its higher mineral content, is greater than its attachment to dentine. This bonding ensures a good cavity seal (Maldonado *et al.*, 1978).

Adhesion was found to be increased by the application, for a 30 s period, of a 50% solution of citric acid to the dentine. This was well washed off with water and the tooth dried with warm air (Prodger and Symonds, 1977).

They showed, in addition, that coating the surface of the setting cement with a protective varnish further improved its adhesive properties and, after a period of 3 months in water, there was no evidence of loss of adhesion.

Levine *et al.* (1977) applied a two component mineralising solution to dentine for 3 min and showed an increase in tensile bond strength of ASPA of more than one hundred per cent.

Working time

When mixed at room temperature, there is a short working time but, as with silicate cement, this can be extended by cooling the glass slab on which it is mixed.

Transverse strength

This was measured by McCabe *et al.* (1979) and found to be lower than that of silicate and much less than that of composite, thus making it unsuitable for high stress situations.

Colour change

ASPA appears to be unaffected by exposure to UV radiation (in contradistinction to tooth coloured auto-polymerising acrylic resin) and it is more opaque than silicate, although, when completely hardened in the tooth, it becomes slightly more translucent. Nevertheless it is not recommended that it be used where maximum aesthetics are desirable.

Abrasion resistance

ASPA has a resistance to abrasion similar to that of silicate. This is of especial importance when considering its use in the restoration of cervical toothbrush abrasion grooves and erosion cavities. Laboratory tests (McCabe *et al.*, 1979) and clinical observation confirm that acid erosion, which causes washing out of silicate cement, does not appear materially to effect ASPA, which has a much lower acid solubility.

Pulpal response

From an investigation into the pulpal response of human and ferrets' teeth to glass ionomer cements and citric acid, Tobias *et al.* (1978) concluded that for periods up to 30 days there was a reaction greater than occurred with zinc eugenolate cement. The reaction to ASPA restorative material was less than to luting material and the greatest reaction followed the use of citric acid conditioner.

They concluded that the degree of toxicity was similar to that of polycarboxylate cement.

These findings are corroborated, with minor differences, by Cooper (1980).

Bearing in mind the reactivity of the pulp to citric acid, it is recommended that dentine in deep cavities be covered by a layer of calcium hydroxide cement. As an alternative to citric acid, the dentine can be cleaned with a chelating agent, such as Ethylene diamine-tetra-acetic acid solution, as used for endodontic treatment. This does not appear to cause damage to the pulp. Hydrogen peroxide in a 3% solution may similarly be used.

Adhesion to non-dental materials

ASPA does not bond to porcelain and the use of ASPA luting agent (Chembond-De Trey) produces an attachment to porcelain similar to that of zinc phosphate cement. Similarly no bond is formed with gold but Hotz *et al.* (1977) showed that precious metal surfaces, such as gold and platinum and their alloys, can be made receptive to bonding with glass ionomer cements by plating them with a 2 μm layer of tin which is then alloyed to the surface at 800°C.

Indications

ASPA IV, the restorative version of glass ionomer cement is indicated primarily for the restoration of abrasion and erosion cavities. It may be used for class III and V cavities in which, apart from the removal of caries and undermined enamel and the placement of a lining, no retention is required other than the adhesive bond to the tooth. It is also effective when used to coat areas of sensitive cervical dentine and, even if it should become detached after some months, there is usually complete remission of symptoms. Pitt-Ford (1979) investigated its use as a filling material for root canals in conjunction with a single gutta percha core. The reaction of periapical tissue has not yet been published, but he claims that ASPA IV βn (a special formula for the purpose) allowed minimum leakage. Despite this fact, the hypersensitivity of ASPA to contamination by moisture would contra-indicate its use in a large percentage of canals in which periapical seepage is a problem.

Restoration of decidious teeth

Although ASPA has low values for transverse strength, it has been used for the restoration of Class II cavities in deciduous teeth. The chief advantage in this context is the adhesion of the material to the cavity walls, thus rendering unnecessary the cutting of undercuts and dovetails. The main problems associated with its use are the long setting time and the need for total avoidance of moisture contamination.

Plant *et al.* (1978) followed up a trial of ASPA restoration in deciduous Class II cavities carried out by Plant *et al.* (1977) in which initial results had been satisfactory. They found 75% of the restorations were intact at review. Of these, 90% were assessed as fair to good, with regard to marginal adaptation, contour and surface finish.

Fissure sealing

McClean and Wilson (1974) reported results obtained from a 2 year trial of fissure sealing with ASPA. In 10 per cent of cases the sealants were lost in the first year and a further 4 per cent in the second year. No caries was noted. They recommended the material especially for the larger fissures and for carious fissures after minimal preparation. They used a double mix, applying cement to the fissure, initially mixed to a P/L ratio of 1.5 g/ml and forcing it home with a stiffer mix (3.0 g/ml), then coating the sealant with varnish.

Mount and Makinson (1978) found the method to be reasonably successful but noted the presence of porosities which prevented perfect adaptation in some cases. They showed that, using the luting cement, mixed in a 3:1 P/L ratio, adequate penetration of the fissures could be assured and less porosity was found.

Glass ionomer luting cement

A fine grain version of glass ionomer cement for purposes of luting was first introduced by Wilson *et al.* (1977) under the name of ASPA IVa.

This was produced by grinding basic glass ionomer cement to a finer particle size. The cement has certain advantageous properties, notably a low film thickness and low creep value, high compressive and tensile strength, molecular adhesion to enamel, dentine and tin-plated gold or platinum by ionic bond, biological compatibility and fluoride-leaching to increase resistance to caries in contiguous enamel. The cement furthermore, being translucent, is ideal for cementation of porcelain jacket crowns.

The cement is mixed on a cooled slab with a P/L ratio of 1.67 g/ml. Clinically the cement is proportioned with a scoop and liquid dispenser. The liquid should be dispensed immediately before mixing because, should it be exposed to the air for a period longer than 60 s, evaporation of water content would

Fig. 11.15 An assortment of Hawes Cervical Matrices for use with class V restorations in silicate, composite or ASPA.

lead to an increase in viscosity. Before cementation, the tooth is cleaned thoroughly with 3% hydrogen peroxide and any traces of oil or varnish eliminated by wiping over lightly with ether or chloroform. Ideally, gold or platinum fitting surfaces should be tin-plated in order to allow chemical bonding to the carboxyl group in the cement (Hotz *et al.*, 1977).

Immediately after the initial set, all marginal

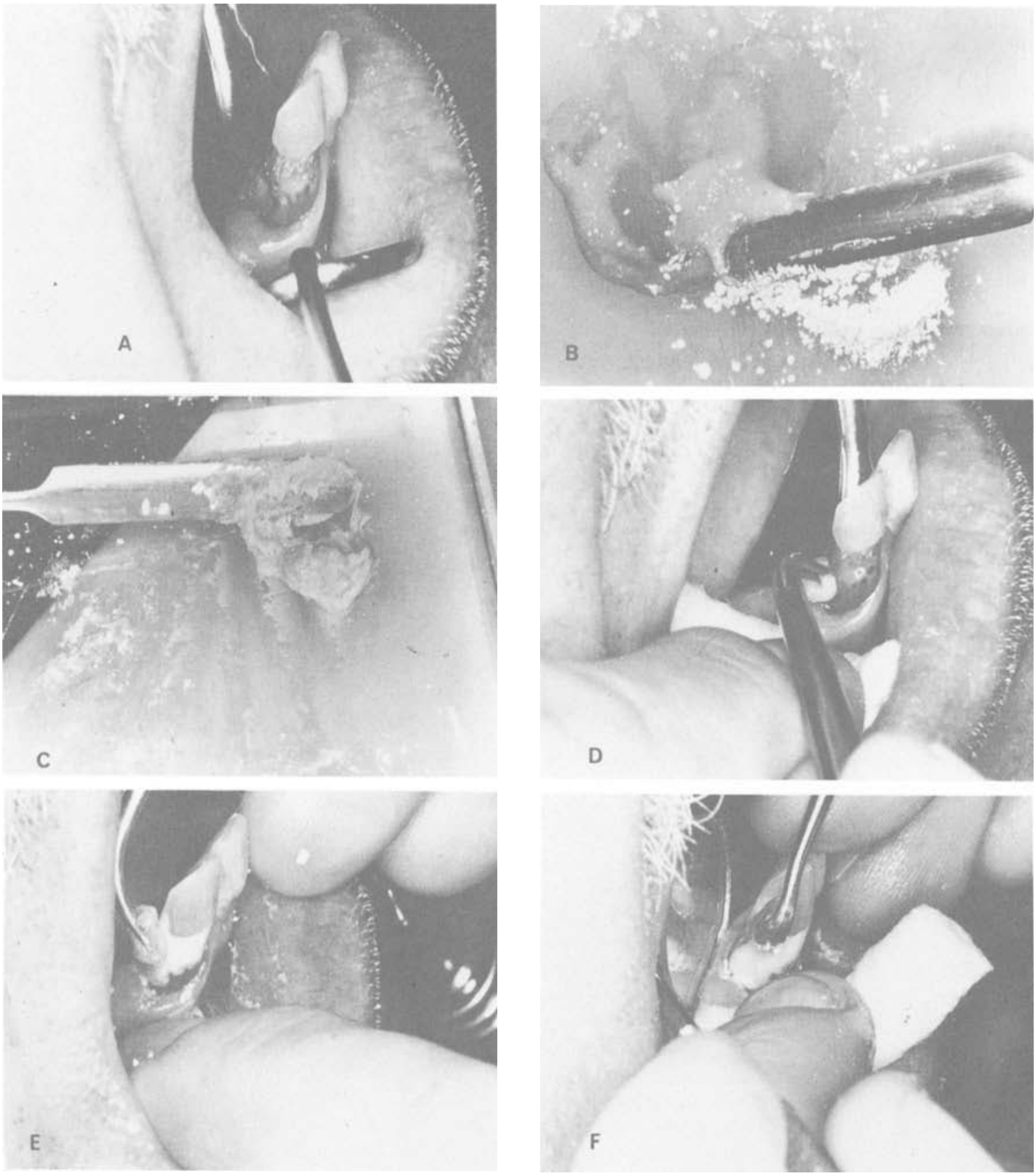

Fig. 11.16 ASPA restorative cement (amalgamated Dental Co.) used to restore a circumferential erosion cavity in a lower incisor. (A) Softened and carious dentine removed. (B) ASPA mixed with a tantalum spatula. (C) Correct consistency obtained after mixing for 30 seconds. (D) Plaque and pellicle removed with a 50% solution of citric acid. (The cavity is washed and dried before placing the ASPA.) (E) The matrix is removed and the restoration is coated with varnish to exclude moisture. (F) After the initial set gross excess is scraped away gently with sharp instruments. The restoration is varnished again and final finishing is done at a later date.

excess of cement should be removed and the margins coated with copal-ether varnish to protect the setting cement from contamination by saliva.

Mode of use of glass ionomer cement

The properties of a glass ionomer cement are enhanced by the exercise of care in mixing and manipulation. Mixing should be carried out using a clean, cooled glass slab and a tantalum spatula. If a stainless steel spatula were used, the abrasive property of the powder would cause greying of the mix because particles would be abraded. Crisp *et al.* (1976) showed that the mix should be as stiff as possible, by incorporation of the maximum permissible ratio of powder to liquid. This increases the rate of hardening, the compressive strength, hardness and resistance to aqueous attack. They recommended that two thirds of the powder be incorporated within 15 s, and the remainder in the next 15 s, mixing being completed in 1 min.

Cavity preparation is similar to that used for silicate and composite restorations without, however, the need for mechanical retention. A matrix is beneficial, because it is not easy to apply the material free-hand; it adheres to instruments. The matrix may be of cellulose acetate or a Hawes cervical matrix (figure 11.15) may be used for Class V cavities. An appropriate Hawes matrix is gently burnished over the tooth surface adjacent to the cavity margins, preferably before carrying out the preparation. Then, after over-filling the cavity, it is adjusted over the cement and pressed gently into place and held there while peripheral excess is removed. The margins are varnished and the patient is dismissed. The outer surface of the matrix, being of a colour close to that of a tooth, is not obtrusive, so the final trimming and polishing may be left safely until the next visit.

Abrasion and erosion cavities, unless complicated by carious attack, require no preparation other than cleansing.

After a setting period of about 5 min, gross trimming of the restoration may be carried out using sharp excavators, chisels and scalpel blades and operating them with a gentle scraping action parallel with the surface, so as to minimise the risk of adhesive or cohesive fracture. Before this trimming is carried out, the restoration should receive a liberal coating of petroleum jelly, followed on completion, by a cover of protective varnish (figure 11.16 (A–F)).

Finishing

Final trimming is best done with diamond drills and white arkansas stones, checking constantly the presence of palpable margins. When these margins have been virtually eliminated, the surfaces are smoothed and contoured with flexible abrasive discs and strips and a final polish obtained using Soflex discs and strips with light pressure.

Although it is not possible to produce a gloss after trimming, the finish obtained is undetectable by the patient.

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12

Gold

Gold, in various forms, has been used by dentists for thousands of years. In early times it was chosen for its indestructibility in oral fluids and used in the form of wire to bind a number of human or artificial teeth together and to attach them to abutment teeth in the patient's mouth to form primitive types of bridge. Much later, the fact that gold possesses the property of cold welding was used to mallet small pieces of pure gold together in a retentive cavity until the tooth contour was restored. For this purpose specially prepared sheets or cylinders of pure gold, beaten microscopically thin and freed from all impurities, were annealed in a mica tray and carried to the isolated tooth on gold foil pluggers, and each increment was welded to the previously condensed portion.

The only limitations for this technique were the accessibility of the tooth, the operator's ability and the patient's stamina – the operation frequently proving to be difficult, time-consuming and painful, because the malleting was apt to cause a severe periodontitis.

Nevertheless, the results were often excellent and many such restorations have been known to endure unaltered for four or five decades. Developments in casting techniques and improvements in other restorative materials have tended to relegate the cohesive gold restoration to the position of an undergraduate technical exercise. There are however many practitioners, notably in the United States of America, who still make these restorations and there has been a renaissance of dental gold foil study clubs on the West Coast of America. The chief reasons for the success of cohesive gold are the absence of cementing medium, the perfect adaptation of the margins and the absence of dimensional change over a prolonged period.

Early attempts to construct full gold crowns ('collar and cap') consisted of measuring the circumference at the neck of a prepared tooth and cutting a strip of gold alloy, which was then made into a collar and soldered to produce a fitting margin at or below the gingival margin. This was then soldered to a circular piece of gold alloy to form a biting surface. The crown was then filled with cement and impacted over the tooth. There were some dexterous practitioners who could obtain a perfect margin, but more commonly these crowns tended to produce a chronic marginal gingivitis due to grossly overhanging margins.

The 'cire perdue' or lost wax process, used for the casting of jewellery and similarly for industrial and dental castings owes its development to an American dentist, Dr. William H. Taggart. The techniques, which he developed in 1907, have enabled the profession to produce gold castings which fit the teeth with precision. Subsequent research and developments in casting investments, impression materials and gold alloys have contributed much to improving cast gold restorations and have enabled dentists to produce well-nigh perfect inlays and crowns.

Gold inlays possess certain advantages over the plastic restorative materials, notably high tensile strength, which permits the use of thin margins and veneers in areas subject to high stress. Furthermore, gold does not corrode in the mouth and takes and maintains a smooth polished surface which is appreciated by the patient and is an aid to the maintenance of good oral hygiene. Although aluminium and chrome-cobalt alloys have been used as alternatives, the former tends to undergo pitting in saliva, whilst the latter have proved to be unduly difficult to manipulate. Moreover, the hardness of a restorative material should approach that of enamel, and chrome-cobalt alloys are very much harder and do not wear at the same rate. This leads to traumatogenic occlusion on restorations of these materials. Gold alloys come much nearer to the recognition of this ideal. They are supplied in three or four different hardness grades, the softest grade being available for inlays subjected to minimum stress, such as Class I and Class V; the medium grade for Class II and Class III cavities and the harder grades being indicated for full and partial veneer crowns, occlusal coverage inlays and Class IV inlays. Whenever heavy stress is expected, e.g. in fixed bridgework and in mouths showing excessive wear, the extra-hard grade of gold is mandatory.

The harder golds contain a small proportion of platinum and palladium with a correspondingly higher quantity of copper, whilst the ratio of gold is higher in the softer gold alloys. Silver and zinc are other normal constituents and manufacturers produce characteristics in their alloys by the addition of other metals, but the formulae are in general not disclosed. By and large, the softer golds tend to be more yellow in colour, whilst that of the harder golds varies between a silvery and a coppery tint.

Indications for use

Gold inlays may be used for all classes of restoration unless contra-indicated on aesthetic grounds. They are of especial value when caries has undermined the enamel to such an extent that the use of a plastic material would entail either undue cutting back of walls and cusps, or the acceptance of undermined enamel which might collapse under stress. This situation may be met by extending veneers of gold over the weakened area and thereby allowing stresses to be transmitted to the inlay rather than to the underlying enamel.

Another indication for the use of gold is the restoration which is subjected to great stress, such as the Class IV gold inlay or pinlay. In the restoration of an incisal tip or corner, a plastic material, even if it is well retained, is subject to wear, but the gold inlay offers greater durability.

Because gold has high tensile strength and thus can be used in thin veneers, it is indicated for full and three-quarter crowns and pontics. It is still the best material available for bridgework, for which it is usually faced with porcelain (bonded or cemented), or acrylic resin, for aesthetic reasons. When a full veneer crown is to be constructed on a broken down tooth, it is essential that an even thickness of gold be obtained, and for this purpose the missing tooth structure should be restored with cement or, in the case of a large defect, with a pin-retained amalgam.

The reasons for having the gold casting of an even thickness are firstly, that it is difficult to cast high volume restorations which exhibit marked variations in width, and secondly, in order to reduce the cost of gold.

In contradistinction to the cohesive gold restoration, gold inlays must be cemented to the tooth, and therein lies their greatest weakness. Phosphate cement does not adhere to the tooth and inlay, but prevents displacement of the inlay by the intrusion of tongues of set cement into microscopic roughnesses on either side. The narrower the cement lute, the stronger the bond, and the better the marginal fit of the restoration, the longer the cement lute will last. This is due to the solubility of all accepted cementing media in saliva. The problem is largely overcome, however, by bevelling the cavo-surface angles and spinning the gold edges against the enamel in order to minimise the thickness of cement at the margin.

The author has observed that gold inlays which have been made with good margins and which possess adequate retention continue to function, virtually unaltered, many years after plastic restorations have disintegrated.

Cavity preparation and impression taking will be considered in later chapters.

13

Porcelain

Composition

The ingredients of dental porcelain are feldspar, silica (flint or quartz), clay (kaolin) and carbonates, which act as fluxes, plus metallic oxides as pigments (known as colour frits). Other materials, such as potash or soda may be added as modifiers.

Feldspar, or potassium aluminium silicate ($K_2O.Al_2O_3.6\ SiO_2$), is a crystalline opaque material, fusing at 2350°F to a glassy mass, which retains its shape unless taken to a higher temperature. The feldspar used for dental work must be pure and free from iron which, if present would modify the colour when the material was fused. Consequently considerable purification is necessary. Feldspar constitutes 80% of the total weight.

Quartz (SiO_2) similarly must be rendered free of iron which is frequently present as an impurity. Silica does not alter at the fusing temperature of porcelain, hence it acts as a matrix around which the other materials fuse. Quartz is present as approximately 15% by weight.

Kaolin ($Al_2O_3.2\ SiO_2.2\ H_2O$) is used in its pure form as an opacifier and a binder for the feldspar and quartz which, because of the adhesive properties of kaolin when mixed with water, are made to cohere better and this facilitates carving. When the porcelain is raised to a high temperature, the kaolin binds the quartz particles and there is marked shrinkage of the mass. There is about 3–5% of kaolin in porcelain.

Metallic oxides are used as colour frits, added in minute quantities to produce a range of hues and shades, and among these pigments are titanium dioxide, the oxides of copper, chromium and nickel. The percentage weight of pigment is usually less than 1%.

Properties

Porcelain teeth have been used in conservative and prosthetic dentistry for more than one hundred years. Improvements in manufacture and composition have made it possible to produce crowns, facings and teeth which match natural teeth with a high degree of accuracy. Nevertheless, the chief drawbacks of porcelain are its extreme brittleness and the difficulty experienced in counteracting its shrinkage when fired. Moreover it is much harder than enamel and wears less under masticatory conditions, with the result that in time the underlying tooth is subjected to traumatogenic occlusion. Also, if the surface glaze is removed, wear of the opposing tooth may be severe or fracture of the porcelain may occur as the stresses increase because of uneven attrition. However, with subsequent adjustments of premature contacts thus formed, porcelain jacket and dowel post-crowns will give good service and be well tolerated for many years. The problem of brittleness has, to some extent, been overcome by the introduction of aluminous porcelain and alumina sheet backings in recent years.

Porcelain is a poor conductor, thus thermal stimulation of the pulp is prevented despite the depth of a crown preparation and the small thickness of the cement lute. It has also a low coefficient of thermal expansion, hence there is no marginal percolation as occurs with methyl methacrylate crowns.

Porcelain does not flow under stress. It is moderately opaque to X-rays and would be visible radiographically if ingested or inhaled.

Indications for use

The porcelain inlay, made from a low fusing porcelain, fired in either a refractory investment or in a platinum matrix, has long since fallen into disfavour because of the difficulties encountered in obtaining a good fit at the margins and a good colour. It is being largely superseded by composite restorative materials, although still taught and advocated in some dental schools.

Porcelain facings are used in crown and bridge construction either with preformed or cast backings (figure 13.1). Following preparation of the proximal

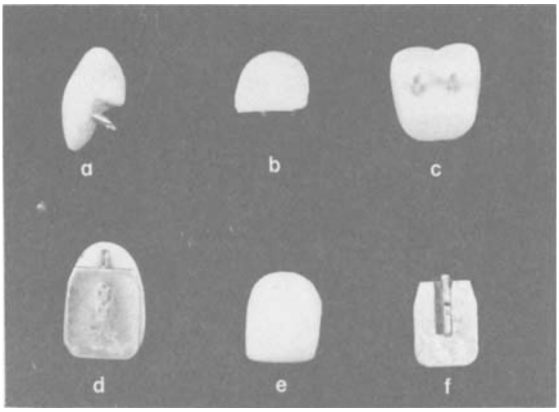

Fig. 13.1 (a) Long pin facing, with porcelain added for use as a pontic. (b) Labio-incisal view of incisor long pin facing. (c) Molar long pin facing. (d) Steele's facing with high heat backing *in situ*. (e) Labial view of Steele's facing. (f) Steele's high heat backing.

surfaces and fine-fitting of the gingival margin, a wax pattern of the backing is produced and the subsequent gold backing is united to the facing with cement (e.g. long pin or Steele's interchangeable facing; Hollenback facing; dowel crown). In similar manner, the facings may be used in the construction of bridge pontics. In the chapters on bridgework and porcelain jacket crowns, the use of these facings will be described in detail.

Apart from its aesthetic properties, porcelain possesses other advantages which make it the material of choice for bridge facings and pontics. It may be fired to a high biscuit or covered with a low fusing glass which produces a highly glazed surface. This glaze allows a constant gingival contact which is well tolerated. Moreover, porcelain keeps its appearance under oral conditions unchanged for many decades, in contradistinction to acrylic resin which soon loses its polish and contour as a result of attrition and abrasion.

There are three fusing ranges for porcelain, namely low, medium and high, with fusing temperatures respectively 1600° to 1950°F, 2000° to 2300°F and 2400° to 2500°F. The high fusing range, which tends to be used mainly for factory-produced teeth and facings, has the advantage that it may be repaired and added to without distortion, then stained and glazed.

Porcelain may be fired in an ordinary furnace or in one devised for the production of a vacuum. The crowns made in a vacuum furnace are thought to be slightly stronger, being more densely constituted with less porosity and superficial roughness. Furthermore, if small adjustments by grinding are carried out, the surface may be polished with sandpaper discs, rubber wheels and felt cones, impregnated with fine abrasives, whereas air-fired porcelain should be reglazed in a furnace.

Aluminous porcelain

In recent years attention has been focused on the use of alumina cores and backings for the reinforcement of porcelain jacket crowns. The alumina core renders the porcelain approximately twice as strong, and the use of a 97% alumina backing gives an even greater resistance to fracture, by virtue of its very high flexural strength. It has also been recommended for use in post-crowns and bridges, constructed either of gold and porcelain or entirely of porcelain, having been made available in the form of rods, bars and tubes for these purposes.

Porcelain bonded to metal

The need to combine the tensile strength of gold with the aesthetics of porcelain led to the development of porcelain fused to gold. The earlier materials were unsatisfactory from the viewpoints of aesthetics and permanence, but subsequently porcelains and alloys have been developed which have largely overcome these difficulties. The chief indications for the use of bonded porcelain are full veneer crowns, when there is limited intermaxillary space, and anterior bridgework.

The preparation differs from that required for an ordinary porcelain jacket crown, in that the labial part, on which the porcelain is to be fused, must be at least 1.5 mm in width at the gingival step. This has to accommodate firstly the gold casting, then a layer of an opaque porcelain over which the dentine and enamel porcelains are fused. Should the step be narrower, there is a tendency to obtain the required aesthetic result by bulging the cervical porcelain. This produces an unnatural bulbosity and a gingival stagnation area, where plaque may build up and cause gingival inflammation.

Some brands of bonded porcelain and some of the available shades give rather a 'dead' look, not having the vitality obtainable with porcelain and aluminous porcelain crowns. Nevertheless they are superior to the acrylic-faced crowns, which at first have excellent aesthetics but ultimately deteriorate as the acrylic is worn away.

The casting is made with an alloy which may contain gold, platinum and palladium, alloyed with other metals to produce a backing metal which melts at a high temperature. Certain chrome/cobalt alloys have been recommended similarly for this purpose. The minimum thickness of alloy is 0.4 mm. The major property of any metal used is that its coefficient of thermal expansion must match that of the porcelain, in order that the bond be maintained when the crown cools after removal from the furnace.

Prior to fusing porcelain over the backing, a layer of opaque porcelain is baked over the labial surface to mask the metal. This is fused at a temperature much lower than that of the metal, whilst at an even lower temperature, the porcelain is fused to match the adjacent teeth. The attachment of porcelain to metal is brought about through the wetting of the surface of the alloy by the fused porcelain, which combines chemically with oxides which have been formed on the alloy when it was heated in the furnace prior to bonding.

The bonded alumina crown

The metal-ceramic crown, because of its metal infrastructure, is often unacceptable from a cosmetic viewpoint. This is due largely to reflection of light from the opaque layer covering the metal and to the lack of adequate transmission of light through the crown.

McLean *et al.*, (1976, 1978) developed a technique for bonding porcelain on to tin-plated platinum foil. This not only improves the appearance but also increases the strength of the crown. After the internal foil is laid down over a primary foil matrix, it is given a flash plating of tin which is then oxidised in a furnace at 1000°C. The oxide-coated foil is then reburnished to the primary foil and an aluminous porcelain crown which bonds to the tin oxide layer is constructed and baked. McLean considers that the increase in strength relates to a reduction in surface and subsurface pores in the porcelain resulting from improved wetting. Fractures in porcelain crowns usually stem from propagation of micro-cracks which initiate in flaws in the internal surface and open up under stresses induced when such areas of porcelain are under tension.

A further benefit from the use of a tin oxide-plated fitting surface to the crown is the ability to use a polycarboxylate or glass ionomer cement which will bond to dentine and to the tin oxide, thus acting as a truly adhesive cement.

Until the present time, this technique has been used successfully solely for individual crowns and is not yet applicable for bridge work.

The choice of porcelain

The operator is influenced in his choice of material by the expected stress and by the patient's aesthetic requirements, e.g. bonded crowns in some mouths have excellent aesthetics in the incisor-canine region, whereas in others they may be used solely in the premolar/molar region, the lighter shades proving the most difficult to match. Aluminous porcelain is the material of choice for aesthetic restorations, but it will not stand up to very heavy stress in the same way as bonded porcelain. If, however, a sheet of 97% alumina is incorporated as a backing with the aluminous porcelain core in a crown subjected to a heavy bite, in a surprising number of cases it will enable the crown to withstand stress without fracturing.

When there is adequate room for a thickness of 1.0–1.5 mm of porcelain, plus sufficient clearance in all masticatory excursive movements, a simple air- or vacuum-fired porcelain will be quite satisfactory.

With bridgework, unless an all-porcelain bridge is to be constructed, the basis of the bridge will be cast gold. Porcelain may be incorporated in the form of facings or by casting the crown or pontic base in gold, in the form of an oval post which fits inside a length of alumina tube. On this tube a porcelain crown can be constructed which, after the bridge has been united by soldering, is cemented to the post.

There are numerous variations of this technique. The reader is referred to the standard textbooks on laboratory procedures (e.g. Stananought (1975)).

Hollenback crown

An alternative to bonding porcelain to gold is found in the Hollenback method of grinding a pin-tooth or dowel crown to fit the labial surface and gingival margin of the prepared stump. By a complicated series of steps, a gold backing is produced into which the facing is cemented, the crown then is ready to be cemented onto the tooth. Aesthetics are very good if the facing is of an adequate thickness, and the retention is satisfactory if the facing is trimmed to produce frictional fit with the gold. This type of facing has the advantage of being enclosed in gold and is thus protected from the effects of direct stress.

Headed pin-tooth facing

Similarly, prior to the introduction of bonded porcelain, a method of boxing-in the pins of a selected denture tooth was described by Makinson (1955). This method was advocated for facing post-crowns and pontics. After a backing had been cast and, if intended for bridgework, soldered, the cement was removed from the pins and the box-like space in the gold was undercut. The pins were spread slightly and the facing was cemented, the pins locking into the undercuts in the gold box. Despite the advent of more sophisticated techniques, this method of facing a crown or pontic is simple and effective, the aesthetics are more easily controlled and the author can recommend it from personal experience.

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14

Cavity Preparation

The objects of cavity preparation and the subsequent restoration of the tooth are the removal of diseased tissue, protection of vital tissue, i.e. the pulp and the contents of the dentinal tubules, and restoration of the form, function and aesthetics of the tooth.

It must always be borne in mind that the tooth is not isolated from the investing tissues and that periodontal and gingival health depend on the degree of plaque retention on the enamel and cementum. Two further factors which influence the development of disease are marginal contour and fit of the restoration and the presence of calculus. Thus, before cavity preparation is undertaken, the teeth should be scaled and polished. The final fit of the restoration should be such that neither excess nor deficiency are present to encourage the entrapment and build up of plaque.

Margins should be placed, whenever possible, coronal to the gingival crest and excessive bulbosity of walls should be avoided, in order to minimise retention of plaque.

Apart from these considerations, no work, other than emergency treatment, should be carried out before the patient has been made aware of the role of plaque in the etiology of caries and periodontal disease, and of the correct method of controlling its accumulation. The patient is shown the use of various oral hygiene aids, such as the toothbrush, dental floss and wood points, and the lesson is reinforced subsequently by checking the effectiveness or otherwise of his efforts.

Preparations are referred to as intracoronal, when the restoration is to be retained within the tooth, and extracoronal, when retention is obtained by means of full or partial coverage of the crown. It is necessary, in order to achieve as permanent a result as possible, to eradicate all peripheral caries, both established and incipient, and to finish margins on sound enamel or cementum in areas where they may be cleaned easily.

G. V. Black established a nomenclature and classification of cavity preparations which is still in use today, although expounded almost one hundred years ago. The nomenclature which he used enables the operator to describe various internal aspects of a cavity.

Cavo-surface angle – the angle formed by the cut surface where it meets the uncut surface.

Line angle – the angle formed by the intersection of two surfaces and designated by the walls involved, e.g. axio-buccal line angle.

Point angle – the angle formed at the intersection of three surfaces, e.g. axio-gingival-buccal (distal or mesial) point angle.

The walls – the cut surfaces. They may be buccal, lingual, mesial or distal, and the term *floor* is reserved for the wall overlying the pulp, i.e. pulpal or axial, although the axial part of the cavity is usually referred to as the axial wall and pulpal floor is the term usually reserved for posterior teeth.

The cervical floor is commonly referred to as the cervical or gingival *step*, and its cavo-surface angle as the cervical or gingival margin.

Outline form

The shape of a cavity which is dictated by the anatomical form of the tooth and the necessity for extension of margins into easily cleansed areas.

Although there are five 'classical' Black's cavities which will be described in succeeding pages, it is incorrect to apply the same outline form to every preparation. The extent of caries; the degree of undermining of the enamel; the strength of residual tooth structure: susceptibility to caries and cosmetic factors, all play a part in the design of the cavity. It is essential that, above all, conservation of tooth structure be uppermost in the operator's mind when he is preparing a cavity. It is all too easy, using a turbine drill, to overcut, especially when the cavity margins are somewhat obscured by the coolant spray. Thus, constant checking is vital, to minimise over-extension. At one time, it was considered essential that every stained fissure in enamel be cut out. Now, provided that criteria of retention are fulfilled, stained fissures which overlay healthy dentine may be left, on condition that they are shallow enough to allow perfect finishing of the restoration, and provided that a probe will not stick in them.

Retention form

That shape of a cavity which prevents the displacement of the restoration under vertical stresses and the various horizontal and oblique components of such stresses. Basically this is obtainable by the use of undercuts which, by making the internal dimension of the cavity greater than that of the orifice, prevent dislodgement of the restoration in the line of its insertion (figure 14.1).

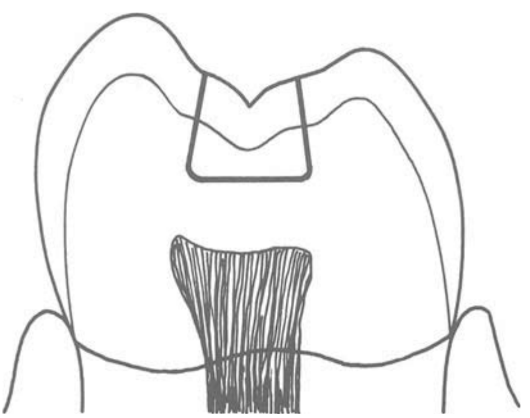


Fig. 14.1 Production of a butt-joint between enamel and amalgam occlusally will ensure an undercut cavity in the majority of cases.

Pins

In those cases where there is gross destruction of tooth structure, accessory retention may be obtained by the use of stainless steel pins embedded in the dentine, around which amalgam is condensed. The pinholes should be cut approximately 1–1.5 mm from the margin and parallel with the estimated slope of the root surface. Any departure from this direction could result in perforation of the root or exposure of the pulp (figure 14.2). The number of pins inserted will vary with the size of the cavity, but it is essential that the holes be cut to a depth of 2.0 mm at least, and that each pin be aligned at an angle to its neighbour. Thus, once the amalgam is condensed around divergent pins, they are unable to separate from the dentine. Roughly 2.0 mm of pin should protrude.

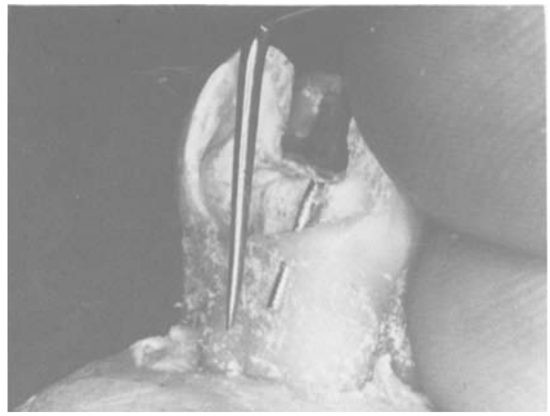


Fig. 14.2 Mal-angulation of a pin resulting in a perforation of the root. The probe is aligned to indicate the correct direction. Parallel with the slope of the root.

It is generally accepted that adequate retention may be obtained by placing one pin per missing wall. Pins should be well spaced and where sound walls are present, undercuts or grooves may be used in conjunction with pins. The root anatomy, especially in relation to furcation areas, must be considered when drilling the holes, if subgingival perforation into the bone is to be avoided. Thus, for example, pins should not be placed in the centre of the buccal wall of an upper molar, especially when the cavity is cut back to the gingival crest, otherwise the bifurcation zone of the buccal roots may be perforated.

In mandibular molars, dentine over-lying the mesiobuccal pulp horn is small in amount and, therefore, the region is unsuitable for placement of pins. A check radiograph may be of help in avoiding traumatic incidents.

There are various types of pin available. Arthur (1897) first described the use of anchor screws in dentine.

Markley (1958) recommended the use of a twist drill (0.027 in diameter) to prepare holes, into which are cemented threaded stainless steel wires (0.025 in diameter). Pins should be inserted to a depth of 2.0 mm, and a similar length protrudes from the hole (figures 14.3, 14.4). Short lengths of wire are cemented into the holes after introducing a bead of cement into each one with a shortened reverse spiral endodontic filler, or Lentulo. Before inserting the cement it is advisable to slide a No. 15 reamer down each hole in turn to ensure the integrity of the dentine. If there should be an exposure of the pulp or a perforation of the root, it is better to know about it, and take the necessary steps to deal with it at that stage, than to have a problem of diagnosis subsequently.

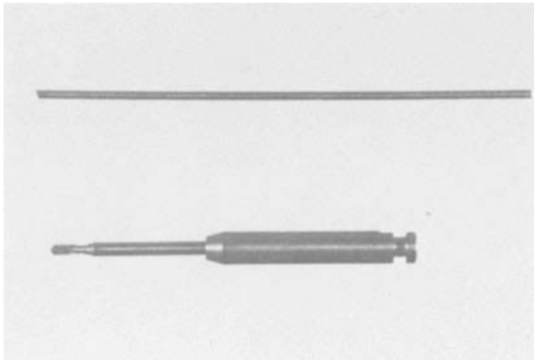


Fig. 14.3 Spirec bur and matching threaded stainless steel wire.

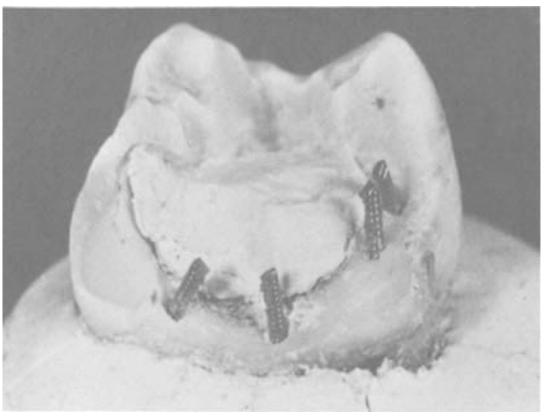


Fig. 14.4 Spirec wire pins in place for the anchorage of a large amalgam restoration.

One of the problems encountered in the use of the Markley pins is the insertion of pins into the holes through a pool of cement. Specially manufactured pliers with grooved beaks aid in the placement of the pins and are preferable to dressing forceps, from which a pin is apt to be expelled by sudden cross-over of the beaks when gripping it firmly.

Different cements have been recommended for luting Spirec wire pins. Of those which have been tried, the best results have been obtained from the use of phosphate cement (preceded by Copal/Ether varnish) or polycarboxylate cement. Hanson *et al.*, (1974) found that cyanoacrylate cement was inferior to these cements and recommended that it should not be used. They found that the T.M.S. minim pin (0.23 in diameter) plus zinc phosphate cement gave the best retention.

An alternative system for pin retention is the friction-lock, or Unitek system devised by Goldstein (1966) (figure 14.5) which employs a fine twist drill minutely narrower than the pin, so that when the pin,

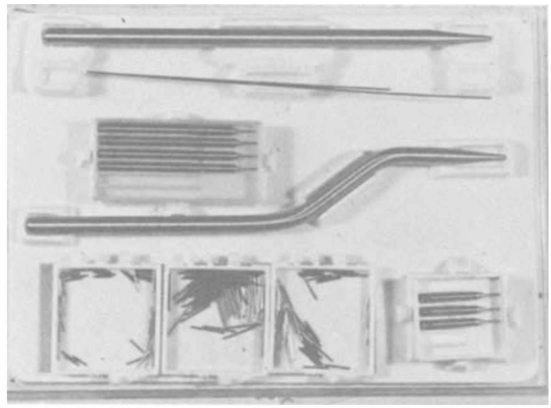


Fig. 14.5 Friction-lock pin set with drills, pins and applicators.

held in a special handle, is forced into the hole, it is retained by the elasticity of the dentine. The drill produces a hole of 0.021 in into which is forced a pin of 0.022 in, therefore, it is important to ensure that the drill is removed immediately the required 2–3 mm depth is reached. Otherwise the over-sized hole will not produce a frictional fit and the pin will be loose.

A variant of this system is found in the Dolphin pin technique in which handle and pin constitute a single entity. The pin shears off on reaching the base of the pin-hole (figure 14.6).

In this technique, as with all techniques for self-shearing pins, care must be taken to avoid excessive widening of the hole through the use of undue pressure and high speed drilling. This results in a loose fitting pin which will not shear off.

The risk of crazing of dentine following the use of friction grip pins, especially the larger diameters, has

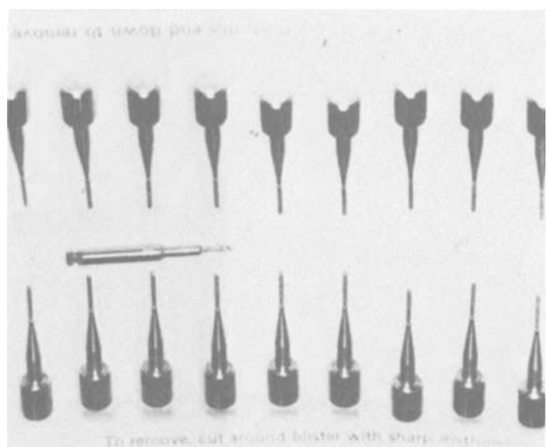


Fig. 14.6 Dolphin self-tapping pin system.

been shown by Dilts *et al.* (1970). Bearing this in mind, it is advisable to use cemented pins or narrow, friction-grip or self-tapping pins for non-vital or slender teeth.

A similar pin is manufactured by Cedia which has a sharp bevelled end and thus is self-cutting. It is mounted in a special mandrel and rotated at 9–12 000 rpm under a coolant spray or jet of water. When it has been embedded into dentine to the required depth, it is rotated in reverse momentarily, thus locking it firmly home. When the mandrel is detached, the pin is seen to be held firmly in the dentine.

The Thread-Mate System (figure 14.7) utilises the principle of locking a fine screw into a hole in the dentine, prepared with a special drill. The end of the screw is located in a special mandrel which is used as a screwdriver and is removed when the screw is locked firmly in dentine.

There are three sizes of pin, namely: the Regular (0.031 in), the Minim (0.023 in) and the Minikin (0.019 in). Khera and Chan (1978) found evidence of dentinal crazing with T.M.S. pins and stated that the risk of fracture of dentine could be minimised by the use of the smallest pins placed not less than 5.00 mm apart.

Ideally, rubber dam should be used when placing pins because there is a risk that the pin or holder may be dropped and inhaled or swallowed (figure 14.8). As an alternative to the hand wrench used for placing T.M.S. pins, a mandrel is available for use in a special 'auto-clutch' handpiece to carry the pin to place and screw it home at slow speed. Nevertheless, the pin may still fall from the mandrel into the mouth.

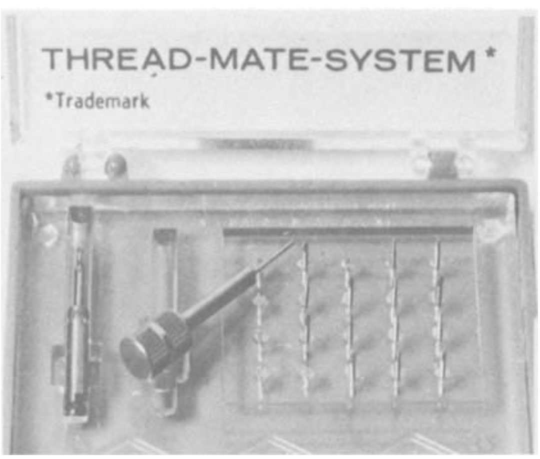


Fig. 14.7 Thread-Mate pin system comprising a drill, a hand chuck and screw-threaded pins which are screwed home into previously drilled holes. Each pin is of double length and will shear at the weakened mid-point when fully seated.

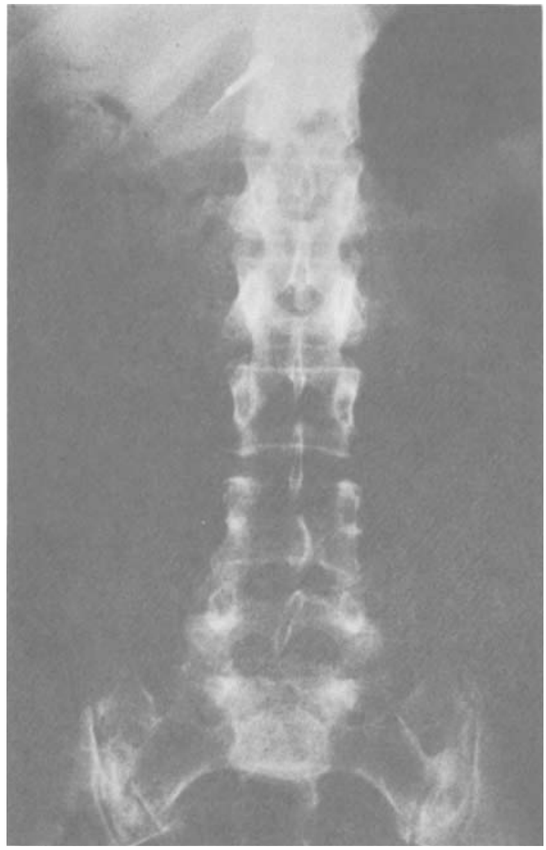


Fig. 14.8 Radiograph showing a T.M.S. holder and pin lying in the oesophagus. It slipped out of the fingers while working on a supine patient without the use of rubber dam.

A new type of self-threading pin is now available (STABILOK – Fairfax Ltd, – UK.) which is in the form of a dental bur with a constriction 4.0 mm from the tip (figure 14.9). There are two sizes: regular and small. A pit is first made with a ¼ or ½ size round bur to a depth of 0.5 mm. Then the appropriate drill is used, in a single movement, to cut a 2.0 mm hole at slow speed. The pin, mounted in a contra-angle handpiece is now placed over the starting pit and operated at minimum speed. This drives the pin home and, on reaching the base of the pinhole, it shears off, locked firmly in dentine.

Moffa *et al.* (1969) showed that, with all pin systems, there is micro-leakage unless a cavity varnish is used. They also found that with cemented pins, failure occurred always at the cement/dentine interface.

Wing (1965) showed evidence that stainless steel wire tended to weaken an amalgam restoration because of a decrease in compressive strength. The function of a pin is not to strengthen the amalgam, but solely to

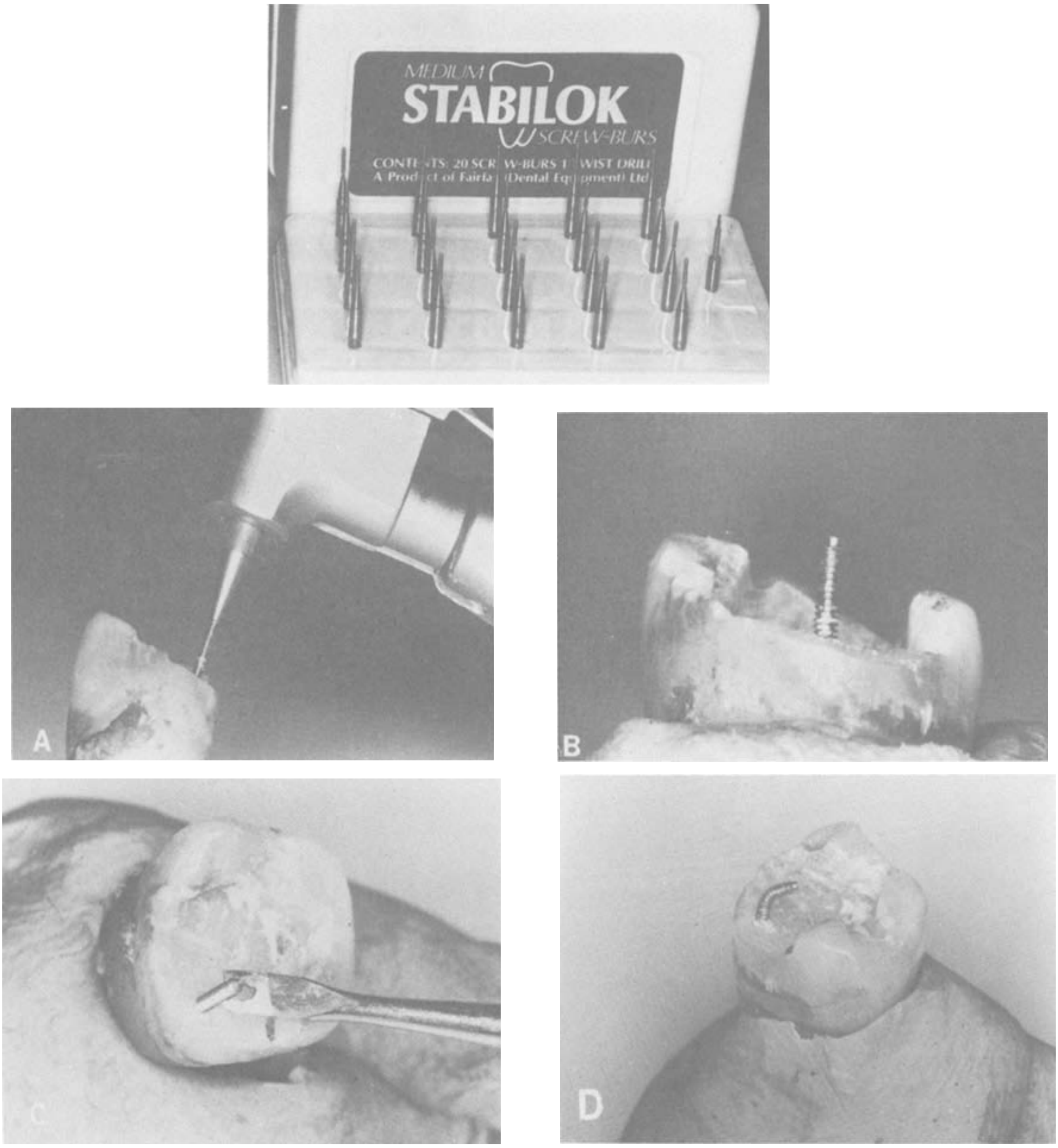


Fig. 14.9 Stabilok Self-tapping screw-bur and twist drill. (A) The pin is lined up with the hole cut to a depth of 2.0 mm and, running the motor at slow speed, the pin shears off on reaching the base of the hole. (B) Using a converted enamel chisel. (C) The pin is bent over so that it will lie well within the restoration, (D).

aid in its retention. Thus the smallest number of pins should be used, combined, whenever possible, with retentive pits and grooves in the dentine.

The Baldwin technique (figure 14.10) (1897), criticised undeservedly in recent years, is of undoubted value as a means of obtaining retention. A sticky cement base is placed in the floor of the cavity, into which, while still soft, amalgam is condensed, so that the mass hardens in intimate contact. Although phosphate cement possesses no adhesive properties, the retention obtained is more than adequate. Care should be exercised to prevent extrusion of cement to the cavity margins, and this may be avoided by condensing portions of amalgam at the margins and drawing portions of it into the soft cement. An underlying sedative base, if needed, should cover only the

Fig. 14.10 The Baldwin Technique used to restore a mesio-occlusal cavity in a lower second molar. Sticky phosphate cement has been placed over the dentine and a plug of silver amalgam deposited over the gingival step. After condensing the amalgam against the enamel margins mesially, it is teased onto the cement and packed gently into the unset surface. The proximal amalgam is then built up, giving time for the cement to harden, and then the remainder of the amalgam is condensed. Any soft cement which extrudes to the cavo-surface angles is removed.

dentine over the pulp. A combination of pins and cement retention may be adopted when circumstances dictate.

There are several other methods of obtaining retention for restorations, such as: dovetails, pits, grooves, cement retention and reverse retention (for gold inlays). These will be discussed under the appropriate headings.

Resistance form

Basically this means the resistance of the floors and walls to dislodgement of the restoration and is bound up with retention form; however, in essence it is satisfied by the production of flat floors and steps at 90° to the main stress, plus one sole line of insertion (for inlays) (figure 14.11a). The antithesis of this is seen to exemplify minimum resistance form (figure 14.11b).

The rigidity of a structure is proportional to the cube of its length and directly to its depth. Thus it is desirable to reduce the surface area of the restoration while increasing the cavity depth to the maximum permissible in order to resist deformation and consequent dislodgement of the restoration.

A cavity designed to receive a preformed restoration should be so prepared that there is one sole direction of insertion, in line with the expected applied load.

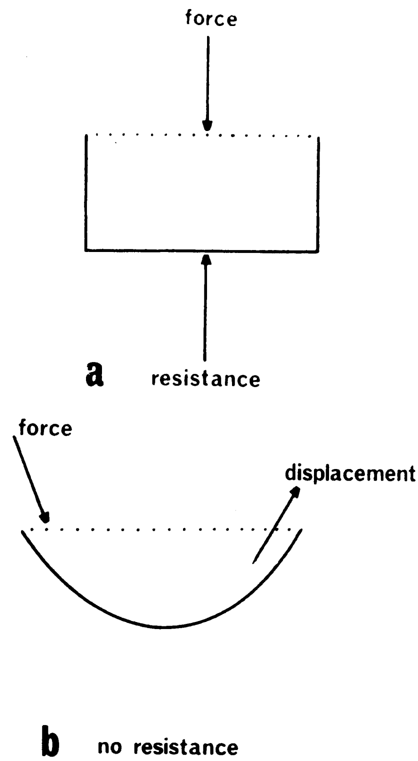


Fig. 14.11 Resistance form, exemplified by the production of flat floors in cavities.

Convenience form

This entails certain modifications in cavity shape to facilitate insertion of the restoration, e.g. removal of labial enamel in a Class III cavity of small dimensions in order to improve access for insertion of retention pits, or removal of part of a wall or cusp in order to improve access to a pulp canal.

Removal of caries

It is permissible to excavate caries with a large round bur rotating at low speed, but it is safer to use a large spoon- or pear-shaped excavator, cutting towards the walls of the cavity. The walls must be rendered caries-free at the amelo-dentinal junction but, in order to avoid exposure of the pulp, a small amount of softened dentine may be allowed to remain under a calcium hydroxide cement in a previously symptomless tooth. The cement stimulates the formation of secondary dentine by the odontoblasts and also recalcification of the demineralised dentine.

Finishing of enamel walls

To obtain maximum strength at the margins of amalgam, silicate and composite restorations, they should be finished to a 90° butt-joint with enamel which, in turn, exhibits maximum strength when the prisms are finished at 90° to a tangent to the surface. apart from finishing the enamel margins at a 90° angle for plastic restorations, it has been shown that better marginal adaptation is obtainable when the enamel is smooth and all weak fragmented prisms have been removed. Smoothing is effected by the use of abrasive discs (sandpaper) and carborundum stones, or by planing and scraping with a sharp chisel. Recent investigations using the scanning electron microscope suggest that the smoothest enamel finish is produced by the use of tungsten carbide finishing burs. Enamel margins are bevelled before etching for retention of composite and also for gold crowns and inlays, because the high tensile strength of gold allows it to resist stress in fine sections which protect the underlying enamel.

The direction of rotation of a bur is of prime importance if smooth margins are to be produced. The bur should rotate into the margin. If it rotates out of the cavity, chipping of the prisms results. Where space permits, fine sand and cuttle discs produce a good finish, however, if pressure is exerted, they bend and produce unwanted undercuts and bevels.

Care must also be exercised when using a chisel on margins. If enamel is planed with the chisel held in a direction parallel to the enamel rods, chipping of the prisms will occur. A smooth surface can be obtained by cutting at an angle across the rods. Gingival margin trimmers with a 30° angulation of the blade to the axis are ideal for scraping and planing gingival margins, whereas a 70° angled trimmer is better suited for scraping proximal margins.

An excellent method for smoothing tooth surfaces and producing bevels and chamfers, was introduced by Baker and Curson (1974). This technique entails the use of bladeless tungsten-carbide burs (T. C. Blanks) (figure 6.4). They are available in four shapes, related to the type of margin to be finished, and used in the turbine handpiece with coolant spray.

Cavity toilet

Cavity preparation is concluded by irrigation with a warm water spray and a short blast of warm air. The cavity is inspected carefully and any modifications are made; then, after particles of debris have been washed away, the cavity is dried with cotton-wool and thus is ready to be restored. No irritating drugs should be used, but in deep cavities a sublining of calcium hydroxide cement is recommended.

Black's classification

Black designated five types of cavity, arising in different areas of teeth and varying as to aetiology and mode of preparation, as follows:

Class I. Cavities arising in pits and fissures, i.e. structural defects, e.g. occlusal surfaces of molars and premolars, buccal surfaces of lower molars and palatal aspects of maxillary lateral incisors.

Class II. Cavities arising proximally in molars and premolars.

Class III. Cavities arising proximally in incisors and canines but not involving the incisal angle.

Class IV. Cavities arising proximally in incisors and canines and involving the incisal angle.

Class V. Caries arising buccally or lingually at the necks of teeth, either initiated in exposed cementum or in the cervical enamel, or in dentine, following abrasion of the enamel.

Cavity Preparation — General Considerations

Procedure

Firstly, the teeth are examined and, making use of special tests such as palpation, percussion, transillumination, vitality tests and radiographs, carious lesions are located and charted in the patient's notes. As soon as possible all gross caries should be excavated and replaced by a reinforced zinc eugenolate cement.

When caries control has been thus effected cavity preparation may be commenced. Entry to the cavity is made through a pit or fissure in the enamel, using a small inverted cone or round bur at low speed or a dome-ended fissure bur at high speed in the turbine handpiece. If there is an extensive cavity, the walls of which are grossly undermined by caries, it is easier to cleave back the enamel with a sharp chisel. The outline form is now established just below the amelo-dentinal junction, cutting horizontally, i.e. parallel to the pulp chamber, and ignoring the presence of caries which extends in a pulpal direction. As a rough guide, the initial depth of an occlusal cavity in a molar should be no more than 3.0 mm, and that in a premolar 2.0 mm. This corresponds roughly with two-thirds and one-half, respectively, of the length of the cutting end of a fissure bur, and is related to the position of the amelo-dentinal junction in a relatively unworn tooth.

The outline form is now modified for retention, resistance to stress, and convenience. The margins are prepared so that the restoration will terminate in 'self-cleansing areas', i.e. areas accessible to the cleansing action of the lips, tongue and cheek and the toothbrush. Margins are extended also just beyond the gingival contact in Class II, III and IV cavities, in order that a good marginal fit may be achieved. The gingival margin is bevelled in order to eradicate all unsupported enamel prisms in Class II, III, IV and V cavities (figure 14.12).

At one time it was taught that every proximal restoration should extend beneath the gingival margin, but now it is realised that, given good oral hygiene and polished well-fitting restorations, the risk of recurrent caries is small, whereas the danger of periodontal irritation is increased when margins are situated in the gingival sulcus. In practice it should be possible to pass the point of a fine probe between the margin and the adjacent tooth without hindrance.

When the final outline form has been completed. residual caries is removed, the inclination of enamel prisms at the cavo-surface angles is corrected and the walls are smoothed. The pulpal and axial walls, in relation to the pulp, are checked for evidence of exposure and the cavity is then ready to be restored. The point of a probe should never be pressed into any lesion in the dentine which is thought to be an exposure. The probe is stroked gently across, the floor; if an exposure is suspected it must not be traumatised. In the absence of caries, it may be treated by capping with a suitable material (see chapter 3).

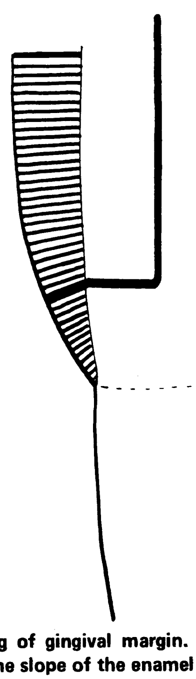


Fig. 14.12 Bevelling of gingival margin. Note the angle of bevel in relation to the slope of the enamel prisms.

Class I Cavities

The Class I cavity occurs principally on the occlusal aspects of molars and premolars, buccally in lower molars and palatally in upper molars and upper lateral incisors, and is usually a four-walled cavity. At present the ideal materials are cohesive gold and amalgam, but for reasons of economy and ease of manipulation, amalgam is used universally. Gold inlays offer no advantage unless it is necessary to build a veneer over a weakened cusp or replace it completely.

The outline form should follow closely the configuration of the fissures, with the cavity margin placed ideally at the intersection of the internal third and the external two-thirds of the distance from cusp tip to fissure (figure 14.13). Subsequent removal of caries which has undermined the walls will necessitate further cutting back of weakened enamel with corresponding modification of the simple classical cavity outline.

When cutting the outline form, the fissure bur should be so angulated that a cavo-surface angulation

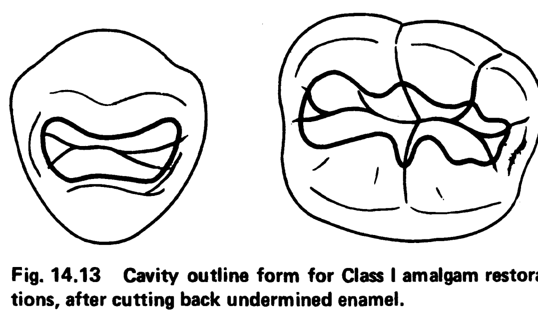


Fig. 14.13 Cavity outline form for Class I amalgam restorations, after cutting back undermined enamel.

close to 90° is produced at all points around the perimeter. By cutting the walls at 90° to a tangent to the surface, a butt-joint, thus created, will impart maximum strength to the margin of the amalgam.

Mesially and distally it is permissible to produce a cavo-surface angle of approximately 100°, in order to avoid any undermining of the proximal enamel when the cavity margin encroaches unduly on the marginal ridge (figure 14.14). Irrespective of the depth to which caries has extended the cavity is prepared, as stated previously, to the amelo-dentinal junction, and any caries which is excavated subsequently is replaced by cement, to produce a flat floor to the cavity which will resist vertical stress.

In order to avoid weakening unduly the small lingual cusp of a lower first premolar, the bur should encroach on the buccal side of the fissure to a greater extent than the lingual, and the overall slope of the cavity should be parallel with the occlusal third of the buccal wall (figure 14.15). Similar modifications are indicated in other situations and are dictated by the necessity to preserve the strength of the tooth.

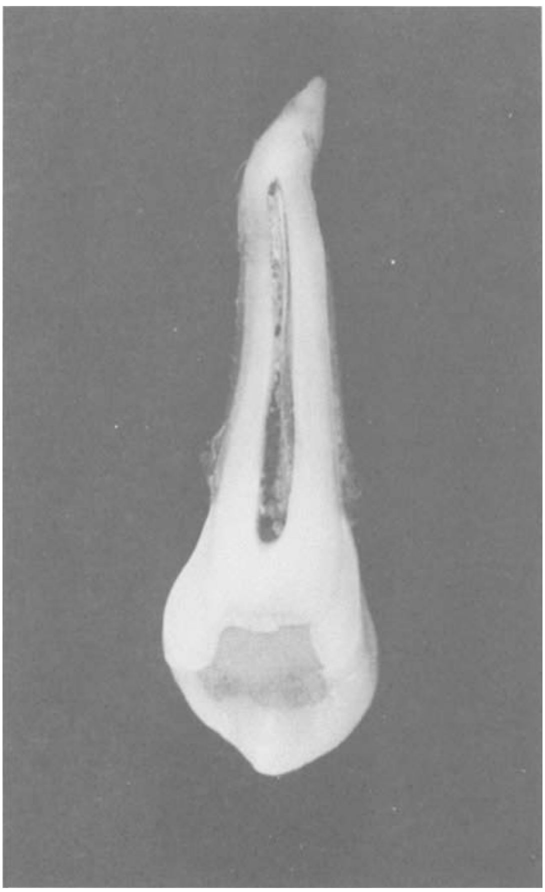


Fig. 14.14 Mesio-distal longitudinal section through maxillary premolar showing amalgam restoration. The mesial and distal walls are seen here to be flared, so that there will be no undermining of the proximal enamel.

Fig. 14.15 In the mandibular first premolar, the cavity is prepared parallel with the occlusal third of the buccal surface. This avoids weakening of the small lingual cusp and also lessens the risk of trauma to the buccal pulp cornu.

A special case of the Class I cavity is to be found in the upper incisor region. Congenital malformation of the incisor teeth can occur, varying from a simple fold or pit, to a complete invagination (so-called 'dens in dente') (figures 14.16 and 14.17). Palatal pits of this kind are very common, and their special significance lies in the proximity of the pulp to the oral cavity at this point. Indeed in some cases the pulp is in direct continuity with the mouth, with the result that the pulp may become infected without giving rise to symptoms, and die slowly. The earliest evidence of this is the observation by the patient that the tooth has darkened slightly, or the dentist may discover a chronic abscess or cyst from the radiograph.

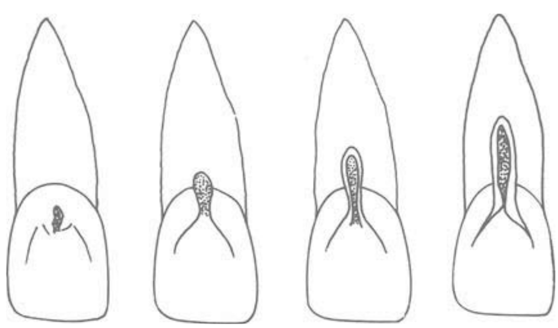


Fig. 14.16 Class I cavities in maxillary lateral incisors. Four variations of the cingulum pit, ranging from a simple pit to a 'dens in dente' invagination.

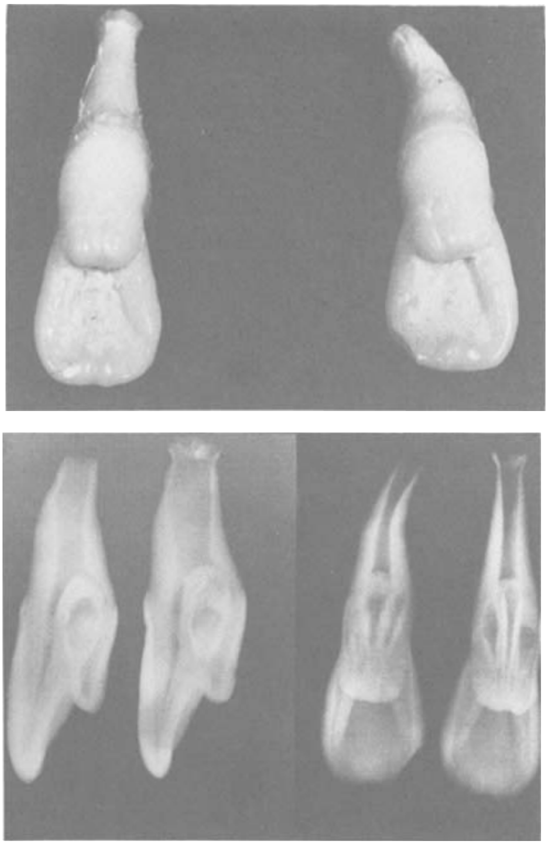


Fig. 14.17 (Top) A pair of maxillary lateral incisors with invaginated pits in the cingula. (Bottom) Bucco-lingual and mesio-distal radiographs of the incisors showing the intricate nature of the Dens in Dente formations.

The obvious prophylactic treatment is to close the orifice of the invagination as soon as it has appeared at the gingival margin during the course of eruption. This may be effected by cutting an undercut cavity in the cingulum pit solely to the thickness of the palatal enamel, and filling it with amalgam. Care should be taken to avoid passing the bur into the opening of the invagination, to avoid exposing the pulp. A small bead of calcium hydroxide cement should be placed under the amalgam.

Teeth with deep pits restored in this way should be kept under observation for some years, and the corresponding tooth on the other side of the arch should be similarly suspect. In such cases the importance of having an effective marginal seal cannot be overstressed; and it is worth considering recent work on the seepage of amalgam restorations, and safeguarding the pulp by painting the walls of the cavity with a copal/ether varnish. Cavities of this sort are not subjected to major stress and for anatomical reasons cannot conform to the general requirements of other Class I cavities, but should follow the basic essentials as far as possible.

Class I cavity for gold inlay

Class I inlay cavities differ from those prepared for amalgam in two main aspects. The walls must be kept nearly parallel or slightly divergent (at an angle of no more than 5°) and the occlusal, cavo-surface angles require to be bevelled at an angle of approximately 45° in order to permit burnishing of the gold onto the tooth surface. The object of the bevelled margin is to reduce the area of exposure of the cement used to fill the space between the inlay and the tooth to a minimum through burnishing of the feather edge of gold into intimate contact with the enamel.

If the enamel of the cusps is undermined, the bevel may be brought over the highest point and made into a reverse bevel, which will enable the gold to embrace the weak enamel and protect it. The undercut is obliterated with cement. It is essential that sufficient tissue be removed to obtain a minimum thickness of 0.6 mm of gold overlying the cusp.

The walls of the finished cavity must be rendered quite smooth by planing with a chisel or by the use of carborundum stones or tungsten carbide finishing burs or T. C. blanks used at high speed and water-cooled. By this means a wax pattern may be produced which mirrors more accurately the surfaces of the walls. Undercuts remaining after removal of caries or restorations may be blocked out with phosphate cement.

Class II Cavities

Class II cavities consist of an extension of a Class I occlusal cavity into either a mesial or distal, or mesial and distal boxes. Either amalgam or inlaid gold can be used to restore cavities of this type.

Amalgam is the restorative material of choice in teeth with only minor carious involvement, partly for reasons of cost, and partly because well-constructed restorations of this type involve less tooth destruction and often have a better prognosis.

Conversely, inlaid gold restorations are to be preferred in those cases in which the small size of the tooth precludes the use of an adequate bulk of material, also where the extent of the destruction involves restorations which flare to produce weak restorative angles i.e. extending well out to involve buccal or lingual walls) and when the restoration is intended to be used in bridgework as a minor abutment. In addition to these considerations, the material may be advised for aesthetic, electrolytic or hygienic reasons.

Class II cavities are frequently diagnosed by the colour change in the overlying marginal ridge enamel, which transmits the colour of the caries to produce a whitish, yellowish or bluish opacity, denoting the type of underlying caries (figure 14.18). White or yellow indicates the presence of rapid caries, whereas a darker colour, from brown to blue, indicates a more chronic type of carious attack. Other factors, such as pain, a palpable proximal cavity and the radiographic evidence of its presence will reinforce the diagnosis. Early caries is discovered often solely by examination of a bitewing radiograph (figure 14.19), although the fraying out of a piece of dental floss which is pulled with a sawing movement through the contact area will indicate a loss of surface continuity.

The method used to open up a cavity will depend on the extent of the proximal caries. When it is

Fig. 14.18 Fissure caries in 76|. Note the opacity in the mesio-lingual cusp of 6| indicating the spread of caries from a Class II cavity to undermine the enamel.

Fig. 14.19 Deep carious lesions apparent in |6, mesial, |8, mesial; deficient restoration-distal |7; gingival over-hang of restoration in |5.

minimal, entry is made through an occlusal fissure, and the outline form of a Class I cavity is produced. The cavity is then extended proximally into the caries and the proximal enamel is cleaved away with chisels after it has been undermined sufficiently. When there is an extensive proximal cavity underlying the marginal ridge on the other hand, this may be entered easily by cleaving away the enamel and paring back the walls with chisels. Caries is then excavated, overhanging enamel is cut back and an occlusal lock is prepared, extending the fissures as for a Class I cavity.

Mondelli *et al.* (1980) have shown that all occlusal cavity preparations decrease the strength of teeth in proportion to the width of the preparation.

The Class II Cavity results in further weakening of the tooth. They concluded that the width of the isthmus is a statistically significant factor in the fracture of cusps, and it should be one fourth the width of the inter-cuspal distance to ensure maximum strength in both Class I and Class II Cavities.

Class II cavity for amalgam

The cavity prepared for amalgam differs in several respects from that intended for a gold inlay. Firstly it must be self-retentive. This is brought about by the use of undercuts in both the box and the lock. The buccal and lingual walls of the box should converge slightly in an occlusal direction, and retentive pits or grooves should be made in these walls near to the axio-gingivo-buccal (and lingual) point angles. Numerous papers have been written about the use of proximal groove retention.

Terka *et al.* (1973) found little difference in the vertical forces needed to displace or fracture a class II amalgam retained by proximal grooves. However, they noted a great increase in the resistance to horizontal fracturing forces and they recommended the use of proximal retention grooves because they permit a narrower occlusal preparation.

These findings were corroborated by Mondelli *et al.* (1974) and Crockett *et al.* (1975). It would seem that, given adequate residual bulk of dentine, and provided that the tooth is not weakened, the insertion of pits or grooves is a factor in increasing the resistance to fracture of the restoration. This gives further resistance against tangential shearing forces. Occlusally the inclination of the walls produced by cutting the cavo-surface angles at 90° gives adequate retentivity. The occlusal outline should be in the form of a lock or dovetail to prevent proximal dislodgement and to minimise creep of the amalgam.

Extension of proximal margins beyond contact with the neighbouring tooth is essential so that the restoration may be polished; so that its marginal fit may be checked and so that the margins may be accessible for cleaning by the patient.

When extending the proximal walls to the buccal and lingual aspects, they must be finished to a 90° butt-joint when viewed from the occlusal, and not over-extended when producing this angle. Thus care should be exercised, when the preparation of the box is begun, to avoid over-cutting towards the proximo-buccal and -lingual angles, otherwise the consequent undermining of the walls would necessitate unavoidable over-extension of the cavity. All preparation of proximal margins should be carried out with chisels, preceded if necessary by undermining of the enamel with a rosehead bur.

The gingival step of the box should be prepared parallel to the occlusal floor and at right-angles to the axial wall with rounded gingivo-lingual and gingivo-buccal angles. The flat surface resists stress and the rounded angles make subsequent adaptation of amalgam easier. The gingival margin should be bevelled to an angle of approximately 30° (figure 14.20) with a gingival margin trimmer (Black's No. 77/78 or 79/80) (figure 14.21). This instrument is used with a planing action down the buccal and lingual margins and with a scraping action along the gingival margin, to remove weak, unsupported enamel prisms and to round off the embrasural angles. Should there be difficulty in obtaining clearance between the gingival margin and the adjacent tooth, a groove is cut along the amelodentinal junction with a round bur (size ½), into which the gingival margin trimmer is introduced and twisted towards the adjacent tooth. This fractures away the undermined

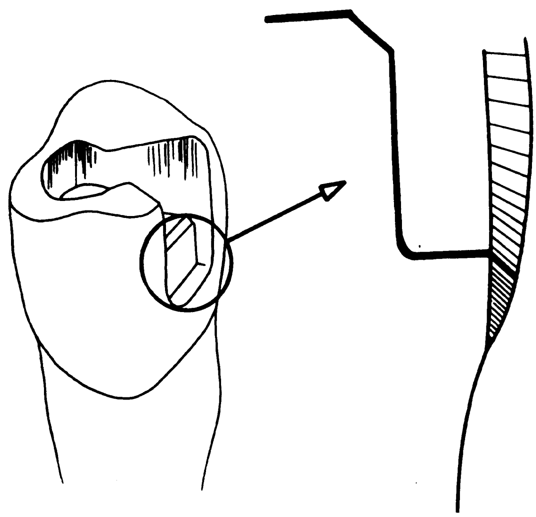


Fig. 14.20 Outline of preparation of proximal cavity, showing gingival bevel in relation to slope of enamel prisms.

enamel and lowers the margin which is scraped until smooth and then bevelled, using the same instrument.

The weakest part of a Class II restoration is the isthmus, hence it should be at least one-third of the width of the proximal box, and in order to minimise the concentration of stresses, the axio-pulpal line angle must be rounded. In the majority of preparations this is done in the lining cement.

If a cusp is largely undermined by caries, it should be cut down approximately 2 mm and restored in amalgam, whilst ensuring that the occlusal lock is still retentive. Should there be undue destruction of tooth structure, pin retention may be necessary or a gold inlay may be indicated.

Great care must be exercised when removing caries or extending the cavity in the gingival area of

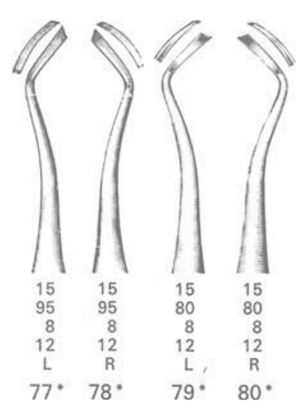


Fig. 14.21 Black's gingival margin trimmers (Ash). No. 77/8 is used to bevel distal gingival margins and No. 79/80 for mesial margins.

the box, especially in cavities which encroach on the neck of the tooth, to avoid accidental exposure of the pulp. This is apt to occur in cavities following gingival recession, particularly in teeth with markedly convergent walls.

Internal line angles should be rounded whenever possible to minimise potential fracture points in the tooth, and this can be achieved more easily by the use of dome-ended fissure burs.

Adaptation of amalgam to the enamel margins appears to be greater when a smooth finish is produced. This may be done by finishing with a carborundum point, a finishing bur or a plain-cut fissure bur at low speed, or by scraping along the margins with a sharp chisel. Ultra-high speed drills (especially if cross-cut) in turbine handpieces tend to leave a rough finish. A T. C. blank will produce a smooth finish at high speed.

Gold inlay Class II cavities

The chief points of difference between cavities for gold and those for amalgam are concerned with the necessity for removal of a wax pattern; hence there must be complete absence of undercuts and the marginal protection to be afforded by the edge of gold requires the preparation of bevels where they are indicated. Furthermore, the proximal walls may be flared, because gold has a high tensile strength and it is only necessary to have a solid tooth angle.

With steep cusped teeth, no occlusal bevel is necessary, except to protect the occlusal-proximal margins, but where there is undermining of the enamel, it may be given a wide bevel to protect the cement-based prisms from stress, in preference to cutting back the enamel.

Retention of cast restorations

The retention of a cast restoration is related intimately to the following factors:

(1) the degree of taper;
(2) the length of the preparation;
(3) the surface area of the preparation;
(4) the dislodging forces applied to the restoration, which, in turn, relate to the resistance form of the preparation.

A convergence angle of 5–8° will suffice for a long preparation, but the shorter the walls, the closer to parallel they must be. An angle of 3–5° will provide optimum retention. At this small angle, great care must be observed in the production of smooth surfaces and avoidance of re-entrants.

Complete cuspal coverage

Complete coverage of the cusps by gold is indicated when they have been undermined to such a degree that there is a risk that they will shear off under normal masticatory stress.

Pulpless teeth are especially prone to such fractures and it is not uncommon for the cusp to fracture off well below the gingival margin.

Reduction of the cusps, in order to carry a reverse bevel over the tips of the buccal and lingual cusps will allow the stresses to be transmitted to the body of the inlay and thus protect weakened tooth structure. An onlay distributes stress over a larger area and avoids the potentially traumatic result of stressing unsupported cusps.

It is essential that the depth of the cavity walls be increased to compensate for the loss of depth, occasioned by the occlusal reduction. In order to prevent undue wear of the occlusal surface of the inlay, leading ultimately to a perforation, platinised gold should be used and a minimum thickness of 0.6 mm should be obtained on the occlusal surface.

When the enamel is grossly undermined, it is nevertheless safer to remove the cusp and restore it in gold, but when the undermining is minimal, the undercut area may be filled with cement and the cusp reduced occlusally, to be covered later with a veneer of gold. A pin (1–2 mm) may be placed in the tip of each cusp to produce a splinting effect when the tooth is non-vital, but the use of pins for splinting a vital tooth is indicated solely to add support to a weakened cusp, in which a short pinhole may be cut (figure 14.22).

Extension

It is at times necessary to extend a fissure onto the buccal or lingual wall, e.g. the palatal fissure of a maxillary molar (figure 14.23).

When this is done, the cavo-surface angles, especially on the occlusal margins should be bevelled at an angle of 45°, in order to protect the prisms at the cut edge.

The proximal walls should converge slightly towards the step which may be given a longer bevel than for amalgam. The bevel on the proximal walls must stop where it reaches the line of maximum bulbosity of the crown, unless the walls have been flared or sliced. This is necessary because any feather edge beyond that line would fracture away as the pattern was withdrawn (figure 14.24).

The overall flare should not be more than 5°, to ensure adequate retentivity, and walls should be cut

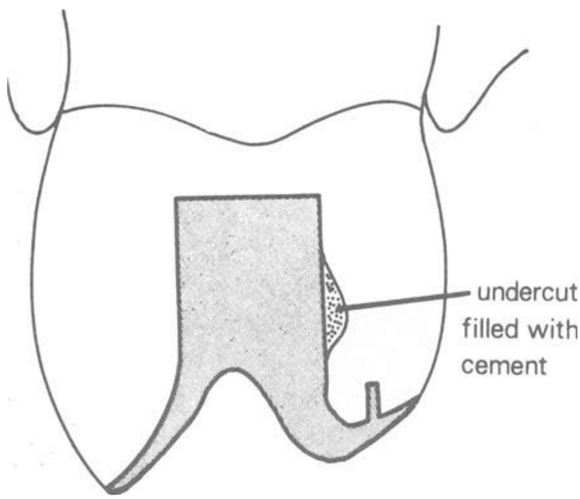


Fig. 14.22 Cusp coverage to protect the weakened walls of a Class II M.O.D. cavity in a maxillary premolar. Extra retentivity and splinting of the lingual wall is demonstrated here by the use of a short pin in the cusp.

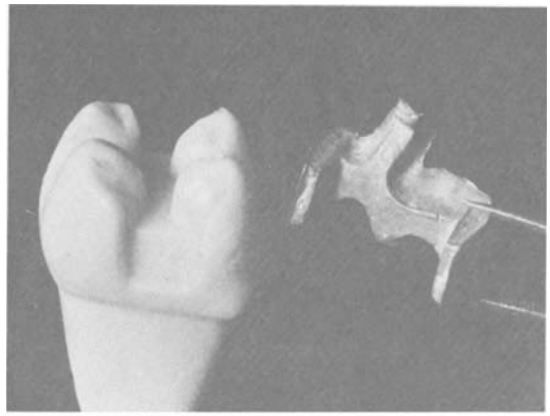
to a depth of approximately 2.0 mm occlusally, where the bulk of the retention is usually located. Further retention may be secured by the use of pins or grooves. This is especially advantageous when the cutting of a dove-tail lock would weaken the tooth, thus a pin placed near the opposite marginal ridge will lock the inlay securely in the cavity (figures 14.25 and 14.26). This technique is used often for minor bridge retainers, where extra retention is mandatory. Care must be exercised to avoid trauma to the pulp or periodontal ligament by careful alignment of the bur.

Slice preparations

Proximal slices confer the advantage of extending bevels over a wide area without undue loss of tooth tissue. They should be used with discretion where they would be visible, but otherwise they facilitate cavity preparation, impression-taking and finishing of margins. Nevertheless they must be used in conjunction with extra proximal retention if the gold is not to be forced away from the cavity under stress. They are especially valuable for conserving small teeth, and when there is minimal caries they are most frequently used in the forms of the box slice and channel slice.

Channel slice inlay

The preparation consists of a proximal slice extended to the gingival crevice from the marginal



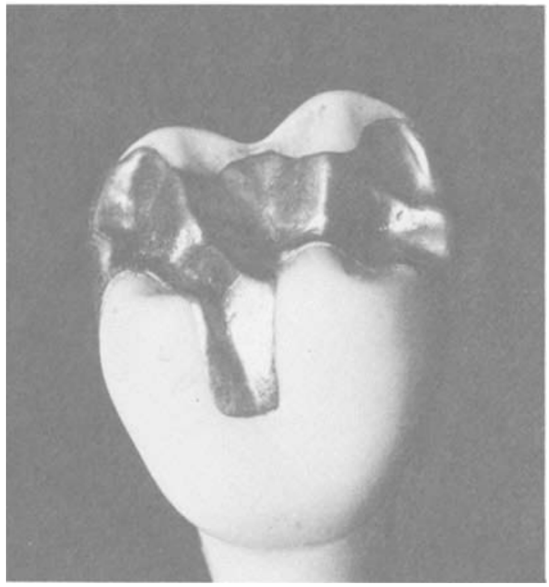


Fig. 14.23 M.O.D. inlay with palatal extension. Note the wide bevel around the extension.

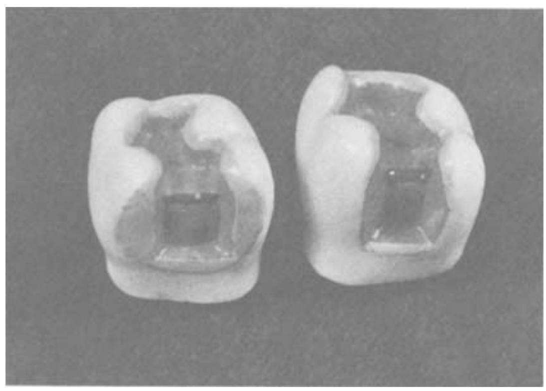


Fig. 14.24 Models illustrating: left, box slice Class II inlay preparation and right, conventional Class II inlay preparation. Note, in the proximal box, how the occlusal bevel is stopped at the line of maximum bulbosity, whereas in the box slice, the slice acts as an extended bevel.

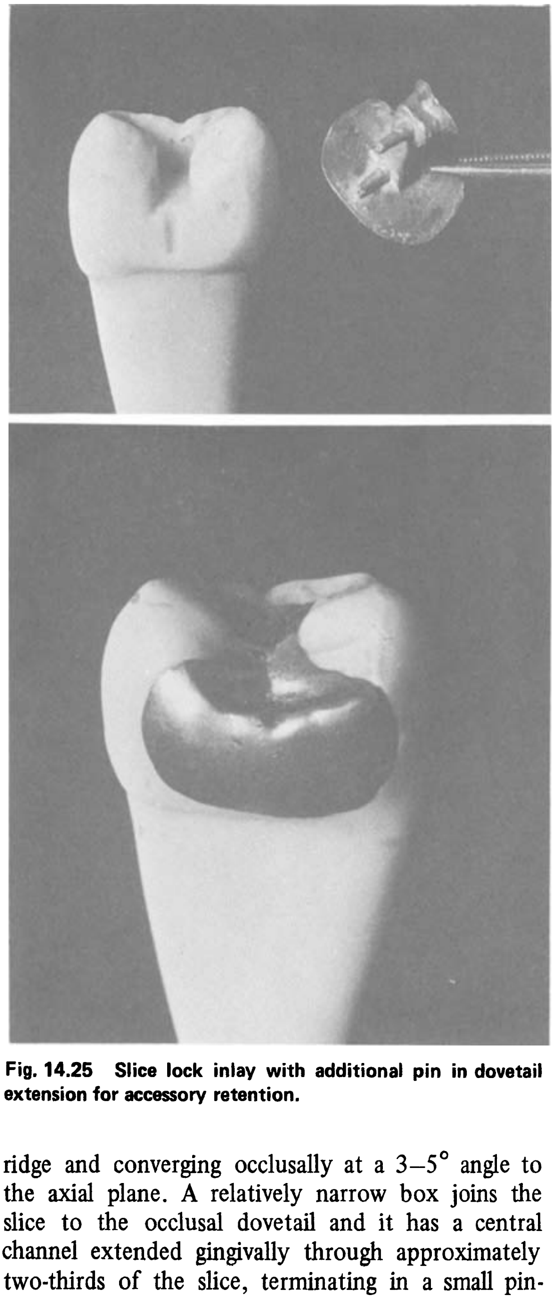


Fig. 14.25 Slice lock inlay with additional pin in dovetail extension for accessory retention.

ridge and converging occlusally at a 3–5° angle to the axial plane. A relatively narrow box joins the slice to the occlusal dovetail and it has a central channel extended gingivally through approximately two-thirds of the slice, terminating in a small pin-hole, 1 mm in depth. This channel ensures rigidity of slice extension and prevents distortion. The caries, which must be minimal, is removed and replaced with cement before completing the channel.

Box slice inlay

If there is a larger quantity of caries present, a small box may be cut and extended into the buccolingual areas with a slice (figure 14.27), although this technique is not recommended for very bulbous teeth because of the large amount of tooth which is lost in cutting a slice. The box slice preparation may be made more retentive by obtaining near-parallelism of the walls of the box, and if necessary including therein buccal and lingual grooves.

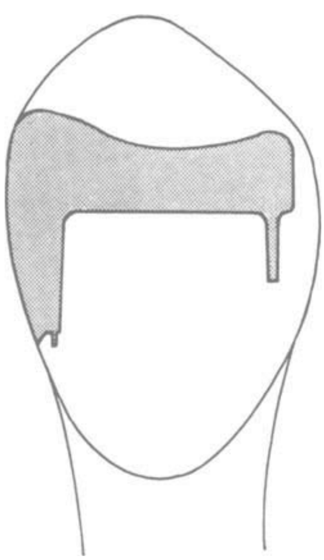


Fig. 14.26 Section to show relationship of pin and pit in gold Class II pinlay for premolar.

In deciduous teeth, a modification of the channel slice inlay, the 'Willet's inlay' may be used. This consists of an occlusal lock and slice, or two slices for an M.O.D. The lock should be relatively narrow with parallel walls in order to increase retention. The effect of keeping the channel narrow is partly to maintain the rigidity of the inlay and partly to increase resistance to rotational forces.

Precautions

When cutting slices it is imperative that care be taken to avoid damage to hard and soft tissues. In the former instance safe-sided discs should be used and a careful watch kept on their alignment in the vertical and horizontal planes. Soft tissues may be protected with a flanged saliva ejector and mirror, or by a retractor held by the nurse. A Killius disc protector (figure 14.28) held in place between the upper and lower teeth affords a very large measure of protection. Disc guards are available which enclose the greater part of the disc, thus shielding the soft tissues (figure 14.29). The greatest danger is that of binding of the disc, so that the high torque makes the handpiece jump out

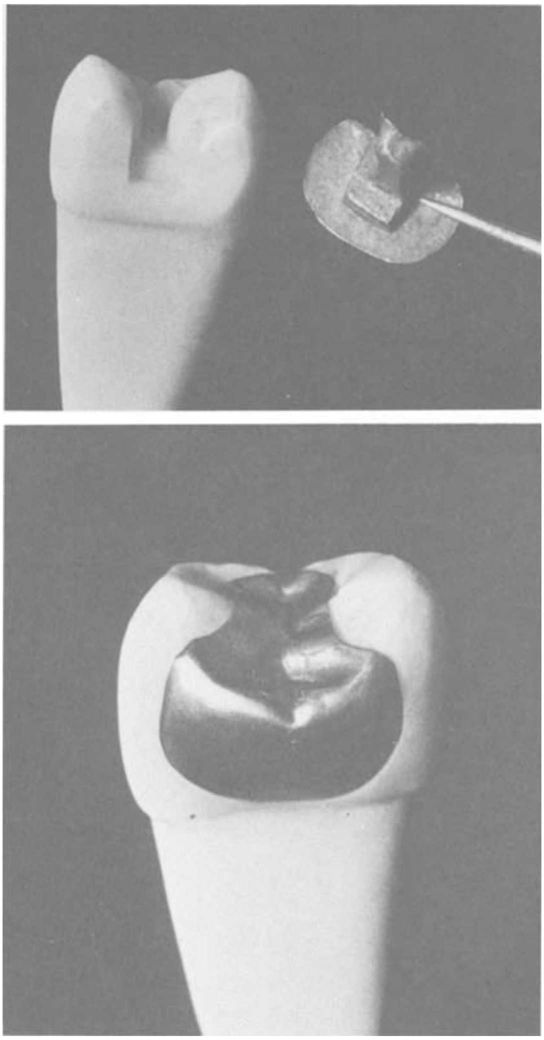


Fig. 14.27 Simple box slice inlay.

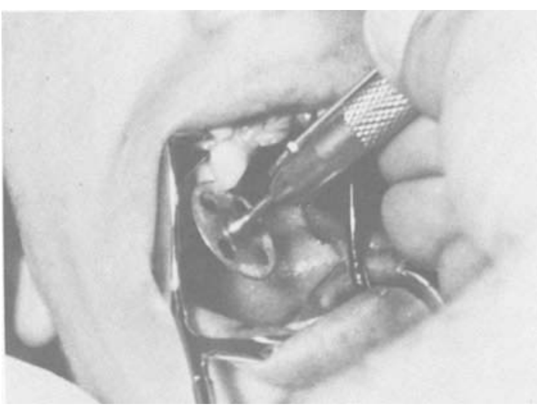


Fig. 14.28 Preparation of the distal slice on a maxillary canine. The engine cord has been slackened and the Killius tongue and cheek protector is used to guard against damage to the soft tissues.

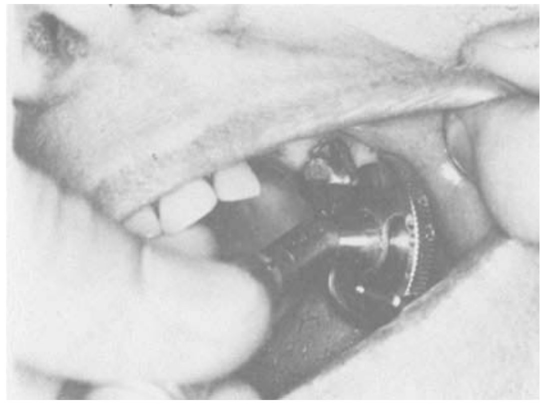


Fig. 14.29 Protection of the soft tissues with a disc-guard.

of the operator's grasp. Instantaneously the disc will free itself and cut into the tissues uncontrollably. This may be prevented by loosening the engine cord, so that it freewheels over the pulleys if the disc should bind. If an air motor is being used, the torque may be similarly reduced by means of a reduction in the air pressure. Flat-sided discs are adequate for anterior teeth and most premolars, but may be used solely for the mesial slices in posterior teeth. This is due to the relationship of the incisor tips which will impinge on the straight handpiece and not allow the correct angulation of the disc. This problem is overcome by (1) the use of convex discs or (2) the use of a Smith's grinding attachment or Kavo disc attachment (with guard) which will deflect the body of the handpiece away from the anterior teeth and allow correct positioning of the disc (figure 14.30).

Class III Cavities

Proximal cavities in incisors and canines may be approached directly from the interproximal aspect when the adjacent tooth is missing. Otherwise, by applying the modification referred to by G. V. Black as convenience form, the labial or lingual aspect of the cavity is extended to enable the operator to reach all parts of the cavity for removal of caries and placement of retentive pits. Aesthetic considerations dictate that the majority of Class III cavities be restored with a tooth-coloured material, such as silicate or a composite. If the cavity is so placed that it will not show, e.g. disto-lingually in a maxillary incisor, distally in a canine or in lower incisors, below the lip-line, the restoration may be made in amalgam, glass ionomer cement, cohesive gold or cast gold. When the cavity is prepared to house the minor retainer of a fixed-movable bridge, a gold inlay is indicated, and it is

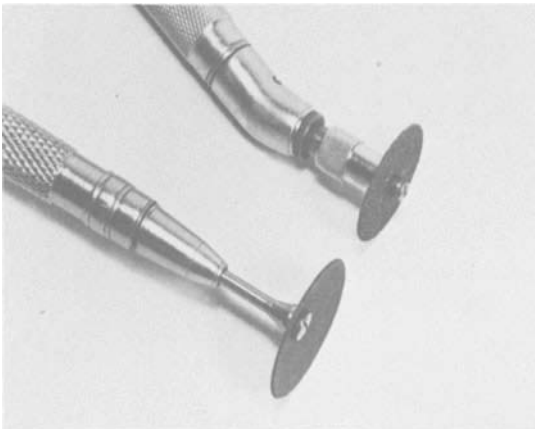


Fig. 14.30 Instruments for making distal slices in posterior teeth. Top: Smith's grinding attachment with flat safe-sided disc. Bottom: Straight handpiece with safe-sided convex disc.

designed in such a way that there will be sufficient proximal depth for a dovetail cross-sectioned, tapered groove to be cut in it to carry the stressbreaker component of the pontic.

The caries, which starts usually at the contact area or slightly to the gingival aspect of it, spreads incisally to undermine the enamel if allowed to progress unchecked. The early sign is a colour change in the overlying enamel, often visible before a Briault probe can be made to engage the margin of the cavity and, even in the early stages, made readily apparent by transillumination (figure 14.31). Some cavities attain a certain size and then, possibly due to an improvement in oral hygiene measures or diet, they become arrested. The caries then hardens and becomes stained. Such cavities may be watched, rather than restored, and usually they remain in the same state for several decades.

Until the present decade the materials in common use were silicate and acrylic resin. Both materials waste and discolour and require to be replaced at varying intervals. Composite resin, especially the latest microfilled material, and glass ionomer cement are now replacing the older, less satisfactory aesthetic restorative materials. Whichever material is to be used, it is essential that cavity preparation be carried out in as conservative a manner as possible, to preserve the incisal angle and to make the minimum extension on the labial aspect. The choice of whether to open up the cavity from labial or lingual aspect is largely dictated by circumstances, although lingual access is possible only in a relatively small number of cavities.

A labial approach is indicated in the following cases: (1) an existing cavity, prepared originally from the labial aspect; (2) gross destruction of dentine

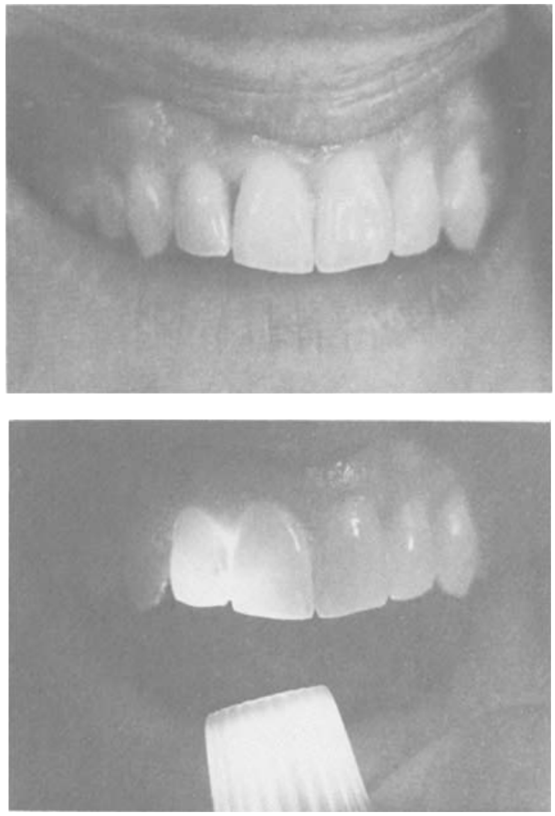


Fig. 14.31 The use of transillumination to demonstrate caries, seen here under a silicate restoration. (a) Caries not apparent under mesial Class III silicate in 2|. (b) Caries visible when tooth is transilluminated.

under the labial enamel; and (3) retroclined incisors, which would prevent access by a lingual approach. Ideally the proximal margins should be finished in such a way that the point of a probe may be passed easily between the adjacent tooth and the cavity margins. This is not practicable for the incisal margin for obvious reasons, but should be applied to all other margins.

Preparation of a Class III cavity for a plastic restoration

Access may be gained, when labial or lingual enamel has been undermined by the spread of caries, through the use of a Fantail chisel (figure 14.32), or alternatively the weakened enamel prisms may be cleaved with a G2 scaler to minimise the extent of the cavity when there is minimal caries. Once the enamel margin has been extended away from the adjacent contact, it is easier to plane it back, thus obtaining access for removal of caries. If, on the other hand, there is only

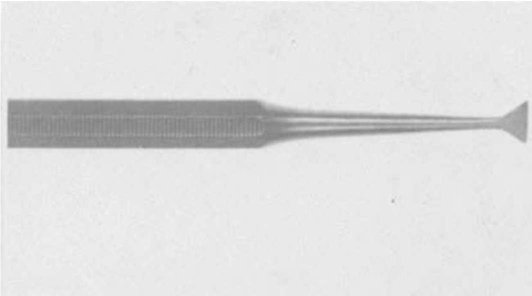


Fig. 14.32 Ash chisel (American pattern).

a small amount of caries which has not yet undermined the enamel, a small round bur is used to enter the cavity, making certain that the line of entry is far enough removed from the adjacent tooth to avoid trauma to it. A straight handpiece may be used if the cavity is opened up from the labial aspect, because it tends to produce less vibration than a contra-angled handpiece. The turbine should *never* be used for Class III cavities because of the risk of over-cutting and trauma to the adjacent tooth.

Once the cavity has been entered and all weak overhanging enamel removed, plus any enamel which interferes with access, the caries is excavated with small spoon and cleoid excavators and dentine hatchets until the walls are seen, by transillumination, to be completely clean and no soft caries is detectable with a sharp probe.

Pulpal caries is excavated gently in a direction from the pulp to the margins and it cannot be overemphasised that large *sharp* excavators may be used safely with light pressure, whereas blunt excavators will not remove caries and in consequence the operator is obliged to use force. The pressure causes discomfort or pain and increases the danger of exposing the pulp. A small amount of caries may be left over the pulp – but solely in that situation – rather than risk the possibility of an exposure in a deep cavity.

The cavity is then extended to lie beyond contact with the adjacent tooth, as stated above, and all cavo-surface angles are chiselled and planed to a 90° butt-joint angle. By using the chisel blade, or the sharpened line angle of the side of the chisel as a scraper, the margins may be rendered smooth. Improved marginal seal around composite resin restorations has been found after marginal bevelling of the enamel and etching the bevelled surface. A bevel of 45° is adequate and may be placed using a fine diamond bar or pointed finishing bar (T.C.) in the turbine handpiece. Temporary insertion of a steel matrix strip between the teeth will protect the adjacent tooth from trauma. Speiser and Kahn (1977) found, from an in vitro study of the butt-joint margin, that if such a margin is etched and a composite resin inserted and finished to a butt joint, there is increased marginal leakage which is made worse by the use of a low viscosity intermediate resin.

Eriksen and Buonocore (1976) found that etching the bevelled margin was instrumental in eliminating microleakage.

Hembree (1980) investigated the degree of microleakage associated with composite resins finished in four different ways as follows. (1) Butt joints, (2) Butt joint, overfilled and finished beyond the margins. (3) Bevelled margin with a 1–1½ mm bevel cut with a diamond stone. (4) Butt joints with a 1 mm shoulder in the enamel, extending to half its depth and cut with a diamond stone.

He found microleakage in all cavity designs. This was reduced or eliminated by etching the enamel at the cavo-surface angle and by applying a layer of unfilled resin before and after inserting the composite resin.

The Achilles heel of the Class III cavity is the incisal corner. Once this has been undermined, the danger of fracture under stress is greatly increased. Undermining by caries must be accepted and the caries removed with tiny excavators, taking care to preserve as much hard tissue as possible. It is inexcusable however to remove, without good reason, valuable hard tissue in excess of what is essential to gain access and to manipulate an instrument. For this reason, the use of hand instruments and slow-running small burs is mandatory.

Cavity shape

In general, when viewed from the proximal aspect, the cavity is seen to be roughly triangular, with the base along the gingival margin, and the sides and angles rounded. Retention may be obtained by cutting a gingival groove and an incisal pit. These must be prepared internal to the amelo-dentinal junction, parallel with the estimated slope of the root and be deep enough to be palpable with a Briault probe.

The majority of Class III cavities are prepared, for convenience sake, from the labial surface and despite the greater area of restoration visible, this is becoming more acceptable in the light of the improved anterior restorative materials that are now available.

When the cavity can be prepared principally from the lingual aspect, but with minimal labial extension, it may be restored with a glass ionomer cement which, because it adheres to the tooth, does not need mechanical retention and thus saves valuable dentine.

Linings in Class III cavities

The technique of lining Class III cavities is simple. In all cases, the proximity of the restorative material to the pulp dictates the necessity for a bland liner which will protect the pulp from the restoration and, at the same time, stimulate the formation of secondary dentine.

The general consensus of opinion is in favour of a preparation based on calcium hydroxide, such as Dycal (Caulk), Life (Kerr) or Procal (3M), which sets hard enough to allow direct placement of silicate or composite with minimum risk of disturbing the lining.

The pulpal wall must be covered and the undercuts similarly lined and, by inserting a small excavator while the cement is still soft, their patency may be assured (figures 14.33 and 14.34).

Although it is permissible to accept some undermined enamel on the labial surface of the cavity, it is necessary to ensure that all underlying stain and lining material are removed, thus avoiding an unsightly blemish should their colour be transmitted through the enamel.

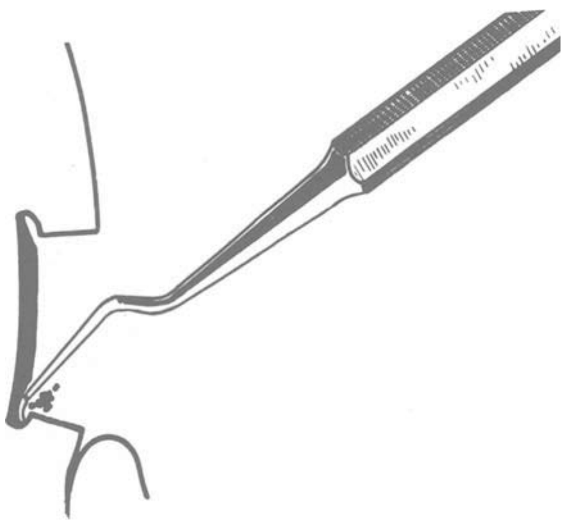


Fig. 14.33 The use of an excavator to remove excess lining cement from undercuts in Class III and Class V cavities, ensuring, at the same time, that the undercuts are lined.

Special types of Class III cavity

A modified type of Class III cavity is prepared in the distal of maxillary canines when an amalgam restoration is to be inserted. The cavity is entered from the palatal aspect and a lingual dovetail is cut which extends just into the dentine. The angles between

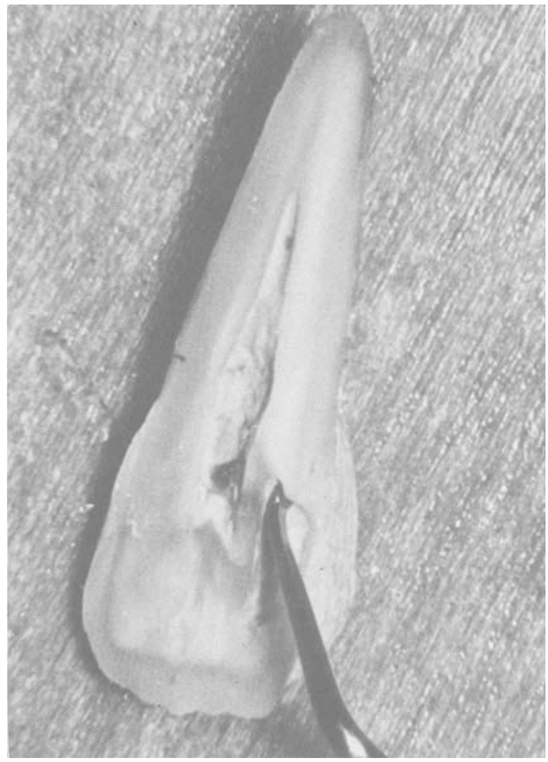


Fig. 14.34 Longitudinal section through an upper lateral incisor showing the placement of a small excavator in the gingival retention groove to check its patency after lining the axial wall.

the box and the lock are rounded and all cavo-surface angles are prepared at 90°. The chief advantage of a metal restoration in the distal surface of a canine is that it holds the first premolar in place; whereas a silicate, as it wastes in saliva, does not prevent mesial migration of the first premolar and this opens up its distal contact area, allowing proximal food impaction. As an alternative to amalgam, composite resin may be used, the contour being built up with the aid of a thin stainless steel strip and a wedge. After they have been removed, it is often necessary to add some resin to the contact area to achieve a firm proximal contact, because despite the burnishing of the matrix, it is not possible to exert the same pressure on the resin as on amalgam.

When teeth are imbricated, obtaining access to a proximal lesion is difficult unless a large amount of enamel is removed; entry may be facilitated by the use of a mechanical separator, which must be used gently, to obtain a restricted increase of access.

In badly imbricated teeth, when adjacent cavities are present, one of which has already been restored, it may be necessary to remove that restoration to improve access to the neighbouring cavity, and to restore the latter prior to replacing the removed restoration.

Class III gold inlay cavity

The Class III inlay may be used when there is extensive undermining of incisal enamel. The gold may be extended over the weakened lingual enamel and thus the danger of fracture can be averted. It is used also as an alternative to a plastic restoration where there would be a minimum amount of gold showing on the labial surface and even, on occasions, where gold would show, but the patient would not consider it objectionable. It is not, however, a commonly used restoration and it is employed most frequently as a minor retainer in fixed-movable bridgework. For this purpose, the cavity should be prepared with a proximal box and lingual dovetail having a path of insertion close to that of the major retainer (figure 14.35) and making use of a pinhole and a pit (figure 14.36) as accessory retentive aids, when indicated by the demands of retentivity.

In this latter preparation, the gingival cornu of the lingual dovetail is extended towards the opposite embrasure and terminated approximately 1.0 mm from it. A hole is cut with a 0.5 mm round bur from the base of this extension and parallel to the line of insertion for the inlay. This pinhole must be prepared with due regard to the positions of pulp and periodontal ligament. The hole is then enlarged with a tapered fissure bur (701), run at low speed, and a small pit, just internal to the amelo-dentinal junction, is similarly prepared in the gingival step of the proximal box which, because of the direction of withdrawal, will tend to be angulated towards the labial wall. The pin should be 2.0 mm in length and the pit, varying slightly according to the size and shape of the tooth, 1.00 mm in depth and 0.5 mm in diameter.

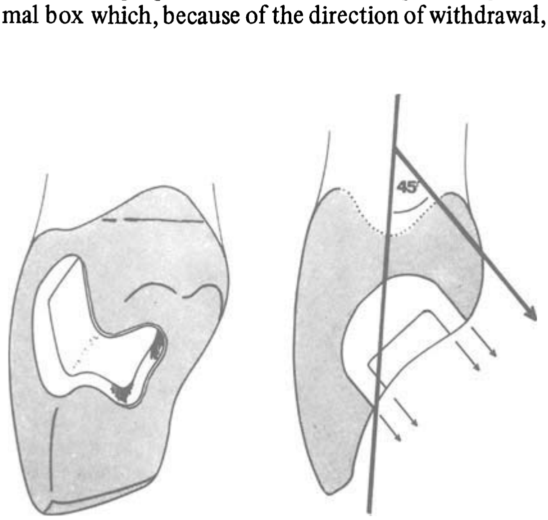


Fig. 14.35 **Class III cavity for a gold inlay, prepared at an angle of 45° to the axial plane.**

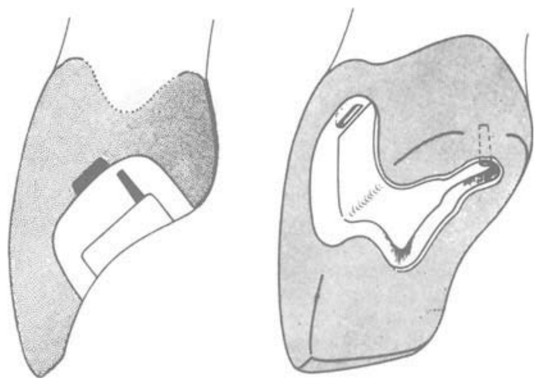


Fig. 14.36 **Class III cavity for a gold inlay, employing a proximal pit and a tapered pinhole as accessory retentive aids. Note the gingival cornu of the dovetail is extended away from the pulp, so that cutting the pinhole will not risk trauma to the pulp.**

The need for accessory retention is increased when there is substantial wear of the lingual enamel, making it impossible to prepare a dovetail of adequate depth without endangering the vitality of the pulp.

When, however, there is adequate intermaxillary space and the lingual enamel is of normal thickness, retention may be secured by paralleling all the walls of the cavity, and bevelling only those walls which, by virtue of the angle of withdrawal, have been cut at an angle of less than 90°.

These bevels must be of minimal extent otherwise retentivity would be impaired. The cavity is cut at an angle of 45° to the axial plane and the lingual dovetail is sited in the middle third of the lingual surface. The dovetail is cut just into the dentine, so that no lining is required and all walls are made smooth by planing with chisels or finishing with plain-cut finishing burs and Alpine white abrasive points. Undercuts which remain after the excavation of caries should be filled with phosphate cement.

Frequently, the depth of the cavity is insufficient to obtain frictional resistance to dislodgement, hence it is advantageous if the preparation is made with parallel walls and not with tapering walls as recommended for Class I and II cavities. It is obvious therefore that any roughness present in parallel walls will interfere with impression-taking, consequently smoothing of these surfaces must be carried out meticulously.

Class IV Cavity Preparations

The Class IV cavity, frequently referred to as a 'loss of tip' preparation, develops as a sequel, in most cases, to weakening of enamel as a result of extensive Class III preparations, or to carious involvement of the amelo-dentinal junction of the incisal angle. Traumatic fractures of the incisal corner, without prior existence of pathology, constitute a proportion of cases which require Class IV preparation.

There are two categories of Class IV restoration. Firstly, a temporary restoration, e.g. following trauma, or an immediate restoration after an incisal corner has been fractured under masticatory stress. Secondly, a permanent restoration using a gold inlay or pinlay, with or without an aesthetic facing.

For the purpose of temporary restoration, self-polymerising acrylic resin or a composite material may be locked into the cavity with one or more anchor pins. The composite materials, possessing greater colour stability and tensile strength than acrylic resin, lend themselves better to the restoration of surfaces of teeth subjected to stress. Silicate has been tried in this context but, despite the use of glass fibre strengtheners and wire anchors, it has proved to be too brittle to withstand the forces of mastication.

Although a well constructed Class IV gold inlay may give life-long service, it is widely considered to be unaesthetic, especially when it is large or displayed by a high lip line.

Since the inception of acid-etching and its application to the retention of Class IV composite restorations, the use of gold inlays for this purpose has diminished.

In the early days of composites, it was still necessary to use pins for retention, however, adhesion to the etched surface is so strong that fracture of the restoration has been shown to be due most frequently to a cohesive fracture in the resin rather than a failure in the adhesion. In consequence, the use of pins should be relegated to cases in which there is massive loss of tooth, so that they act as accessory retentive devices.

Preparation of incisor or canine for Class IV composite restoration

Firstly, after removing all vestiges of old restorations, stain and caries and ensuring the presence of a vital response and the absence of pulp exposure, a radiograph is viewed and the size and position of the pulp are noted.

Next, the cavo-surface angles are cut back to provide straight or slightly curved walls, labially and lingually, finished to a butt joint, then the margins are given a 45° bevel, etched and washed. Gingivally, a bucco-lingual groove is cut, internal to the amelo-dentinal junction, and is extended bucco-lingually so that it is undercut at each end (figure 14.37).

A calcium hydroxide type of liner is placed over the dentine and a cellulose acetate corner is loaded with composite and held in place until the restoration has hardened, when it is trimmed and polished.

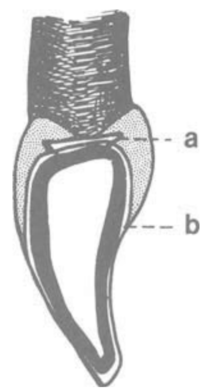


Fig. 14.37 Cavity preparation in maxillary incisor for a Class IV composite restoration with a gingival groove (a) in the dentine, and an etched, bevelled margin (b) for retention.

Class IV incisal angle restoration in composite material

When the incisal angle has been lost as a result of trauma, protection of the injured dentine, especially in young patients, is mandatory. An effective and simple restoration using composite material and two pins may be employed, which is more acceptable than a metal temporary crown and less bulky than a plastic crown.

Having made certain that the pulp is not exposed, a layer of calcium hydroxide cement is placed over the dentine and two pinholes, 2.0 mm in depth, are cut close to the amelo-dentinal junction. Pins are inserted and bent towards the lingual surface (figure 14.38). Enamel margins are then rendered smooth and bevelled and etched as described for the previous preparation, and a cellulose acetate crown form corner is filled with composite and held *in situ*, pressed firmly against the neighbouring tooth, until set. Then the restoration is trimmed and polished. If the operator is careful to avoid generation of heat when cutting the pinholes and if he places them well clear of the pulp, there is no reason why this type of restoration should endanger the vitality of the pulp. A similar preparation may be used when the fracture involves the whole incisal edge (figure 14.39). It is imperative that the pins do not extend too close to the incisal edge and are kept to the lingual aspect of

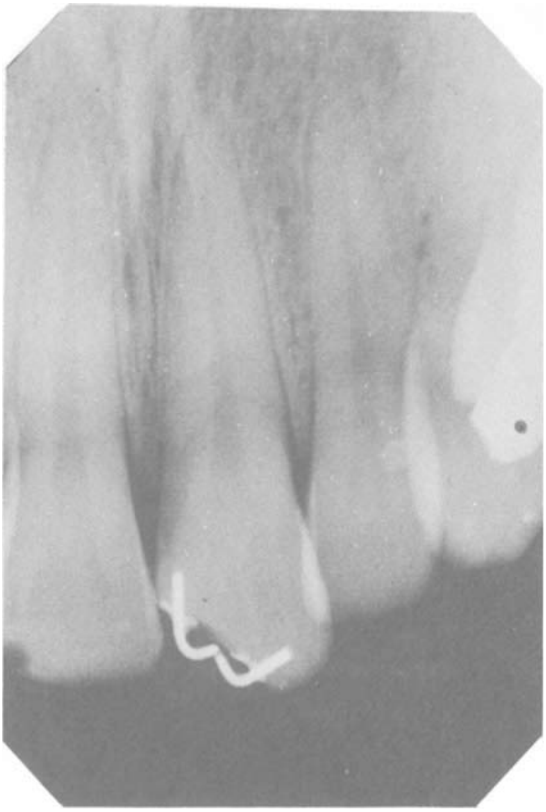


Fig. 14.38 Composite restoration retained by two friction-locked pins in fractured upper incisor.

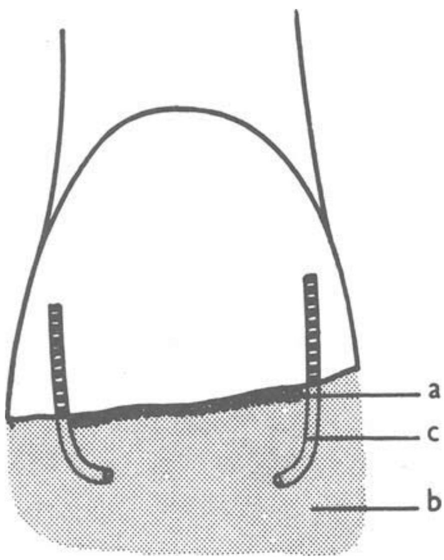


Fig. 14.39 Composite incisal restoration: (a) Calcium hydroxide cement over dentine. (b) Composite restoration. (c) Retention pins in the dentine.

the restoration: otherwise they would interfere with the colour. The shadow cast by the pins may be minimised by coating them with an acrylic masking cement (JUSTI) or a smear of phosphate cement. It must be emphasised that these restorations are primarily long term temporaries for use in patients who, at the time of fracture of the tooth, are too young for jacket crowns. Because of the size of the pulp below the age of 18 years, it is safer to delay crowning until the patient is older.

Class IV gold inlay cavities

There are two main groups of Class IV inlay cavities; those retained by means of dovetails and those retained solely by pins. The lingual dovetail is used chiefly for maxillary incisors and canines and the pinlay chiefly for mandibular incisors and canines, but in either type, as circumstances dictate, alternative forms of accessory retention may be employed. Lingual dovetail retention is contra-indicated for lower teeth, in which stress is directed towards the lingual.

The basic Class IV gold inlay, as recommended for an upper incisor or canine, consisted of a proximal slice ending gingivally in a step, with a lingual dovetail appended to it in order to resist lateral dislodging forces. There was a tendency for this inlay to pivot about the axio-pulpal line angle, frequently causing breakdown of the cement lute when tipping forces were concentrated on the proximal portion.

The author has for many years used and taught a modification of the cavity preparation which has been highly successful. It is used where there is less than 2.00 mm of tooth loss proximally, otherwise a better result aesthetically is obtainable by crowning. In this preparation, the labio-proximal cavo-surface angle is straightened, bevelled lightly at the incisal angle, rounded where it reaches the gingival margin and smoothed to a perfectly polished butt-joint, using a sandpaper disc. Next the lingual enamel is prepared in the form of a Class III box, within the proximal extension, and so angulated that its line of withdrawal is approximately 45° to the axial plane (figure 14.40).

The gingival margin is now seen to lie mainly on the labio-gingival junction.

The marginal enamel is cleared from contact with the adjacent tooth and the angles of the box are rounded. In the middle third of the lingual surface, having the same line of withdrawal as the box, a lingual dovetail is prepared and the acute cavo-surface angles are bevelled lightly. The increase in resistance form is undoubted, and provided that

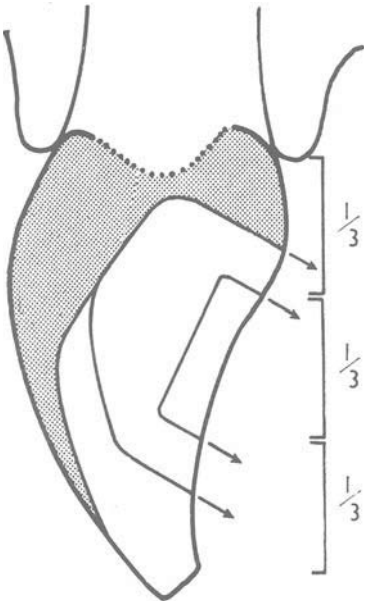


Fig. 14.40 Class IV inlay – parallelity of walls of proximal box and dovetail in line at 45° to the axial plane. The dovetail is placed in the middle third of the crown.

near-parallelism of the walls is obtained, the cavity possesses ideal retention (figure 14.41).

Similarly, when an incisal angle is to be restored, a box-like extension is made between the body of the inlay and the dovetail (figure 14.42).

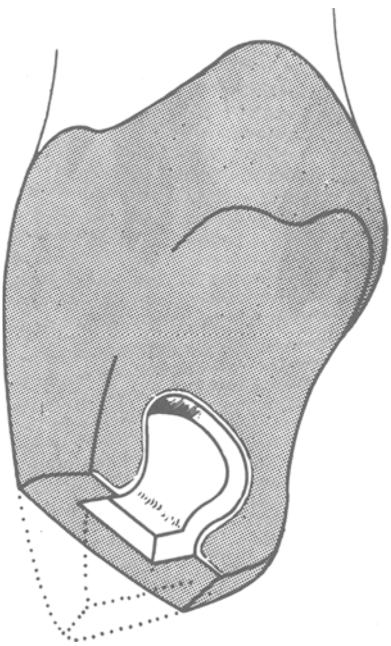


Fig. 14.41 Class IV inlay preparation with 45° angle of insertion and proximal box.

In these cases, provided that the width of the proximal cavity is small and that the patient does not take exception to a show of gold in an upper incisor, a well-finished and polished restoration is not necessarily unaesthetic. However, when such a restoration might be considered objectionable, a labial window should be cut in the wax pattern and the space in the gold inlay made undercut. The gold is painted with an opaque masking varnish and a facing of composite material inserted which will hide totally the underlying metal (figure 14.43).

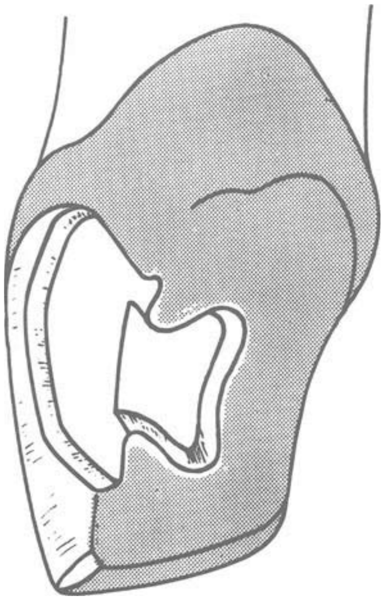


Fig. 14.42 Restoration of incisal angle with a gold inlay. Note box-like extension between dovetail and angle of restoration.

Class IV pinlay

The Class IV pinlay preparation may be used in upper teeth but, because of the direction of masticatory stress, it is the preparation of choice for lower incisors and canines because it is designed for withdrawal in the axial plane. It consists of an incisal groove which, close to the amelo-dentinal junction, terminates in a 2.0 mm tapering pit. The proximal aspect may have an axial groove, if space permits, which ends in a 1.0–1.5 mm gingival pit, or the groove may be cut, instead, in the axial wall (figures 14.44 and 14.45). Alternatively two small pits, labio-gingival and linguo-gingival, may take the place of the axial groove (figure 14.46).

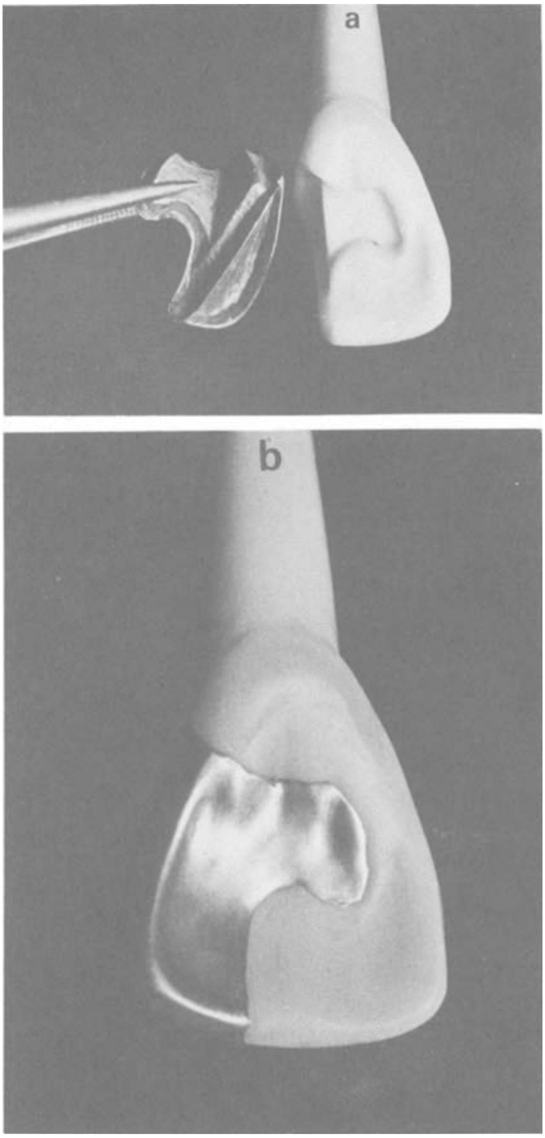


Fig. 14.43 Class IV Gold inlay. (a) Lingual dovetail cut in the middle third of the lingual surface. (Note the window in the labial surface to house a composite resin facing.) (b) Lingual aspect of the inlay.

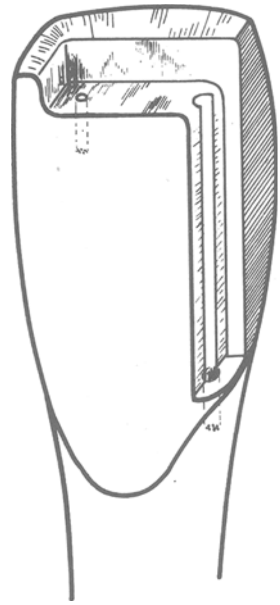


Fig. 14.44 Pinlay preparation in lower incisor with axial groove terminating in a 2.00 mm gingival channel.

Class V Cavities for Amalgam, Silicate and Resin

The majority of Class V cavities tend to be restored with plastic materials, amalgam being used where aesthetics are not of prime importance and silicate, acrylic or composite material where they are.

Undoubtedly, the advent of composite materials has tended to oust the other aesthetic restoratives and largely relegated Class V cohesive gold and inlay restorations to the position of student technique exercises. However, the format of the Class V restoration, similar in all cases, has undergone a slight modification since Black's day. His idea of 'extension for prevention' was to include in the outline form the buccal or lingual gingival contour, from mesial

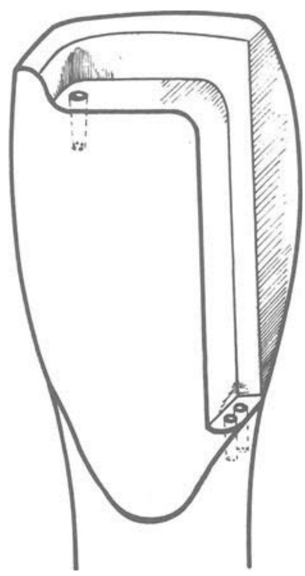


Fig. 14.45 Alternative design for pinlay preparation in lower incisor.

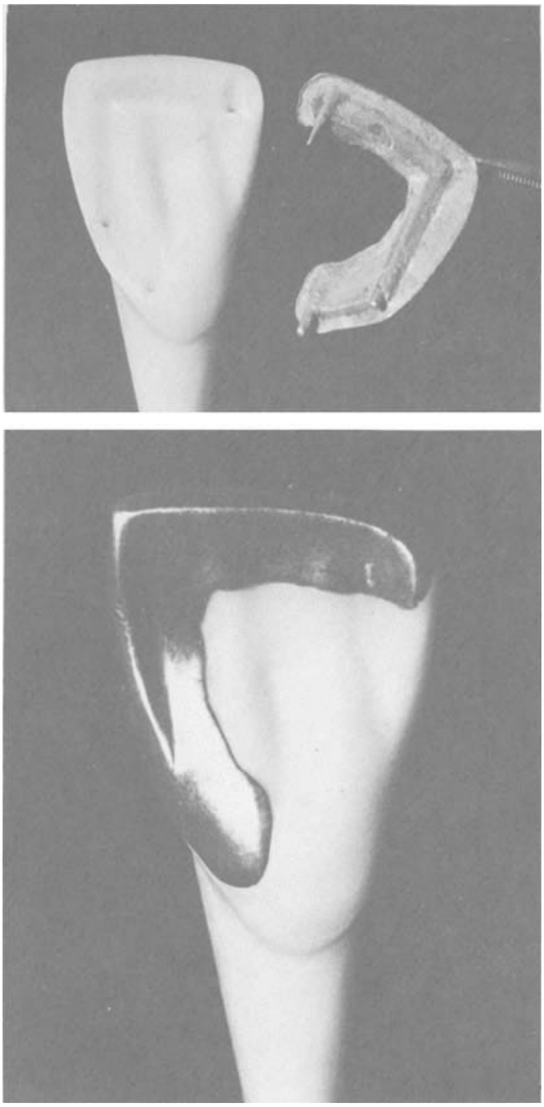


Fig. 14.46 Class IV incisal pinlay, lingual view.

to distal, and to finish the cavity margin within the gingival crevice, irrespective of the extent of the caries.

It is now considered essential to involve solely the area of caries and decalcified enamel, and to carry the cavity subgingivally only when the carious involvement demands it, thus limiting the extent of gingival contact and potential irritation. If the cavity extends below the gingiva, it should be packed away from the cervical margin with a length of retraction cord impregnated with 25% aluminium trichloride, before inserting the restoration, and should the cavity extend so deeply that preparation and restoration are impossible, a gingivectomy should be performed.

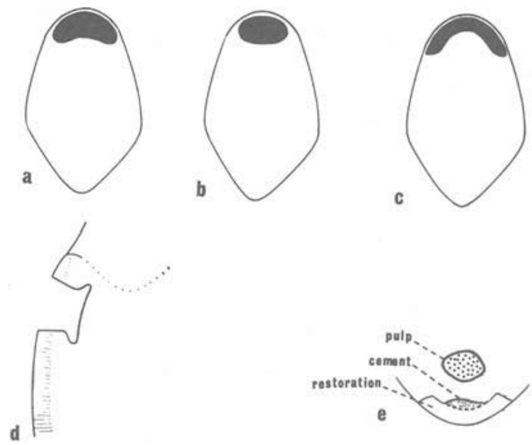


Fig. 14.47 Variations in form of the Class V cavity. (a) Bean shape; (b) oval shape; (c) classical shape. Linings in Class V cavities, (d) undercuts in Class V cavity placed in dentine and lined with cement; (e) caries in depths of Class V cavity, replaced by cement.

The shape of the cavity will thus vary from a small discrete oval or bean-shaped outline to a mesio-distal strip following the gingival contour (figure 14.47).

After gingival recession and exposure of the root surface, there is a tendency for food packing and stagnation in the crescentic depression now exposed to view. Frequently caries develops in this stagnation area therefore, when the cavity is prepared, it should be extended mesio-distally so that the bulbosity of the crown may be increased as far as the new gingival margin and thus allow food to be deflected away from it (figure 14.48).

The essential features of a 'plastic' cavity are as follows: a butt-joint must be produced, with the exception of a cavity destined for composite material,

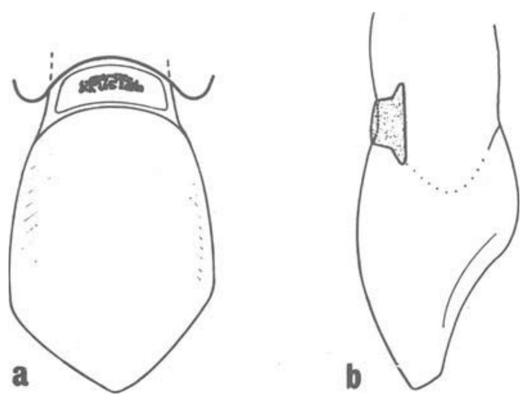


Fig. 14.48 Restoration of Class V cavities in cementum. (a) Outline form in relation to caries. (b) Slight exaggeration of contour to deflect food away from the gingival crevice. (The original contour is shown by the dotted line.)

for which a small 30° bevel is recommended before etching the margins.

No retentive grooves should be made mesially or distally to avoid undermining the enamel. Two opposing grooves are recommended, cervically and incisally, directed away from the enamel and cut in dentine (figure 14.47).

In addition to the pulpal floor, the grooves also should be lined, but care must be exercised to ensure that they are not obliterated by the cement.

The relationship of the Class V cavity to the pulp chamber alters as the cavity proceeds apically. Thus any cavity on the root surface must be close to the pulp and the operator should bear this in mind when preparing the cavity. All areas of enamel which show a milky discolouration, or have become chalk-like in colour and consistency, should be included in the cavity preparation, except in those cases in which access would create a severe problem, e.g. a distal extension of a buccal Class V cavity in a maxillary third molar.

Class V gold inlay preparation

Class V gold inlays have never been popular because it is difficult to obtain sufficient retention, without which they seem to be a prey to forces exerted by the toothbrush. There is, however, one method of ensuring good retention and that is by the use of two pins, placed on either side of the pulp (figure 14.49). From an examination of a bitewing radiograph, the position of the pulp can be assessed, and after preparation of the cavity outline, which is carried out to the embrasures, two holes are cut with a round bur (size ½) and then prepared with a (700) tapered fissure bur to a depth of 2 mm to receive Williams plastic pins (figure 14.50). Margins are bevelled to an angle

Fig. 14.49 Plastic pins in a Class V cavity in relation to the pulp and proximal walls of the root.

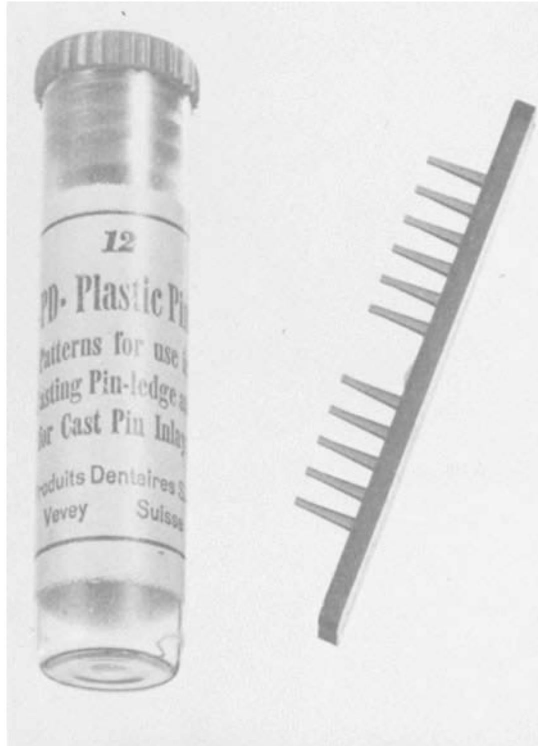


Fig. 14.50 Williams plastic burn-out pins for use in direct and indirect inlays when pinholes are cut with a 700 tapered fissure bur.

of 45° and enamel walls are smoothed with an enamel finishing bur. The Williams pins are inserted and the projecting ends are softened with a hot plastic instrument and mushroomed over to lie within the confines of the cavity. Then, after waxing-up to contour, the pattern is removed and cast, the pins burning out with the wax and forming a part of the gold inlay. A U-shaped sprue allows removal of the wax pattern by equalising the tension on both pins.

This technique is especially useful for restoring wedge-shaped erosion and abrasion cavities. Apart from cutting the pinholes, no cutting is required, other than some slight marginal adjustment.

Pin retention

From the foregoing examples of inlay cavity preparations, it is apparent that pins greatly increase retentivity with the minimum amount of cutting (figure 14.51). They may be cast or wrought, parallel-sided or tapered, or incorporated in wax as 0.6 mm iridio-platinum wire or as preformed plastic pins which burn out with the wax and are replaced by cast gold. Although there is a theoretical possibility that

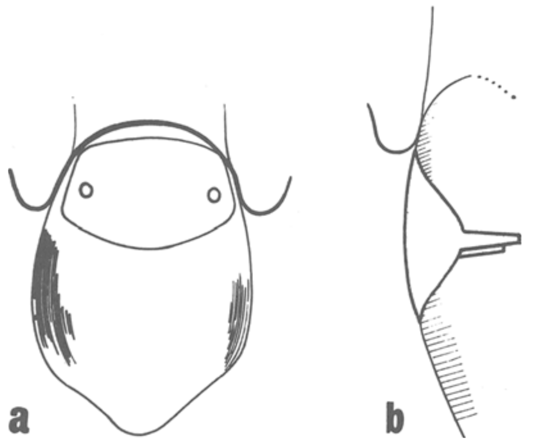


Fig. 14.51 (a) Retention of a Class V gold inlay by the use of two tapered pins. (b) Gold inlay in a wedge-shaped defect retained solely by the use of two tapered pins.

cast pins, being more brittle, might fracture under stress, this is compensated by their bulk, which is greater than that of wrought wire pins, and consequently fracture of pins is rare in practice, provided that the casting is without porosity.

Pinholes should be drilled to a depth of 2.0–4.0 mm, the depth being related to the retentivity needed, and the junction of the pin with the inlay should be rounded by eradicating the sharp edge of dentine at the orifice of the pinhole. This is most easily accomplished by the use of a flame-shaped finishing bur. This rounding minimises the stress concentrations, which tend to be greater at sharp line angles, and also reduces the risk of fracture of fine edges of stone dies when the technician incorporates metallic or plastic pins into his wax pattern.

Polished iridio-platinum wire pins, possessing poor retentivity, may be made more retentive by sandblasting them lightly to remove the polish. They are used in diameters of 0.6 or 0.7 mm which can be fitted to holes prepared with a size ½ or 1 round bur.

The longevity of an inlaid restoration

To sum up, the durability of a gold inlay, onlay or extracoronal restoration will depend on the following factors:

(1) retention and resistance form;
(2) strength of the residual tooth structure and the degree of protection against stress afforded by the restoration;
(3) the marginal fit of the gold and placement of margins to enable the patient to keep them free from plaque;
(4) correct occlusion.

Retention form must be such that forces along the path of insertion of the restoration are resisted, whereas resistance form provides resistance to forces from other directions.

The greater the surface area of the cavity walls, the greater will be the retention, and where cavities are shallow, the use of pins, grooves, extracoronal extensions of boxes will be indicated for accessory retention (figure 14.52). By increasing the frictional fit through a decrease in the angle of divergence of the walls, the retention is increased, i.e. there are fewer paths of insertion. The minimum thickness of gold in areas which are not under stress should be 0.6 mm, the average overall thickness should be 1.0 mm, and that over functional cusps should be 1.5 mm. Attention to these criteria will avoid perforation of the gold or bending of thin veneers under stress.

Finally, margins should be finished short of the gingival line, wherever possible, to minimise retention of plaque in contact with gingivae, whilst firm, correctly located contact areas between teeth will prevent food impaction on to the proximal gingivae.

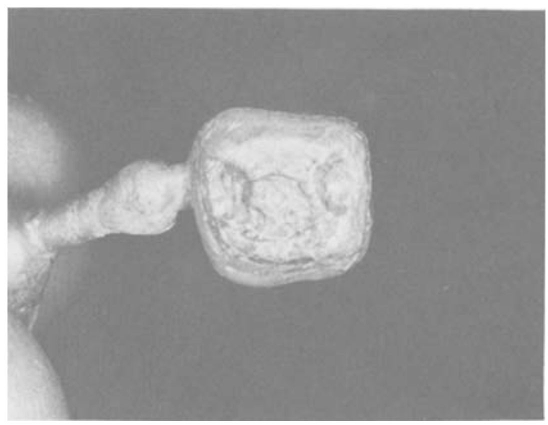


Fig. 14.52 Gold casting for a molar with a short crown. The lack of retention has been overcome by utilising the proximal boxes, previously filled with amalgam.

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15

The Insertion of a Lining

The need to use a lining is related directly to the depth and sensitivity of a cavity and the nature of the restorative material. If a cavity is extremely shallow, e.g. the occlusal lock of a Class II cavity which has been cut to the amelo-dentinal junction and is not especially sensitive, no lining is indicated. On the other hand, if a cavity is deep, it will probably need a sub-lining of calcium hydroxide to protect the pulp, covered with a phosphate or polycarboxylate base. In a cavity for amalgam, a half- to one-millimetre depth of cement provides adequate insulation for the pulp. The technique for lining a Class II cavity for amalgam is as follows. If phosphate cement is to be used, it should be mixed to a putty-like consistency, so that a small pellet may be picked up on the point of a straight probe, rolled lightly between thumb and forefinger and carried into the cavity in such a way that it does not touch the walls. A suitable plugging instrument, such as a G plastic (Ash) or a Porro special A, is dipped in alcohol, the excess of which is shaken off, and the cement is packed against the pulpal floor, making certain that it does not fill the undercuts. Then the cement is pressed into contact with the axial wall using a flat plastic instrument (Ash 156), similarly dipped into alcohol, which prevents adhesion of the cement to the instrument.

Any cement which has obliterated the undercuts may be flicked away with a small excavator while it remains in a plastic state. It is essential that no cement extends over any margins of the cavity, otherwise it would dissolve away slowly leaving a deficiency.

When a cavity is prepared for a gold inlay, all undercuts must be obliterated by cement and, where the cement covering the axial wall reaches the gingival step, a Briault probe should be used to ensure that there are no re-entrants (figure 15.1). While the cement is still plastic, it should be pushed down to the gingival step with a flat plastic instrument, which is then moved from side to side, pressing the cement downwards and laterally into firm contact with the floor and walls of the cavity. Once the cement begins to harden, it must be left undisturbed until hard, even when the final shaping is incomplete. Final smoothing is carried out later using burs and carborundum stones.

Whether gold or amalgam is to be used, the axio-pulpal line angle should be rounded, because with amalgam there would be a severe concentration of stresses along a sharp line angle, which could result in fracture of the amalgam. With regard to the gold inlay, a sharp internal axio-pulpal line angle in the wax pattern would produce a corresponding sharp line in the investment, which is a weak, brittle material. As a general rule the sprue former is attached directly over this line angle, and thus, at the time of casting the inlay, the inrush of molten gold could damage a sharp edge of investment and produce an ill-fitting casting.

The method of lining Class I cavities for plastic restorations is similar to that used for the occlusal part of a Class II cavity. However, when placing cement on the axial wall of a Class III cavity, a very tiny bead should be transferred to the cavity on a

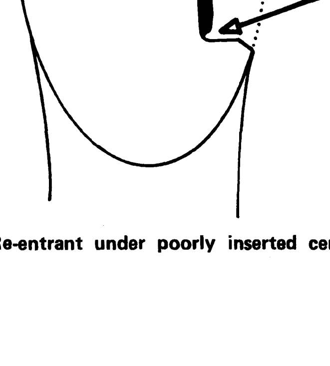


Fig. 15.1 Re-entrant under poorly inserted cement lining for inlay.

straight probe, and packed home with the undersurface of a small excavator (Ash 206–207 or Ash 246), which has been dipped in alcohol. Then the excavator may be inserted into the undercuts, to carry the cement along the pulpal wall and to ensure that the bulk of the undercut remains patent. The same technique may be applied also to Class V cavities.

For the majority of cavities prepared for plastic restorative materials, and which do not extend far beyond the amelo-dentinal junction, a calcium hydroxide cement, such as Dycal or Procal, may be inserted easily and of a minimal thickness, sufficient to insulate the pulp from noxious stimuli.

A few important points should be borne in mind when handling phosphate cement.

(1) The mix should not be too fluid otherwise it is difficult to manipulate, tending to stick to instruments and cavity margins, despite the use of alcohol.

(2) Excess alcohol should be shaken off after dipping the instrument, because it would tend otherwise to run onto the dentine and prevent the cement from adhering.

(3) The cavity must be free from saliva, which would also interfere with the adhesion of the cement.

(4) The cement should be placed with the minimum number of taps and in the shortest possible time. If the cement were manipulated when amost set it would fail to adhere and probably it would come away in an impression or break away when amalgam was condensed.

(5) The cement should be left smooth if possible at the time of placement but, if this should prove difficult, it can be trimmed with stones, burs and diamonds at a subsequent visit. Frequently, the vibration associated with trimming at the same visit will shatter the attachment of the cement to the dentine.

Although these remarks refer to zinc oxyphosphate cement, they hold true for polycarboxylate and quick-setting zinc eugenolate and E.B.A. cements. However, the author has found that if polycarboxylate cement is allowed to set for ten minutes before trimming it appears to resist dislodgement with greater tenacity, doubtless due to chelation with the calcium in dentine and enamel.

Alcohol may be used to prevent polycarboxylate cement adhering to instruments, but the insertion of zinc eugenolate cements is most easily accomplished by exerting pressure with a moistened pledget of cotton-wool.

16

Matrices

Basically there are two main types of matrix; the circumferential (e.g. Ivory No. 8, Bonnalie and Tofflemire) and the unilateral (e.g. the Ash No. IX) (figure 16.1). The former are intended for use on both M.O.D. and MO or DO cavities and the latter are solely for MO and DO cavities. In the first category, the Ivory No. 9 and the Tofflemire are to be recommended because of the facility with which the retainer may be disconnected in the mouth. There are short and long bands for use on molars and premolars. They are curved in such a way that, when the ends are approximated, a conical form is produced. Thus when the band is tightened on the tooth, it flares out from the gingival margin, giving better adaptation gingivally. The bands have either one or two convexities which are positioned over the gingival margins of two- or three-surface cavities. The matrix is threaded through the space provided in the retainer and held firmly in place by a locking bar at the end of a knurled knob, which is screwed up until it is tight. Then the other knurled knob is turned to adjust the circumference of the band and to allow it to slide over the tooth, after which it is also screwed up tight and a wedge is inserted at each proximal gingival margin abutting on an adjacent tooth.

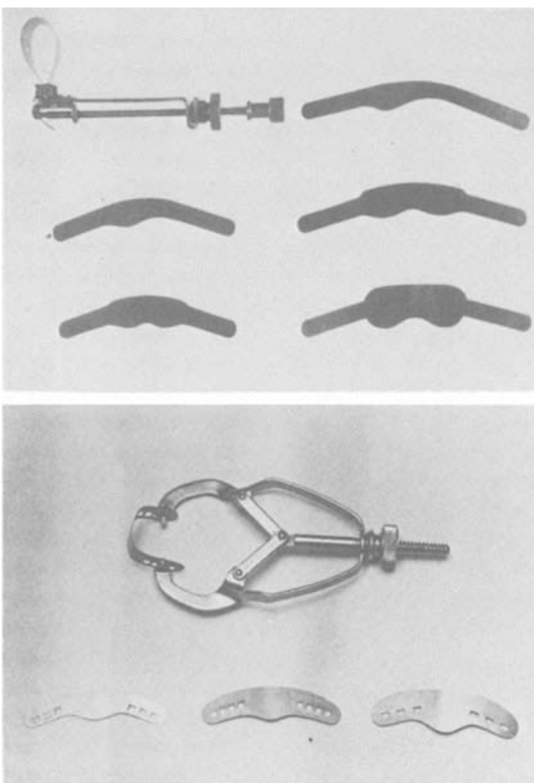


Fig. 16.1 (Top) Ash Matrix Retainer No. 8 (Ivory). (Bottom) Ash Matrix Retainer No. IX.

When there is a wide space between the prepared tooth and its neighbour, or the cavity has extended round to the buccal and lingual surfaces from the proximal aspect, the tightening of the band will pull it inwards towards the axial wall and prevent the development of a contact area. This may be corrected in the following manner. After the wedge has been inserted, the adjusting knob of the matrix retainer is released by one or two turns to slacken the band, which is then burnished hard against the neighbouring tooth, especially towards the buccal aspect. This allows a firm contact to be obtained plus a proximal wall of the correct contour, while at the gingival margin the band is wedged into contact with the gingival step, thus avoiding the condensation of excess amalgam beyond the gingival margin.

The Ivory No. 1 matrix Band, for use with Ash No. IX retainer, consists of a short strip of metal, convex at its upper border and markedly convex at its gingival border. At either end are four square holes, through which the band is speared onto two diamond-shaped projections at the ends of the adjustable caliper arms of the retainer. By engaging different holes with the projections the length of the band available to be tightened against the proximal surface may be altered to accommodate small or large molars or premolars.

In addition, the bands are supplied in different gauges of metal; the wider gauge, being stiffer, is used when the neighbouring tooth is absent, whereas the thinner band facilitates the production of a contact area with a neighbouring tooth. Wider bands are also available to allow sufficient coverage of the proximal walls in teeth with deep gingival extensions. When the band has been adjusted and the wedge applied, the proximal contour may be modified by burnishing the band *in situ* with a large ball burnisher. On the other hand, an external convexity may be produced with a pair of contouring pliers (figure 16.2) prior to inserting the matrix. Either method will give a similar end result, enabling the operator to produce a nicely-rounded proximal surface on the restoration, similar to the contour of the original surface.

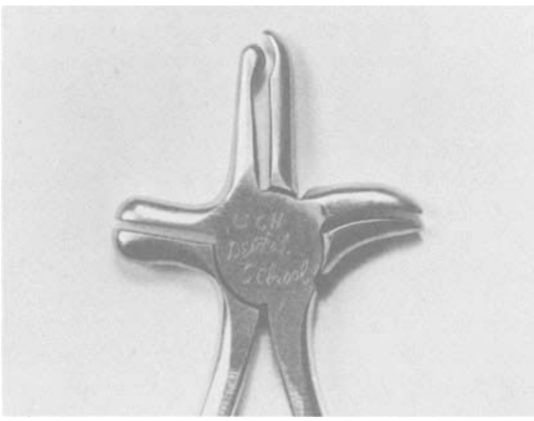
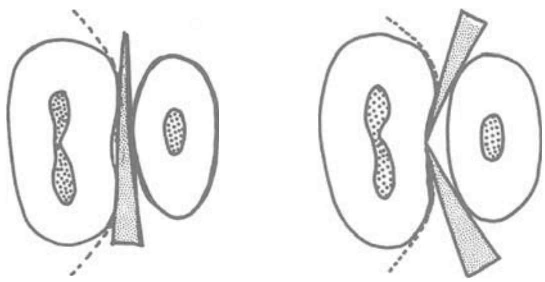


Fig. 16.2 Clark's Triplex contouring pliers.

Concave gingival margins

Some gingival margins, notably the canine fossa of upper first premolars, or the mesial and distal trifurcation areas of upper molars, exhibit varying degrees of concavity. To apply a single wedge would still leave a central space into which amalgam would be forced during condensation. In such cases, two short thick wooden wedges, carved from a tongue spatula, should be inserted from buccal and lingual aspects, in an attempt to obliterate the space (figure 16.3). In certain instances even this measure is unsatisfactory, therefore every effort should be directed towards avoiding heavy condensation pressure against the gingival defect with hand instruments, preferably condensing the amalgam with an automatic condenser. As soon as the matrix has been removed, a Hollenback amalgam carver should be insinuated into the concavity in order to scrape away any slight overhang of amal-



a b

Fig. 16.3 (a) A single wedge, when used for a concave gingival margin, will fail to occlude the space at the gingival margin. (b) Improved marginal adaptation of the band will result from the use of two thicker wedges.

gam while it is still plastic. If the overhang is discovered when the amalgam has hardened, it may be removed by planing it away with a G2 scaler, as though it were subgingival calculus. The final finishing of the proximal amalgam surface may be accomplished using a T. C. blank under water spray.

Copper band matrix

A tooth which is so badly broken down that it requires pin retention to hold an amalgam base for a full veneer crown, should be encased in a contoured, well-fitting copper band, which is reduced in height to clear the bite. After the amalgam has hardened – at least 24 hours later – the copper band may be removed.

It is essential that the bur of copper, produced by cutting with shears, is rounded off with a carborundum point, in order to avoid trauma to the soft tissues.

The T-band (Dr. Levett's matrix)

When the fitting of a conventional matrix band and retainer proves difficult, which is frequently the case with deciduous molars, a T-band may be applied and wedged in place. Although available from the dental depots (figure 16.4), it is easy to make a T-band from a strip of thin german silver or copper sheet, or even a

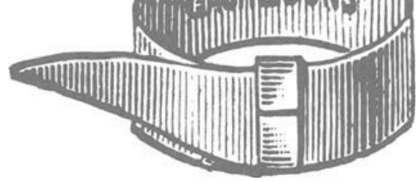


Fig. 16.4 Ash matrix (Dr. Levett).

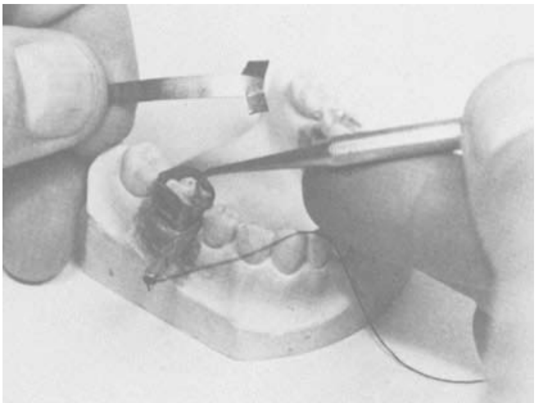


Fig. 16.5 The use of a T-band for the restoration of a Class II cavity in a deciduous tooth. The unfolded band is shown in the left hand, and a silver wedge is in position with a length of nylon thread protruding from the mouth.

size 20 copper band, which is divided, opened out and cut to shape (figure 16.5). The copper may be thinned by grinding with a carborundum stone at the contact area. This will facilitate the production of a good contact.

The use of a matrix strip and composition will be described in chapter 17. The Manipulation of Amalgam.

Separators

The separator was designed originally to create a space between two teeth by wedging them temporarily apart so that improved access might be gained to a Class III cavity for the insertion of a gold foil restoration and a good contact ensured. Its use is indicated also when it proves impossible to insert a celluloid strip between two incisors. The separator (figure 16.6) is placed proximally, close to the gingival papilla, and the teeth are moved apart sufficiently for insertion of the strip, after which the separator is removed.

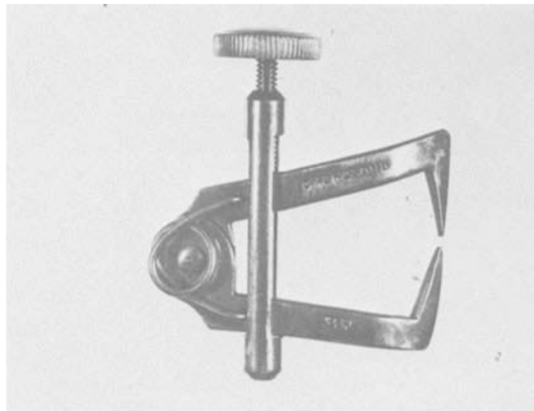


Fig. 16.6 Ash separator.

Alternative methods of separating teeth are the use of silver or wooden wedges, or, more slowly, by inserting strips of rubber. Separation is not practised as much today as in earlier times, largely because of the periodontal trauma which may ensue from its abuse.

17

Manipulation of Amalgam

Correct manipulation of amalgam is essential if a sound, durable restoration is to be produced. Before considering the individual features of each type of restoration, there are certain general aspects which are of importance.

Dispensing of alloy and mercury

It is important to remember that in order to ensure accurate proportioning of mercury and alloy, when using volumetric proportioning bottles, the mercury must be kept free from dross, the bottle constantly topped up so that it is never less than half full, and the mercury always discharged with the bottle held vertically.

The alloy bottle should be shaken firmly from side to side in the inverted position, so that the well is fully charged with alloy before being emptied into the mortar.

Encapsulated alloys

Many manufacturers today supply their alloy in pre-measured quantities, for small and large restorations, in a capsule with an internal barrier isolating it from a similarly pre-measured volume of mercury. Before use, the capsule is compressed to mix the alloy and mercury by removing the barrier, and the capsule is placed in a mechanical amalgamator for a given trituration time. Although this method is simple and accurate it is also more costly (figure 17.1).

Condensation of amalgam

Conventional amalgam must be condensed with heavy pressure, using 1 mm diameter condensers, into undercuts and pits and out towards the margins where a matrix has been applied. Small increments of amalgam should be added and condensed fully before any further amalgam is inserted. Once the deeper layers of amalgam have been condensed into the undercuts and into any other retentive features of the cavity, larger condensers may be used. Their ends may be smooth or serrated but, if serrated, it is essential that any set amalgam be removed from the serrations after use, otherwise it might contaminate a subsequent restoration. Whether to use condensers with serrated ends is a question of personal preference, but there does not appear to be any advantage in their use.

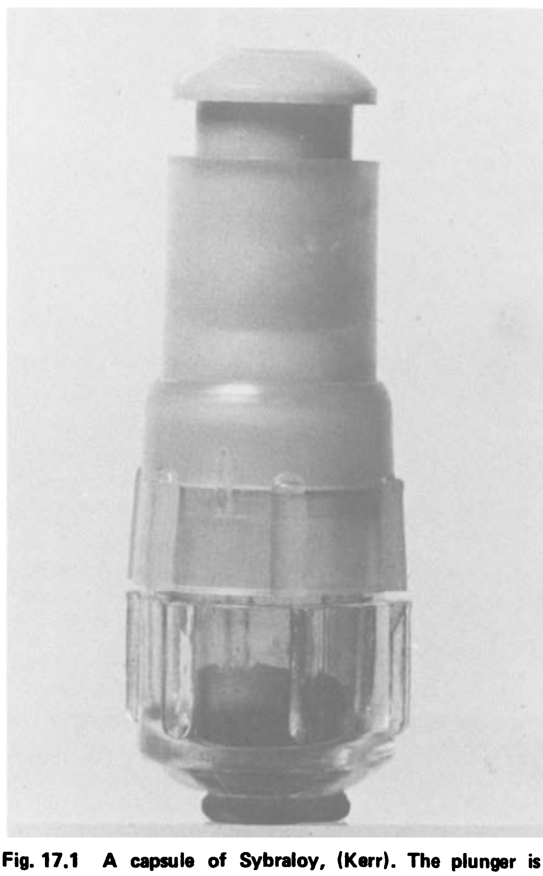


Fig. 17.1 A capsule of Sybraloy, (Kerr). The plunger is pressed down before trituration, in order to bring the mercury into contact with the alloy, seen here in the clear compartment of the capsule.

A variety of automatic condensers are obtainable which deliver a series of blows of low amplitude and high frequency. Some are operated by ultrasonics, while others rely on a mechanical drive which sets up a vibration through an eccentric or multi-facetted cam, the frequency being adjusted by varying the speed of the motor (figure 17.2).

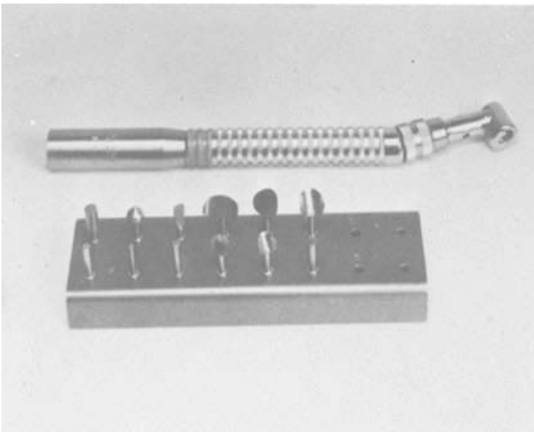


Fig. 17.2 Dentatus mechanical condenser and an assortment of points.

Mechanical condensation is considerably less fatiguing than manual condensation in which, it has been remarked, if the fingers and arm do not ache after the amalgam has been condensed it is underpacked!

Even after a busy day condensing amalgam, homogeneous restorations may still be produced without undue effort when mechanical condensation is employed. Nevertheless, despite the apparent efficiency of mechanical condensation, the operator must avoid the insertion of large masses of amalgam because mercury will be trapped, unable to rise to the surface. This will leave the final restoration with a high mercury content. Furthermore, because it is impossible to condense through a mass of amalgam, poor marginal adaptation will result.

Carving

Once the cavity has been over-filled so that approximately 1 mm of excess amalgam covers the margins, the restoration is ready for carving. A variety of shapes of carver have been designed for this purpose, but the author achieves the best results with the No. 3 carver (Ash) as designed by Hollenback (figure 17.3). This instrument is kept sharp and is used to cut away excess amalgam, carving along the margins or in a direction from enamel to amalgam, keeping the instrument constantly in contact with the enamel surface, to ensure that the final amalgam surface is in line with the enamel surface around the whole perimeter (figure 17.4). When the restoration is carved in this way, the presence of feather-edges of amalgam beyond the cavity margins is more easily discernible. A Ward's wax carver may be used instead of the Hollenback carver, being of similar design.

Fig. 17.3 Ash carver (Hollenback).

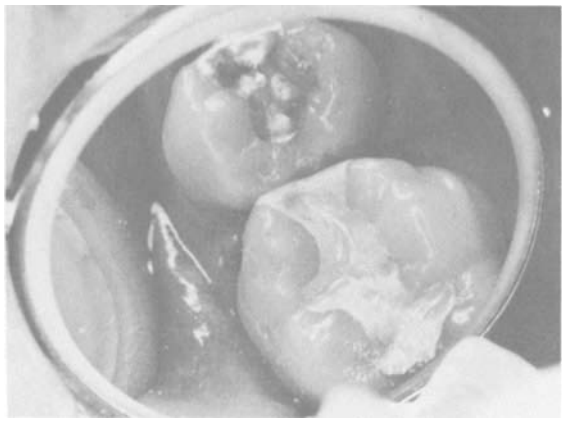


Fig. 17.4 Premolar showing a polished amalgam restoration. The molar has a newly inserted amalgam restoration. Note the clear-cut margin and the harmonious contour.

Transfer of amalgam to the cavity

Amalgam may be carried to the cavity with dressing forceps, but the technique is difficult when inserting a restoration in maxillary teeth. Similarly, amalgam will cohere to a sterling silver-bladed plastic instrument from which it may be wiped into the cavity. The silver carrier is of value when carrying amalgam to singularly inaccessible positions. The majority of operators use an amalgam gun to transfer amalgam and two types are obtainable: the universal gun for general use, and the contra- or right-angled gun for less accessible cavities, such as buccal cavities in maxillary third molars (figure 17.5).

After use, all amalgam remaining in the gun should be expelled, but should any residue be inadvertently retained, its removal may be facilitated by holding the nozzle in a bunsen flame for a few seconds.

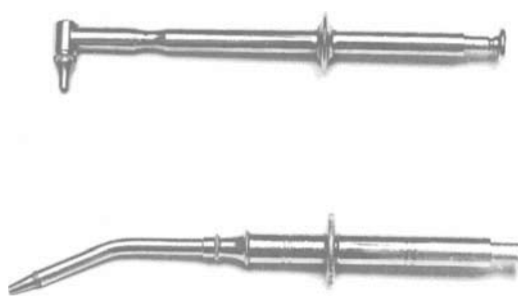


Fig. 17.5 Ash amalgam carriers (colloquial term 'amalgam guns'). (a) Right-angled (9 x L). (b) Universal (Hampel).

Amalgam, after trituration, can be picked up from a Dappens glass or from a special polypropylene pot designed specifically for the purpose (figure 17.6).

After excess mercury has been expressed from amalgam, mulling in a rubber thumbstall will restore plasticity.

The setting of amalgam commences as soon as trituration is completed and the speed of set depends on the type of alloy, the ratio of alloy to mercury and the method of trituration. When a large restoration is to be constructed, it is preferable to make two or three mixes of amalgam than to use one large mix and run the risk of condensing partially crystallised amalgam, which would produce a weak, porous restoration.

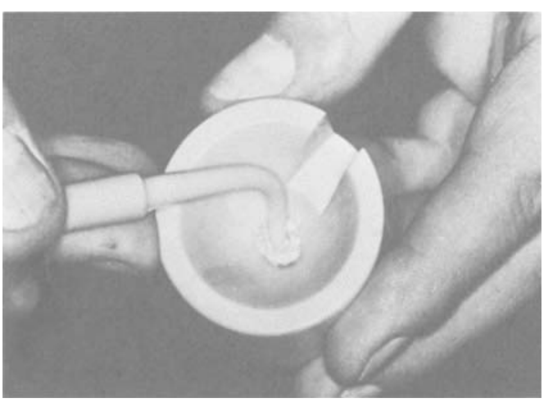


Fig. 17.6 Amalgam is loaded into an amalgam carrier from a plastic receptacle.

After twenty-four hours the amalgam should be smoothed with finishing burs and fine sandpaper discs, after which the proximal surface, with the exception of the contact area, is polished with fine grit strips coated with polishing paste. The surface of the restoration is then polished with a prophylaxis paste using a rubber porte-polisher cup or junior cup brush. Finally a very high lustre may be produced by the use of a small lambswool buff or porte-polisher cup, used at high speed and minimum pressure, with a suspension of whiting or titanium dioxide in water.

The use of rubber abrasive wheels, except under water spray, or a rubber porte-polisher cup without an adequate volume of polish, is apt to produce a high level of frictional heat.

Grajower *et al.* (1974) found that, especially in deep cavities, there was a greater increase in temperature when continuous polishing and rubber polishers were used than occurred with intermittent polishing and cup brushes. They found that the presence of cement bases and cavity liners conferred limited protection. Such an increase in temperature may cause severe damage to the pulp and it is more apt to occur if the restoration is polished under a local anaesthetic.

Restoration of Black's Cavities with Amalgam

(1) Class I occlusal cavity

A Class I cavity has four walls, therefore no matrix is required when restoring it with amalgam. The amalgam, when triturated, should exhibit a smooth, shiny, homogeneous surface. It is placed in a Dappens glass (or amalgam well) from which small portions may be picked up in an amalgam carrier. The first layer is inserted with full mercury content and, after it has been thoroughly condensed, subsequent increments of amalgam from which excess mercury has been expressed are condensed until the restoration is overbuilt. After this, the mercury-rich layer is carved away until the final contour has been achieved. Carving should be directed along the margins or from tooth to amalgam, but never in the opposite direction, otherwise marginal ditching is apt to develop. Rounding of the fissures is effected by very light burnishing with a Baldwin burnisher (Ash No. 49) after which, any mercury brought to the surface by burnishing is wiped away by a light sweeping action with dry cotton-wool. When the patient occludes his teeth, premature contacts are indicated by the presence of shiny patches on the amalgam. By means of alternate checking and adjusting, the final occlusal contour is produced.

(2) Class II cavity

In order to condense amalgam with sufficient pressure into a Class II cavity, it is essential that a temporary scaffolding, or matrix, be placed. Many types of matrix are available commercially and dental surgeons tend to favour the simplest matrix or the one which they became accustomed to using as students.

Matrices and wedges

The simplest, and frequently the most effective, type of matrix consists of a strip of thin stainless steel band material (0.002 in in thickness) which is contoured to produce a concavity across its centre, and then placed between the teeth with the concavity facing the axial wall. A wedge is placed at the gingival margin and the matrix is pressed against the buccal and lingual walls of the tooth by inserting pieces of softened composition, which are held until chilled, while the operator burnishes the band against the adjacent tooth (figure 17.7). This type of matrix is indicated especially for teeth with short crowns which give inadequate purchase for a matrix retainer. The function of the band is to confine the amalgam to the area of the cavity, to permit adequate condensation and prevent extrusion of excess, especially subgingivally (figure 17.8). To facilitate this function, in the majority of cases, the use of a wedge is mandatory. The wedge should close any gap at the gingival margin after tightening of the band, but its other function is of equal importance. The wedging effect on the periodontal fibres separates the teeth, but when the matrix and wedge have been removed, the teeth return to their original positions, thus compensating for the space taken up by the thin matrix band.

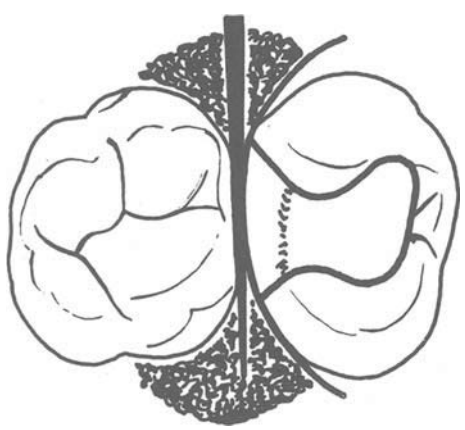


Fig. 17.7 Strip matrix retained by a wedge and two buttresses of composition.

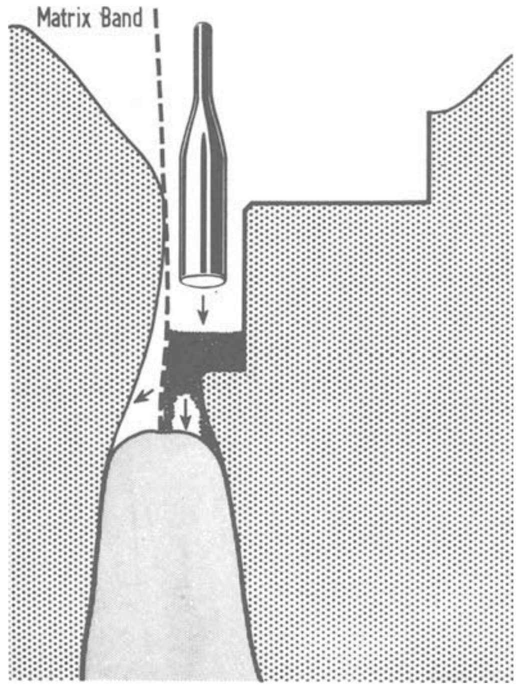


Fig. 17.8 When no wedge is used, the condensation pressures tend to force the band away from the gingival margin, allowing excess amalgam to build up against the gingival papilla. (Reproduced by kind permission of the British Dental Journal.)

Numerous types of wedge are available. Some dental surgeons carve one at the chairside from an orangewood stick or matchstick, whilst others use pre-formed wedges in plastic or balsa wood or Interdens gingival massagers. The chief difficulty in the use of such wedges is that of applying pressure at the margin alone. If the wedge is incorrectly shaped it will tend to distort the band and produce defective contour in the proximal surface of the amalgam restoration, which will lead to food stagnation and gingival irritation (figure 17.9). The author has overcome this problem for the majority of teeth by designing sterilisable, anatomically-contoured silver wedges made in two sizes, large and small, which, by virtue of having a curved surface in contact with the band, avoid buckling of the metal and consequent loss of contour (figure 17.10). Wedges are available as 'left' and 'right', for application to mesial and distal spaces (Produits Dentaires).

The P.D. silver wedge is manufactured with a small hole through the handle so that a length of fuse wire or dental floss may be attached to it and to the matrix retainer. Failure to observe this precaution might lead to inhalation or swallowing of a wedge which could become detached during condensation.

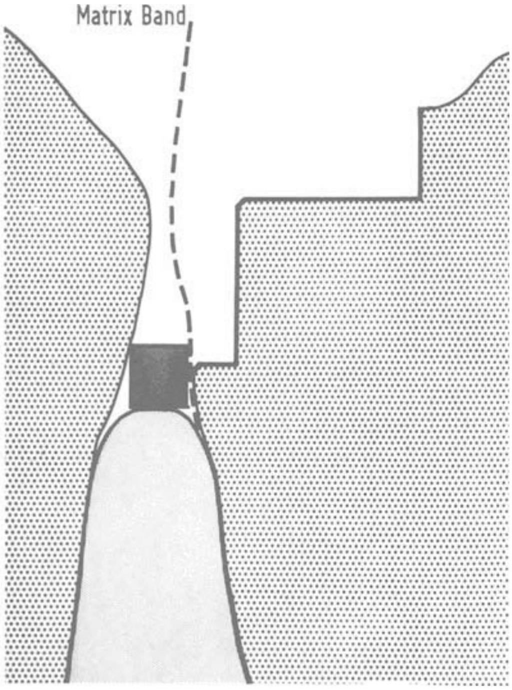


Fig. 17.9 A poorly designed wedge tends to produce a badly shaped proximal wall and a deficient area of contact with the adjacent tooth. (Reproduced by kind permission of the British Dental Journal.)

When matrix and wedge are in place and the band has been burnished and pressed against the adjacent tooth, the gingival seal of the matrix should be tested by pressing a probe into the margin (figure 17.11). If a defect is noticed, the wedge should be pressed more firmly into the interspace. In teeth with concave gingival margins, e.g. the canine fossa on the mesial aspect of 4| rules, it is not possible to adapt a normal wedge, although the space may be occluded, at least in part, by the use of two pieces of Interdens balsa-wood stimulators, applied from buccal and lingual aspects. In all cases, the gingival margin must be checked for over-spill of amalgam after removal of the matrix, and any excess removed while it is soft. Moreover, to prevent any disengagement of the wedge when condensing the amalgam, a finger should rest against it to keep it in place.

The wedge is better applied from the lingual aspect in the majority of cases, but occasionally the shape of the cavity dictates the necessity for a buccal path of insertion.

When there is a very wide space between the teeth, a tailor-made wooden wedge becomes necessary, but in such cases it is frequently impossible to bridge a wide gap and make a satisfactory contact in amalgam.

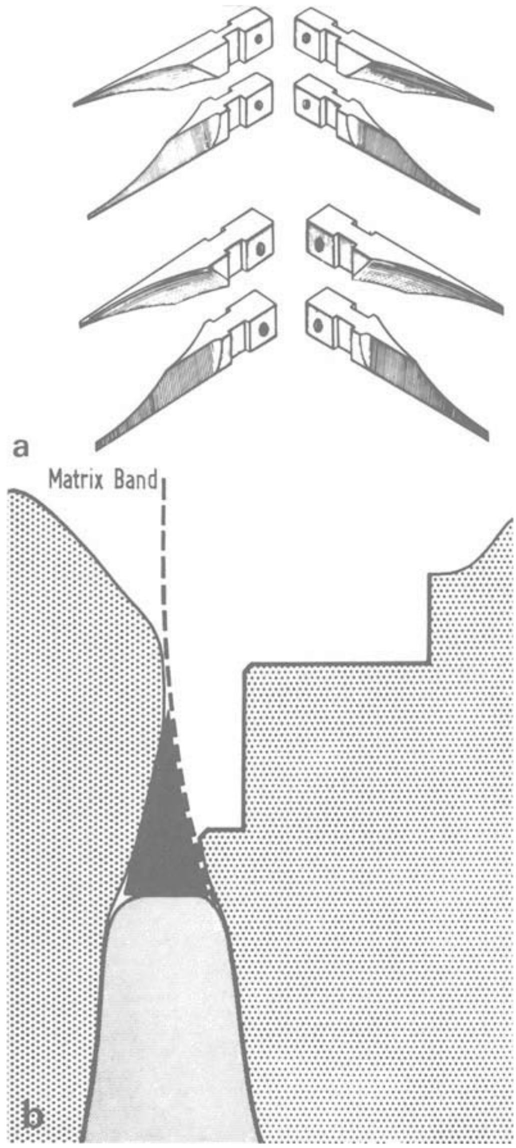


Fig. 17.10 P.D. silver wedges (a) designed with a concave tapering side, to allow continuity of contour of the proximal surface of the restoration. (b) Silver wedge in situ. Note (i) the hole for wire or floss to allow attachment to a matrix retainer, (ii) the grooves, for engagement of the beaks of dressing forceps, (iii) wedges supplied in left and right and small and large sizes.

Ideally, a gold inlay is to be preferred for establishing a good contact but when amalgam is used and a firm contact is not feasible, as wide a space as possible should be left so that food impaction will not occur between the teeth.

Amalgam is condensed at first into the gingivo-buccal and gingivo-lingual angles and into the proximal undercuts, exerting considerable pressure with a 1 mm

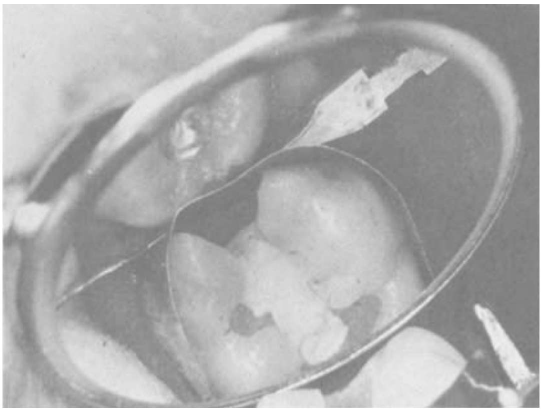


Fig. 17.11 Matrix band and silver wedge in position, with band burnished well to the buccal aspect.

condenser (e.g. Porro special A) or using a fine point in a Dentatus mechanical condenser (figure 17.12). The whole proximal portion having been condensed, the occlusal dovetail area is similarly built up, condensing towards the walls and building up an excess of drier amalgam to take up the mercury-rich layer brought to the surface during condensation.

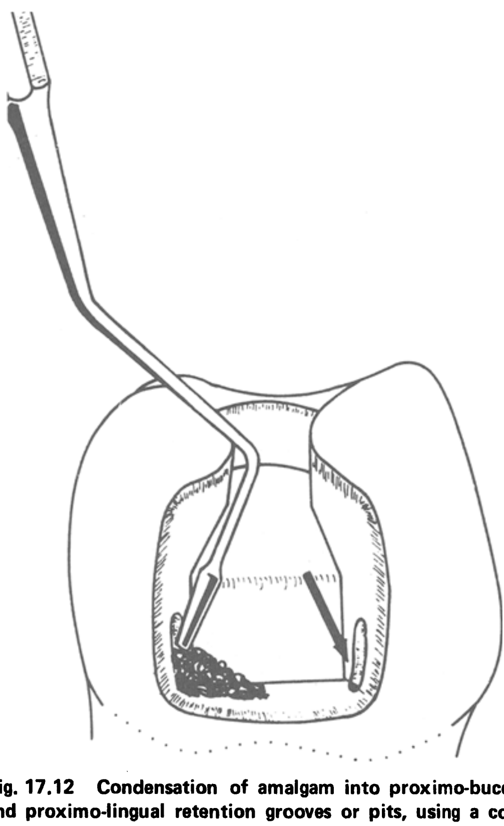


Fig. 17.12 Condensation of amalgam into proximo-buccal and proximo-lingual retention grooves or pits, using a condenser of narrow diameter.

The occlusal contour is carved roughly and a straight probe is stroked around the band, to clear excess amalgam away from the proximo-occlusal area, directing the instrument from lateral to proximal. At this stage, the wedge is removed, the matrix retainer is released and removed and the band is extricated with a side-to-side rocking and sliding action, meanwhile supporting the proximal amalgam with a flat plastic instrument (figure 17.13).

Fig. 17.13 To avoid damage to the marginal ridge of the amalgam restoration, it is seen here supported by a Hollenback carver, whilst the band is pulled and rocked out gently in a palatal direction.

The carving is continued with a straight probe which is stroked along the margins while kept simultaneously in contact with the tooth surface. It is also used to check the marginal integrity proximally and to remove any overhanging amalgam. Contouring is carried out as for a Class I cavity, but it is necessary to build a well-formed marginal ridge and the corresponding marginal groove. Gentle burnishing of the surface of the amalgam, while it is still carvable, has been shown to improve the adaptation of the amalgam to the enamel (Chan *et al*., 1977).

Before removing the saliva ejector, the patient is instructed to wash out but not to close his teeth together. When checking the occlusion, the patient must not be told to bite, but to place his teeth very gently together. This will avoid fracture of the amalgam in most instances although, if gross occlusal excess is present, even gentle contact might cause fracture of the proximal extension. Inspection of the surface will reveal any premature contact, but a better burnish mark will be produced if the patient slides his teeth from side to side without exerting pressure. When the occlusal contour is correct, the marginal ridge is rounded and burnished gently at the same time as the grooves and pits are rounded. This aids the production of a good contact area and gives a natural, rounded, proximo-occlusal angle. If this part of the restoration were to be left sharp, it would tend to fracture subsequently. The patient is instructed that he must chew on the opposite side for the first 4–6 hours, i.e. until the amalgam has hardened sufficiently to resist stress. Any high spot, which could remain undetected by the patient because of anaesthesia in the area, may cause a severe periodontitis. Hence, the patient should be warned that any tenderness or pain in the tooth must receive prompt attention.

At the next visit, the bloom on the amalgam is removed occlusally by a gentle stroking action with a round or pear-shaped finishing bur run at low speed, and proximo-occlusally with a fine-grit abrasive disc. The gingival area is smoothed by cutting a spear-point on a sandpaper strip, passing it through the interspace and pulling it to and fro until the grit has vanished. It is then loaded with polishing paste and again drawn to and fro until the amalgam feels smooth when probed. At this stage, any modification to contour is carried out and the remainder of the restoration is polished with an abrasive paste on a porte-polisher cup and given a brilliant lustre with a suspension of whiting or tin oxide in water. The contact area, *per se*, is not polished to avoid the risk of opening the contact.

(3) Class III cavity

Amalgam is used chiefly for Class III cavities in lower incisors and the distal of upper canines. It is not possible to use a conventional matrix for such cavities, but the following method will achieve satisfactory results.

Restoring, for example, a distal cavity in a maxillary canine to which access has been obtained from the lingual aspect, a thin strip of stainless steel, which will cover the proximal cavity margins, is contoured and inserted and wedged from the labial side.

Softened composition is pressed over the labial aspect to maintain the band and wedge in position, and this is held firm with the thumb whilst amalgam is inserted from the lingual aspect and condensed. When the cavity is full, the matrix, wedge and composition are withdrawn labially and final contouring and smoothing of the restoration are completed.

(4) Class V cavity

No matrix is required for the Class V cavity when condensing amalgam except in those instances when, as a result of massive stagnation, hemicircumferential carious involvement is found. This occurs frequently under partial lower dentures which are worn at night and associated with an habitual lack of oral hygiene. When the cavity has been prepared, extending from mesial to distal around the lingual surface of the crown or root, a problem is posed concerning the possibility of condensing amalgam, which, on being packed at one side, tends to be dislodged from the opposite side.

The author has used the following technique satisfactorily in such cases. A steel band is passed through the adjacent interspaces so that the free ends lie lingually; it is secured with wedges inserted from the labial aspect, over which a piece of hot composition is moulded, to cover also the adjacent teeth.

This leaves the proximal surfaces of the cavity supported and allows condensation of amalgam but, in this position, firm condensation is difficult. In consequence, a spherical alloy is used which requires only minimal packing pressure, and thus the restoration is built up and carved and the matrix is removed when the amalgam has begun to harden. Hardening occurs much more rapidly with spherical alloy than with a conventional alloy.

As an alternative method, a window may be cut in a circumferential matrix, corresponding in position to the cavity but of slightly reduced circumference. The matrix is threaded onto a retainer and tightened on the tooth and thus the amalgam may be condensed firmly into the cavity without the danger of dislodging those portions previously condensed.

Condensation of amalgam into a normal Class V cavity (figure 17.14) is facilitated by the use of a mechanical condenser, especially in regard to final contouring of the restoration with the concave condenser points.

Removal of excess amalgam from the gingival margin may be carried out most easily with a straight probe (Ash No. 6), the side of which is carried along the cavity margin, and the point making contact with the tooth beyond the margin to avoid over-trimming. This technique allows the production of a restoration which is contoured in harmony with the adjacent enamel and cementum and is easily polished.

The technique for restoring badly broken down teeth

A tooth which has been restored with an extensive M.O.D. amalgam restoration and subsequently develops caries in the residual enamel and dentine, has a poor prognosis when it is patched with amalgam. Sooner or later the weakened walls will tend to fracture and insufficient tissue will remain to obtain further retention. In such a case, a full veneer gold crown will offer the better prognosis, but it is of little

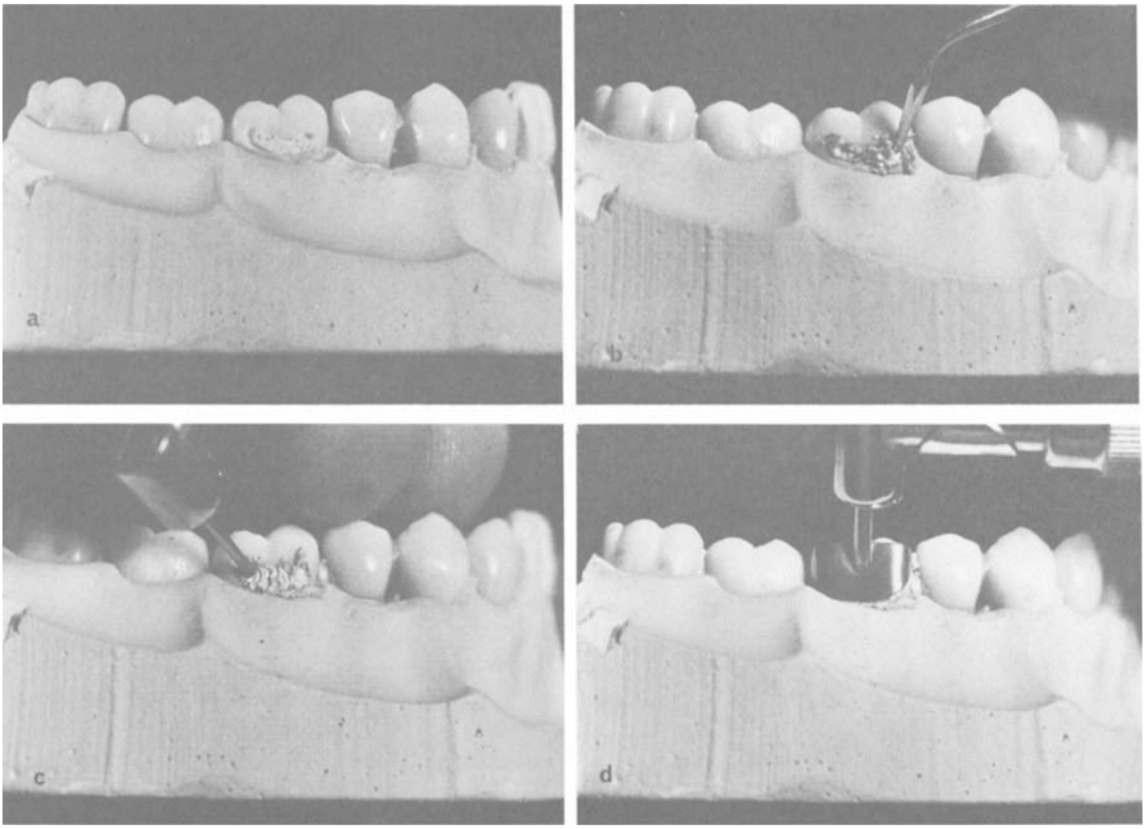


Fig. 17.14 Class V restoration in $\overline{6}|$. (a) Lined cavity. (b) Amalgam is packed into the undercuts with a 0.5 mm condenser (e.g. Porro Special A plastic). (c) Further condensation and contouring with a Dentatus mechanical condenser. (d) Dentatus mechanical condenser.

use to fill up the missing parts of the tooth with amalgam before starting the preparation because, once the enamel has been cut back, the amalgam, having lost its retention, will tend to fall out.

Retention can be made for the amalgam by locking it to the roots with a number of pins, inserted in areas which are not too close to the pulp or to furcations of the root. They are placed approximately 1.5 mm from the margin, more or less parallel with the surface of the root, as near as can be estimated, and each pin should be at an angle to the others and bent inwards, so that subsequent cutting of the amalgam will not expose it (figure 17.15). Each pin should be buried to a depth of 2.0 mm leaving the same length exposed for retention in the amalgam. As few pins as are necessary should be inserted. If it is not possible to apply a matrix band and retainer, a tightly-fitting copper band should be contoured and trimmed so that it will not interfere with the occlusion. Amalgam is condensed with heavy pressure (or spherical amalgam may be condensed using smaller condensation pressures) and when the tooth has been restored sufficiently, the matrix band is removed. If a copper band has been used, its removal is delayed until the next visit, but any sharp margins must be rounded, so that the soft tissues will not be traumatised. After the amalgam has hardened, the preparation is carried out as though the tooth were sound, but the marginal chamfer should extend just beyond the amalgam and finish on tooth whenever possible.

If the tooth has been root-treated, retention for the amalgam may be obtained by embedding one or more Dentatus screws in the root canals (figures 17.16 and 17.17).

Causes of failure of amalgam

From time to time the operator should ask himself whether his technique is as good as it ought to be. In order to assess this, the following check list shows most of the common faults underlying the failure of amalgam restorations and, in particular, the Class II restoration.

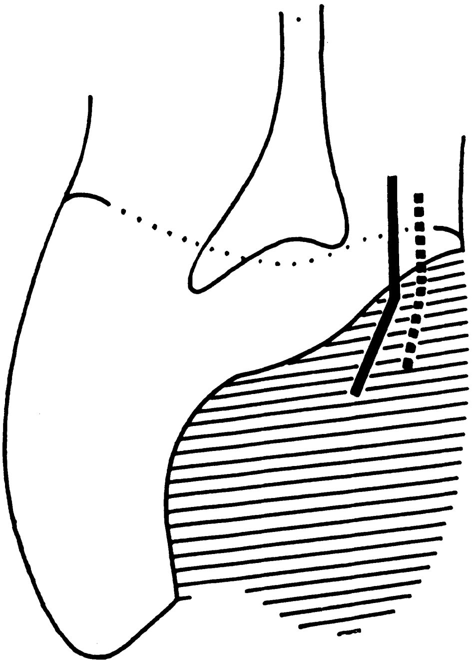


Fig. 17.15 Relationship of pins, for retaining amalgam, to the pulp and root surface of a maxillary premolar. If a full veneer or three-quarter crown preparation is to be cut, it is essential that the pins be bent inward so that they may remain embedded in amalgam.

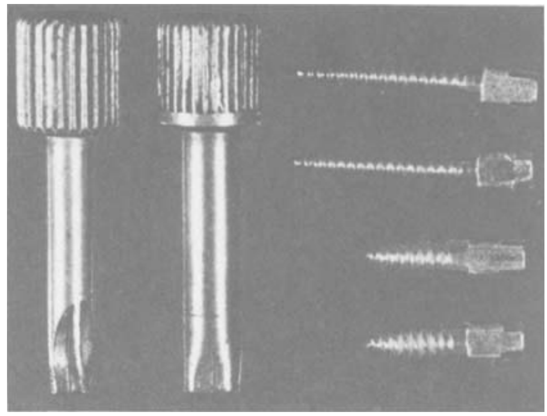


Fig. 17.16 Dentatus screws with 'box' and 'cruciform' spanners.

I. The cavity

Cause	*Effect*	*Result*
1. Cavity too shallow	Amalgam thin	Amalgam fractures
2. Cement lining too thick	Amalgam thin	Amalgam fractures
3. Sharp axio-pulpal line angle	Stress concentration	Amalgam fractures through the isthmus
4. Sloping gingival step (to the proximal) or step is too narrow	No resistance form	Amalgam fractures through the isthmus
5. Isthmus too narrow	Inadequate bulk, hence weak amalgam	Amalgam fractures through the isthmus
6. Sharp angles in occlusal outline form of Class II restoration	Stress concentration	Fracture of restoration or tooth
7. Cusps restored in amalgam to inadequate depth	Insufficient depth for strength	Fracture of amalgam cusp
8. Excessive removal of tooth structure undermining the enamel	Weakens tooth	Tooth fractures
9. Absence of undercuts	No retention	Amalgam falls out
10. Dovetail with only one cornu	No resistance to dislodgement	Proximal creep of restoration or loss of restoration
11. Cavo-surface angle is more or less than 90° angle	Weakness of enamel or amalgam margin – whichever is less than 90° butt joint	Fracture of margins – 'ditching'

II. The amalgam

	Cause	*Effect*
1.	Over-trituration	Amalgam shrinks on setting
2.	Under-trituration	Amalgam is weak and porous
3.	Excessive pressure on pestle while mixing	Amalgam sets slowly and shrinks
4.	Insufficient mercury	Amalgamation incomplete, hence restoration is weak and porous
5.	Excess mercury in finished restoration	Restoration has low compressive strength
6.	Contamination of amalgam with sweat from fingers	Restoration is porous and has high degree of delayed expansion (if alloy contains zinc)
7.	Inserting excessively large amounts of amalgam into cavity	Impossible to condense thoroughly – tendency to porosity and deficient margins
8.	Initiating condensation with large condensers	Undercuts and margins not filled with amalgam – deficient edges and inadequate retention
9.	Condensing amalgam which is too rich in mercury	Impossible to condense well – restoration tends to be weak and porous
10.	Amalgam squeezed too dry	Lack of cohesion of layers leads to 'bridging' and weak restoration
11.	Condensation of partly crystallised amalgam	Weak, porous restoration
12.	Failure to condense amalgam towards margins	Marginal defects
13.	Insufficient amalgam mixed and hence surface not over-built before carving	Surface layers too rich in mercury – hence weak and porous
14.	Restoration carved from amalgam to enamel	Produces marginal deficiencies
15.	No wedges used	Gross overhang left under gingiva – difficult to remove. Also, contact area deficiency
16.	Fissures carved too deep	Weakens restoration. Diminishes functional efficiency. Leads to stagnation of food, tarnish and corrosion
17.	Surface left high in bite	Periodontitis or fracture of amalgam
18.	Excess amalgam left beyond cavo-surface angles	Breaks away leaving rough or deficient margins
19.	Contamination of zinc-containing amalgam with saliva	Porosity and delayed expansion
20.	Condensing amalgam with serrated pluggers, with set amalgam in serrations	Old amalgam may contaminate restoration and weaken it
21.	Failure to polish	Tarnish and corrosion
22.	Overheating when polishing	'Burns' amalgam and releases mercury, causing porosity
23.	Failure to polish the proximal surface	Food stagnation, tarnish and corrosion
24.	Burnishing set amalgam	This tends to break up the superficial crystalline structure and release the mercury, causing superficial porosity
25.	Failure to warn the patient to avoid chewing on amalgam for first few hours	Possible fracture of restoration
26.	Failure to ensure proximal contact	Food packing and periodontal disease
27.	Failure to support proximal part of restoration when removing the matrix	May cause immediate or delayed fracture of the marginal ridge

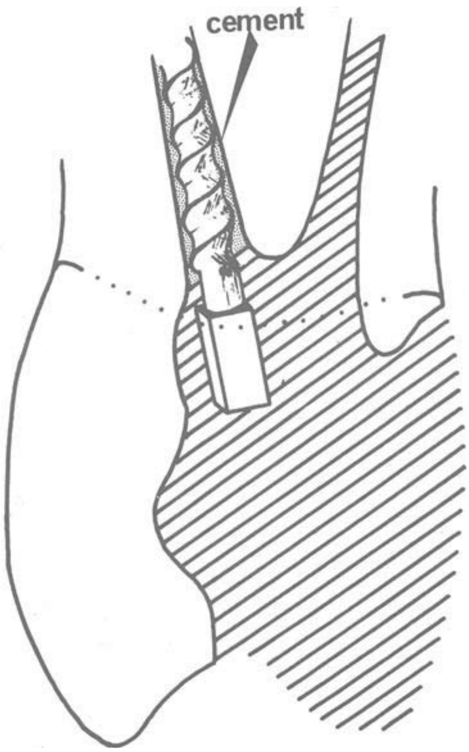


Fig. 17.17 Retention obtained for an amalgam restoration by the use of a Dentatus screw, locked into the root canal by cement.

Some Recent Investigations

Alloy with a fluoride content

Fazzi and Zucas (1977) investigated the properties of an amalgam with a fluoride content which released fluoride to the surrounding enamel. They concluded that it was unsatisfactory on account of its reduced compressive strength.

The interface between old and new amalgams

In a study of the junction of old and new amalgams after a repair, Consani *et al.* (1977) found, using an infiltrate of a radioactive solution, that the repaired zone was imperfect. This work emphasises the need to use mechanical retention when adding to an old amalgam restoration.

Effect of varying trituration time

Osborne *et al.* (1977) found that the amount of creep was influenced by an increase in trituration time, but the degree of creep varied from one alloy to another. They found also that creep is reduced by an increase in condensation pressure.

The relative strengths of amalgam over various bases

Hormati and Fuller (1980) investigated the strength of base materials and amalgam restorations overlying them, using zinc phosphate cement and Dycal, a calcium hydroxide cement. They concluded that the cements did not fracture under amalgam and that the restorations were stronger over bases with a high modulus of elasticity, which is a more important factor than compressive strength, in the support of an amalgam restoration. Dycal proved to be as effective a support as phosphate cement and no advantage was gained by covering the Dycal with phosphate cement. This finding is of great practical value because the mixing and insertion of Dycal, or a similar calcium hydroxide preparation, are simple and quick procedures and the risk of pulpal irritation, which could occur under a badly mixed phosphate lining, is eliminated.

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18

Impression Techniques

Following the preparation of a tooth for a gold inlay, a gold crown or a bridge retainer, a wax pattern, carved to the approximate shape of the tissue removed, must be produced to be cast in gold. When the cavity preparation is simple and the tooth is accessible, the best method, in the majority of cases, is to build up a wax pattern on the tooth. This is referred to as the *direct* technique.

On the other hand, many cavities and extra-coronal preparations present a variety of difficulties, not the least of which is the inordinately long time required to work under exacting conditions and to the detriment of the patient's comfort. In such instances, and this tends to include the majority of cases for crowns and inlays, the *indirect* technique is preferable. This entails the registration of impressions of the prepared tooth or teeth and the neighbouring and opposing teeth, so that exact replicas of the teeth may be made in stone and plaster, from which the wax pattern is produced for casting. This technique has the added advantage that, should there be a miscast, the patient need not be recalled for the making of a new pattern.

There are two techniques commonly used to produce wax patterns by the indirect method; the copper band technique, used mostly for single restorations, and the tray technique, in which the whole or a portion of the arch is recorded. It is, of course, possible to use the tray technique for single restorations and the copper band technique for multiple restorations; the operator's choice must be determined by his own ability to handle the materials, and his own personal preference.

Inlay wax

Dental wax intended for use in the 'cire perdue' process for inlay work must be eliminated without residue during the burn-out process before casting the inlay.

Different types of wax are available for use in the mouth and for laboratory procedures. The wax to be used for direct patterns must exhibit less flow at mouth temperature to prevent distortion during removal and to allow carving to be carried out. Wax used for indirect patterns, on the other hand, must be softer to facilitate carving at room temperature.

An ideal wax for direct patterns should possess the following features:

1. Be of a contrasting colour to the enamel.
2. Be plastic just above mouth temperature to record detail of the cavity.
3. Harden at mouth temperature to allow removal without warpage.
4. Should neither chip nor flake when carved.
5. Possess known thermal expansion characteristics.
6. Burn out without residue from the mould.

When wax is removed from the mouth and cools to room temperature, there is a contraction for which compensation must be made, in order that the inlay produced will be an exact fit in the cavity. Furthermore, when gold is cast it contracts on cooling from the casting temperature down to the point at which it solidifies, when there occurs a change of state contraction. Then it contracts further when cooling down to room temperature. The method of compensating for these two contractions entails the use of a casting investment which expands to a high degree of setting and on heating-up to the casting temperature. It is also possible to obtain further, less easily controllable expansion by allowing the investment to set under water or by using a wet asbestos liner in the casting ring. This is known as hydroscopic expansion and is especially useful when full and partial veneer crowns and M.O.D. inlays are to be produced. The higher the investment/water ratio and the longer the spatulation time, the greater will be the expansion obtained.

Manipulation of wax

In order to obtain the best results with inlay wax, it should be heated evenly in a thermostatically-controlled oven or water bath at 65°C or held and rotated *above* a gas flame, without allowing the wax to melt and drip away, which would vaporise some of the more volatile constituents and modify the properties. The softened end of the wax stick is moulded between thumb and forefinger until it is of a pointed shape that will make contact with the deepest part of the cavity without being held up between the teeth or at the margins of the cavity. Whereas the end of the wax stick must be as hot as possible without melting, the rest of the wax should be hard, in order that pressure can be exerted on the plastic wax.

When carving a direct wax pattern in an upper tooth, it is a good plan to stretch a piece of gauze or Kleenex across the mouth, between the tongue and the palate, to collect wax shavings and to aid in reflecting light onto the tooth.

The direct wax impression technique

Most simple cavities lend themselves to the direct technique because of its simplicity and the economy in time. In this category the following should be considered: Classes I, III, IV and V (with or without pin retention), and small *accessible* Class II cavities, e.g. mesio-occlusal or disto-occlusal cavities in premolars and mesio-occlusal cavities in first molars. It should not be forgotten that one of the major factors influencing accessibility is the size of the mouth and this, coupled with the degree of opening and the position of the tooth, will determine the choice of direct or indirect technique. When recording wax patterns of Class II cavities, the method used will depend on the presence or absence of the adjacent tooth. The wax must be confined under pressure to the area of the cavity when it is introduced, in order that it may be compressed against the walls to reproduce the detail of the cavity. Furthermore, the wax contracts as it cools, hence the contraction must be directed towards the walls by means of external pressure. Thus, some form of matrix is indicated when a proximal cavity faces a space, e.g. Classes II, III and IV, but the adjacent tooth, when present, will suffice to confine the wax to the immediate area of the cavity. To prevent the wax sticking to the tooth the cavity should be lubricated with a thin film of separating medium, such as Dei-Sep (Jelenko), Microfilm (Kerr), or saliva.

Impression Techniques for Class I Cavities

No matrix is required for the production of a wax pattern from a Class I cavity because it has four walls. It is lubricated and filled with soft wax under pressure. The pressure is maintained until the wax has cooled, then the surface is softened with a heated wax carver and the patient is asked to bite and chew around on the wax. Next the pattern is contoured with warmed burnishers and trimmed back to the prepared margins, making certain that the bevels are covered with wax. Occlusal grooves are rounded and the wax is polished, using first a pledget of moistened cotton-wool, followed by a gentle massaging with dry cotton-wool. A sprue-former, 1.0 to 1.5 mm in diameter, depending on the size of the pattern, is heated and held until cold on a bead of sticky wax, deposited previously on a chosen spot on the pattern, away from the margin and in the thickest area. Grasping the sprue-former between thumb and index finger, the pattern is withdrawn. Any difficulty experienced in removing the pattern may indicate the presence of undercuts, the wax showing a burnish mark where it was forced out of the undercut and had, in consequence, become warped. On the other hand, the cavity may have been lubricated insufficiently and the wax could have adhered to the walls. If the wax has not recorded sharp detail, there might have been excessive lubricant in the cavity (liquids are incompressible), the wax may not have been soft enough to record detail, or inadequate pressure might have been applied while the wax was cooling.

Undercuts may be remedied simply by obliterating them with cement and correcting the pattern. Lack of detail in the pattern is corrected by melting a thin film of soft inlay wax onto the fitting surface of the pattern and reseating it under pressure. The margins and occlusion are then rechecked and the pattern is reshaped, sprued and removed.

When a wax pattern has been removed from a cavity, it should be invested within 30 min, especially in a warm surgery, because the higher the temperature, the greater the tendency for stresses to be released, which leads to warpage of the pattern. Such distortion may be minimised by temporary storage of the pattern in a refrigerator, or eliminated in the following manner. The pattern is washed with a solution of a surface-active agent and placed on a crucible former. A few drops of water, at room temperature, are put into a Dappens glass and a small quantity of cristobalite or Luster-cast investment (Kerr) is mixed with a cement spatula and painted and vibrated over the pattern. Dry investment is dusted over the wet investment until all surface moisture has been soaked up. This takes only a few minutes and protection of the pattern is assured. Later, the asbestos-lined ring may be placed on the crucible former, the dry set investment covering the pattern moistened with water and the ring filled with investment.

Class II Cavity Impression (upper first premolar)

When the second premolar is missing it is necessary to use a matrix and retainer to confine the wax. Either an Ivory No. 1 or a Bonnalie or Tofflemire matrix retainer may be used. The matrix is placed on the retainer and adjusted over the tooth so that it extends beyond the cavity margin gingivally but does not interfere with the bite when the teeth are occluded. The retainer is opened, just enough to allow it to slide off the tooth, then it is lubricated, warmed and filled with softened inlay wax, the fitting surface of which is flamed lightly. The matrix band is then replaced on the lubricated tooth, seated over the cavity margin and the retainer is tightened while digital pressure is exerted on the wax in the open end of the band. When the wax has cooled, the surface is softened with a heated Ward's wax carver and the patient is asked to bite and chew around. At this stage the gross excess of wax is forced away from the occlusal surface of the tooth and may be scraped away. Next, the retainer is loosened and removed, along with the matrix band and wax pattern, which are chilled under cold water. The matrix band is then pulled back and separated from the pattern, which is returned to the tooth. Any gingival excess of wax is melted with a heated wax carver, and burnished over the surface of the tooth to hold the pattern immovable while it is being trimmed. The occlusal carving is finished, using first a warmed burnisher (Ash J) (figure 18.1) and then a cold Ward's wax carver (figure 18.2) and finally, the occlusion is checked. The proximal and gingival margins are best trimmed by means of a stroking action with a straight probe (Ash 6), the side of which is kept in contact with the surface of the tooth, and stroked parallel with the cavity margins. The probe should not be heated (to avoid ruin of its temper) although, should there be gross excess, its removal may be facilitated by the use of a warmed probe. Finally a tightly rolled pledget of cotton-wool is dipped in water and heated in the bunsen to a temperature of approximately 60–80°C and used to sponge the wax surface lightly once or twice. The surface is then polished with a pledget of dry cotton-wool, but care must be exercised

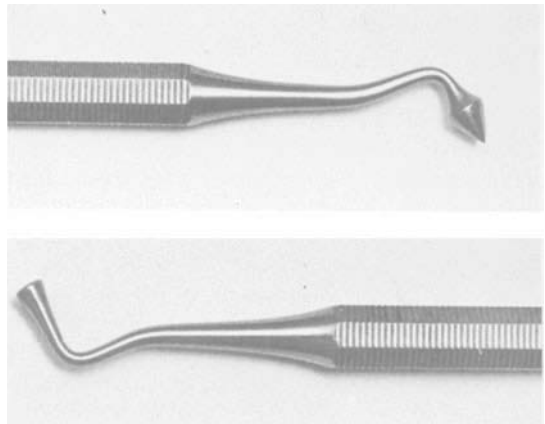


Fig. 18.1 Ash J plastic.

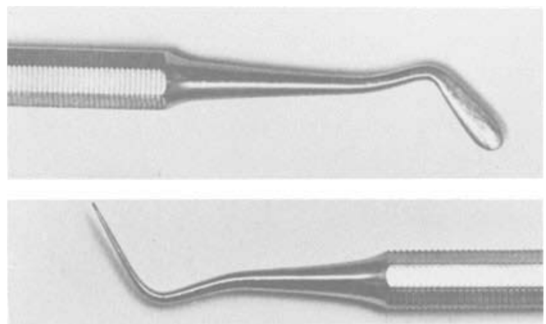


Fig. 18.2 Ash carver (Ward).

to avoid excessive pressure because the wax margins could be abraded away. The pattern should be perfectly smooth before removal, because wax is easier to polish than gold.

Removal of the wax pattern

The wax pattern can be removed by attaching a sprue-former or it can be removed on a curved probe or a wire handle. It is essential, when removing a Class II pattern, that there is even tension on both box and lock elements, otherwise distortion may result. Thus the sprue-former should never be inserted solely in the marginal ridge (figure 18.3a). If it is to be attached directly, a U-shaped wire should be bent to seat in the dovetail at one end and the marginal ridge at the other, so that a firm pull will unseat both elements simultaneously (figure 18.3c).

Alternatively, a curved probe may be warmed and laid on the occlusal surface of the pattern, so that it will melt the wax and adhere to it, but taking care

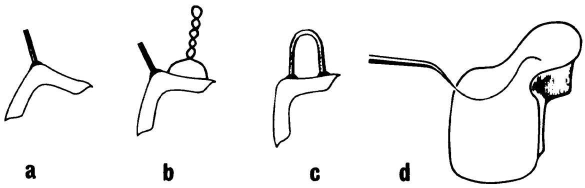


Fig. 18.3 Methods used for the removal of a Class II wax pattern from the mouth. (a) Single sprue-former (not advisable due to the risk of distortion). (b) Brass, or 10 amp fuse wire, handle, replaced by a sprue-former and then removed after contact with a heated wax knife. (c) U-shaped sprue-former. (d) Heated curved probe laid on the surface of the pattern and replaced later by a sprue-former (as in b).

Fig. 18.4 Mal-location of sprues results in rounding of margins of the casting because the gold has to flow against gravity.

neither to sink it deeply nor to encroach on the margins (figure 18.3d). The probe is chilled with cold air or water spray and the pattern is lifted from the cavity. A sprue-former is attached to the pattern which is held a few inches above a gauze napkin, while a heated wax knife is placed in contact with the probe, about 10.0 mm from the pattern. This softens the wax around the probe so that the pattern can be lifted off and placed on the napkin. The defect in the occlusal surface is then obliterated with soft carding wax, which melts at a temperature considerably lower than inlay wax. Similarly a length of 10 amp fuse wire can be twisted up to form a handle and two prongs, which may be heated and placed in the opposite ends of the pattern (figure 18.3b). When cool, this 'handle' is used to remove the pattern, which is then sprued and the handle removed by grasping it with heated soldering tweezers. The holes in the pattern are filled with carding wax.

The sprue-former should be attached by a bead of heated sticky wax to the thickest part of the pattern and angled in such a way that when the gold is cast it will flow solely downhill and never against gravity, which would result in rounding of the margins (figure 18.4). If a pattern consists of two bulky areas joined by a slender bridge, as frequently occurs in M.O.D. patterns, two sprue-formers or a U-shaped former should be attached in order to prevent distortion of the wax (figure 18.5). Failure to unite a sprue-former to the pattern with sticky wax might allow the pattern to come adrift during investing. The first sign that this had occurred would be the casting of a sprue without the inlay.

Technique for the production of a wax pattern from a Class II cavity, with the adjacent tooth present

In such cases the main problem is the carving and perfecting of the gingival part of the pattern. Although a matrix can be used, it is easier to achieve a good result without it, especially because the pattern is locked into the cavity by the excess wax until the carving is completed and consequently the risk of warpage is lessened.

The wax is softened and shaped and pressed into the cavity with considerable pressure, while it is prevented from escaping bucco-lingually by the confining action of thumb and forefinger. The occlusal surface is softened with a heated burnisher and the occlusal limits are defined by closure of the teeth and side-to-side movements of the opposing jaw. The occlusal contour is then carved and gross excess at the buccal and lingual cavo-surface angles is removed with a warmed, Ward's wax carver, which may be used also to trim the gingivo-buccal and gingivo-lingual angles.

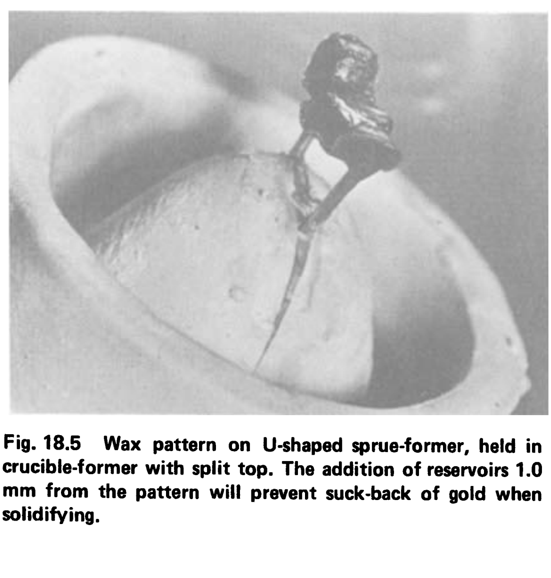


Fig. 18.5 Wax pattern on U-shaped sprue-former, held in crucible-former with split top. The addition of reservoirs 1.0 mm from the pattern will prevent suck-back of gold when solidifying.

At this stage the mid-gingival excess of wax locks the pattern into the cavity. To remove it, about 30 cm. of fine nylon thread is held wrapped around both index fingers, leaving approximately 5.0 cm of thread between the fingers, which is placed between the proximal wax and the adjacent marginal ridge. Pulling the thread taut, it is sawn to and fro until the resistance of the wax is felt to cease. The lingual end of the thread is carried across to the buccal side through the contact area and the loop of thread so formed is withdrawn buccally, bringing out the piece of excess wax. Proximal trimming may be repeated, and the gingival edge is then checked with a fine straight probe, to be certain that all the excess has been eradicated. The proximal surface is then polished with a linen strip using the smooth side, having scraped away the abrasive particles first, to avoid contamination of the wax with siliceous material which would not be eliminated during burn-out. If a finger is placed occlusally, premature movement of the pattern will be prevented. The pattern is removed and inspected by transmitted light and wax is added to very thin areas and it is then rechecked on the tooth. When the pattern has been sprued, a film of carding wax is added to restore the contact area and to allow for polishing of the proximal surface of the inlay.

Technique for Classes III and IV Wax Patterns

The methods for producing wax patterns for Classes III and IV cavities are similar, hence they can be considered together. When a Class III cavity has been prepared for a minor bridge retainer (i.e. the Class III inlay will have a tapered groove into which a stress-breaker will lock) the cavity faces a space and a matrix should be used. A cellulose acetate strip, coated with a film of lubricant, is held over the labial surface of the tooth while softened wax is forced into the lingual aspect of the cavity. Immediately, the strip is pulled round to the lingual aspect compressing the soft wax firmly into the cavity, the pressure being maintained until the wax has been chilled with cold water. When the matrix has been removed, the labial excess of wax is left to lock the pattern into the cavity and the lingual wax is softened with a heated burnisher, so that the patient can close into centric and protrusive positions thus shaping, in part, the lingual contour. The wax is burnished into perfect contact with the cavity margins using the flat end of a J burnisher (Ash), which has been heated sufficiently to soften the wax, but not enough to melt it. Finally, after the lingual and proximal parts of the pattern have been completed, the labial excess is carved away and final smoothing of the butt-joint is done with the side of a straight probe, which is kept in contact with the enamel surface and stroked along the margins. If a window is to be cut in a Class IV pattern, it should be done before removal of the pattern from the cavity. A rim of wax at the incisal tip should be left to protect the facing, but the gold should not be visible otherwise, hence the proximal finishing line should be extended into the contact area. The gross removal of wax may be carried out with a small inverted cone bur, run at very slow speed. Then the final shaping of the margins is done with sharp chisels and excavators.

Spruing

The sprue-former is inserted at the junction between the box and the dovetail into a bead of sticky wax, which is picked up on a probe and, while warm, is deposited on the chosen spot. The hot sprue-former melts it and unites it to the pattern. The pattern is inspected and invested if found to be satisfactory, but first the contact area is built out in wax if necessary.

Class III and IV cavities with an adjacent tooth present

The sole difference in the method of producing a wax pattern when the adjacent tooth is present is that no matrix is necessary. The wax is forced into the cavity from the lingual aspect and is compressed, while soft, between the thumb and forefinger. The wax is trimmed as described above, firstly on the lingual, then labially and finally the contact is opened and the gingival margin corrected with nylon thread and perfected with a smooth linen strip. Before the pattern is withdrawn, the strip should be pulled through the interspace several times in the line of withdrawal, to make certain that the proximal surface of the pattern does not impinge on the proximal bulbosity of the adjacent tooth and cause warpage of the wax. A small film of carving wax is added at the contact area prior to investing the pattern.

Class V Cavities

The Class V cavity, having four walls, calls for the same impression technique as used for the Class I cavity. The technique differs when tapered plastic pins are used to improve retentivity. The pins are shortened until, when they are placed in the pinholes, the projecting ends are level with the cavo-surface angles of the cavity. They are then touched lightly with a hot burnisher which softens and mushrooms the ends. Having then filled the cavity with inlay wax, the pins are seared to the wax with a hot plastic instrument, the contouring of the pattern is carried out with warmed burnishers, the wax is polished and the margins are checked. A U-shaped sprue-former is then used to remove the pattern. After removal, each plastic pin is touched gently with a probe to ascertain whether it is locked into the wax. If either should move, the pattern is replaced in the cavity, the wax over the pin is softened and a spot of sticky wax is added. This is covered with blue wax and the surface re-contoured.

The Indirect Techniques

1. Copper band and composition

Composition is a thermoplastic material which hardens at a temperature slightly higher than that of the mouth. When hard it is inelastic, thus any attempt to remove an impression which extends into undercut areas, either in the cavity or beyond the cavity margins, will result in fracture of the composition. Consequently, in order to use composition, a copper band must be chosen which is a close fit on the tooth and is trimmed in such a way that it extends a fraction of a millimetre beyond those margins which are below the line of maximum bulbosity of the tooth. Because of the difficulties inherent in the use of materials which become unworkable as they cool down and are not resilient, the use of composition should be reserved for full veneer and jacket preparations and some slice preparations.

Technique

The best type of copper band to use is the medium hard variety. The soft bands tend to collapse easily, while the hard bands are difficult to manipulate. The band is tried over the tooth and held there while the relationship of the cavity margins to the internal surface is inspected.

It should slide freely over the tooth, but not impinge on the gingival margins. Exerting finger pressure, the shape of the band may be modified and adapted to the perimeter. If a band is found to be over- or under-sized it should be replaced; however, it may happen that one band is too small, whereas the next size is too large. This problem may be overcome by either stretching the smaller band or grinding some of the copper from the internal gingival fitting surface to make the band a looser fit.

Alternatively, the perimeter of the larger band may be reduced in circumference by contouring it inwards with a pair of Clark's Triplex pliers (figure 18.6).

Fig. 18.6 Contouring a copper band in order to reduce its circumference at the margin, using Clark's Triplex pliers.

The perimeter is then cut with short curved scissors so that it extends just beyond the cavity margins and no further than the contour line on the buccal and lingual aspects (figure 18.7). The burr of copper produced by cutting the band with scissors is ground away with a carborundum stone, which is used also to roughen the internal surface, whilst the opposite margin of the band is bent out at a right-angle with a pair of snipe-nose pliers to form a 1.0–2.0 mm flange (figures 18.8 and 18.9). The roughness of the internal surface increases the attachment of the composition; the smooth margins are less traumatic to the gingivae and the flange aids removal of the impression.

The stick of composition is heated in water to the temperature recommended by the manufacturer and then it is passed quickly through the bunsen flame until the surface has become glossy. The band is filled and the composition at the fitting surface is made concave by pulling on the excess at the flanged end. The band is placed over the tooth, centred and forced home by pressing on the flange. When it has been seated fully home, pressure is exerted on the excess composition which has been forced out through the

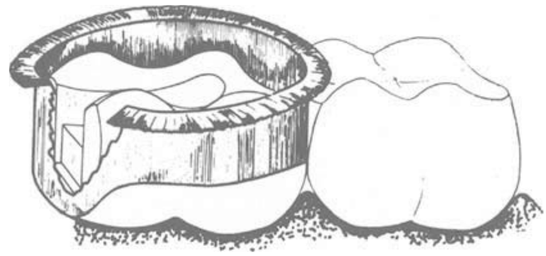


Fig. 18.7 Copper band trimmed just above the contour line for impression technique using composition. Note the flange which stiffens the band and gives purchase for removal.

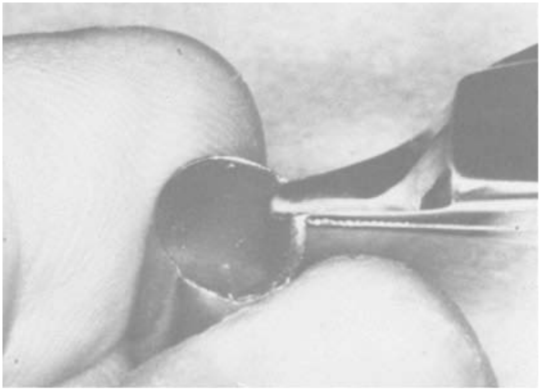


Fig. 18.8 A flange is produced at the margin of the copper band with pin-bending and roughening pliers.

Fig. 18.9 Copper band flanged and contoured.

flanged end. The band is chilled with a jet of cold water for about 30 s. There are many techniques for removal of the band, but the author has found that the following one gives satisfactory results. A piece of cotton napkin (approximately 15.0 x 8.0 cm in size) is damped with cold water and folded lengthwise into a strip. Then it is twisted into a cord, wrapped under the flange of the band and the ends, brought out to the buccal side, are twisted one over the other and held in the right hand whilst the left thumb is engaged under the material on the lingual of the band. Thus the band is pulled off the tooth. It is inspected, paying particular attention to the following points:

1. Are all the margins recorded in sharp detail?
2. Are there any shiny 'areas of drag'? (denoting slight undercuts from which the impression has been pulled).
3. Have any pieces of composition broken away?
4. Are there any cracks or folds in the impression?
5. Has the band impinged on a margin and been turned over?

Any of these faults may be remedied by modification of the preparation, re-cutting the margins of the band or merely repeating the impression without alteration of the band.

When a good impression has been obtained, a locating impression is recorded (see below) and the band impression is coated with an electroconductive material, such as Aquadag or colloidal silver. Then the surface is copper-plated.

2. Copper band and elastomeric materials

The advantages of the elastomeric impression materials over composition are as follows: firstly, it is easier to seat a band when the impression material remains plastic for a reasonable time; secondly, it is possible to record undercut areas beyond the cavity margins, thus a more accurate impression is obtainable; and thirdly, thermal insult to the pulp is avoided. On the other hand, greater care in preparing the cavity is called for because an undercut wall, which it would be impossible to record with composition, could be recorded in mercaptan rubber or silicone, with disastrous results in the laboratory. Moreover, great care must be exercised in the choice of copper band and in its manipulation, because it is possible to warp the impression when taking it off the tooth.

Having tried a variety of materials and techniques, the author has obtained the best results with a high viscosity silicone material, namely Super-Cardex. The copper band is prepared in the same way as for composition, but it is essential that no hint of tightness be apparent when the band is seated, otherwise it would spring back when removed and distort the impression. The inside of the band should be painted with a silicone adhesive, but if this is not available it may be roughened with a coarse stone and a few circumferential grooves cut with a size 1 inverted cone bur.

Super-Cardex is supplied as a heavy green paste which is mulled in the fingers with 2–4 drops of catalyst for about 15 s. It is loaded into a flanged band which is placed over the tooth and immediately the gingival perimeter is palpated with a probe to make certain that the band has seated fully. If it is found that the band has impacted on a step, it may be moved over and re-seated. Until correct positioning has been verified, the pressure should have been exerted solely on the flange but, once the band is seated, a finger is moistened with water and the silicone is pressed home firmly, after which the band is held without movement for about 2 min. In order to test the degree of polymerisation, the points of a pair of dressing forceps should be pressed into the silicone. If depressions are left after the instrument has been removed, the material requires more time to set. When it resists deformation, the impression is removed by inserting the blades of a pair of dressing forceps under the flange and giving the band a tug in the axial direction of the cavity, meanwhile restraining any tendency of the forceps to squeeze the band by placing a thumb and forefinger across the forceps (figure 18.10).

Fig. 18.10 Copper band impression with a silicone 'putty' (Super Cardex). Note the location of the dressing forceps beneath the flange, while pressure from the finger and thumb prevent any tendency to squeeze the band which could produce a distorted impression.

The impression is examined with special attention to the following points:

1. Sharpness of cavity detail.
2. Total recording of the margins.
3. Absence of folds or cracks.
4. Pulling away of silicone from the band.
5. Impaction of the band on a margin.

Any shortcomings must be rectified by repeating the impression.

Silicone in a copper band may be copper- or silver-plated, using Aquadag or colloidal silver as the cathodic coating. A plated die is ideal for swaging a platinum matrix for a jacket crown, but for ease of manipulation of inlay wax, a stone die is preferred by many technicians.

The stone (e.g. Kerr's Velmix) is mixed to a heavy consistency and vibrated into the impression. A Ney dowel pin is then embedded into the stone and the die is allowed to harden for several hours, prior to removing the impression and trimming away the excess stone from the margins.

As an alternative, a special metallised resin may be used, such as Kol-Dur, supplied as a powder and liquid which are mixed to a paste and packed into the impression. A dowel pin is inserted and the die is placed into an oven or dry heat steriliser for 20–40 min at 80°C. When it is hard, the die material is resistant to abrasion and may be used equally for jacket crown work or for gold inlays.

Locating impressions

A time-honoured but greatly over-rated method of locating the die in relation to the neighbouring and opposing teeth is the making of a wax squash bite. As its name implies, the patient is asked to bite into a sausage-shaped roll of heated pink wax, made into a sandwich with a strip of gauze, polythene or cellophane, which is interposed to avoid perforation by the cusps when the teeth have made contact. The operator presses the wax against the outer surfaces of the teeth whilst the patient exerts lingual pressure on the inner aspects. After chilling with cold water, the bite is removed and dried. A thin layer of low fusing aluminised wax is melted over the fitting surfaces of the bite, which is returned to the mouth and the jaws are closed again. The bite is chilled, removed and inspected and, if satisfactory, is placed in cold water.

The die is placed in position in this bite, locked home with sticky wax and the model and counter are cast in plaster and located, using either a small disposable plastic articulator or making a block articulation.

The chief disadvantages of this method are the tendency of wax to distort initially, when removed from undercut areas and, subsequently, when strains are released while awaiting the making of the die, a further warpage is apt to occur. Also, because wax tends to offer resistance when the patient bites into it, there may occur a deviation of the mandible into a false centric position.

From these observations it may be concluded that such an inaccurate method is far from ideal if precisely fitting inlays are to be produced. Modifications of the technique have been introduced with minor improvements only, e.g. a bite matrix is available which consists of two pieces of cardboard joined by a strip of gauze, which acts as the separator in the wax whilst the cardboard confines the wax bucco-lingually. This does not materially alter the shortcomings of wax as a bite-recording material.

Location by means of transfer copings

When difficulty has been experienced in obtaining a tray impression with an elastomeric material a two-stage impression and location technique may be adopted, using transfer copings.

Copper band impressions, using silicone or thiokol, are recorded of all the prepared teeth and dies are produced, either in metallised resin or by copper-plating the impressions. Accurately fitting copings are produced with buccal and lingual projections, to lock them into the impression to be recorded in a special tray at the next visit.

The copings may be cast in silver or gold, or constructed in acrylic although, because of its polymerisation shrinkage, acrylic is less accurate, hence it cannot be recommended except when it is impossible to produce metal copings, despite the fact that it is used by many practitioners.

When the copings are tried on the teeth, a good indication is obtained of the accuracy of the dies and the degree of retention of the preparations.

If they are satisfactory, they may be removed and coated with rubber adhesive, as an extra safeguard against movement in the impression. At the same time the special tray is painted with adhesive.

A heavy-bodied polysulphide rubber impression paste is mixed and the tray is filled and seated over the copings.

When the rubber has set, it is removed with a sharp tug. The copings should be locked firmly in place and detail of the teeth and soft tissues should be apparent.

The dies are placed into the copings, secured with a rim of sticky wax, and the model is cast in stone. This technique may be used for multiple units of bridgework, for crowns and precision-attached dentures.

Silicone as a locating agent

The author has used silicone successfully for the location of dies for many years. There are two techniques, the first of which is for use with single restorations and the second, for crown and bridgework.

The single restoration technique consists of a simple modification of the wax squash method, in which a high viscosity silicone, such as Optosil (Bayer) or Verone G (Davis, Schotlander, Davis) is used. Both materials are supplied in the form of a putty-like silicone paste with a liquid catalyst. The requisite amount of putty is placed on a clean glass slab and the surface is cross-hatched with a spatula. The catalyst is deposited evenly over the surface and, using a folding action, it is brought into intimate contact with the whole mass of putty, the final incorporation being effected by thorough mulling in the fingers for about 5 s.

The roll of mixed silicone is placed over the prepared tooth and its neighbours. The patient closes his jaws and the silicone is moulded by the patient's tongue and the operator's finger. When the operator is satisfied that sufficient of the required buccal area is covered, the final moulding of silicone is done by massaging the patient's cheek. The patient is told to press with the side of the tongue against the lingual surfaces of both arches equally, otherwise there is a tendency for certain patients to push the silicone up, spread it across the palate and produce a fine but unwanted impression of the rugae. Also, if they are not told otherwise, they may press with the tip of the tongue. This may encourage the jaws to separate and cause distortion. The silicone sets to a firm consistency in approximately 60–90 s and may be stored in water, which keeps it flexible, for several weeks without deterioration.

The die is inserted in the bite, to which it is secured by means of a circumferential rim of sticky wax, and a model and counter are cast in plaster. In order to allow movement between the models, they are either articulated on a simple articulator or located at one end only (figures 18.11, 18.12 and 18.13).

An alternative technique, used especially for jacket crown preparations, involves the use of a special tray made from a previously recorded alginate impression of the full arch. The tray may be perforated or painted with a silicone adhesive. It is loaded with a silicone material of medium viscosity, (e.g. Lastic 55, Silflex or Verone) and placed over the teeth, to be held undisturbed for the recommended period of time. When it has set and been trimmed, the die is inserted in the impression and secured with sticky wax and the model

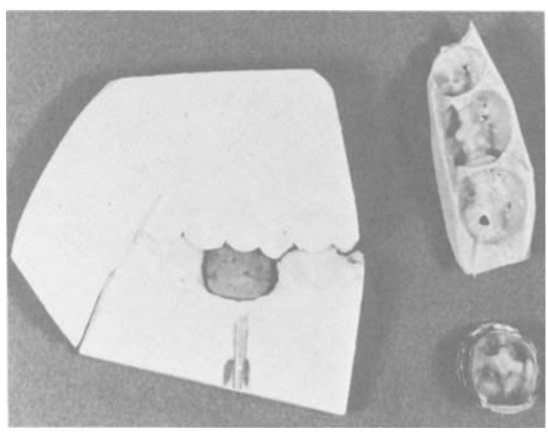


Fig. 18.11 Articulated models, with area cut away to show position of Ney pin.

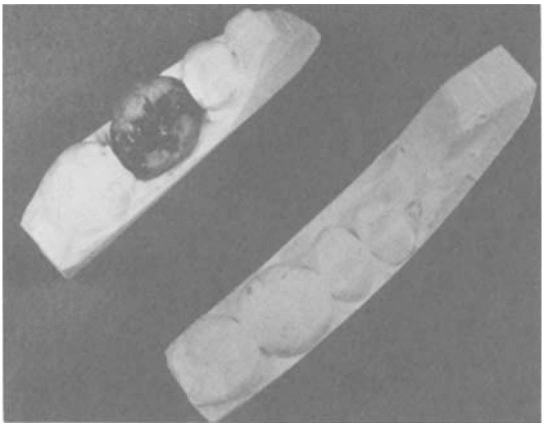


Fig. 18.12 Zinc stearate dusted on opposing plaster tooth has rubbed off on wax, indicating areas of impingement.

is cast. A full alginate impression of the opposing jaw is recorded and, if the intermaxillary relationship is not obvious, a wax wafer will aid location of the models. However, if an extensive bridge is to be constructed, resin keys will ensure perfect location. These are made in a plasticised self-polymerising resin, such as Dentan or a tray material such as Traymaker. Two pieces of resin, each the size of a walnut, are pressed over the buccal surfaces of the molar and premolar teeth in centric occlusion and allowed to harden. Their setting is accelerated by syringing with warm water. In order to avoid chemical irritation of the gingivae, the maximum quantity of polymer should be incorporated and the resin should be trimmed, while soft, so that it does not extend over the gingival margins. The technician assembles the models and the two resin keys, secures them temporarily with sticky wax and mounts the models on an articulator which allows

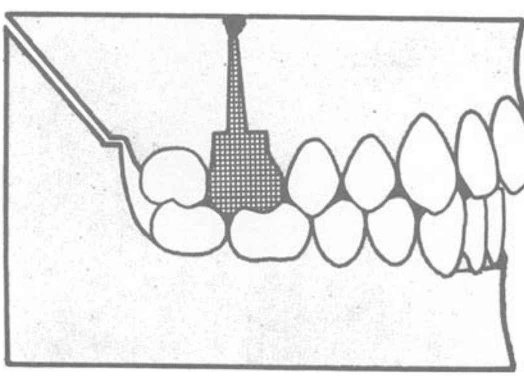


Fig. 18.13 Diagrammatic representation of block articulation of quadrant models at one end only, with the die on a Ney pin.

simple hinge movements. If necessary, face-bow readings may be made and a Dentatus or similar articulator used.

Although this location technique may be used for the production of bridge retainers, the possibility of small discrepancies in the accurate placement of dies would contra-indicate the completion of a bridge, with the possible exception of a simple cantilever bridge.

There is, however, a similar technique which may be adopted if the operator wishes to complete the bridge on the original model. Silicone impressions are recorded in flanged bands which are left *in situ* and not removed for examination, because it would be impossible to ensure their accurate replacement. A box tray, perforated or coated with adhesive, is loaded with a silicone impression material and placed over the arch and rocked gently from side to side during insertion to allow the silicone to flow fully around the bands. It is also advantageous if the bands have been so contoured that a space remains between the copper and the adjacent tooth surfaces, so that a good impression may be recorded of those surfaces. Furthermore, just prior to insertion of the tray, the external surface of the bands should be coated with adhesive to minimise the possibility that the vacuum created within the band impression during removal of the tray might allow slight separation of the band from its silicone matrix.

This technique should not be used until the operator has mastered the impression technique with copper band and silicone, because any faults in the individual die impressions would require repetition of the whole procedure.

Although it is possible to use this technique with quadrant trays, the difficulty in obtaining exact articulation, plus the need to include teeth of the contralateral side to obtain symmetry, favour the use of full arch impressions.

Unless a precision-attached prosthesis or a spring cantilever bridge is to be constructed when an impression of the palate would be needed, a lower tray may be used for an upper impression. This is more economical in the use of impression material and is less unpleasant for the patient.

Despite the author's preference for the use of silicone for copper band impressions, other operators have found that they obtain good results with polysulphide rubber used either in copper bands or in aluminium crown forms (which have one end closed). What is always patently obvious, when various techniques are discussed, is that irrespective of the technique employed and, given that the materials used are capable of producing a good result, a careful operator will master a technique so that his results are consistently satisfactory.

Impressions by the tray and elastomer technique

The technique of taking the impression of the prepared teeth and their neighbours at the same time is especially attractive when there are several abutment teeth prepared for bridgework or when a group of teeth is to be crowned. There are numerous difficulties inherent in the technique which must be overcome before good results can be obtained routinely.

(1) In order to have an even thickness of rubber, which is essential for accuracy, a special tray must be constructed. (2) Any gingivitis must be treated, otherwise the hyperaemic tissues are apt to bleed at a crucial moment and ruin the impression. (3) The cervical finishing lines of the prepared teeth should not extend too far subgingivally, because it would become virtually impossible to retract the gingivae and obtain a perfect impression of the cavity. (4) Gingival retraction must be effected and usually this requires the administration of a local anaesthetic. (5) If a patient suffers from ptyalism (usually of psychic origin), the large volume of saliva might interfere with the manipulation of rubber, hence it may be necessary to administer an antisialagogue, such as methantheline or propantheline bromide, prior to taking impressions. (6) The mixing of rubber base for injection and for loading the tray requires the services of a trained chairside assistant, while the whole technique is time-consuming and the materials are costly.

Nevertheless, the results, in careful hands, are excellent and much of the time spent in the subsequent fitting of the inlay or crown may be saved.

The stages are as follows:

1. Make a special tray.
2. Retract the marginal gingivae.
3. Mix light-bodied rubber and fill the syringe. Then mix heavy-bodied rubber and fill the tray.
4. Remove retraction cords and inject rubber around the prepared teeth.
5. Seat the tray in the mouth and hold it steady for 4–8 min (according to the manufacturer's instructions).
6. Remove the impression, dry, check and cast in stone.

Stage 1

When the decision has been made to prepare the teeth for gold inlays, crowns or bridges, alginate impressions are recorded to make study models and special trays. A special tray may be made quickly by taking a plaster impression in a stock tray with a sheet of thin expanded polystyrene foam as a separating layer, which prevents the plaster flowing into undercuts between the teeth and thus facilitates removal (Norton, 1967). When the plaster is hard, the polystyrene sheet is peeled away, leaving a stippled surface, which aids the retention of the rubber.

When time permits, an acrylic resin tray should be made. The method for its construction is as follows (figures 18.14, 18.15 and 18.16).

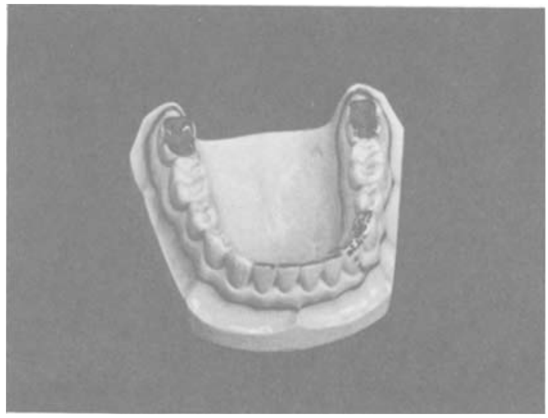


Fig. 18.14 Perimeter of tray and stops delineated with a pencil.

(1) Adapt a sheet of denture wax to the model and cut away three transverse strips of wax to expose the teeth. This is to allow the tray to impinge on three areas, away from the prepared teeth, and the stops so produced allow a space of 2.0 to 3.0 mm to remain

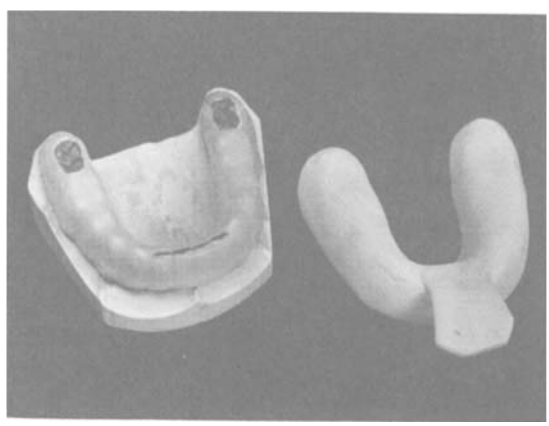


Fig. 18.15 Wax spacer on model with stops exposed, and showing completed tray.

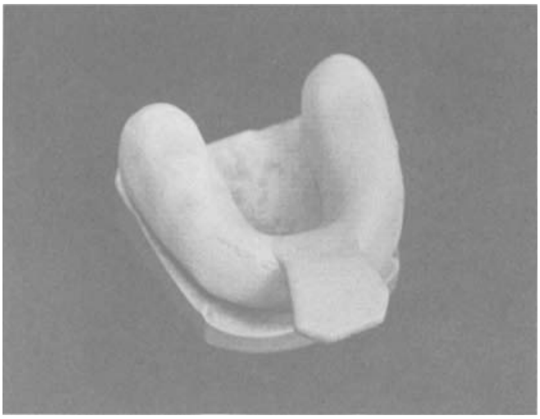


Fig. 18.16 Tray on the model.

around the other teeth to make room for the rubber base.

(2) With a sharp instrument, scribe in the wax the proposed outline of the tray, and paint all exposed areas of plaster with cold mould seal. This aids the removal of plaster from the acrylic.

(3) A tray material, which is a heavily filled methyl methacrylate resin, consisting of monomer and polymer, catalyst, initiator and filler is now mixed according to the manufacturer's directions and moulded firmly over the model. The margins are trimmed with a sharp knife and the excess material is formed into a handle, which is attached by moistening it and the tray with monomer so that it will adhere. When the tray is hard, the wax is eradicated from its fitting surface with boiling water, and the margins are smoothed and rounded. An expanded composition impression in a box tray should never be used, because there is a chemical reaction between the composition and the adhesive which causes it to soften and distort the impression.

Whichever type of tray is to be used, it must be coated with rubber adhesive, using the minimum amount possible and leaving it for at least ten minutes to dry. If it is still wet when the rubber base is placed in the tray, there is a possibility that the impression might pull away from the tray when removing it from the mouth. At this stage any pins or wires which are to be incorporated in the rubber should be similarly covered with a film of adhesive.

Stage 2

Rubber base is too soft to force back the gingivae and enter the gingival crevice, therefore it is necessary to pack back the marginal gingivae mechanically using cord impregnated with an astringent such as zinc chloride (8%), aluminium trichloride (25%), racemic epinephrine (8%) or a saturated solution of alum. The cord is supplied either as a single, double or treble strand. Short lengths of the single braid are cut and tucked gently into the dried gingival crevice with a plastic instrument (figure 18.17). If the cord is held down at one end and pressed home bit by bit, moving the first instrument along to hold the cord as the second instrument continues to press it home, the insertion of even a circumferential cord is not too difficult.

Fig. 18.17 Retraction cord is packed gently into the gingival crevice with the point of a Hollenback amalgam carver.

When the first braid has been inserted, a double braid is then pressed down over it. Some operators remove only the top cord, leaving the first one until the impression has been removed, in order to reduce the risk of seepage of blood into the rubber. The cord should remain in contact with the gingivae for about five minutes.

Following gingival trauma, the bleeding margin will be further traumatised when it is packed back. Haemostasis can be effected by damping the cord with a 25% solution of aluminium trichloride (Racestyptine).

The author prefers to remove all cords after 4–5 min. Further exposure of soft tissues to astringents may cause irreversible damage. When a cord is in position, it should be visible in the crevice, showing that the gingival crest has been retracted. If pushed down too far, there may be inadequate exposure of the cavity margins.

Formula of Racestyptine

Liquid	
Aluminium chloride	25 g
8-Hydroxyquinoline	0.10 g
Excipient q.s.	100 ml
Cord Impregnated with:	
Aluminium chloride	10 g
8-Hydroxyquinoline	0.04 g
Lidocaine	6.50 g
Excipient q.s.	100 g

Gingival retraction is painful in the majority of cases, consequently the discomfort may be alleviated by the injection of a few drops of local anaesthetic into the area. When there is only a small area of gingiva to be retracted, 10% cocaine used topically will be adequate.

Frequently, a margin is situated deep in the crevice, and gingival retraction is not practicable. Here the solution is to resect the gingiva and re-contour the margin, thereby removing the pocket, and to allow healing to occur before taking impressions. To avoid troublesome bleeding, the soft tissue should be made firm and healthy by the assiduous application of oral hygiene measures.

As an alternative, when the gingival tissue is hyperplastic and bleeds easily, it can be removed, with the aid of the electro-cautery, in order to expose the cavity margins. The main advantage of this technique is the ability to take an impression at the same sitting because there is no troublesome bleeding.

When cavities have been prepared for Class II inlays and there is to be a delay of not more than a few days before taking impressions, the gingivae may be retracted with strips of gutta percha, warmed and pressed gently into the crevices, lubricated with a film of vaseline and covered with a heavy mix of polystyrene-bonded zinc eugenolate cement, incorporating a few fibres of cotton wool. This dressing is removed easily at the next visit, along with the gutta percha, leaving the gingivae retracted and ready for impressions.

When a tooth prepared for a jacket or full veneer crown has been covered with a temporary crown, the crown should be left *in situ* because it will facilitate the insertion of retraction cord. Prior to packing, the crown is removed and any fragments of temporary cement are eliminated from the gingival crevice. Then it is replaced to act as a temporary support for the cord whilst it is being pressed home. It is taken out finally at the same time that the cord is removed.

Every attempt should be made to keep the gingivae free from saliva to avoid dilution of the astringent drug. Should there be an intractable haemorrhage due to recent trauma, it will be necessary to postpone taking the impression until the tissues have healed. Care should be exercised to ensure the perfect fit of margins of temporary crowns, especially if they are to be left for a lengthy period, because any irritation will lead to hyperaemia of the marginal gingivae, so that they will bleed freely at the slightest touch.

Slight seepage of blood may be dealt with by the application of a spot of hydrogen peroxide (3%) for a few minutes. If this is ineffective, the application of a minute quantity of 30% hydrogen peroxide (Superoxol), or of 40% zinc chloride, washed away after ten seconds contact, should arrest the haemorrhage.

Stage 3

As soon as the gingivae have been retracted, the chairside assistant begins the preparation of the polysulphide rubber impression material. There are numerous brands of rubber base on the market, some of which are supplied in the form of a medium- to heavy-bodied polysulphide rubber material, with a diluent, to reduce the viscosity of part of the mix and facilitate its ejection from a syringe, while the remainder is used as a paste of heavier consistency in the tray (e.g. Kerr's Uniflex, Astra's Neo-Galt).

The other form of polysulphide rubber, perhaps the more commonly used form, consists of two separate sets of base and catalyst, one for producing the heavy-bodied rubber and one for the light-bodied (e.g. Kerr's Permlastic, Coe's Coe-Flex).

The dual paste technique will be followed in this description.

Each kit consists of two tubes, one of which, the base, is a white paste and the other, the catalyst, a brown paste. There are two mixing pads, composed of disposable cards, and a bottle of adhesive for application to the tray.

A syringe is necessary for injection of the light-bodied material and it must be easily dismantled for cleaning.

The mixing pads are set out, each with a separate spatula, and equal lengths of base and catalyst are squeezed out onto each pad; light body on one and heavy body on the other.

The light body is mixed first, spatulating the brown and white components thoroughly with a flexible spatula until complete homogeneity of colour is obtained. Any streaks of white or dark brown through the mix would mean that areas of unset impression material could ruin the final result.

If a decreased setting time is desired, one drop of water may be added to the catalyst, i.e. the brown paste which contains lead peroxide. However, it is safer to follow the manufacturer's instructions regarding working times, so that setting is not too far advanced when the tray is positioned in the mouth.

If a Coe-Flex syringe is used, the plunger and tip are removed and the end of the barrel (on which the injection tip is located) is stroked through the mixed light-bodied rubber until the bulk of it has been collected. The tip is screwed into place and the plunger inserted. The assistant hands the syringe to the operator, who meanwhile has dried the teeth with a few blasts of warm air after removing the retraction cord. An alternative method for loading the syringe is to transfer the light-bodied rubber to a Dappens glass, remove the nozzle from the syringe and place the end of the barrel into the rubber, which is drawn up into the syringe by withdrawing the plunger.

Immediately, while the light-bodied rubber is being injected into the cavity, the assistant mixes the heavy-bodied rubber in similar manner and loads the adhesive-coated tray.

Stage 4

The reasons for injecting a light-bodied material into the cavity are to avoid the entrapment of air bubbles and to ensure flow of the material into the detail of the preparation. The nozzle of the syringe should be inserted into the gingival crevice and rubber injected there. Then, moving the nozzle inwards to the cavity recesses, they are coated liberally before moving on towards the cavity orifice and injecting over the external surface and onto the adjacent teeth.

The injection of rubber should not cease until the syringe is well away from the tooth, otherwise air could be drawn in between the interrupted deposits of rubber. As an alternative method for filling the gingival crevice, after a small quantity of rubber has been syringed into it, a gentle stream of air is directed onto the rubber in order to carry it right into the crevice. This is then followed by injection of the remainder of the rubber.

Stage 5

When the light-bodied rubber has been injected around the teeth, it soon starts to flow away. Consequently the assistant should endeavour to have the tray loaded with heavy-bodied rubber in readiness. The tray is inserted slowly with a rocking movement until it locates on to the stops, when it is held firmly in place for the time specified by the manufacturer.

Stage 6

When the rubber has polymerised fully, the tray must be removed with a firm pull. It should not be teased out gently, because the rubber is able to withstand a sudden pull out of undercuts without producing the permanent deformation which would occur if a slow determined pull were exerted.

After the impression has been removed, it should be washed under the tap to remove any blood or saliva, dried with a blast of warm air and inspected carefully with a magnifying glass.

The impression is checked for 'drags', where the material has pulled away from the teeth, and for air, saliva or blood bubbles, especially when they are large or occur at margins. Gentle pressure is exerted with a burnisher in and around the area of the cavities, to check for sub-surface bubbles, which might pass unnoticed on visual inspection. The impression is sent to the technician to be cast as soon as possible because, although polysulphide is more dimensionally stable than the condensation silicones, there is evidence that delay in pouring a cast results in slight shrinkage. The first cast is the most accurate and is used for waxing, whilst subsequent casts should be poured as a check for inaccuracies resulting from rubbing of the stone die during waxing procedures.

The Ney model technique

In this technique, the individual dies are cast in stone and made removable from the model. The stages are as follows:

(1) The rubber is marked with a pencil to indicate the centre of each prepared tooth so that dowel pins may be positioned correctly (figure 18.18).

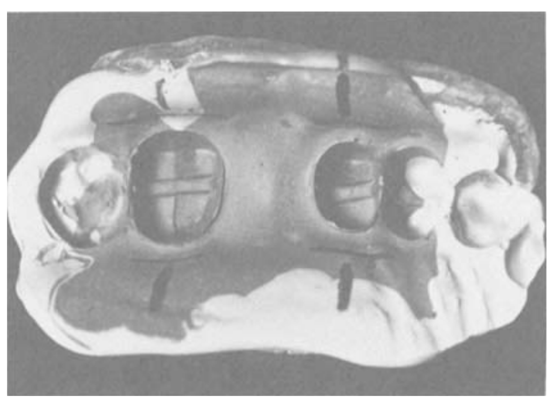


Fig. 18.18 Rubber base impressions with centre of each abutment marked.

(2) Stone (e.g. Velmix) is vibrated into the impression to a height of 2–3 mm above the necks of the teeth, dowel pins are placed in the centres of prepared teeth, and serrated retention washers in intermediate areas, ensuring that the pins are inserted in the axial planes of the teeth (figure 18.19).

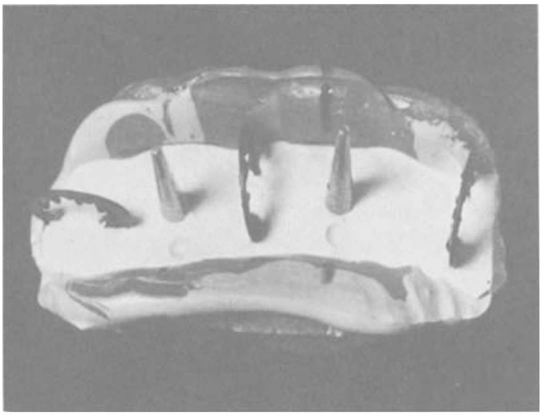


Fig. 18.19 First pour of stone, with Ney pins and washers in place and depressions cut to aid location.

(3) When the stone has hardened, buccal and lingual hemispherical pits are cut on either side of each dowel pin and the immediate vicinity of the pins painted with a separating medium (e.g. Cold Mould seal). A ball of wax or plasticine is placed on each pin.

(4) The base is poured in plaster and allowed to harden. The impression is removed and the model left for several hours in a warm place to dry out. Then, with a fretsaw, converging cuts are made through the stone proximal to each die (figures 18.20 and 18.21),

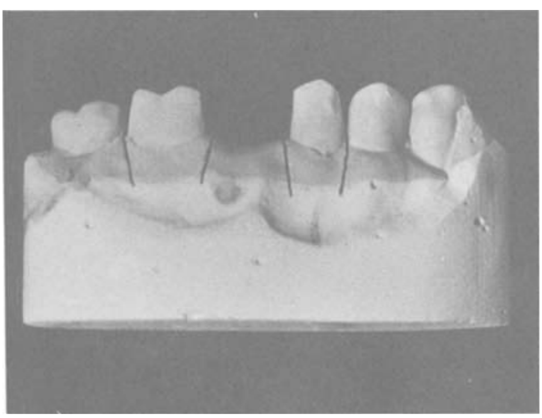


Fig. 18.20 Base cast and converging saw cuts made.

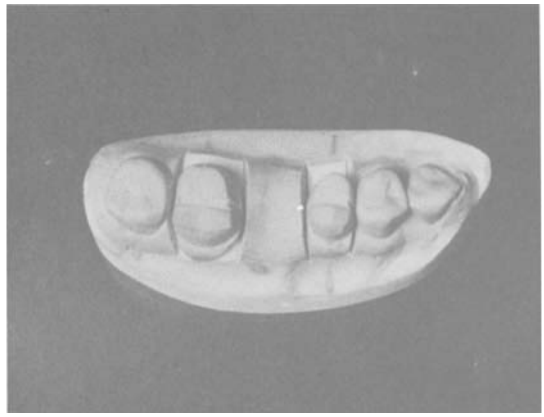


Fig. 18.21 Occlusal view of cut model.

the wax or plasticine at the base of the model is removed and the die is extruded by exerting pressure on the pin (figure 18.22). The excess stone is trimmed beyond the cavity margins of the dies. The counter model is cast and the two models articulated on a movable hinge articulator in readiness for making the wax patterns.

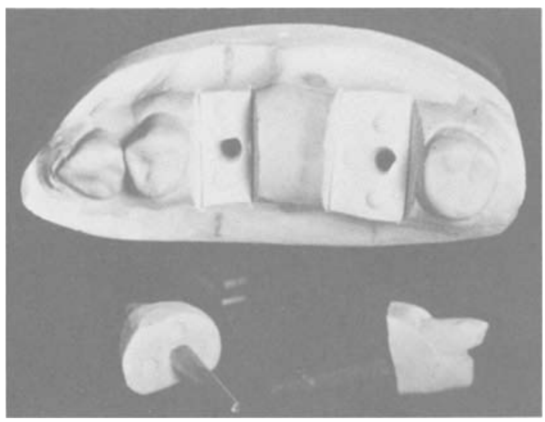


Fig. 18.22 Model with dies removed showing locating keys.

Methods for obtaining the correct occlusion

When a full arch model has been made, an impression of the opposing arch should be recorded in alginate and the two models apposed on an articulator (figure 18.23). However, when an impression of one quadrant only is recorded, there is some margin for error when trying to relate the models of opposing quadrants and the smallest inaccuracy could involve the operator in a considerable amount of occlusal grinding when the restoration is fitted.

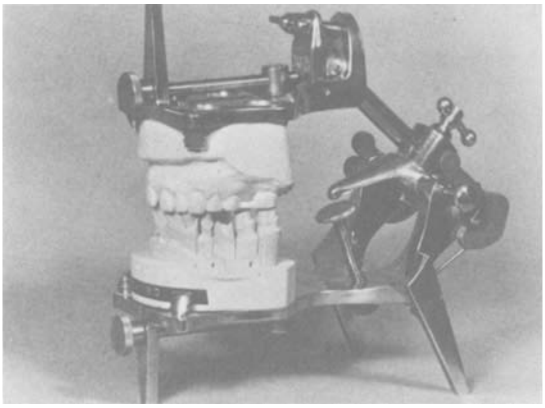


Fig. 18.23 Split working model and over-cast mounted on a plaster-less, free plane articulator. (GALETTI)

One method of avoiding this problem is to employ the functional bite stone technique (figure 18.24). In this technique, no impression is taken of the opposing arch, but the cavities are filled with soft, red bite wax and the patient bites and chews around on the wax in order to produce a functional pattern of the cuspal paths of the opposing teeth.

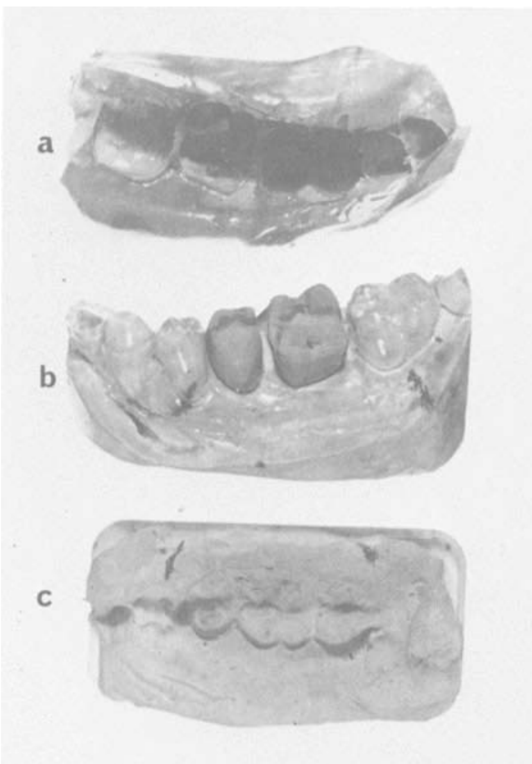


Fig. 18.24 Functional bite technique. (a) Quadrant silicone impression in special tray. (b) Model with removable dies constructed from above impression. (c) Functional stone bite, which locates accurately on the working model and is articulated against it for waxing-up.

When there are full or three-quarter veneer preparations, the wax is confined by fitting oversized copper bands, trimmed so that they do not interfere with the occlusion, and placing them, full of warm wax, on the prepared teeth prior to obtaining the functional occlusal record. At this stage, a plastic tooth holder, of the type on which denture teeth are supplied, is trimmed so that the well which housed the teeth can be orientated over the arch. A small quantity of functional bite stone (Surgident) is weighed in the ratio of 26 ml of water to 100 g of powder, spatulated thoroughly and loaded on to the plastic holder, which is then placed on the wax record with a vibratory side-to-side movement and held steady for $2\frac{1}{2}$–3 min until the stone has hardened.

This functional impression is then articulated against the working model using a simple hinged articulator. The technician builds up the patterns roughly in wax and, having softened the superficial layer with a heated instrument, brings the bite into apposition, thus producing the functional occlusal contour which he can then modify to produce a cuspal pattern. If he dusts some whiting or zinc stearate powder onto the stone bite, it is transferred, on closure, to any areas of premature contact thus facilitating the final contouring of the wax.

Accurate articulation of upper and lower models

When two models are placed into centric occlusion, it is usually possible to obtain an accurate intercuspation without further aids when all the teeth are present.

However, when several teeth are missing and other teeth have been prepared out of the occlusion, an accurate bite registration is necessary.

This may be obtained by the use of Ramitec (ESPE), a polyether material which is injected, after mixing, over the biting surfaces of the teeth. The jaws are then closed in centric occlusion and the polymerisation, which occurs quickly, produces a firm, accurate registration without the potentially deflective interference of a wax bite wafer (figure 18.25).

Impression technique for a post crown preparation

Since the introduction of the elastomeric impression materials, the taking of an impression for a post crown has been greatly simplified. A special tray is made and coated with adhesive and a piece of wire (e.g. cut from a paper-clip) of narrower diameter than the canal is cut so that it will project approximately 5 mm from the canal. The protruding part of the wire is bent into

Fig. 18.25 Inter-maxillary record (Squash bite) recorded with Ramitec, poly-ether material (Espe).

a loop and the tray is tried in the mouth, with the wire in the canal, to ensure that it does not rock on the wire. In the event that it does, the wire or the tray may be trimmed.

The wire is then painted with adhesive and put to one side, whilst the gingivae are packed back with astringent cord. The light- and heavy-bodied rubbers are prepared and a syringe is loaded with the light body. In order to introduce the rubber into the root canal a syringe may be used if it has a very fine nozzle. Otherwise the rubber should be carried up the canal on a Lentulo spiral filler which is coated with rubber and withdrawn slowly while rotating at about 500 rpm. This should be repeated, then the wire is pushed to the end of the canal to force the rubber against the walls and evacuate any trapped air. The retraction cord is removed and the syringing is completed. Then the tray, loaded with heavy-bodied rubber, is inserted and held in place until the rubber has polymerised.

The technique for making the model differs in one respect from that described. Either a hollow dowel pin is filled with stone and placed over the impression of the post, or normal dowel pins are inserted into the two neighbouring teeth, so that they are removable and the die becomes a part of the model.

The author also prefers to take impressions of pinholes by the same technique, using short lengths of orthodontic spring wire (0.5 mm) looped and coated with adhesive, and introducing the rubber with a Lentulo filler which has been shortened to about 5.0 mm in length.

Alternative impression materials

The polysulphide impression materials possess good dimensional stability and provide accurate castings from dies cast within a few hours of taking an impression. However, the lead peroxide-catalysed paste tends to stain fabrics if accidentally brought into contact with them. A cleaner polysulphide was developed in which cupric salts were substituted for lead peroxide (OMNIFLEX-Coe Products). The material has a characteristic blue colour and its dimensional stability is good. The same mix is used for injection into the cavity and for filling the tray.

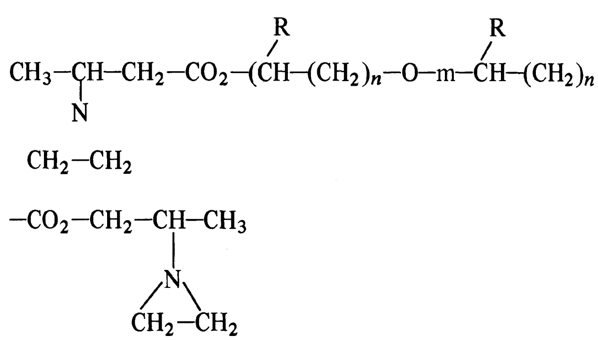
Another alternative to lead peroxide as a setting reagent is the organic hydroperoxide (e.g. MIM and Rubber-Jel). These, however, tend to be volatile which results in shrinkage. Thus the dimensional instability, coupled with objectionable taste and smell, rule out this group as unsatisfactory impression materials.

Imine-terminated poly-ether

Impregum (Espe), an imine-terminated, polyether impression material was developed specifically for dental impressions. It consists of two pastes; a base paste containing a polymer with terminal imine groups, and a 'catalyst' paste in which the setting reagent is a benzene sulphonate ester. The material sets rapidly and, if kept dry after setting, exhibits good dimensional stability. It is clean to use and acceptable to the patient, being free from unpleasant odour and taste.

The material sets to a rather hard, rubbery consistency which demands great care by the technician when removing it from the model. The polymer is hydrophilic and, when the impression is kept wet, it undergoes dimensional change. In consequence, after removal from the mouth and rinsing under the tap, it should be dried carefully with a jet of warm air before it is sent to the technician in a sealed polythene bag. Allergies to the Epimine materials have been reported.

Braden *et al.* (1972) give the formula of the polymer used in the base paste as follows:



This ring-opening mechanism, catalysed by an aromatic sulphonated ester, acting as a source of cations, results in polymerisation and cross linking to produce a rubber material.

Silicones

The early silicone impression materials, and many in use at present, rely on room temperature vulcanisation for setting. The polymerisation is effected by cross-linking hydroxyl-terminated poly-dimethyl-siloxanes with tri- and tetra-functional alkyl silicates. Tin octoate is commonly used as the catalyst.

The great problem inherent in this type of reaction is the production of an alcohol as a by-product of the reaction, especially in the light body pastes. The evaporation of alcohol has been cited as the most likely reason for shrinkage of silicone impressions.

Tests of dimensional stability have shown that it has a high unrestrained linear polymerisation shrinkage and consequently the model should be made within two hours if maximum accuracy is to be achieved. 'After three hours silicone elastomer reached shrinkage figures which were unacceptable in clinical practice – 0.25%' (McLean, 1961). Furthermore, silicone catalyst has a poor shelf-life, but this may be prolonged by storage of the catalyst in a refrigerator.

In an attempt to overcome this problem, the putty and wash technique has been evolved (e.g. Xantopren and Optosil: Verone G; Cardex blue; Coltex). In this technique, the polymerisation shrinkage and thermal contraction of the heavy body putty are controlled by addition of a high content of filler and that of the perfecting paste is nullified because the shim of material undergoes a negligible shrinkage.

A further advantage of this method is the use of a box tray instead of the special tray required for the paste injection technique.

Putty and Wash Silicone Technique

If needed, astringent cord is placed in the gingival crevice and left in place during the first part of the technique. A box tray is selected which fits the arch and the fitting surface and rim are painted with a thin film of silicone adhesive. A quantity of putty, sufficient to fill the tray, is put onto a glass slab and cross-hatched with a spatula. The recommended number of drops of catalyst fluid are spread evenly, and the putty is folded and spatulated to bring the catalyst into contact with the whole mass of silicone.

The material is scooped up from the slab, wiping up simultaneously any residue of catalyst, and mulled for a few seconds in the fingers before loading it into the tray. Variation in the speed of set can be produced by an increase or decrease in the volume of catalyst.

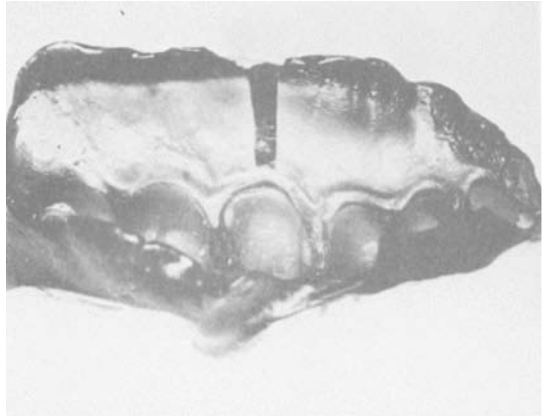


Fig. 18.26 Putty and wash silicone impression (Optosil & Xantopren (Bayer)) showing the shim of Xantopren around the margins and filling a spillway. The ideal impression is one with the minimum thickness of low viscosity silicone.

The tray is placed over the teeth and held steady until the surface of the silicone does not show a permanent depression when an instrument is pressed into it.

When polymerised, the material is firm but slightly resilient, producing an impression without intricate detail. The impression is now washed and dried thoroughly with a blast of hot air. V-shaped grooves are cut buccal and lingual to the impressions of prepared teeth to act as spillways (figure 18.26). These spillways are necessary when relining a resilient material which could be deformed under the pressure of a build-up of perfecting paste and thus produce an inaccurate impression.

The low viscosity silicone is next dispensed on to a glass slab; the cords are removed and the astringent washed away. Surplus fluids are wiped or blown away from the prepared teeth and the catalyst is incorporated into the silicone wash material which is then loaded on to the impression. When seated home, considerable pressure is used to ensure that the bulk of the low viscosity silicone is squeezed out, but after about 5 s, all pressure is released and the tray is maintained in position solely with the fingertips.

When the wash has polymerised, the impression is removed and inspected before sending it to the technician. The thinner the wash, the better the dimensional stability (see figure 18.26).

Addition-curing silicone rubber impression materials

A relatively new group of silicone impression materials have become available, which differ in their method of polymerisation from conventional silicones in that no by-products are produced and, in consequence, no shrinkage occurs. These are known as the 'addition' or 'hydrosililation-cured' silicones. McCabe and Wilson (1978) describe the reaction as the addition of Si–H bonds across vinyl double bonds, which can occur at mouth temperature in the presence of small quantities of platinum-containing catalysts.

The material is available as a two paste system (e.g. Reprosil; Reflect; President; Permagum) and McCabe and Wilson (1978) from an examination of the physical properties of these silicones, found that they possess longer working times and better dimensional stability than the condensation silicone materials, although their resistance to tear is less than that of polysulphides or condensation silicones. However, this factor may not be of such clinical import, being preferable to the permanent deformation that can occur in materials, such as the polysulphides, which do not tear as readily.

Hydrocolloid

Before the elastomeric materials, silicone and mercaptan rubber, had been developed for dental impression techniques, the only satisfactory tray material in common use was reversible hydrocolloid. There are many dental surgeons, especially in the United States, who consider that it is still superior to all other impression materials. However, the chief drawback to its use is the elaborate armamentarium required for its preparation. The hydrocolloid conditioner is an electrically-heated, thermostatically-controlled container with three water compartments, each being controlled at a different temperature. The hydrocolloid is heated to just below boiling point in a large syringe, in which it can be mixed by pumping the perforated plunger when the material is softened. It is then injected into a perforated box tray which is placed in the tempering bath at 115°F for 10–15 min, while the operator packs back the gingivae.

A small injection syringe, filled and tempered at the same time as the tray, is now used to fill the cavities with a continuous flow from the deepest parts to the surfaces so that air is pushed out ahead of the nozzle. The tray, loaded with material, is seated and held steady while being chilled for 4–6 min with cold water. This may be directed onto the tray and aspirated simultaneously, or a special tray with inlet and outlet tubes for water-cooling may be used, with rubber tubes attached to the tray. The latter method is more comfortable and more efficient than surface cooling. The tray is removed with a sharp snap to avoid permanent distortion. To prevent the hydrocolloid pulling out of the perforations of the tray, the operator should encircle the buccal flanges of material with his index finger, in order to exert even pressure both on the hydrocolloid and the tray.

It is essential that a large box tray be used so that the bulk of material provides adequate toughness. In thin sections, hydrocolloid tends to tear when removed.

Ideally the impression should be cast right away after removal, but if this is not feasible, it should be stored in a humidor and cast as soon as possible.

If the impression is allowed to dry out or to come into contact with water for any length of time, it will tend either to lose water (syneresis) from the gel and contract, or to absorb water and swell (imbibition).

When removed from the mouth, the impression is washed under the tap to get rid of saliva. It is then placed in a solution of potassium sulphate (2%) for about 10 min in order to produce a better surface when the hydrocal (stone) model is poured.

Some factors relating to the accuracy of elastomeric impression materials

The following factors should be remembered when handling the impression rubbers.

(1) Before relining a defective polysulphide or silicone impression, relieve it well and make spillways.

(2) Always ensure that mixing of the material is thorough and, with dual paste rubbers, that there are no streaks of the individual pastes in the final mix.

(3) Never remove the impression before it has polymerised fully. It is safer to allow a further 2 min.

(4) The first pour of die-stone is the most accurate and the casting should be finished on it whenever possible.

(5) When a special tray is used, the optimum thickness of impression material is 2.0–3.0 mm. A greater thickness allows greater shrinkage, whereas a thin layer is apt to tear.

(6) Models should be cast as soon as possible after recording an impression, but only after an interval of about 30 min, to make allowance for elastic recoil of the rubber.

(7) Good adhesion to the tray is vital. Minimum adhesive should be applied and sufficient time allowed for it to dry.

(8) A 'snap' removal of the tray is preferable to a lengthy pull, which is apt to cause permanent deformation of elastomeric impressions.

Investments

Most gold alloy castings are made with the aid of plaster-bonded refractories which expand during burnout and subsequent heating to compensate for the contraction of the molten metal between melting and room temperatures. The factors which control the expansion of the refractory are as follows:

1. The investment water ratio.
2. The properties of the investment and accuracy of manufacturing control.
3. The time of spatulation.
4. The temperature of the water.
5. Constraint within the casting ring.
6. Water absorption during setting.
7. The casting temperature.
8. Changes resulting from separation of the refractory within the tin.

Most of these requirements are specified by the manufacturer and great care should be taken to comply with the exact instructions prescribed (figure 18.27). Notwithstanding these, absolute accuracy is impossible, and certain precautions should be taken. Still water should be kept at a constant room temperature for the purpose, the refractory should be tumbled within the tin before use, the last few measures of refractory discarded, and the details of casting technique organised so that they can be repeated with a reasonable degree of constancy.

Finally, casting techniques should be used to known error. To ensure this a brass block is machined to represent a simple M.O.D. casting and a series of castings made to determined variations of casting temperature or plaster:water ratio until one can forecast either a variation which will give a perfect casting or a slight contraction, and another which will give a perfect casting or a slight expansion. Having recorded the precise details of the techniques the latter should be applied in all general work and the former for all full crown castings. If these methods are adopted certain problems will arise in complex cases but these can then be resolved by easing, e.g. in an M.O.D. casting if the axio-pulpal walls are slightly relieved then a small contraction is acceptable. Similarly, if a post-crown is involved then either a wrought post of predetermined size can be incorporated in a slightly expanded full crown casting, or the post and stump should be prepared separately from the remainder of the crown.

Fig. 18.27 Failure to cast owing to cracking of investment. Note the fins and bubbles which indicate disintegration of investment. Either the mix was too thin, or the investment was not set when the ring was put into the oven or the temperature was raised too quickly.

Investing a wax pattern

In order to ensure that a casting is an exact replica of the wax pattern, a small number of rules must be followed. (1) The sprue former must be wide (1.5–2.0 mm) or be furnished with a reservoir approximately 1.0 mm from the pattern. This compensates for the contraction of the gold when cooling and avoids the problems of rounded margins (suck-back) or porosities in the casting. (2) The sprue former should be attached to the thickest part of the pattern and at such an angle that gold will not have to flow against gravity. (3) To prevent accidental detachment of the pattern while investing, the hot sprue former should be inserted into a bead of cement ('sticky') wax previously applied to the pattern. (4) The pattern should be aligned on the crucible former so that (a) it is in the centre of the casting ring and (b) it is no further than 5.0–6.0 mm from the top of the ring. This is to allow venting of air through the investment when the molten gold enters the mould. (5) The pattern is painted with a surfectant solution to reduce the contact angle (i.e. lower surface tension). All excess should be blown off before applying the investment. (6) The investment should be mixed in the proportions suggested by the manufacturer and preferably mixed and applied under a vacuum to eliminate entrapped air bubbles.

The pattern contracts when cooling, after removal from the mouth or the die, and the gold casting also contracts when cooling from the melting temperature to the solid form (change of state contraction). The casting contracts further when cooling to room temperature. These two factors may be compensated for by (1) the known expansion of the investment when the powder:water ratio is constant and (2) thermal or inversion expansion of the investment when, after burning out the wax, the mould temperature is raised to 700°C. The ring must be lined with a layer of asbestos to make room for the expansion of the investment. Thermal expansion is due largely to the silica inverting from its alpha to its beta form.

A third method for increasing expansion, when using a gypsum-bonded investment, is to soak the ring in water at room temperature as soon as the investment has started to set. This is known as the hydroscopic expansion method and relies on the growth of gypsum crystals from saturated solutions. It is used only when extra expansion is required, e.g. when many bridge units are being cast together.

Cast restorations (physical considerations)

Retention in cast restorations is achieved by sandwiching a crystalline 'cement' layer between the casting and the tooth. This cement layer serves the double purpose of occluding the space between the casting and the tooth, and of providing a crystalline interlocking mass between the irregularities of the prepared and cast surfaces.

The factors affecting the strength of the cement bond have been investigated (Smyd, 1948) and the following factors determined. The strength is equal to a constant (dependent on the physical character of the cement) multiplied by the total area of the interface times the number of irregularities at the interface, divided by the area of each cross-section of an irregularity times the distance between the faces (figure 18.28).

Thus it follows that the surfaces should consist of a great number of even irregularities of maximum area and small size, in order to allow maximum retention. It is important to realise that set cement has no adhesive qualities, and that its strength is related to its shear strength. In addition it will follow that unless two separate faces acting as a couple exist, retention will be negligible.

Jorgensen (1955) has investigated the importance of the parallelity in developing the couple and has shown that the convergence angle between the two respective interfaces acting one to the other is extremely critical, retention falling sharply when convergence angles of more than five degrees are employed.

Clearly the distance between the faces will also be of importance; thus the moment of resistance of the couple will be increased as the distance between the faces, though this is dependent on the fact that the larger the distance between the faces the bigger the casting and therefore the more likely it is to suffer deformation.

Jorgensen also showed that retention and fit were clearly interrelated. He investigated the discrepancy found when seating inlays and crowns and found that the discrepancy varied with the volume of the casting, its compressibility and the angle of convergence. Thus:

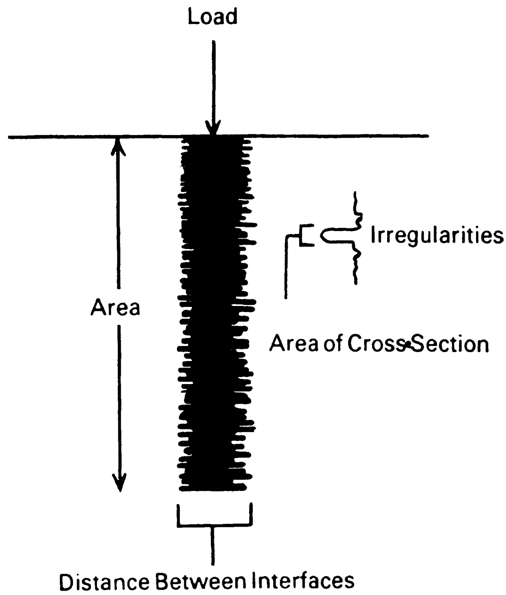


Fig. 18.28

Discrepancy =

$$\frac{\text{Volume}}{\text{Compressibility} \times \frac{1}{2}\text{ cot. angle of convergence}}$$

Because of the limits imposed by casting techniques and the retentive and structural needs of any large cast restoration, we need to reduce the volume of the casting to a minimum and similarly to reduce the angle of convergence and the degree of compressibility of any cast structure. In short, the requirements of fit are almost utterly opposed and clearly some sort of compromise is necessary.

Since a very small angle of convergence makes a difference between infinity (0°) and values between 9 and 5 for $\frac{1}{2}$ cot. angles between 3° and 5° it is obviously better to prepare the walls at the slight angle of convergence of between 3° and 5°. Secondly, in selecting the alloy to be used it is advisable to use as compressible a gold as possible consistent with the type of construction required; fortunately in the one case (i.e. that of volume), both interests coincide.

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19

The Fitting of a Gold Restoration

When the gold inlay has been cast and separated from the sprue, it is cleaned thoroughly by scrubbing away all attached investment with a small hard brush, e.g. an old toothbrush. Then it may be placed in an ultrasonic cleaner for about 5 min to ensure complete removal of investment. The oxide layer is removed by boiling in a 50% solution of sulphuric acid in water, after which the inlay is ready for trimming and polishing.

The technician smoothes and polishes the external surface of a direct Class II inlay leaving unpolished the contact area, which was overbuilt, after removing the pattern from cavity or die, in order to compensate for the polishing.

When he has cast a Class I inlay, the technician should send it to the dental surgeon with about 2.0 mm of sprue still attached. Othersise, if a well-fitting Class I inlay is tried in and found to be a tight fit, it may be difficult, or even impossible, to remove it without ruining the margins. To fit a Class I inlay, the sprue is held in a pair of fine pliers and the inlay is pressed home. If it does not go completely into place, the cavity should be examined for vestiges of temporary cement. Similarly the inlay should be closely scrutinised under a magnifying glass for faults, such as: (1) edges turned over, (2) retained investment, (3) gold bubbles (due to poor investing), (4) a shiny area – which denotes a premature contact with part of the wall, indicating a distortion resulting from removal of the pattern from an undercut cavity.

Removal of the impediment should allow the inlay to seat home. Once it appears to be seated, pressure should be exerted at each corner to check for any rocking movement. If there is a rock, it is evident that the wax pattern has warped and consequently it must be repeated. Should the inlay go fully into place, it is removed from the cavity and the sprue is undermined around its circumference, where it joins the inlay, and is cut off. The inlay is then cemented and the occlusion is adjusted, but burnishing and polishing are completed at a subsequent visit.

The special problem in the fitting of a Class II inlay is in relation to the contact area. There must be a firm contact with the adjacent tooth, located in molars and premolars, largely on the buccal aspect of the proximal surface, and close to the occlusal margin, and so shaped that no food can pack interproximally, either buccally or lingually.

If the direct or indirect technique has been followed with care, there should have been a slight overbuilding, which means that the inlay will not seat fully. The operator, on noting this, removes the high polish at the contact area by touching it lightly with a coarse rubber abrasive wheel.

When the inlay is reseated and pressure exerted, a shiny burnish mark indicates the location of the prematurity. Thus, by alternate checking and grinding with rubber abrasive wheels, the point is reached at which the patient is conscious of gentle pressure against the adjacent tooth when the inlay is fully seated. The proximal surface is then polished to a high lustre and the inlay is checked again before cementing.

The gingival margin is then palpated with a fine probe, to check for overhang. The excess is then dressed down with fine abrasive discs and rubber wheels, keeping the disc parallel with the surface of the gold and checking the edges frequently on the tooth. The fine fitting of the other margins is done on the tooth, using cuttle discs and a selection of Alpine white abrasive stones. The latter produce a matt surface and, because they remove minimum substance, tend to burnish the margins. They should be used along the margins or, if used across the margins, with the stone rotating towards the enamel. When the edges are no longer palpable, and the inlay, as tested with articulating paper, is not high in the bite, it is ready to be cemented. The formation of deep fissures and pits occlusally should be avoided, because they act as stagnation areas.

Soldering a contact area

If the inlay, for any reason, does not make a satisfactory contact with its neighbour, an area of contact must be established by adding gold solder and refitting in the mouth. To test whether the contact is adequate, a piece of nylon sewing thread is pulled in an apical direction between the inlay and the next tooth. It should snap or pull through only after the exertion of considerable pressure if the contact is adequate.

To solder a contact in the surgery, a suitable gold solder as recommended by the manufacturers of the casting alloy (usually 18 carat fine solder) is selected and cut into small sections. Having decided where the solder is to be added, the area is delineated by rubbing the perimeter with a soft graphite pencil, or painting with Aquadag, as an antiflux, to prevent the molten gold flowing over the edges.

The inlay is held at a point distant from the proximal surface to be soldered, in a pair of fine soldering tweezers in the reducing part of the bunsen flame for a few seconds. The gold solder is dipped into a suspension of borax in water and held in contact with the hot inlay until the water has evaporated. This leaves the solder glued by the borax to the gold. The inlay is then returned to the reducing area of the flame and held there until the solder melts and flushes over the delineated area.

When the inlay is nearly cool, it is put into a beaker of acid and boiled until the oxide layer has dissolved, when the acid is rinsed away and the inlay is fitted to the tooth, as described above.

Cementing the inlay

The type of cement to be used will depend on the experience and preference of the operator. Phosphate cement has stood the test of time and, although not ideal in every aspect, may be relied upon when used correctly. On the other hand, polycarboxylate has the advantage that it is apparently innocuous to the pulp and causes no pain at the time of cementation, whereas the contact of the necessarily thin but more acidic mix of phosphate with the dentine may be extremely painful. At present there is some argument concerning the value of polycarboxylate as a cementing medium, but the author has found it to be entirely satisfactory. Another sedative cementing medium, ortho-ethoxy benzoic acid cement (see chapter 8), also appears to be quite satisfactory for cementing small retentive inlays unexposed to stress, but there is insufficient evidence at present to recommend it for cementing fixed prostheses.

Oilo and Espevik (1978) examined the compressive strength, modulus of elasticity and the plastic strain at fracture of a number of dental luting cements, at 23°C and 37°C. They found that a zinc phosphate cement exhibited high strength and modulus of elasticity and small plastic strain at fracture.

Although a resin cement had high strength, its elastic and plastic strains were high.

Both polycarboxylate and E.B.A. cements showed low values for strength and modulus of elasticity, coupled with a high degree of plastic deformation at fracture. These findings highlight the wisdom of using phosphate cement as a routine cementing medium except on those occasions when circumstances demand a non-irritating substitute.

Whatever cement is to be used, the cavity must be isolated from saliva by placing cotton-rolls in the sulcus and a saliva ejector under the tongue. The cavity is dried with cotton pledgets and a sharp blast of warm air, to remove the last minute traces of moisture. The cavity must not be desiccated by the use of a continuous blast of hot air, because an anaesthetised pulp would not let the patient know that serious damage was being inflicted on it – at least not until later.

A slow-setting mix of phosphate cement is made by the addition of small increments of powder to the liquid and mixing for an overall time of 1.0–1.5 min on a cool glass slab. The inlay is coated with cement and pressed home into the cavity. Intermittent pressure is exerted and each time that a line of cement is expressed at the margins, it is wiped away. When, after probing the margins, it is apparent that the inlay is fully home, it is coated with vaseline so that saliva will not contaminate the marginal cement and weaken it. The patient is then asked to bite firmly on an orangewood stick for a couple of minutes, after which time the excess cement is detached and removed and the patient is dismissed.

It is not advisable to coat the cavity with cement, instead of coating the inlay, because the elevated temperature of the tooth increases the rate of setting of the cement. In the event that the inlay be dropped, or that there be difficulty in finding the line of insertion, the cement may become too hard to allow seating of the inlay.

Should the inlay, when coated with cement, be dropped in the mouth or elsewhere, the cement may be disintegrated by immersing the inlay in a concentrated solution of sodium bicarbonate.

When polycarboxylate cement is to be used, the inlay and the cavity should be swabbed down with acetone or choloroform, to eradicate every trace of grease or oil.

Good adhesion to the tooth, and also to a tin-plated fitting surface of an inlay, may be obtained by cementing with glass ionomer luting cement. Even without plating the inlay, the retention is apparently equal to that of phosphate cement without the risk of pulpal irritation. Prior cleansing of the cavity walls with citric acid or, in deeper cavities, E.D.T.A. solution, is essential for good adhesion. The cavity must be completely dry.

Multiple crowns can be cemented simultaneously by attaching them to a strip of autoclave tape, which is pressed on to their occlusal surfaces while they are in correct relationship on the model. They are teased off the dies and placed on the bracket table while the cement is being mixed. After the fitting surfaces have been coated with a film of cement, the crowns are carried to the teeth on the tape (figure 19.1).

At a subsequent visit the margins are burnished with a serrated burnisher, which may be made by running a large round bur against an old carborundum stone until the blades are blunted. The gold is then polished using a cup brush and abrasive paste and a high lustre is produced with a felt buff and a suspension of whiting in water. Alternative polishing agents are zinc oxide, titanium dioxide and jeweller's rouge. It is important to ensure that excessive heat is not generated during polishing, otherwise there may be damage to the pulp. If an inlay is polished soon after it has been cemented, the heat generated may affect the strength of the cement and any vibration, e.g. from an engine burnisher, may shatter the partly set cement. If abrasive rubber wheels are used, they should be operated under a water spray or used wet and at low speed. Heat may be generated also by brushes, porte-polisher cups and felt buffs, hence these should be used at low speed, with light pressure and with a liberal coating of polishing agent. However, when producing the final lustre, the handpiece may be operated at about 10 000 rpm, but with the exertion of minimum pressure.

It is essential that every trace of excess cement be removed from the gingival areas of proximal and cervical inlays, otherwise a chronic marginal gingivitis would develop. Cement is detached, using the point of a probe, or by pulling dental floss through the contact point and engaging the cement. This must be done carefully, to avoid snapping it on to the papilla.

In conclusion, the finishing of a gold inlay is of vital importance, to render it comfortable and to minimise the risk of recurrent caries. The polish should be as perfect as possible; the margins impalpable and the contour harmonious with that of the contiguous enamel (figure 19.2). When failure occurs, it is due usually to recurrence of caries under a faulty gingival margin, possibly because an inadequate bevel had been produced, or because the inlay was not fully seated home. The other major cause of

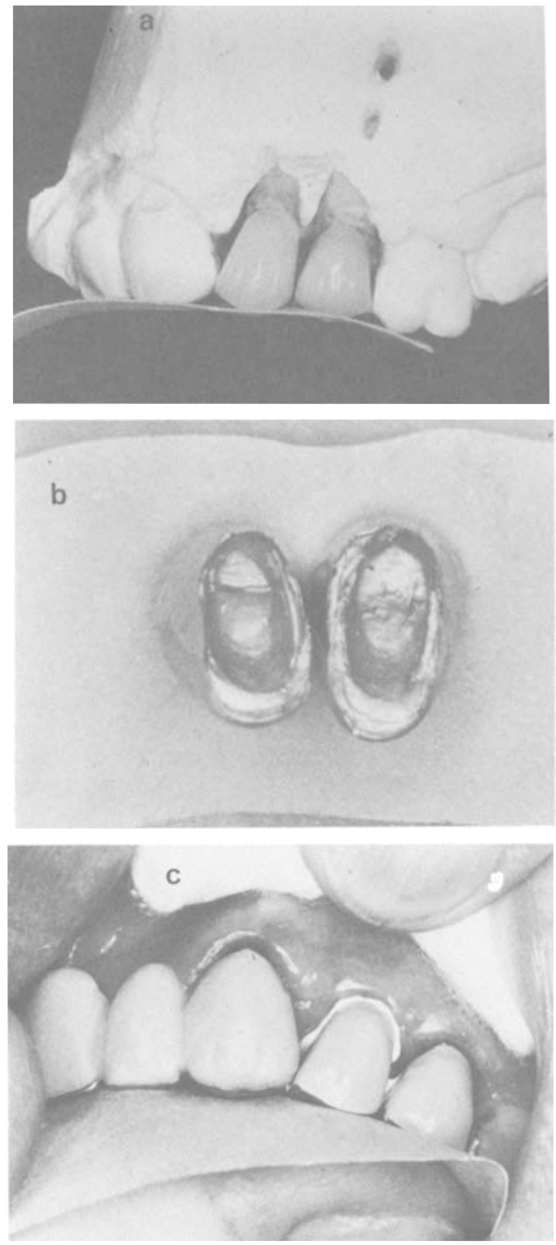

Fig. 19.1 Cementation of multiple crowns using Autoclave Tape (3M, 1222). (a) A short length of tape adherent to occlusal surfaces of crowns. (b) Crowns, after removal from the model, held in the correct inter-relationship on the tape. (c) Crowns, with cement on their fitting surfaces, carried into place simultaneously on the tape.

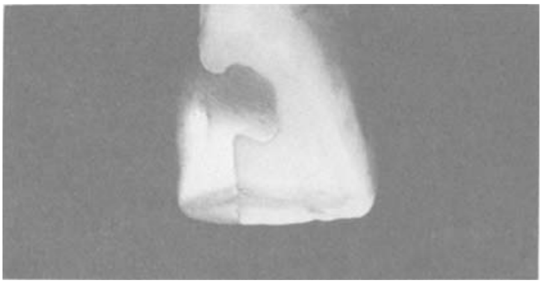

Fig. 19.2 Gold inlay with impalpable margins, in harmony with the adjacent enamel surface.

failure is lack of retention, so that the inlay falls out under normal masticatory stress. Attention to detail is the sole antidote to these faults. A poor inlay is no better than the cement in which it is embedded.

Aids to the construction of gold inlays

Thickness of gold

The minimum permissible thickness of gold under stress from opposing contacts is 0.6 mm. This will give, on average, at least 10–15 years of service before a perforation appears, when hard gold is used. Ideally, these areas should have a thickness of 1.0 mm. Platinised gold must be used.

The problem of ascertaining how much more gold may be removed, when a high spot on an inlay is being ground, may be overcome by the use of a caliper type measuring gauge. The author has used the Iwansson inlay gauge for many years on crowns and gold restorations and considers it indispensable. The gauge is calibrated in tenths of a millimetre which may be read on a scale opposed to the fine points which are placed in contact with the surfaces of the inlay (figure 19.3).

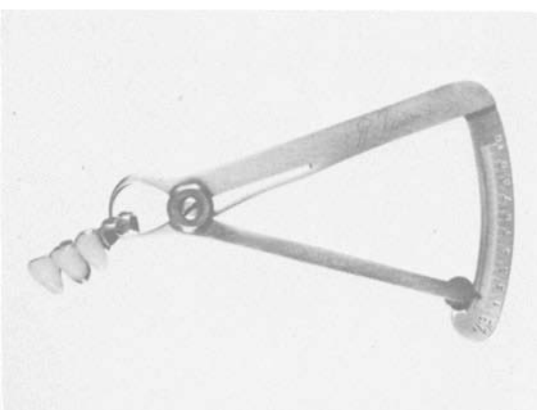

Fig. 19.3 Iwansson inlay gauge. Calibrated in tenths of a millimetre for checking the thickness of crowns and inlays.

Paralleling

The majority of gold inlays are paralleled by eye, taking advantage of a slight convergence of the walls to allow a margin for error. When teeth are to be used as abutments in bridgework, or where parallel-sided pins are used, a Pontostructor or Prec-in-dent paralleling device may be employed to assure absolute parallelity of preparation, but this is beyond the scope of this chapter. There is, however, an ingenious mirror, devised by Dr. Böttger (figure 19.4), which has a series of vertical parallel lines and is most useful for lining up mesial and distal walls and checking for parallelity.

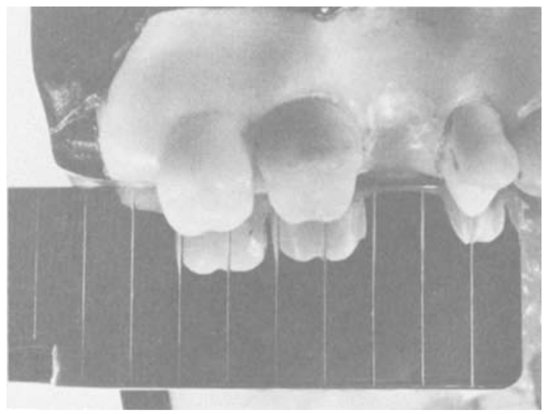

Fig. 19.4 The use of Böttger's paralleling mirror when preparing abutments for bridgework.

When cutting a series of tapered pinholes, it is a good guide to place a friction grip, tapered fissure bur in the first hole and to line up the direction of cut from it when cutting subsequent holes.

The use of cavity varnish

When cementing crowns or inlays on to hypersensitive dentine, varnish is valuable as a means of protecting the pulp, especially when phosphate cement is to be used. A coating of Tresiolan (ESPE), a liquid containing Siloxane ester compounds, will help in desensitising the dentine. It is applied to the dry dentine surface and allowed to dry for about 30 s, after which the tooth surface may be dried with warm air prior to cementing the inlay. As an alternative, Copal-ether varnish may be applied. Lund *et al.* (1978) found that two applications gave a better marginal seal than one, although the retention for luting agents was reduced if more than two applications were made.

The influence of surface roughness on retention

The smoother that the walls of cavities are prepared the more precise will be the seating of the inlay. However, light sand blasting of the fitting surface of the gold of a well fitting retentive inlay will increase slightly its retention, but it must not be over-done, otherwise retention will be lost.

Faults in gold castings

Porosity may be encountered as a result of suck-back and it is seen in the region of the sprue attachment. There may be simultaneous rounding of the margins and it may be due to the use of a sprue of inadequate diameter. Superficial porosities, due to back pressure, may be seen as voids and pits, and investment inclusions may be due to contamination of the mould by loose debris. Similar inclusions may result from the application of an excessive quantity of flux or due to carbon residue from inadequate burn-out of wax or plastic. Discolouration or tarnish may occur if the inlay is removed from acid with hot forceps. This produces a flash plating of copper which is difficult to eradicate. The same problem will emanate from pickling gold in exhausted acid, which has turned green.

Superficial porosity leads to tarnish in the mouth, and under-polished gold and gold contaminated with mercury tend to become black within a short time.

These facts should be borne in mind, so that the technician may review his techniques on those occasions when a faulty inlay is produced.

When an inlay will not seat into a cavity

When a gold inlay, which fits well on a die, will not seat home, despite a check for foreign matter in the cavity or on the inlay's fitting surface, there are two checks which may be made. Firstly, press the inlay as far as it will go, then ask the patient whether there is a feeling of wedging between the teeth. If the answer is in the affirmative, the patient will be able in most cases to discern whether the pressure is forward, backward or in both directions. The exact location of the proximal prematurity may be ascertained by placing a small strip of thin articulating paper between the inlay and the adjacent tooth and pressing the inlay into the cavity. This transfers a mark to the surface of the gold and ensures that corrections are made in the exact area.

The other zone which must be checked, if an inlay rocks or fails to seat all the way home, is the fitting surface.

Both the inlay and the cavity are dried and, using a fine camel hair brush, the cavity is coated with a fine film of 'Engineer's Blue' (a methylene blue preparation, available from model making and engineers tool shops). Alternatively Dr. Steiger's paint may be used. Both are harmless and will wash away with methylated spirit. The inlay is gently seated to the point of interference, rocked from side to side and removed. The points to which dye has been transferred are eased with a small round bur. After a few adjustments, the inlay may seat home. This would denote possible damage to the die by the technician. If it still refuses to seat home, the operator should re-examine the cavity for undercut areas and a new impression would be necessary. Haphazard grinding away of the fitting surface of the inlay is rarely successful and only produces an ill-fitting restoration with inadequate retention.

If, before the pattern is made, the fitting surface area of the die is given a coating of die relief paint to a line just short of the margins, fitting of the restoration is made easier and, according to Eames *et al.* (1978), retention is increased by 25%. This measure is applicable when there are long preparations with minimum taper of the walls. If it were used in other cases, retention would be jeopardised.

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20

Advanced Restorative Dentistry

The dental profession tends to consider the subject of advanced restorative dentistry as applying to fixed and removable prostheses, multiple crowns and total or sub-total oral rehabilitation, using various combinations of crowns and bridges.

The subjects of fixed and removable bridgework are too immense and complex to be considered in detail in this book and the reader is referred to other publications, in which they are covered admirably, at the end of this chapter.

Nevertheless, it is essential to indicate the area of advanced treatment which relies on the application of fundamental techniques of coronal restoration to be covered in succeeding chapters.

Advanced restorative dentistry is the phrase used to cover those procedures involved in bridge and precision attachment-retained denture work. Precision attachments are wholly or partly machined articulated joints principally used in the construction of removable or semi-removable prostheses (Ray, 1978), thus they may be used in either bridge or denture work.

A bridge differs from a denture in that it makes little or no contact with the mucosa, is entirely tooth-supported, and is only capable of replacing teeth. In contradistinction a denture derives some support from the mucosal and submucosal tissues, is always removable, and replaces not only the teeth but also the lost alveolar tissues.

Both types of prosthesis are intended to restore the functional integrity and aesthetic quality of the dentition, without prejudice to the remaining teeth and tissues. With very few exceptions this means the close reproduction of the original condition of the mouth, after the elimination of pathological or potentially pathological factors, and with due allowance for such biologic and mechanical limitations as may exist.

When designing any such appliance, it is of prime importance to consider the problem presented by the mouth, to define the objectives of treatment for each individual case, and only then to consider what gadgets or gimmicks are available to achieve the desired result. Under no circumstances should the decision to use a particular device be allowed to dictate the design. It may seem pedantic to emphasise this point, but it is a snare that all too often entraps the novice, and it is precisely because of this that it is unwise to dogmatise over specific techniques.

The choice between a bridge or a denture, or a combination of the two, is determined by the advantages inherent in them. Basically a bridge has three advantages; it makes little or no contact with the mucosa, and therefore is less of a tissue irritant; in most cases bridges are rigidly fixed into the mouth, and therefore are less subject to patient mismanagement; and finally, because they usually involve smaller spans and have greater tooth support, they are better tolerated. On the other hand a denture can be removed from the mouth for cleaning and, because it derives support from the residual alveolar tissues (and possibly the palate), it can be used to repair extensive losses in situations where a bridge is precluded. It follows that, given a choice, a fixed restoration is to be preferred to a movable restoration.

Terminology

Before discussing the respective merits and design factors involved in this type of work, it is advisable to define some of the terms to be used. Thus:

1. An *abutment* is a point or surface provided to withstand thrust, and in this case a tooth support.
2. A *cantilever* is a beam or girder, fixed at one end and free at the other.
3. A *pontic* is a word derived from the zoological word pons, meaning a bridge of connecting tissue, and in this case refers to each artificial replacement tooth of a bridge.
4. A *retainer* is some form of retaining or holding

device, rigidly cemented to the abutment, in order to fix the appliance to the teeth.

5. A *saddle* is that part of the denture covering the residual alveolar tissue, which when terminating adjacent to the abutment teeth is said to be bounded, and which when placed substantially mesial or distal to the abutting tooth or teeth, is said to be free-ended.
6. A *span* is the horizontal distance between two abutments.

Further, a bridge involving only one span is said to be *simple*, whereas when it involves multiple spans, it is said to be *complex*. A simple bridge may therefore be either cantilevered, *fixed-fixed* (i.e. rigidly anchored at either end), *fixed-movable* (i.e. terminating in a rigid joint at one end and a movable joint at the other), or *movable* (i.e. terminating in movable joints at either end).

Tooth movement

The mechanism of the dentition is so arranged that wear in the contact region is taken up by a mesial drift of the teeth. In addition the arch relationships change as a result of attrition, an Angle Class I relationship tending to become edge-to-edge. The degree of wear and tear depends to a large extent on the diet, being much greater when a large percentage of fibrous food is present. In the absence of sufficient roughage less wear and tear occurs, and any inherent malposition of the teeth tends to increase with age, orthodontically treated cases often reverting to a pattern reminiscent of the original abnormality. If the pattern is altered either, for instance, by some periodontal lesion tending to extrude a tooth, or as a result of an alteration of wear pattern arising from the differential hardness and abrasion resistance of restorative materials, an adverse lip relationship may be established and in that case more extensive and damaging movements will follow. For this reason it is essential when designing restorations to leave sufficient occlusal thickness to allow for occlusal adjustment, and to keep the occlusion under regular inspection.

The sequelae following tooth extraction have already been mentioned, but the effect differs from region to region, partly because of root formation, partly owing to the differing size of the teeth, and partly as a result of the overall anatomical and physiological design of the arches. Thus the loss of an upper third molar is unlikely to be followed by tooth movement of particular significance, unless either a pre- or post-normal arch relationship already exists. Similarly the loss of a maxillary tooth is often of less functional moment than the loss of a corresponding lower tooth, because loss in the upper arch is generally followed by slower changes and is usually restricted to tilting rather than to rotational movements, whereas tilting, rotation, and fairly rapid collapse of the lower arch follow the loss of mandibular teeth. Hence the design of mandibular bridgework (particularly in the anterior segment) should incorporate an anti-rotational factor.

In addition to the above mentioned details, regard must be paid to the special nature of the attachment of the teeth. Human teeth are gomphosed, i.e. they are suspended by a series of ligaments which are not fully taut in the resting position. Under load, a very small slack is taken up by the ligaments in a vertical direction, with resulting tension on the alveolus, which (within limits) tends to stimulate bony deposition. In contrast lateral force tends to thrust the tooth about a pivot centred about halfway up the ligamentous suspension, producing tension on one side and pressure on the other, and (within limits) pressure stimulates bone resorption. Thus a resultant constant or intermittent force applied laterally to the bone will result in resorption and apposition and consequent tooth movement, and the application of varyingly directed loads such as may occur during the insertion and removal of a removable appliance, or from leverage during function, will tend to result in thickening of the periodontal ligament and increased tooth mobility. Further, connective tissue subjected to pressure will realign itself in order to reduce the applied force to a minimum, and these changes are vital factors in determining the choice of design of a prosthesis.

We may therefore conclude that the following design factors should be borne in mind in any decision regarding the replacement of teeth in the partially edentulous dentition:

1. The need to allow for occlusal adjustment over a long period.
2. The need to hold the teeth in a fixed relationship one to the other.
3. The need to reduce any applied pressure on connective tissue to a minimum, and in particular to design appliances in such a manner that, whenever possible, any applied force is directed axially to the teeth.
4. The need to use well-fitting and stabilising temporary restorations between the preparatory stages and completion of the work.
5. The need to expedite work, so that once treatment is undertaken a minimum time lapse occurs before the final fitment of the prosthesis.

6. The need to consider the long-term prognosis of the mouth, and thus to design appliances with a view to their possible modification at a later date.

Diagnosis and treatment planning

A large percentage of bridges which fail, owe their demise to inadequate consideration of the suitability of the mouth for bridgework. Firstly, the patient must be rendered dentally fit before any thought of making a bridge can be entertained. Secondly, the choice of a fixed or removable bridge should be discussed with the patient, the dentist explaining the various factors involved and giving his advice as to which type of replacement would be in the patient's best interest.

If there are alternative solutions to the problem, each should be presented and the clinical and financial aspects discussed.

Primarily, the patient may express a desire to have some form of advanced treatment carried out, and it is the duty of the dentist to explain the implications of various alternative treatment plans and to guide the patient in deciding which treatment is best in their particular circumstances.

There are basically four ways of dealing with the problem. Given that the mouth is healthy, a bridge or bridges may be made: a removable prosthesis may be constructed; a hybrid prosthesis may be made, in which, by means of some forms of attachment, there is a combination of cemented retainers and a removable prosthesis, and finally, following orthodontic realignment of the teeth and closure of the space, the tooth or teeth on either side may be crowned and reshaped to obviate the need for a bridge. Of equal importance is the decision not to bridge a gap which has existed for a lengthy period and where cosmetic considerations do not pertain, and where drifting and over-eruption have reached an equilibrium and ceased.

By means of photographs and models the sequelae of tooth loss are explained to the patient, indicating over-eruption of the opposing tooth, the drift, tilting and rotation of teeth adjacent to the space, the open contacts and potential for food impaction and caries, and the increased likelihood of periodontal disease.

Economic factors tend to play a major part in the decision as to whether fixed or removable prostheses are to be made, but the number and length of the spaces and the patient's attitude to the situation are the main considerations.

If there is poor oral hygiene: if there are pocketing and bone loss or, if there is marked susceptibility to caries, no promise can be made that bridgework is feasible, and frequently, the correct action is to dissuade the patient from having a bridge. If and when the mouth can be rendered healthy and maintained in that state, further consideration may be given to more complex restorative measures.

Initially, before any decision can be made, impressions are recorded for study models, and all questionable teeth are tested for vitality and, for preference, a full mouth radiographic check is made. Between visits, the models are examined with a view to discovering actual or potential problems regarding available space, angulation of teeth and the height of their crowns, over-eruption and the presence of occlusal prematurities, denoted by wear-facetting. The radiographs are examined for the presence of bony pathology, such as retained roots, cysts, infrabony pockets or periapical radiolucencies, and the roots are evaluated as to suitability for bridge abutments. The shape, length and number of roots decide the degree of resistance to stress and the consequent prognosis for the bridge. The simple rule of thumb of Ante (1926) states that the periodontal ligament area of the abutment teeth of a fixed bridge must be equal, at least, to that of the missing tooth or teeth to be replaced. Although this rule is subject to interpretation in individual situations, if it is followed in the majority of cases it will save many problems.

Any teeth of doubtful vitality should be devitalised, root filled and kept under observation for six to nine months before being used as abutments. Similarly, inadequate root fillings should be replaced, even though they may have been free of symptoms for many years. The reason for this is that, when using the root canal for a retentive or reinforcing post, the root filling may be disturbed, and oral fluids and organisms gain access to the periapical zone with consequent immediate or delayed inflammatory sequelae.

If there has been generalised periodontal breakdown, which is now under control, and the patient is motivated to a high level of oral care, and provided that the teeth have not lost more than half their bone and are firm, bridgework is feasible. Also under these circumstances, but where some teeth show grade I mobility, the extension of bridgework to splint such teeth to firm teeth will often preserve them for many years. However, the ratio of abutments to pontics must be increased. Preparation of vital teeth should be planned to avoid excessive loss of dentine which would weaken the tooth, irritate the pulp, with the risk of irreversible change, cause pulpal recession, due to laying down of secondary dentine, and sclerosing of coronal dentine, which is thus rendered brittle and apt to fracture under stress.

Bridgework should never be undertaken for patients under 18 years of age for two reasons. Firstly, the teeth are often not fully erupted and secondly, the risk to a large pulp is great, although it diminishes as the patient ages with simultaneous narrowing of the pulp space.

At the other extreme of age, due to recession of the gingivae, problems arise, often of an aesthetic nature and, if margins are extended apically to the new gingival level, the crowns tend to be very long and the preparations narrow and weak, especially in the incisor region.

When there has been loss of vertical height due to abrasion, attrition or erosion, the measure of 'opening the bite' should not be entertained unless there are accompanying symptoms from the temporomandibular joints, or because diminished intermaxillary space will not permit reconstruction of the worn coronal surfaces.

However, if joint symptoms are present, no immediate crown or bridgework should be undertaken, but a bite raising appliance may be constructed and worn until symptoms have ceased, and thenceforward as and when they recur. In the interest of maintaining this rediscovered equilibrium, it may be necessary to consider a full oral rehabilitation, building up the occlusal level by means of full coverage restorations. This treatment is, however, beyond the scope of this book.

Individually over-erupted teeth and occlusal prematurities must be dealt with before starting the preparation of abutment teeth. If a tooth has over-erupted and is biting within the space to be bridged, a minor degree of over-eruption can be overcome by grinding the occlusal enamel and polishing it. A larger amount of enamel removed from the tooth would involve the dentine but, provided there is adequate recession of the pulp, the tooth may be reconstructed with an M.O.D. onlay or full veneer crown at the correct occlusal height. If the degree of over-eruption is such that there is extensive exposure of the root and furcation areas, it may be better to extract the tooth and provide bridges in both arches.

Severe tipping of solitary teeth, such as third molars, may present insoluble problems if they are to be used as bridge abutments. Apart from the question of alignment of retainers, the tipped tooth, which will receive greater stress when acting as an abutment, is physiologically ill-designed to withstand such stress because the majority of axial forces will tend to fall mesial to the roots and thus the bone disto-apically and mesio-gingivally will tend to resorb and the tooth will become loose. For this reason it is widely accepted that a tooth which is tilted more than 24° should not be used as an abutment. Orthodontic uprighting of the tooth is an established procedure which should be used prior to preparation of the tooth.

There are many indications and contra-indications for bridge work and the majority of them will be decided by common sense and experience, e.g. bridges should not be made on teeth which have apical resorption resulting from over-enthusiastic orthodontic movement; bridges are physically and psychologically advantageous in the treatment of cleft palate problems. No bridges should be made for patients suffering from Paget's disease, because continued enlargement of the jaws and spreading of the teeth can cause severe occlusal dysfunction. Distal cantilever bridges can be given greater function when occluding with removable prostheses because the stresses are less than with natural teeth. The use of apicected, short, conical or fractured roots to support bridgework should be considered only as a last resort, and in conjunction with additional abutments.

When maxillary incisors are to be replaced by a bridge, retained on the canines, and there is a bilateral lower unbounded prosthesis replacing molars and some or all premolars, the stresses from the lower anterior teeth will tend to cause labial migration of the upper canines. This can be prevented by the inclusion of the upper first premolars in the bridge.

Before bridgework can be undertaken, any pathological state in the arches should be treated. Buried roots lying deep in the bone, and without radiolucent areas, may be retained, but root fragments lying just below the surface in the area to be bridged should be removed, because they are apt to 'erupt' under a pontic and make cleansing difficult thus causing gingival inflammation. Similarly residual cysts, which might increase in size if left, should be removed.

When there is inadequate space between the ridge and the opposing teeth, it may be necessary to reduce the height of the ridge surgically. A careful examination of radiographs will reveal whether this is possible, e.g. the size of the maxillary antrum might contra-indicate such treatment.

If the teeth are short and margins are carried subgingivally in order to increase retentivity, the difficulty in obtaining good impressions is coupled with the risk of chronic marginal gingivitis around the retainers. A more satisfactory method of dealing with the problem is the use of an apically repositioned flap after removal of enough crestal bone to increase the height of the crown. Following this treatment, a delay of six weeks is necessary to allow stabilisation of the periodontal tissues.

Teeth which are heavily restored to an extent that little dentine remains, will not be strong enough to serve as bridge abutments without pinning an amalgam or composite core to the root before preparation. Anterior teeth, similarly weakened, are better served by elective devitalisation and use of the root canal for post retention of a cast or preformed metal core.

To sum up, the mouth should be rendered healthy and the patient motivated to keep it that way. Conditions for bridgework should be as ideal as circumstances allow and, if the patient demands a fixed bridge despite advice to the contrary, he must be informed of the prognosis and asked to sign a declaration that he takes responsibility for premature failure of the bridge which he insists must be made. Alternatively the patient may be told that he must find another dentist.

Clinical procedures — first visit

Before detailed planning of a bridge can be undertaken, alginate impressions and a squash bite are recorded to construct articulated study models. The model of the opposing jaw may be used subsequently by the technician in making the bridge. Radiographs and vitality tests are recorded at this visit and a full medical and dental history is written in the patient's notes. As stated previously, the dentist, armed with these aids to diagnosis, plans the work he intends carrying out. At the next visit, the patient is presented with a verbal or, preferably, a written treatment plan. If this plan is accepted, the work is started with a view to completing it within as short a time as possible, in order that the risk of drifting and over-eruption of teeth, which may follow wear or loss of a temporary bridge, can be avoided. When submitting an estimate of cost, it is a good plan to add a contingency fee to allow for unexpected problems. This supplement is deducted if everything goes according to plan, but if the contrary occurs, it is preferable to presenting an account in excess of the estimated amount.

Many patients prefer to have an injection of local anaesthetic followed by an extended treatment session, so that the preparation of abutments and impression taking may be completed. Other patients, unable to tolerate long periods in the chair, e.g. those with spinal disc lesions, prefer shorter visits. This must be ascertained in advance and arrangements made appropriately.

Second visit

A local anaesthetic is most often required and allows a more relaxed relationship between patient and operator. While the anaesthetic is becoming effective, an impression for a temporary bridge is recorded in silicone putty of the space and abutment teeth, plus one or two adjacent teeth, using a swivel quadrant tray. Before this is done, a pontic is carved, in wax, on the study cast, transferred to the space and, by overbuilding the contacts, is wedged in between the abutments.

When the set impression is removed, it pulls the pontic out and the operator then removes it from the impression.

Also, at this stage, if the daylight is expected to be inadequate by the end of the visit, the patient is taken to a window and the shade of the teeth is selected and recorded.

The abutment teeth are then prepared and, after any necessary addition of cement to eliminate undercuts, a careful examination is made to ensure absence of undercuts and to check the relative alignment of abutments for which a bilaterally soldered bridge is to be made.

When the preparatory work is judged to be completed, gingival retraction is effected where indicated. While the cord is being packed into the crevices, the chairside assistant coats the impression tray with adhesive. The impression is recorded, using polysulphide, polyether or silicone impression material, according to the operator's preference, and if the previously recorded opposing cast is unsuitable, an alginate impression is made of the other arch.

Dovetailing the various procedures saves valuable time, e.g. before the impressions are recorded, the silicone matrix is loaded with a suitable temporary bridge resin, such as Trim (Bosworth) and returned to the mouth. When the resin is almost set, the matrix is removed and the temporary bridge, if it is not trapped within the matrix, is teased off the teeth and placed in hot water to harden completely. Then, while the impression is setting in the mouth, the gross trimming of the temporary bridge is done. Finally, it is checked on the teeth and, after ascertaining that its marginal fit, occlusion and contour are correct, it is cemented with an appropriate temporary cement. If it has to last for more than three weeks, the teeth are coated with petroleum jelly and it is cemented with a polystyrene-bonded, zinc eugenolate cement, e.g. Kalzinol (Amalgamated Dental Co.). However, for temporisation of shorter duration, Temp-bond (Kerr) is satisfactory, allowing easy removal of the bridge. The cut dentine should first be protected by an application of copal-ether or Tresiolan (ESPE) varnish.

If, on completion of the preparation of the abutments, there is troublesome bleeding from the marginal gingivae, it may be preferable to delay impressions until healing has occurred. Some operators prefer to eliminate gingival tags or coagulate bleeding points using an electro-surgical unit. If margins can be kept away from the gingival line, such problems are less apt to arise, but in many situations that is a council of perfection which is unattainable. It is unwise to start the preparation of the teeth before the marginal gingivae have been rendered firm and healthy.

Types of Bridge

A fixed bridge may be attached at both ends, either by a soldered joint at one end and a slot and lug at the other, or the pontic may be retained by a soldered joint at one end only and be free at the other end. The latter type of bridge is known as a cantilever and may be supported by single or multiple abutments. When a bridge is soldered at both ends, it is imperative that the abutment preparations present equivalent degrees of retentivity. Failure to observe this fact will result in failure of the cement under the inadequate retainer.

Cantilevered bridges

Because cantilevered bridges are only supported at one end they must be short in span, and the supporting abutments must be periodontally strong; they are therefore limited to the replacement of isolated units. Further, because of the rotational factor they are unsuitable in the lower anterior region of the mouth. On the other hand rotation does not appear to be a problem in the upper anterior region. Schweitzer has reported that cases reviewed after a ten-year period of upper lateral pontics supported by single canine abutments showed no tendency to rotate, and a similar review of our own case histories has confirmed this observation. Moreover, in the relatively fewer cases, where a small lateral was carried by a single abutment on the central, no rotational problem was found over similar periods.

If the pontic has no occlusal contact with its opposing tooth or teeth, as, for example, occurs with anterior open bite or in many maxillary lateral incisors in Angle Class 2 division II malocclusion, it may be cantilevered from a single abutment. Similarly, if the occlusion, in all excursions, is not heavy, as evinced by an absence of heavy wear facets and over-developed muscles of mastication, a pontic with a reduced masticatory load may be cantilevered from a single abutment. There are, however, two provisos. Firstly, the abutment root must be long and broad and secondly, the bony support must be completely sound (figure 20.1).

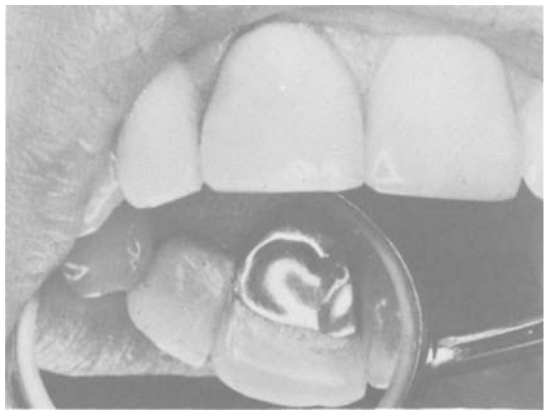

Fig. 20.1 Bonded porcelain bridge. $\underline{2|}$ cantilevered from jacket crown on $\underline{1|}$.

Where the load is heavy on the abutment, either a fixed/fixed or fixed/movable bridge may be made, or an additional abutment adjacent to the first abutment can be used (figures 20.2 and 20.3). A combination of these designs can be adopted when multiple pontics are required (figure 20.4).

If a molar pontic is cantilevered distally in the arch from two teeth, e.g. $\overline{65|}$, in order to prevent

Fig. 20.2 Bonded porcelain bridge constructed on $\underline{1|1}$ with a cantilevered $\underline{2|}$ pontic. $\underline{1|1}$ jacket crown preparations.

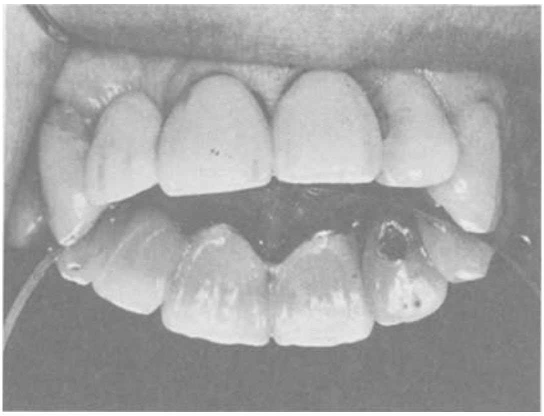

Fig 20.3 Bonded porcelain bridge *in situ*. The alloy has been covered with porcelain, except for the palato-gingival edge.

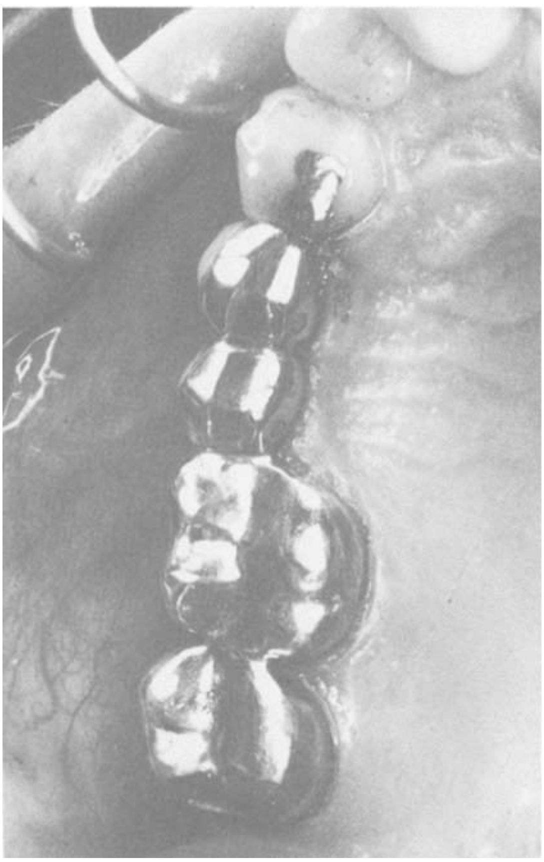

Fig. 20.4 Fixed movable bridge, with full veneer crown on 7| , ¾ crown on 6| , 54| -pontics, using long, platinum pin porcelain facings, and a stress breaker in the distal class III gold inlay in 3| .

over-eruption of the unopposed 7/, it should be designed so that the main stress falls close to its junction with the retainer and it should be narrower and shorter than the tooth it is replacing. This minimises the transference of stress to the abutments (figure 20.5).

Fig. 20.5 7| pontic cantilevered from full veneer crowns on 65| .

Fixed-movable bridgework

One of the main advantages of fixed-movable bridgework is the smaller amount of tooth reduction of the minor abutment. Also, it can be used to replace a single tooth in a space where the neighbouring teeth are so malaligned, due to tipping and drifting, that parallelling the preparations would be difficult and hazardous to the pulp.

A bridge to replace a maxillary lateral incisor may be made, using a full or partial veneer crown on the canine and a stress breaker in a distal class III inlay in the central incisor. The latter restoration must be highly retentive, otherwise it could be dislodged, although, it would be prevented from falling out by the stress breaker in its slot. Consequently the loose inlay would not be discovered until sub-total carious disintegration of the coronal dentine had occurred or the patient were forced to seek help because of pulpitis.

The class III restoration is not extended beyond the contact area but the depth of its proximal box should be 1.5 mm, in order to allow room for the dovetail cross-section, tapered slot, cut in the line of insertion of the major retainer (figure 20.6). Retention is good if the walls are prepared with minimum divergence (3–5°) and bevels, where indicated, are of minimum width.

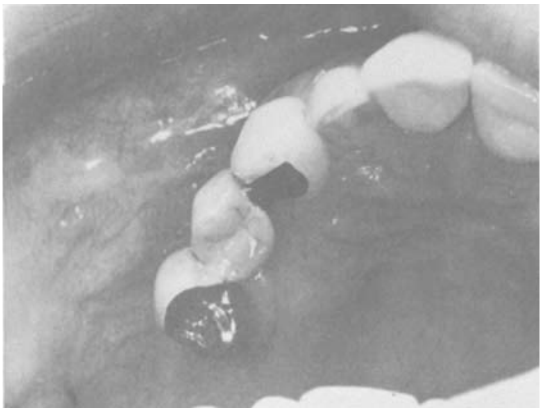

Fig. 20.6 (Top) Bridge, replacing 4|, stress-broken in a Class III inlay in 3|. (bottom) This stress-breaker, which lay previously in the slot in the |5 inlay, did not have a dove-tail cross-section and has ridden out of the slot. Occlusal stress has caused tipping of the |7 abutment with loosening, pocket formation and, finally, a painful periodontitis.

Additional retention may be indicated and accessory pins can be used (see chapter on Gold inlays).

Similarly, posterior bridgework may be stress-broken using a slot in a two surface class II pinlay or an M.O.D. inlay. If the buccal and lingual cusps, however, are weakened or heavily worn, this type of retainer, after a few years, would not give sufficient protection to the cusps, thus an onlay type of preparation (figure 20.7) or a three quarter crown should be used in preference.

Bridgework of this type has been markedly improved by the substitution of solid slide-channel attachments (similar to the Cendres Métaux Omega attachment) for the simple laboratory-made movable joint but the introduction of the bolt bridge (Ray, 1969) has reduced its advantages.

The use of the fixed-movable principle is extremely useful in complex bridge design, because by this means

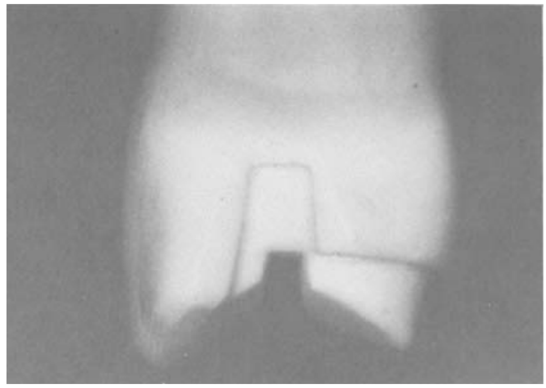

Fig. 20.7 Gold onlay preparation for maxillary premolar. Note the coverage of the buccal cusp with a small reverse bevel and the reduction of the palatal cusp. A chamfered or bevelled finishing line is cut about half way up the palatal wall.

it is often possible to design the pontic section so that it is operator-removable. Bridgework of this type uses at least one bolted joint and either attachments or anchors, and possesses three major advantages; firstly, the removable part of the bridge can be easily serviced, hence it is possible to use less durable materials, and therefore to reduce cost. Secondly, for the same reason a bridge of this type can be used for immediate replacement work, and is then easily repaired or modified after resorption has been completed, and thirdly, in the event of the loss of an abutment tooth the appliance can be easily altered. These advantages are less apparent in the posterior regions of the mouth, because the uniform direction of applied loads favours a fixed-fixed construction.

Fixed-fixed bridgework

In discussing the respective merits of fixed-fixed bridgework versus fixed-movable bridgework, the nature of the movable joint must be taken into consideration. Firstly, unless the articulation is constructed so tightly that the joint can only be assembled with considerable force (a so-called driving fit) some latitude for movement and food stagnation within the joint is always present. Secondly, sticky foods will exert considerable traction on the pontic area, which is then transmitted to the major abutment, and clinical observation confirms that the mobility of major abutments in simple fixed-movable bridgework is much greater than that found in equivalent fixed-fixed bridgework. It follows that this factor increases with the length of the span, and that if the pontic section is fixed at both ends the effect of any leverage will be halved. Further, as has already been stated (with a few minor exceptions) all movable joints allow a degree of movement, thus flexion within the pontic section can to a certain extent be relieved within the joint; on the other hand, unless the span is long this is likely to be very slight, and if this is the case it is usually not only possible but advisable to include a stress-breaker hinged towards the cervical area (such as the Pini Romagnoli conjunctor, figure 20.8) within the span. This has the double advantage of reducing the strain on the abutments, and facilitating the conversion of the bridge in the event of failure of an abutment.

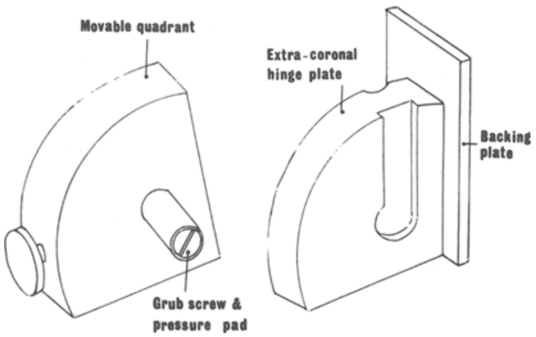

Fig. 20.8 The P.R. conjunctor (Pini Romagnoli).

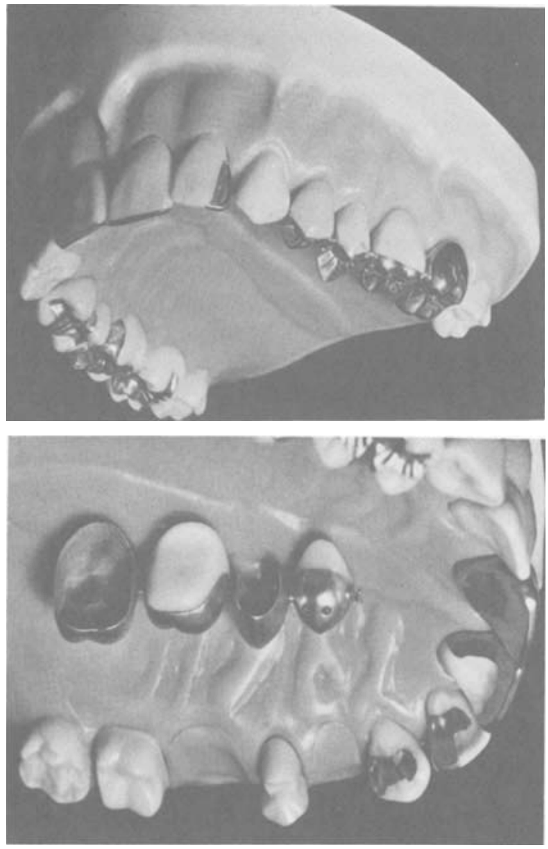

Fig. 20.9 Fixed bridge |34567. Full veneer crown |7.; Trupontic facing |6.; Three-quarter veneer crown |5.; Long pin facing |4 which is cantilevered from the |5 retainer and stress-broken in |3 distal Class III inlay.

From a periodontal standpoint the advantage of linking teeth rigidly together stems partly from the fact that the load is distributed more evenly through the entire periodontal attachment and thus weaker elements are supported by their stronger neighbours, and partly from the stabilisation of the abutments one to the other (figure 20.9).

Consideration of the above facts may well cause the reader to ask why any other type of design is ever contemplated? Two reasons immediately spring to mind; firstly the fact that in many cases other designs have presented the operator and technician with simpler and cheaper alternatives, secondly because more cases of unseated retainers have been reported following the use of fixed-fixed bridgework. Both factors stem from the fact that if sufficiently retentive restorations are to be constructed, the walls of the individual preparations must be paralleled very closely one to the other and a sufficiency of crown length is essential. At the same time, for a single section bridge to be inserted all the individual abutment preparations must be paralleled. It follows that the greater the number of abutments to be incorporated the more difficult the task, and the greater the deviation of alignment of the individual teeth the harder it is to retain their biologic integrity and the individual parallelity of the abutments. In consequence the retentivity of an individual preparation has sometimes been prejudiced in an endeavour to meet these other requirements, and if such a retainer subsequently becomes unseated rapid caries often ensues.

Until recently, fixed-fixed bridges were always made in single sections, and the most successful examples were always short span, simple, or complex bridges, and in many cases it was necessary to include multiple abutments. The advent of the bolted bridge has changed the picture, because it is possible to concentrate on the individual abutments and to ignore the alignments of the individual teeth. A bridge of this type is assembled in two or more sections and, after cementation, the varying sections are then united by suitably placed bolts; thus the disadvantage previously posed by the differential alignment of the abutments is turned into an advantage, such bridges being firmly held by mechanical locking, even without cementation. The importance of the cement bond is therefore reduced principally to that of a filler which will ensure that the space between the abutment and the retainer is rendered impermeable, and the shear strain to which such cement work was previously subjected is largely eliminated. Thus, far from seeking to align the abutment preparations, the reverse is true, and the contraindications associated with long spans and short crowns can be minimised, if not entirely disregarded.

Special cases do arise, particularly with very inclined teeth and very short spans where a bolt either cannot be used or the pontic cannot be rigidly fixed to either end. Two alternative approaches to these problems can be adopted; either a fixed-movable bridge can be used and the movable joint cemented and/or pinned, or the abutments can be constructed with overlapping flanges and a U-shaped pontic can be slid over the flanges and pinned or bolted into place.

The basic concept of this type of approach was first demonstrated by John Lee in 1951 in connection with denture design, and its development furthered by Lindstrom and Ray; thus, like so many other developments, it arose for differing reasons on an almost international basis.

The spring cantilever bridge

The spring cantilever bridge is a partially tooth-borne prosthesis which obtains much of its support from the tissues, with the pontic attached at the end of a long resilient cantilever arm. The indications for this bridge are as follows.

(1) To place a pontic in a wide space, maintaining diastema on one or both sides.

(2) Replacement of a tooth between teeth which are unsuitable for use as abutments, either because their crowns are too short to obtain retention, or because their roots are too conical or short to resist stress. These teeth would also be inadequate abutments if they had lost some bony support, even though the bone loss had been arrested.

(3) In a case where the abutment teeth are flawless but those more posteriorly in the arch are extensively restored, e.g. premolars with large M.O.D. amalgams can be used as twin abutments for a spring cantilevered central incisor pontic carried by full or partial veneer crowns (figure 20.10).

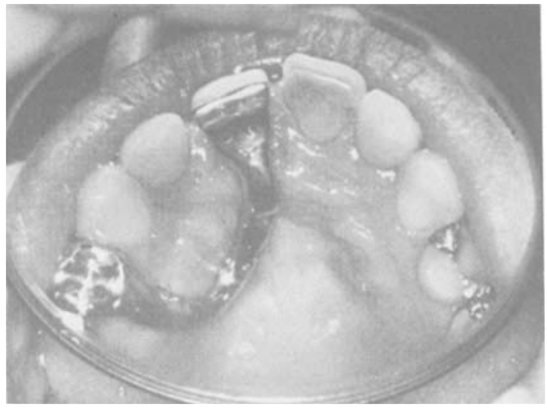

Fig. 20.10 Maxillary central incisor pontic cantilevered on a bar from three-quarter veneer crowns on both premolars.

Construction of a spring cantilever – essential considerations

The leverage on the retainers is such that maximum parallelism of axial walls ($1-3^\circ$ convergence) is needed to prevent the attachment of the bar to the retainer acting as a fulcrum when the pontic is stressed in a gingival direction, and lifting the retainer off the second premolar. This could be avoided by soldering the bar to the more posterior retainer, but the bar then ceases to be a U-shape and transmits more direct stress from pontic to abutments.

When the technician has cast the retainer (or retainers, if reciprocal retention is indicated), the U-shaped outline to be followed by the bar is drawn on the model. In the upper model the outline is cut into the stone to a depth equivalent to the radius of a size 10 round bur (1.5 mm), and a width of 3.0 mm. The cut terminates about 2.0 mm short of the retainer and the intervening area is relieved with a strip of (X-ray film) lead foil. This is to avoid any pressure on the marginal gingiva from the bar.

The bar is then waxed and cast with a bi-convex cross-section, the greater convexity lying in the groove. The pontic can consist of a long pin or headed pin porcelain facing, or porcelain, bonded to gold. The backing, bar and retainer, are united finally by soldering.

When first inserted, the bridge blanches the palate when pressed home and the pontic appears to be too long. The operator must resist the temptation to shorten it, because within a few days the bar beds home into the palatal mucosa and the pontic settles into the desired position.

Spring cantilevers in the mandible

The chief difference in the lower anterior spring bridge relates to the thin, sensitive mucoperiosteal ridge tissue. Instead of recessing the model to embed the bar, the ridge is relieved with a sheet of lead foil and the bar is kept as short as possible. Replacement of a lower central incisor by the preparation of adjacent incisors for full or partial coverage crowns, leaves the teeth weak and may cause irreversible pulp changes. If bonded porcelain is advocated, there is usually inadequate depth of preparation to produce a good cosmetic result. In such a case, the canine may be used as the abutment carrying a pin-ledge or full coverage bonded crown (figure 20.11).

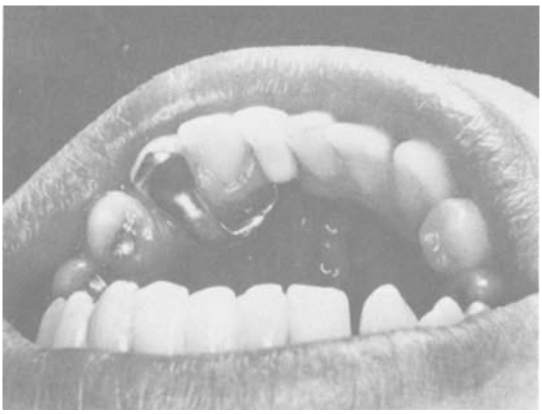

Fig 20.11 Three-quarter pin-ledge retainer on mandibular canine, with spring cantilever bridge replacing a central incisor.

When the impression is recorded, the tongue should be lifted and retracted forcibly to mould the rubber in the shape of the mucosal reflection, so that the bar will not impinge on it. The bar is kept as short as possible, slightly less bulky than the upper spring bridge and 2.5 mm width (figure 20.11). Its surface must be finished to a high lustre and the patient is shown, by the use of dental floss, the correct method for cleaning it, i.e. looping the floss over the pontic and pulling it several times along the fitting surface of the bar up to the retainer.

Abutments

The classic requirements for an abutment are a reasonably long clinical crown, vertically correct alignment, and good periodontal support. The first two factors relate to the retentivity of the preparations and the parallelisation of the prepared surfaces, and the third to the amount of support over which the load can be shared. It may be taken as a *sine qua non* that the walls of the individual preparations should be made as parallel as possible to one another, no other arrangement will give adequate retention; on the other hand, the use of bolted sectional units and other modifications of the same conception has eliminated the need for parallelity between abutments. Moreover, the mechanical advantage which can be gained from the use of angled abutments has reduced the need for clinical crown length, and even short crowned teeth can be made sufficiently retentive, although in some cases they will need a little preliminary periodontal surgery. Nevertheless, if the angulation of an abutment is such that an occlusal load is translated into a lateral thrust, i.e. an angulation in excess of 24° to the normal, then the limit of tolerance may be exceeded.

The question of periodontal support is more complicated; obviously if a mobile tooth is asked to accept greater strain without some additional support it will adversely affect its stability, but the improvement in surgical techniques and materials has made it easier to use multiple abutments, and in a multiple splinted unit even poorly attached teeth have value, thus the splinting of exceedingly mobile lower incisors can result in an astonishingly functional improvement. The improvement results from three factors; firstly, during mastication, the teeth can no longer move apart to allow food impaction between them; secondly, the load which in other circumstances is applied to one or two teeth is now shared by the total sum of the units included in the splint; and thirdly, because the mechanical advantages gained are not solely related to the sum of the periodontal area of attachment, but depend partly on the direction of application of the forces involved and the intrinsic mechanical advantage offered by the splint itself.

In special circumstances the root-filling of abutment teeth and the use of root-cap supported anchors or connectors reduces the clinical leverage on the coronal portion of the tooth, and lowers the centre of thrust on the periodontal attachment, which is why this arrangement is often favoured when only a few abutment teeth remain to support what would otherwise be a full denture.

One factor that is often overlooked is that if a routine impression technique is adopted mobile teeth may be displaced during the taking of the impression, particularly if a heavy-bodied impression material is used. In such cases it is preferable to use standard techniques and to make up individual retainers which are then fitted *in vivo* and ground to fit closely without undue displacement of the teeth. The retainers can then be located together within an overall plaster impression, and soldered together in the laboratory.

It follows that to assert dogmatically that periodontally weak teeth cannot be used in this type of work is unsound. Nevertheless, if they are to be included it is advisable to use multiple abutments, to use rigid fixation between them, to warn the patient of the probable prognosis, and whenever possible to so design the appliance that if one or more of the abutments is lost, alterations can be made without total loss of the prosthesis. In this context several possibilities exist; either convertible devices may be used such as the Schubiger or Crismani, a conjunctor may be included within a fixed span, or operator-removable units may be designed.

Retainers

The principles involved in the use of either abutments or retainers in bridge or precision attachment work are basically the same; moreover it will be apparent that, with few exceptions, the retainers of choice are the full crown and the post-retained root-cap. Some operators favour three-quarter preparations because it is possible to reduce the amount of tooth destruction, to avoid the aesthetic complications which follow the loss of buccal enamel, and to use single section designs without prejudice to the pulp. This last factor is very valid, and where for instance incisors are to be included in a bridge extending into the canine and premolar regions, pinledge preparations are often the preparations of choice if root treatment is to be avoided. Similarly, in the upper molar region the teeth are often anatomically so well suited to the three-quarter crown that they may well be the retainers of choice, but elsewhere the greater rigidity of the full crown, the smaller peripheral border, and the technical advantage offered by its constructional simplicity are of greater moment.

The third possibility is the inlaid restoration. In general the use of inlaid restorations for this type of work is to be deprecated, partly because of the lesser rigidity of small castings of this type, partly because, to be effective, they must be deeply embedded into the tooth, and partly because, instead of enclosing and binding the remnants of the coronal portion of the tooth together, they weaken the residual tooth structure. Nevertheless, they can and have been successful, but should only be used with the greatest discretion and they require a very high standard of operative excellence. Failures associated with the use of three-quarter crowns and inlays are greater than with any other type of retainer, but comparisons are difficult to make because when they fail it is commonly due to either an obvious design defect or technical inadequacy.

Full crowns may be either faced veneer crowns, full veneer crowns or jacket crowns. Jacket crowns are used principally in porcelain bridgework, faced veneer crowns in the anterior and premolar regions, and full veneer crowns in the molar regions. Obviously the choice is partly dependent on the type of bridge to be constructed and partly on aesthetic considerations. Of the three the jacket type of preparation is the weakest, partly because it involves greater tooth destruction, and partly because following preparation of the teeth the pulp chamber is slowly filled with secondary dentine and the residual peg may become very brittle and snap. If failure occurs in this way the root canal is usually reduced to threadlike proportions and entry to the canal may be very difficult to find. Faced crowns, while not quite as prone to failure for this reason may, if thin, suffer from the same defect, and in choosing the restoration of choice it is often wise to consider the alternative of a post crown, particularly if the tooth has previously been the subject of extensive restoration.

Faced crowns may be faced with either porcelain or acrylic; porcelain is more durable and has greater aesthetic value, though both are aesthetically inferior to the porcelain jacket. Acrylic-faced crowns do deteriorate, but can be easily refaced and serviced and are far less costly, but the improvements in bonded porcelain work have reached a point where the advantages outweigh their disadvantages.

Pontics

The variety of pontics which can be made, and details relating to their construction do not fall within the remit of this book, but the design of pontics is of vital concern to the dentist. A pontic must function well in occlusion with its antagonists; be compatible with the soft tissues it touches; be aesthetically pleasing and comfortable and be easy to clean. It must also be sufficently strong to withstand masticatory stress.

In order that bucco-lingual stress may be minimised and coverage of the ridge decreased, the pontic should be designed so that it is narrower than its neighbours (figure 20.12), and reducing the mesiodistal contour lingually to allow maximum cleansibility and permit food shedding.

Occlusal pits and fissures should be shallow and an attempt should be made to imitate the occlusal anatomy of the arches, bearing in mind the wear

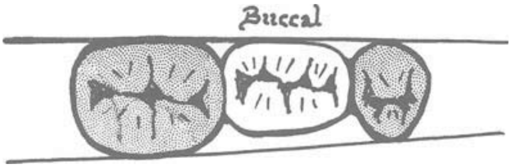

Fig. 20.12 Design of pontic to minimise the transmission of bucco-lingual stress to the abutments.

patterns associated with the chronological age of the dentition, and providing buccal and lingual grooves for food shedding. Such spillways prevent occlusal food packing and aid the passage of food into the embrasures where the friction stimulates the soft tissues.

Embrasures should be as wide as is consistent with aesthetics, so that the introduction of cleansing aids, such as dental floss and the interspace brush, is facilitated (figure 20.13).

Contact between pontic and ridge must be minimal but firm, without causing blanching of the gingiva. The labio-gingival margin must be rounded and highly polished or, if it is porcelain, highly glazed. Sharp pontic margins, dipping into the gingiva, produce a chronic ulcer and the soft tissues swell up around the pontic and interfere with cleansing. In this way, a vicious circle is set up and an abscess or granuloma may develop (figure 20.14).

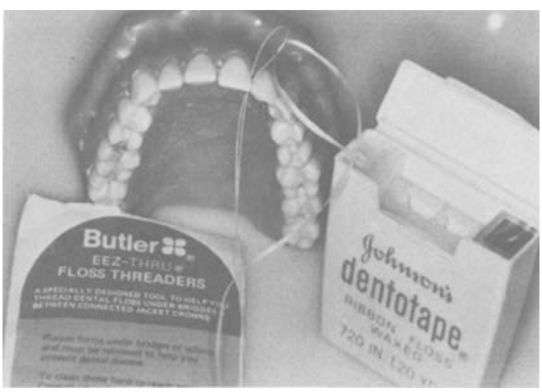

Fig. 20.13 A model used to demonstrate the use of a floss threader and dental tape to clean the fitting surface of a pontic.

Ideally, there should be no contact between pontic and ridge (e.g. sanitary pontic), leaving a space large enough to admit a toothbrush or inter-space brush. The un-aesthetic appearance of this type of pontic precludes its use except in the lower molar region and on occasions to replace an upper second molar.

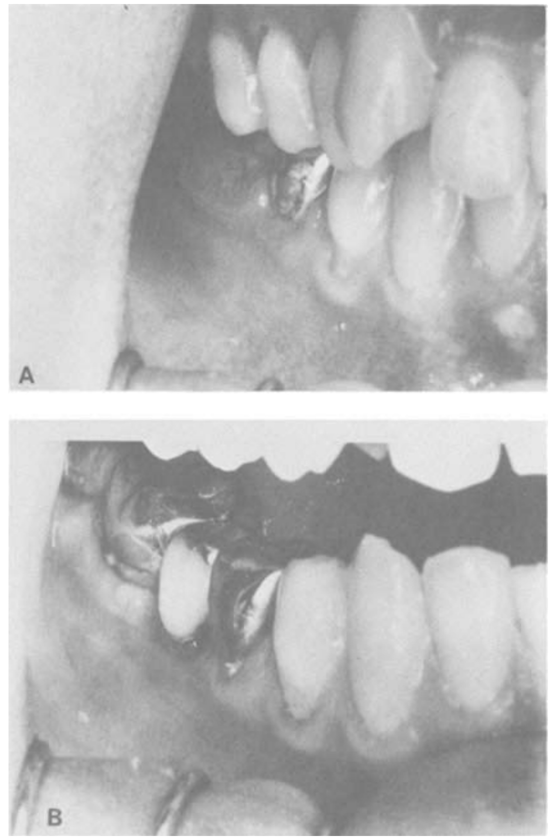

Fig. 20.14 (A) A large chronic inflammatory swelling caused by the sharp, rough margin of the pontic (6|). (B) One week after excision of the swelling and smoothing and rounding of the margin of the pontic.

A viable alternative is the bullet-shaped pontic which makes solely a tangential contact with the ridge and is easy to clean, but is almost entirely limited to the lower anterior region. For posterior bridges, the eccentric ellipse pontic (figure 20.15) is a sound, aesthetic alternative.

Occlusal stresses must be reduced by producing a series of symmetrical points of contact on the pontics and retainers. Thus, large areas of contact must be reduced in size by grinding when the bridge is being fitted.

The ridges

At the time of extraction, all sharp bony edges and loose or projecting spicules of bones should be removed. If there is insufficient vertical space for a pontic following healing of the socket, the ridge may be reduced in height, but a delay of one or two

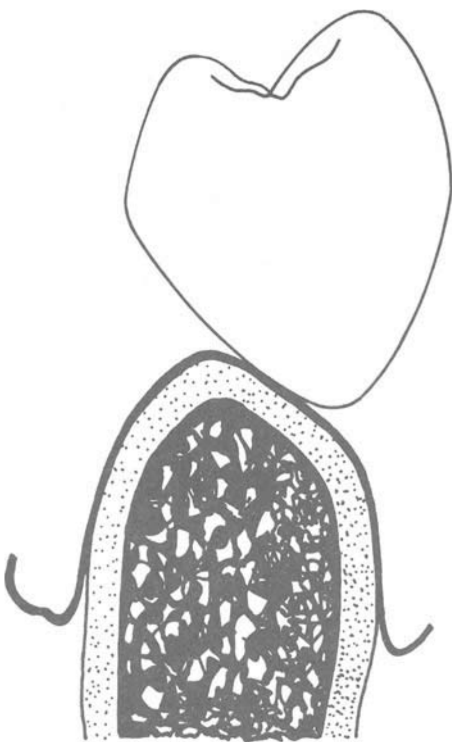

Fig. 20.15 Vertical section through an eccentric ellipse pontic in a lower bridge.

months is necessary to allow stabilisation of the ridge tissues before making a bridge.

Temporisation between extraction and bridgework

Until the present decade it was necessary to construct an immediate removable prosthesis, to replace an extracted tooth, for the duration of the three or four month period of healing of the soft tissues and resorption of the alveolus. Now, thanks to the acid-etch technique, it is possible, with a reasonably intact natural crown, to excise the root, after extraction of the tooth and use the crown as a temporary pontic. Retention is cut in the pulp chamber and the crown is converted to a temporary pontic by building a cervical dome in composite resin or S.P. acrylic. After cessation of bleeding, the rubber dam is applied or, if for any reason this is not feasible, the socket is covered with a strip of ORAHESIVE intraoral bandage (squibb) which adheres to the dried mucosa and acts as a seal to the socket. The adjacent teeth and the prepared natural pontic are polished with a pumice slurry, etched and washed. Then, holding the crown in position between the abutments, they are all coated with bonding resin, and a small quantity of composite resin is placed at the contacts and allowed to set. At this stage, having checked the alignment, it is no longer necessary to support the pontic, and more resin is added lingually to build up strong joints, ensuring that no excess is present gingivally. When set, the occlusion is checked and the resin is trimmed and polished. Provided that the occlusal forces on the pontic are minimised, such a temporary bridge can last up to two years (figure 20.16). If it should fracture prematurely, it is easy to recondition the enamel and re-cement it with fresh resin. If further gingival recession exposes a gap cervically beneath the pontic, further resin can be applied after roughening the composite and coating it first with bonding resin.

Although this technique is ostensibly a stop-gap measure, various reports of long-term, etch-retained bridges, incorporating pins and metal strengtheners, have been published. However, the present status of the composite resin is such that no guaranteed prognosis could be forthcoming, so the transitory nature of the etch-type bridge must be emphasised.

An alternative measure is called for when the tooth to be extracted has a gold or porcelain crown or has no crown at all. An acrylic denture tooth of the appropriate size and shade is selected and modified to fit the space. Then, a mesio-distal, undercut groove is cut through the whole middle third of the lingual surface, extending as far as the proximal contact areas. The adjacent teeth are etched and dried and the acrylic tooth is filled with composite resin and placed in position with the resin extending on to the linguo-proximal surfaces of the abutment teeth. As in the previous technique, the excess hard resin is ground away and the occlusion adjusted. In the case illustrated (figure 20.17), an upper left lateral incisor root had fractured and the post crown had dropped out. The bonded acrylic tooth held for six months, when a silicone impression was recorded before breaking off the pontic and preparing the abutments. This matrix was used to construct a direct temporary bridge.

Another method, employed successfully by the author, is to take the silicone impression of the arch; prepare the abutment teeth; extract the unsavable tooth and then make a temporary bridge as described in an earlier chapter. The only differences are the trimming of the gingival area of the pontic so that it does not enter the socket, and cementation of the bridge with polycarboxylate or EBA/zinc eugenolate cement, to provide adequate retention for several months during the period of remodelling of the tissues.

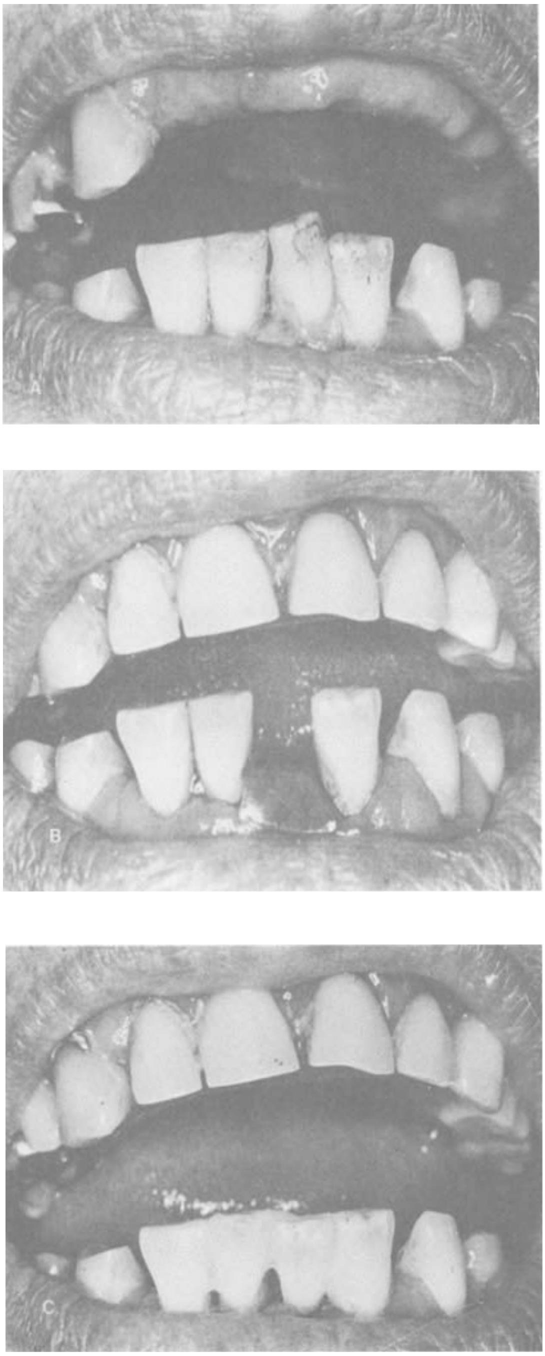

Fig. 20.16 Immediate temporary bridge attached with composite resin. (A) Loose extruded lower incisor. (B) Adjacent teeth cleaned, tooth extracted and socket covered with a strip of Orahesive (Squibb). (C) Root removed from tooth and enamel of adjacent teeth and extracted crown etched and washed. Cervical region of crown built up in composite resin, rounded and polished. The 'pontic' was then anchored to its neighbours with composite resin, which served also to stabilise all the loose incisors as a temporary expedient.

Fig. 20.17 Acrylic Denture tooth used as a temporary pontic to replace |2. The root of |2 suffered a vertical fracture and the post crown was dislodged. After removal of the root, a wide, undercut groove was cut across the lingual surface of an acrylic denture tooth. This was filled with composite resin and placed between the acid-conditioned surfaces of |1 and |3. The fitting surface of the pontic was polished to a high lustre and care was taken to eliminate excess resin from the cervical margins. This pontic was still firm when, 6 months later, it was due to be replaced by the 'permanent' bridge.

The precision attachment-retained denture

Where either a long free-ended prosthesis or the replacement of lost alveolar tissue is necessary for functional or aesthetic reasons, bridgework may be precluded on mechanical or hygienic grounds. The alternative is a denture, and precision attachment-retained dentures can be shown to be superior to most other types of appliance in the majority of cases. They are more retentive, more stable, and less apt to retain plaque against the adjacent enamel; moreover they allow a greater flexibility in design, which encourages the preservation of the remaining teeth.

In the upper anterior region the common problems which present themselves are the need for anterior support forward of the residual ridge, and resistance to tilting movements in the sagittal plane. This can be accomplished in an attachment-retained denture; by means of a fixed-fixed bar, by means of interrupted cantilevers, or by the retention of one or more isolated roots.

If a simple attachment-retained denture is supported at either end by single strong attachments, then the abutments must be sufficiently strong to withstand the leverage which will be imposed, and the attachments must be of a corresponding strength (e.g. Ney-Chayes, Stern type 7, or the Crismani, etc.)

Added strength may be obtained by the use of multiple abutments, and extra counterleverage can be provided by the use of additional attachments in the molar region.

If the span is not too long, a bar fashioned to correspond with the ridge can be used with rigid fixation to the posterior abutments and a denture made to fit over the bar, retention being obtained with the aid of Ipsoclips, Press-O-Matics, or Cekas (figure 20.18). Alternatively two Dalbos angled along the ridge may be used as cantilevered supports, an arrangement which facilitates cleaning and reduces the amount of tooth destruction involved in the use of intracoronal attachments. In this case the Dalbos are used as attachments, the springs are removed, and the housings obliterated with acrylic.

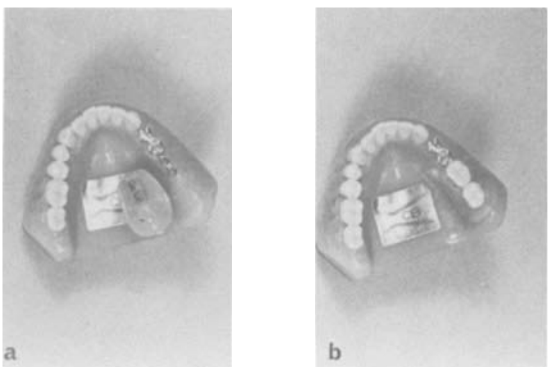

Fig. 20.18 Demonstration models showing rigid free-end saddle using a Ceka (a) with saddle removed; and (b) with saddle *in situ*.

The problem is simplified if one or more incisors or canines can be used in order to provide tripodic support. If only incisors are available they may be linked by means of a bar and a Dolder clip or some similar device, or they may be used independently. Much depends on the strength and number of the teeth remaining and, while it is not possible to dogmatise, it will be found generally preferable to root-treat and fit incisors with post-retained root-caps, and either anchors or connectors. Functionally, either can be used, but anchors are usually less bulky, thus a Conod is smaller than a Dalbo 604, and an inverted Ceka connector is less fragile than an Eccentric connector. No hard and fast rule favours any particular arrangement, choice depending on size, serviceability, and operator preference.

More rarely the anterior and part of the posterior segments may be denuded of teeth, the loss extending well into the molar regions. In the upper the palate offers considerable support, and the need to provide a stable occlusal table favours the use of strong attachments of the intracoronal type, preferably with multiple soldered retainers. Many operators would extend this reasoning to the lower, but the available connective tissue support is less satisfactory in this region, and any flexion within the appliance bears most hardly on the extreme anterior portion of the ridge, in fact that part least well able to accommodate the load. When the latter fact is taken in conjunction with the poorer retention generally available in the lower, the alternative of using two conjunctors with some transitional movement is more attractive, and in practice two Crismani conjunctors have proved very serviceable.

The treatment of upper posterior free-end saddle replacements is covered by much the same considerations (i.e. the rotational factor, and the need to find adequate connective tissue support) and both unilateral and bilateral free-ended saddles are probably best treated as rigid attachment- and palatal-supported dentures. In the lower the complication of the lingual connecting bar, the absence of support in the floor of the mouth and the divergence of the ridges favours a different approach, and both from the standpoint of maintaining the occlusal table and the situation of maximum support areas, simple hinged conjunctors are to be preferred. Further, as both must act independently of one another, they can either be considered as one or two unilateral saddles (e.g. using Pini Romagnoli or Ancorvis conjunctors) or the lingual bar may be cast incorporating hinges aligned to the ridges, and soldered to attachments.

In addition to the above-mentioned conditions, the situation may arise where it is considered advisable to temporise before reaching the fully edentulous condition. The advantages of retaining one or more teeth to stabilise what would otherwise be a full denture is most apparent in the lower jaw, and the most common possibility is the situation in which two canines are the sole saveable survivors. Here the Dolder bar retained by two Schubigers is the arrangement of choice because the variation in canal alignment increases the retentivity of the connector. In other circumstances the available teeth do not lend themselves to this arrangement and in these, the governing design factor is the position of the remaining teeth in relation to any possible hinge movement, and the periodontal condition of the abutments.

In considering general problems of design some reference must be made to the stability of the occlusal table. Problems arising from this source are of small moment when the opposing occlusion is rigid, thus a stress-broken lower unilateral denture occluding with natural teeth offers no particular difficulty. However, when a full denture is opposed by an appliance with inbuilt movement, the situation becomes more complex, and the operator must weigh the strength of the abutments and the serviceability of the devices of choice against the instability of the opposing denture. Any movement in these circumstances will concentrate the load on specific areas, setting up a vicious circle of movement, resorption, and more movement. Thus the need for constant occlusal adjustment and modification of the bases in order to compensate for these factors is essential.

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21

The Crowning of Vital Teeth

The types of crown used in the treatment of vital teeth may be grouped into three categories: jacket crowns, full veneer crowns, and partial veneer crowns. Both full and partial veneer crowns may be widely modified according to individual requirements, and the distinction between a partial veneer crown and any other kind of partial veneer is considered to be of semantic, rather than functional validity.

Indications

There are four indications for the crowning of vital teeth:

1. To preserve the functional anatomy of excessively weakened teeth, either following caries, or extensive restorative treatment.
2. To provide a retainer for some prosthesis.
3. To remedy a grossly discoloured, malpositioned, or anatomically aberrant tooth.
4. To support periodontally weakened teeth.

Preliminary treatment

Notwithstanding that any treatment plan may have to be modified in special circumstances, it is considered mandatory to carry out routine procedures before embarking on more advanced work. A clear understanding of the importance of oral hygiene must be reached, and any necessary instruction given. The teeth must be scaled and polished, and wherever possible any periodontal surgery completed and the gingivae given time to heal. Nevertheless, it may be that periodontal health cannot be achieved without undertaking advanced work, or that some modification of the soft tissue contour only becomes evident at the time of working, and in these circumstances the two procedures will have to be coordinated at the operator's discretion.

Grossly weakened teeth should be investigated, unsupported enamel and caries removed, and the tooth rebuilt in cement or amalgam, so that the preparation can assume the classic form, terminating cervically on sound tooth. Minor defects can be remedied on the working model, but unless the ultimate preparation has been properly designed, accurate castings are impossible.

In most cases study models are essential, and in others they are a great advantage, partly to assist in planning treatment, partly to assess any probable complications, and partly for the construction of special trays.

The gingival margins

Periodontal irritation may result from injury at the time of surgery, from the poor adaptation of temporary restorations, or from constructional failure. Of these factors, the least damaging is that caused by minor injury at the time of surgery. Over-extension of temporary restorations or cement beyond the preparative margins can give rise to acute pain, may result in severe gingival inflammation, and ultimately lead to gingival recession. It follows that the time spent on the careful construction and placement of temporary restorations is of vital importance, and it is a common fault of the novice to leave too little time for this work.

However, both the preceding factors are transient considerations, and those resulting from constructional failure are far more serious. Periodontal injury from this source may be due to poor contacts, inadequate embrasures, from the under- or over-extension of the buccal and labial contours, or from improper marginal adaptation. Unsatisfactory marginal relationships will result in food stagnation, gingival inflammation (usually hyperplastic in character) and interfere with normal gingival stimulation. Hence it is essential that the margins of the restoration and the

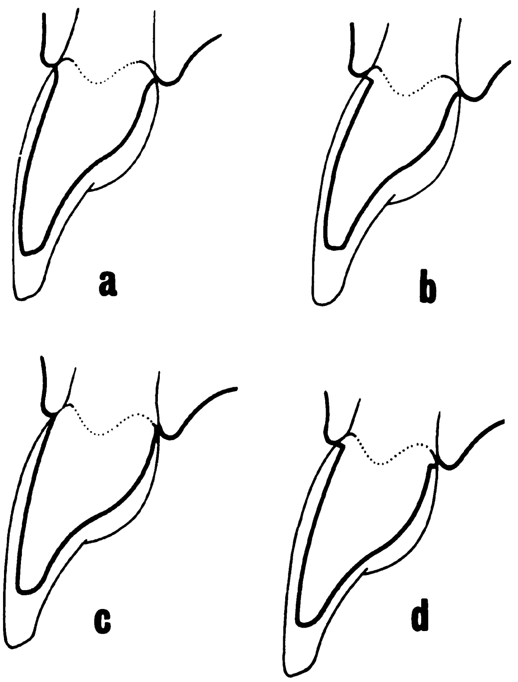

Fig. 21.1 Methods of finishing margins gingivally. (a) Chamfer; (b) labial step with chamfer palatally; (c) feather edge; (d) step (or shoulder).

preparation should match as closely as possible (figure 21.1). It would be nice to be able to say truthfully that 'this could be accomplished to perfection' (i.e. to a painted finish, imperceptible to the finest probe); unfortunately, no matter how high our craftsmanship, this is an impossible standard, and some degree of error has to be acceptable. It is therefore valid to observe that a slight excess is less well tolerated than a slight deficiency particularly if a lapped joint can be used (figure 21.2).

For precisely the same reason it has been found that a joint finished within the gingival crevice is more likely to cause tissue irritation than one finished level, or just short of, the gingival crest. Further, it can be demonstrated that in those cases where there has been some deepening of the crevice, the desired position is coincident with the level of the *retracted* gingival crest.

When recontouring of the gingivae is necessary at the time of operation, the best response follows the use of a clean incision, but the odd inaccessible tag can be effectively contoured with a rotary-diamond instrument, operated at high speed under spray. Further, if difficulty is found from bleeding at the time of taking this impression, the Mill-tray technique can be used with advantage.

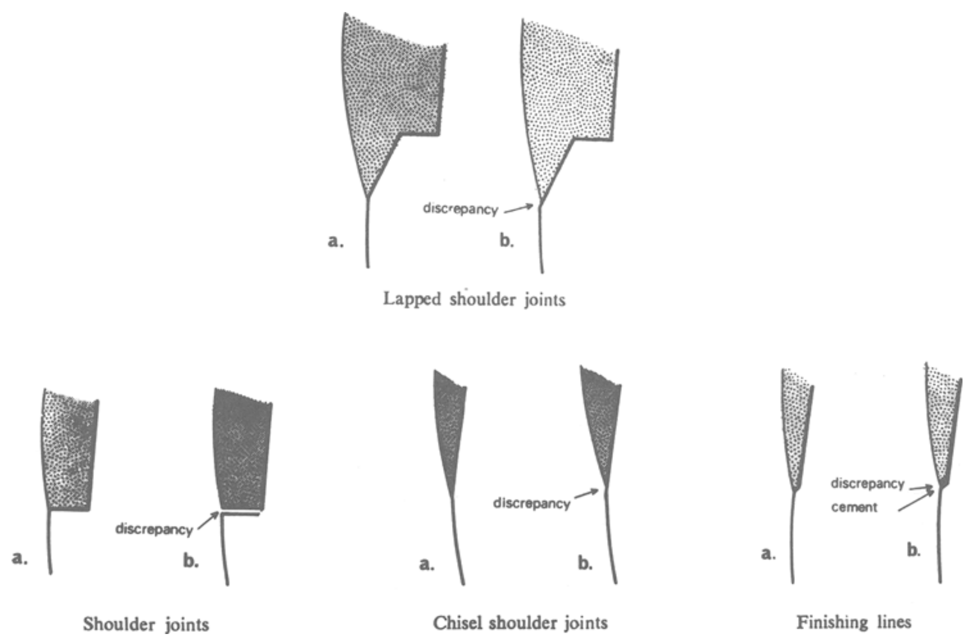

Fig. 21.2 The diagrams show (a) the desired result and (b) the effect of a slight contractual error and hence the value of lapping and the problem presented by the finishing line.

Jacket Crowns

Indications

The principal indication for using porcelain jacket crowns is for the restoration of individual incisor teeth, though they are also used for retainers in all porcelain bridgework. Porcelain can simulate the natural appearance of the teeth better than any other material available at the present moment; for this reason, and because of its relatively low cost, crowns made of porcelain have achieved a wide popularity. Nevertheless, problems of colour may prove extremely intractable, especially when subjected to extreme forms of lighting; moreover porcelain is brittle, harder than the natural tooth, and poses several constructional difficulties. For these reasons the search for alternative materials has continued and acrylic resin, though less durable, is sometimes substituted.

Colour

The term porcelain as applied to dentistry is really a misnomer, because so-called porcelain powders are really mixtures of glass frits and metallic oxides (from which their colour is derived). When fused this combination is extremely translucent and if employed without an opaque alumina backing its colour will be affected by the choice of cement. On the other hand, if an alumina backing is used the colour of the core (particularly over a proclinated tip) may present problems. Further, the wide variety of tone and colour present in the natural teeth can also make difficulties, particularly when the adjoining teeth vary widely in appearance.

It follows that with a complex of variables, such as those described, it is a great advantage if the technician can see the patient. Where this is not possible the operator must endeavour to make good the deficiency by the provision of a detailed drawing showing the proportion of incisal, body and cervical colours, and any special markings which the operator regards as necessary. While no hard and fast ruling can be given, if there is any doubt it is good advice to err on the darker side, and where neighbouring teeth vary widely in colour it is generally advisable to take a guide from its opposite number.

The shade should be taken in daylight, in a North facing room for preference, and never in direct sunlight or tungsten-based artificial light. A colour corrected fluorescent light may be used. The shade should be checked and recorded on the patient's record card at an early visit when lighting conditions are suitable, and it is advisable to obtain the opinions of the patient and chairside assistant if the choice of shade is difficult. Prolonged staring at shades proves tiring to the eyes and may lead to errors in judgement. The teeth on the shade guide should be moistened and held briefly under the shadow of the lip at the same angle as the adjacent teeth and placed there singly, comparing light with dark until the shade is determined. There are three main factors to be borne in mind. These are (1) the colour (hue), (2) the chroma (intensity of hue) and (3) the value (the degree of whiteness or greyness). It is vital to bear in mind that the shade guide teeth are much thicker than the 1.0–1.5 mm thickness of the porcelain. This often indicates the choice of a slightly darker shade. Production of a personal shade guide of thin slips of porcelain makes the choice of shade much easier. Before taking the patient to the window to choose the shade, the teeth should be cleaned and polished.

The final colour of the earlier air-fired crowns was affected markedly by the colour of the cement, and even the vacuum-fired crowns with an aluminous core are similarly subject to minor colour variations. The shade may be checked by using an aqueous slurry of the cement powder in the crown and having available a number of different coloured cements for this purpose. When the correct shade has been chosen, the same colour is obtained with the appropriate cement.

Silico-phosphate cement, being translucent, although slightly irritating to the pulp, may be used for non-vital teeth, but glass ionomer cement has the advantages of being well tolerated, possessing good cementation properties and interfering least with aesthetics, thus, its use for vital teeth is preferable. Slight modification of the hue and value may be effected with stains and superglaze, but if the overall hue is wrong, a remake of the crown may be necessary.

The operator must ascertain whether he is relatively or completely colour-blind. In this event, the choice of shade must be made by his chairside assistant or, for preference, by the technician who will make the crown.

Vitality

It is axiomatic that the tooth should have a vital, healthy pulp. If there is any abnormality in the response to a vitality test, coupled with a history of previous trouble or radiographic evidence of pathosis, an elective devitalisation, with subsequent construction of a post and core, is advisable.

Relationship to adjacent teeth

Any imbrication of the neighbouring teeth which might interfere with impression taking and subsequent insertion of the crown must be considered before embarking on the preparation of the tooth.

Strength

Alumina-backed crowns are capable of reaching compressive values of 24 000 lb/in^2 but the corresponding values in tension are much less, hence it is vital to avoid torsional stresses, and to use reasonably thick masses. These factors preclude the use of this type of restoration on very small or thin teeth; in those cases where the residual stump has been unduly weakened; or in the presence of a 'locked bite'.

McLean *et al.* (1978) have shown that fractures in porcelain crowns are commonly initiated in fine cracks on the fitting surface of the crown which tend to propagate and coalesce in areas of tension until a visible fracture line is apparent or part of the crown breaks away. They showed that, by the use of a bonded sheet of tinned platinum foil on the fitting surface, these cracks were eliminated and a considerable increase in resistance to fracture was developed (see chapter 13) (on porcelain).

Despite this finding and the ingenious solution of the problem, there are other predisposing causes of fracture.

(1) If the tooth to be crowned or the prepared stump, is shorter than a third of the final crown length, there will be too little support for the incisal porcelain. At one time this was overcome by making a thin gold coping to restore the length, over which a porcelain crown was made. Today the use of a porcelain-bonded to metal crown is simpler and more effective.
(2) Finishing the crown stump with sharp line-and point-angles will allow concentrations of stresses in those areas, with greatly increased likelihood of fracture.
(3) Preparations with uneven width of shoulder, or with thin areas abutting thick areas, will tend to fracture. The ideal is an over-all minimum thickness of approximately 1.0 mm of porcelain but slightly thicker in the cingulum and proximo-lingual buttress areas.
(4) Insufficient lingual space in protrusive and lateral excursions – a common fault when the technician has made a gold core and the associated crown without reference to the dynamic inter-jaw relationship. This may cause periodontal trauma with ultimate proclination of the teeth, if it is not arrested by fracture of the porcelain.
(5) Faulty manipulation of the porcelain when it is fired, e.g. exposure of the crown to cold air when taken out of the furnace at a high temperature. This produces occult cracks which coalesce under stress.
(6) The labial surface of the crown should be nearly flat, mesiodistally and curve slightly inwards incisally to follow the contour of the pre-existing surface. The lingual surface should mirror the lingual fossa. Any tendency to produce a round dowel-shaped stump will run counter to the need for an anti-torsion configuration, and if the cement weakens and breaks down under stress, either the crown will fall out or it will fracture.

Porcelain crowns are made by condensing frits on to a platinum carrier or matrix (figure 21.3), and their strength is related to the density of the mass and the absence or presence of internal voids, and therefore to the success of the technician in condensing the particles. Vacuum firing is of great assistance in increasing the density of the mass and eliminating internal voids; however, unless the frit has been well-condensed in the first place considerably greater contraction will occur. Sometimes palladium is substituted for platinum, partly on grounds of cost, and partly on grounds of availability, but this is not a practice to be commended, because palladium tends to oxidise and darken the crown.

The ultimate strength of the crown will also be dependent on the absence or presence of surface defects and the nature of the glaze, small irregularities leading to stress build-up, whereas the smoother curved surface of a highly glazed crown distributes loads better. It follows that a dense high glaze is desirable, and that any subsequent surface grinding is to be deprecated.

Fit

The fit of the crown is obviously related to the accuracy of adaptation of the foil carrier, and this in turn to the surface of the die. If the foil is well fitted to a corrugated surface it will be impossible to remove without distortion, and for this reason (and incidentally to facilitate the subsequent removal of the foil from the inside of the finished crown) the surface of the preparation should be rendered as smooth as possible. But no matter how well the foil is adapted, some discrepancy is found at the lapped joint of the carrier, which is therefore placed in an accessible position lingually in the mid-line.

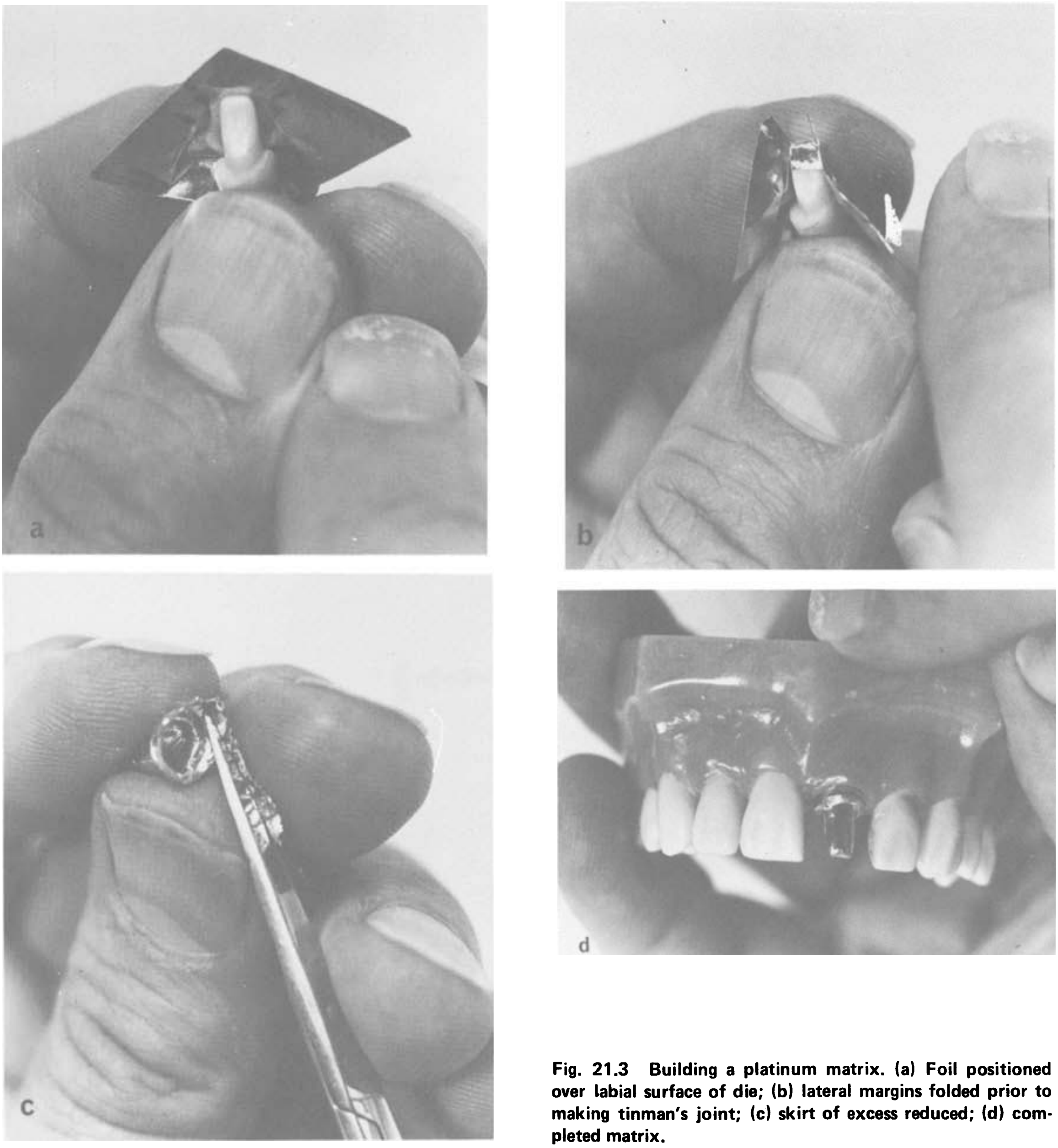

Fig. 21.3 Building a platinum matrix. (a) Foil positioned over labial surface of die; (b) lateral margins folded prior to making tinman's joint; (c) skirt of excess reduced; (d) completed matrix.

A considerable improvement in the adaptation of porcelain at the joint may be obtained if the technician cuts out a narrow wedge of foil down to the axio-gingival line-angle before making his tinsmith's joint. Alternatively, after he has made it, the quadruple foil thickness covering the shoulder can be thinned by careful reduction with a diamond bur run at slow speed.

Preparation design

Because of the need for adequate support and sufficient bulk, the cervical margins should terminate in well-defined shoulders, and in order to avoid wedging or displacing stresses, the shoulders should be cut at right-angles to the axial alignment of the tooth, and as closely in one plane as possible. This has the additional advantage of reducing the marginal perimeter to a minimum. A depth of shoulder on the labial and lingual aspects of one millimetre is advocated, but this is subject to the degree of taper, and the extent of cervical recession; thus, if the anatomical cervix of the tooth has not been reached, the depth available will be greater than when the crown extends onto the root.

The labial and lingual reductions should uniformly follow the contours of the tooth (figure 21.4), though a small correction of alignment may be possible if there is sufficient bulk of tooth. The labial wall of the finished crown must be concavo-convex, with the convexity directed labially (figure 21.5), so that the applied loads are met in compression. Too flat a labial surface will result in bending stresses which will promote labial meniscus failure, and attempts to improve retention by paralleling the labial and cingular slices (though possibly considered advisable on theoretical grounds) are likely to result in stress failure at the junction of the cingular and palatal slices.

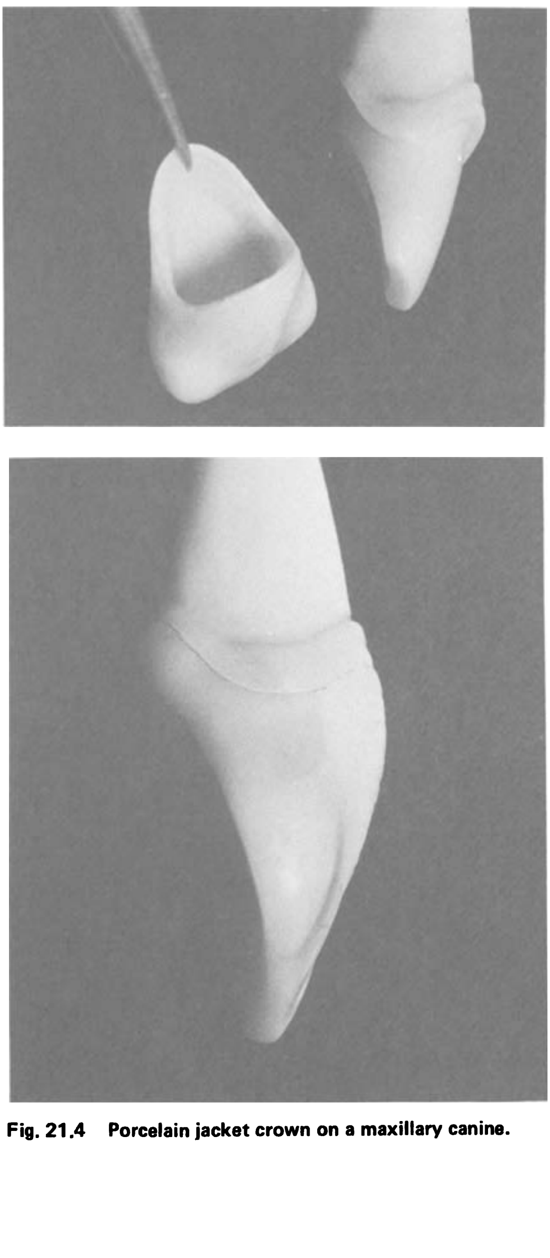

Fig. 21.4 Porcelain jacket crown on a maxillary canine.

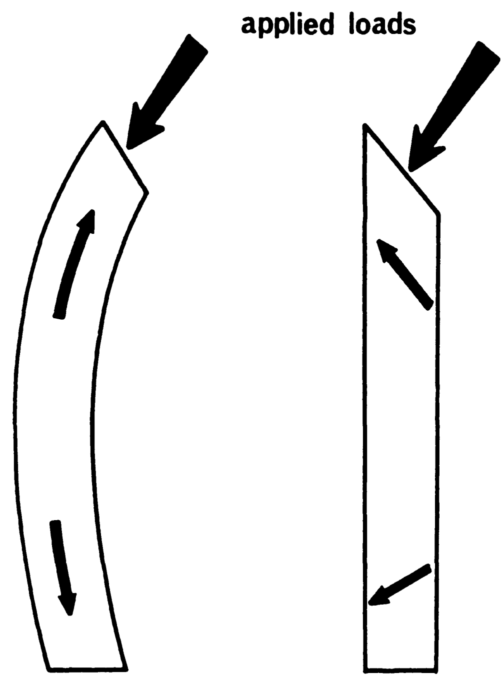

Fig. 21.5 Effect of curvature on stress distribution.

The proximal walls should exhibit minimum convergence (3–5°) and the width of shoulder should be as close as possible to that on the labial, although teeth with flattened cervical cross-section, such as maxillary lateral incisors, will, of necessity, require narrower proximal shoulders. Existing restorations tend to drop out during preparation. They should be replaced, if small, with a polystyrene bonded zinc eugenolate cement or, if large, by polycarboxylate cement. If their size is such that the strength of the stump is prejudiced, elective devitalisation, followed by the construction of a post and core, is advisable.

Siting of the margins of the preparation is related to two factors: aesthetics and gingival health. Aesthetic considerations are served by extending the labial margin approximately 0.5 mm below the gingival crest. This is necessary only if a full normal retraction of the lip, when smiling, reveals the margin. Periodontal health is best maintained by keeping those cervical margins which do not show, slightly short of the gingivae. This reduces the effect of plaque retention on the soft tissues and facilitates the recording of impressions. Numerous investigators have shown that pathological pocket depths are more common in teeth with crowns which have subgingival margins.

The only reason, therefore, for finishing margins subgingivally are:

(1) if caries has already extended there, and should the extension be more than 0.5 mm, it is better to remove the soft tissue surgically and allow it to heal before completing the preparation,
(2) where more retention is required, although in many such cases, gingival health is better maintained by surgical preparation, including reduction in the height of the crestal bone, so that the longer crown allows more space for subsequent cervical cleansing measures,
(3) aesthetics, in anterior regions where margins are visible.

Incisally the tooth should be reduced sufficiently to ensure a strong biting edge (usually the equivalent of the extent of the enamel covering), and angled to oppose the tips of the occluding teeth at an angle of about 45 degrees. Finally all line-angles (with the exception of the cervical shoulders) should be rounded to avoid stress concentration (figures 21.6, 21.7 and 21.8).

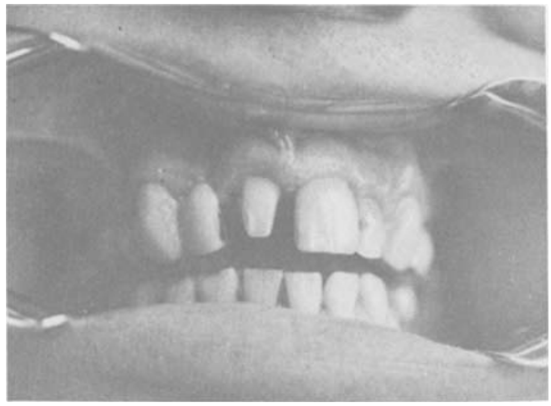

Fig. 21.7 The preparation showing the extent to which the disto-proximal wall has been prejudiced, and the use of cement to avoid further loss.

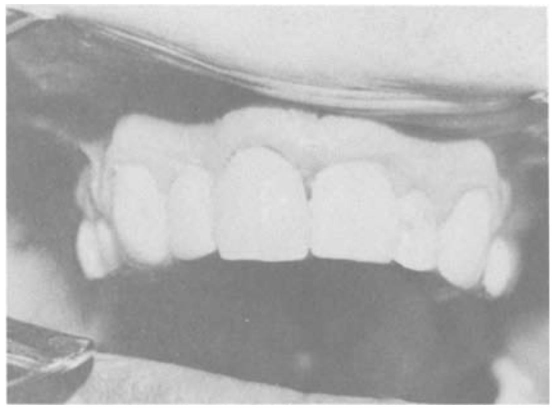

Fig. 21.8 The finished crown.

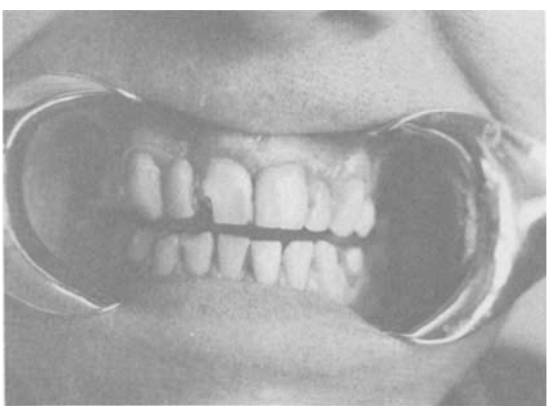

Figure 21.6 Gross proximal caries following the displacement of an inlay which had been used as the minor retainer of a fixed-movable bridge.

Fitting and cementation of porcelain jacket crowns

It is usual for the technician to remove the platinum foil before giving the crown to the dentist, however, if the foil is still present, because some modification of the porcelain may be required, the skirt should be reduced to a depth of 0.5 mm, before trying in the crown.

If it feels tight at the contacts, the adjacent enamel surfaces may be marked with a dye, or with a soft graphite pencil, so that the mark is transferred to the high spot on the porcelain. The contacts are ground in until the crown seats fully home without causing a feeling of pressure, and then they are polished with a smooth abrasive disc and a polishing buff impregnated with whiting. The margins are checked with a probe and minor degrees of 'flash' are eliminated by using a coarse sandpaper disc, held almost parallel with the margin. When corrected, this margin should be re-glazed.

If the foil has been removed, a low fusing glaze can be applied which melts at about 900°C.

Vital dentine should be dried with cotton wool plus a short blast of warm air. It must never be desiccated by a prolonged blast of hot air, because irreversible damage to the pulp can occur. When dry, the surface should be coated with a protective varnish, such as Copal/ether or Tresiolan (Espe).

The majority of crowns can be cemented safely with a slow setting mix of phosphate cement. However, if the dentine is hyper-aesthetic, it is more prudent to avoid potential pulpal irritation by using either polycarboxylate cement or glass ionomer cement, both of which have been shown to elicit minimal pulpal reaction.

Cement should not be mixed too thick because the force necessary to seat the crown may result in fracture of the porcelain. A thin film of cement is placed on the fitting surface and the crown is slowly adjusted into place, exerting firm digital pressure until no further cement exudes from the margin, and no edges are discernible when the margin is probed.

Excess cement should be coated with petroleum jelly to protect the unset cement from saliva which would weaken it. When it has set, all excess is eliminated and the occlusion is rechecked in all excursions.

Full Veneer Crowns

Indications

Full veneer crowns are particularly suitable for the restoration of grossly weakened teeth, and for the retention of bridges or precision attachment dentures. This is principally due to the rigidity of their design, a factor which they share with jacket type restorations. However, when used in the premolar and anterior regions of the mouth they are contra-indicated on aesthetic grounds unless a facing is provided.

The alternatives to the full cast crown are either the jacket or the partial veneer crown, and when considering the possibilities the operator must take into consideration:

1. The complexities involved in facing a crown.
2. The strength required, and the amount of leverage to which the restoration may be subjected.
3. The extent of tooth destruction.
4. Cost.

Facings

If facings are needed, sufficient room must be provided for the gold alloy backing, and the facing, a factor which will determine the amount of buccal or labial tooth substance to be removed. Facings may be made of resin or porcelain, and can be boxed or bonded to the surface of the castings. At present we lack a suitable adhesive for the bonding of plastic facings to cast backings, and though mechanical locks can be provided the union is insufficient to prevent seepage and discolouration, hence it is customary to box facings of this type. Boxed facings are also used in the Hollenback technique, i.e. a method of facing in which a ground porcelain facing is inlaid first into a wax pattern, and then cemented into the cast crown.

Despite their poor abrasion resistance and tendency to discolour, plastic facings have many attractive qualities, and the last word on this subject has yet to be said. Thus they can be used when insufficient room is available for porcelain, they are easily replaced and do not need expensive or technically complicated apparatus for their construction. In making a choice between plastic and porcelain, the overriding factors are those of aesthetics and durability. Hence the question of wear is all-important, and some indication of the possible success of this type of material can be obtained from an examination of the mouth. The points to consider are the degree of facetting, the extent of cuspal attrition or cervical abrasion, and the wear shown by dentures or other plastic restorations.

In recent years, a new type of acrylic resin for facings on crowns and bridges has been developed by Vita (Vita Zahnfabrik-Säckingen, Germany). Vita K & B resin is a modified acrylic without fillers, which, when polymerised, contains no free monomer, hence it does not shrink, possesses high colour stability, and is much harder than conventional methyl methacrylate resin. Because of its greater resistance to abrasion, it should remain satisfactory in the mouth for at least ten years. The new system dispenses with the need to flask and pack the resin before processing. After coating the surface to be faced with the appropriate shade of opaque resin, which is polymerised by dry heat, the crown is built up with soft resin and processed in a special apparatus, the Drufomat (Ratiodent) by a hydropneumatic technique.

Processing, which is carried out in a vacuum, is done in glycerine at 115°C under 6 atmospheres pressure, and is complete in 10 min. Further additions can be made until the required shape and shade have been obtained.

Bonded facings are retained partly by the mechanical interlock between the metal backing and the fired mass, and partly by a chemical union between the oxidised surface of the metal and the oxides present in the frits employed. If a porcelain-bonded facing is chosen, the following design factors should be borne in mind:

1. Alloy backings should be $\frac{1}{3}$ to $\frac{1}{2}$ mm thick.
2. Excessive porcelain bulk should be avoided – never more than $1\frac{1}{2}$–2 mm on the buccal or labial aspect.
3. There should be no sharp points, corners or angles on the porcelain-bearing surface.
4. Buccal or labial areas must be finished convexly, and boxes or concavities should be avoided.
5. The porcelain must be supported by a sturdy lingual shoulder.

When aesthetic demands must be met, labial and buccal margins may be finished in the gingival crevice without any show of metal. This will require a labial step of 1.25–1.5 mm depth. Elsewhere, a narrower bevelled step is cut, and the metal is built out to form a shoulder at 1.5–2 mm distance from the gingival crest, at which line the porcelain is finished.

Physical considerations

The choice of material for the construction of full veneer crowns is dependent on the desired physical properties (e.g. corrosion resistance, hardness, colour, etc.) and the type of facing, if any. Castings must be uniform in width, thin and rigid, and for these purposes a Class C gold alloy (i.e. one containing 78% gold-platinum type metal, with a Brinell hardness of between 90 and 100), or one of the special alloys developed for use with bonded facings is required.

Crowns intended for use in more extensive restorations should be constructed as individual units and soldered together wherever possible, in order to reduce volumetric casting errors. On the other hand the difficulty posed by soldering bonded faced-crowns favours the use of one-piece castings.

Design

Unless a false shoulder can be provided within the buccal wall of a faced crown, a cervical shoulder (such as described for the jacket-type preparation) will be needed on the buccal or labial aspect. Elsewhere the cervical margin should finish at a clearly marked position either at a well defined line-angle with the remainder of the tooth, or in a light finishing line (i.e. a shallow bevelled shoulder, figure 21.9).

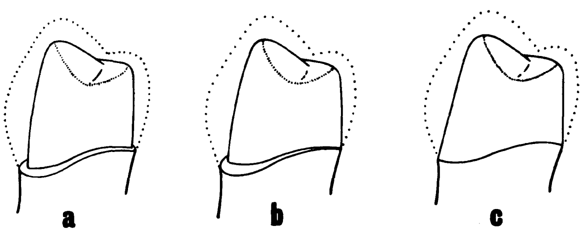

Fig. 21.9 (a) Jacket preparation. (b) Faced full crown preparation. (c) Full veneer crown preparation.

The mesial and distal, and buccal and lingual, slices should be made parallel to one another and at the most, should converge towards the occlusal surface at an angle of five degrees. If, in an endeavour to maintain parallelity, a slight undercut is produced at some point this can be easily remedied, but the Egyptian pyramid with which one is so often confronted is not only extremely unretentive, but also hopelessly prejudiced.

The reduction of the occlusal surface should follow the cuspal contours leaving an interocclusal space of about 1½ mm, the amount of clearance depending to some extent on the length of the axial slices which, if relatively short, may be compensated for to some degree by grinding the opposing teeth or by using a set-screw or pin. The shorter the tooth, the greater the need for paralleling the walls to obtain retention. However, if retention has been prejudiced by a previously excessive degree of convergence, a short groove on each of the four walls will provide adequate retention. Existing proximal boxes may also be used. Overemphasis on following the occlusal contours can be self-defeating and it is better to err on the side of overreduction, in order to ensure sufficient gold for occlusal adjustment and wear. A full veneer gold crown should be finished to a tiny bevelled step or, alternatively, a chamfer, terminating, where possible, a fraction of a millimetre short of the gingival line. If there is a large restoration in the tooth, it should be removed and the underlying dentine checked for caries and evidence of pulpal exposure. The cavity is lined with a calcium hydroxide cement and varnished and, after insertion of one or two dentine screws, plus some minute undercuts made in the walls with a small wheel bur, the contour is restored with amalgam. As an alternative, if the tooth has been root-treated, a composite core can be built up, but margins must be finished on the tooth surface. When the preparation is finished a check is made to ensure that there is adequate occlusal clearance. A double thickness of pink (denture) wax is softened and placed over the preparation and the patient is asked to occlude his teeth in centric relation. The wax is held up to the light and, if there are any thin areas, it is replaced on the tooth. A probe is speared through the thin spot and the wax pulled up the probe, which is left in contact with the area requiring further reduction. After adjustment of the surface, this is repeated until the wax exhibits a homogeneous colour by transmitted light.

If internal or Channel-Shoulder-Pin attachments are to be used, proximal space (or occasionally lingual room) must be provided, and this should be checked on the model beforehand. Again a conservative approach is preferred, partly because the natural flare of the teeth is often sufficiently accommodating, and partly because it may be possible to mount these within slightly exaggerated contours, without affecting the general anatomy of the arch.

Sometimes the occluso-gingival depth of the preparation results in too narrow a stump, and restoration of the full contours would make an excessively bulky casting. In this case the operator has to choose between some modification of the design or a double casting (telescopic coping). Castings of this type consist of an investing inner veneer which is firmly cemented to the tooth, and an enveloping ring casting supported cervically by a shoulder, which can be left free or cemented as desired, when constructing a removable prosthesis.

Venting

Trapping of air or cement within full crowns during cementation produces a reactionary back pressure, which particularly affects long, narrow, well-fitting crowns. These pressures can be very great; thus they may be sufficient to crack a porcelain crown, to strain a bonded crown sufficiently to damage a facing, or to interfere with the correct seating of a crown on its preparation.

A possible solution to this problem (in the case of full cast crowns) is to provide a vent near the occlusal surface of the crown (to allow the escape of air or cement) which is subsequently occluded by whatever means the operator chooses. Whaledent Vent-o-matic pins provide a neat, ready-made system for this purpose with the added advantage that they can also be used to provide additional retention for short crowned teeth.

Depending on the need to provide additional retention, a suitably placed hole is drilled two to three millimetres deep into the dentine (0.6 mm in diameter) into which a perlon pin is positioned before taking the overall impression. In the laboratory the perlon pin is substituted by a nickel-silver threaded proforma (fusing point circa 900°C) which is included in the wax-up and casting. After casting the proforma is dissolved out with nitric acid, leaving a delicate thread through which a matching gold pin can be bolted.

Nickel-silver pins cannot be used with Degudent gold because of the high melting point of the gold alloy which fuses the pin, but special alternative pins are available.

Partial Veneers

Types

Partial veneers may take the form of:

1. Three-quarter or Carmichael crowns.
2. Isodromes (i.e. parallel pin-retained veneers, from the Greek iso- meaning the same, and -dromes meaning an avenue lined by pillars or statues, and in this special case, pins) (figure 21.10 a)
   (a) Pinledge preparations.
   (b) Channel-slice pin preparations.
3. Non-parallel pin systems.
   (a) The horizontal non-parallel pin system.
   (b) The vertical non-parallel pin system.

Three-quarter crowns

Three-quarter crowns consist of thin veneers covering three-quarters of the clinical crown of the tooth, which gain their retention from parallel proximal grooves, and a parallel lingual or palatal slice (figure 21.10 b, c). Three-quarter preparations on incisor teeth may endanger the pulp, because of the proximal prolongations of the cornua; moreover the lingual or palatal contours do not lend themselves to satisfactory cingulum slices, though this problem may be overcome by the use of a suitably placed pin in appropriate cases.

The intrinsic advantage of the three-quarter crown lies in the superficial nature of the preparation, and in the fact that it enables the operator to preserve intact the buccal wall. Its basic disadvantage stems from the absence of a tie restraining the proximal flanges, and hence in a lack of resistance to bending stresses.

For these reasons the restoration is principally confined to sound canine, premolar or molar teeth, either for the provision of retainers (for short span bridges on sound abutment teeth in younger patients) or for the preservation of teeth in which one wall has collapsed.

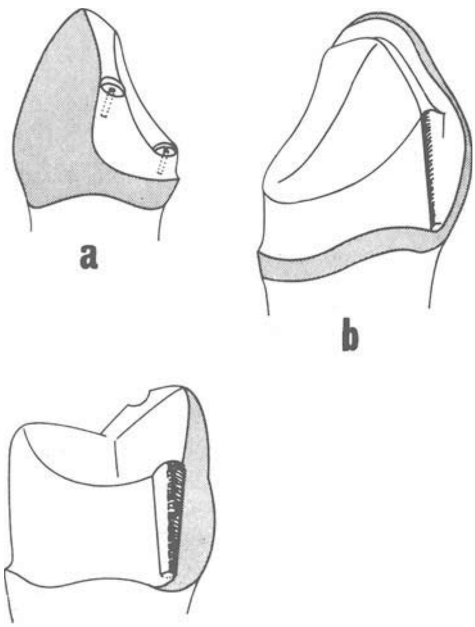

Fig. 21.10 (a) Partial pin-veneer preparation. (b) Three-quarter canine preparation. (c) Three-quarter premolar preparation.

Isodromes

Parallel-pin retained veneers fall into two categories, pinledge veneers (which are principally used in the anterior region, where pins have to be entered from a sloping face, (figure 21.10a) and channel-slice veneers (figure 21.11).

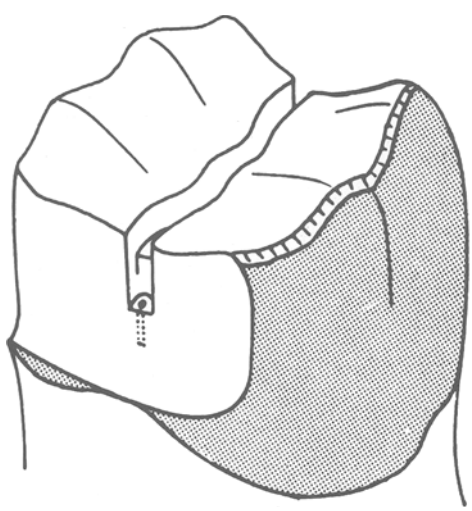

Fig. 21.11 Posterior channel-slice preparation.

Anterior veneers cover the incisal and palatal surfaces finishing beyond the cingulum just short of, or level with, the gingival crest and extending proximally into the contact area far enough to reach self-cleansing areas. Three pins are usually used to anchor the veneer, two at the incisal corners, and one just to one side of the cingulum (or a little further up the linguo-proximal border, in the case of lower incisors).

In the upper, pins of 0.6 mm are usually used, but the small size of the lower teeth favours the use of 0.5 mm pins (assuming that the teeth are large enough to be used at all). Three-millimetre pinholes (arranged in accordance with a predetermined plan) are started from centring pits milled in the centre of ground ledges. The purpose of the ledges is to provide a flat surface from which the pinhole can be drilled without drifting or bending, and to give additional bulk in which to embed the head of the pin.

Channel-slice preparations consist of vertically parallel, proximal slices, which are joined by an occlusal reduction of about 1 to 1½ mm. In the midline of each slice, parallel channels are cut to about half the depth of the slice and of a width of circa 1¼ mm; these are used as guides for pinholes 0.7 mm in diameter and 3 mm in depth. If desired the rigidity of the veneer can be increased by adding a lingual or palatal slice parallel to the channels.

In any isodrome technique it is essential to parallel the pins to one another and, while it is possible to prepare pinholes by eye, it becomes increasingly difficult as their number and distance of separation increases. Hence for most operators the use of a parallelometer is obligatory.

With the exception of the Bertolini system such parallelometers must be designed for intra-oral use. The Bertolini system differs in that the slices and ledges are prepared, and the castings waxed up with gold tubes aligned in the laboratory over the pinhole sites. These are then cast into the splint and act as guides and stops for drilling the pinholes. The pin wires are then soldered into place and the excess cut off and the surface is polished.

Intra-oral parallelometers

Any intra-oral paralleling device must operate from a predetermined and stable platform; usually some form of acrylic plate covering as many occlusal surfaces as possible. Several types of instrument are available but, whichever type is chosen, it should incorporate guides to align the drills, stops to control the depth of cut, and some arrangement to allow free passage of the drill despite slight handpiece shake.

The Parmlid for instance uses an oiled phosphor bronze bushing at the end of a sliding bar which acts both as a stop and a guide (figure 21.12). The bar is free to slide along a Fluon carriage, and can rotate about a lockable pivot which is attached to the supporting plate. The position of the pivot is determined before processing with the aid of a laboratory paralleling instrument, and can be finely adjusted within 30° when finally fitted to the model. The vertical height of the bar is determined by rotation about the pivot, a 360° rotation providing a vertical movement of 0.5 mm. Free passage of the bur is permitted by the use of special instruments fitted with paramax grips, i.e. tapered shanks which when inserted within a latch type handpiece can wobble about an arc of 5° (Parmlid, 1967).

Fig. 21.12 Parmlid's parallelometer.

By contrast the Ney system uses a set of steel tubes through which matching drils can operate. The tubes are aligned and embedded within the plate controlling both the direction and depth of passage of the drills. The tops of the drills are surmounted by hemispherical cups which engage in a special mandrel mounted in the handpiece which is capable of a wide arc of movement without affecting the operation of the drill. A system of this type is very easy to use and stable, but is limited to the drilling of holes, while other systems such as the Parmlid can also be used for aligning channels and grinding slices.

Non-parallel systems

Non-parallel pin systems use the same type of veneers but, instead of incorporating a set of fixed parallel pins, are constructed with a view to the insertion of threaded pins at the time of cementation. Two systems are available, the horizontal non-parallel pin system (which is used for the periodontal fixation of lower incisors) and the vertical non-parallel pin system which is used as an alternative to isodrome systems in the upper anterior, or posterior regions of the mouth.

The Horizontal Splint/Mate system

Periodontally unstable lower anterior teeth (because of their relative lack of bulk, and anatomical configuration) present particular problems. The teeth are difficult to stabilise during preparation and impression-taking, the residual stump of a full or three-quarter preparation is structurally weak, and pins are likely to endanger the pulp.

The Horizontal Splint/Mate system devised by Weissmann (1965) offers a technique which simplifies some and obviates other of these difficulties. Basically it consists of a method of bolting 16 B.A. cheesehead bolts through a series of labiolingual perforations into a cast gold backplate which is sealed into position with cement.

Technique

The teeth should be scaled thoroughly and polished and, if possible, the pockets eliminated (though in grossly mobile teeth this is often more easily accomplished after splinting). Holes are drilled labiolingually at points midway between the tips of the pulps and the incisal edges, the alignment and height of the holes being determined by comparison of a study model and radiographs with the teeth.

Long-shank T.C. burs are provided for this purpose but half-round F.G. burs at ultra-high speed are less likely to cause enamel fracture. The perforations are then enlarged with an end-cutting bur and the lingual orifices lightly countersunk. A silicone or rubber elastomer impression is then taken in a special tray with a labial window and positioning pins are thrust through the perforations.

It is important to ensure that the tray is sufficiently relieved lingually to the teeth so that when the pins are thrust through they come to lie within a sufficient bulk of impression material for easy relocation. Difficulty may also be encountered in finding the holes while the material is setting. This can be overcome by wiping the labial window clear, positioning the pins and then refilling the window with a syringe. When the material has set the pins are withdrawn, the tray is removed, and the holes are filled with a temporary filling material. The impression is then returned to the laboratory where a refractory model is cast.

Special steel threaded pins with plastic sleeves are then inserted into the perforations from the lingual aspect; the sleeves are made to conform with the model and tacked down with sticky wax. The backing-plate is then waxed-up to the thickness of the plastic sleeves, invested and cast.

The pins are then unscrewed or, if this impossible, dissolved out with concentrated hydrochloric acid, the casting polished, placed on the model, and the plastic-headed bolts checked in position.

At another visit the temporary filling material is removed, the bolts and plate checked for fit, and the labial orifice countersunk with the depth-control bur provided. A thin mix of cement is then applied to the splint and the bolts are screwed home with a special spanner.

Care must be taken when bolting the backing plate into position not to apply too much pressure otherwise there is a real danger of fracturing the incisal edge. Finally any excess is cut off and the remainder polished. Basically this is a sound and relatively simple technique, but it is expensive; the refractory model is very fragile, and experience hardly bought.

Modified system

More recently Cross (1971) has described an alternative technique which is less costly, and reduces the surgery to a single stage operation. In this technique the backplate is cast and fitted before cutting the perforations. The plate is then held in position with an acrylic splint while the teeth and plate are perforated, and the holes tapped at the chairside. The assembly is then bolted together with 14 B.A. stainless steel bolts in a similar manner to that already described.

The special tools required are:

1. Meisinger 203 twist drills No. 2/0 and No. 2.
2. 14 B.A. plug and taper taps.
3. A No. 5 rosehead bur.
4. A Meisinger No. 5 end cutting bur.
5. 14 B.A. stainless steel cheesehead bolts.

Apart from the obvious advantages of lower cost and the elimination of the period required with a temporary filling, the difficulties in locating the rods within the impression and the danger of fracturing the refractory model are eliminated, but the larger size of bolt involved will limit its use. Notwithstanding, these are useful methods of extending the lives of otherwise hopeless teeth, and the modified method has other attractive possibilities when considering the necessary modification of some forms of fixed bridgework.

Vertical non-parallel pin system

This system differs from the horizontal non-parallel pin system in that, in this case, the threaded pins are introduced through the backing plate into the teeth. The system is costly and in general offers little advantage over more conventional methods. However, it sometimes happens, when aligning a series of pins, that one or two may be malpositioned, and in these cases it is invaluable to be able to use one or more supplementary non-parallel pins.

The suspect pinholes are drilled with the 0.024 (2 mm) depth-limiting drill and the opening bevelled with a cone abrasive. 0.6 mm perlon pins are placed in the pinholes and removed in the impression with the other similar parallel pins. In the laboratory the malaligned pins are replaced with nickel silver countersunk formers and included in the wax-up, later being dissolved out of the casting with nitric acid. In due course the splint is tied in, the 0.024 holes are enlarged with 0.027 drills, and special countersunk self-tapping non-parallel screws are bolted into place while the cement is setting.

The problem of fractured porcelain facings

One of the great drawbacks to fixed bridgework and crowns constructed in porcelain bonded to gold is the unexpected fracture of a facing or any other area of the porcelain. This may be due to internal porosities: failure in bonding, due to faulty manipulation of the materials: bending of weak veneers of metal which shears off the overlying veneer, or traumatic occlusal forces on the porcelain.

Although the correct remedy is to remove the bridge and repair or replace the porcelain, this is frequently hazardous and unpleasant for the patient. If a veneer can be repaired in situ, it saves time and expense and is often quite satisfactory. Numerous repair kits are now available which rely on the method of modification of the porcelain surface by means of an organo-silane coupling agent, such as methacryloxypropyltrimethoxysilane. These may be used in conjunction with acrylic resin, e.g. 'FUSION' (Taub, New York) or with a special composite resin, e.g. Den-Mat repair kit. Highton, *et al.*, investigating the effectiveness of various repair systems, found that the use of 'Fusion' with acrylic gave the best results.

An alternative technique entails exposure of the underlying metal and cutting minute undercuts with a tiny wheel or round bur. A layer of composite is locked to this surface and opacified with titanium dioxide or stains available for the purpose. The appropriate shade of composite is then added and finished to a bevelled margin of the porcelain.

If feasible, holes can be drilled through the metal into the tooth and self-shearing pins inserted. Then, after bending the pins over they are used to retain composite. Even if these measures are not permanent, they may be invaluable as temporary expedients and can be repeated subsequently when necessary.

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22

The Three-quarter Crown

The three quarter crown was introduced to the profession in 1901 by Carmichael and is even today referred to in some schools as 'The Carmichael Crown'. It has several good features;

(1) It is easier to seat than a full veneer crown,
(2) It is possible to check vitality subsequently,
(3) There is less destruction of tooth tissue,
(4) Aesthetics are more easily maintained.

Shillingburg (1976) showed that they are less retentive than full veneer crowns. He suggested that retention could be enhanced by the use of proximal boxes, rather than grooves.

Of all the different types of bridge retainers, the three-quarter crown is regarded as the least successful by many practitioners.

This criticism is partly due to its misuse. Either because of design and preparation (and to the use of a three-quarter crown on a tooth for which a completely different type of restoration is indicated) or to the limitations of laboratory techniques.

In view of these considerations, it was felt that a detailed analysis would be of value to both students and practitioners.

The three-quarter crown is a special type of veneer inlay designed primarily as a bridge retainer in which the labial or buccal surface remains unprepared. At the time it was devised, there were no satisfactory techniques or materials for facing gold crowns. hence the three-quarter crown became an established bridge retainer. In recent years, with the advent of bonded porcelain and improved heat-cured resins, the need for partial coverage has decreased. Nevertheless, provided that the buccal or labial surface of the tooth is sound and aesthetically acceptable and that the crown is of adequate height and not too bulbous, the three-quarter crown is still, in many instances, the retainer of choice. A highly platinised gold must be used.

Indications

Apart from its application as a bridge retainer the three-quarter crown may be used to restore a molar or premolar which has suffered trauma resulting in the loss of a lingual cusp (figure 22.1). This occurs frequently after the cusp has been undermined by caries, or following endodontic treatment if full cuspal coverage with gold has not been implemented.

In cases of traumatic loss of a cusp, having ascertained that the vital response of the tooth is unimpaired, a pin-retained amalgam restoration is constructed which, when hard, is treated as part of the tooth for the purpose of three-quarter crown preparation. If the tooth has received endodontic treatment, an amalgam restoration of a similar type may be built upon one or more Dentatus screws locked into the root canal with cement.

Occasionally the mandibular first premolar, when prepared for an M.O.D. gold inlay, exhibits excessive diminution of the lingual cusp. In this case, the gold

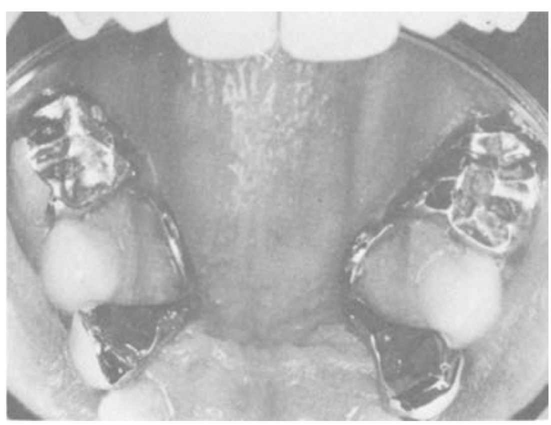

Fig. 22.1 Treatment of partial anodontia by spring cantilever bridges on three-quarter crowns 6|6.

should be extended over the lingual wall and the buccal cusp overlaid with a veneer of gold, thus converting the M.O.D. preparation to a three-quarter preparation.

Types of three-quarter crown preparation

Basically, the three-quarter crown consists of a veneer of gold extending over three walls, namely the two proximal walls and the buccal or lingual wall, covering the occlusal surface or incisal edge and retained by a combination of the following: grooves, pins, bevels, pits or boxes. The method of obtaining retention will vary according to circumstances, e.g. the lack of sufficient bulk of dentine, after removal of caries or old restorations, may necessitate the use of pins or accessory-grooves.

Three-quarter crowns for anterior teeth

The typical three-quarter preparation on an anterior tooth is feasible solely when the tooth is of adequate length and has minimum curvature of the proximal walls. Crowns with excessive bulbosity, or very short crowns, are not suitable for conventional three-quarter crown preparations. This is because the proximal retention grooves tend to be inordinately short and unretentive, unless the slices are extended further which, in turn, would produce an unaesthetic show of gold on the labial aspect of the crown. This problem may be solved by the use of pin retention (vide infra).

The maxillary canine, because it has adequate bulk, is the ideal anterior tooth for a three-quarter crown. For the converse reason, mandibular incisors are rarely suitable unless they are large and have nearly parallel proximal walls. Maxillary incisors follow the same general rule, and those which are narrow labio-lingually or have undergone severe lingual attrition are unsuitable, because difficulty may be experienced in obtaining adequate retention without endangering the integrity of the pulp.

Steps in the preparation of maxillary canine

With the advent of the turbine handpiece, variations in technique have been developed by individual operators. However, it matters little which technique is followed as long as the end-result is satisfactory. The following procedures have been tried and tested over many decades and have proved effective.

Stage 1

Mesial and distal slices are cut with a safe-sided diamond disc and made to converge to the lingual in order to avoid an excessive show of gold labially. As a safety measure the disc should be used in a disc-guard or, alternatively, the engine cord may be slackened to lower the torque of the disc. This will allow the engine pulley to rotate without sufficient friction from the cord to drive the handpiece, should the disc jam during cutting. Modern dental units are usually equipped with air-motors for low speed drilling. The air-motor tends to have less torque than the belt and pulley drive. Hence any need to diminish the torque may be satisfied by slight diminution of the air pressure. With normal torque the handpiece would go out of control and twist from the operator's grasp; the disc would then free itself and damage to the soft tissues would be apt to occur. The fear that this might happen has influenced some operators in their avoidance of the use of discs, but no other instrument will produce flat smooth slices with well-delineated margins. Electric motors, noted for their high torque, are unsuitable for use with discs. An alternative method for cutting the slices is to use a fine tapered, plain cut T.C. bur at ultra-high speed. The slices must converge in an incisal direction (3–5° angle) to allow withdrawal. At this stage the slices, finished out of contact with the adjacent tooth or teeth at the gingival margins, are separated lingually by an area of bulbous enamel. This is now prepared and finished with a chamfer at the level of the gingival crest and the slice (figure 22.2) is aligned with the slope of the middle third of the labial surface.

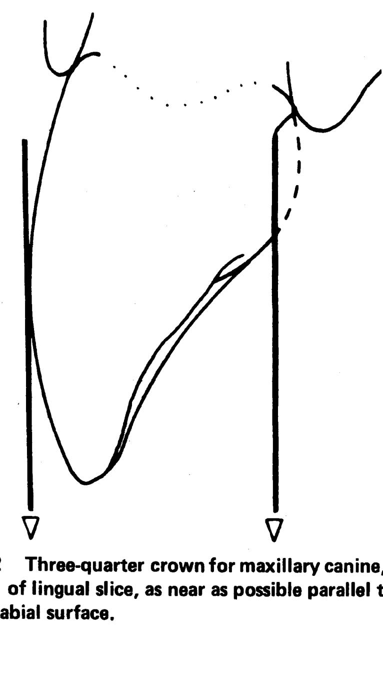

Fig. 22.2 Three-quarter crown for maxillary canine, showing direction of lingual slice, as near as possible parallel to middle third of labial surface.

Stage 2

The three slices having been cut, the sharp proximo-lingual angles at their junctions are rounded. Then the lingual enamel is cut away using a diamond wheel approximately 5 mm diameter x 2 mm wide and with rounded edges. This is operated under a water coolant at about 12 000 rpm and the occlusal clearance is checked repeatedly in centric, protrusive and lateral excursive movements until a 1.0 mm clearance is noted in all positions. An incisal bevel of 45° is then cut and the dentine surface is smoothed to a satin finish with green carborundum abrasive stones, operated with light pressure and at low speed, and perfected by scraping the surface with the spoon end of a Mitchell's gold trimmer.

Stage 3

The final stage consists of the cutting of two retention grooves. These are placed mesially and distally, as close to the labial surface as aesthetic considerations will allow, and parallel with the middle third of the labial surface. They are prepared with a tapered bur, which allows a certain latitude when cutting parallel grooves by eye. The grooves should be taken to the full depth of the slices and checked for parallelity prior to their completion (figure 22.3).

It is advantageous to made the initial cut with a turbine bur, creating a slight groove, which will help to hold a slow-running tapered steel bur and prevent it from skidding over the slices and producing a larger groove than necessary.

The first groove is made with a 700 fissure bur on that proximal aspect which is visible, e.g. the mesial aspect of a maxillary canine when the lateral incisor is missing. When the groove has been cut, the bur is carried back to the distal aspect and its relation to the buccal margin of the slice is adjusted. It should not be re-angulated, but reliance should be placed on the taper of the bur to produce retentive, non-undercut grooves. When placing the bur in position to make the distal cut, it may be aligned in the bucco-lingual plane on the first groove. After the second groove has been drilled, the degree of parallelism is checked. Viewing through a front-surface silvered mirror, the point of a straight probe is placed at the base of one groove and the operator moves his head until it can just be seen. Then the probe is placed at the base of the other groove without altering the position of the head. If the point of the probe is not then visible, the groove is undercut. The bucco-lingual alignment is checked by placing a long straight probe on one groove and seeing whether it is in line with the other groove.

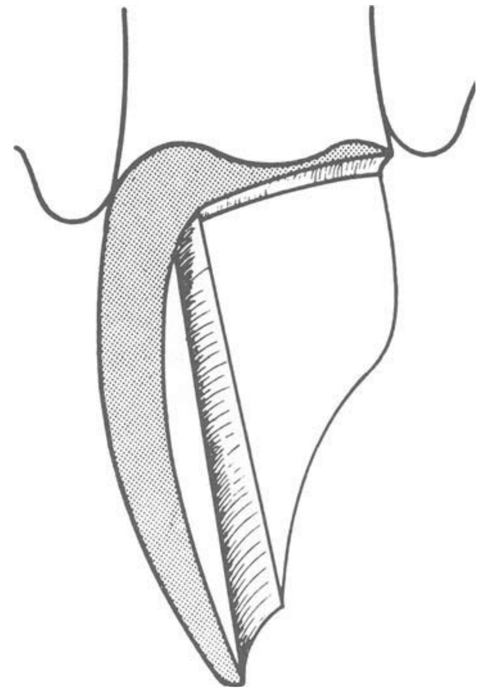

Fig. 22.3 Three-quarter crown preparation with grooves parallel to the middle third of the labial surface, and palatal chamfer.

When the operator is satisfied that there are no undercut areas, the grooves are widened with a fine tapered diamond bur and the angles they make with the walls are rounded off.

If the grooves extend beyond the slice, the diamond bur is operated with a pulling action towards the lingual from the grooves, in order to remove the triangular undercut area between slice and groove gingivally (figure 22.4). This will tend to diminish the retentivity of the preparation and can be compensated by increasing the depth of the grooves slightly.

In many cases existing Class III restorations will fall out in the course of preparation leaving a large defect. If the bulk of the cavity was confined to the labial aspect of the tooth, an excessive show of gold would result after the wall has been straightened. Alternatively, an aesthetic restoration could be inserted after completion of the three-quarter crown, but this is inferior to a faced, full veneer crown, both as regards aesthetics and retentivity. Consequently, in such a case, a full veneer restoration should be the initial choice. When the Class III cavity does not involve the labial surface, but extends lingually, the

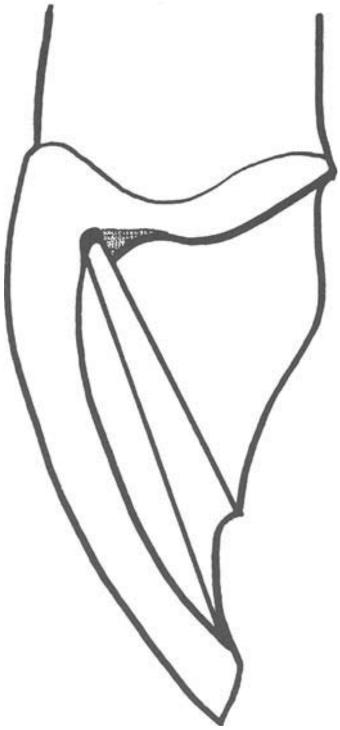

Fig. 22.4 Three-quarter crown preparation in maxillary canine. The groove extends beyond the confines of the slice, leaving a small triangular undercut area which must be included in the preparation. This area is cross-hatched in the diagram.

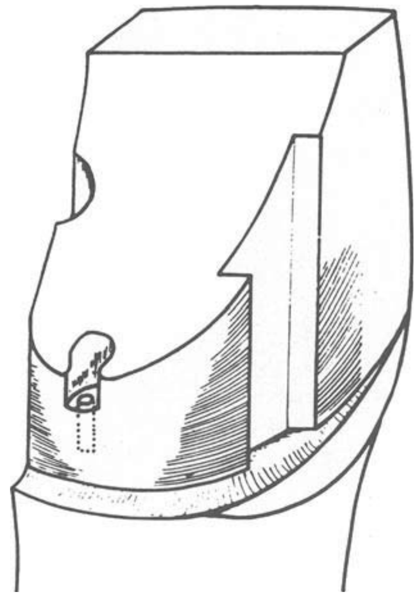

Fig. 22.5 Schematic representation of modified three-quarter crown preparation – to be used when there is loss of retentivity, due to caries or large restoration. The retention here consists of a box, a groove and a pin.

loss of retentivity may be marked, even though a box-like retention cavity could be prepared. When this situation arises, accessory retention may be obtained by the use of a pin inserted gingivally to a depth of 3.0 to 4.0 mm (figure 22.5).

Many textbooks recommend an incisal groove, which joins the proximal grooves to produce a staple type of retentive lock and imparts increased strength to the veneer. The groove is placed at the intersection of the labial two-thirds and the lingual third of the incisal edge and is V-shaped in profile. This measure is feasible solely in bulky canines, because any thinning of the incisal dentine in a narrow incisor or canine tends to cast a dark shadow along the labio-incisal angle without an appreciable increase in retention form.

Three-quarter crowns on posterior teeth

The crown preparation on a molar or premolar is essentially similar to that described for a canine. There are, however, certain points of difference which require to be noted.

A safe-sided convex diamond disc is used to prepare the distal slice and a flat diamond disc to prepare the mesial slice (figure 22.6), taking care to keep the angle of convergence of the slices to as near 5° as possible. In the horizontal plane, the slices should be parallel to the proximal surfaces (figure 22.7).

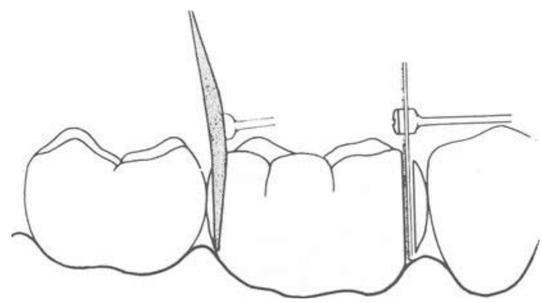

Fig. 22.6 The use of a convex disc to cut the distal slice.

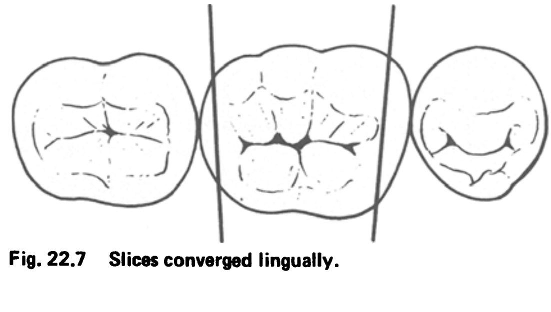

Fig. 22.7 Slices converged lingually.

The lingual slice is cut with a tapered diamond bur held in the axial plane and the gingival margin is finished in the form of a chamfer at the level of the gingival crest (figure 22.8). The angles of junction of the three slices are rounded and the gingival chamfer made continuous with the proximal chamfer.

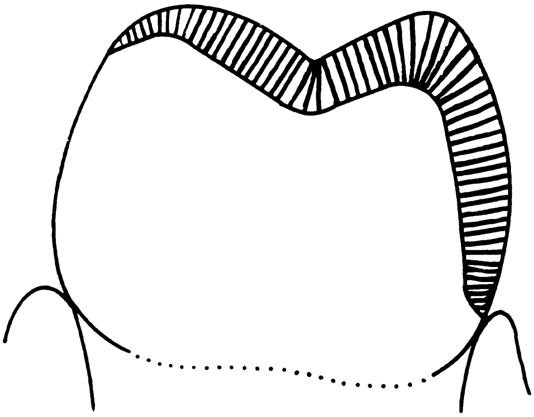

Fig. 22.8 Reduction of the occlusal surface and the making of a lingual slice, finished at the gingival margin (or, in a long crown, just short of it) in a chamfer.

Under no circumstances should a proximo-lingual step be cut, because resistance to lingual displacement would thereby be diminished or lost (figure 22.9).

The height of the cusps is reduced by approximately 1.0 mm. This is effected by reducing each cusp, facet by facet, and not forgetting to deepen the fossae and grooves by the same amount. The clearance of the bucco-occlusal surface may be checked visually, but it is difficult in most cases to ascertain whether sufficient tissue has been removed from the lingual cusps. The following simple test provides a guide to the adequacy of occlusal reduction.

A piece of baseplate wax, approximately 1 x 4 cm, is softened and folded twice to form a 1 cm square block. This is placed over the prepared tooth and the patient is asked to bite into the soft wax in the centric position. The wax is removed and inspected by transmitted light and any translucent areas are noted. The wax is then returned to its position on the tooth and the point of a straight probe is speared through the thin spot and held in contact with the tooth whilst the wax is pulled up the probe. The area requiring further reduction is designated by the position of the probe. This operation is repeated after the removal of more tissue until the wax overlay is homogeneous in colour when viewed against the light.

The grooves are cut close to the buccal wall in order to obtain maximum resistance to lateral displacing forces and maximum length of groove (figure 22.10). They are cut in the axial plane with a tapered fissure bur and enlarged and rounded with a diamond bur. The preparation is smoothed with carborundum points, or T. C. blanks.

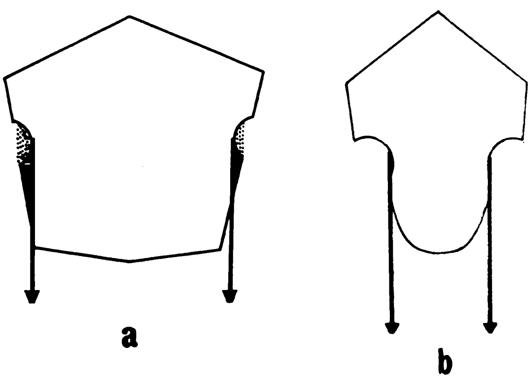

Fig. 22.9 Diagrammatic representation of the basic retention factor in three-quarter crown preparation. The arrows show the direction of stresses resisted by the struts. (a) The shaded area denotes the parts of the tooth which confer retentivity to the cavity and the dotted area indicates the zone of retention in the grooves. (b) Due to excessive loss of lingual tissue, the retentivity is nil.

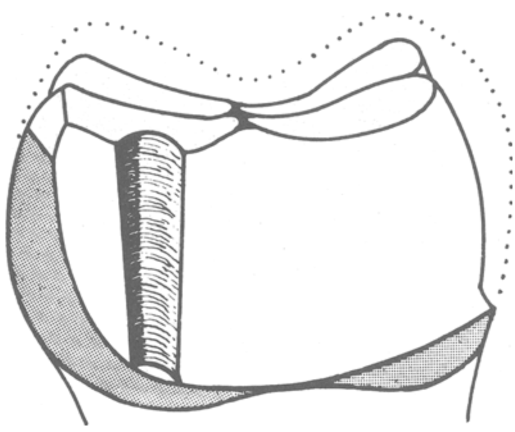

Fig. 22.10 Three-quarter crown preparation on lower molar, showing shape and position of proximal groove and lingual chamfer.

When an amalgam Class II restoration has been present, one or both proximal boxes may be substituted for the grooves (figure 22.11), and when removal of caries or amalgam has diminished the necessary retentive potential of the tooth, the lost tissue may be restored by condensing amalgam around non-parallel pins embedded in the dentine. The

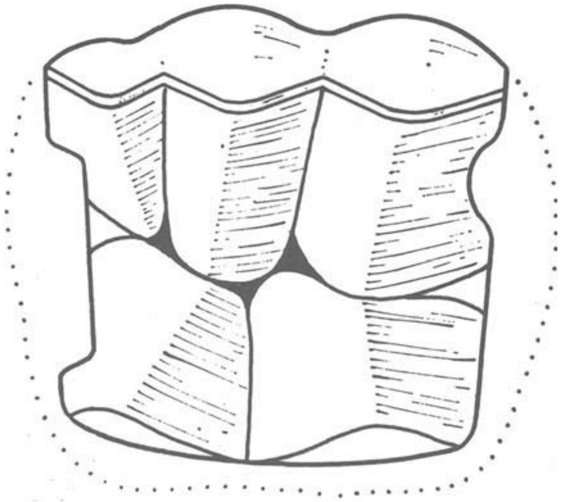

Fig. 22.11 Three-quarter crown preparation on lower molar-mesial groove and distal box.

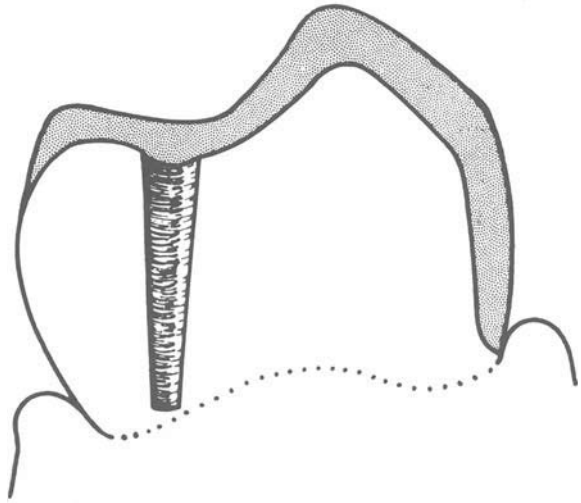

Fig. 22.12 A special type of three-quarter crown in which, to overcome the problem of lingual inclination, the buccal wall is prepared, the groove is orientated in a more upright line than the axial plane of the tooth and the lingual wall is left untouched.

projecting ends of the pins should be shortened and bent inwards, so that they will not be exposed when the amalgam is cut down.

If the underlying dentine is close to the pulp, it should be protected with a layer of zinc eugenolate cement or calcium hydroxide.

When an abutment tooth is inclined lingually, the lingual wall may be left untouched, but the buccal wall is sliced and chamfered. This is done when a three-quarter crown on a molar is indicated, but where the grooves require to be angulated in line with another abutment tooth which has no lingual tilt (figure 22.12). If such a tooth were to be cut down for a full veneer crown, there would be excessive removal of lingual tissue and it would be necessary to produce a large buccal step in order to obtain retentivity.

Reverse retention

An alternative method of retaining a three-quarter crown is to carry the buccal margins of the slices round to embrace part of the buccal wall, thus preventing dislodgement by lateral stresses. The principle has been applied to three-quarter crowns on lower incisors, but the advent of bonded porcelain has rendered the technique obsolete, in this connection.

There are occasions on which maxillary premolars and molars are rendered unsuitable for a three-quarter veneer preparation due to considerable loss of tissue disto-buccally, or the presence of caries or a restoration in that area. In order to produce an aesthetic crown, full coverage and a porcelain veneer facing is the conventional method of choice. However, preservation of the mesio-buccal wall intact has four advantages:

(1) it maintains the strength of the tooth;
(2) it avoids a show of gold or the need to make a deeper preparation to allow room for a porcelain veneer;
(3) the cost is kept down by avoiding the need for a porcelain facing;
(4) there are fewer inroads towards the pulp, thus lessening the risk of degenerative pathosis.

This type of preparation is cut with a box or groove mesially, but the distal slice is extended buccally to obtain reverse retention. The technique may be employed in the restoration of a single unit or for a bridge retainer (figure 22.13).

a

b

Fig. 22.13 Three-quarter crown retained by: A mesial, axial groove; and a disto-buccal slice (reverse retention). (a) Buccal show of gold. (b) Outline of retentive features.

Potts *et al.* (1980) tested five preparation designs for retention and resistance, and showed significantly lower retention values for partial veneer crowns than for full veneer crowns. An increase in axial surface coverage produced a significant increase in resistance values.

Addition of grooves, with or without an increase of axial surface coverage, gave a small increase in retentivity but markedly increased resistance values. In the light of this finding, although a single groove at one proximal surface with reverse the retention at the opposite surface will provide adequate retention, grooves are to be recommended at both surfaces in seven-eighths crowns.

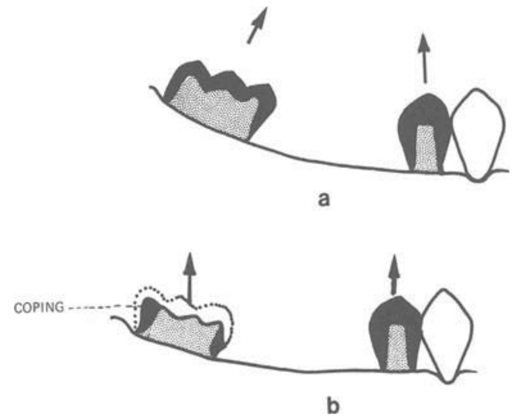

Fig. 22.14 Production of axial line of withdrawal in a tilted tooth, by the use of a telescopic coping. (a) Disparity of alignment of retainers resulting from mesial tipping of molar. Any attempt to cut back the mesial and distal walls would prejudice the vitality of the pulp. (b) Preparation re-aligned by means of an open-topped, telescopic coping.

Telescopic crown and three-quarter crown on a mesially inclined molar

When the mandibular first and second molars have been lost, the third molar tends to drift and tip mesially until its axial plane is vastly different from that of the premolars. This presents a severe problem of alignment when considering the preparation of the teeth for a fixed bridge. Although the bridge could be fixed to a full crown on the molar and stress broken in a slot, cut in the distal aspect of the second premolar, the stresses transmitted to the tipped molar would ultimately cause bone resorption and mobility of the bridge. This solution would be feasible if only one molar were missing but the long cantilever resulting from two pontics almost invariable leads to failure.

If the third molar is tipped at an angle greater than 24°, the force transmitted to it through the pontics will fall mainly along a line mesial to the roots, and subject the periodontal tissues to unacceptable stress, leading to gross bony resorption. Thus, bridgework is contra-indicated. In such a case, it is possible to upright the tooth by orthodontic treatment, stabilising it in the new position by making a bridge.

Third molars which are tipped at a less acute angle may be rendered amenable to parallelisation by the use of a telescopic coping in the following manner.

(1) Cut full veneer preparations on the molar and premolar, each in line with its own axial inclination.

(2) Record elastomeric impressions.

(3) The technician waxes up a thin gold coping on the molar die. This is left open on the occlusal surface and is fitted accurately to the gingival margin. It is built out disto-occlusally and mesio-gingivally in order to align it to the plane of withdrawal of the wax pattern on the premolar (figure 22.14).

(4) The coping is cast in a hard, platinised gold alloy, trimmed, sand-blasted and placed on the molar preparation.

(5) The bridge is next waxed up and completed.

(6) The coping is cemented on the molar and the bridge is cemented to it. (Preferably at the same time, and with one mix of cement.)

It is necessary to prepare the axial walls slightly deeper than normal to allow a thickness of 0.4 mm for the coping. This technique, although satisfactory, entails two stages and relies on double cementation, thus there is greater margin for error plus added expense. The author (J.J.M.) has used a special modification of the three-quarter veneer principle with great success for many years. A further advantage accruing from this veneer, which involves all surfaces other than the distal, is found when the distal gingival tissue is heaped up, extending on occasion as high as the occlusal surface.

Technique of preparation

(1) Prepare the premolar for a full veneer casting.

(2) Assess, from a bitewing radiograph and study model, to what depth the mesial slice on the molar can be cut without risk to the pulp. It is now prepared.

(3) Assess the amount of enamel to be removed in order to provide adequate occlusal clearance. The angulation of the occlusal surface will often indicate that the enamel on its distal aspect alone be reduced. This reduction is carried back as far as the crest of the distal marginal ridge.

(4) The buccal and lingual walls are now sliced, finishing the slices at or just short of the gingival margins, extending distally to points where two lines, from the distal marginal ridge, directed parallel with the mesial slice, terminate.

(5) Along these two lines, grooves are cut with a 701 tapered fissure bur and the margins are flared, the distal margin being finished to a distinct bevel. Two pits are cut in the mesial cusps to a depth of 1.0 mm, using a 701 fissure bur, and parallel with the buccal and lingual grooves.

(6) All sharp line angles are rounded: buccal, lingual and gingival margins are chamfered and the walls of the preparation are smoothed with T.C. blanks, water cooled at high speed. Angulations are checked.

(7) Impressions are recorded (figure 22.15a, b, c).

The pinledge preparation

This preparation, introduced in the section on partial veneers in chapter 21, is primarily of use for a bridge retainer and is indicated for short, or bulbous teeth or, with the aid of a paralleling device, for a multiple pinledge splint.

Prior examination of a radiograph will establish the position and approximate size of the pulp chamber. It is recommended that pinledge preparations should never be used for patients younger than 20 years of age and preferably, only after the age of 25. This is because young pulps are larger than the radiographic appearance suggests and traumatic exposure is often discovered surprisingly close to the amelo-dentinal junction. Furthermore, in older patients gingival recession provides a longer tooth with consequent increase in surface area for easier placement of the pins and added frictional retention. The commonest situations in which pinledge crowns are used are the upper and lower canines. The retention stems largely or totally from the pins and these should be as long as possible (i.e. 3.0–4.0 mm). If a free-hand preparation is employed, sufficient margin for error is provided by cutting with a size 700 or 701 tapered fissure bur. Increased retention can be provided by the use of parallel sided cast pins or iridioplatinum wrought pins, cutting the holes with the aid of a paralleling device (e.g. *Prec-in-dent).

Because there is no need, in this preparation, to embrace the proximal walls with gold in order to gain retention, the appearance of the tooth remains virtually unaltered. Extension proximally to provide a surface for soldering to a pontic may be kept to a minimum, whereas, provided there is no existing restoration or caries at the other proximal surface,

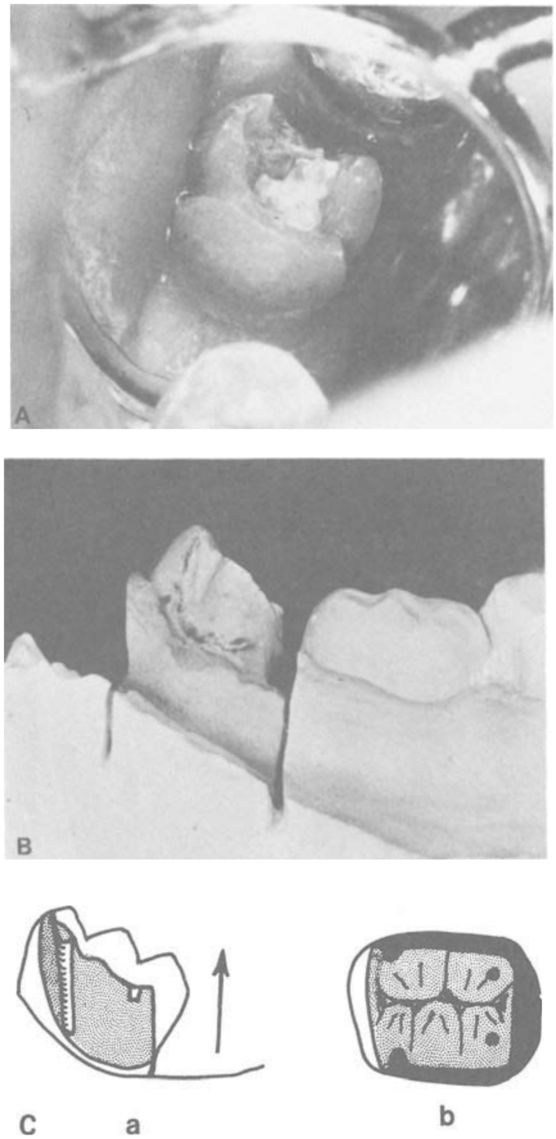

Fig. 22.15 Modified Design of Three Quarter Crown on Lower Right Second Molar Grooves cut in buccal and lingual walls and distal wall left uncut. (A) Prepared tooth. (B) Model with die. The buccal finishing line is outlined, roughly, in pencil. (C) Diagrams showing (a) mesio-distal and (b) occlusal aspects of cavity form for modified three-quarter crown on a tipped lower molar.

the margin of the pinledge can be sited in a cleansible area, fractionally short of the proximal contact (figure 22.16a).

The stages of preparation are as follows:

(1) A slice is made with a diamond disc at the proximal surface facing the space. In the axial plane

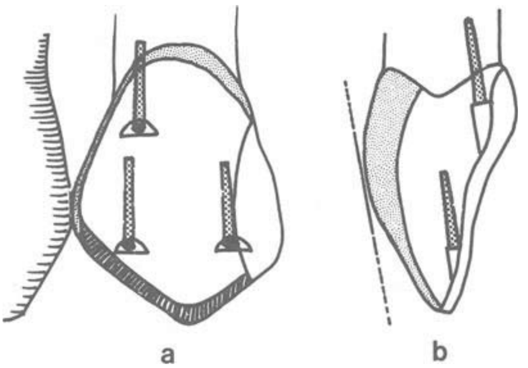

Fig. 22.16 Pin-ledge preparation on maxillary canine. (a) 3 pin-holes of 3.0 mm length offset from pulpal area. The mesial slice is continuous with the incisal bevel which is continued distally, just short of the contact area, to merge with the gingival chamfer. (b) The pin-holes are cut in a line parallel with the middle third of the labial surface.

the slice is directed at an angle of 3–5° convergence to the axis, whilst the disc is angulated lingually so that the labial margin of the slice will not extend beyond the proximal surface of the pontic.

(2) Using a fine tapered F.G. diamond bur in the turbine handpiece, the gingival margin of the slice is continued lingually, terminating at, or fractionally short of the gingival crest. This palatal slice is cut at an angle more or less parallel to the middle third of the labial surface, and is continued until a chamfer has been made. This chamfer is then continued (in the form of a groove at this stage) along the proximo-lingual junction, 0.5 mm from the adjacent tooth, until the incisal edge is reached.

(3) An incisal bevel is cut, at an angle of 45°, from the proximal cut to the proximal slice.

(4) Approximately 1.0 mm of palatal enamel is removed between the groove and the slice, checking constantly that sufficient space for gold is available in protrusive and lateral excursive movements.

(5) The prepared surface is now smoothed, using fine carborundum stones, water-cooled at low speed, or tungsten carbide finishing blanks in the turbine handpiece. All sharp line angles are rounded and a clearly defined perimeter is established.

(6) The number of pinledges to be cut varies between different operators. Three is the commonest number, but four have been recommended. In the opinion of the author, the most important factor is the length of the pins. If they are less than 3.0 mm, the degree of retention is inadequate. The ledges give resistance to bending of the veneer and thus constitute a vital factor in the longevity of the retainer. They are cut in the dentine, two incisally and one gingivally, the former being well away from the pulp but not so near to the incisal tip or proximal walls that they are weakened, and the latter is offset towards the adjacent tooth. A number 3 fissure bur is angled parallel with the middle third of the labial surface and the three ledges are cut. In the centre of each ledge, maintaining the same angle of cut, a pit is drilled with a ½ round bur and, keeping the three channels as parallel as possible, deepened to 1.5 mm. It is not possible to drill deeper at this stage because the shank of the bur becomes wider than the rose-head. The holes are now widened, using a 700 tapered fissure bur and, by alternating the two burs, the channels are cut to a depth of 3.0–4.0 mm (figure 22.16b).

(7) The orifices of the channels are rounded by the light application of a flame-shaped finishing bur. This strengthens the junction of pin to veneer.

(8) A straight probe is inserted into each channel in turn to check their alignment, and any necessary modifications are carried out.

(9) The pinholes are coated with a protective film of Copal-ether varnish, applied on an absorbent endodontic point. Evidence of an exposed pulp must also be sought routinely at this stage by introducing a fine reamer into each channel. If the pulp is exposed, the reamer will enter the pulp cavity. Endodontic treatment should be carried out as soon as possible to prevent the development of an acute pulpitis. Dressing the exposure with calcium hydroxide should not be contemplated, because, although healing of the pulp could be expected in a percentage of cases, the risk of irreversible changes in the pulp under a crown or bridge is unacceptable.

(10) A special technique is required for recording an impression of a pinledge. A custom-made impression tray, with about 3.0 mm clearance over the prepared tooth, should be available, and adhesive is applied, allowing sufficient time for it to dry. Lengths of 0.5 mm diameter orthodontic stainless steel wire are cut, each measuring 6.0 mm. One end is bent to form a loop, leaving the straight portion equal in length to the pin-hole. It is a good plan to prepare a number of such pins in advance when time permits. The pins are painted with adhesive which is allowed to dry.

Using a mercaptan rubber material, light bodied paste is spun slowly up each channel, with a shortened reverse spiral filler (Lentulo). The excess rubber is wiped off the surface of the tooth to aid location of the orifices and the pins are pressed into the channels. Further light bodied rubber is syringed around the margins and the tray, filled with heavy bodied rubber, is pressed home. The advantage of this technique lies in the ability to pour several casts, whereas, when polystyrene burn-out pins are used for taking impressions of pin channels, there is a risk that they may remain in the die when it is separated from the impression, making the pouring of further dies impossible. Polystyrene pins should be used only for impressions which are to be plated with silver or copper.

The author uses the following method for making a temporary cover. A silicone impression of the sound tooth and its neighbours is recorded. A polystyrene pin is placed in each channel and the projecting end is softened and flattened by exerting light pressure with a heated plastic instrument. The temporary crown material is prepared, packed into the impression of the tooth, solely on the lingual aspect, and the silicone matrix is placed over the teeth. When the acrylic has hardened, the matrix is removed and the temporary pinledge is teased off the tooth, first cutting off any excess material which has flowed beyond the margins. It is trimmed and polished. A bead of petroleum jelly is placed in each channel to prevent the entry of cement and a film of Tempbond (Kerr) is spread over the fitting surface, but not on the pins, and the temporary pinledge is pressed home (and the occlusion adjusted). It is sound practice to retain the silicone matrix so that, in the event that the temporary cover is broken or lost, a new cover can be made.

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23

The Post-retained Crown

When a tooth has been restored on numerous occasions over a lengthy period, the quantity of dentine which remains to give retention for further restorations is often inadequate. Moreover, the residual incisal angles or cusps are so undermined that they are apt to fracture off under stress. When the tooth is pulpless the residual dentine is brittle; thus any subsequent restoration must be anchored into the root if its longevity is to be assured. To obtain anchorage in a vital tooth, the restoration may be locked into the dentine of the root by means of pins, but with a pulpless tooth the root canal should be used for anchorage in the majority of cases.

Problems arise when making posts for multirooted teeth because of divergencies of the canals, and despite the possibility of constructing interlocking two-part posts and cores, it is simpler to build up the cores in amalgam on retention screws (Dentatus) locked into the canals, provided a fair proportion of the coronal dentine remains. When the residual dentine is undermined and weak, it is preferable to remove it and prepare one canal to the maximum length and to extend the other post a shorter distance into the divergent canal, up to the point at which it can be removed in line with the longer post. This may be only a few millimetres, but it will enhance the retentivity and stability in many cases. If the length of the master post is, of necessity, inadequate, the technician may construct the two posts separately in such a manner that the second one locks into the first and, once cemented, a very strong and retentive unit is established.

As a prerequisite to the construction of a post crown, a radiograph must indicate that there is no obvious pathological change in the periapical region and that the apical portion of the canal is sealed with a non-resorbable root-filling material. It is essential that there be sufficient bulk of dentine around the coronal orifice and that the canal be of sufficient length to take a post which is at least as long as the crown. If, as a result of excessive loss of dentine or removal of caries, the canal is very wide at its orifice, it may be necessary to construct a collar of gold around the circumference of the root in order to splint it.

There are two main categories of post crown, viz. the one-piece crown and the post-retained core, over which a porcelain jacket or gold veneer crown is cemented. There is, however, one great disadvantage in making a one-piece crown in the maxillary incisor region if the lip line is above the necks of the teeth when the patient smiles. In such cases the gingivae tend to recede after a few years and expose the root, which may have become discoloured by root canal medicaments or the breakdown products of the dead pulp or extravasated blood. Replacement of the crown would pose the problem of removing the post, with the possibility of damage to the root. However, with the post and core technique, the crown may be removed and replaced by a new crown, following further preparation of the cervical margin to carry it subgingivally. In other areas, e.g. mandibular premolars, any margin of gold cervically is not normally visible and a one-piece crown incorporating a collar is the restoration of choice.

Preparation of a tooth for a post and core

When constructing a gold post/core, the nature of the preparation will depend on several factors. The quality and quantity of residual dentine are of major importance. If there is sufficient tooth structure available, the core may be prepared in a shortened form in dentine and then lengthened and strengthened with gold (figure 23.1); otherwise, a longer post will be indicated (figures 23.2 and 23.3).

When there is palatal tooth loss subgingivally, a frequent corollary of trauma, the lingual step can be constructed in gold (figure 23.4) and, when the crown is unduly weak or has already been lost, the core is constructed solely in gold, making a slight eccentricity in the cross-section of the coronal part of the canal as

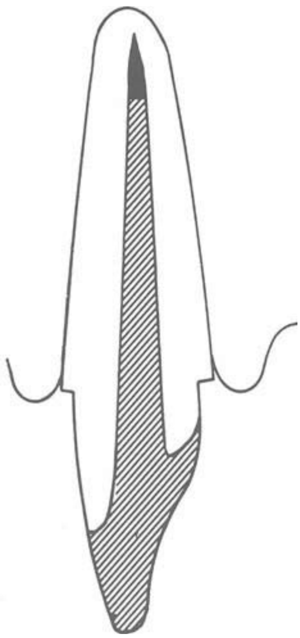


Fig. 23.1 Utilising as much of the dentine as possible so that the production of a direct wax pattern is facilitated.

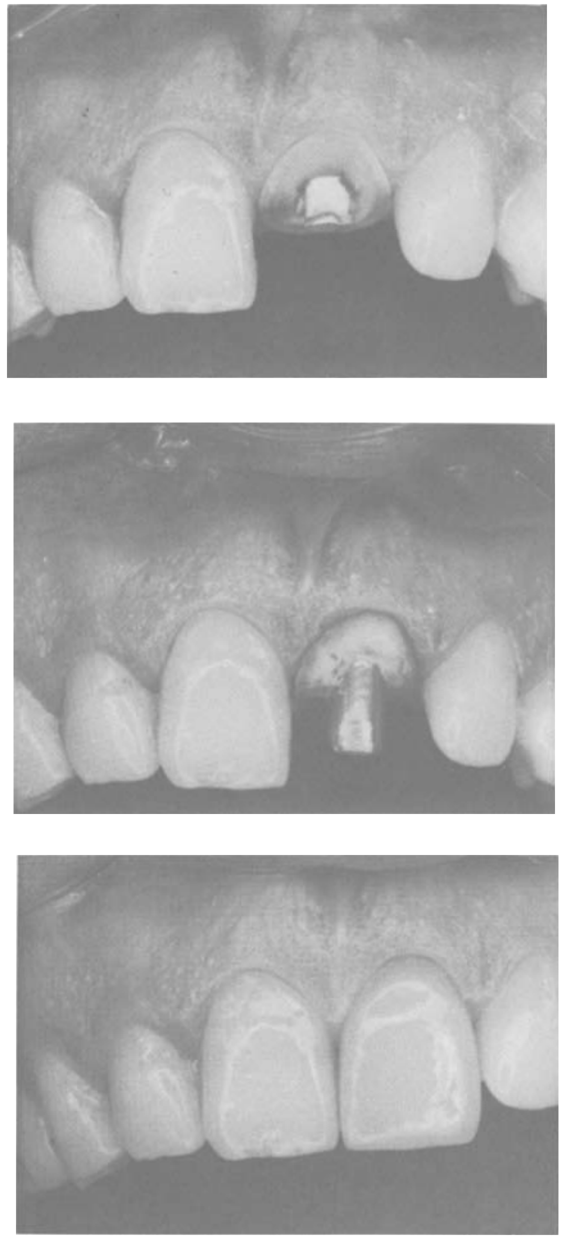


Fig. 23.2 (Top) Upper central incisor, after removal of residual, weak dentine, prepared, with anti-torsion lock, for cast post/core. (Middle) Post/core cemented in root canal. (Bottom) Porcelain jacket crown cemented.

an antitorsion lock (figure 23.5). Should it be necessary to procline or retrocline a crown, the core may be realigned in gold (figure 23.6).

In all cases the root canal is prepared for reception of a post. If the apex has been sealed with a sectioned silver point or an apical silver tip, the remainder of the canal is enlarged and smoothed with tapered Beutelrock drills. The first engine reamer used must be a loose fit in the canal to avoid the risk of a lateral perforation, and graduated sizes of hand or engine reamers should be employed. If the lumen of the canal has been obliterated with laterally condensed gutta-percha cones, removal of gutta percha is aided by softening it with a heated instrument or by the use of a solvent such as chloroform. Precious metal posts or plastic 'burn-out' posts are available matched in size to the larger reamers (Mooser, Tical, Produits Dentaires and Johnson Matthey). The orifice of the canal should be bevelled where it opens onto the stump, at which level it should have a diameter of 1.5–2.0 mm. Some operators insist that the canal should be prepared with parallel-sided instruments to which non-tapered posts are matched. Undoubtedly the retentivity of parallel-sided posts is superior to that of tapered posts, but provided that the post hole is at least as long as the proposed crown and the post fits the canal closely, the final clinical result is indistinguishable. Apart from the need to obtain retention for the post by embedding it in the root to the maximum possible length, stresses are distributed over a larger area of root by a long post. If it is short, the greatest stress is exerted at the tip of the post. In a maxillary incisor with a short post, the forces borne by the palatal area of the crown produce a leverage at or near the neck

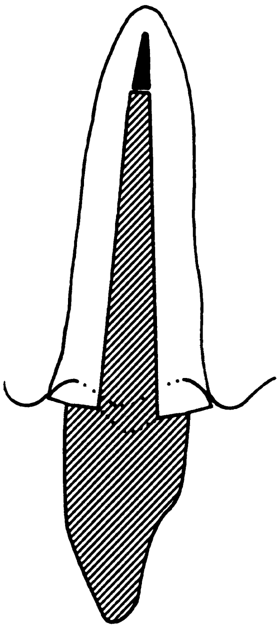


Fig. 23.3 Gold post/core preparation for those cases exhibiting total loss of crown.

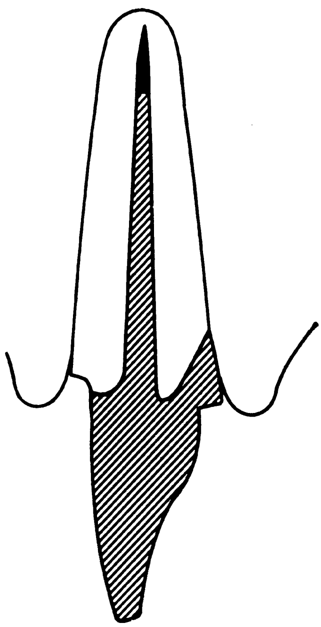


Fig. 23.4 Building up a lingual step in cases of subgingival fracture of the crown or caries.

of the tooth, and this exerts undue lingually-directed stress on the palatal aspect of the root. This accounts for the preponderance of vertical palatal fractures in such teeth, resulting from the concentration of stresses at the tip of the post (figure 23.7).

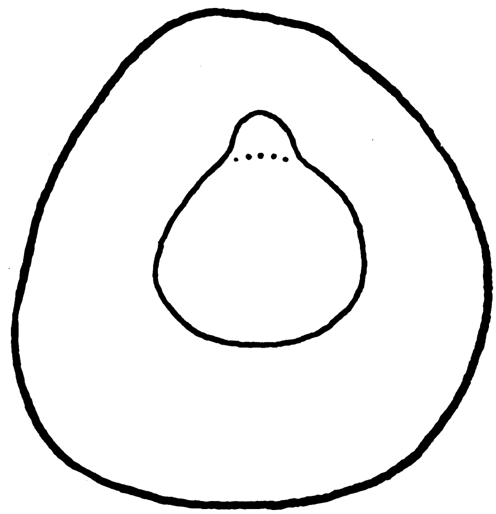


Fig. 23.5 Eccentric shape of coronal part of root canal for anti-torsion lock.

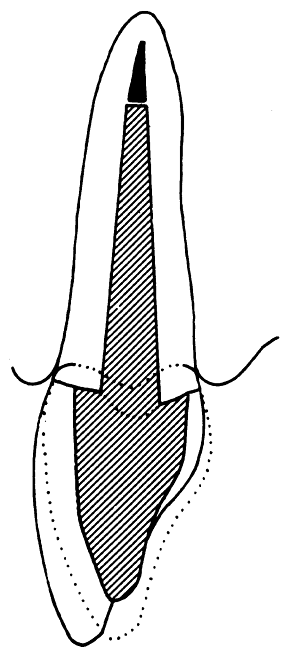


Fig. 23.6 Re-angulation of crown to root by means of gold post/core. Solid line of crown indicates original position, broken line shows new position.

The gingival step is finished at the level of the gingival crest, and the canal and stump are lubricated in preparation for the making of a wax matrix. If a performed post is to be used, it is tried in the canal and shortened so that it does not extend beyond the proposed confines of the core. That part of the post which extends from the canal is heated and touched

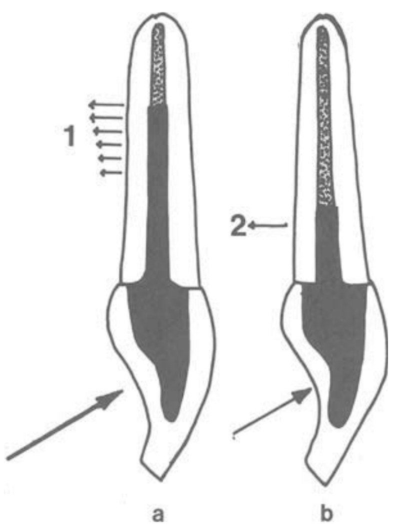


Fig. 23.7 (a) Adequate length of post allows greater area of stress distribution at (1). (b) Short post – producing a stress concentration at (2).

on a piece of sticky-wax, then it is placed in the canal and the wax pattern is built up. When the final contour has been established, the amount of space on the palatal aspect is inspected while the patient slides his lower jaw into protrusive and lateral positions. A minimum clearance of 1.0 mm is mandatory if a porcelain crown is to be made.

The matrix is then smoothed, sprued and removed to be cast for the next visit. In the meanwhile a temporary resin crown is made and cemented, prior to which the dentine is built up with gutta percha to the approximate shape of the wax which was removed. This may be facilitated by inserting a piece of wire, surrounded by gutta percha, in the canal. The reason for this step is apparent when, at the next visit the gold post/core is cemented. The gutta percha is removed from the temporary crown which, after some minor adjustments, may be used again until the porcelain crown is ready.

An alternative technique for taking an impression of the root canal is necessary if no matched posts are available. A length of Q.A. wire or platinised gold wire is selected which is a loose fit in the canal. It is roughened slightly by nipping it lightly in several places with a pair of wire cutters. A short length of heated blue inlay wax is rolled between thumb and forefinger until it is a loose fit in the canal, which is lubricated. The cold wax post is placed in the canal and the wire, held in grooved pliers, is heated and thrust home into the canal. If it cools prematurely and does not reach the predetermined position, it may be grasped with a pair of heated soldering tweezers and, when the wax in the canal softens, it is pushed right home. The soft wax is pressed against the walls of the canal and an accurate fit is thus obtained. The post is withdrawn and inspected, after which it is replaced and the wax core is built up, invested and cast in hard gold.

After the post/core has been cemented, the labial step is carried into the gingival crevice to a depth of 0.5 mm and the preparation and gold are rendered smooth, but not polished. The impressions and shade are recorded for the making of the crown.

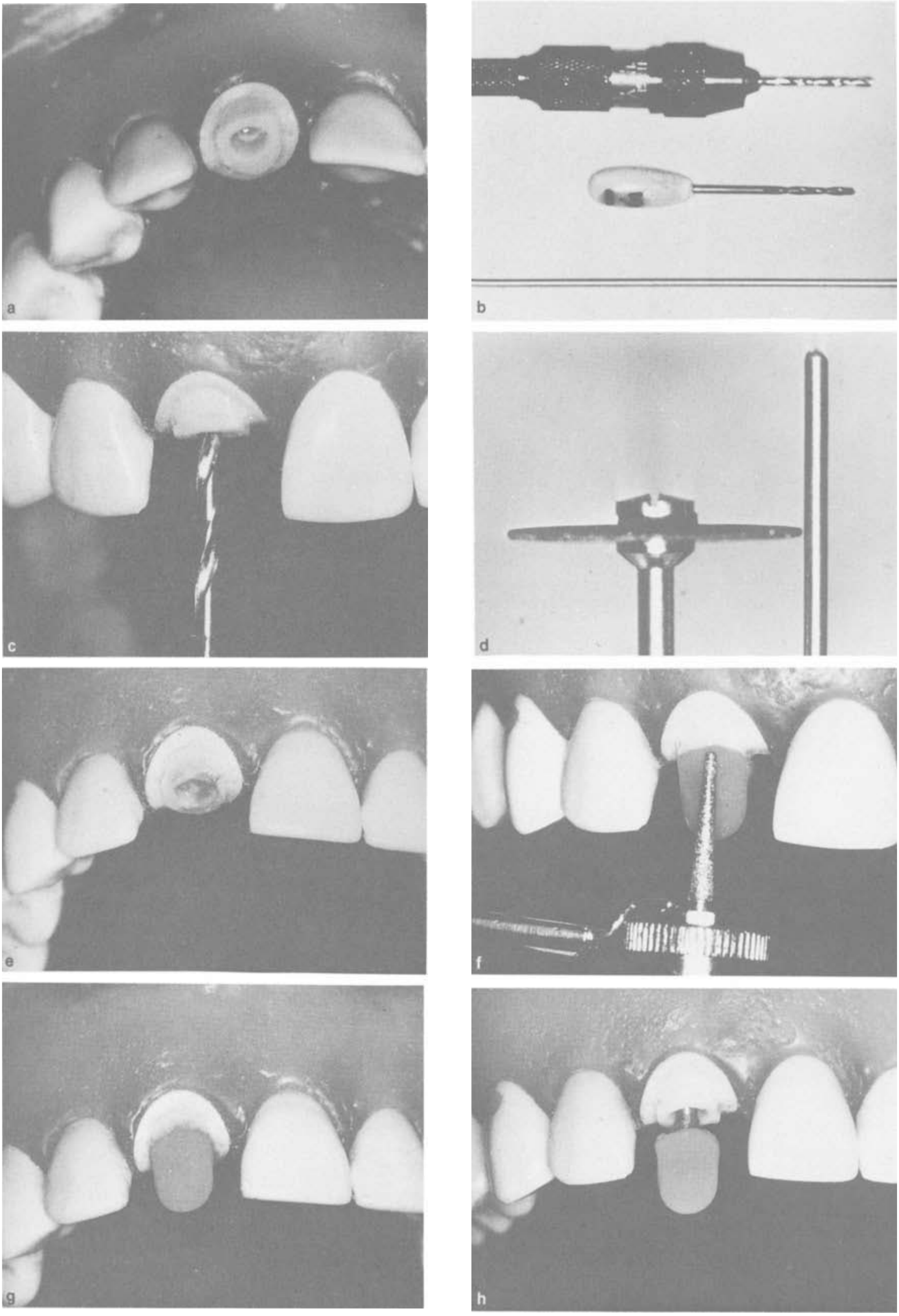
The Wiptam Technique (figure 23.8)

An alternative technique for the construction of a direct pattern on a wrought post entails the use of Wiptam, nickel–cobalt–chromium wire (Fried, Krupp–Essen, Germany) used in conjunction with either blue inlay wax or Duralay inlay pattern resin (Reliance Dental Manufacturing Co., Worth, Illinois, USA). The use of Wiptam wire as a post material was described by Harty & Leggett (1972) and the foregoing technique is a modified version of the method they suggested.

(1) The canal is prepared, leaving undisturbed the 3.0–4.0 mm of apical seal and enlarging the lumen with reamers approximately to size 100. The Wiptam wire is available in a variety of widths. The most useful sizes are 1.1, 1.2, 1.3 and 1.5 mm, and the size selected should be related to the width of the root, using the narrower gauge for fine roots and the wider gauge for thicker roots, such as maxillary canines.

Twist drills matched in size to the wire can be obtained either from the firm who provide the wire or from an engineers supplies shop. They are used by hand in a pin vice for the maxillary incisors and canines, but elsewhere the length of the pin vice precludes their use, hence a small handle can be constructed. The shaft of the drill is notched with a diamond disc to afford retention for a handle of self-polymerising acrylic resin, which is moulded over the shaft and polymerised in hot water.

The drill is rotated to and fro, the reciprocating action, plus slight pressure, enabling it to widen the canal to the predetermined position. This is aided by constant cleansing of swarf from the flutes of the drill, and a rubber stop is used to indicate the position of the drill in relation to the apical seal. When the drill is rotating freely in the canal, the wire is tried in. It must not be too tight a fit because some room is necessary for cement. An improvement in retentivity may be achieved if the wire is sandblasted to remove the surface shine.



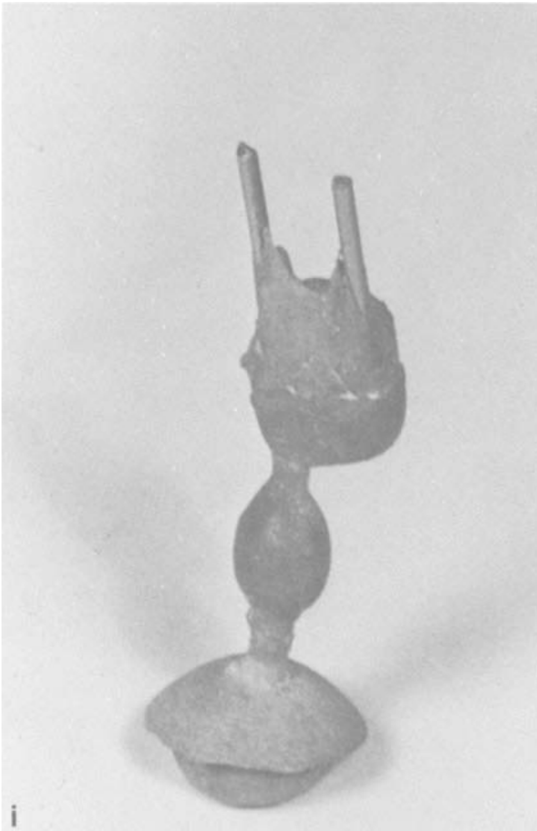


Fig. 23.8 The Wiptam Technique. (a) Shoulder preparation for crown. Post hole enlarged to maximum depth. (b) Twist drills, in pin-vice for anterior canals and with plastic handle for posterior canals. Below is length of Wiptam wire (1.3 mm diameter). (c) Canal lumen enlarged to match Wiptam wire of 1.3 mm diameter. (d) Wire cut and ridged with a Carborundum disc. (e) Canal lubricated with Duralay wax. (f) Core, built up in Duralay on wire, allowed to harden and shaped with stones and diamonds. (g) Duralay smoothed and checked for relationship to neighbours and antagonists. (h) Post/core removed for sprueing and casting. (i) Gold cast on to Wiptam double post for upper premolar.

(2) The coronal orifice of the canal is bevelled lightly and its lumen is drilled slightly wider in order to achieve an anti-torsion lock by means of an eccentric cross section, without weakening the root.

(3) The wire is reduced in length so that it will not project beyond the confines of the core pattern and it is checked in relation to the labial plane of the maxillary incisors and the tips of the lower incisors in centric and protruded positions. Any premature impingement can be prevented by bending the projecting part of the wire. To retain the core, several fine notches are then cut into the visible end of the wire. This mechanical retention is needed because there is no chemical union between the metals.

(4) If the pattern is to be recorded in wax, the canal and coronal dentine are lubricated with a separating liquid such as Microfilm (Kerr) or Die-Sep (Jelenko), and a little sticky wax is seared to the coronal end of the post, followed by a film of inlay wax. The post is pressed into the root while the wax is soft, and thus an impression of the anti-torsion lock is obtained. When the wax has cooled, the effectiveness of the lock is checked and if there is lateral or rotational movement, further addition of wax and reseating of the post are carried out.

Wax is now added to construct the full or partial core, (the more coronal dentine that remains, the easier is the wax-up). When completed the wax is checked to ensure (a) that it relates correctly to neighbouring and opposing teeth, (b) that it is shaped correctly without undercuts or re-entrants, (c) that it is not loose on the wire. A sprue former is inserted and it is removed for casting.

(4a) An alternative and easier technique may be employed through the use of a non-residual acrylic (Duralay) to construct the pattern. Dentine surfaces are coated with a film of the lubricant supplied with the Duralay. The author prefers the use of blue inlay wax to obtain the pattern of the anti-torsion lock. If this is used, it must be cleared from the retention grooves cut in the wire, otherwise the Duralay will not be held firmly in contact with it.

Two Dappens pots are required, one of which holds a few drops of monomer, into which a clean Wards wax carver can be dipped, and the other contains a thin, runny mix of Duralay. Small quantities of the mix are picked up and deposited around the wire and on to the lubricated dentine. The carver is used to push and pat the soft acrylic into roughly the proposed shape, dipping the blade constantly into the monomer to facilitate moulding and smoothing.

The core should be over-built and then left to harden for a minute or two.

When set, the core/post is pulled out of the root and gross trimming is carried out using a coarse sanding disc. Final trimming is done on the tooth and any deficiencies produced can be rectified by the addition of inlay wax or more Duralay. When it has set hard the acrylic is dimensionally stable, hence it may be cast when convenient. The technician drills a small hole in the Duralay, fills it with sticky wax and presses a hot sprue former into the hole. The precaution of an extended burnout time should be observed if Duralay is used, and when casting on to metal, the temperature of the mould should be maintained up to the moment of casting, in order to prevent premature 'freezing' of the gold.

The cast post

Posts may be cast in hard, platinised gold by waxing on to acrylic or polystyrene 'burn-out' posts which are matched in diameter and taper to the reamers. A wrought post is considerably stronger than cast metal when canals are narrower than 1.5 mm, but with shorter canals having an irregular cross-section, a cast post is indicated, e.g. in single rooted maxillary premolars with short roots.

Indirect impression technique

The majority of posts and cores can be prepared for casting by the direct technique, but some operators prefer to use an indirect impression technique in difficult cases or for multiple crowns. In such cases, the two full arch impressions received by the technician are used to construct both cores and crowns. When these have been tried in the teeth and found to be satisfactory, it is essential that each post/core and crown is cemented with one mix of cement in order to ensure that both are seated home fully.

Mercaptan rubber in a special tray is the best impression material. The tray is constructed so that there is room for the coronal end of the post, which is bent and grooved and coated with adhesive in order to ensure that, when the impression is removed, the wire is locked in the set rubber.

Care should be taken to force the light bodied rubber into the widened coronal part of the canal.

Cementation of a post/core

After final trimming of the cast core, the canal is dried with a blast of warm air followed by insertion of a blunt absorbent paper point. A thin, slow setting mix of phosphate cement is deposited over the walls of the canal, using a slow-running spiral filler, and the post is carried up with a side to side, rotary action to allow escape of air and excess cement. When the cement has set, the shoulder, which can be made wider than that on a vital tooth, is taken subgingivally where indicated by aesthetic considerations.

The dowel crown

The original technique for casting a post and diaphragm to fit a dowel crown was difficult, both as regards obtaining an accurate marginal fit and sufficient retention between gold and porcelain. For these reasons the technique has fallen into disuse. In recent years, a brilliant modification of the technique has been suggested by McLean (1967) in which the great strength of alumina tube allows it to be the basis for a dowel crown composed largely of aluminous porcelain. The root canal is prepared to receive a cylindrical gold post, not less than 1.5 mm in diameter, and the coronal end of the root canal is made eccentric to prevent torsion of the post. The part of the post extending from the canal is cast to fit the inside of a length of oval 97.2% alumina tube, which is bevelled internally where it contacts the root face, in order to thicken the gold there and strengthen it. Approximately 3.0 mm of tube are required. The technician waxes-up the post and places the wax-filled tube, in good alignment, over it, joining the two wax components together. The tube is removed and the pattern is sprued and cast in platinised gold. To complete the crown, platinum is burnished to the root face and an aluminous porcelain core is built up, over which the dentine and enamel veneers of porcelain are baked (figure 23.9).

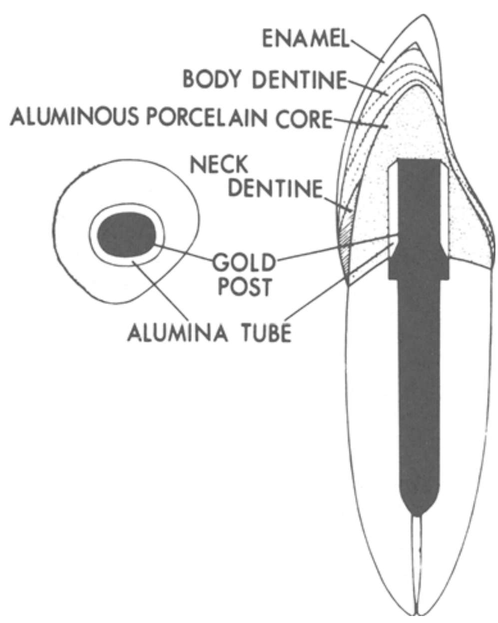


Fig. 23.9 The alumina tube post crown (Courtesy of J. W. McLean).

Finally, after fitting the gold post and the crown in the mouth, the platinum matrix is removed. The canal is coated with a thin mix of phosphate cement, using a spiral filler, and the post is forced home, then, in turn, coated with a thin layer of cement and the crown is seated over the post and pressed home firmly. It is then held in position until the cement has hardened. Figure 23.10 illustrates a crown on |5.

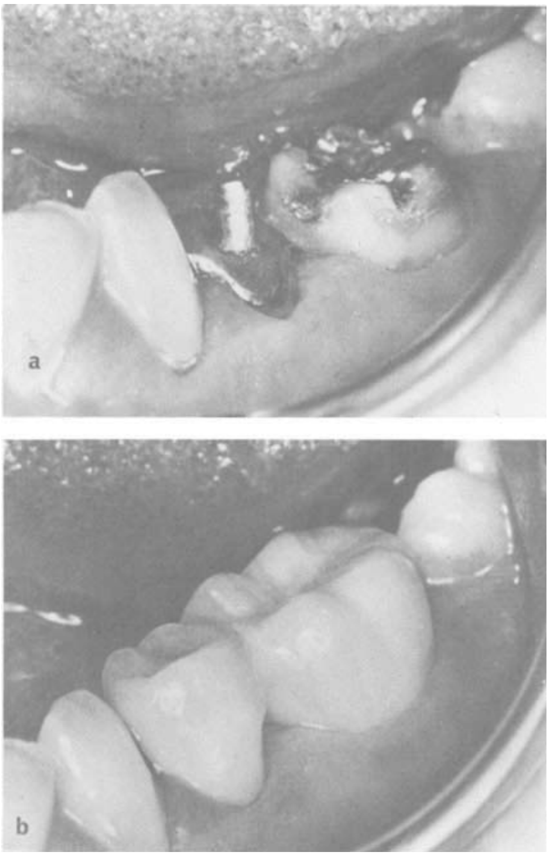


Fig. 23.10 (a) |5 alumina tube post crown. Gold diaphragm with spigot in position on root. |6 preparation for metal-ceramic crown. (b) |5 alumina tube post crown cemented to position on gold spigot. |6 metal-ceramic crown cemented to preparation. Note good embrasure spaces and the absence of compression of the gingivae. Occlusal tables of crowns have also restored the anatomy correctly without over-contouring of the buccal and lingual surfaces. (Courtesy of J. W. McLean.)

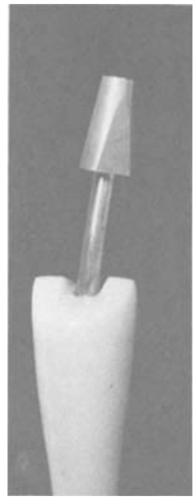


Fig. 23.11 Charlton stainless steel post/core.

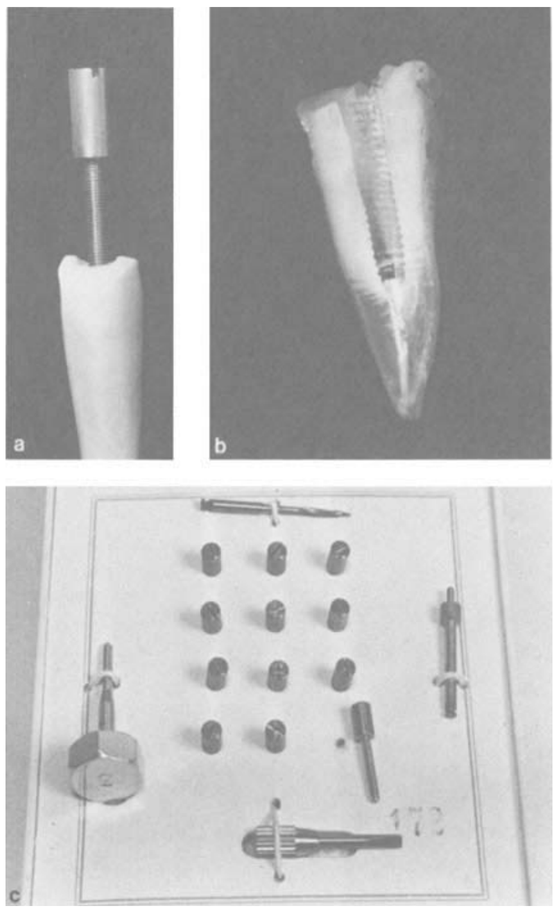


Fig. 23.12 (a) Kurer screw post/core. (b) Section through a root showing the screw thread. (c) The posts with (top) the engine reamer, (left) the tap, (right) the countersinking bit and (bottom) the screwdriver.

The use of a preformed post/core

(a) The Charlton post (figure 23.11).

The Charlton post is constructed in stainless steel with a partially contoured core with flat facets, mesially and distally. The post is parallel-sided. The canal is prepared with a reamer matched to the post and a labio-lingual groove is cut involving the root canal orifice, into which the core is made to lock, as an anti-rotation device. After the post is cemented into the canal, preparation is completed with high speed drills.

(b) The Kurer post (figure 23.12)

In 1967, Kurer described a technique for making a core by screwing a brass-headed stainless steel screw into a root canal. The technique consists of reaming the canal to size 110 or 120, having cut off the natural crown about 1.0 mm from the gingival margin, and then enlarging it with a special engine reamer. A hand tap, slightly larger than the reamer, is used to tap a screw thread in the dentine of the canal and the stainless steel post, on which the staked brass head is grooved to receive a screwdriver, is screwed home. In the majority of roots it will not go right home, so the excess length is cut off and the coronal 1–2 mm of dentine is countersunk, using a countersinking bit, the hub of which pivots in the orifice of the canal.

When the post has been checked again, the canal is dried and coated with a film of cement, through which the post is screwed home. After the cement has set, the brass head is trimmed to the shape of a conventional jacket crown stump and impressions are recorded.

This technique should not be used when the canal, or part of it, is already wider than the special reamer, otherwise the risk exists that the unsupported post might be subjected to excessive stress which could result in fracture or dislodgement. Also the technique is unsuitable for teeth which are very narrow mesiodistally, such as maxillary lateral incisors and mandibular incisors, in which it would be impossible to use the countersinking tool without weakening unduly the coronal portion of the root.

In the earlier Kurer posts, the screw thread was cut with a Z-profile thread. This, combined with a correspondingly narrow core, resulted in many reported cases of fractured posts. The post was redesigned and subsequently manufactured with a rolled thread, having an S-profile and a wider core diameter. An investigation by Messing and Wills (1973) showed a great increase in resistance to stress, the Z-thread posts fracturing under test, whereas none of the S-thread posts fractured. These results have been substantiated by clinical experience.

It is sometimes found that, after cementation of a Kurer post and its associated crown, a minute rotational movement of the crown develops. The patient complains of slight looseness of the tooth and a bad taste that can be sucked from under the crown. This problem arises when the cement lute, holding the post in the canal, breaks down under stress, and it is related directly to the absence of an anti-torsion lock. The remedy is to remove the crown, unscrew the post and recement it, and cut a small lingual cavity to involve the dentine and the brass core. The cavity is made retentive and filled with amalgam or composite resin. When set, this 'filling' effectively prevents torsion and no Kurer post should be cemented without it.

Another problem has been encountered by the author when trying to use a Kurer post on a proclined tooth in order to realign a crown back into the arch. So much of the core had to be cut away labially that insufficient bulk remained locked on to the cemented steel post, and the core broke away. This was remedied by insertion of two pins into the root face and construction of a composite core, which, though not ideal, made possible the provision of a jacket crown. However, this factor should be determined before a mistake is made, and an alternative method can then be adopted to construct a realigned core.

Screw-post retention for composite cores

Kurer has devised a special threaded shank which incorporates two fine nuts, or pins over which, after cementation of the shank in a canal, a composite or amalgam core can be built up. He refers to this modification as the 'Fin-lock system' and it is recommended mainly for teeth with an oval cross section and for restoration of a large crown. The function of the root face fin is to distribute stress to the countersunk root face and act as an anti-rotation device, whilst the incisal fin aids in retention of the core. The advantage of this technique over the use of the Dentatus type of screw lies primarily in the more positive retention of the post within the canal.

The one-piece post crown

When the gingival margin of the tooth to be crowned is not normally visible, the construction of a single-unit post crown, instead of one in two parts, is a simpler procedure.

As with the other techniques the root canal apex must be sealed hermetically, but occasionally the preoperative radiograph shows an inadequately sealed canal with a periapical lesion. In such a tooth, if the crown is missing, it may be impossible to carry out satisfactory endodontic treatment because of inability to apply the rubber dam. A good result may be obtained by preparing the total length of the canal to receive a post, after which, impressions having been recorded, the post crown is cemented and the end of the post is used to seal the apex, which is smoothed and checked when a periapical curettage is performed.

One of the causes of failure of post-crowned teeth is vertical fracture of the root. The chief predisposing causes are over-preparation of the root canal or widening of its coronal end as a result of caries; too short a post, causing stress concentration over a smaller area than would occur with a long post; and too large or too angular an anti-torsion lock at the orifice of the canal.

In order to minimise the danger of fracture, these factors must be borne in mind when preparing the root canal. However, by preparing the root perimeter in such a way that a half, three-quarter or full circumferential collar is included in the crown, it is possible to splint the root and this is mandatory when there is a heavy bite and when the root is to act as an abutment for a bridge or precision attachment.

The only drawback to a circumferential collar is the unsightly show of gold, but from a technical viewpoint it is simpler to finish the porcelain or resin facing to gold than to a tooth margin.

Preparation of a root for post crown with full collar

The tooth is cut down to approximately 1.0 mm short of the gingival margin and the root canal is enlarged and smoothed. Clearance is obtained between the root and the neighbouring teeth to allow the passage of the point of a probe. Using a tapered diamond bur in the turbine handpiece a chamfer is produced around the perimeter of the root. The bur, which should have a dome-shaped tip free of diamond chips in order to avoid trauma to the soft tissues, is operated at the level of the gingival crest. The tapered bur is held in a line parallel with that of the root canal and, thus the slight convergence of the walls and the lack of undercuts will allow maximum retentivity. When the teeth are close together, the chamfer is more easily prepared proximally with a diamond disc. The impression is recorded with an elastomeric material after gingival retraction has been effected.

Preparation of a root for post crown with half or three-quarter collar

The half or three-quarter collar is used when a labial or buccal gingival margin is visible and it entails direct fitting of an edge of porcelain or resin to the cut edge of the root. The preparation will vary, depending on the type of facing to be used. If it is to be porcelain, a labial facet is prepared, the slope of which should be 45°, and terminating 0.5 mm under the gingival crest. The lingual chamfer is continued round proximally to merge there with the labial slope, and the area of the canal orifice is left flat. No anti-torsion lock is necessary because the half-collar prevents dislodgement.

However, if a resin facing is to be used, greater bulk gingivally is required, hence a step 1.5 mm in width is cut labially and is merged proximally with the chamfered lingual margin (figures 23.13, 23.14).

In both preparations the angle between the canal orifice and the root face should be well rounded to

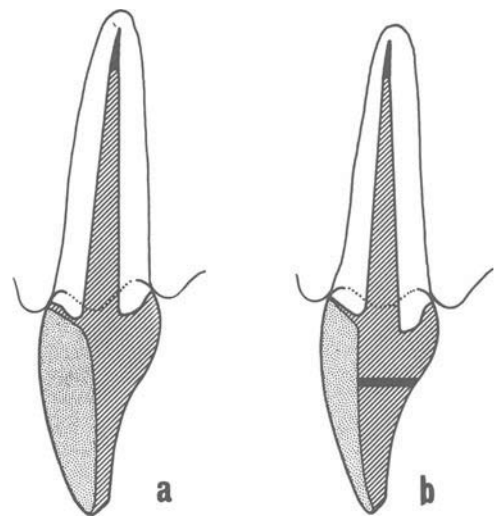


Fig. 23.13 Diagrammatic representation of (a) post crown preparation for acrylic-faced crown. (b) long pin facing. Both roots are finished lingually with a chamfer. Here the acrylic is locked into the gold, leaving a fine gold margin sub-gingivally. This margin can be omitted if necessary on aesthetic grounds.

impart greater strength to the junction between the post and the crown. Furthermore, if the angle were to be sharp and stone dies constructed, there would be a risk that the sharp prominences might be broken off unobserved, thus ruining the fit of the crown.

Apart from the splinting and anti-torsion properties of a collar or half-collar, they will impart a degree of accessory retention to the preparation, depending on the degree of parallelism between the root canal and

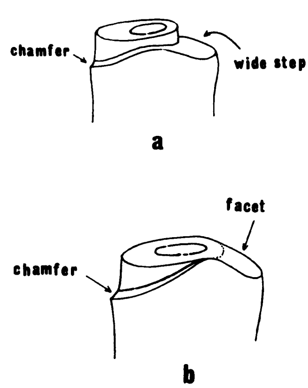


Fig. 23.14 Detail of preparations for (a) acrylic-faced post crown, showing deep labial step merging proximally with gingival chamfer lingually, (b) porcelain-faced post crown. Here the labial surface is prepared as a facet, but the lingual chamfer is unchanged.

the prepared lingual wall. Moreover, because the root is left slightly longer than in the conventional collarless preparation, the crown length will be correspondingly less. Consequently a shorter post will be required; a factor of importance when the root is short or the canal impassable beyond a metallic seal.

The impression is recorded with an elastomeric material in a special tray (see chapter 18).

The acrylic resin post crown

It may happen that a tooth which requires a post crown has a poor prognosis, but for a variety of reasons its retention is indicated, even though it may be only for a limited period. In such a case acrylic resin may be processed directly onto a post and diaphragm. In this way the acrylic is locked mechanically to the post and diaphragm which are cemented to the root. If acrylic is processed onto a standard stainless steel post, the cement bond between the resin and the dentine tends to break down and wash away in a short time, due to percolation of saliva which results from the high coefficient of thermal expansion of acrylic resin.

If the crown is required for a number of years, it should be backed with gold, otherwise the wear which results from attrition will allow the opposing tooth to over-erupt. On the other hand, should it be necessary to make a very simple crown for an indefinite period, a small piece of gold plate or stainless steel gauze (of the type used for reinforcement of dentures) should be incorporated on the lingual aspect during processing of the acrylic.

Methods of facing post crowns

Acrylic resin

Despite the disadvantages inherent in acrylic resin as a facing material, it is still used for reasons of economy. If the facing has a depth of 1.5–2.0 mm, it should retain its colour for approximately seven to ten years, but abrasion from toothbrushing frequently exposes the gold near the incisal margin after a shorter period. Recently developed cross-linked resins are more resistant to abrasion, and acrylic masking varnishes, matched to various shades, are now available to prevent undue change in the colour of the acrylic as wear continues.

The technician may select an acrylic denture tooth and, after grinding it to fit the gingival margin, wax-up a backing and join it to the post. The backing, when cast, is undercut and united to the facing with a resin cement. Alternatively, the post and backing are waxed-up and cast; the labial aspect of the backing is made retentive and a facing is waxed-up, invested in a flask and replaced by a heat-curing resin, after the application of masking varnish to the backing.

In view of the poor resistance to wear, it might be argued that there is no place for acrylic resin, but the simplicity of replacement of the facing *in situ* should not be overlooked. When this is necessary, an impression of the labial surface of the tooth and the shade are recorded. A high-grade acrylic tooth, slightly larger than required, is purchased and cut down until close to the dimensions of the existing facing, and the fitting surface is hollowed out. At the next visit, the facing is cut away, exposing the metal, and the gross reduction of the new facing is done with an acrylic bur until the marginal fit and general contour are close to the desired result. If a 4B pencil is rubbed over the metal the acrylic will be marked on contact, and in this way the final fitting may be achieved. Finally, the metal and resin are made retentive and any grease is removed by washing the surface with methyl methacrylate monomer. The facing can be cemented with a self-polymerising acrylic resin such as Texton, Sevriton or Orthofil. Having seated the facing, the tooth is held firmly between thumb and forefinger and excess resin is removed from the margins with a probe. Once the resin has reached the dough stage the excess should not be disturbed, otherwise it could be pulled out from under the facing. The setting should continue under a film of silicone grease or vaseline to prevent evaporation of monomer. Finally, any necessary adjustments and polishing of the margins are carried out.

Porcelain facings

Porcelain is without doubt the better material for facing post crowns because it is resistant to abrasion. However, it is necessary for the operator to inform the technician regarding the type of facing which should be used. The Steele's facing, which is interchangeable may be used solely when there is no bite on the incisal edge, because it is not possible to cover that edge with a protective layer of gold, due to the direction of insertion of the facing onto the backing. On the other hand, the boxed-pin facing, devised by Makinson, and the long-pin facing are inserted into the backings at right-angles to the axis of the tooth, hence they may be encased in protective veneers of gold. Fused porcelain to gold is similarly satisfactory but the backing must be cast onto a highly platinised gold or cobalt–chromium wrought post, and the incisal third of the crown should be composed entirely of porcelain. This is stronger than a gold backing which must be thin incisally and consequently may bend under stress which, in turn, can set up stresses in the porcelain and cause it to fracture. Moreover, the absence of metal in the incisal region improves the aesthetics. The author has seen two bonded crowns in which the posts, which had been cast in one piece with the backing, had fractured within the root. For this reason it is recommended that a wrought post should always be used.

The accepted and most commonly used technique for post crowns, however, is that in which a core is constructed on a wrought or cast post and then, after it has been cemented, a crown of gold, porcelain, or a bonded combination of the two is made. The preparation for a bonded crown on a non-vital tooth permits a labial or buccal step of 1.5–1.75 mm width which merges proximally with a substantial lingual chamfer. There should be an occlusal clearance of 1.5–2.0 mm, and all line angles and point angles should be rounded. The wide step allows sufficient bulk of porcelain to produce a good aesthetic result, and the absence of sharp angles in the preparation enhances the strength of the metal component.

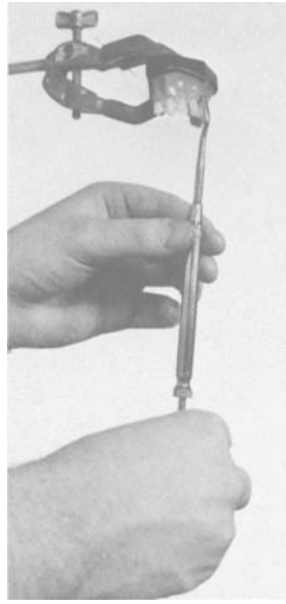


Fig. 23.15 Crown remover. The instrument is engaged under the margin of the crown and the lower member is pulled down sharply, producing a jarring shock to the crown, with a view to causing disintegration of the cement.

Removal of posts and post crowns

If a post crown has to be removed, a method of breaking down the cement lute is required. The author has used the following method with success on many occasions.

A hole is cut approximately 1.0 mm in diameter, from labial to lingual using a diamond bur in the turbine handpiece. 90 cm of 0.8 mm soft, stainless steel orthodontic wire is threaded through the hole and the ends are twisted firmly together. A metal bar is placed in the loop of wire, which is held taut, while the chairside assistant supports the patient's head with one hand on either side. One or more sharp blows on the bar with a surgical mallet will usually suffice to luxate the crown, but occasionally more will be needed. The patient must be warned that an unpleasant jarring sensation will be felt, but that it will not be painful. However, if the patient is of a nervous disposition an alternative method should be tried. To avoid trauma to the lower lip, a gauze swab should be interposed between it and the wire. A crown-removing instrument is also available, which operates on the same principle (figure 23.15). This instrument (Crescent Manufacturing Co. Chicago, USA) will only be usable if there is an obvious ledge around the margin of the crown, under which the instrument can be applied. In consequence, when a crown has perfect margins, a groove can be cut gingivally to allow purchase by the remover.

If the radiograph reveals that the post is short, or that there is a history of periodic loss of the crown, a chisel may be insinuated between crown and root and twisted, or a small groove may be cut in order to allow insertion of the chisel under the crown.

If these methods fail, a post extractor (figure 23.16) must be used. The crown is cut down until the post alone is left projecting from the root canal. The post extractor is adjusted over the post and the jaws are tightened until they grip the labial and lingual sides of it. Then the flat-sided knob is rotated; this causes the jaws on the proximal sides of the post to advance into

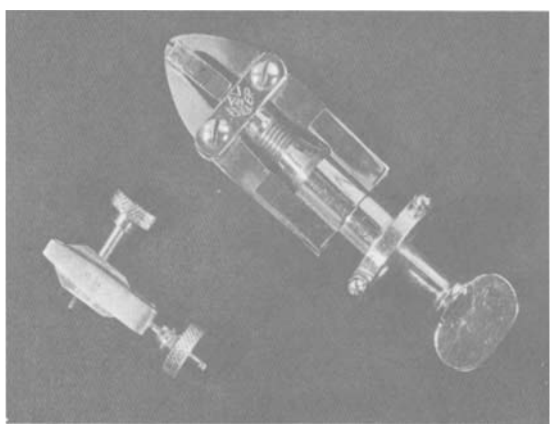


Fig. 23.16 Two versions of a crown post extractor having the same basic mechanism.

contact with the root face. This draws the post out of the canal without difficulty.

In those instances when the patient presents with the post fractured within the canal, the problem of drilling it out may be insuperable. If a powerful pen-torch light is used to transilluminate the labial aspect of the root, the end of the post remains visible while, by direct vision, a small diamond bur is used to drill it under water spray. The drilling is done intermittently and it may be necessary to extrude the bur slightly from its chuck in order to reach down the canal.

Even if the whole post is not removed, a compromise solution may be reached by locking a Dentatus screw in the canal and placing three or four pins at varying angles in the dentine around the canal. A copper band is then wedged over the root and a core built up in amalgam, which is shaped later for a jacket crown.

Removal of posterior veneer crowns

At this juncture it is convenient to include methods for the removal of posterior veneer or bonded crowns and of fixed bridges. The single crown may be removed, using the reverse mallet instrument (Crescent Mfg. Co. (Chicago)) but, because the point of application of force is unilateral, there is a considerable shearing stress applied to the underlying stump or core, which causes total or partial fracture to occur in a percentage of cases where there is strong retention. The author has applied the principle of orthodontic band removal to this problem with a large measure of success. A hole, wide enough to admit the occlusal component of a pair of band removing pliers, is cut through the occlusal surface as far as the underlying dentine or core material. The pliers are adjusted with one end through the hole and the other under the cervical margin of the crown and, when squeezed, the cement lute is broken and the crown dislodged (figures 23.17 and 23.18). Care must be taken to ascertain first whether any laterally placed pin or set screw has been inserted to provide retention, because it would be necessary to drill it out before removing the crown.

A simpler technique for dislodging a crown, using the same principle, entails the use of a crown remover (patent pending), which is soon to become available. This instrument is tightened over the buccal and lingual walls of the crown by screwing the cylindrical rod through an occlusal hole into contact with the occlusal surface of the underlying tooth. When tightened further with a ratchet spanner, the force directed against the tooth breaks the cement and the crown comes loose. The insertion into the device of an

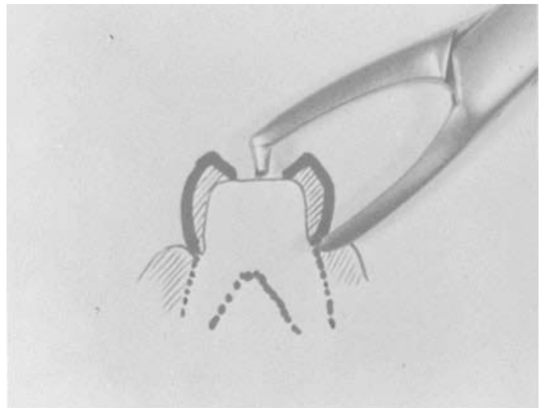


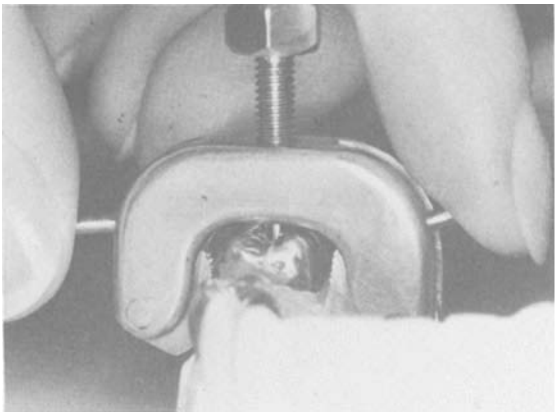
Fig. 23.17 Application of orthodontic band removing pliers to dislodge a cemented crown.

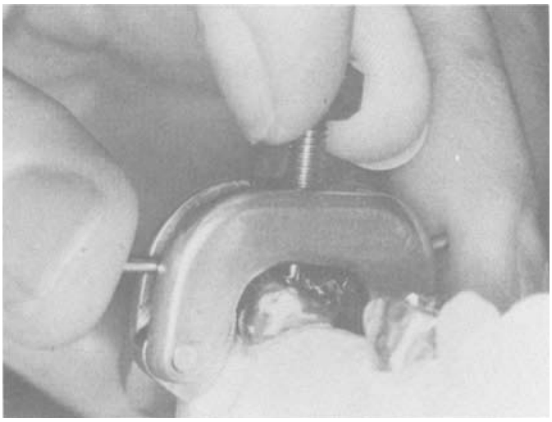
extra-oral extension is planned in order to avoid the risk of accidental dislodgement and swallowing during use.

Some crowns resist all such attempts at removal and, as a last resort, the crown should be hemisected from buccal to lingual and by twisting an instrument in the groove thus produced, the two halves may be removed.

Soft gold shell crowns, often made of thin, wrought gold, may be removed by drilling a T-shaped cut on the buccal surface, and peeling back the buccal segments to allow insertion of an enamel chisel between the occlusal metal and the tooth. When the chisel is twisted or levered upwards, the cement lute is fractured (figure 23.20). It is then feasible to bend back the buccal segments and use the old crown as a temporary cover for the tooth. Similarly, when removal of a crown has been effected by a device necessitating

Fig. 23.18 Removal of a sub-luxated bridge by the application of band removing pliers.





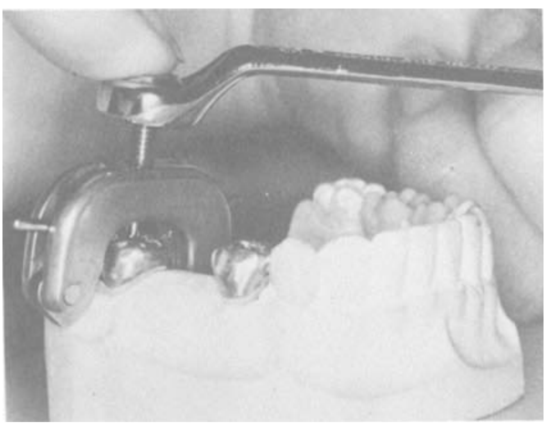


Fig. 23.19 Crown remover (prototype). (Top) The lateral guides are adjusted to bring the serrated members into close contact with the most bulbous parts of the lateral aspects of the crown. The central post is screwed down into contact with the underlying tooth through a hole cut in the occlusal surface of the crown. (Middle) Holding the device in contact with the crown, through pressure on the guide pins, the central post is tightened onto the tooth. This fixes the serrated members against the crown. (Bottom) Finally a box spanner (ratchet) is used to screw down the post. This fractures the cement, and the crown separates from the tooth.

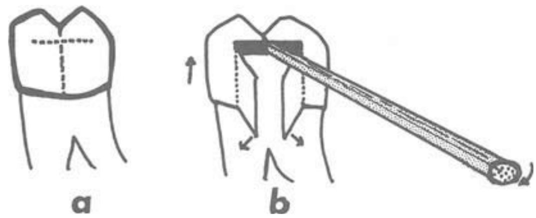


Fig. 23.20 Removal of a soft gold wrought crown or thin cast crown. (a) T-shaped cut made through buccal surface of crown. (b) Buccal segments bent outwards and an enamel chisel is inserted between tooth and crown, which is dislodged when the chisel is twisted.

the cutting of an occlusal hole, the crown could also be used as a temporary cover.

The removal of bridges

Removal of bridges is more difficult and requires great care to avoid fracturing the abutments, especially when they are fragile, and it necessitates also the exercise of ingenuity. If the operator knows that the abutments are vital and robust, an attempt may be made to break down the cement, using either a reverse mallet, crown and bridge remover or a double loop of 0.8 soft steel wire (vide supra), passed through each embrasure between the pontic and the retainer (figure 23.21). Otherwise, occlusal holes may be cut and the

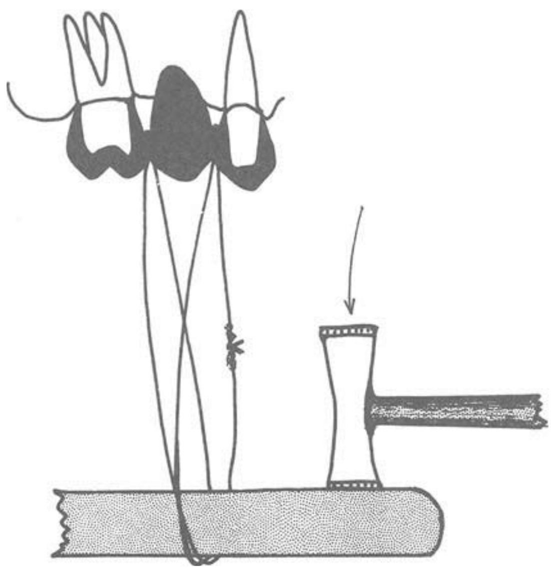


Fig. 23.21 Removal of a bridge. Soft stainless steel wire is looped through both embrasures and the ends of the wire are twisted together. A sturdy metal bar is placed through the loops, pulling them taut, and is struck sharply with a surgical mallet with the object of shattering the cement.

cement at either end fractured by the use of one of the methods described above. Sometimes it may be easier, especially if one retainer is to be left temporarily in place, to drill through the junction between pontic and retainer in order to remove half of the bridge.

It is advantageous to take an impression of the arch, using heavy bodied silicone putty, before removal of the bridge. This will provide a matrix for the construction of a temporary bridge after any necessary modification of the abutments has been done.

When drilling through gold alloy or non-precious metals, such as chrome–cobalt, fissure burs (T.C.) should never be used because they fracture too easily. A small round T.C. bur is more efficient used with a gentle, stroking action. For cutting through porcelain veneers, a long fine diamond bur, also used in the turbine handpiece and under a copious spray of coolant, has proved most effective.

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24

Temporary Crowns

(1) For jacket crown preparations

After a vital tooth has been prepared for a porcelain jacket crown, it is imperative that the dentine be protected from thermal and osmotic stimuli and that a temporary restoration, as lifelike as possible, be cemented securely for the interval between visits.

Apart from the protection of the pulp, a well fitting temporary crown will prevent proximal food packing, and also prevent hyperplasia of surrounding gingivae, which would occur quickly if crown margins were left overhanging, rough or deficient, resulting in entrapment of plaque.

Similarly the occlusion should be adjusted to prevent drift or over-eruption. It is sound practice to apply a layer of protective varnish (copal/Ether or Tresiolan) to vital dentine before making the temporary restorations.

Prior to starting the preparation, any defects in the natural crown should be waxed-up to normal contour, if necessary, and an alginate or silicone impression of the arch recorded in a box tray. The impression is then washed and stored in a self-sealing polythene bag.

Before the impressions for die and locating models are recorded, the alginate impression is dried off with a blast of warm air and the space corresponding to the prepared tooth is filled with a resin, such as Temp-Span (Kerr) (a self-polymerising acrylic resin), Trim (Bosworth) or Scutan (E.S.P.E.), (an epimine plastic). With the acrylic resin, it is necessary to choose a shade and to lubricate the tooth stump with vaseline or silicone cream, in order to minimise irritation of the pulp and to avoid adhesion of resin to dentine. With Trim and Scutan, however, this is not necessary, because the resins neither cause irritation nor do they adhere to dentine.

The impression is seated firmly back onto the teeth so that the resin flows around the stump and the excess is spread beyond it as an easily removable film. When the resin is hardening, the impression is removed and this, as a rule, brings the temporary crown with it. The impression is then placed in a warm place to accelerate polymerisation of the resin while the working impressions are recorded.

When the impressions have been completed, the temporary crown is teased out of the alginate and trimmed. Acrylic resin contracts on polymerising, hence it is often necessary to drill a thin layer from the fitting surface of the crown, whereas this difficulty does not arise with Scutan; however, the latter is obtainable in one shade only, hence it may not be acceptable on the grounds of aesthetics. 'Trim', however, is supplied in two shades and is tougher than 'Scutan', although its setting time is slower, but its polymerisation shrinkage is negligible, so it is preferable to methyl methacrylate. It contains N. Iso-butyl methacrylate.

When using the matrix technique to make a temporary crown and exerting pressure on the tray, a fine flash of the resin may be left on the hard or soft tissues because, as a result of its translucency, it tends to be relatively invisible.

The operator should make a careful search for such retained flash and remove it.

The author has found that, to avoid inclusion of air bubbles, Scutan is best introduced into the impression by injection from a disposable plastic hypodermic syringe, used without a needle, and filling the impression area from the deepest part in exactly the same manner as used for the injection of rubber base.

When filling the impression of the tooth with acrylic resin, it should have reached the 'dough' stage, and is best packed in small increments, each of which is pressed firmly into the corners of the impression area, to avoid entrapment of air. If a strip of lead foil, from an X-ray film, is wrapped around the tooth stump and secured labially with a tinman's joint and burnished firmly into place, it will be removed with the temporary crown. When the foil, in turn, is removed from the crown it should compensate for the contraction of the acrylic resin, and so obviate the need to grind a layer out of the fitting surface. This step is not necessary when using 'Trim'.

The chief advantage of this technique is in obtaining a temporary crown almost indistinguishable in contour from the natural tooth. The same method may be used for the construction of a temporary bridge, by placing an acrylic facing in the space in the mouth and holding it there with sticky wax while the impression is recorded. The tooth and wax are then removed from the impression, leaving a space which is filled with resin to unite the temporary crowns and thus make a temporary bridge.

Crown forms

In place of the tray technique, a cellulose acetate or polycarbonate crown form may be used. By reference to a mould guide, a suitable form is chosen and trimmed with curved scissors until it relates to the gingival margin of the preparation, and is in line with the neighbouring teeth. Holes are then made with the point of a probe in the incisal angles or tips of cusps, to allow the escape of entrapped air, and the form is filled with a dough of self-polymerising resin, of a selected shade, and positioned over the vaselined stump.

When the resin is almost hard, the crown is teased off the tooth and placed on a heated area, such as a steriliser or lamp, and allowed to harden for a further one or two minutes.

Then the crown form is divided and peeled off and the marginal excess is ground away, down to the line designating the perimeter of the preparation. A small amount of resin is drilled out of the fitting surface with a round bur and the crown is tried on. The occlusion is adjusted and, when the crown is satisfactory, it is cemented with Temp-Bond (Kerr). Alternatively, after light lubrication of the stump with vaseline, the temporary crown may be cemented with a quick-setting zinc eugenolate cement, which will hold the crown firmly for a longer period if delay is unavoidable.

A problem associated with the use of polycarbonate crowns is their tendency, when used as long term temporary crowns, e.g. on fractured incisors in children, to separate from a composite resin cement.

Nitkin *et al.* (1977) found that, by priming the polycarbonate with a syrup of methyl methacrylate before filling it with composite resin and seating it on the tooth, its separation from the composite was prevented. When such temporary crowns are placed over fractured vital dentine, pulpal protection with calcium hydroxide cement is recommended.

(2) For post crowns

The above techniques may be adapted to restore temporarily a tooth prepared for a post crown, or for a post and core which is to be cemented at a subsequent visit. When a post crown preparation has been completed, a crimped wire, bent in the form of a loop where it extrudes from the root, or a temporary German silver post may be used to anchor a resin crown. If wire is used, it should be heated and surrounded by a layer of hot gutta percha, in which state it is thrust into the root canal. All excess of gutta percha is removed from the root surface with a hot instrument and the dentine of the root face is lubricated with a film of vaseline. It is necessary to check the position of the wire loop in relation to the contour of the labial, lingual and occlusal or incisal aspects of the adjacent teeth, so that it will not affect the aesthetics or interfere with the occlusion. In the majority of cases, the wire may be cut from a paper clip. Experience has shown this to be quite satisfactory.

Having placed the pin or temporary post *in situ*, a resin crown is made over it (figure 24.1). When the resin has hardened, the crown is removed and any trimming and polishing which are necessary are carried out, making quite sure that the crown is ground free from the bite. The wire-based crown is secured solely by heating the gutta percha and pushing

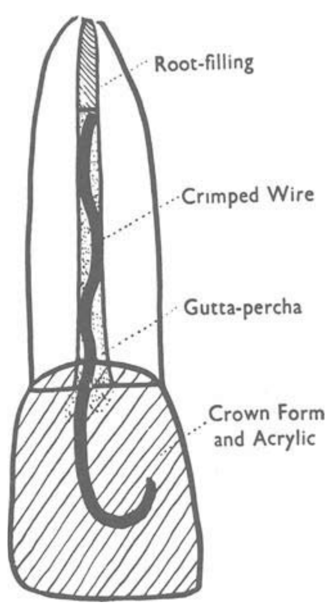

Fig. 24.1 Temporary crown constructed for a tooth prepared for a one-piece crown.

the crown home. The root canal should be dried and any excess of gutta percha, which is extruded around the gingival margin, is removed with a scaling instrument. The temporary crown, constructed on a ready-made post, on the other hand, is given a light coating of Temp-Bond, to which the modifier has been added to facilitate its subsequent removal, and this is usually sufficient to hold the crown. It is inadvisable to use a temporary cement with strong adhesive properties once impressions have been recorded, because it may prove difficult to eradicate every vestige of it from the canal when the permanent crown is fitted. Temp-bond may be dissolved out with chloroform.

Post/core preparation

When a part of the natural crown is left to form a portion of the stump, the technique may be modified, so that only one temporary crown will serve both before and after insertion of the gold core.

In such a case, a crimped wire is preferable to a post and it is fitted in such a way that the loop occupies a position within the confines of the gold core which is to be inserted (figure 24.2). The contour is then shaped in gutta percha, similar in form to the wax which was removed. The temporary crown is then constructed, removed and trimmed and replaced after heating the gutta percha.

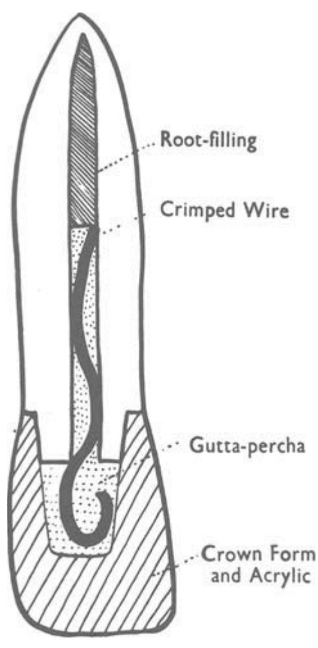

Fig. 24.2 Temporary crown constructed for tooth awaiting insertion of gold post/core.

At the next visit, the gold post/core is cemented and the preparation is completed. Then the gutta percha is removed from the wire, which is heated to release it from the resin crown. Any gutta percha left in the crown is removed and sufficient resin is drilled out to allow the crown to seat home, after which it is cemented with Temp-Bond.

(3) Full veneer preparations on posterior teeth

In many cases, temporary crowns may be made for posterior teeth, using Scutan or acrylic resin in an alginate impression, but should there be a strong bite or minimum occlusal clearance, resin crowns would tend to fracture. In such instances, the aluminium temporary shell is more apt to withstand stress without fracturing. Two types of aluminium shells are available; those which are cylindrical with a closed end and those which have a contoured occlusal surface (figure 24.3).

A shell of appropriate size is selected and the margins are trimmed with band shears to allow it to seat loosely over the tooth and cover the margins, without interfering with the occlusion. The margins of the shell are then contoured to produce a gingival bulbosity with an internal convergence of the edges, using Clark's Triplex pliers.

This makes the marginal fit of the shell too tight, but when pressure is exerted in an apical direction the shell is forced home and, because of the contouring of the edges, a good marginal fit is obtained. Should there be any blanching of the gingivae, the margins of the shell must be trimmed back and recontoured, otherwise trauma to the gingivae would lead to gingival hyperplasia, which would make the fitting of the crown extremely difficult.

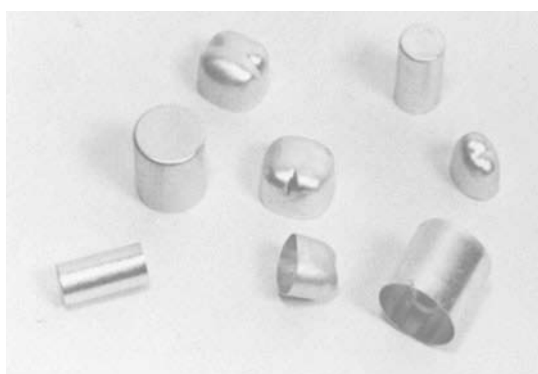

Fig. 24.3 Two types of aluminium temporary crowns, 'shaped' and 'pill-box'.

Aluminium shells may be cemented with zinc eugenolate cement or Temp-Bond when the tooth is vital, but the author has used hot gutta percha to hold aluminium shells on non-vital teeth. This has proved quite satisfactory, both with regard to comfort and retention, and has the additional advantages that there is no marginal residue of cement to remove, while the gingival condition is optimum at the next visit, provided the crown form has been correctly contoured.

(4) Three-quarter crowns

The nature of the prepared area of a tooth, cut down for a three-quarter crown, renders it unsuitable for the use of cellulose acetate crown forms, because the three-quarter resin crown tends to be too flimsy to withstand stress on either anterior or posterior teeth. On the other hand, an alginate impression with Scutan or resin will produce quite satisfactory results in many cases. Aluminium shells, however, are preferable for posterior teeth because of their toughness.

For three-quarter pinledge preparations, the dentine should be lubricated, and three Williams plastic pins inserted into the holes, after their bases have been touched with a heated plastic instrument and flattened. An acrylic resin backing is then made which locks the pins together. This may be built up freehand on the tooth or by the use of an alginate impression matrix. To avoid the entry of cementing medium into the pinholes, it is necessary to put a bead of vaseline into each orifice, and then the temporary pinledge may be fixed in place by smearing Temp-Bond between the pins. Should the temporary cover be required for a few days only, sections of absorbent paper point may be coated with vaseline, placed in the pinholes and covered with a thin layer of polycarboxylate cement.

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25

Endodontics

This chapter deals with the subject of root canal treatment (or endodontics, in present day nomenclature), but it is impossible to cover in full detail every aspect of this ever-expanding subject in the available space.

The reader, having made use of the information presented but wishing to pursue the subject in greater detail, is referred to the standard works listed in the bibliography at the end of the chapter.

The subject of root canal therapy comprises all aspects of treatment of the pulp and related periapical tissues, the resolution of infective processes and the prevention of their recurrence.

The commonest causes of pain of dental origin are acute pulpitis and apical periodontitis, the latter resulting from the spread of inflammation or infection into the periapical region. Although it is possible to resolve some early cases of pulpitis by the use of corticosteroid-antibiotic mixtures, after dealing with the causative factors (e.g. by the removal of caries), it is usually necessary to remove the pulp and replace it by a sterile, impermeable solid root-filling.

There are certain systemic conditions which contra-indicate endodontic treatment, such as a history of rheumatic fever or chorea, or a congenital valvular lesion of the heart, which would predispose to the development of a subacute bacterial endocarditis, should a bacteraemia result from instrumentation in the root canal. On the other hand, certain conditions which lower local resistance, e.g. leukaemia, uncontrolled diabetes, or post-irradiation endarteritis, might indicate a palliative approach, and it would appear that less risk could attend careful endodontic therapy than extraction of the offending tooth.

Indications for root canal therapy

Root canal therapy is indicated in the following conditions:

(1) Severe pulpitis, in which pain arises spontaneously. Also, when a history is presented of thermally induced bouts of pain, but without either tenderness on percussion, abnormal reaction to vitality tests or radiographic abnormality, the pulp may be undergoing irreversible pathological change. If the symptoms persist despite attempts at palliative treatment, and a decision is made to extirpate the pulp, administration of a local anaesthetic will be necessary, but there is often a marked absence of viable pulp tissue, judging from the lack of bleeding when cleansing the canals.
(2) Acute infection in the periapical region of a pulpless tooth.
(3) Subacute or chronic periapical lesions.
(4) Symptomless teeth which give no response to vitality tests, and despite the absence of radiographic signs.
(5) Where an elective pulpectomy must be performed, to be followed by preparation and use of the root canal for retention of a post.
(6) Although not invariably indicated, because of the possibility of resolution in certain cases, pulpectomy may be necessary after traumatic or carious exposure of the pulp.
(7) Chronic proliferative pulpitis (pink spot), provided that the internal resorption has not perforated the wall of the root or crown.

Local contra-indications to root canal therapy

Root canal treatment should not be carried out:

(1) When it is not possible to follow an aseptic technique, e.g. in a tooth which is badly broken down to a point far below gingival level, so that isolation of the crown is impracticable.
(2) When subsequent restoration of the crown is impossible.
(3) When teeth have abnormally shaped roots, especially in relation to vital structures such as the maxillary antrum or mental nerve, so

that both conservative and surgical approaches are hazardous.

(4) When the position and alignment of the tooth prevent access to the root canals.
(5) When internal resorption has perforated the root.
(6) When posterior teeth have periapical lesions, but access is impossible because of irremovable previous root-fillings, broken instruments, curved and blocked canals.
(7) When teeth are fractured just below the gingival attachment and the crown is loose.

Basic principles of endodontic therapy

The main objectives of root canal treatment are the control and eradication of infection; the preservation without injury of vital tissues, at and beyond the apex; and the subsequent obliteration of the canal lumen at or near the apex, to produce an hermetic seal.

The majority of acute pulpal and periodontal inflammations are exacerbations of existing chronic conditions and, in order to bring them under control, they must be converted initially into chronic states once again. This is effected by pulpectomy, local antiseptics and antibiotics, drainage, debridement, and systemic antibiotics, various combinations of which are indicated under varying circumstances.

Basically there are five fundamental factors to be considered. These are:

(1) The control of infection.
(2) Relief of masticatory stress.
(3) Biomechanical preparation of canals.
(4) The avoidance of damage to the periapical tissues.
(5) Perfect sealing of the apical part of the canal.

(1) The control of infection

Every effort must be made to prevent the spread of infection into previously healthy areas. An acutely inflamed pulp with a cornual abscess, associated with a carious exposure, must be treated with respect. The infection may be carried into the periapical region by injudicious instrumentation and cause an acute suppurative osteitis.

Pulp tissue has a high degree of resistance in a healthy individual, and infection will be held back by a barrier of polymorphs, beyond which are lymphocytes and giant cells, adjacent to normal pulp tissue. Ultimately, without treatment, the infection will spread slowly, overwhelming the defences, until the whole pulp becomes necrotic.

It is obvious that when access has been gained into the pulp cavity, further passage of the instruments into the canals can transmit bacteria into the apical and periapical areas and cause an acute reaction.

This may be avoided either by incineration of the anaesthetised pulp with the actual cautery, or by flooding the pulp chamber with a solution of antiseptic, prior to entering the canal. Similarly, all root canal preparation should be carried out through a pool of antiseptic solution, to prevent the transference of viable bacteria to the bone through the apical foramen. When the pulp chamber of a non-vital, symptomless tooth is opened, a dressing of tricresol/formalin on cotton-wool should be placed in the pulp chamber. The cotton should be damped only and not soaked in the drug, so that the formaldehyde vapour reaches the root apex in a non-injurious form, but nevertheless attenuates the virulence of the organisms and thus minimises the risk of spreading the infection.

If an acute periodontitis develops, the pulp chamber may be opened to allow drainage of inflammatory products for a few days.

When there are signs of systemic disturbance, such as cervical lymphadenitis, a rise of temperature, increase in pulse rate, anorexia and malaise, drainage through the tooth should be accompanied by the administration of a suitable antibiotic, either orally or parenterally, to help in localising the infection.

If an abscess is pointing through the mucosa, its evacuation may be accelerated by the use of hot hypertonic saline mouth baths or, if the swelling is fluctuant, by incising through the most dependent part of the swelling and inserting a drain.

(2) Relief of masticatory stress

A tooth with closed pulpitis does not become tender when biting until the inflammation spreads through the apical foramen to cause a periodontitis. However, after amputation of a pulp close to the apical foramen and preparation of the root canal, some degree of apical periodontitis is bound to develop in a number of cases. Oedema of the apical periodontium tends to extrude the tooth into premature contact with the opposing tooth and the traumatogenic occlusion exacerbates the apical inflammation.

This vicious circle may be broken at its source by preceding any root canal treatment by relief of the bite.

(3) Biomechanical preparation of canals

The term 'biomechanical preparation' has been coined to imply the alternate cleansing and enlarging of the canals.

Enlargement is carried out with reamers and files and cleansing is effected by irrigating with a suitable antiseptic solution, which washes away dentine filings, necrotic tissue and bacteria, so that antibacterial drugs which are put into the canal between visits can sterilise the walls and exert their effect on the tissues in lateral canals.

(4) The avoidance of damage to the periapical tissues

Damage to the periapical tissues may occur as a result of forcing infected tissue through the apical foramen, or by passing instruments into the bone and traumatising it. Chemical trauma is also a potent cause of osteitis, produced by forcing irritating fluids into the periapical region. This may result from placing sharp paper points, either dry or soaked in disinfectant drugs, through the apical foramen, or by exerting pressure when sealing the coronal orifice, so that the drug is forced into the bone. Similarly, when irrigating the canal, if its lumen is blocked by the needle of the syringe, the fluid may be forced through the apex.

When a root canal is obturated with an irritant sealing agent, some of which is deposited at the apical foramen or in the bone, a severe reaction may occur. This is especially apt to occur when sealers containing formaldehyde or cresols are used.

As a corollary to the prevention of periapical trauma, any treatment based on the partial amputation of the pulp, or its capping with drugs, must be accomplished without trauma to residual pulp tissue. Should such trauma inadvertently occur, the remainder of the pulp should be extirpated, because its reparative powers would be greatly diminished.

(5) Perfect sealing of the apical part of the canal

The majority of endodontists agree that the best results are obtained when a perfect seal is produced at or just short of the apical foramen, i.e. at the apical constriction (Engström and Lundberg, 1965).

Rickert and Dixon (1933) showed, by animal experiments, that inflammation occurred at the ends of hollow tubes, embedded in the peritoneum, which did not occur around solid rods. This, they claimed, was due to percolation of tissue fluids into the space. The proteins then broke down with the formation of irritant by-products. The toxic products then entered the periapical region and were responsible for the development of granulomas and apical cysts.

Doubts have been cast on the validity of this hypothesis by Phillips (1967) and Goldman and Pearson (1965) and it is now thought that many cases of breakdown of periapical tissues are due to failure to seal the apical foramen, coupled with the presence of viable bacterial colonies in lateral canals of the apical delta or even in the main canal (Butler, 1970).

Factors influencing the decision to embark on root canal treatment

Before starting a root treatment, an assessment of the following factors will help the operator to decide whether the prognosis is favourable.

The most important factor is the strategic importance of the tooth, e.g. whether it is, or can be made functional, or would be better extracted and replaced by the addition of a tooth to an existing denture or by the construction of a fixed bridge. The state of the other teeth must be considered. What is the caries experience? Are the teeth mobile and is there any periodontal disease? If so, are these conditions controllable?

The general health of the patient must be investigated to rule out any condition which might contra-indicate a conservative or surgical approach, with special reference to rheumatic fever, debilitating diseases, and conditions controlled by steroid therapy.

Age must be taken into account, especially in childhood, when the root apex may not be fully formed, or in old age, when the canals may be obliterated by the formation of secondary dentine. Although these conditions may not contra-indicate endodontic treatment, their presence will require the application of special techniques, such as the use of chelating agents.

When periapical bone is involved in the disease process and the condition requires surgical intervention, the relationship to maxillary antrum, inferior dental canal or mental foramen may contra-indicate surgery, whilst abnormal curvature of the roots or blockage of the canals could preclude a conservative approach. Careful examination of the radiograph will help in the assessment of each case and doubtful anatomical relationships can be clarified by taking further radiographs from different angles.

The degree of co-operation in what could be a lengthy and uncomfortable series of visits should be assessed from discussion with the patient before endodontic treatment is recommended.

The operator should have the necessary experience and ability to carry out the work and there should be sufficient room in the mouth to obtain access to the canals. It may happen that the patient is unable to open his mouth sufficiently, or the tooth may be inclined distally or lingually, thus creating an insuperable barrier to a conservative approach.

The condition of the crown should be conducive to the implementation of an aseptic technique or, at least, it should be possible to build it up with suitable restorative materials, in order to prevent leakage of saliva into the pulp chamber between visits and during treatment, which could occur through a faulty restoration even though rubber dam were used.

Finally, it is a waste of time to save a root if the crown is so badly broken down that its subsequent restoration would not be possible.

Diagnosis of pulpal and periapical pathology

It is important to follow a careful and logical system of diagnosis when searching for a cause of pain in the mouth and jaws. Because of the central connections of the branches of the trigeminal nerve, there is poor localisation of pain of pulpal origin, with overflow into the other branches of the nerve. Frequently, a patient complains of pain in a lower molar and, after a prolonged investigation, the cause may be revealed as a non-vital upper lateral incisor or a dying lower incisor. Successful diagnosis will only follow painstaking investigation and the operator must never jump to conclusions, never accept, uncritically, the patient's history and never diagnose solely from a radiograph.

A careful history is first taken and a tentative differential diagnosis is made from it. Then the teeth and soft tissues are examined and the vitality of the teeth is checked using, as a refrigerant, ethyl chloride on cotton-wool, then heated gutta percha and finally an electrical pulp tester. When teeth have been restored with full coverage gold veneers, only thermal stimulation may be used. Porcelain jacket crowns, being efficient insulators, will not transmit a stimulus, but occasionally a response may be obtained if a thermal stimulus is applied at the porcelain-to-root junction. Whenever possible, control teeth (preferably without restorations) of the same series should be tested for comparison with the suspected teeth. It should not be forgotten that the results of vitality tests will indicate whether or not a tooth has vital pulp, but never whether that pulp is diseased, or whether there is necrotic pulp in one canal, and vital pulp in the other. Even when the circulation of blood has ceased in a canal, nerve fibres in the apical third may still give a response for a period of time until they too undergo autolysis. Fluid or gaseous contents may expand and press on apical or periapical vital tissue, giving a marked response when heat is applied. Furthermore, pain may be experienced in the course of instrumentation, as a result of pressure transmitted thereby to the periapical region. From these observations it is apparent that the results of the tests should be viewed in the light of the history.

The teeth, when examined, may show evidence of one of the following conditions: a carious cavity; a discoloured crown indicating death of the pulp; a fracture line, involving dentine or pulp; gingival or periodontal disease; a pink spot, indicating a chronic proliferative pulpitis; or a large silicate or composite restoration, which may have been inserted without a lining.

Examination of the soft tissues may reveal the presence of a swelling, which may be inflamed and tender, or there may be a sinus presenting over the apex or over the lateral aspect of the root, from which it might be possible to express pus (figure 25.1).

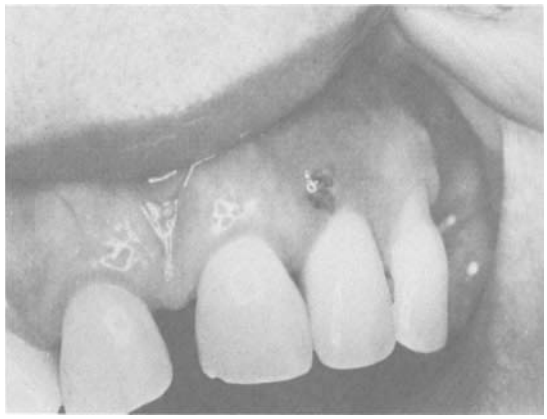


Fig. 25.1 Sinus presenting periodontally over a lateral incisor but originating in a peri-apical lesion associated with a dead pulp.

Percussion of the teeth is one of the most important diagnostic aids. If tenderness is elicited on percussion, it can indicate one of three possible causes. Firstly, a periodontitis which is secondary to an acute, subacute or chronic pulpitis; secondly, a periodontitis caused by direct trauma to the ligament, such as a high spot on a restoration or food-packing between teeth with a deficient contact area or, thirdly a periapical abscess which owes its origin to a necrotic pulp. The cause can be confirmed after careful observation of signs and consideration of the history.

Cracked tooth syndrome

There is one cause of chronic intermittent pain associated with chewing and biting which does not originate in pulpal or periodontal disease. This is the pain elicited by chewing on an area of fractured enamel. There is no tenderness when the tooth is percussed nor is there, as a rule, any change in the vital response, all other factors being equal. The patient may also complain of hypersensitivity to thermal changes.

Frequently the crack is visible but sometimes the only way to find the offending cusp is by asking the patient to bite on a rubber polishing disc or a rolled strip of rubber dam, testing the cusps one by one until pain is felt (figure 25.2).

Treatment consists of cutting out the fractured cusp and replacing it as part of a restoration, preferably cast, which transfers the stress to sound tissue (Messing, 1967).

The radiograph

The radiograph has been left to the last advisedly, because it should be used either to supply confirmatory evidence, or to ascertain the existence of changes in the tissue which require further investigation. Certain features however, such as unlined silicate restorations, root fillings, lateral perforations, periapical radiolucencies, condensing osteitis, extra roots and accessory canals, can only be ascertained from a radiograph.

The operator must examine the radiograph carefully to ascertain how many roots there are on the tooth to be treated. If they are superimposed in the horizontal plane, a double periodontal shadow is usually discernible under a magnifying glass. Improved delineation of the roots may be afforded by pointing the cone of the X-ray machine obliquely at the roots at an angle of 15 degrees to the horizontal plane. This deflection produces separation of the images of the roots, the buccal root appearing to move towards the side opposite to that from which the tube was angled.

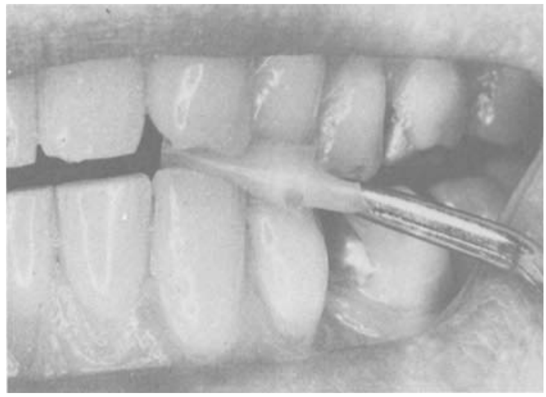


Fig. 25.2 The use of a plug of rubber dam to locate a fracture in the enamel.

Figure 25.3 shows the 'ghosting' effect of a super-

Fig. 25.3 (Left) 'Ghosting' of a superimposed root in a normal radiograph of an upper first premolar. (Right) Radiograph recorded at an angle of 90 degrees to show bifid root close to the apex, but there are two separate canals with sinuous outlines.

imposed root. The other radiograph, taken at 90 degrees to the first one, shows how variable root canals can be.

It is a valuable diagnostic aid that, in a normally aligned radiograph, showing a dividing canal, there is an increased radiopacity over the course of the divided canals. This does not indicate a canal with dystrophic calcification of the pulp, but denotes the greater bulk of dentine overlying the narrower canals.

Despite a careful search, it is at times impossible to find the cause of pain and, when this is the case, the patient should be asked to keep a close watch on the nature of the pain, its duration and intensity and those factors which exacerbate or relieve it, such as biting, chewing, drinking, thermal and osmotic stimuli and the use of analgesics. Also, the effect of posture is important. If the pain is worsened when the patient is recumbent, this indicates the presence of a pulpitis, exacerbated by the increase in blood pressure in the region when lying down.

Table 25.1 gives the differential diagnosis between pulpitis and periodontitis.

When listening to the patient's history, the dental surgeon should be on the look-out for salient points which might indicate a possible cause of pain.

For example, the patient might say that, when a tooth was prepared in the recent past for a crown, the smell of burning was constant and unpleasant, and that no coolant spray was used. Such a history would suggest that the pulpitis was caused by overheating and desiccation of the dentine. Some of the common causes of pathological changes in the pulp are listed in table 25.2.

Acute apical periodontitis may owe its origin to many causes, only some of which are endodontic. Awareness of the possible aetiology may help to avoid errors in diagnosis and treatment.

Causes of acute apical periodontitis

(1) Spread of infection from an infected pulp.
(2) A high spot on a restoration.
(3) A lateral perforation of the root through a root canal.
(4) A lateral perforation with a retention pin.
(5) An over-extended root filling or overspill of an irritant sealer beyond the apical foramen.
(6) A paper point or irritant drug extruded beyond the apex.
(7) Trauma to the tooth, e.g. a blow, or the malleting of a cohesive gold restoration.
(8) Proximal impaction of food, causing periodontitis which spreads throughout the ligament.

From this short survey of the causative factors associated with pain of pulpal and periodontal origin, it is obvious that great care must be exercised when investigating the cause of pain.

Selzer *et al.* (1963) checked the vitality and took exhaustive histories relating to 166 teeth which were later extracted and examined histologically. From their observations, they came to the following conclusions:

(1) Pain resulting from insertion of a restoration in a deep cavity is due to an acute inflammation superimposed on an existing chronic inflammation.

TABLE 25.1 Differential diagnosis between pulpitis and periodontitis

Pulpitis	*Periodontitis*
Pain rarely localised	Pain always localised
Pain may be sharp, shooting, stabbing or a severe ache, worse at night when recumbent	Pain, unaffected by posture, is a dull continuous ache
No tenderness on percussion unless apex is involved	In early stages, pain is relieved by pressure, but later it is intensified
There may be sensitivity to thermal and osmotic change	Usually unaffected by thermal or osmotic stimuli, but sometimes severe traumatic periodontitis may cause a mild degree of hyperaemia of the pulp, and sensitivity to thermal change
Tooth is not extruded	Tooth extruded by periodontal oedema
There may be large cavity or restoration present	Tooth may be sound
No rise in body temperature unless there is involvement of the periodontal ligament	There may be a rise in body temperature of 2–3°F
Lymph nodes are not enlarged	Lymph nodes are usually enlarged and painful to touch

TABLE 25.2 Some of the more common causes of pulpal pathology

(1) Caries and trauma	Carious or traumatic exposure
(2) Thermal	(a) Cutting at ultra-high speed, or with excessive pressure, and without coolant spray. (b) Heat resulting from the setting of self-polymerising methyl methacrylate resin (plus the irritant effect of the monomer)
(3) Traumatogenic occlusion	This may cause a periodontitis, but a concomitant mild pulpal hyperaemia may also be evinced as a hyper-reactivity to thermal stimuli, which ceases when the bite is relieved
(4) Chemical irritation	(a) Methyl methacrylate or composite resin restorative or silicate cement (unlined). (b) Phosphate cement (mixed too rapidly)–free acid present. (c) Arsenic–used to devitalise a pulp, but rarely used today. (d) Caustic drugs on dentine close to the pulp, e.g. phenol and silver nitrate
(5) Galvanic shock	This may occur while amalgam is setting, and produce hyperaemia of the pulp
(6) Orthodontic movement	If too rapid, will cause death of the pulp, due to apical ischaemia
(7) Periodontal pocketing	Pulp death may follow infection, which reaches the pulp through a lateral canal which opens onto the exposed root surface
(8) Anachoresis	Blood-borne spread of organisms to a pulp, which in all probability sustained damage in the past

(2) From the histological picture of various symptoms, no categorisation of pulp disease is complete. Many overlappings occur and the diagnosis of tissue sections depends upon complete examination at all levels.

(3) The incidence of pain varies with the severity of the pathological condition.

(4) There is no separation between pulpitis and periodontitis at the apical foramen, but there is a reaction throughout the pulpo-periodontal complex.

(5) Apical regions of rarefaction may be seen, on X-ray, when a pulp is chronically inflamed and the apical pulp tissue is vital.

(6) Pain in chronic pulpitis may be induced by either heat or cold or be completely absent.

(7) It was thought that a pulp with an acute serous inflammation reacted more to cold, while one with a suppurative inflammation was hypersensitive to heat. The investigation showed that an inflamed pulp may react to either stimulus or to both.

(8) A pulp may become necrotic in the absence of pain. Regions of liquefactive necrosis appear in the apical granuloma and a chronic periodontitis becomes acute, with the development of severe pain, until drainage is established, when it reverts to the chronic state. Pain is elicited when drainage does not occur.

(9) A previous history of pain is an important diagnostic aid in establishing the presence of destructive pulp pathology.

(10) There appears to be no significant correlation between the type of pain and the histological diagnosis.

(11) Pain on percussion is found more frequently in the presence of partial or total necrosis.

(12) A pulp tester will not determine the presence of partial necrosis.

(13) There is no special significance in responses to heat and cold, other than to suggest that there is some pulpal pathology.

Some of these findings run counter to many of the ideas which have been accepted and taught in the past, and the upsurge of research into the symptomatology of endodontically involved teeth is lending weight to this reappraisal, so that future techniques may be modified in the light of improved understanding.

Sterilisation of materials and instruments used for endodontic treatment

Once the dentine has been breached and the pulp is exposed, the operator has made contact with the patient's blood stream, but the pulp chamber is ill-suited for combating infection, due to the unyielding nature of the dentine and the small diameter of the apical foramen. Any reaction by the pulp against a noxious stimulus will result in severe pain and may, through intrapulpal venous stasis, end with total necrosis of the pulpal tissue. Introduction of organisms into the pulp and thence into the periapical tissues, in the course of treatment, will militate against a successful result, and even though infection may be present already, no new bacteria should be allowed to enter because, if they should be of high virulence, they could overwhelm the local defences.

In order to avoid contamination, an aseptic technique must be used. Rubber dam should be applied and all instruments sterilised. The hands should be scrubbed for 3 min with soap and hot water. Instruments should be sterilised by dry heat (160°C for 60 min) in a metal box, divided into compartments and closed with a well-fitting lid, and stored there until needed (figure 25.4). Dressings may be sterilised by autoclaving and kept in special sealed packets. Paper points should be sterilised in used anaesthetic cartridges, sealed with a cotton-wool plug, with a sufficient number stored in each one for an average case.

Rubber dam may be scrubbed with hexachlorophene soap and dried. When in place, it should be swabbed with a 2% solution of benzalkonium chloride in 50% iso-propyl alcohol (Ray, in 1955, found that this solution would produce sterilisation in 94% of cases).

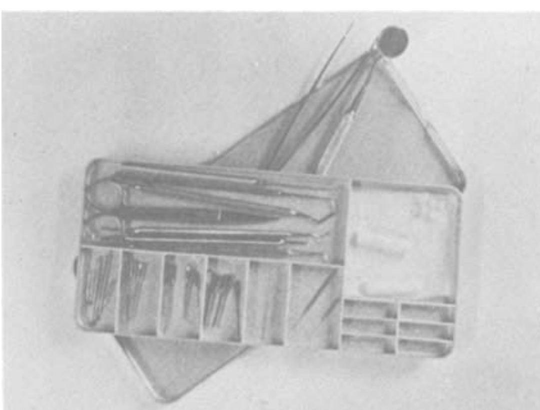


Fig. 25.4 Root canal box, constructed in aluminium (Produits Dentaires). The inner surface of the cover may be used as a sterile surface on which to place instruments, etc.

Sterilisation of broaches, files and reamers during use may be carried out by immersing them for 10 s in glass beads or salt in a glass bead steriliser at approximately 240°C (figure 25.5).

Endodontic instruments must never be sterilised by flaming, and the operator must ensure that his staff never use flaming as a speedy method of sterilisation, because thereby, the temper of the metal is destroyed and fracture during use becomes a distinct possibility.

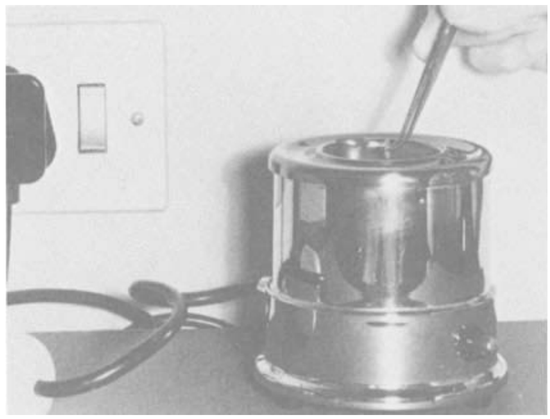


Fig. 25.5 Glass bead steriliser. Sterilisation of a reamer by a 10-second immersion in heated glass beads (at 240°C).

Flaming, however, has its use for sterilisation of the glass slab and steel spatula prior to dispensing and mixing a root canal sealer. The author (Messing, 1972) conducted experiments with glass slabs and spatulae, contaminated with bacteria and sterilised by igniting 70% alcohol on their surfaces. It was found that, after a minimum of 4.0 s exposure to the alcohol flame, complete sterilisation occurred. However, because of the water which condensed on the surface of the glass, further flaming was required to evaporate it. The method of choice was to invert the slab over a cotton swab, soaked in alcohol and ignited. This must be done well away from the patient and from inflammable objects and, in the interest of safety, it should be done over a washbasin.

A Technique for Root Canal Treatment

As a prelude to the treatment of root canals, all caries must be excavated and any missing walls restored. In anterior teeth, this may be done by preparing the cavity and inserting a silicate or silicophosphate cement (figure 25.6 top). In posterior teeth, however, an effective gingival seal may be produced by the insertion of a temporary amalgam restoration,

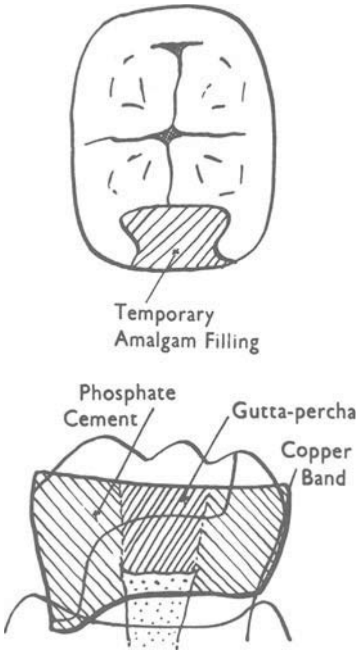


Fig. 25.6 Defective areas in posterior teeth built up in (top) amalgam, silico-phosphate or composite resin; (bottom) by cementing a copper band.

or by trimming a copper band to be free of the occlusion and contoured to the gingival perimeter and cementing it with zinc phosphate cement (figures 25.6 (bottom), 25.7). If there is no occlusal cavity communicating with the dentine overlying the pulp, it should be filled with gutta percha, prior to cementing the band, in order to prevent the cement blocking the access to the pulp. The gutta percha is removed subsequently with a heated plastic instrument.

The main disadvantage inherent in the use of a copper band or amalgam is the need to delay treatment until the next visit. Cement and amalgam, even if fast setting, are too weak and brittle during the early stages of hardening and would tend to fracture if stressed prematurely. It is a good practice to avoid clamping a copper band whenever possible, because a tight clamp can fracture the cement. For preference, an adjacent tooth should be used to hold the clamp and the banded tooth extruded through a hole in the dam. If necessary the rubber dam may be retained by means of a ligature of dental floss.

As an alternative, pins, undercuts or etched enamel may be used to retain a composite resin temporary restoration. A matrix is applied or, if the crown is unduly broken down, a copper band may be contoured and fitted. The area of the access cavity is temporarily isolated with a plug of gutta percha, and composite resin is packed into the depths of the cavity using a flat plastic instrument (Ash no. 156) or amalgam plugger (dipped in alcohol and the excess shaken off). Composite is condensed using a tamping action with a tightly bound pledget of cotton wool, damped with alcohol, exerting maximum axial pressure.

When the resin has hardened and the matrix has been removed the margins and occlusion are checked and corrected where necessary.

The rubber dam should be applied to one tooth only whenever possible although, if greater access is called for, it may be applied to several teeth (figure 25.8).

In order that the seal produced around the neck of the tooth may be as perfect as possible, the following measures should be adopted. When more than one tooth is isolated, that part of the dam stretched over the crowns should be lightly lubricated with petroleum

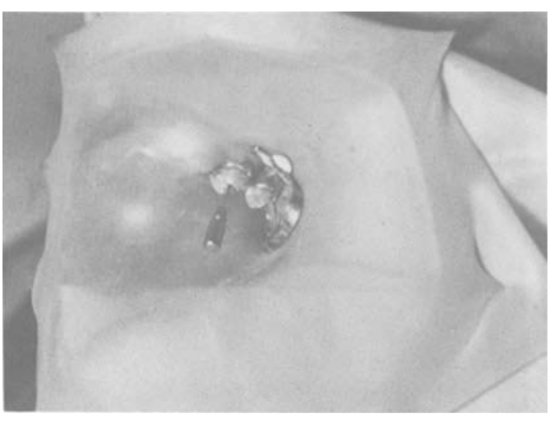


Fig. 25.7 Reamer in root canal of badly broken down maxillary premolar. For the purpose of endodontic treatment, copper bands have been cemented on both premolars.

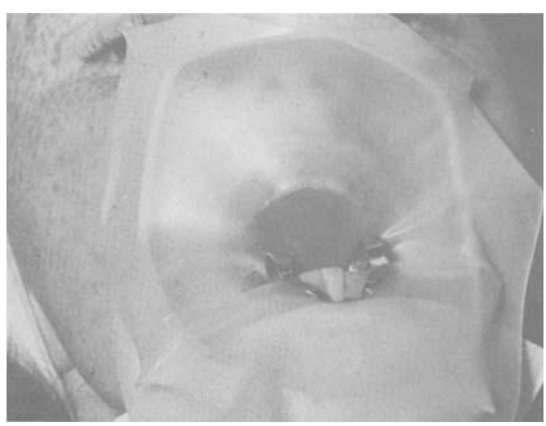


Fig. 25.8 The use of a 'butterfly' clamp to isolate one tooth for endodontic treatment.

jelly or brushless shaving cream, so that it will be easier to press it home interproximally with dental floss.

The dam should be inverted into the gingival crevices, using a flat plastic instrument (Ash no. 156). This is aided by drying the necks of the teeth with a blast of warm air.

The clamp should be applied initially to the lingual aspect of the tooth, then, after adjusting the buccal jaw over the buccal bulbosity, the forceps are released slowly, making certain that the clamp will neither slide up to impinge on the gingivae nor slip off the tooth.

This is less apt to occur when the jaws of the clamp are sharp, and thereby able to obtain a grip on the enamel. Also, stability can be assured only if all four points of the arcs of the jaws contact the tooth simultaneously.

If the rubber dam tends to slide off the tooth, it can be retained by the application of a ligature of dental floss. Alternatively, a wooden wedge or interdental massage stick may be placed interproximally with greater ease, and is just as efficient in holding the rubber out of the way.

In every case, the affected tooth should be ground to free it from occlusal stress and thus give it physiological rest.

If the pulp to be extirpated is vital, it should be anaesthetised with lignocaine (2%) or Citanest (prilocaine) (4%).

When there is an acute pulpitis, difficulty may be experienced in obtaining adequate anaesthesia. If, after a further quantity has been injected, pain is still experienced, an intrapapillary injection of 5–10 minims of anaesthetic should be given. If this too is of no avail, an intra-osseous injection may be administered, after a pathway into the spongiosa has been made with a hand reamer or engine reamer. Approximately 5.0 minims of anaesthetic are injected using a syringe with a short needle and a long hub.

If the patient is very apprehensive, it may be necessary to carry out the extirpation under an intravenous injection of diazepam, followed by local anaesthesia. Alternatively, the pulp may be covered with a corticosteroid antibiotic preparation until a subsequent visit, when it should be easier to obtain anaesthesia.

Prior to gaining access to the pulp chamber, the rubber dam is applied and a solution of Savlon or Povidone iodine is swabbed liberally over the crown, the clamp and the dam.

Application of rubber dam to a crownless tooth

Provided that some of the crown is visible supragingivally and the margins are intact, it is possible to

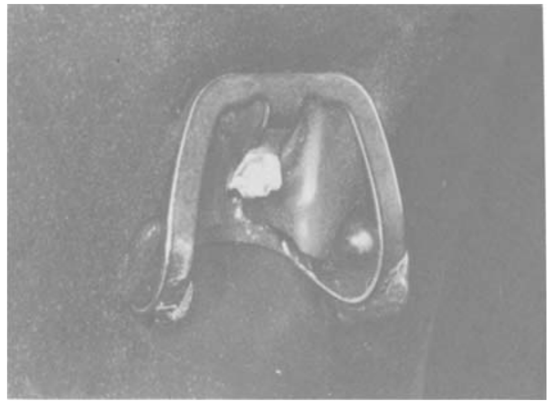


Fig. 25.9 **Ferrier clamp holding rubber dam on a root which has lost most of its crown. Note the stabilisation of the clamp by pieces of impression compound, wedged between the bows and the teeth.**

isolate it, using a Ferrier Clamp (figure 25.9). If the coronal fragment is so lacking in retentivity that the clamp will not grip, retention may be provided by cutting tiny labial and lingual grooves at the gingival margin with a small wheel bur (figure 25.10).

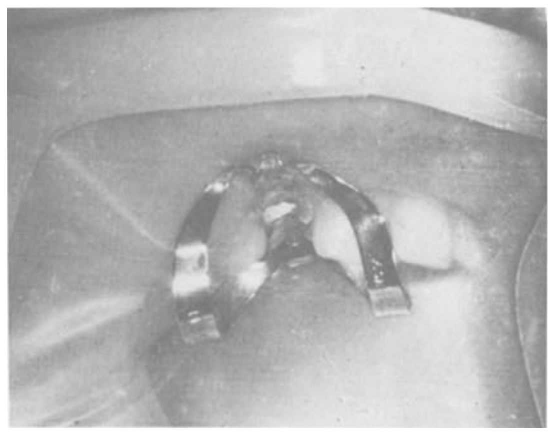


Fig. 25.10 **Grooves cut in the lingual and labial cervical areas of a lateral incisor to allow retention of a 'butterfly' clamp. The rubber dam is pulled over the wings of the clamp which is then adjusted over the tooth. The dam is displaced from the clamp on to the tooth.**

An alternative approach, suggested by McGibbon (1956) is to widen part of the canal in order to cement a length of stainless steel tube, on to which a temporary acrylic crown is made, using a plastic crown form. This method, although it provides a means of isolating the tooth, severely restricts the degree of apical preparation in many cases and results in over-preparation and consequent weakening of the coronal aspect of the tooth.

The author (Messing, 1976) devised a method for building a temporary crown which maintains the integrity of the canal without the need to over-prepare the coronal part of the root canal (figure 25.11). Where indicated, initial preparation must include removal of caries and excision of overgrown gingival tissue in order to expose submerged margins. After the possible presence of vertical fracture has been excluded, the

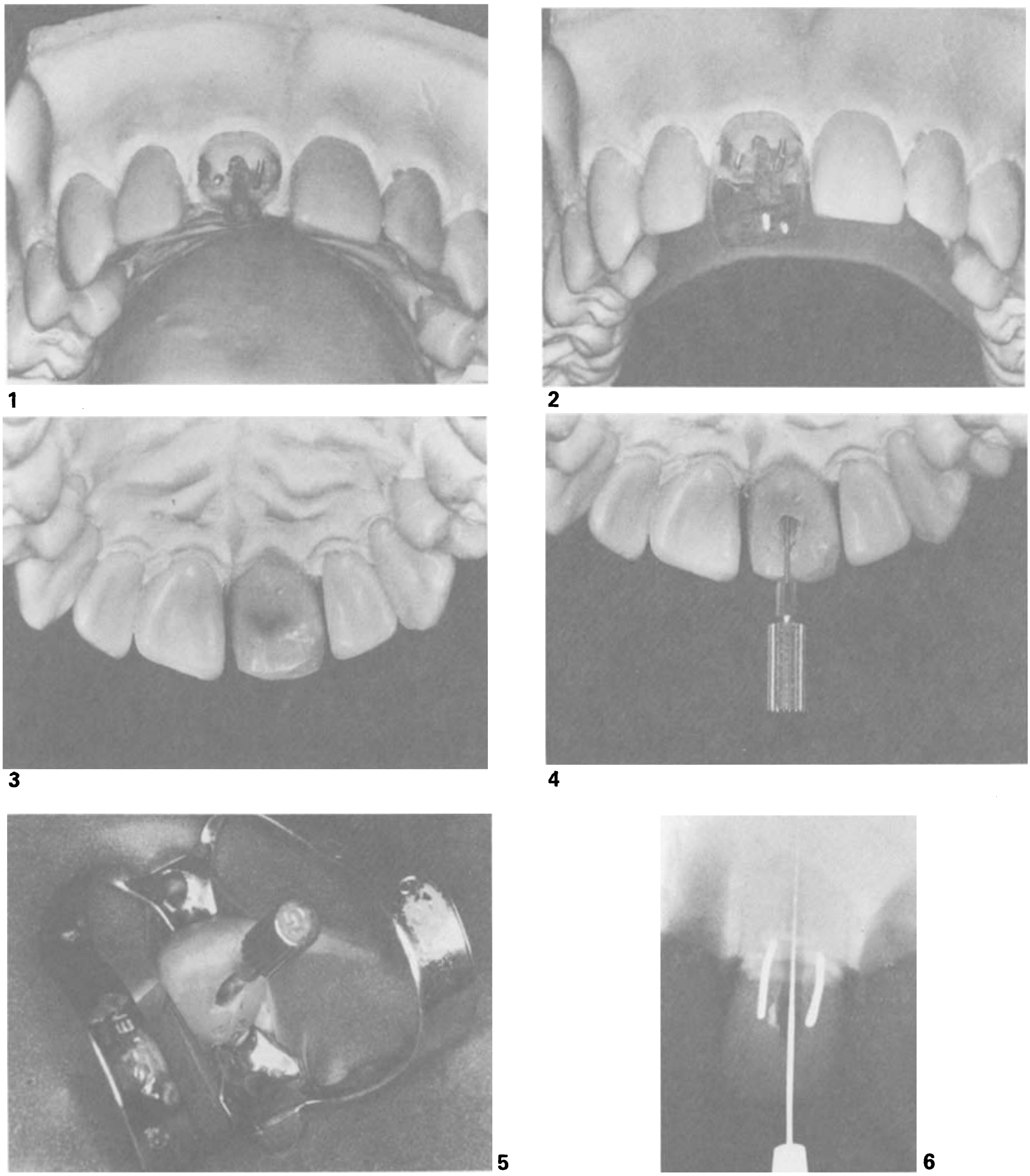


Fig. 25.11 (1) Root canal enlarged to a depth of approximately 5 mm. Two small self-tapping screwpins are inserted in the dentine, and a gutta percha cone is placed to obliterate the canal and project at an angle palatally. (2) A crown-form is trimmed, filled with composite resin and adjusted over the root. (3) Temporary crown after removal of the crown form. Note the proximity of the gutta percha cone to the normal access zone for pulpectomy. (4) Endodontic instrument in the access cavity. (5) Rubber dam applied. (6) Radiograph showing reamer in the canal. (Photographs reproduced by kind permission of the editor of the British Dental Journal.)

pulp canal is opened up and reamed to a depth of 5.0 mm, and to the diameter of a size 80 or 90 reamer. A corresponding matched gutta percha cone is seated firmly into the canal and its length is reduced, so that the protruding part, when moulded into a ball and bent lingually, will correspond in position to the point at which an access cavity would be cut.

Self-tapping, threaded pins, (e.g. T.M.S. or Stabilok), are now inserted on the mesial and distal aspects of the canal and bent slightly so that they are not parallel. A temporary crown form, either of cellulose acetate or polycarbonate, is fitted carefully and, filled with composite resin, is adjusted over the root. Simultaneously, resin is packed around the pins. If a cellulose acetate crown form is used, it is removed after the resin has hardened. Marginal excess of resin is removed and the occlusion is checked, then, where the gutta percha is seen to be showing through the surface of the composite, an access cavity is drilled and the gutta percha is removed by spearing it on a heated root canal spreader. Access to the root canal is further modified to allow uninterrupted passage of root canal instruments and the rubber dam is applied.

(On completion of treatment, the tooth may be strengthened by the cementation of a length of chrome–cobalt (Wiptam) wire, or a Kurer Crown Saver, in the root and up to the coronal orifice. This will allow subsequent preparation of the composite core to retain a porcelain jacket crown. Alternatively, the temporary crown can be cut off, leaving the pins flush with the root face, and a post/core preparation carried out.)

Access to the pulp chamber (figure 25.12)

Access to the pulp should be made in line with the canal and never through a proximal or cervical cavity. The orifice should be large enough to allow unhindered movement of the endontic instrument, so that it will not bind on the walls of the access cavity. Any departure from this rule may result in fracture of an instrument or in perforation of the root.

Access is gained firstly through the use of a round bur in the turbine handpiece, to enter the dentine and cut the approximate shape of the orifice in enamel. Progress towards the pulp is continued at slow speed with a small round bur (size 2 or 3 for an incisor and 4 or 5 for a molar and premolar). When the resistance to cutting ceases suddenly, denoting entry into the pulp chamber, the bur is operated with a pulling action around the whole circumference of the pulp chamber until all resistance to its removal ceases. At this stage the roof of the pulp chamber will have been cut away. It is important to use a bur which is small enough to rotate freely in the pulp chamber and never to use a fissure bur, which may create grooves in the walls or floor. The bur must never be allowed to cut the floor of the pulp chamber, because of the danger of perforating the roots of posterior teeth in the furcation area. Any damage to the floor of the chamber also makes subsequent location of the canal orifices more difficult. When a conventional contra-angle handpiece and bur are used to open the roof of a chamber in a large, long, imbricated or sclerosed tooth, it may be found that the bur will not be long enough to reach into the pulp. This problem may be overcome by using special, long burs or through the

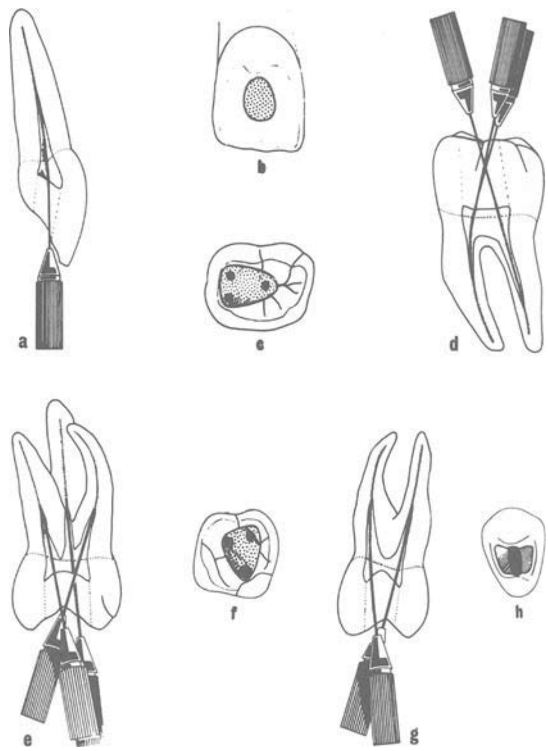


Fig. 25.12 Access to pulp chamber. (a) Access cavity in maxillary central incisor, (b) position and shape of access cavity, (c) triangular shape of access cavity for mandibular molar. Note apex of the triangle is directed distally. (d) Position of reamers in mandibular molar, (e) position of reamers in maxillary molar, (f) access cavity for pulp chamber of maxillary molar, (g) position of reamers in maxillary premolar, (h) access cavity for pulp chamber of maxillary premolar. N.B. Approximately 25% of maxillary first molars have a fourth canal, located palatal to the mesiobuccal orifice, which may coalesce with the mesio-buccal canal or have a separate apical foramen. Some mandibular first molars have two distal canals, whilst a percentage of second molars have only one canal in each root. The maximum number of canals should always be sought.

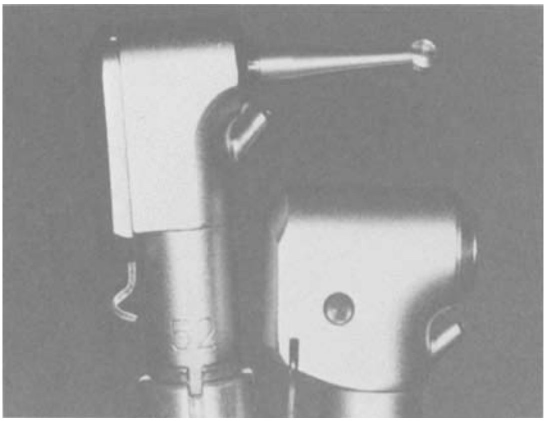


Fig. 25.13 Use of a pedodontic handpiece to improve access to the root canals of teeth which are either long or imbricated, or in which there has been severe pulpal recession. Compare the difference in the depth of a conventional handpiece.

use of a normal bur in a pedodontic handpiece (figure 25.13).

In anterior teeth, the access cavity should not be started too close to the cingulum, because cutting in the line of the root canal requires that access be obtained closer to the incisal margin. Furthermore, all vestiges of cornual pulp tissues should be removed, otherwise it would tend to break down and cause discolouration of the crown. Also, if the pulp were infected, it would act as a nidus for bacterial contamination of the canal during the course of treatment.

In the majority of cases there is already infection in the coronal pulp, or it may be carried there when the access cavity is being prepared. As a necessary precaution in every case, the bacteria in the pulp chamber should be eliminated rather than run the risk that they could be implanted in the apical part of the root or forced beyond the apex (figure 25.14). This may be done simply by irrigation with a 3% solution

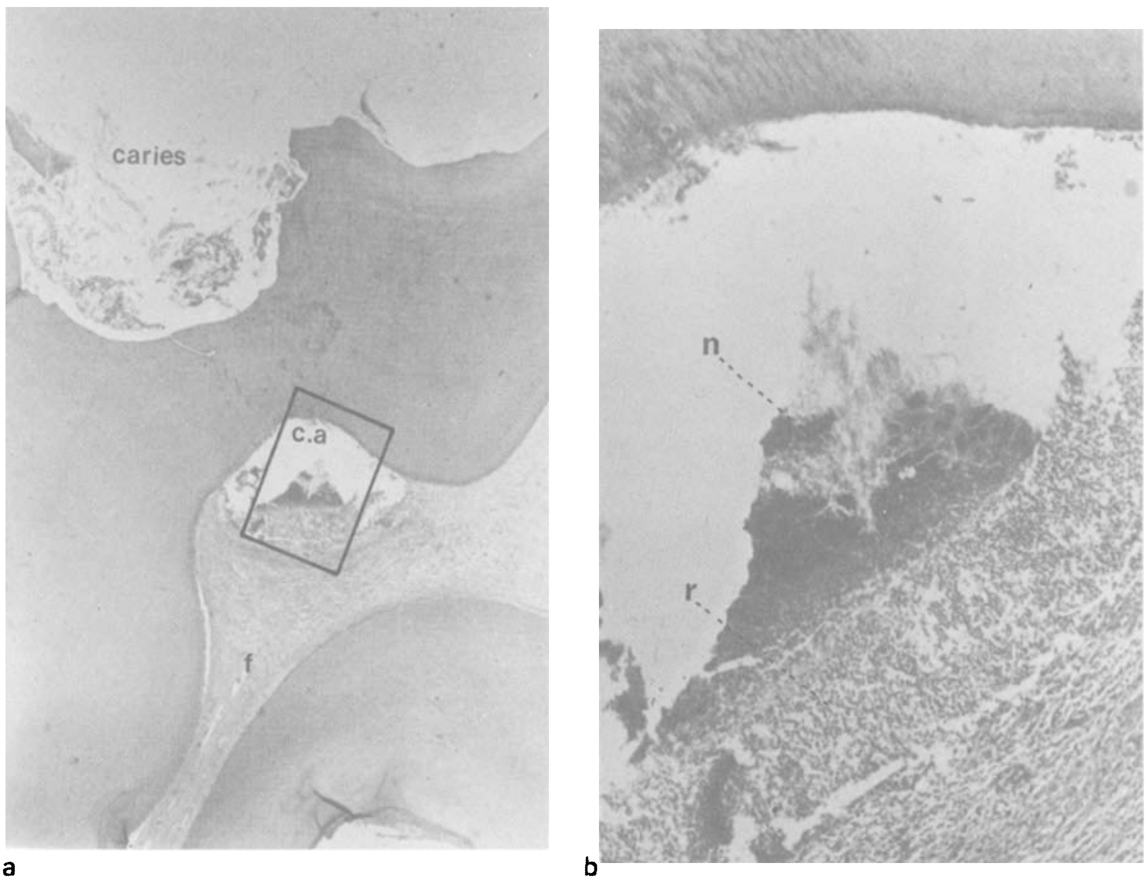


Fig. 25.14 (a) Photomicrograph of a cornual abscess of the pulp (c.a.) beneath which there is a generalised fibrosis (f) in the chronically inflamed pulp. (b) Enlarged portion of abscess showning small round cell infiltration (r) and necrotic tissue (n).

of hydrogen peroxide, which is broken down by the peroxidase present in the blood with the evolution of a large volume of oxygen. Further irrigation with a solution of electrolytic sodium hypochlorite (1–2% Milton) will release a further quantity of oxygen and neutralise the peroxide.

Alternatively, the coronal pulp and any bacteria present may be destroyed by the use of the electrocautery or by the actual cautery. In the latter instance, a length of wire, heated until red, may be thrust into the pulp chamber and held there for a few seconds.

Extirpation of the pulp

Removal of a vital pulp is carried out with a barbed broach (figure 25.15), which is a fine wire from which minute sharp barbs have been teased out at an angle, to engage the pulp and amputate it. Broaches are available in a variety of widths, some being supplied with handles while others are for use in a broach holder, into which they are locked by means of a pin vice. In order to facilitate the passage of the barbed broach up to the apical end of the canal, a fine reamer should be passed gently alongside the pulp until resistance is encountered. A barbed broach is then inserted along the pathway thus opened and given a turn to engage the pulp, which is withdrawn and inspected. If the pulp appears to be shorter than was to be expected, the broach is reinserted and used to scrape the walls of the canal in order to eradicate any vestiges of pulp. Should the broach bind, it must not be forced or twisted because, being of a fragile nature, it would probably fracture and removal of the broken tip would be extremely difficult or even impossible. It should simply be removed with a gentle tug before it has jammed irrevocably, and replaced by a finer broach or, if that is not possible, a file. Undoubtedly it is wiser to select a broach which is a loose fit in the canal.

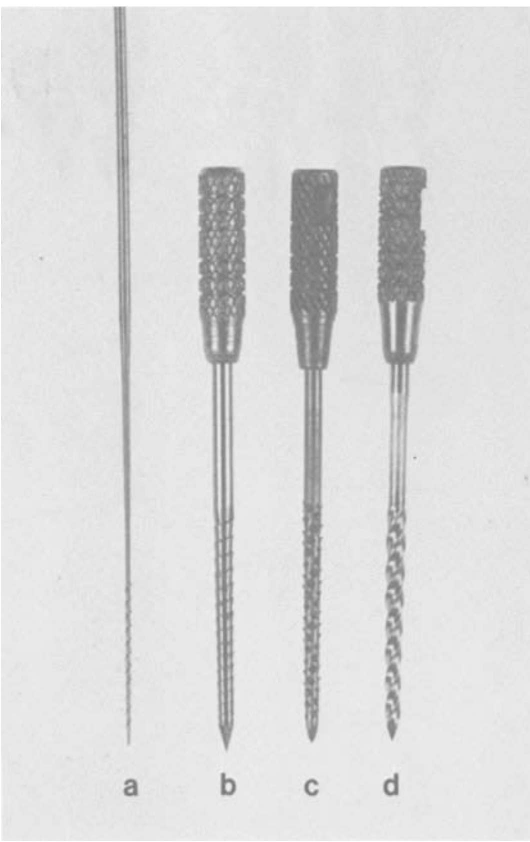


Fig. 25.15 Root canal instruments. (a) Barbed broach. (b) Hedstroem file (c) Rasp. (d) Reamer.

A rasp (figure 25.15), which is a type of file related in design to a barbed broach, may also be used to scrape out the remains of the pulp tissue which are still adherent to parts of the wall.

Stemming apical haemorrhage

Following extirpation of a vital pulp, there is haemorrhage from the amputation stump, which is located usually at the level of the apical constriction – approximately 1.0–2.0 mm from the apex. This may be stemmed by irrigation with 3% hydrogen peroxide, used alternately with a 1–2% solution of sodium hypochlorite. The last solution used, prior to dressing the canal, should be sodium hypochlorite, which will react with and neutralise the hydrogen peroxide. Should any trace of peroxide remain, oxygen would be given off and pressure could develop in the periapical region and cause pain. After a few minutes, the haemorrhage slows and finally ceases and the canal is dried with sterile paper points. The needle of the irrigation syringe should fit loosely in the canal, otherwise fluid could be forced through the apical foramen (figures 25.16; 25.17; 25.18).

At this stage, a diagnostic radiograph should be recorded to enable the operator to calculate the correct length of the tooth. Ray (1954) has shown that in the majority of maxillary anterior teeth, a wire 20.0 mm in length will not pass through the apical foramen. The author has adopted the following method which may be used in the majority of cases. A size 30 reamer will only pass through an immature apex or one which has undergone resorption. Reamers and files are available in lengths of 21 mm, 25 mm and 30 mm, however the length of a 25 mm reamer (size 30) should be checked, because there are occasional variations between 24 and 26 mm. The

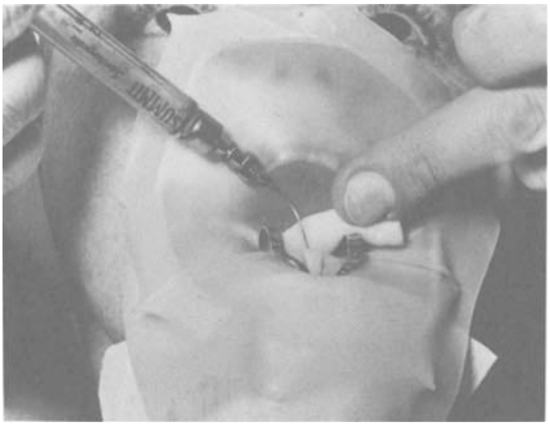


Fig. 25.16 Irrigation of a root canal, using a cotton-roll to absorb the fluid. This technique may be used when an aspirator is not available.

reamer is inserted gently until resistance is encountered and the length of shank between incisal edge, or tip of cusp, and the reamer handle is measured and noted.

Stops should be placed on root canal instruments so that a canal may be prepared to a length, previously calculated and designated by the position of the stop.

A variety of adjustable gauges exist to facilitate the adjustment of stops on endodontic instruments. Two such easily adjustable devices are illustrated in figure 25.19. The stops may be purchased separately and sterilised with the instruments or the reamers and files may be supplied with fitted stops (figure 25.20).

Small pieces of sterilised rubber are used most frequently. They may be made by cutting square portions of a 3.0 mm elastic band, which are sterilised

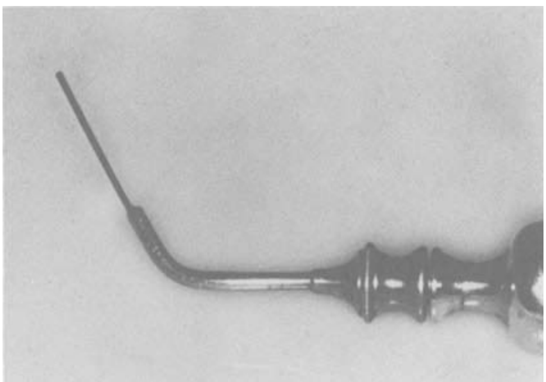


Fig. 25.17 Modification of a Hunt's syringe for irrigation of root canals, by soldering a length of 0.5 mm orthodontic tubing (internal diameter) into the nozzle.

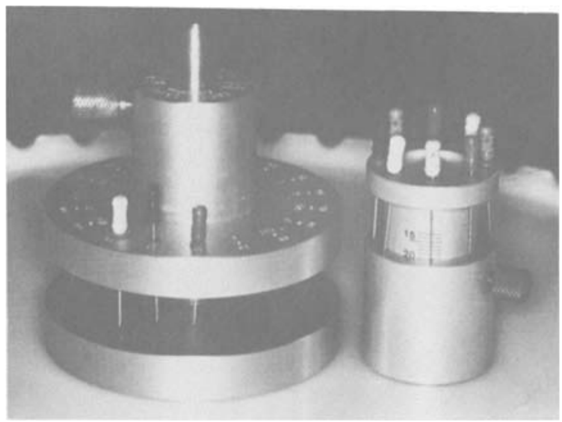


Fig. 25.19 Adjustable gauges for endodontic instruments. (Left) Endo-gauge. (Right) Polydent gauge.

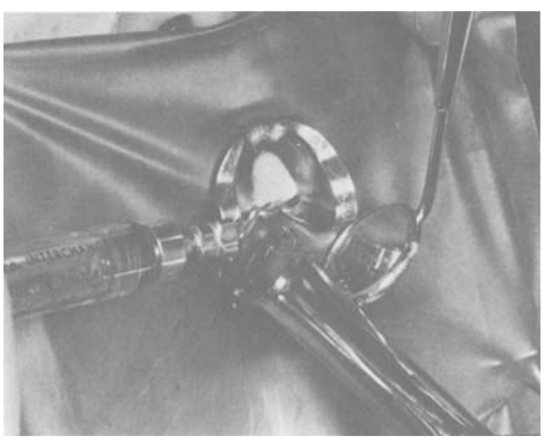


Fig. 25.18 Irrigation of a root canal with a 2% solution of electrolytic sodium hypochlorite, using a Record syringe and a high volume aspirator.

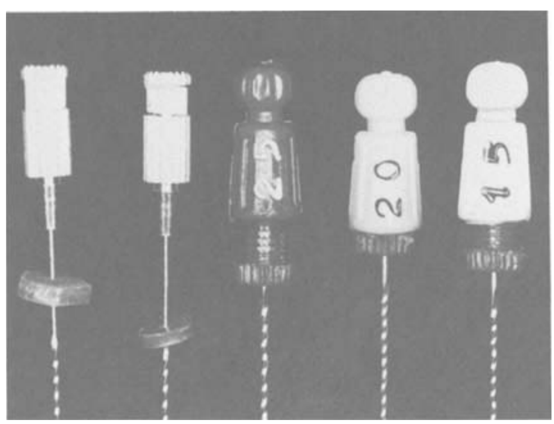


Fig. 25.20 Stops on root canal instruments. First on left – stop cut from a rubber band. Second from left – commercially available rubber stop (micro-mega). Middle and right – adjustable screw stops. Thomas endodontic instruments (Bayer).

in an autoclave or by immersion in benzalkonium chloride (2% solution).

Alternatively, a touch of hot gutta percha or quick-setting zinc eugenolate cement on the instruments will give a quick indication of the position at which instruments must be stopped.

Several manufacturers now supply root canal instruments with adjustable handles (e.g. Zipperer and Produits Dentaires) (figure 25.21), which may be fixed in any given position to correspond with the calculated length of the tooth, and which prevent over-instrumentation. In this respect they are more efficient than reamers and files with stops which may be moved inadvertently.

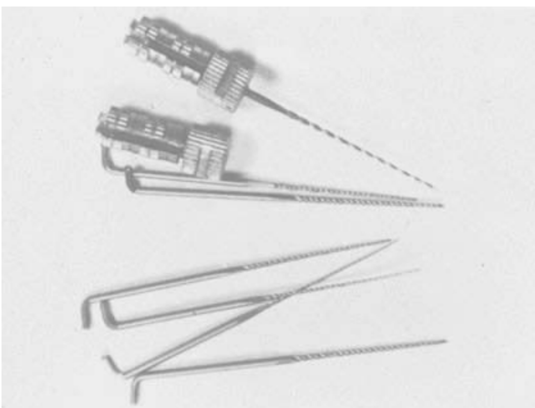


Fig. 25.21 Zipperer files and reamers with 'test' handles.

The rubber dam frame is removed and a radiograph is recorded with the reamer *in situ*, and the film is held without pressure, in order to avoid the distortion which would be produced if it were bent. Care is exercised to ensure that the central ray is at 90° to the line which bisects the angle between the film and the reamer, in order to obtain an image dimensionally comparable with the tooth.

Three other factors aid in the production of a good diagnostic radiograph. Firstly, the film should be placed so that it is aligned to project beyond the apex, thus preventing 'cut off' of the periapical zone. Secondly, whenever possible, the film should be placed on the crown side of the dam, by careful positioning of the rubber to prevent stimulation of the retching reflex. This allows easier application of the bisecting angle technique because both film and tooth are visible simultaneously. Thirdly, the central ray should be aimed at the root. If it is aimed at the crown, there is a risk that the apex will be missing from the radiograph.

It is a good plan, when recording the initial radiograph before starting treatment, to use a long cone technique with a holder, so that the film and tooth are parallel. This method causes less distortion and will produce a more accurate representation of the tooth, making subsequent measurements easier.

When the film has been processed, the image of the reamer is measured and, if it is the same length as the reamer, the distance between the point of the reamer and the apex can be measured directly, in order to ascertain the correct length of the tooth. Then 1.0 mm should be deducted from the final figure to allow for errors of parallax and because the apical foramen does not necessarily lie at the apex. Moreover, the majority of endodontists favour the apical constriction as the end point for the ideal root filling.

If, due to mal-angulation of the central X-ray, the reamer is foreshortened or elongated on the radiograph, the correct length of the tooth may be calculated. The length of reamer between the incisal edge and the tip of the reamer having been noted, the radiographic image of that distance and the length of the tooth may be measured.

Then

$$L^{T} = \frac{L^{R} \times L^{TX}}{L^{RX}}$$

i.e. length of tooth =

$$\frac{\text{length of reamer} \times \text{length of tooth on radiograph}}{\text{length of reamer on radiograph}}$$

For reasons stated above, 1.0 mm is subtracted from the final figure.

Diagnostic radiographs of posterior teeth

A diagnostic radiograph for a posterior tooth is recorded in the same way, except for the use of a cusp tip instead of an incisal edge as a fixed point (figure 25.22). In multirooted teeth, when several reamers protrude from the orifice, one fixed point of reference should be chosen and noted for all measurements. Moreover, because the canals are often very fine, it is usually necessary to insert the finest reamers. The approximate length of the tooth should be assessed from the initial radiograph and the reamers inserted to points somewhat short of the apparent length. Subsequently, calculations may be made to ascertain the correct dimensions after a diagnostic radiograph has been recorded.

The canals of a two-rooted upper premolar, or those in the mesial root of a lower molar, are in the same plane bucco-lingually, so that the images of the

Fig. 25.22 The placement of a film for taking a diagnostic radiograph of |6. The film is inserted on the tooth side of the rubber dam, after removal of the retractor, so that angulation of the cone will be made easier when bisecting the angle subtended by film and reamers.

reamers tend to be superimposed in the picture. This problem may be solved by rotating the cone of the X-ray machine in the horizontal plane through approximately 15° so that it faces across the mesial embrasure of the tooth. The radiograph should be taken with a file in the buccal canal and a reamer in the lingual, to aid differentiation when the film is viewed (figure 25.23), although, if the direction from which the radiograph was taken is known, the orientation of the roots on the radiograph is self-evident.

Despite this variation in radiographic technique, it is sometimes difficult to obtain adequate separation of the roots on the radiograph. Consequently two films may be used for a lower molar, the first to include, for example, the distal and mesio-buccal reamers and the second the mesio-lingual alone.

After taking the radiograph, the canal may be dressed with an antiseptic until the next visit. This is not intended to combat infection, which should not be present after extirpation of a vital pulp, but to

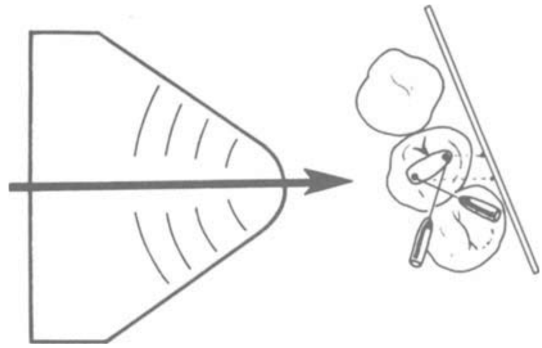


Fig. 25.23 Separation of images of buccal and lingual reamers by modifying the angulation of the central ray in the horizontal plane.

take care of any organisms which may inadvertently gain entry. Camphorated paramonochlorphenol is a good antiseptic which has stood the test of time. It should be inserted on a pledget of cotton-wool or on a short blunt paper point, which will extend no further than halfway to the apex. If a fine paper point is carried up to the apex it may pass through the foramen and, if it is soaked in antiseptic, a severe periodontitis could ensue.

The cotton or absorbent point should only be damped with the drug, otherwise when the pulp chamber is sealed, the drug might be forced into the periapical region.

The antiseptic dressing should be covered with a small pellet of hot gutta percha, which is pressed against the walls to prevent the temporary cement entering the canal. Finally, the coronal orifice is sealed with a plug of polycarboxylate cement or E.B.A. cement. In order to prevent this seal from being forced, under masticatory stress, into the pulp chamber, which would allow contamination of the canal, the orifice should be flared out slightly to make the margin wider than the interior, so that the cement plug is conical. It has been found that when a zinc eugenolate cement is used, it is less apt to be disturbed if it is mixed to a heavy consistency, with a few fibres of cotton-wool incorporated as a binder.

Another material for sealing the coronal orifice is Cavit (Espe) (see Appendix), which hardens on contact with the saliva. It has proved satisfactory, even when subjected to masticatory stress in posterior teeth. It must be packed firmly against the walls of the cavity to obtain a good seal.

After the coronal orifice has been sealed, the rubber dam is removed and the occlusion is checked again, in case the dressing has been overbuilt. If it were to pass unnoticed that the dressing was high, a severe periodontitis could develop.

The patient is dismissed with the instruction to take a mild analgesic if slight pain is experienced, but to return if swelling or more severe pain should develop. These would be treated by removal of the dressing, gentle irrigation of the canal and insertion of a corticosteroid antibiotic dressing for a few days. Between visits the radiograph is used to calculate the length of the tooth.

Biomechanical preparation of the canal

The term 'biomechanical preparation' has been coined to refer to the enlargement, shaping and irrigation of root canals. The irrigation is necessary firstly, to wash away debris, which might otherwise block the canal, or be forced through the apical foramen; secondly, to exert an antibacterial action and dilute toxins and if possible, to dissolve protein debris; and thirdly, to lubricate the canal and thereby facilitate instrumentation.

Enlargement of the canals is necessary to convert their irregular rough cross-section into a smooth circular cross-section, thus eradicating any areas which might harbour necrotic and infected pulp remnants, and produce a shape which will allow the insertion of a good root filling.

Finding the orifices of the canals is, generally speaking, a simple procedure in teeth with single roots, although at times, due to excessive narrowing or the presence of pulp stones, this may be difficult or even impossible. Should such difficulties arise, the access cavity may be enlarged to improve visibility and the floor of the pulp chamber swabbed with liquor iodi mitis. This will stain the orifice a darker hue than the surrounding dentine, and a sharp probe may be used to locate the canals and attempt to force an entry, after which a fine file may be inserted and advanced with a gentle reciprocating, hemirotational action. A complete blockage may be opened, in some cases, by a few gentle touches with a size ½ round bur, operated at slow speed and with gentle pressure. If this is of no avail, it may be better to attempt apical surgery than to run the risk of perforating the floor of the pulp chamber.

If the canal is found, but will not admit the finest file, the pulp chamber should be flooded with a solution of ethylene diamine tetra-acetic acid, a chelating agent, which will slowly soften the dentine by the removal of calcium. It is safe to leave the drug, combined with an antiseptic drug, e.g. cetrimide, between visits, because its action is self-limiting and ceases when all the calcium-hungry bonds are satisfied. The drug combination is referred to as EDTAC and was first recommended by Ostby (1957).

All canals which are relatively wide and roughly circular in cross-section may be prepared largely with reamers, which cut when turned in a clockwise direction. Canals which are very fine or curved or are flattened in cross-section are better prepared with root canal files, which cut when a pulling action is exerted. The file is advanced by giving a quarter to half a turn and pulling when the tip binds, then repeating the action and removing the file in order to irrigate debris from the canal from time to time. The file should never be rotated more than a limited distance when it binds, otherwise the tip is apt to fracture.

Hedstroem files (figure 25.24) have a more fragile cross-sectional shape and thus require careful manipulation if fracture is to be avoided (figure 25.24). It is a good plan to file all canals initially, because the scraping action of a file on the dentine is more apt to eliminate adherent pulp remnants and avoid the possible retention of vital tissue which would require local anaesthesia for its removal at a subsequent visit.

Fine files may be advanced around a curved canal and the continuous pulling action brings the cutting blades more into contact with the lesser curvature, thus tending to produce a straighter canal which is more accessible for the use of larger files and ultimately easier to fill.

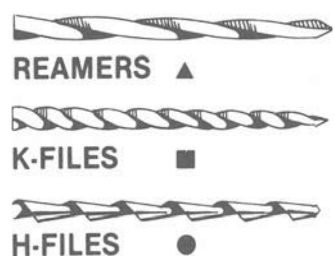


Fig. 25.24 Cross-sectional shapes of wires from which root canal instruments are manufactured. (Courtesy of Bayer Dental Manufacturing.)

Canals in lower incisors, upper lateral incisors and upper premolars may be flattened mesio-distally, and their preparation should be accomplished mainly with files, paying especial attention to the buccal and lingual walls of the canals, in which a fine file should be used. The canals tend to be more circular in their apical regions and thus preparation of the apical third can be completed with a reamer.

When an obstruction is found near the apex, the radiograph should be examined. If the canal appears to be more radiopaque in that area, this could indicate a division into buccal and lingual branches. A further radiograph, recorded at a different angle in the horizontal plane, may give a clearer indication of this anomaly. If the tooth is vital and no further progress is possible, or only one canal is negotiable with an instrument, it is permissible to amputate the pulp at that level and prepare and fill the canal to the obstruction. When infection is present, a surgical approach is indicated.

The technique for reaming and filing

Reamers are given a quarter turn, then withdrawn and their blades wiped clean on a sterilised cotton-roll. The action is repeated until the reamer may be rotated freely at the apical constriction, then the next reamer is substituted and the operation repeated through a graduated series of reamers, until clean dust appears on several successive occasions in the grooves between the cutting blades.

If a fine reamer binds in the canal and is rotated further, the tip will be stressed and ultimately it will fracture. Figure 25.25 shows instruments the blade of which have been thus distorted. As soon as such distortion is seen, the reamer must be discarded. Similarly, any reamers or files which are bent may fracture in use and consequently they should not be used again. Fine reamers should only be rotated fully when they do not bind on the walls.

After each use of the smaller sizes of reamers and

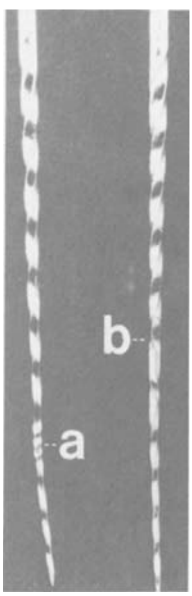


Fig. 25.25 The effects of over-strain on reamers. (a) The reamer has jammed apically and, by continued torsion, has been twisted to a tight spiral. (b) After jamming, the reamer has been unwound by turning it in an anti-clockwise direction, unwinding the flutes. Both reamers are in imminent danger of fracturing.

files, namely sizes 8 to 25, they should be discarded. Sizes 30 to 50 may be used, depending on the amount of preparation in each case, approximately 2 or 3 times, whilst the largest sizes, 60 to 140, may be used a number of times until their cutting efficiency becomes reduced. This is assessed by a line of reflected light from the cutting edge and the finding that increased pressure is required to use them. The onus is on the operator to check the condition of root canal instruments before using them. It is far less trouble than attempting to remove a fractured instrument from a canal.

Fracture of a root canal instrument

If an instrument should fracture in a canal, the patient must be informed of the fact and a note made in the patient's record card. A radiograph will show the length and position of the fragment, and the remainder of the instrument should be retained in case of future litigation. Grossman (1968) assessed the outcome of leaving fragments of endodontic instruments in canals in 66 cases, after periods varying from 6 months to 5 years. He reported that, where previously normal bone structure existed periapically, it remained normal in the majority of cases, whereas existing periapical areas of rarefaction persisted in about fifty per cent of cases.

These observations enable us to take a less gloomy view of fractures, however, every care must be taken to avoid the use of excessive force during instrumentation and to ensure that instruments are maintained in optimum condition.

It is imperative that each instrument be followed by the next one in the series, because the gradation of sizes is adjusted to allow the use of minimum force. If any size is missed out, greater force is required to cut into the dentine and the risk of fracture is increased. Furthermore, constant irrigation, by lubricating the canal, facilitates preparation.

The I.S.O. specifications state that the length of the cutting blade shall be 16 mm, and a range of sizes is available in the following numbers: 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 70, 80, 90, 100, 110, 120, 130, 140. The number refers to the diameter of the blade, 1.0 mm from its tip, expressed in hundredths of a millimetre.

The taper is constant throughout the range, the diameter being 0.3 mm less at the point 1.0 mm from the tip than at the 16 mm point where the cutting zone ends.

A recent development which helps in the selection of instruments is colour coding. Chart 1 shows the internationally recognised code.

Chart 1 Colour code reference chart (courtesy Bayer Dental Manufacturing)

ISO number	008	010	015	020	025	030	035	040	045	050	055	060	070	080	090	100	110	120	130	140
Actual dimensions $(m \times 10^{-5})$	0.08	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40
Old number	0.0	0	1	2	3	4	4½	5	5½	6	6½	7	8	9	10	11	12			
ISO colour	Silver	Purple	White	Yellow	Red	Blue	Green	Black	White	Yellow	Red	Blue	Green	Black	White	Yellow	Red	Blue	Green	Black

Once the canal has been reamed beyond size 30, it is usually feasible to give the reamer several turns, remove it for cleaning and continue reaming with a rotary action until it can be turned freely, when the next size may be substituted.

Some practitioners prefer to use engine reamers, which they consider to be more efficient than hand reamers and which enable them to prepare canals at greater speed. While this is a reasonable argument when straight wide canals are to be treated, there are many dangers inherent in their use. They may bind and fracture, drill through the apex or make a false path and perforate the root. Hence they cannot be recommended for general use.

Preparation of a canal should never be started until a diagnostic radiograph has been recorded and the length of the canal calculated.

It is important to remember that markedly curved canals may only be reamed and filed to a maximum diameter of size 25 or 30, because instruments of greater diameter are too stiff to negotiate the curvature. In order to facilitate the passage of a file around a bend in a canal, a gentle curve may be produced at the apical 5.0 mm of the file and this curve helps to guide the instrument around the bend, when the instrument is advanced gently with a side-to-side hemi-rotatory action.

The bulk of the preparation of fine canals should be carried out with files, reserving the use of reamers for preparing the apical portion of the canal, so that it will have a circular cross-section to receive a matched filling point. Wider, straight canals, however, may be prepared exclusively with reamers, if their cross-section is roughly circular.

When preparing the canal of a curved root, the decreased flexibility of files wider than sizes 20, 25, or 30, prevents their use in the apical curve. Any attempt to continue filing or reaming will produce a ledge, and ultimately, a 'tear-drop' perforation of the root.

To prevent the occurrence of these problems the technique of serial preparation by filing and reaming has been evolved. Various modifications of technique have been described, for example, that of Schilder (1974), however, basically the method entails shaping the canal in such a way that its taper, from coronal to apical, allows increased access to the apical part without weakening the root unduly. The access cavity must be so devised that inimpeded, direct access to the canal is possible. Then, having ascertained the position of the apical constriction by means of a diagnostic radiograph, the apical part of the canal is filed until difficulty is experienced in placing the file to the constriction. The mid-portion of the canal is now widened by proceeding through ascending diameters of files and resetting the stop 1.0 mm shorter at each increase in size. The steps thus produced are 'ironed out' by recapitulating at each stage with the smaller file, until a flare is produced in the canal. This flare often will enable the operator, using small files, to re-enter and enlarge the previously prepared apical part of the canal.

Thus, by recapitulating with flexible instruments, the apically curved part of the canal is shaped and its curvature maintained. The canal, when ready, ideally is filled with gutta percha, using a technique of thermal softening and lateral or vertical condensation, or a combination of both.

As an additional aid, when producing the flare, a loose fitting Gates-Glidden drill (figure 25.26) operated slowly and with a pulling action, will speed the preparation of the coronal two-thirds of the canal. Constant irrigation will avoid blockage of the canal with dentine dust, which could impede progress with files and interfere with subsequent filling.

The canals should be prepared using files, to a minimum size of 40, although some highly sclerosed roots with severe curvatures may not be amenable to that degree of preparation. Each case must be treated in accordance with circumstances. Pre-curving the tip of each instrument will help it to negotiate the bend in the canal.

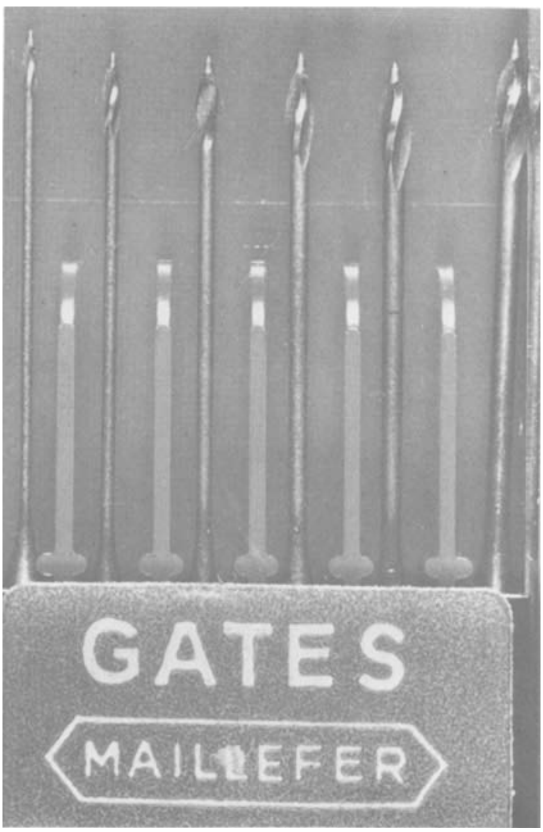


Fig. 25.26 A set of Gates-Glidden drills.

When preparation has been completed, a further radiograph is recorded with a trial gutta-percha cone at the apical constriction as a check prior to filling. Although the gutta-percha cones are matched, theoretically, to the size and taper of the reamers, it is often found that some minor variations occur. Thus, selection of an accurately standardised cone may require a trial of a number of cones, but the smaller size of cone should not be used because its adaptation to the apical third of the canal would be poor.

The chief difference between K-type files and Hedstroem files is that the former may be used with a half turn and pull action, similar to that employed when reaming, whereas the latter cut dentine only when withdrawn. Personal preference plays a large part in the choice, because both are held to be equally efficient, however, Hedstroem files appear to cut more quickly but, because of their design, may fracture more easily if abused.

Irrigation

Whatever method is used to shape canals, the scraping of dentine from the walls produces debris which, when it forms a slurry with blood and tissue fluids, can cause blockage of fine canals. Prevention of what can become a serious problem is best avoided through constant irrigation, preferably after the use of each instrument. The chief property of an irrigant is that it must be innocuous to periapical tissue.

A 2.0% of solution of sodium hypochlorite or a mixture of two quaternary ammonium compounds (Savlodil-I.C.I.) are both well tolerated. A gentle flushing action, with the needle lying loosely in the pulp chamber, is all that is required. Rubin *et al.* (1979), using various solutions to irrigate root canals of extracted teeth, found, with the aid of a scanning electron microscope, that the most important factor in cleaning canals is the biomechanical preparation, regardless of the nature of the irrigant, but he found that sodium hypochlorite (2½%) was an excellent solvent of pulp and predentine and left the canals well cleaned.

The canal should be prepared, as previously stated, to a point approximately 1.0 mm from the radiographic apex, i.e. to the apical constriction. When it is found that a small reamer tends to pass through the apical foramen, or if the foramen has been accidentally enlarged, a larger reamer should be inserted gently, and, if necessary, a further radiographic check carried out to ascertain whether the correct point has been reached before reaming is recommenced.

Mechanical preparation of canals

Special handpieces are available, such as the Giromatic (Micro-mega) which takes special barbed broaches and graduated files for cleansing and enlarging canals (figure 25.27). It works with a side-to-side reciprocating action, moving the instrument a half turn in each direction. It should be operated at low speeds, while being advanced and withdrawn, and the canal should also receive constant irrigation. The instruments available are extremely flexible and fracture is an uncommon complication, because they do not bind.

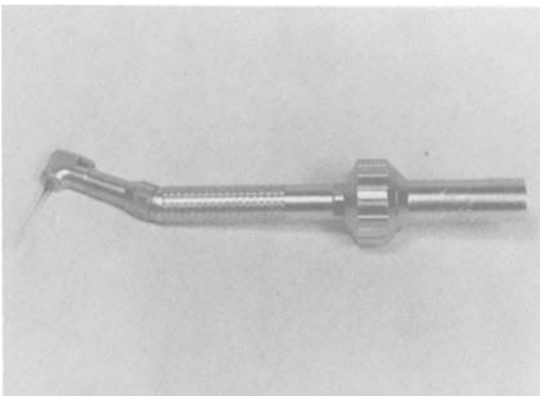


Fig. 25.27 The Giromatic (Micro-mega) reciprocating handpiece with a barbed broach.

Mizrahi *et al.* (1975) carried out a scanning electron microscope study of the efficiency of the reciprocating handpiece, as compared with the normal hand instruments. They showed that the best results were obtained when a regular file and reamer were used in combination. The worst results stemmed from the use of the Giromatic broach.

Klayman and Brilliant compared the efficacy of serial preparation as opposed to Giromatic preparation and concluded that the former is far more effective in removing tissue debris from root canals.

The majority of root canal instruments available at present are made of stainless steel. Should such an instrument fracture, it is impossible to corrode the fragment out of the canal, whereas it is possible to corrode a carbon steel fragment out of a canal with liquor iodi fortis (figure 25.28).

Formula	Potassium iodide	28% by weight
	Iodine crystals	28% by weight
	Water	44% by weight

Fig. 25.28 (a) Fragment of reamer in canal. (b) After dissolution of fragment with liquor iodi fortis. (c) Canal filled.

Drugs for use as root canal dressings

Theoretically, no drug is required after extirpation of a vital pulp and irrigation of the canal, but it is customary to insert a bland antiseptic in the tooth between visits as an insurance against bacterial contaminants. However, in teeth with necrotic, fibrotic or suppurating pulp remnants, it is imperative that antibacterial drugs be used in order to combat any infection, whether suspected or obvious.

No caustic drugs should be put into root canals, because they are apt to reach the periapical tissues and cause a severe reaction. The sole occasion on which a caustic drug, such as formo-cresol, may be used is after opening into the pulp chamber of an obviously infected tooth which is symptomless. If a dressing of formo-cresol on cotton-wool is sealed in the pulp chamber, the heat of the body allows the formaldehyde vapour to assail the canals and penetrate into any lateral ramifications, in such a weak concentration that its effect is to attenuate the virulence of the bacteria and render them innocuous, should they reach the periapical tissues. It has been demonstrated that no damage to the tissues is produced, however, by the low concentration of formaldehyde.

Even relatively mild drugs, such as creosote (beechwood) and camphorated para-monochlorphenol (C.C.P.) should not be placed in the apical part of the canal, because they may cause severe chemical irritation and upset the precarious balance existing in the periapical region, with dire results.

It has been found by many endodontists that, provided a drug is not of an irritant nature, the type used does not materially affect the result and is of less importance than the cleaning and ultimate sealing of the canal. A drug is most effective when it is present in a high concentration and is not inactivated by organic debris or pus.

The author recommends the use of a mild antiseptic, e.g. C.C.P., or a quaternary ammonium compound, such as a mixture of cetrimide and chlorhexidine. Good results have been obtained also with polyantibiotic paste, e.g. P.B.S.C. (Grossman's formula). This contains penicillin, bacitracin, streptomycin and sodium caprylate which are able, through antibacterial synergism, to destroy the vast majority of organisms found normally in infected root canals.

Recently Grossman has modified the formula by substituting nystatin for caprylate, because it is a more effective fungicide.

Similarly, Sommer, Ostrander and Crowley recommend the use of a mixture of C.C.P. and penicillin as a medicament for use in root canals. The mixture is made ready for use by spatulating a tablet of soluble penicillin (50 000 i.u.) with one drop of C.C.P., and the paste so produced is introduced into the canal on a reamer. It is suggested that this paste should be used after C.C.P. alone has proved ineffective in controlling an infection.

Recently, in keeping with the tendency to use less irritating drugs as root canal dressings, a 6% aqueous solution of parachlorphenol and a 2% solution of glutaraldehyde have been advocated. Both have proved to be highly effective. The latter must be prepared fresh each month because of its short shelf life.

Calcium hydroxide

Calcium hydroxide, apart from its use as a pulp capping agent, has now gained wide acceptance as a medicament for the treatment of open apices, infected canals and associated periapical lesions. Matsumiya and Kitamura (1960), Binnie and Rowe (1973), Heithersay (1975), Cvek (1972) and Cvek *et al.* (1976) demonstrated that elimination of infection and healing of periapical tissues follow the dressing of canals with a suspension of calcium hydroxide. Vernieks and Messer (1978) placed an 'intermediate' dressing of calcium hydroxide for a period up to 12 months prior to filling the canal, and claimed a 79.5% success rate after 18 months.

Calcium hydroxide, which is highly alkaline (–pH 12.2), appears to influence the healing of bone through its bactericidal properties and its local buffering action. Also, through the control of periapical exudation due to the high calcium ion concentration, calcification appears to be encouraged. Heithersay (1975) postulates that the calcium-ion dependent enzyme, pyrophosphatase, which alters pyrophosphate to orthophosphate, may be activated by the calcium hydroxide and thus increase the energy utilisation to favour the repair mechanism.

The mode of use in non-vital infected teeth is as follows. Firstly, all symptoms should be eliminated through careful preparation of the canal and dressing with a cortico-steroid/antibiotic paste (such as Ledermix or Septomixine). If required a suitable antibiotic may be given orally or by the intramuscular route.

When the tooth is comfortable, a suspension of calcium hydroxide in carboxymethyl-cellulose is spiralled slowly to a point slightly short of the apex, and a good seal, such as polycarboxylate cement or silico-phosphate cement, is placed in the access cavity. This is left for a variable time from 4 to 12 weeks, after which it is removed and replaced by a conventional root filling.

When there is an immature apex, associated with a non-vital pulp, further apical development can be induced by this technique, which has been called 'Apexification'. Large files are used to cleanse the canal, taking precautions to avoid their use beyond the apex. After temporisation with a bland or anti-inflammatory drug in the canal, the calcium hydroxide is introduced on a spiral filler until the space is filled, and a composite or amalgam seal is placed. Radiographs are recorded at the time of filling and after 6, 12 and 24 months. When there is evidence of further apical formation, with closure of the apical foramen, the canal is re-entered, the dressing removed and a conventional root filling is inserted.

Calcium hydroxide should never be used when acute symptoms are present, because severe pain is apt to develop. If this should occur, the dressing may be replaced temporarily by an antibiotic/corticosteroid mixture.

Frank (1966) advocated the use of a mixture of calcium hydroxide powder and camphorated parachlorphenol for apexification (figure 25.29). However, in the light of subsequent evidence that methyl cellulose, used as a vehicle for calcium hydroxide, produces similar results, and the known irritant properties of camphorated parachlorphenol, its use is no longer justified.

Calcium hydroxide suspension may be used also in the conservative management of root perforations, transverse fractures of the root, internal resorption and, in order to prevent external resorption following tooth replantation, it may be used as a temporary dressing, to be replaced by a filling after re-attachment has occurred.

Cvek and Sundstrom (1975), reporting on apical closure with calcium hydroxide, showed that the tissues forming the apical seal showed mild inflammatory changes and consisted of a cementoid tissue plus areas of calcification. Few teeth showed a complete apical closure and there were vital, uninflamed areas of loose connective tissue included in the hard tissue barrier.

A multitude of different drugs and combinations of drugs, both antiseptics and antibiotics, have been

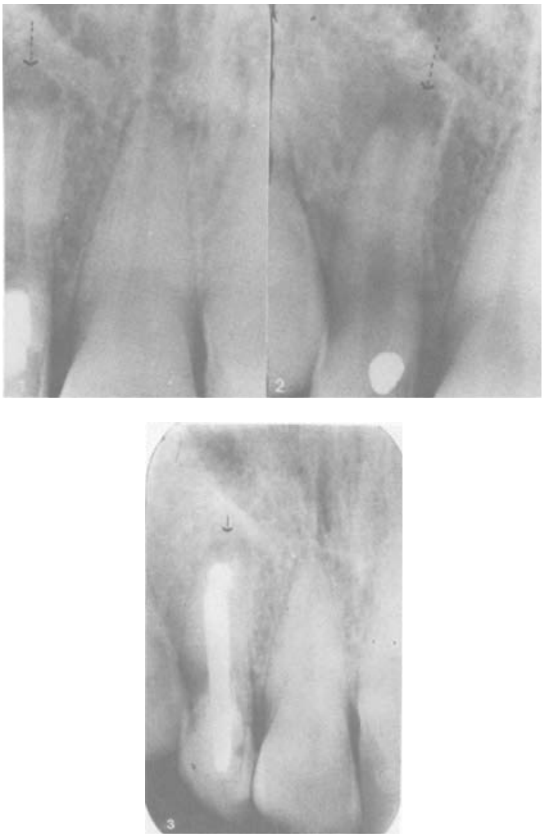


Fig. 25.29 Treatment of an infected canal with an open apex and peri-apical area, using calcium hydroxide. P.L. (age 27 years). (1) Discoloured lateral incisor. Radiograph shows peri-apical area. No history of pain or trauma. Canal cleaned and prepared, then dressed with suspension of calcium hydroxide in mono-chlorphenol. (2) After 2 years, apical closure was palpable with an endodontic instrument. (3) Canal obturated. (Courtesy of Mr. W. L. Rumun, Hounslow, Middlesex.)

advocated over the years and undoubtedly many of them have proved to be of value in assisting the biomechanical eradication of infection.

Biocalex

The Biocalex technique for the sterilisation of root canals was developed by Bernard (1967) and relies, for its effectiveness, on a massive expansion of a slurry of calcium oxide in a mixture of ethylene glycol (79.5%) and ethyl alcohol (6%) and distilled water (14.5%) when sealed in a root canal system. The original Biocalex '4' required a special mixing technique to break up the inter-molecular cohesion of the particles of calcium oxide in order to obtain an expansion in the region of 200–280%. Subsequent modification of the formula was made in 1973 when Bernard substituted a 'heavy' form of calcium oxide, which had a different crystallographic structure from the original. The new powder, which contained one-third by weight of zinc oxide, underwent 2–3 times the expansion of Biocalex '4' and was marketed as Biocalex '6–9' with a liquid which consisted of distilled water (20%) and ethylene glycol (80%). The mixing technique for the modified product was changed, in that only normal spatulation was necessary to produce the correct consistency. Basically the mode of use entails preparation of at least one third of the endodontic area to produce a large provisional canal space. The only cases in which Biocalex should be used are those in which there is a non-vital pulp associated with suppuration of bacterial origin. Before the treatment is started, any acute symptoms should be eliminated by the use of systemic antibiotics and by obtaining direct drainage through an opening into the pulp chamber.

The coronal third of the canal is opened widely with files and moistened with distilled water, and a slurry of Biocalex is spatulated to a creamy consistency on a glass slab and carried up the provisional canal on a reverse spiral filler.

Operating the spiral at slow speed, to avoid cavitation and air entrapment, it is rotated while being withdrawn from the canal and the procedure is repeated 2 or 3 times to ensure complete filling of the canal with the paste. A small pledget of cotton wool is placed in the pulp chamber and the access cavity is sealed with a temporary cement such as polycarboxylate cement. Zinc eugenolate cement should never be used because the eugenol would form a chelate with the calcium ions and thus all expansion would cease.

The expansion which occurs as a result of the reaction (which slakes the lime and forms calcium hydroxide while heat is produced and chemical energy is released), forces the calcium hydroxide into the apical, unprepared part of the canal and along accessory and lateral canals where dead organic matter is subjected to chemical disintegration.

The initial reaction is: $CaO + H_2O \rightarrow Ca(OH)_2$. As a result of the breakdown of organic debris, carbon dioxide is evolved and reacts with calcium hydroxide to form calcium carbonate, thus: $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$.

Bernard hypothesises that success is due to expansion of the slaked calcium oxide and the accompanying 'chemical incineration' plus subsequent obliteration of the whole canal system by calcium hydroxide and calcium carbonate. He concludes the treatment by the use of a chelating liquid cement which, in contact with the calcium carbonate and calcium hydroxide end-products, hardens instantly and radiopacifies the contents of the canals. This hardened material is then destined to remain as the definitive root filling.

However, Donnelly & Harty (1979), in an investigation of the in vitro behaviour of Biocalex, found a mean percentage expansion of only 64%, and they were unable to demonstrate any radiopacity of the paste, because the zinc oxide was left behind when expansion occurred.

They were also unable to demonstrate any ability of Biocalex 6:9 or the hydroxyl ions in particular to effect chemical incineration of residual organic debris in extracted teeth with necrotic pulps. In consequence, they felt unable to recommend the material as an alternative to conventional endodontic preparation and sealing.

The author has used Biocalex for 11 years with great success in a large number of cases in which difficulty was experienced in reaching the apical third of roots with putrescent pulps and periapical lesions. The technique advocated by Bernard is followed, in relation to the mode of application of the Biocalex. However, when the first dressing of Biocalex has been removed, with the aid of root canal files, after a period of 1–2 weeks, a diagnostic radiograph is recorded and an attempt is made to reach the apical constriction. A dressing of calcium hydroxide paste (Hypocal) is then inserted and, when ready, the canal is filled with conventional materials (figure 25.30). If, however, the apex can not be reached, a further dressing of Biocalex is applied and subsequently, subject to complete remission of symptoms, the canal is filled as far as the obstruction, using a conventional filling material (figure 25.31).

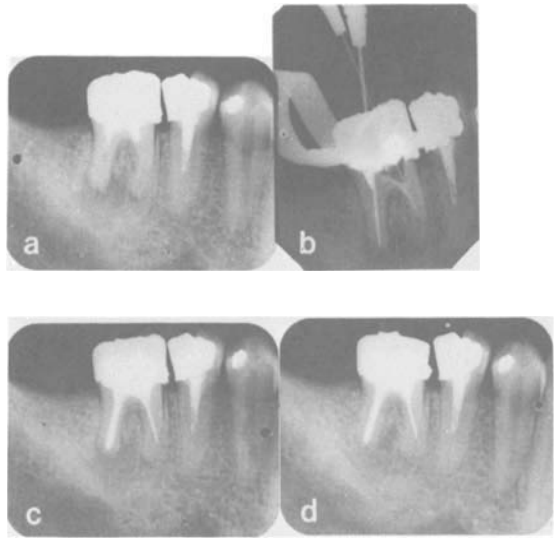


Fig. 25.31 Treatment of infected molar root canals with Biocalex (a) Crowned $\overline{6|}$ with inadequately treated root canals and associated periapical areas with root-end resorption. Patient was complaining of a continuous dull ache. (b) Diagnostic radiograph showing reamer in false canal in mesial root. Only one mesial canal located. (c) Both canals filled after preparation and treatment with Biocalex. All symptoms disappeared after the first treatment and the canals were filled with silver points and AH 26. (d) Virtual elimination of periapical areas after eleven months. No reoccurrence of symptoms.

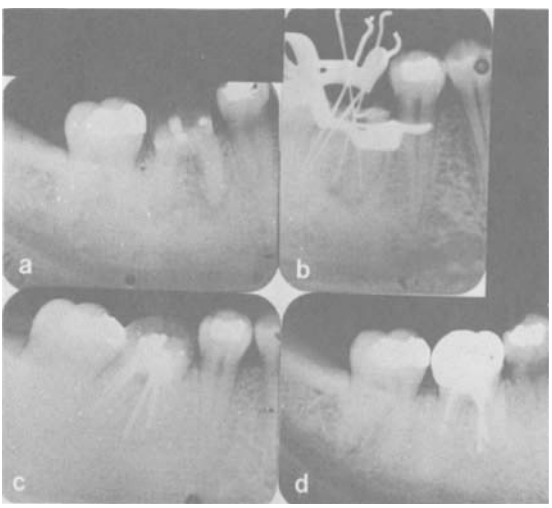


Fig. 25.30 (a) Lower first molar with peri-apical radiolucency associated with suppurative infection of all four canals. Canals enlarged coronally and dressed with Biocalex. (b) Diagnostic radiograph. Canals prepared to apices and dressed with a suspension of calcium hydroxide. (c) Canals obturated with silver cones and AH 26. (d) Healing of periapical bone two years later.

Biocalex should never be used when there is vital pulp in the canal or when the canal has been prepared previously as far as the apex, because the patient may experience pain. When there are acute symptoms, a corticosteroid/antibiotic paste may be placed in the pulp chamber and a systemic antibiotic administered. After the symptoms have subsided the canal may be prepared to receive the Biocalex.

The notable features of this technique are the absence of reaction to the Biocalex, unless it is forced through into the bone in the presence of an acute apical periodontitis, and the rapid disappearance of a sinus. Also, on completion of a root filling, resolution of a periapical lesion, as judged by radiographic changes, occurs more quickly and often more completely than after the use of conventional root canal disinfectants. This healing propensity is due probably to the favourable influence of the high pH of calcium hydroxide on repair, notably osteoblastic activity, following on its earlier antibacterial effect within the canal.

The author feels strongly that a pragmatic view should be taken regarding the use of endodontic materials such as Biocalex. We know that the end-product of the reaction is calcium hydroxide, the use of which in the treatment of suppurative endodontic conditions is well documented and universally accepted. In consequence of these facts, plus the high degree of success encountered in cases which might otherwise have proved impossible to treat without surgery, Biocalex appears to have an important place in the treatment of suppurative conditions of the pulp and periapical tissues (figures 25.32, 25.33).

The use of corticosteroids

Use has been made of the anti-inflammatory effect of the glucocorticoids by Schroeder (1962) to calm down an acute pulpitis. Two preparations are available which consist of one or more antibiotics and a corticosteroid, the antibiotic being used to destroy organisms which could otherwise spread unchecked following suppression of the inflammatory response by the corticosteroid. In one preparation – Ledermix (Lederle), triamcinolone, an analogue of cortisone, is combined with demethyl chlortetracycline, whereas in another–Pulpomixine (Septodont), dexamethasone is used with a group of antibiotics not intended for parenteral administration – Polymixine B and Framycetin. These preparations are recommended for the treatment of acute pulpitis. A further preparation – Septomixine (Septodont) contains dexamethasone with Polymixine B, Tyrothrycin, Neomycin and a fungicide. This mixture, when used in root canals, is effective in calming down an acute apical periodontitis

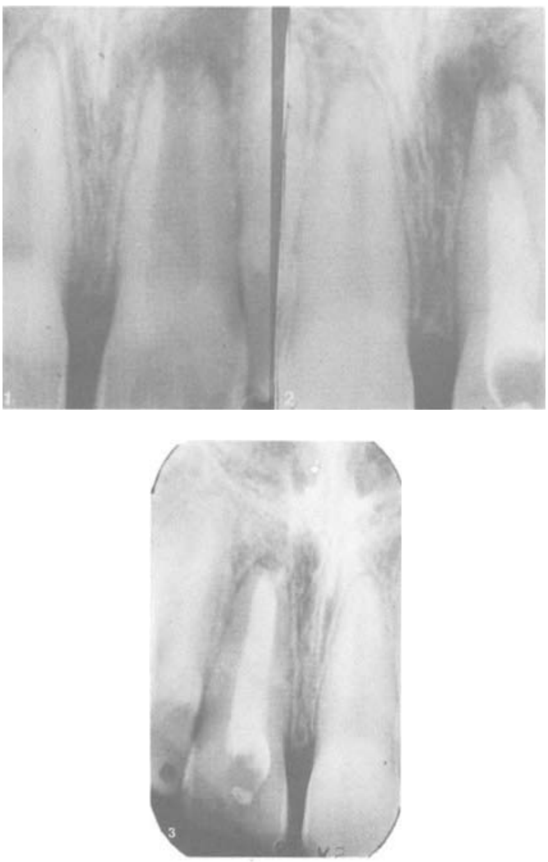


Fig. 25.32 (i) Treatment of an open apex with a dressing of Biocalex. I.S. (age 12 years). (1) Upper incisor crown fractured 3 years before first visit. (2) Canal prepared and dressed with Biocalex. (3) Apical area healing three years later. Canal filled permanently. (Courtesy of Mr. W. L. Rumun, Hounslow, Middlesex.)

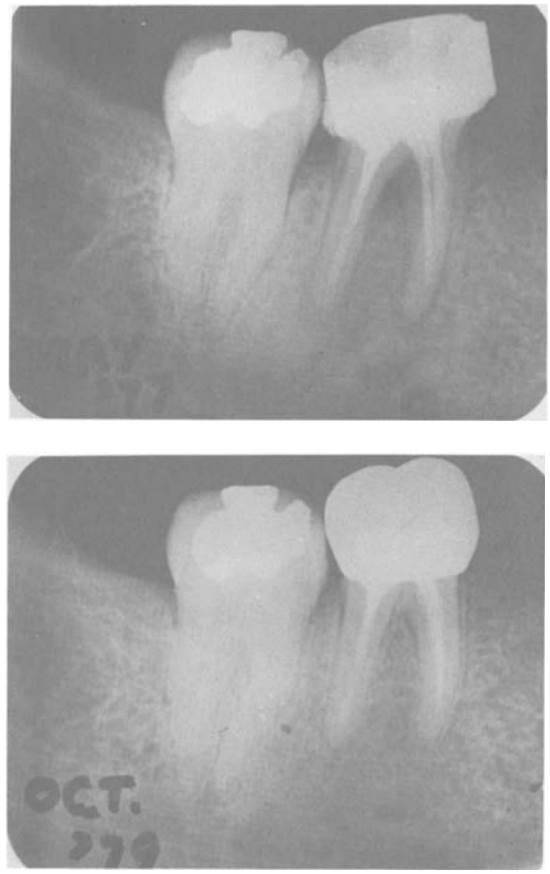


Fig. 25.33 Canals of mesial root of lower first molar impassable short of apex. Canals first treated with Biocalex, then, after preparation of remainder of canals, obturation carried out with gutta percha and AH 26. Radiograph taken after 2½ years shows virtual healing of peri-apical bone.

which may follow injudicious reaming in the periapical region, especially in the presence of a severe pulpal infection. If the operator finds that, inadvertently, he has penetrated the apex or perforated the pulp chamber or canal, the mixture should be inserted as a prophylactic against afterpain.

The stage at which the tooth is ready for root-filling

The endodontic world is split into two camps over the necessary prerequisites for sealing a root canal. One group demands two successive negative bacterial cultures from the canal prior to filling (e.g. Engström and Lundberg, 1965), while the other group, conscious of the shortcomings and the inadequacy of culturing techniques, prefers to rely on clinical signs and the absence of symptoms, combined with a sound preparation and thorough sealing of the canal.

The advocates of culturing, especially in Europe, tend to be centred in academic institutions, whereas the majority of dental practitioners do not use culturing techniques, and recently academicians and research workers have begun to cast doubts on the need for bacteriological controls.

Matsumiya and Kitamura (1960) investigated periapical healing following root canal therapy in dogs. They found that periapical healing occurred irrespective of the presence of organisms in the canals and their lateral branches and the lacunae of the cementum. The organisms tended to die out in time after the canal had been treated and obturated, regardless of the drugs which were used.

Selzer *et al.* (1964) carried out an investigation into the histology of repair following positive and negative cultures from root canals. They concluded, after examining the results of root treatment on 2,335 teeth, that the end-result was more dependent on the method and completeness of root canal filling than on sterility.

They detail the criteria for repair as follows:

(1) Newly elaborated cementum deposited on previously resorbed apical cementum.
(2) Osteoblasts forming new bone on the periphery of old trabeculae.
(3) Reduction in density of inflammatory cells and capillary buds.
(4) Replacement of collagen fibres with new bone trabeculae.
(5) Reduction in width of previously widened apical periodontal space.

They found that violent reactions followed overfilling of canals.

Culturing of samples from root canals

From the foregoing, it will be seen that there is a tendency today in many circles to relegate the culturing of root canals to the sphere of research. However, there are other areas in which culturing is of value; firstly, it provides a useful means of testing the effectiveness of the aseptic technique, and secondly, by growing the culture on a blood agar plate, in which holes are punched and filled with known dilutions of different antibiotics or culturing on a plate upon which a series of discs impregnated with antibiotics is placed, the effectiveness or otherwise of each antibiotic may be judged by the diameter of the growth-free zones (figure 25.34).

Fig. 25.34 Antibiotic sensitivity test on seeded blood agar plate showing maximum sensitivity of organism to chloramphenicol and erythromycin, and complete resistance to streptomycin.

This will enable the operator to choose the most appropriate antibiotic for use, either in the canal or for systemic administration. This does not mean that there should be a delay of 48 h before giving a systemic antibiotic, but it does confirm the effectiveness of the antibiotic used or indicate a preferable alternative.

The technique to be adopted requires a supply of Bijou bottles, containing glucose broth or, for both aerobic and anaerobic culture, Robertson's cooked meat medium.

When the dressing inserted at the previous visit has been removed, a sterile paper point is passed up to the apex, left there for 15–20 s and removed. If there is no visible exudate on it, it is dipped into the broth and the procedure repeated.

The metal cap of the Bijou bottle is unscrewed and held in the crook of the little finger, while the mouth of the bottle is passed through the flame. The point is dropped into the broth, the cap is flamed and screwed tightly home and the specimen is labelled and dispatched to the laboratory, or placed in an incubator (at 98.4°F), which may be constructed cheaply with a thermostatically-controlled light bulb as the source of heat.

Turbidity in the broth, as seen when it is held up with a control bottle of broth, indicates a positive culture, but subculturing on nutrient agar plates would be necessary for identification of organisms or for antibiotic sensitivity tests. The canal is considered to be ready for filling after two negative cultures have been obtained.

Clinical criteria of readiness for root-filling

Any attempt to fill a root canal before the symptoms have subsided may be succeeded by a prolonged period of subacute periapical inflammation, which may become chronic or develop into an acute suppurative condition. On the other hand, the continued use of irritant drugs in the apical region of the root may induce a subacute apical periodontitis which will subside only after discontinuation of the drug and filling of the root canal.

As a general rule, following an aseptically performed vital pulpectomy, a dressing is sealed in the coronal part of the canal until the next visit when, provided the coronal seal has remained intact and the tooth is free from symptoms, the canal may be prepared and filled. Provided an accurate technique has been used and there are no signs of infection, there is no objection to carrying out the extirpation, preparation and filling in one visit, as may be dictated by the traumatic exposure of a pulp during the preparation of a bridge abutment.

A non-vital or septic pulp, however, will require at least two dressings, in order to control any infection that may be present, especially in any lateral canals, the filling of which is unpredictable. In the absence of bacteriological control, clinical manifestations must be taken into account in assessing the state of readiness of the canal for filling.

The final reaming of the canal should reveal clean dentine swarf between the blades of the reamers, and the eccentric areas of the canal should have been cut back to sound dentine by the use of files. The canal is ready to be filled, firstly, when pain, odour and discharge are absent; secondly, when any sinus, previously discharging, has healed and vanished; and thirdly, when there is no tenderness if the tooth is percussed, and no swelling or tenderness in the soft tissues overlying the root.

The hermetic sealing of root canals

Since the discovery that root canal and periapical infections were influenced by the presence of bacteria in canals, a large variety of bactericidal drugs has been incorporated in numerous root canal sealers, with the intention of destroying residual organisms and deterring others from gaining entry to the periapical tissues.

In much the same way as Lister's antiseptic surgery has given way to aseptic techniques, the tendency today is towards the production of a perfect apical seal under aseptic conditions, using cements which are either totally inert when hard, or at most bacteriostatic.

There are, furthermore, numerous different methods of sealing canals. Some operators fill only the coronal half, whereas others seal only the apical end. Some use sealers alone and others use hard plungers, matched to the canal and sealed in with cement. There was at one time a vogue for the use of absorbable pastes which, it was stated, were replaced as they were resorbed by an ingrowth of fibro-osseous elements.

Despite the variety of techniques, the operator should choose a method of sealing which (1) gives as perfect a seal as possible; (2) leaves the canal sealed solidly at the apex so that, if required, the canal could be used subsequently for retention of a restoration; (3) does not carry the risk of disturbing the apical seal, should it be necessary to change the coronal restoration; and (4) does not produce a severe reaction in the periapical tissues if it is inadvertently extruded beyond the apical foramen. (5) In multirooted teeth, because of the possible presence of accessory and lateral canals, especially in relation to furcation areas, every attempt should be made to fill the whole endodontic space. This will have the effect of sealing them off from the risk of future contamination, should leakage develop around coronal restorations.

The chief objections to filling canals solely with a paste type of sealer which hardens are (1) the difficulty of avoiding the entrapment of air bubbles; (2) the risk that voids will form as a result of the setting contraction of the cement; and (3) the potential difficulty of removing a hard cement from a canal, in the event of failure of the root treatment, or the subsequent need to use the canal to hold a retention post.

It has been found, in general, that the simplest and most effective way of producing a good seal is by using a combination of a plunger and a sealer; the former consisting of gutta-percha cones or silver or titanium cones and the latter of a suitable cement.

Metal cones should be used only when the apical third of the root canal can be enlarged and shaped, so that its cross-section is circular and involves the whole cross-sectional area of the pre-existing canal. This allows perfect fitting of a matched cone or apical section of a cone. On the other hand, filling of a canal with an elliptical cross-section, the centre part of which has been reamed, whilst the poles of the ellipse have been prepared with files, must be effected with a plastic, deformable material in order to eliminate voids. This is best achieved with gutta percha, using vertical or lateral condensation.

Kerekes and Tronstad (1977a, b, c), investigating the possibility of using a standardised endodontic preparation and obturation technique, found that, provided the canals were not unduly curved, preparations with a circular cross-section could be prepared with acceptable frequency in the apical 2–3 mm of upper second premolars and lower premolars; the apical 5 mm of upper central incisors and canines; the apical 3 mm of lower canines and the apical 1–3 mm of the buccal roots of upper molars. The distal roots of lower molars, upper lateral and all lower incisors could be thus prepared only to a 1 mm level.

They concluded that the technique is not generally applicable in molars and maxillary first premolars.

Sealers

The properties of an ideal sealer are as follows:

It should be (1) Non-irritant.
(2) Dimensionally stable.
(3) Adaptable to the canal.
(4) Radiopaque.
(5) Insoluble in tissue fluids.
(6) Non-staining.
(7) Easy to manipulate or remove.

The author has found that Rickert's paste and Grossman's paste come close to the fulfilment of these criteria. Rickert's paste, however, which contains colloidal silver, causes some staining of tooth substance due to the formation of silver sulphide by reaction with the albumin in dentine. Consequently it should be used in posterior teeth only. The silver has the advantage of being a useful bacteriostatic agent.

A different type of sealer, AH 26 (De Trey), developed by Schroeder, has proved to be an excellent material. It is an epoxy resin, bisphenol glycidyl ether, setting of which is activated by hexamine tetramine, a cyclic aliphatic amine, and the powder contains, in addition, bismuth oxide and titanium dioxide as opacifiers and silver powder, included for its oligodynamic action. Despite the presence of silver, no staining has been noticed, probably due to its combination in the resin.

The principal advantages of AH 26 are its great adhesion to the dentine, even in the presence of moisture, its lack of irritancy and the absence of shrinkage on setting. Moreover, it takes 24–48 h to harden, thus allowing time for removal of an inadequate root filling. Any excess deposited in the bone is well tolerated and is absorbed slowly over a lengthy period. It hardens in the presence of moisture.

Fogel (1977) compared a number of materials with regard to their sealing properties and found that AH 26 produced the least seepage after 1 month and displayed the most satisfactory handling properties.

Weinberg (1980) carried out a biological evaluation of the tissue-irritating properties of four root canal sealers and concluded that AH 26 showed the least irritant effect on the tissues. These reports confirm the experience of the author who has used AH 26 for more than 20 years with excellent results.

It should not be used immediately prior to a surgical intervention because of the delay in setting, although there is no contra-indication to its use if surgery is to be carried out after a lapse of 48 hours.

Gutta-percha cones

Gutta-percha cones are available, either in a variety of sizes from fine to large, or matched in size to the root canal instruments (15–140). An approximate assessment of their composition was published by Friedman *et al.* (1975). They found that there was 20% of gutta percha, 66% of zinc oxide, as filler, 11% of radiopacifier and 3% plasticiser. The differences between various makes of cones, with regard to stiffness and compressibility, were found to be a function of the relative concentrations of gutta percha and zinc oxide.

Ideally, the finer cones should be firm enough to give some tactile sensation when they are being introduced into a canal, whereas the larger sizes should be slightly more compressible, so that they can be moulded under pressure and conform to the shape of the canal.

It is not possible to sterilise gutta-percha cones at high temperatures, hence they may be stored for several hours in a solution of povidone iodine or 70% alcohol and subsequently dried out on sterile gauze and then replaced in the dried phial, into which a small paraform tablet has been placed. This will maintain a state of sterility through the antimicrobial action of formaldehyde vapour. The cones should be withdrawn only with sterilised forceps, and any adherent paraform powder wiped off.

Alternative techniques using gutta percha

Apart from the use of gutta-percha cones, in conjunction with the sealer which fills in the spaces between the root filling and the walls of the canal, there exist alternative techniques for sealing the spaces. Chloro-percha, prepared immediately before use by dissolving a number of cones in chloroform, or a mixture of chloroform and eucalyptus, may be introduced into the canal on a spiral filler. A gutta-percha matched cone is inserted and residual solvent in the sealer softens it and bonds sealer and cones into a homogeneous mass, which may be condensed. Although this technique gives a radiographically good appearance, the setting contraction of the sealer is such that an hermetic seal can not be assured. The author carried out dye experiments using methylene blue to check the sealing properties of chloro-percha and found gross leakage of dye around the root filling.

Nygaard-Østby (1971) modified the formula, which he called Kloroperka N–O, by adding Canada Balsam, colophony resin and zinc oxide to white gutta-percha powder and chloroform. He reported a high success rate.

Recent reports in the literature recommend the use of heated gutta percha injected with a pressure syringe (Yee *et al.* 1977), and a new device, the McSpadden Compactor–(DENTSPLY) (figure 25.35) for softening and condensing gutta percha in canals. If these techniques prove to be satisfactory, there is every possibility that they will replace the slow, painstaking procedures used at present for condensing gutta percha in canals.

Filling canals with pastes

The recent vogue for filling canals with pastes alone, using such materials as N2, Spad, Endomethasone and Diaket, is to be deprecated for many reasons. Firstly, it is impossible to avoid entirely the entrapment of bubbles of air. Secondly, control of paste is difficult in a tooth with a resorbed apex or a wide foramen, and the irritant nature of these pastes may lead to severe periapical pathological change and pain. Thirdly, the shrinkage which occurs on setting may result in leakage and failure of the root treatment, and finally, there may be difficulty subsequently in re-negotiating a canal blocked with a sealant. The greatest problem with this technique is that a percentage of successful results may be obtained, but predictability of success, when the highest criteria are applied, is much lower than that obtainable by recognised techniques.

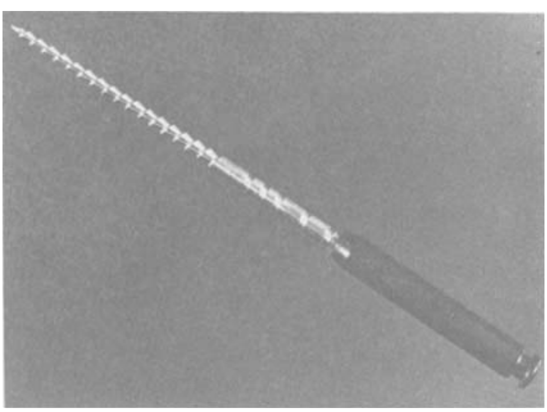


Fig. 25.35 The McSpadden Compactor for thermal softening and compaction of gutta percha in root canals.

Friedman *et al.* (1979) found little evidence to show that pastes which contain formaldehyde could 'fix' either vital or necrotic pulp tissue. They found that the toxicity of freshly mixed N2 paste was high, but decreased on hardening.

Hydron

Poly (2-Hydroxyethylmethacrylate) or 'Hydron', is a soft resilient, hydrophilic plastic which is also used for soft contact lenses. Rising *et al.* (1975) showed that, when used as a root filling, it allowed periapical healing to occur, and Benkel *et al.* (1976) claimed not only biocompatibility with tissue, but also complete filling of irregularities and subsequent calcification of all excess material which had been forced beyond the apical foramen. The material is mixed on a glass slab and injected into the canal with firm pressure. It sets in 8–15 min. Efficient and thorough preparation of the canal is a prime requisite. The material is now commercially produced for endodontics and further evidence of its efficacy is awaited.

Pyner (1980) reported a case of paraesthesia in the distribution of the inferior dental nerve following over-filling a root canal with Hydron which was then forced into the inferior dental canal.

However, this form of nerve injury will occur when the majority of root canal pastes are similarly mishandled. Thus care must be experienced whenever lower root canals, in juxtaposition to the inferior dental nerve, are prepared and filled.

Kaufman and Rosenberg (1980) reported a similar accident and sequel following the use of Endomethasone, which contains paraformaldehyde.

Technique for filling canals with gutta-percha cones

After the canal has been prepared as far as the apical constriction, a gutta-percha cone, matched to the last reamer used, is selected and tried in the canal. If the operator wishes, a radiographic check may be made. Should it happen that the cone does not seat home, the reamer should be given a few more turns, to enlarge the canal slightly, and the debris should be washed away. If the cone still does not seat home, its dimensions may be checked on an endodontic instrument comparison gauge (figures 25.36 and 25.37). Despite the matching of gutta-percha cones to reamers, there are still slight variations between one cone and another in a bottle, and even minor differences will prevent seating.

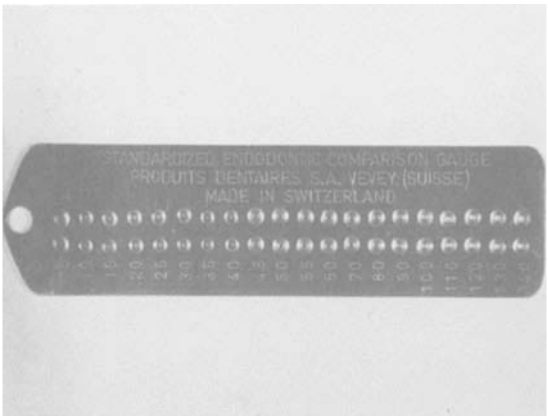


Fig. 25.36 Gauge for checking the sizes of silver and gutta-percha cones.

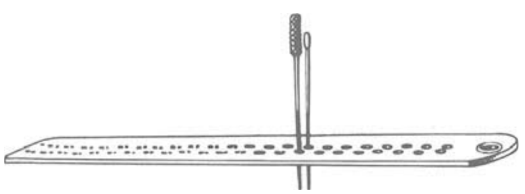
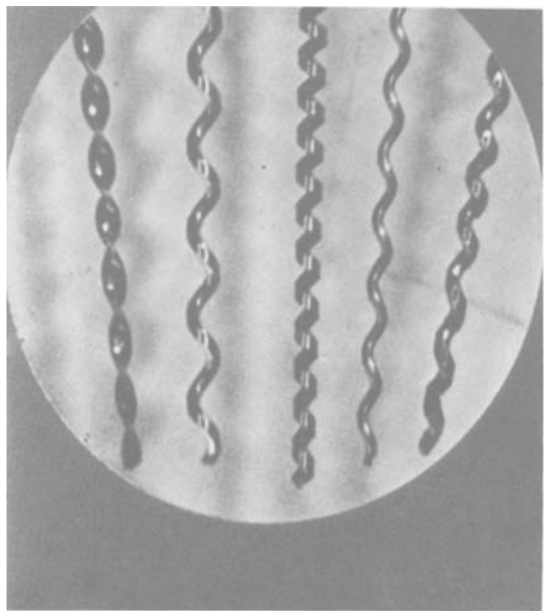


Fig. 25.37 When the point protrudes 5.0 mm, its size may be read on the gauge. The second row of holes relate to half size deviations.

When the cone is seated at the predetermined apical position, its removal should require a slight tug. This is referred to as 'Tug-back'. If, to the contrary, the cone is a loose fit and passes beyond the apical foramen, it should be shortened by removing 0.5 mm sections from the apical end until it exhibits tug-back at the apical constriction. Should the constriction be absent, it can be produced by enlarging the canal with reamers to a point, 1.0–1.5 mm short of the apex and the larger cone can be fitted to that point.

The apices of the majority of cones are blunt whereas the root canal instruments terminate in a sharp point. Thus, there will always be a slight apical discrepancy of fit. This may be adjusted by dipping the tip of the cone into chloroform for a few seconds and pressing the cone hard against the apex of the canal, which should be lubricated with irrigant to prevent adhesion of chloro-percha to the dentine. This moulds the apex of the cone to the shape of the canal. It may be necessary to repeat this measure a few times to achieve the desired shape. By the time the sealer has been prepared, the chloroform will have evaporated.

The sealer to be used is mixed on a sterile glass slab to a creamy consistency. It may be introduced into the canal at low speed (less than 1000 rpm) on a Lentulo (reverse spiral) filler (figure 25.38), placing the instrument at the apex and allowing it to rotate only when it is withdrawn, so that the sealer with which it is loaded remains in the apical part of the canal.



25.38 Differing types of spiral paste fillers. (Photograph by kind permission of Messrs. Maillefer (Switzerland).)

While withdrawing the Lentulo, the sealer may be deposited evenly around the canal by moving the instrument around the wall. Sufficient sealer should be inserted solely to coat the wall, because any excess would tend to be expelled through the foramen on insertion of the cone.

As an alternative, the sealer may be deposited from a Lentulo turned in a clockwise direction in the fingers, or by turning a reamer, two sizes smaller than the canal, in a counter-clockwise direction.

The spiral filler must always be of narrower diameter than the canal, in order to avoid binding and fracture.

The gutta-percha cone is then carried *slowly* up to its pre-measured position and pressed home firmly. A root canal spreader is now pushed alongside the cone and then removed, after compressing the cone firmly against the wall. A fine gutta-percha cone is pressed home into the space thus produced, and the action is repeated, first spreading and then inserting cones until no further spreading is possible. By this means, the canal is filled with a solid mass of gutta percha and sealed with a lute of cement.

The spreader is chosen from a matched set after ensuring that it will reach to a point 2–3 mm from the end of the canal without jamming. If too wide a spreader were used, there would be a risk of fracturing the root, and if it were too fine, it could be forced beyond the apex. A rubber stop may be placed to show the point of maximum insertion (figure 25.39).

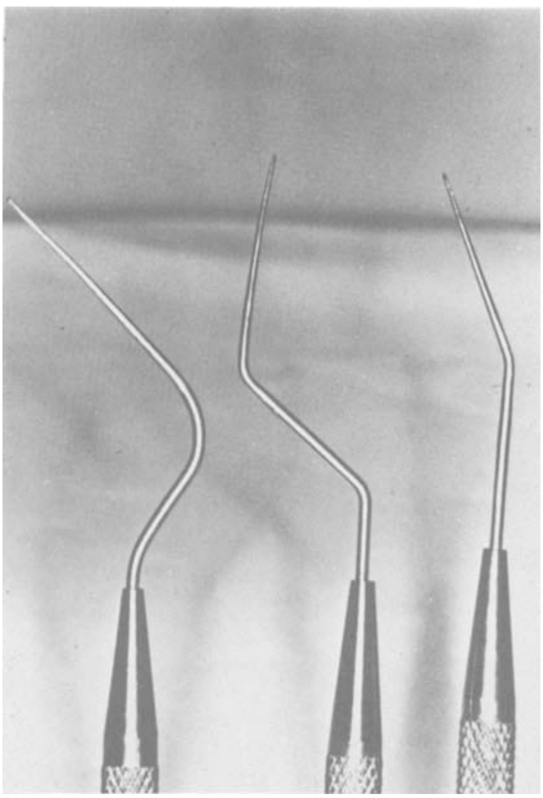


Fig. 25.39 Gutta-percha spreaders (Kerr).

The matched gutta-percha cone, having been seated at the apex, will prevent the extrusion of sealer or fine points through the apical foramen. It is necessary to avoid a pumping action when seating the original cone, otherwise there is a risk of forcing sealer through the apex.

Various methods have been tried for using fine gutta-percha cones in narrow canals, but it is easier to use silver points because, relying on the sense of touch alone, it is frequently impossible to locate gutta-percha cones in the orifices of canals of posterior teeth. If a jet of ethyl chloride is directed on the cone, the low boiling point and consequent evaporation lowers the temperature of the cone, making it temporarily less flexible and thus easier to manipulate. Nevertheless, the difficulty remains in relation to carrying out a lateral condensation technique and adding further points.

Vertical condensation technique

Schilder (1967) introduced 'the three-dimensional method' for filling root canals with gutta percha by vertical condensation. The master cone is fitted about 2.0 mm short of the apex after coating it with sealer at its apical end. The coronal excess of cone is shortened by touching it with a heated plastic instrument.

The coronal part of the cone is heated and softened by plunging a heated canal spreader into it, and this is followed by condensation with pluggers (figure 25.40). Alternately softening and plugging, the apical part of the cone is progressively forced apically and into all interstices of the canal and even into lateral canals. (It is probable that sealer alone is forced into lateral canals.) Those portions of gutta percha which adhere to the spreader are finally replaced by inserting further cones which, in turn are softened and condensed until the canal is filled.

A combination of the vertical and lateral condensation techniques has been used with great success for

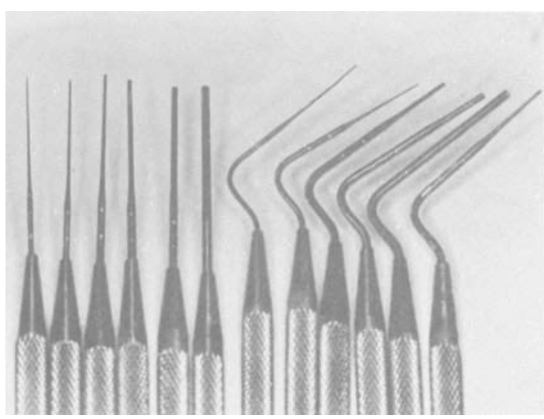


Fig. 25.40 A set of root canal pluggers (Kerr).

many years by the author. After insertion of the maximum number of subsidiary cones, the mass of gutta percha is softened and vertically condensed, as described above.

If the residual coronal dentine is unduly weakened, it is a good plan to fit and cement a retention screw into the canal on completion of the endodontic treatment, in order that an amalgam or composite core can be built up, prior to the restoration of the tooth with a full or partial veneer crown.

Silver cones

Silver cones have been used for filling root canals for nearly 40 years. Invented by Jasper in 1933, they have since been improved through more sophisticated methods of manufacture and are now available matched accurately to the reamers (figure 25.41). They should never be used in single rooted teeth without first separating an apical portion which is sealed in place, leaving the rest of the canal empty or sealed with gutta percha. If this is not done and a crown is subsequently required, removal of part of the silver cone to make room for a post may prove impossible.

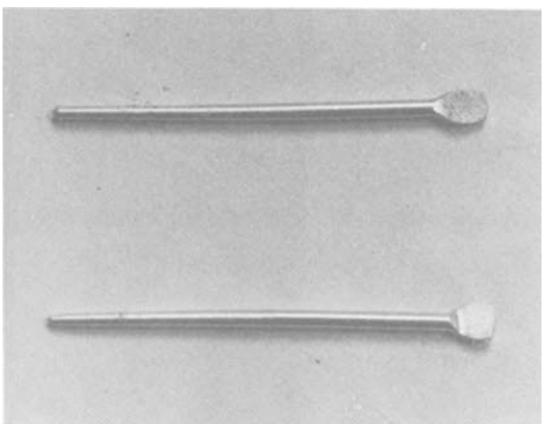


Fig. 25.41 Silver cones (Produits Dentaires).

When canals have been prepared, silver cones are selected which are matched in size to the last reamer used. At a point corresponding to the tip of a cusp or any other fixed point from which measurements have been made, the blunt end of each silver cone is bent over at a right-angle. The cones are inserted into the canals and a check radiograph is recorded. If a silver cone projects beyond the apical foramen, the excess is removed until it is seen to extend exactly to the end of the reamed part of the canal. If the cone does not reach the end of the canal, a few more turns with the reamer may allow it to seat further. Minor variations in size between reamer and cones may necessitate trying several cones until one is found which will seat home and exhibit tug-back.

Having chosen and fitted all the cones, they should be laid out on a sterile surface in such a manner that there will be no confusion about the canal for which each is destined.

It has been found that excellent results can be obtained by the use of AH 26 as a sealer. Having been mixed to a creamy consistency, the sealer is picked up on a reamer, two sizes smaller than the canal and carried up to the apex. The reamer is rotated in a counter-clockwise direction, using simultaneously a gentle pumping action to carry the paste to all parts of the wall as a light coating. The cone is coated too, by dipping it into the sealer on the slab, and it is passed slowly up the canal, with a side-to-side rotation, until it has seated home, as indicated by the location of the bent end of the cone against the tip of the cusp.

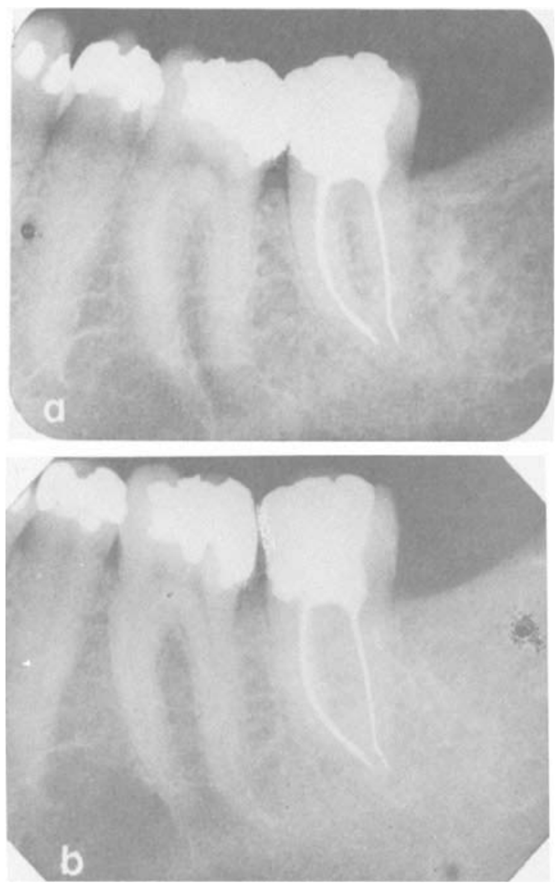


Fig. 25.42 (a) Non-vital $\overline{|7}$ immediately after root filling with silver cones and AH 26. (b) One year after root-filling. Note the absence of periapical change.

If the canal is wide coronally, some gutta-percha cones should be used to obliterate the space. The excess of sealer may be removed by swabbing the cavity with a cotton pledget damped with acetone or chloroform, after which the pulp chamber is filled with phosphate cement. When the cement has hardened around the cones, the projecting ends may be removed at the level of the roof of the pulp chamber by the application of a small round diamond bur in the turbine handpiece. A coronal restoration is inserted and a radiograph is recorded as a control, for comparison with check radiographs after six months and thence annually for a period of 4–5 years. Examples of cases in which silver cones have been used are shown in figures 25.42, 25.43 and 25.44.

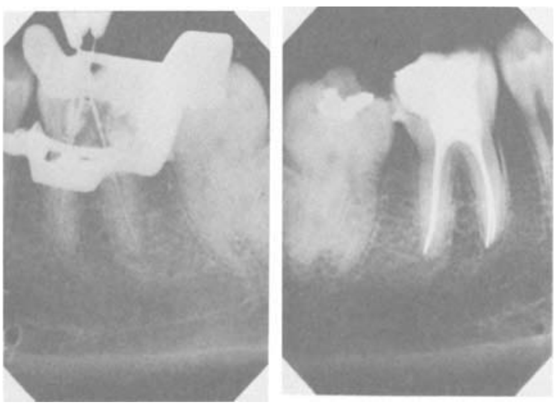


Fig. 25.43 (Left Diagnostic radiograph of $\overline{6}|$. (Right) Completed root filling, using silver cones and AH 26, plus accessory gutta percha cones.

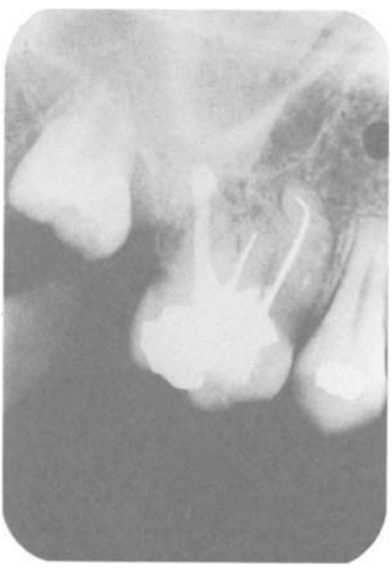


Fig. 25.44 $\underline{6}|$ root filled with silver cones in the buccal canals and gutta-percha cones in the palatal canal, the apical foramen of which was patent as a result of apical resorption.

Instead of cutting the cones some operators prefer to hemisect them at the level of the roof of the pulp chamber, so that, after their insertion, the ends may be fractured by bending them to and fro. This leaves three short ends, standing up in the pulp chamber, which are then embedded in cement.

The distal roots of lower molars and the palatal roots of upper molars do not in general, lend themselves to the use of silver cones because of their large size and variable cross-section. The author prefers to fill these canals by the condensation of gutta-percha cones, so that when indicated room may be made to house a retention screw. However, when canals are very fine, the use of metal cones is often the most satisfactory technique (figure 25.45).

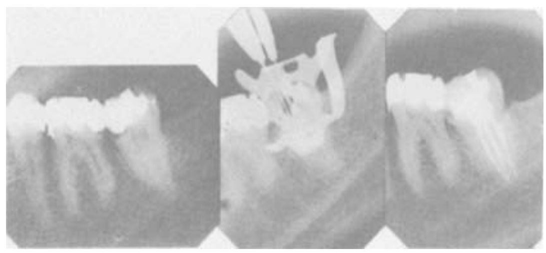


Fig. 25.45 Root filling of silver cones and AH 26 in four canals in a mandibular third molar.

Sealing of canals prior to using them as an aid to retention

When a tooth has lost the major part of its crown, and a root treatment has been carried out, the root canal may be used to retain a crown or to anchor a restoration.

In the multirooted tooth the widest canal may be used as the recipient of a Dentatus screw, around which amalgam is condensed, either as a completed restoration or as a preliminary stage before preparing the tooth for a gold veneer crown.

Similarly, a root-filled incisor or canine, the crown of which has fractured or discoloured, necessitating post-crowning, will require a post-hole at least as long as the crown.

If the root has been filled previously with gutta percha and a sealer and there is no pathological change periapically, the coronal two-thirds of the gutta percha may be removed with the aid of hand and engine reamers, after softening it with a heated wire. If engine instruments are used, they must be narrower than the canal and used with light pressure and at slow speed, to avoid the risk of a lateral perforation.

When, at the time of filling the root canal, it is known or suspected that root canal retention may be required, the apical 3–5 mm alone should be filled. This may be done by carrying up portions of gutta percha and condensing them into the apex with a lute of sealer. This technique is difficult, however, and the silver cone section technique is more commonly employed.

Apical silver cones

In this technique, a silver cone is fitted to the prepared canal and an estimation of the length to be obturated is made. At this distance from the apex of the silver cone, two deep notches are cut with a diamond disc, leaving the apical section hanging by a fine fragment of silver. Sealer is carried up to the apex and the cone is inserted and, when seated home, it is pressed hard into the apex and twisted from side to side until the apical section separates. The remainder of the cone is removed, leaving the greater part of the canal empty.

The problems inherent in this technique are as follows: firstly, unless the apical tip is hanging by a thread it is difficult to break off, because silver is extraordinarily malleable; secondly, it may break off in mid-canal and become locked in that position and impossible to dislodge (figure 25.46); and thirdly, if a faster setting cement is used to grip the tip while the remainder of the point is twisted off, it is possible that the tip also may be loosened from the cement. Furthermore, once a section of silver has been sealed at the apex, it is impossible to remove it without recourse to surgery.

Bearing these points in mind, the author designed an apical silver tip, with a screw-threaded projection which engages in a handle (figure 25.47). The cone is carried up to the apex for a radiographic check, corrected if necessary and then re-seated with a sealer, after which the handle is unscrewed and withdrawn (figure 25.48). If it should be necessary at a later date to remove the tip, the canal is flooded with a solvent, such as acetone or chloroform, for a few minutes to soften the sealer, the handle is re-applied and the tip is removed.

The tips are matched to reamers of sizes 45–140 and are of two lengths, 3.0 mm and 5.0 mm.

It is essential that care be exercised when they are being tried in, because if they do not go all the way home and subsequently are forced, so that they jam, their removal will be impossible because the fine silver thread will be stripped when a tensile force is applied. If the tip does not go fully home, it should be removed immediately and the last reamer used given several more turns in the canal, which is then irrigated and dried. Invariably this is sufficient to allow the tip to seat home. The technique should never be used for a curved canal because of the risk that the tip will jam at the curvature.

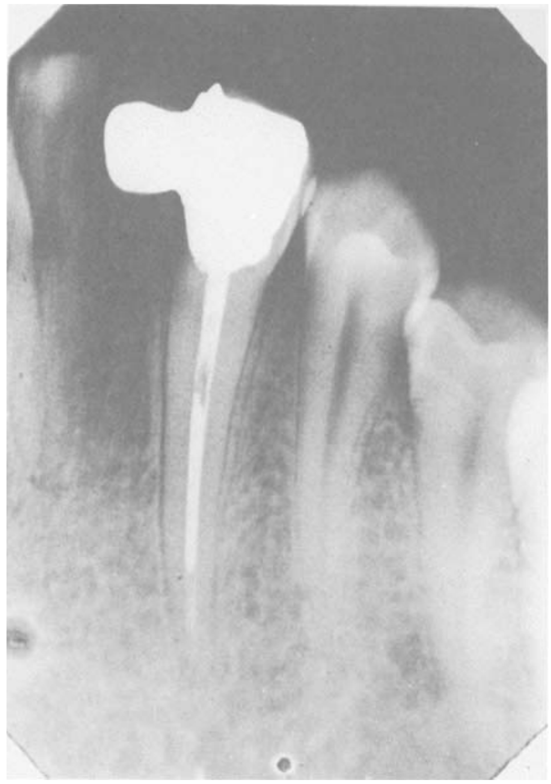


Fig. 25.46 A 'break-off' type of silver tip which broke off prematurely and jammed, proving impossible to remove – fortunately the AH 26, which had preceded it, provided a satisfactory seal.

When the tip has been placed at the apex, a slight pressure should be applied in an apical direction while the handle is being unscrewed. If the canal has been over-enlarged so that the tip cannot be wedged at the apex, the next larger size should be chosen and the canal prepared to receive it. If the crown-post or Dentatus screw is not to be inserted in the foreseeable future, the remainder of the canal may be filled with gutta-percha cones. This is of greater importance in multirooted teeth because of the incidence of lateral canals which communicate with the root surface and furcation area. Although favourable results may follow sealing of the apex alone (figure 25.49), and this is seen frequently after retrograde obturation, the author prefers whenever possible to fill the entire canal.

The apical tips (Produits Dentaires) are supplied in phials of each size and length, mounted on a hollow

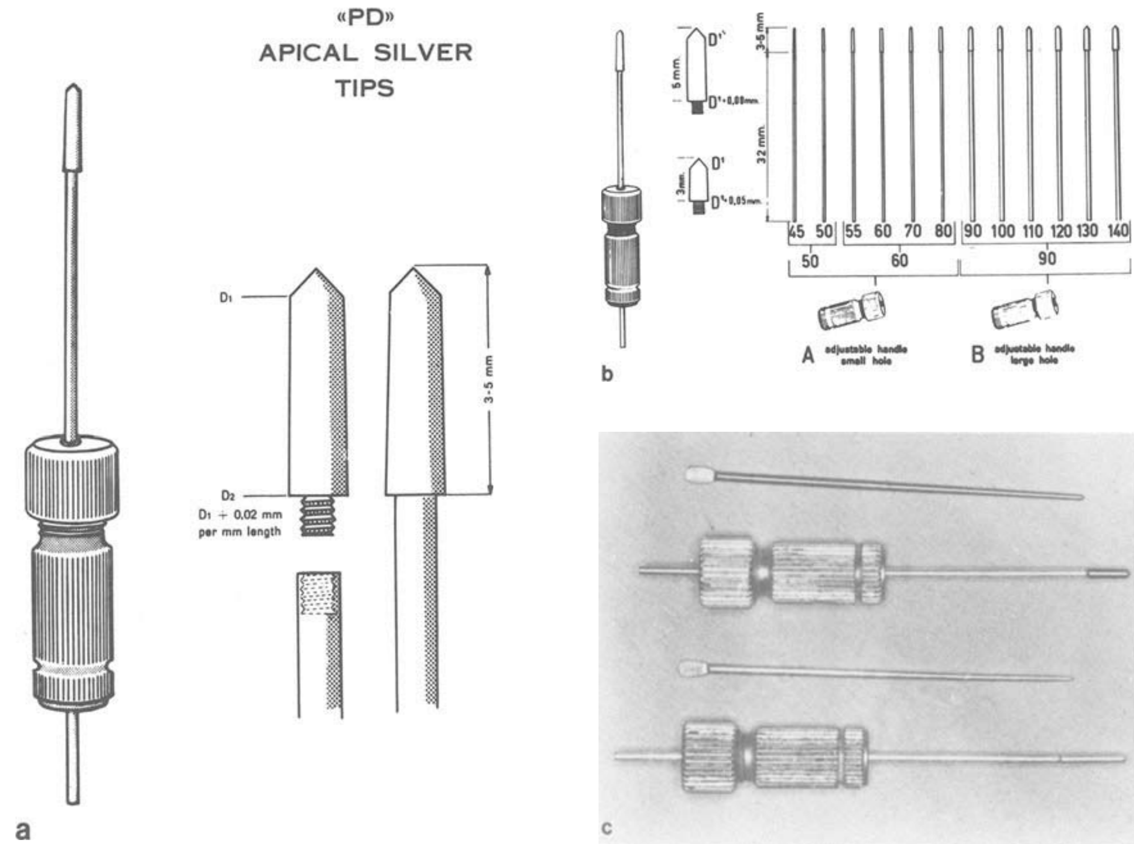


Fig. 25.47 (a) Mandrel and screw-threaded apical silver tip. (Produits Dentaires-Vevey, Switzerland.) (b) Complete set of Titanium tips with appropriate mandrels for sizes 45–80 and 90–140. (c) (Bottom) 5 mm mandrel-mounted silver tip, and silver cone. (Top) 3 mm mandrel-mounted titanium tip and titanium cone.

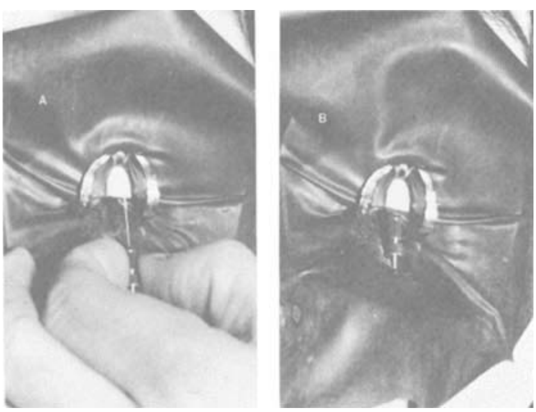


Fig. 25.48 Apical silver tips. (A) The mounted point is inserted gently up to the predetermined position. (B) After insertion of sealer, the pin-vice handle is turned anti-clockwise and the handle is withdrawn, leaving the tip at the apex of the canal.

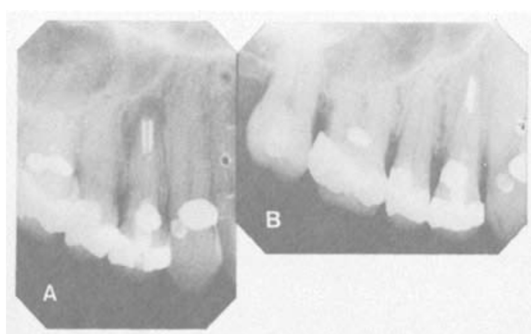


Fig. 25.49 (A) Radiograph of 4| immediately following root canal sealing with apical silver tips and AH 26 sealer. (B) The same tooth six months later, showing resolution of the periapical lesion. The canals were used subsequently for retention of a post-retained crown.

rod. There are two adjustable pin-vice handles which are designed to slide over the narrow (45–80) or wide (90–150) rods, and which can be adjusted and tightened so that they correspond with the incisal margin or tip of the cusp (figure 25.48).

Sterilisation of silver cones and tips may be effected by dry heat, autoclave or glass bead steriliser, whereas gutta-percha cones should be sterilised by prolonged immersion in a 2% solution of benzalkonium chloride and then dried off, after rinsing in absolute alcohol, before use, and stored with a paraform tablet.

Titanium cones and tips

In recent years, the attention of the dental profession has been drawn to the corrosion of silver cones, when they are in contact with tissue fluids. This corrosion has been inculpated as a possible cause of localised osteitis, resulting from the action of insoluble toxic corrosion products (Luks, 1974). Jones and Green (1966) have suggested that there is a risk of systemic reaction to soluble corrosion products of silver. Although the author had used silver cones and tips without apparent ill-effects, provided that they were well sealed in the canal and not projecting into the bone, he felt that there was a need for a less reactive material as an alternative to silver. Four years experience of the use of pure titanium as a root filling material have shown that it fulfills that criterion admirably. Titanium has a lower atomic weight than silver (Ag = 107.86, Ti = 47.90) and its radiopacity is close to that of gutta percha. Its ductility is 13% less than silver but, in sizes up to 30, it can be made to negotiate a moderate apical curvature of the canal. In an investigation of the use of titanium cones and tips in monkeys and humans, the author (Messing, 1980) showed that titanium is easy to manipulate, produces an effective seal and is well tolerated by bone. Despite the effectiveness of silver when correctly used, it is advocated that it should be replaced by titanium, especially for root canals which have widely prepared apical foramina or apical resorption (figures 25.50–25.54).

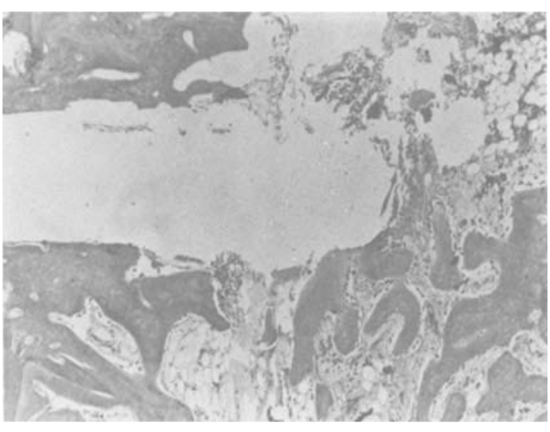


Fig. 25.50 Silver cone embedded for 38 days in a monkey femur. New bone and macrophages are present. Particles of silver pigment are evident. (H. & E., x 100.)

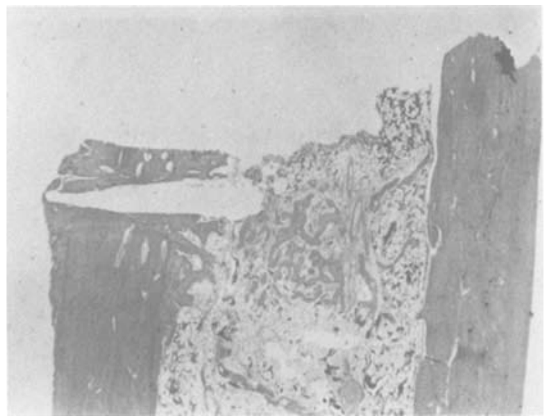


Fig. 25.51 Silver cone embedded for 38 days in a monkey femur, under low power. New bone is forming in the medullary cavity. No evidence of inflammation. Pigment is visible. (H. & E., x 25.)

Fig. 25.52 Titanium cone embedded for 38 days in a monkey femur under low power. New bone in medullary cavity. Absence of inflammation. No sign of pigment. (H. & E., x 25.)

Chronic and Acute Periapical Conditions

If an acute pulpitis remains untreated, the subsequent course of the condition will depend on the resistance of the tissues, the virulence of invading bacteria, if they are present, and the possibility of drainage of

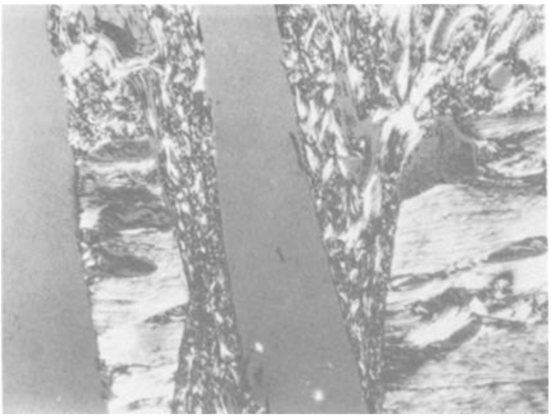


Fig. 25.53 Titanium cone embedded for 38 days in a monkey femur viewed by polarised light. New bone in apposition to titanium; no inflammatory response visible. (H. & E., x 100.) (Photomicrographs reproduced by kind permission of the Editor of the *British Dental Journal*.)

inflammatory fluid. Depending on the severity of the inflammation and the ability of the operator to remove the cause, the condition will either resolve, become chronic, or progress to total necrosis.

A condition of venous stasis may develop in a pulp after the insertion of an unlined silicate or composite restoration, as a result of the severe inflammatory response provoked by the chemical irritation.

Usually there are no symptoms, although acute pain can occur, but the tooth tends to darken slowly as the pulp dies. Radiographically, the signs vary from slight apical thickening of the periodontal space to a large radiolucent area. This is usually a granuloma and is indicative of the body's resistance to irritant products from the decomposed pulp. In this zone of granulation tissue there may be small islands of epithelial cells which, under certain circumstances, the nature of which is not understood, are stimulated into growth. This epithelium was described by Malassez in 1885 and consists of remnants of the fragmented dental lamina. As the cells divide and grow away from their source of nourishment, the central cells break down until there remains a sac in the bone filled with fluid which contains cholesterol crystals, and lined by a layer of flattened cuboidal cells with a fibrous capsule and encompassed by a layer of compact bone. Such a cyst tends to grow slowly, possibly as a result of the high osmotic pressure exerted by the contained fluid.

Diagnosis is possible only by excision and histological examination, although aspiration of any contained fluid may demonstrate the presence of cholesterol crystals. Cysts are usually sterile unless they communicate with the oral cavity.

Treatment of non-vital teeth, with or without periapical involvement, should be conservative in the majority of cases, with the exception of those which exhibit large areas with a clear-cut compact margin. These tend to be cystic and it is customary to treat them by surgical intervention, either by enucleation or by marsupialisation.

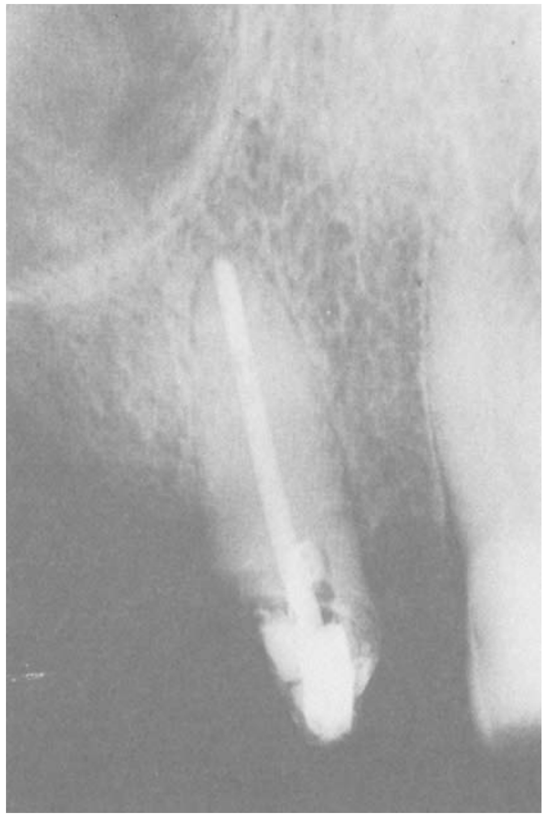


Fig. 25.54 Apical titanium tip, sealed at the apex of root canal with AH 26. Remainder of canal filled with gutta percha. There was apical resorption, hence the tip is certain to be in contact with the bone. This is the prime indication for titanium, because it is tolerated well by the periapical tissues.

Conservative treatment of infected root canals

The canal is entered, as described for pulpectomy, and flooded with a solution of electrolytic sodium hypochlorite. Using the radiograph to obtain an approximate idea of the length of the tooth, two-thirds of the canal is rendered free of pulp debris by filing and a dressing of C.C.P. or Biocalex is sealed in the canal. The bite is relieved by grinding.

At the next visit, after a delay of seven to ten days, a diagnostic radiograph is recorded and the canal is fully prepared and dressed. The canal may be filled at the next visit, provided that there are no adverse signs or symptoms. A radiographic check after six months should indicate a diminution in size of the periapical lesion, while subsequent checks after one and two years should show its complete elimination, otherwise it may be necessary to resort to surgery.

Acute periapical abscess

When an acute suppurative inflammation of the pulp spreads into the periapical region, the initial lesion, characterised by great tenderness and extrusion of the tooth, is an acute periodontitis, but this soon becomes an acute suppurative condition unless drainage is established via the pulp chamber. Thus an acute apical abscess develops and pus finally spreads through the alveolar bone, taking the line of least resistance to discharge. Until this happens, the pain increases until it is almost unbearable and the tooth is extruded further. The patient states that the pain is alleviated only when the abscess points into the sulcus through the mucoperiosteum, or onto the skin (if hot fomentations have been used, inadvisedly). An epithelium-lined sinus track is established through which pus is discharged intermittently. Thus the acute infection becomes chronic as a result of natural drainage. Nevertheless, acute exacerbations of the abscess may occur from time to time if the sinus track should become blocked, although the symptoms tend to be of decreased severity because drainage is easily re-established.

Conservative treatment for acute periapical abscess

Treatment should be aimed at converting the acute condition to a chronic one as quickly as possible, and then attempting to remove the cause.

Drainage is instituted through the pulp chamber by trephining the crown, the bite is relieved and a suitable antibiotic is given parenterally, e.g. 1 mega unit daily of penicillin (soluble and 'depot', i.e. procaine penicillin, in equal parts) or erythromycin (250 mg Q.I.D. orally) as first choices. Antibiotics should be administered early, in large doses, using bactericidal in preference to bacteriostatic drugs.

If the abscess is fluctuant and obviously ready to discharge, it may be incised and the wound kept open with an H-shaped rubber drain (figure 25.55). The incision should be made at the most dependent part of the swelling.

Supportive measures should also be adopted. An analgesic, such as codeine or paracetamol is prescribed and the patient is told to rest. Hot hypertonic saline mouthwashes and ice-packs applied to the skin may reduce swelling, but drainage and time are essential factors in the return to a chronic state.

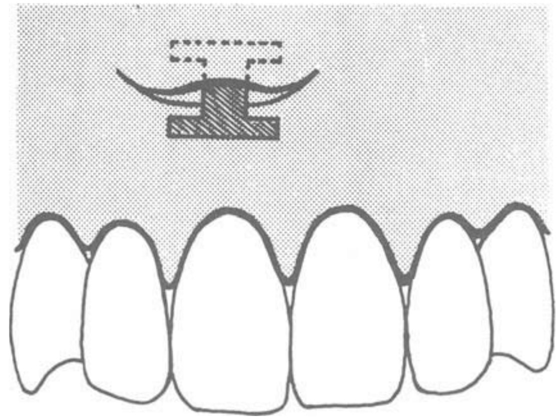


Fig. 25.55 An H-shaped rubber dam drain inserted into an abscess cavity through an incision at the most dependent part of the swelling.

Once symptoms have subsided, the canal should be opened up and cleaned, gently irrigating any food debris from the pulp chamber with sodium hypochlorite solution. A diagnostic radiograph is recorded and reaming and filing are completed, but the canal is left open for at least 24 h more to avoid an acute flare-up.

At the next visit, the canal is irrigated and dried and a corticosteroid/antibiotic cream is inserted and the coronal orifice is sealed. Dressings of antiseptic or polyantibiotic paste are inserted subsequently until the sinus has healed and symptoms have disappeared. A calcium hydroxide dressing may be left for a number of weeks if an earlier appointment is not feasible. Then the canal is filled and an annual radiographic check of the periapical tissues is continued for 3–5 years.

Endodontic Surgery

Ideally, the majority of infections of the pulp canal and periapical region should be treated by conservative measures. However, there are numerous contra-indications to a conservative approach and frequently a surgical approach is the sole alternative to extraction.

The following list of contra-indications to conservative endodontics should not be taken as indications for endodontic surgery, although, excluding unfavourable anatomical factors such as proximity to the maxillary antrum, and systemic conditions such as cardiac valvular disease, a surgical approach may be used in a large number of cases.

Some contra-indications to conservative endodontics

(1) Inability to reach the apex because the canal is too curved, excessively narrow or blocked by the tip of a fractured instrument or a pulp stone.

(2) Inability to locate a canal or to negotiate a major offshoot from the main canal, found frequently in lower premolars and canines.

(3) Extensive periodontal involvement, leaving poor bony support.

(4) Cystic types of lesion. Bhaskar (1967) claims that many cysts will disappear following correct endodontic treatment, but frequently large areas, which may prove subsequently to be cystic, do not respond to a conservative approach and may require surgery.

(5) Gross apical resorption of the root.

(6) A chronic apical lesion draining into the gingival crevice. This is included because it may not respond to a conservative approach, although it is worth attempting the combined treatment of the periodontal and pulpal lesions, because it is still possible in many cases to resort to surgery if the result is not satisfactory.

(7) Fracture of a root in the apical third of a non-vital tooth.

(8) Perforation of a root canal. If this occurs despite the correct preparation of the main canal, it may be possible to fill it at the same time that the root filling is inserted, but when a root filling or crown-post is projecting into the bone, surgical correction is often necessary.

Endodontic surgery includes the operations of apicectomy, retrograde obturation, closure of lateral perforations, reimplantation, transplantation and hemisection (or root resection).

Apicectomy

The operation of apicectomy consists of the removal of a small part of the apex of a root in order to close hermetically the lumen of the canal, or check the accuracy of fit of a previously inserted root filling. Resection of the apex is accompanied by the excision of pathological periapical tissue. The original reason for performing an apicectomy was to resect the apical third of the root and thus remove the 'diseased' area of permeable cementum and, incidentally, the region in which were found the bulk of lateral ramifications of the pulp canal. This concept often led to undue shortening of the root and, although the bone often healed, there remained inadequate support for a natural crown and insufficient length of root canal for the anchorage of a post-crown.

Endodontists in many continents have reported satisfactory results following conservative root treatments, in which, after perfect obturation of a well-prepared canal, the periapical area has healed completely.

Hence the indications for apicectomy may be modified to include the following:

(1) When a tooth is not responding to conservative endodontic treatment.

(2) When an apical approach must be made, because the tooth is crowned (especially when there is a post-crown), or because the operator does not wish to drill through an otherwise satisfactory bridge.

(3) When time is limited. An apicectomy may be completed in one visit.

(4) Where failure to negotiate a bend with a root canal instrument has produced a perforation, or formed a ledge at which all instruments are arrested.

(5) A canal blocked by a broken instrument, or a perforation of the root, e.g. during preparation of the canal for a post.

(6) Resorption of the apex or uncompleted formation of the apex may make the production of an apical seal difficult and result in extrusion of filling material into the tissues, hence surgery may become necessary if an attempt at filling the root canal has been unsuccessful.

(7) Very large areas – they may be cystic and not respond to root treatment alone.

Pre-operative considerations

Prior to carrying out endodontic surgery, it is important to check the patient's medical history, with special regard to rheumatic fever or chorea in childhood, haemorrhagic diatheses, liver or kidney disease. If there is any doubt, the patient's physician must be consulted.

If the periapical condition to be treated is acute, it should be rendered chronic by the administration of antibiotics and by obtaining drainage until the symptoms have abated. In this context, any known allergy to antibiotics must be taken into consideration prior to their use.

The size of the lesion, as viewed on a periapical radiograph, is misleading, because lesions in cancellous bone may not be detectable until further resorption has eroded part of the cortical plate (Bender and Selzer, 1961). When a large radiolucent area is seen, the actual size of the bony lesion may be at least double the radiographic representation.

Teeth which may be suitable for apicectomy

In general, maxillary and mandibular incisors and canines, the buccal roots of upper molars and also the upper and lower premolars (when they are not in close relation to vital structures) are suitable candidates for apicectomy. Premolars with two roots, especially when the lingual and buccal roots diverge markedly, may prove to be extremely difficult to treat, because the lingual apex tends to be inaccessible.

Technique

The canal is enlarged to a point 1.0–2.0 mm short of the apex, thoroughly irrigated with sodium hypochlorite and dried. Then the apical end is obturated to a depth of 3.0–5.0 mm with a matched apical silver tip, using as a sealer either E.B.A. cement, Grossman's paste or Rickert's paste. Alternatively, silver amalgam, preferably free from zinc, may be condensed at the apex. The author has developed a special amalgam carrier (figure 25.56), in which small increments of amalgam can be carried up to the apex for condensation with a converted Dentatus amalgam condenser point (figure 25.57) or with root canal pluggers (P.D. or KERR). The amalgam is triturated, using equal parts of alloy and mercury, without expression of excess mercury from the mix. Approximately 3.0 mm of amalgam is condensed at the apex. The amount used depends on the length of canal which would be required if a post-retained crown were subsequently needed.

As an alternative to the use of amalgam, a silver or titanium apical cone may be sealed at the apex, using a fast setting sealer, such as Grossman's or Rickert's root canal sealer. After approximately 15 min, when the sealer has set hard, the apex of the root is resected and the apical seal is checked (figure 25.58).

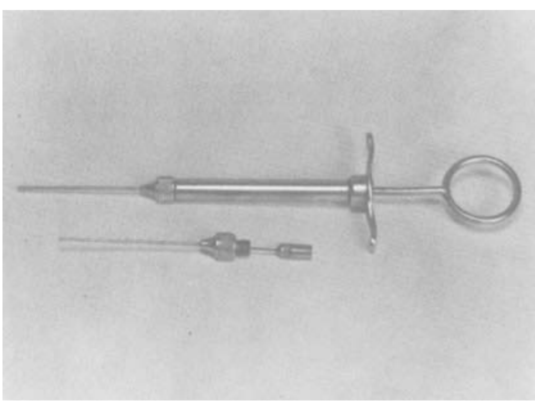


Fig. 25.56 The Messing endodontic amalgam carrier (Produits Dentaires), with a fine nozzle and plunger for obturation of the apex via the canal.

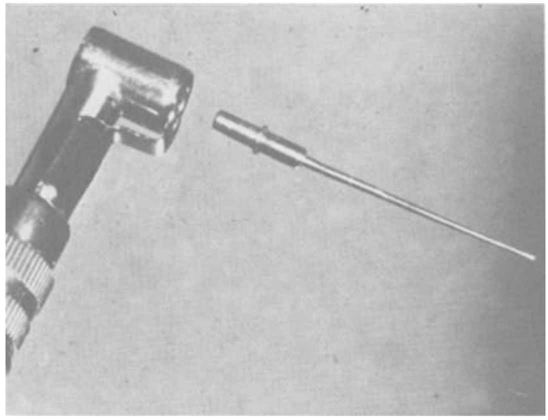


Fig. 25.57 Special condenser point for apical amalgam for use in the Dentatus mechanical condenser.

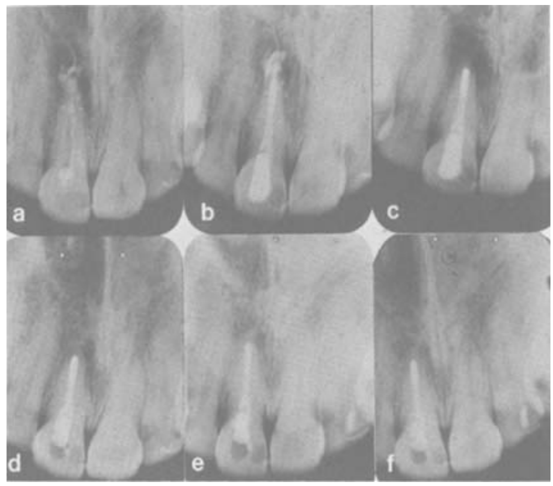


Fig. 25.58 Use of an apical silver cone to seal the canal prior to apicectomy. (a) Chronic periapical inflammation due to faulty apical seal and filling material extruded into the bone. (b) Canal prepared and sealed with an apical silver cone. (c) Immediately after resection of apex and curettage. (d) After 6 months. (e) After 1 year. (f) After 2 years.

When the apical third of the root has been filled, a temporary restoration is inserted in the coronal cavity and the occlusion is checked with articulating paper. Any areas of contact with the opposing teeth are ground away, to create a state of physiological rest while the periapical tissues are healing.

Towels are placed around the patient's head and shoulders and the skin is prepared by swabbing with a 2% solution of benzalkonium chloride. A local anaesthetic is injected to cover an area extending to one tooth on either side of the operation area, and the lingual area is anaesthetised also. It is important to remember that, unless the needle is advanced apically beyond the apex of the root, inadequate anaesthesia may result.

Access to the periapical region may be made either through a semilunar incision, when there is sufficient sound bone between the gingival margin and the bony lesion, or by means of two vertical incisions joined by a horizontal incision along the gingival margins (figure 25.59). The full flap is usually preferable; firstly, because access is better when operating on a large or deeply situated lesion; secondly, because haemorrhage is less troublesome; and thirdly, because trauma to the soft tissues is more easily avoided.

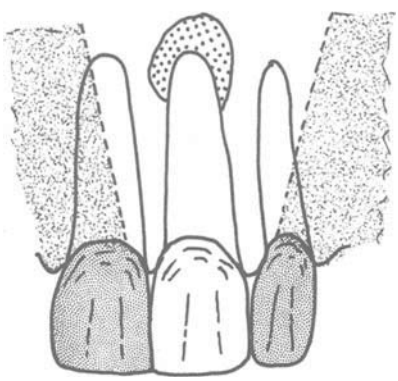


Fig. 25.59 Design of Trapezoidal flap.

When crowns are present on anterior teeth, a full flap tends to contract when healing and the consequent apical migration of the gingival margin discloses the junction of crown and root, with an adverse effect on the appearance. This may be avoided, provided there is no undue coronal extension of the periapical lesion, by joining the two vertical incisions by a horizontal cut which should be placed not less than 5.0 mm from the gingival margins (figure 25.60). This is to avoid loss of blood supply to the gingivae and consequent necrosis.

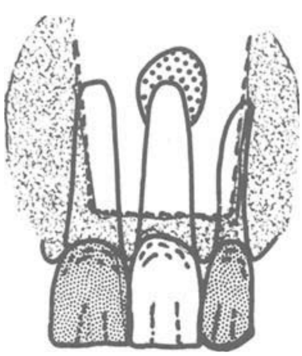


Fig. 25.60 Modification of Trapezoidal flap to avoid apical migration of marginal gingivae.

Whichever type of flap is reflected, it should be borne in mind that, when the flap is replaced on the bone for suturing, the incisions should lie on sound bone and never be sited directly over the bony cavity. The incision must be made right down to bone so that elevation of the whole mucoperiosteal flap is facilitated. Fibrous adhesions, which have resulted from previous surgical intervention or chronic inflammation, should be dissected away with a scalpel (Bard-Parker no. 11 or 12).

Frequently, after retraction of the mucoperiosteal flap, a defect in the cortical bone is seen, the undermined margins of which can be drilled or chiselled away to disclose the apex and pathological tissue. However, when this defect is not present, the bone over the apex should be tested for soft spots with a straight probe, and often the exact area can thus be identified. Bone can then be removed with a straight tungsten carbide chisel, used with a planing action. If no soft spots are found, the compact bone should be removed with a size 6 round steel bur, run under a jet or spray of saline. The radiograph is examined in order that the relationship of the root apices may be ascertained, and care is exercised to avoid trauma to adjacent roots when access is being obtained.

After the bone cavity has been opened, the soft tissue is curetted gently from the bone and put into a bottle of formol-saline for histological examination.

The apex is then ground away with a cylindrical diamond stone, at an angle of 20–45°, the angulation depending on the degree of visibility, until the root filling can be seen. The surface and perimeter of the apical seal are checked with a Briault probe and, if any defect is found, it is opened up with a small round bur and filled with zinc-free amalgam. After irrigation of the wound with a warm sterile isotonic solution of saline, it is re-examined to ensure complete eradication of debris and soft tissue, and then the flap is closed with nylon sutures. Before suturing is started, the fixed flap should be mobilised to facilitate placement of the needle without tearing the tissues. This can be done with a flat plastic instrument (Ash no. 156). If the area is large, care should be exercised, when curetting, to avoid damage to the apices of adjacent vital teeth and, before closure of the wound, a piece of Dequaspon (Allen and Hanbury) (a cellulose sponge impregnated with dequalinium hydrochloride) may be inserted as a prophylactic against breakdown of the clot. The author has found that by covering the incision line and sutures with a strip of Orahesive dental intra-oral bandage (Squibb), the patient is more comfortable in the immediate post-operative period (figure 25.61).

Orahesive consists of a sheet of material composed

Fig. 25.61 Orahesive dental bandage (Squibb) in place over flap following apicectomy of 1 | 1.

of pectic, gelatin, poly-isobutylene and sodium carboxy-methyl cellulose, which is cut to shape and placed with the tacky surface against the mucosa, to which it adheres when held under pressure for 30–40 s. It dissolves slowly and disappears within 24 h.

Before dismissing the patient, a radiograph is recorded and instructions are given about aftercare, as follows:

The lip should not be lifted to look at the wound, to avoid trauma to the flap. Hot drinks or food should not be taken until the anaesthesia has worn off. Teeth should be cleaned normally, except in the area of the operation where, after a few days, cotton-wool and toothpaste may be used gently in place of the toothbrush. Mouthwashing after meals is of definite value, preferably without making vigorous muscular movements, and using hot hypertonic saline (a teaspoonful of common salt in a tumbler of water).

The patient is told to expect tenderness, swelling and possibly some bruising, which can occur in a small number of cases. It is important to stress that these signs and symptoms are normal but that any bleeding or more severe pain should be reported. Antibiotics should not be prescribed unless a definite indication exists. Paracetamol or aspirin tablets should be prescribed, bearing in mind the risk of gastric irritation by aspirin, which should not be given to people who suffer from gastric or duodenal ulceration or hiatus hernia. A pain killer is most effective when taken as soon as the effects of the local anaesthetic begin to wear off, and the patient should be warned against waiting until there is more intense pain or discomfort before taking the drug.

For those who are able to take aspirin, it is the safest and one of the most effective pain killers, preventing the formation of prostaglandins and thus reducing the inflammatory reaction with its associated manifestations, oedema, pain and fever (Vane, 1971). The patient may also be told that the use of an ice pack on the face for a few minutes of each hour, for the first few hours after operation, may help to reduce swelling. Sutures are removed after 5–7 days, the patient is recalled after six months and thence annually to check the progress of healing (figures 25.62, 25.63).

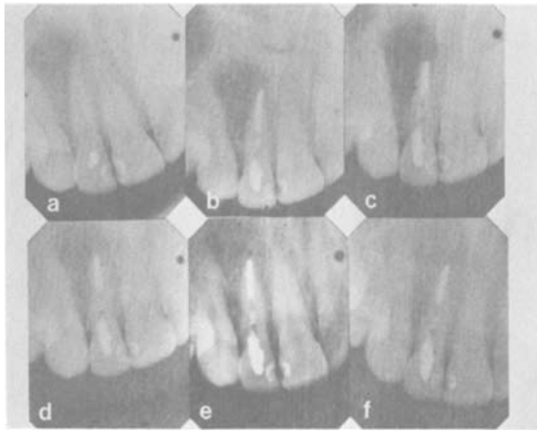


Fig. 25.62 Treatment of 2| periapical lesion by apicectomy after apical filling with amalgam. (a) Before treatment. (b) Immediately after root filling. (c) Immediately after apicectomy. (d) Six months post-operative. (e) Twelve months post-operative. (f) Two years post-operative.

Retrograde obturation

When an obstruction exists to prevent the passage of instruments along a canal to reach the apex, the alternative technique entails the resection of the apex, preparation of a cavity involving the canal orifice and the subsequent filling of the cavity with silver amalgam. This is known as retrograde obturation.

For reasons previously described, a full flap is to be preferred and the apex should be cut at an angle of 45° so that direct visibility of the cut end is made possible.

A cavity is cut in the end of the root, of minimum lateral extent but involving the root canal and extending 2.0–3.0 mm into it. This may be prepared with a size 2 or 3 round steel bur, in a straight handpiece, and undercut by making a slight side-to-side movement of the bur when it is at the base of the cavity. When access is poor, the cavity may be prepared with a Kavo Micro-angle handpiece (figure 25.64) which was designed specially by Dr. Böhme for use within a bony cavity, to allow axial alignment of the bur in the root canal.

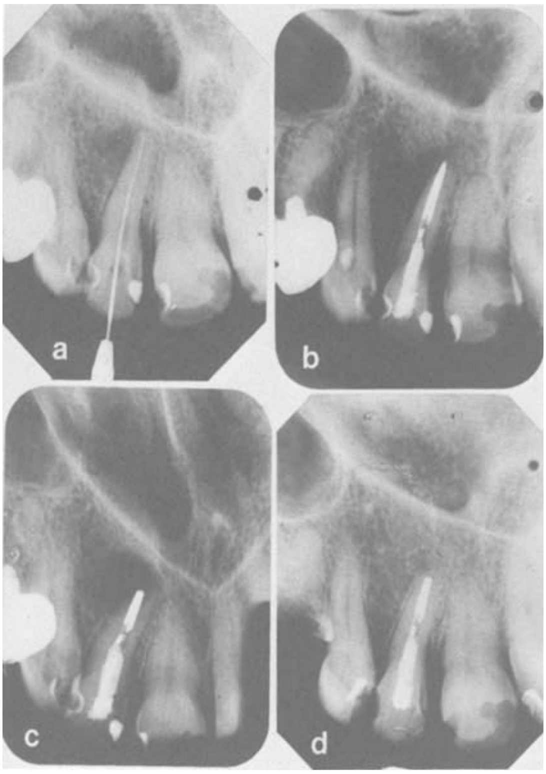


Fig. 25.63 Treatment of a periapical lesion on 2| by apicectomy after apical filling with amalgam. (a) Diagnostic radiograph. (b) Immediately after root filling. (c) Immediately after apicectomy. (d) Six months after operation.

Fig. 25.64 Kavo miniature (Micro-angle) handpiece and bur for retrograde filling technique.

The root canal may be difficult to locate when it has been largely obliterated by calcific deposit, but a sharp Briault probe will help in its location (figure 25.65).

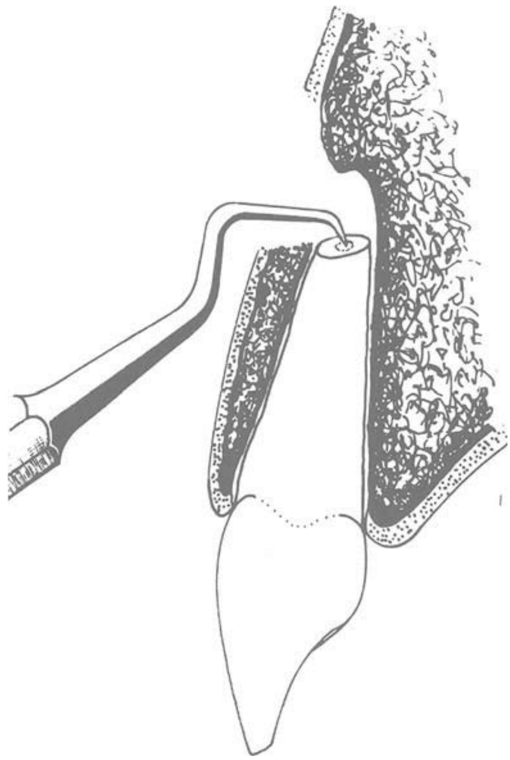


Fig. 25.65 Location of the apical orifice of the root canal, using a Briault probe.

When the cavity has been prepared, it is irrigated with saline, dried and packed with a small pledget of cotton-wool. The bone cavity is then filled with Horsley's bone wax (Selden, 1970), a portion of which is scooped out to disclose the apex of the root. The cotton pledget is removed and the cavity is dried again. The bone wax is used to ensure a clean, blood-free zone. Zinc-free silver amalgam is inserted with an apical amalgam carrier and condensed into the canal until it is level with the surface, at which point the wax is removed, the bony cavity is irrigated, dried and checked for particles of amalgam, wax or granulation tissue, and the flap is sutured (figure 25.66).

In place of bone wax, a strip of gauze soaked in 1/1000 adrenaline solution may be inserted and left for two or three minutes to obtain haemostasis. It is then replaced by a strip of dry gauze which is packed against the bony walls to entrap loose particles of amalgam. The author has found that visibility, freedom

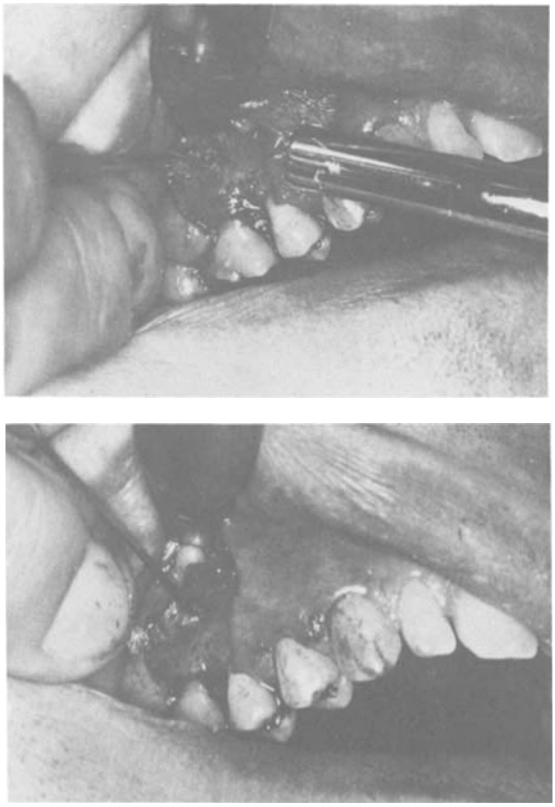


Fig. 25.66 Retro-filling technique with amalgam. (Top) Removal of granulations. Note the good access provided by a full flap. (Bottom) Insertion of silver amalgam from a P.D. Amalgam Carrier into the apical cavity, kept dry by a temporary 'dam' of Horsley's bone wax.

from haemorrhage and entrapment of amalgam are superior when bone wax is used.

It is often difficult, because of poor access and limited visibility, to avoid the loss of minute particles of amalgam in the periapical bone, and lingually, in the periodontal ligament or bony defect. A careful search should be made to find and wash away any such foreign bodies, but if their presence is noted subsequently in a radiograph, there is no cause for alarm, because they are almost invariably well tolerated.

The author has found that a very high percentage of teeth treated by apicectomy and retrograde obturation heal fully within 6–12 months, despite the fact that the pulp chamber and canals are full of necrotic or gangrenous pulp tissue. This appears to add support to the finding that when canals are sealed solely in the apical third, the healing of periapical areas, with or without apical surgery, may be equal to those in which total obliteration of the canal is effected (figure 25.67).

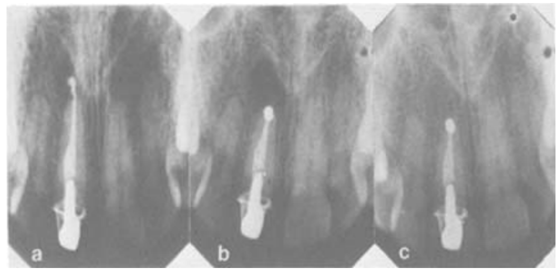


Fig. 25.67 Treatment of a chronic apical lesion (associated with overfilling of 1| root canal), by retrograde obturation with amalgam. (a) Before treatment. (b) Immediately after operation. (c) One year later.

If, despite apparent healing of the tissues after apicectomy, either with orthograde or retrograde obturation, the patient still finds the tooth is tender when touched, the following points should be checked.

(1) The occlusion may be traumatogenic.
(2) The crown–root ratio may be too low due to excessive shortening of the root.
(3) The apical seal may be defective.
(4) There may be continued infection from a lateral or separate unfilled apical canal, especially if a part of the canal contains necrotic tissue. (Whenever possible the whole canal should be filled.)
(5) A neighbouring non-vital tooth may be feeding infection to the periapical tissues.
(6) There may be a vertical fracture of the root.

The closure of lateral perforations

There is no doubt that prevention is better than cure. To avoid perforating a root, any engine reamer used in a handpiece should be of narrower diameter than the canal, while attempts to cut out gutta-percha root fillings, prior to post-hole preparation, should be preceded by softening the gutta percha with a heated wire or chemical solvents, followed by the use of hand instruments.

Nevertheless, many chronic periodontal abscesses with discharging sinuses owe their origin to a portion of root filling or crown-post projecting through the side of the root. If the perforation has been caused on the lingual aspect of the root, surgical treatment may indeed be impossible although, if it is near the gingival margin, a lingual flap may be raised sufficiently to repair the defect.

The surgical technique for repair of a lateral perforation (figure 25.68) involves the raising of a full flap and removal of sufficient bone and granulation tissue to gain access to the defect. If there is no root

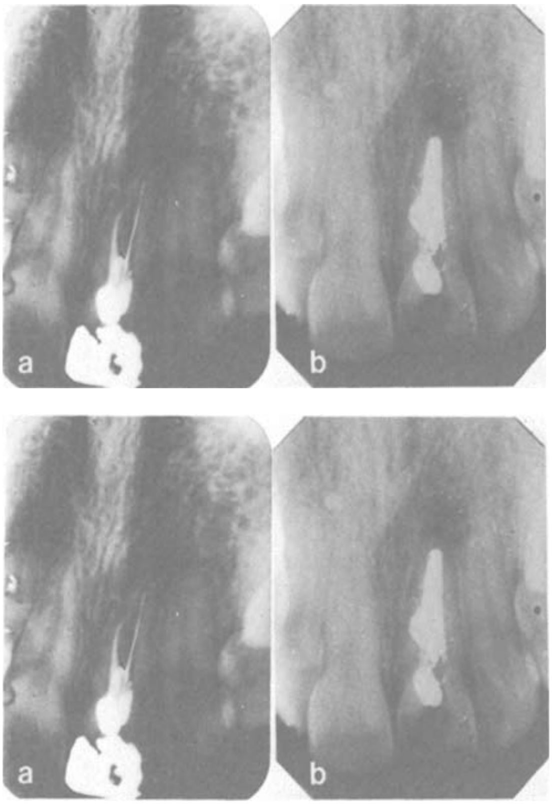


Fig. 25.68 **Repair of lateral perforation of |1 root using silver amalgam. (a) Underfilled root canal and gutta-percha cone projecting through lateral perforation. (b) Root canal prepared and filled with amalgam and perforation repaired when apical curettage carried out. (c) Three months after operation. (d) One year after operation.**

filling in the tooth, a retrograde filling may be inserted at the same time, should access to the canal be blocked coronally. Otherwise, a gutta-percha cone should be jammed in the canal to obliterate its lumen opposite the defect, so that the canal will not be blocked with amalgam when the perforation is closed.

Using a small wheel bur, the perforation is undercut and then filled with zinc-free silver amalgam, after which the gutta-percha cone may be withdrawn from the canal, if it is necessary to insert a temporary crown. When repairing a defect the use of bone wax is not recommended, but a pack of 1 : 1000 adrenaline hydrochloride, held under pressure for a minute or two, should control bleeding. After debridement and irrigation, the flap is sutured back into place. No special treatment is required for the sinus, which should disappear if the defect has been adequately sealed. The amalgam is introduced into the cavity with an apical amalgam carrier and condensed with pluggers of narrow diameter. Old probes with their ends ground flat are invaluable for the condensation of amalgam in such cases.

Repair of internal resorptions

If the canal can be prepared to the apex and filled with amalgam, or a silver or titanium apical cone, the resorption defect can be filled with amalgam at open operation.

Figure 25.69 shows a lower lateral incisor with a large periapical area. Root canal preparation was carried out under general anaesthesia, the patient being an extremely nervous girl, aged 15 years. The apical third of the canal was obturated with a well-fitting silver cone and Grossman's sealer, while the remainder of the canal was filled with gutta percha. The walls of the resorption defect were smoothed with a carborundum point and undercuts were made with a small wheel bur. The cavity was filled with silver amalgam.

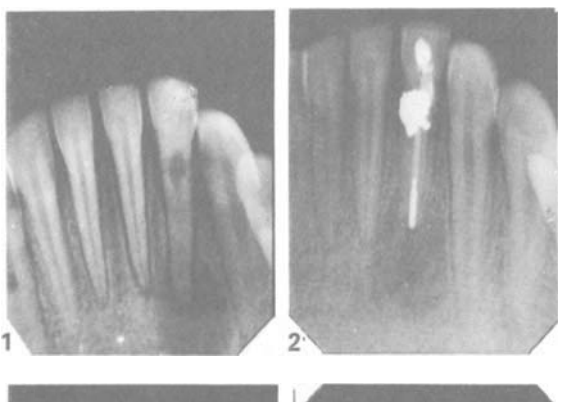


Fig. 25.69 **Repair of an internal resorption with amalgam. (1) Pre-operative radiograph. (2) Post-operative radiograph showing silver cone sealed at the apex, and the resorption defect obliterated with amalgam. (3) Two years after the operation . . . note the cobalt-chromium strengthener (placed a short time after operation). (4) Three years after operation, no change at the peri-apex.**

When the soft tissues had healed, the gutta percha was replaced by a length of cobalt–chromium wire (Wiptam, Krupps), diameter 1.2 mm, which was cemented in the canal as a means of strengthening the weakened junction with the crown. The tooth has remained free from symptoms and the periapical bone radiographically normal for the past 12 years.

Subsequent recession of the labial gingiva disclosed the amalgam. It was replaced with composite resin.

Replantation

When a tooth has been luxated from its socket by a blow, provided that it can be cleaned, root-treated and returned to the socket within a few hours, there is a good chance that it will become attached again to the bone. Often this attachment is in the form of an ankylosis, which may be ascertained subsequently from the disappearance of the periodontal space on the radiograph, but in some cases a new periodontal ligament appears to develop.

When ankylosis occurs the prognosis is poor, because it is followed before long by resorption of the root in the majority of cases, until all that remains are the root-filling and a loose crown which ultimately is exfoliated.

Despite the variability of prognosis, replantation is usually worth attempting, especially in children, because the tooth makes an excellent space maintainer (figure 25.70).

A tooth should be replanted as soon as possible after the accident. It has been observed that the prognosis varies inversely with the length of time that the tooth has been out of its socket, probably due to the desiccation and death of the periodontal fibres.

If the parent of the patient informs the dentist by telephone that the tooth has been knocked out, he should be told to wash the tooth under the tap and, except in the case of a very young child, the tooth should be replaced in the mouth and left in the buccal sulcus until he reaches the surgery. This will prevent drying out of the periodontal fibres and increase greatly the chance of successful re-attachment.

Van Hassel *et al.* (1980) showed that the vitality of the periodontal ligament is established as an important factor in deterring resorption of replanted teeth. They also demonstrated, in a post-replantation evaluation of air-dried and saliva-stored, avulsed teeth, using Macaca monkeys, radiographic evidence of re-establishment of intact periodontal ligament. Histological evaluation of one tooth, stored in saliva for 25 months, showed an intact periodontal ligament.

Kemp *et al.* (1977), investigating the survival time of teeth which, after luxation, had been replanted,

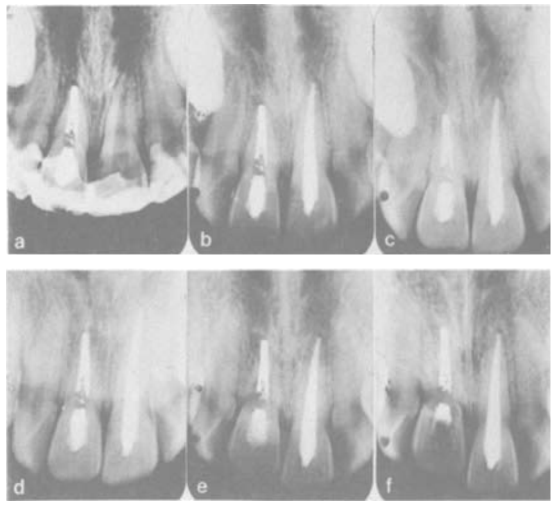


Fig. 25.70 Replantation of luxated 1| in a boy aged 11 years. (a) Root canal filled with amalgam and apex resected. Splint applied for one month. (b) Splint removed and subluxated |1 root treated. (c) Six months later – note loss of periodontal ligament space. (d) One year later – some apical resorption in 1| and |1 further erupted, showing ankylosed state of 1| . (e) One year later – root largely resorbed. (f) Three months later – root resorbed, crown loose, tooth extracted.

concluded that, despite the fact that the measure was only temporary, replantation was justified.

Technique

The tooth, when brought to the dental surgeon, should be washed thoroughly with warm water and an antiseptic soap and put into a solution of penicillin V or G (provided that there is no history of a previous reaction to penicillin). The patient is given an injection of anti-tetanus serum and 500 000 i.u. of penicillin, Distaquaine (Fort.) or, if this is contra-indicated, tetracycline may be given. A local anaesthetic is administered and blood clot is removed from the socket and replaced by a strip of gauze soaked in isotonic saline.

The tooth is now held in sterile gauze, also soaked in saline, and the apical 2.0 mm of the root is excised with side-cutting rongeurs or drilled off with a bur under saline spray. The pulp is extirpated from the apical opening of the canal, using a barbed broach. The apical part of the canal may be enlarged with an engine reamer and a matched silver cone cemented with E.B.A. cement. When the cement has hardened, the silver point is cut off flush with the root end. Alternatively, silver amalgam may be condensed at the apex after blocking off the bulk of the canal with a gutta-percha point to prevent the extrusion of amalgam into the pulp chamber.

The tooth is then returned to its socket and pressed home and any expansion of the socket walls is reduced by the application of firm pressure bucco-lingually with thumb and forefinger. Splinting is essential and may be carried out with interdental wiring, secured with self-polymerising acrylic.

Alternatively, if a full arch impression is recorded in alginate, an acrylic splint (in tooth-coloured acrylic) may be made in a hydroflask with self-polymerising resin. The use of a full splint ensures complete immobilisation without the risk of over-eruption of unsplinted teeth. The splint is cemented with white copper cement or polycarboxylate cement and left in place for 4–6 weeks. Effective splinting can be accomplished also by etching the labial enamel of the avulsed tooth and its immediate neighbours, using rubber dam, whenever possible, to exclude contamination by saliva. A piece of hard stainless steel wire (1.2 mm diameter) is cut and bent to conform to the arch and lie over the labial surface of the 3 teeth. Composite resin is then placed on the three teeth, and the wire, which has been roughened, is placed in position and covered with resin while the loose tooth is held firmly in position. When the composite resin has hardened, the occlusion is checked and adjusted if necessary, and the coating is smoothed and polished with soflex discs (3M).

The splint should not cover the gingivae and the patient is given explicit instructions about toothbrushing after meals, to remove debris and plaque from the splint and thereby minimise gingival irritation. After removal of the splint the patient is recalled annually for a radiographic examination to check for resorption of the root.

Intentional replantation

Conservative endodontic treatment may be practised on root canals which can be negotiated by root canal instruments as far as their apices. If there is any reason to prevent access to the apical part of the canal, the operator may resort to the operation of apicectomy, with retrograde obturation if necessary. However, there are many teeth for which this operation is unsuitable, because of inaccessibility or the proximity of vital anatomical structures, such as the maxillary antrum and inferior dental canal.

When such a situation arises, there is no satisfactory alternative to extraction. If the patient is willing, however, the operator may carry out the necessary apical root filling while the tooth is out of the mouth and then replant the tooth. No promise should be given that the operation will be carried out, because of the risk of fracturing a root while extracting the tooth, nor should a definite prognosis be given. The tooth may last only six months if conditions are unfavourable, whereas many teeth, replanted by the author, are still functioning satisfactorily after 16 years.

The operation should be carried out only on teeth with chronic infection. If there are symptoms of acute infection, this must first be brought under control by the use of antibiotics and by drainage and the relief of masticatory stress. An impression of the arch should be recorded so that a wire splint may be prepared.

Operative technique

Anaesthesia is obtained by local infiltration or regional block and any calculus is removed from the tooth. The gingival attachment is severed in order to avoid trauma to the gingivae when the forceps are applied to the tooth.

Extraction of the tooth is effected with root forceps, and the beaks are advanced slowly along the root and as far apically as possible, bearing in mind the increased brittleness of pulpless teeth. If the tooth is delivered whole, it is dropped into a bowl of warm isotonic saline and the socket is inspected.

Any loose fragments of bone or pieces of granulation tissue are removed, but the walls of the socket should not be curetted, because it is probable that the remnants of periodontal ligament play a vital part in the reattachment and formation of new periodontal fibres. A strip of sterile gauze, soaked in isotonic saline, is inserted into the socket and the apices of the roots are drilled away under saline spray, while the tooth is held in gauze which has been soaked in saline. Approximately 1.0–2.0 mm of apex is resected. Apical cavities are prepared and filled with silver amalgam, after drying them out with paper points.

Then the tooth is returned to the socket and pressed fully home, while the walls of the socket are squeezed inwards to reduce the expanded state resulting from the extraction (figures 25.71–25.73).

Splinting

Splinting may not be necessary in a small number of cases but, as a general rule, the tooth is loose and its fixation is essential if reattachment is to occur.

When there is an M.O.D. cavity in the replanted tooth, a pack consisting of polystyrene-bonded zinc eugenolate cement and cotton-wool fibres may be inserted and pressed into the proximo-gingival under-

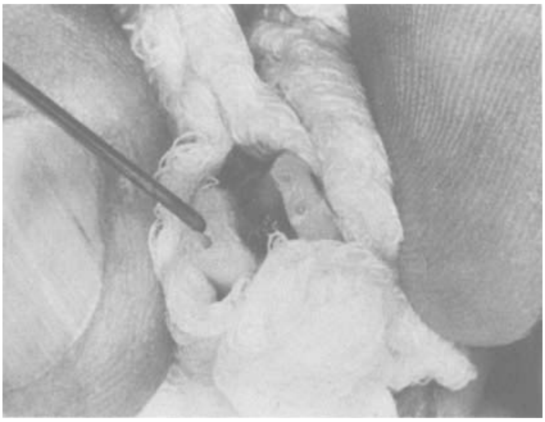


Fig. 25.71 Amalgam carrier in place, just prior to inserting amalgam into the apical cavities. The sterile gauze, in which the tooth is held, is soaked in saline.

Fig. 25.72 Condensation of the amalgam.

cut areas of the adjacent teeth, while being extended over the gingival margin of the replanted tooth (figure 25.74). This sets hard and gives sufficient fixation for a firmly replanted tooth. If there is some mobility however, undercut cavities may be prepared occlusally in adjacent Class II amalgam restorations and two lengths of roughened 0.8 mm stainless steel wire extended between the cavities and through the M.O.D. cavity in the replant, being fixed in place with a self-polymerising acrylic resin or composite restorative material.

Whichever of these methods is used, it is of great importance to ensure that the tooth and splinting material are totally free from masticatory stress. If the second method is adopted, the gingival margin may be protected with a dressing of Coe-pak periodontal dressing.

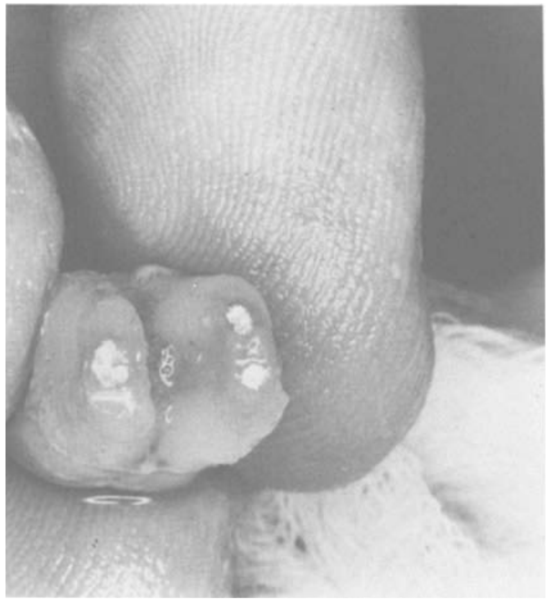


Fig. 25.73 The completed amalgam restorations.

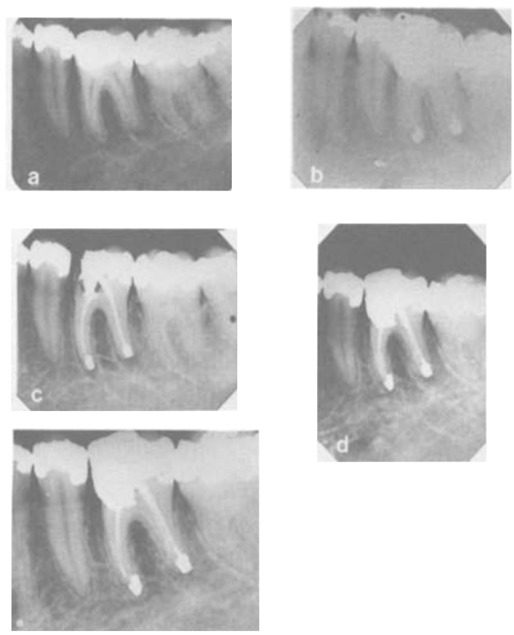


Fig. 25.74 (a) Before replantation. (b) Immediately after replantation. (c) One month later. (d) Six months later. (e) The replanted tooth, two years later.

Wire splint

If there is a space on one side of the replanted tooth, or if the adjacent teeth are unfilled the author uses interdental wiring in conjunction with a preformed wire splint, constructed on a model made from an impression previously recorded (figures 25.75–25.79).

Soft, stainless steel wire, 0.4 mm, is passed through the embrasures to lie first above and then below the wires, and the ends are brought out buccally, twisted up, and tightened and cut. The twisted ends are turned over to lie close to the teeth proximally, and covered with a mix of self-polymerising resin, which hardens within a few minutes. The acrylic locks the teeth and wires together, but it is necessary to make certain that it is smoothed and kept away from the gingival margins, which are then covered with Coe-pak.

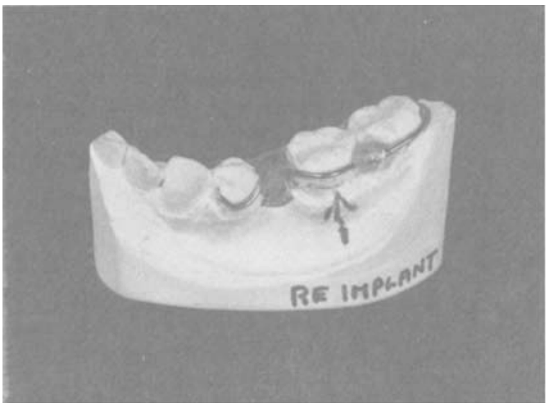


Fig. 25.75 A wire splint, locked to the teeth by interdental wiring and self-polymerising resin, made on the model for use after replantation of $|\overline{6}$.

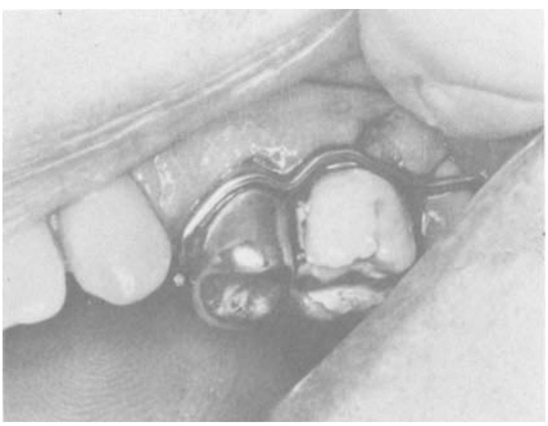


Fig. 25.76 A wire splint *in situ*.

Fixation is maintained for approximately four weeks, after which a radiograph is recorded to check for signs of resorption. The splint is removed and, if possible, as much of the pulp chamber and canals as can be cleaned out and enlarged are obliterated with

Fig. 25.77 Wire splint in process of being locked to teeth by interdental wiring.

Fig. 25.78 Gingival margins covered with Coe-pak, beneath which the acrylic resin may be seen.

Fig. 25.79 Wire splint used to hold $\underline{6}|$ after replantation (on a different patient). The wire and ligatures are locked to the teeth with self-polymerising acrylic resin.

a sealer and gutta percha. This is an insurance against the possibility of reinfection of bone through lateral canals, which may be found communicating with the furcation area.

A radiographic check is made annually and if healing of the periapical tissues has occurred without resorption of the roots, a crown or gold inlay may be inserted after one year (figures 25.80–25.83).

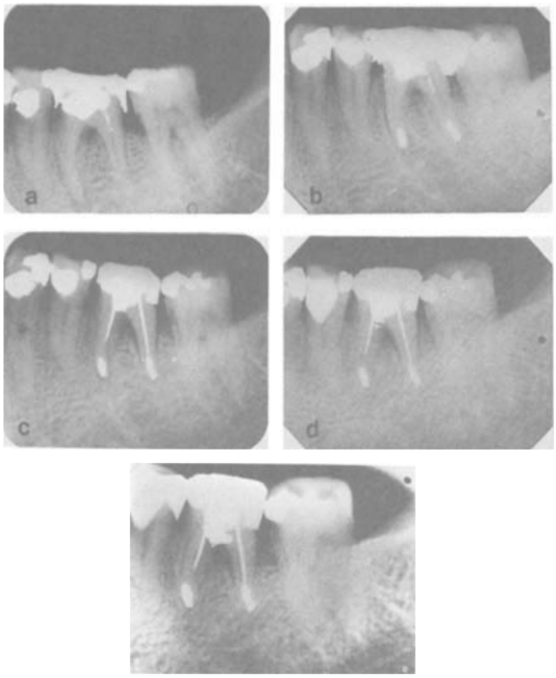


Fig. 25.80 Replantation of $|\overline{6}$ – note retrograde filling of perforation in bifurcation area at time of filling apical cavities. (a) Before replantation. (b) Immediately after replantation. (c) Six months later. (d) One year later. (e) Five years later.

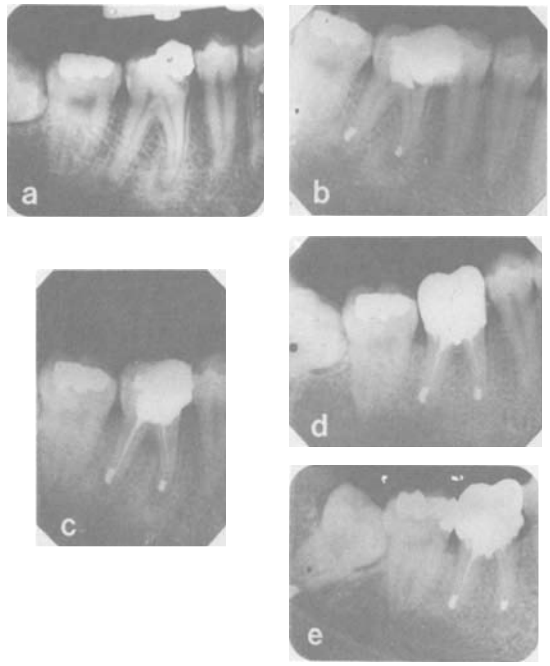


Fig. 25.82 Replantation of $\overline{6}|$ (a) Pre-operative rarefying osteitis below distal root and productive osteitis around mesial root of $\overline{6}|$ (b) Immediately post-operative, showing amalgam at apices and splinting with polystyrene-bonded, cotton fibre-reinforced, zinc eugenolate cement. (c) One month after operation. (d) One year after operation. (e) Five years after operation. Tooth still symptomless.

Transplantation

The operation of transplantation may be carried out when a tooth requires to be extracted and, at the same time a redundant tooth of similar size, such as an impacted molar or a grossly imbricated premolar, can be used as a replacement.

The socket is packed with gauze after the tooth has been extracted and the tooth to be transplanted is removed as atraumatically as possible. The apices are resected and the canals filed out from the apical end. If the pulp can be removed with barbed broaches it is extirpated, but difficulty may be experienced in negotiating fine canals in molars and premolars. The canals should then be filled with silver points and a quick-setting sealer, or amalgam, may be condensed in apical cavities. The root surfaces must be kept moist with isotonic saline.

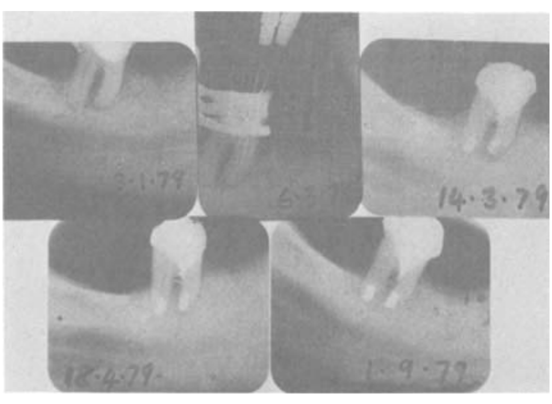


Fig. 25.81 Replantation of lower second molar after perforation of bifurcation. The canals were sclerosed. The perforation and apical cavities were obliterated with amalgam.

The tooth is tried in the socket and after ascertaining the points of impaction, the crown is reduced with discs and the socket enlarged with a surgical bone bur.

By means of progressive reduction of the inter-radicular septum and enlargement of the socket, by drilling under saline spray, the tooth is finally made to bed down into a position of relative harmony with adjacent and opposing teeth. If necessary, the occlusal anatomy is modified by grinding, to prevent traumatogenic occlusion, and the tooth is splinted, surrounding the marginal gingivae with a protective layer of Coe-pak. Subsequent treatment and checking are carried out as described for a replanted tooth (figure 25.83).

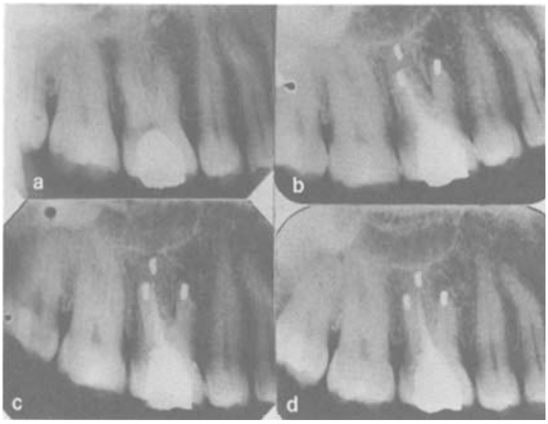


Fig. 25.83 Replantation. Eight year result. Some apical resorption present on mesio-buccal root.

It may happen that a tooth must be extracted, but an unwanted tooth which could be transplanted to its socket does not have a suitable crown, e.g. extraction of a maxillary incisor and the presence of a badly imbricated mandibular premolar.

In such a case, following extraction of both teeth, the crown of the premolar is resected, the pulp extirpated and replaced by a calcium hydroxide dressing which is then sealed into the canal with cement. The root is then placed in the socket and covered with Coepak. When attachment has occurred, the root apex is filled and a post and core prepared and cemented, so that a suitable crown may be made.

Burke (1976) reported on the arrest of external resorption of a replanted maxillary incisor by filling the root canal with a paste of calcium hydroxide and camphorated parachlorphenol. Thus, it would appear to be a sound practice to dress the canals of transplanted or replanted teeth in this manner, as a prophylactic measure against resorption.

Moss (1970) has transplanted buried canines without interfering with the vital pulp tissue and, inexplicably, after reattachment had occurred there was an apparent revascularisation and renervation, evidenced by the progressive diminution in width of the root canal and a return to normal values of the vital response. The result was not influenced by the degree of maturity of the apex.

Hemisection

It is occasionally found that the mesial or distal root canal of a lower molar is impenetrable, but there exists an associated periapical involvement which requires attention, while the other root canal can be negotiated as far as the apex without difficulty.

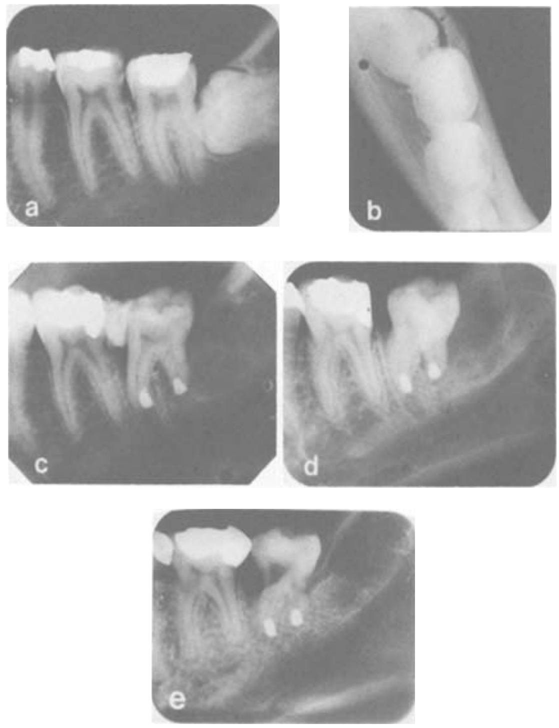


Fig. 25.84 Transplantation of $|\overline{8}$ into $|7$ socket. The $|\overline{7}$ was extracted as a result of a chronic suppurative condition related to a bifurcation involvement during endodontic treatment. (a, b) Horizontally impacted $|\overline{8}$. (c) Immediately after extraction of $|\overline{78}$ and transplantation of $|\overline{8}$ to $|\overline{7}$ socket. (d) Three months later. After nine months, the contact between $|\overline{6}$ and $|\overline{7}$ was restored with a full veneer cast gold crown. (e) One year later – tooth is firm and symptomless and periodontal condition is good.

Although, in such a case, it would be possible to carry out a replantation, such treatment should be undertaken only as a last resort. The operation of hemisection offers a better prognosis (figures 25.85–25.89). Firstly, the operable canal is prepared and dressed and subsequently it is filled in the apical third, leaving the bulk of the canal open to make room for a post or a Dentatus screw.

Then, under local anaesthesia, the crown is sectioned bucco-lingually as far as the bifurcation, using a long, friction-grip, diamond bur in the turbine handpiece. The cut wall of the section of crown which is to remain *in situ* is then smoothed and rounded with sandpaper discs, and all debris is flushed away. It is essential to check that the arch of the furcation is eliminated. Otherwise it would act as a plaque trap and render cleaning difficult, if not impossible. Care is exercised to ensure that the tooth is hemisected completely and it should be possible to place an elevator between the roots and, by exerting a gentle

Fig. 25.85 Hemisection of $\overline{|6}$. Death of pulp by infection after periodontal surgery performed around mesio-buccal root surface (see radiograph, Figure 25.88).

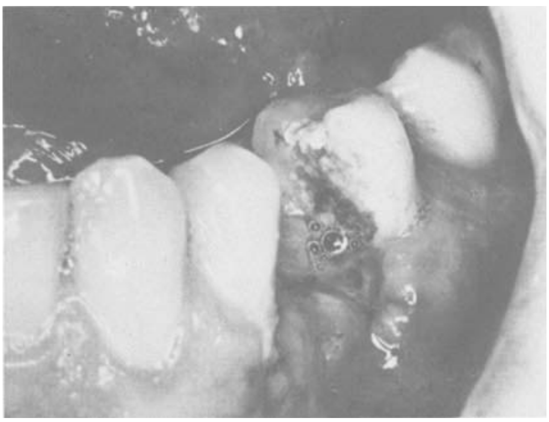


Fig. 25.86 One week after division of the crown and removal of the mesial root (endodontic treatment of the distal root was first carried out).

Fig. 25.87 $\overline{|6}$ with gold inlay to effect conversion to a $\overline{|5}$, three years after hemisection.

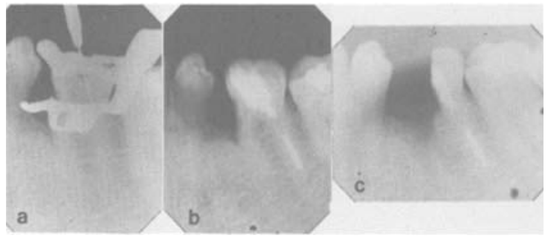


Fig. 25.88 (a) Non-vital $\overline{|6}$ with inaccessible mesial root canals. (b) After filling distal canal with apical silver tip. (c) Immediately after hemisection.

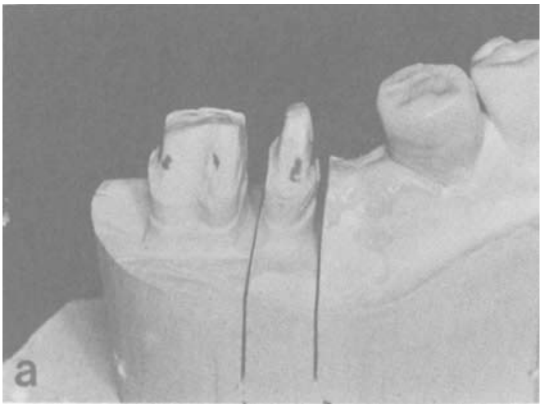
Fig. 25.89 Radiograph recorded four years after hemisection.

twisting force, elicit a slight independent movement of the two parts. The unfilled root is then extracted.

When the socket has healed, either a post crown, an amalgam restoration or a gold inlay may be constructed according to circumstances. It may even be feasible to crown the root and use it as a bridge abutment (figure 25.90).

Root resection

From time to time it may be necessary to resect the whole or part of a palatal or mesio-buccal root of a maxillary molar. If the reason for resecting the root is the finding of a completely untreatable canal, approximately one-half of the root is resected, at an acute angle, and a retrograde amalgam restoration is inserted (figure 25.91). It may be necessary, however, to remove a whole root, such as a palatal root, because of periodontal pocketing which has progressed unduly in an apical direction or involved the furcation. If possible, the pulp chamber, in the region of the palatal root canal orifice, should be filled with amalgam, after the other root canals have been treated and filled,



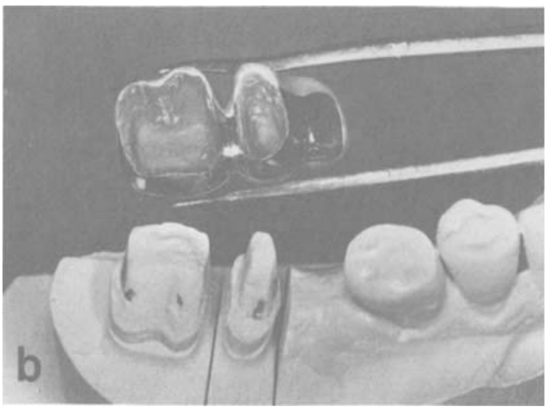


Fig. 25.90 (a) Hemi-section of lower first molar and removal of mesial root, necessitated by a bifurcation involvement. Distal root canal prepared and filled and a cast core cemented. (b) Cantilever bridge ready for cementation.

then the root is sectioned and removed and the area between the trifurcation and the palatal wall of the tooth is packed with Coepak.

When the palatal socket has healed, the cut area of root is trimmed and made smooth and easily cleansible and the patient is instructed to use wood points, supplemented with other oral hygiene measures, such as the Interspace toothbrush or the Water-Pik irrigation apparatus to remove deposits of plaque.

Cleansing of the gingival area related to the resection may be improved by recontouring the crown to eliminate the coronal bulge from which the root stemmed. Reduction of the occlusal table overlying the resection zone, diminishes the increased stress load thrown onto the remaining roots.

The treatment of roots with immature apices

Fracture of the crown or accidental exposure of the pulp during preparation of a cavity in a tooth, the apex of which is not fully formed, poses the problem of arresting the root filling at the apex and concomitantly producing an apical seal.

In order to bring about closure of the apical foramen, use may be made of the fact that calcium hydroxide exerts a stimulating effect on the odontoblasts, encouraging them to lay down a calcific barrier after pulpotomy of a vital tooth, and this is followed in successful cases by the completion of apical development.

Pulpotomy

The operation of pulpotomy consists of the excision under aseptic conditions of vital pulp in the pulp chamber, leaving the radicular pulp covered with a suspension of calcium hydroxide in methyl cellulose. This treatment is indicated for fractured and exposed teeth with symptomless, uninfected pulps and open apices, but good results have been obtained by some operators in teeth with closed apices.

The pulpotomy should be carried out within 48 h after the trauma, if there is to be a favourable prognosis, because infection will tend to spread through a pulp which is left open to the oral cavity. The technique is as follows:

(1) Anaesthetise the tooth and apply rubber dam.

(2) Sterilise the surface with 2% benzalkonium chloride.

(3) Remove the roof of the pulp chamber with a round bur and irrigate with warm isotonic saline.

(4) Excise the pulp to a level approximately 1.0 mm beyond the neck of the tooth, using a sharp spoon excavator or a steel bur run slowly in reverse. The latter method should be adopted only when there is difficulty in using an excavator, because it is more traumatic. If the bur were to be operated in a forward direction, there would be a risk of avulsing the whole pulp.

(5) Haemorrhage is controlled by irrigating with saline and placing a sterile cotton pledget in the chamber. If this is not successful, a 1/1000 solution of adrenaline may be used.

(6) Cover the pulp stump with a dressing of calcium hydroxide, made into a paste with sterile water (or methyl cellulose), and fill the rest of the pulp chamber with polycarboxylate or phosphate cement, over which an amalgam restoration is inserted.

(7) Take a control radiograph and follow this with further radiographic checks at six-monthly intervals. The radiograph is examined for evidence of closure of the apex and the formation of a bridge of dentine between the pulp and the calcium hydroxide dressing.

Even though these two criteria may be fulfilled, the pulp frequently degenerates after a few years and there is a marked tendency for internal resorption to occur.

In consequence, once it has been ascertained that apical closure has been completed, the pulp should be extirpated under local anaesthesia and the canal prepared and filled.

It is generally accepted that pulpotomy is more successful when there is an open apex, but the author has seen many apparently successful pulpotomies carried out in mature adult molars, and has personal knowledge of cases which have remained free of symptoms and radiographic signs for ten or more years. The procedure has been carried out in two stages, using a dressing of corticosteroid/antibiotic cream, applied to the pulp stump on cotton-wool and sealed in for four to seven days. After this period, the dressing was replaced by a calcium hydroxide suspension and the cavity restored with amalgam. Laws (1967) obtained good results using a similar technique. The indications for pulpotomy in mature multirooted teeth are firstly, in order to avoid the preparation of obviously difficult canals and secondly, as an alternative to pulpectomy when the tooth is so situated that access is impossible for instrumentation. Pulpotomy would appear to offer a better prognosis than pulp capping, because the area of traumatised tissue is reduced.

Treatment of teeth with necrotic pulps and open apices

If a pulp dies at an early stage of apical development, the canal is found to be markedly divergent at the apex, presenting a 'blunderbuss' opening into the bone. Various techniques have been suggested for producing an apical seal after the canal has been sterilised, ranging from hand-rolled gutta-percha cones, fitted to the apical canal orifice and condensed laterally with the addition of further cones, to a surgical approach and retrograde obturation. The chief drawbacks of these techniques, aside from the purely physical difficulties, are the subsequent shortness of the root and the thin, weak walls, because no further deposition of dentine can occur.

It has been found that, once the infection has been controlled, Hertwig's sheath is able to resume its formative function and complete the closure of the root-end.

The treatment consists of careful debridement and irrigation of the canal walls with sodium hypochlorite, preparing the walls with large files and making careful measurements of root length to avoid trauma to the periapical tissues. Further avoidance of trauma to the apical bone may be secured by removing the sharp pointed end of each file. Antiseptic or antibiotic dressings are used to control the infection and, when all signs and symtoms have disappeared, the canal is filled (using a Lentulo reverse spiral filler) with a suspension of calcium hydroxide in paramonochlorphenol-camphor (C.C.P.), mixed to a heavy consistency. This may be impacted against the walls by the insertion of a short thick gutta-percha cone to a point midway down the canal. If there is a sinus present which does not clear up within a few weeks, the dressing should be replaced after further biomechanical preparation of the canal has been carried out.

A dressing, consisting of gutta percha covered with a zinc eugenolate seal, should be inserted and the coronal orifice closed with a temporary amalgam restoration.

The patient is recalled after six months and one year and ultimately, when the radiographic appearance of the apex suggests that healing has occurred, the root canal dressing is removed under rubber dam. Evidence of an apical calcific bridge may be deduced by probing with a reamer, when a firm barrier should be apparent. There is no narrowing of the root canal, however, but it may be filled by any of the aforementioned techniques. A continued radiographic check-up is instituted at yearly intervals.

Treatment of resorbed apices and enlarged apical foramina

Roots which have been the seat of a chronic infective osteitis over a prolonged period tend to exhibit apical resorption. This may also occur following injudiciously rapid orthodontic movements. In both cases there will be an absence of the normal apical constriction of the canal, so that instruments, drugs and root filling materials will tend to be extruded into the bone. Similarly, over-enthusiastic preparation of the canal, especially in the absence of a suitable diagnostic radiograph, may enlarge the apical foramen and bring about a similar situation.

When it is realised, either from a study of the radiograph or from clinical signs and symptoms, that the foramen permits the passage of the larger reamers, the canal should be irrigated and dried with blunt paper points. It is then filled with a preparation consisting of an antibiotic and a corticosteroid and left undisturbed until there is complete subsidence of any post-traumatic apical periodontitis. Inclusion of a corticosteroid will exert an anti-inflammatory effect which may prevent a post-operative reaction.

Obviously the subsequent preparation of the canal should be carried out with meticulous care, avoiding the use of root canal antiseptics in the apical region and taking precautions to avoid blocking the canal with the irrigating needle, which could force the fluid into the periapical bone.

The sealing of the apical foramen constitutes the chief problem, because there is the risk of forcing the silver, titanium or gutta-percha cone, or the sealer, through the foramen.

Moreover the silver, or preferably, the titanium cone should be measured carefully, trimming the sharp point away and testing the fit until it is felt to bind at a predetermined point, which should be approximately 1.0 mm short of the radiographic apex. A check radiograph is then recorded and any further adjustments are made.

Sealer should be painted over the walls of the canal, using a reamer which is two sizes smaller than the canal, and rotating it by hand in a counter-clockwise direction. The cone should then be advanced slowly, with a side-to-side rotation, until it has reached the desired position. If it is pushed up quickly or through the mass of sealer, which might have been deposited at the apical end of the canal if a Lentulo has been used, the sealer could be forced through the foramen, or the cone might be held up by the back pressure which could develop if the sealer were too viscous to pass through the foramen.

Despite these precautions, sealer may still be extruded beyond the apical foramen. However, if AH 26 is used, it does not produce a severe reaction and, after a lapse of one or two years, it will tend to be resorbed and will not affect the deposition of new bone after successful endodontic treatment.

The Pulpal–Periodontal lesion

One of the greatest advances in both endodontic and periodontic treatment has been the recognition and acknowledgment of the relationship between diseases of the pulp and the periodontal tissues. Presently referred to as 'endo-perio' lesions, they provide a fruitful field for co-operation between periodontists and endodontists.

The basis of the problems which may arise, exists in the communications between the pulp and periodontal ligament, not only at the apical foramen, but also in furcations or at any part of the root surface.

Thus, the pulp may become infected when the openings of lateral canals are exposed to the oral environment, especially following root planing, whilst the existence of necrotic pulp is a potential source of infection for the periodontal ligament. An example of the latter condition is frequently observed when a discrete radiolucent area is found associated with a lateral branch of an infected pulp.

When accessory canals are exposed to the saliva, organisms and toxins may enter the pulp, interfering with its blood supply. After pulpal necrosis has occurred, this new source of organisms and their toxins can re-infect the periodontium.

The endo-perio lesion occurs in areas of destruction of the periodontal attachment extending from the gingival sulcus to the root apex and associated with a diseased pulp. Provided that the periodontal condition is ultimately treatable, the endodontic problem should be solved first. However, in many cases in which both lines of treatment are being carried out by the same operator, concomitant treatment of both problems will hasten resolution.

There are many parameters of the joint problem, e.g. the conversion of a pulpal necrosis into a periodontal lesion through a lateral perforation of the root in the course of endodontic treatment.

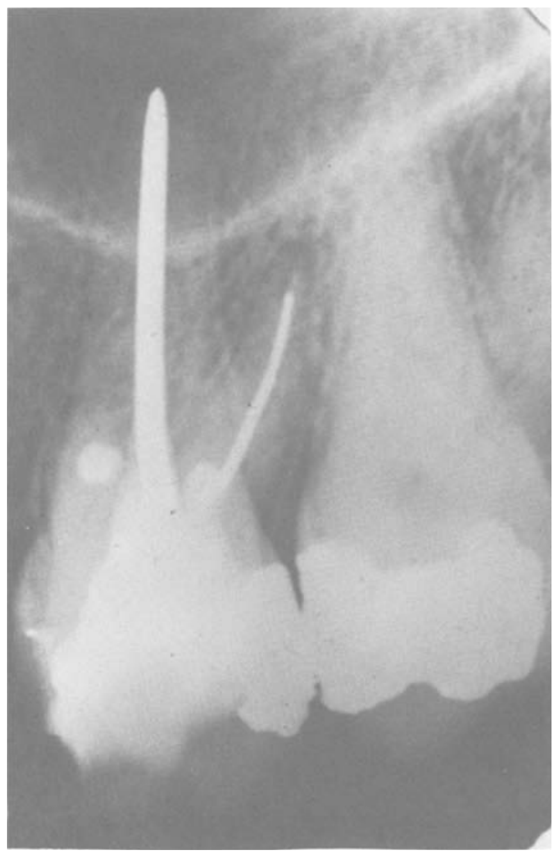


Fig. 25.91 Retrograde obturation of impassable mesial root canal in a maxillary first molar. Radiograph recorded 1 year after operation.

The treatment of endo-perio lesions may consist of:

(1) Endodontic treatment alone.

(2) Periodontic treatment alone, provided that apical or furcation involvement has not produced irreversible damage to the pulp.

(3) Combined treatment, which might be simple (figure 25.92), or involve a surgical approach, such as root resection, hemisection and removal of half of the tooth, or conversion of the two parts into separate teeth in order to eliminate the bifurcation (bicuspidisation).

Diagnosis of the Endo-Perio lesion

In common with other lesions, a good history is mandatory, as are radiographs and vitality tests. The source of a sinus or deep pocket can be elucidated by inserting a silver or gutta-percha cone and recording a radiograph, using, for preference, a long-cone technique.

The criteria of success in endodontics

The failure of a crown, a bridge or an inlay is manifested by a recurrence of caries or the loss of part of the supporting tooth substance or loss of the restoration. When a root treatment fails, the manifestations may be dramatic or there may be no clinical evidence whatsoever.

In consequence, it is mandatory that, after every root treatment, whether of a conservative nature or involving surgical intervention, a clinical and radiographic check be made at regular intervals for 3–5 years. The following criteria may be taken as evidence of success.

(1) The absence of pain, tenderness and swelling.

(2) Normal function – the tooth being firm and as comfortable as a normal tooth.

(3) No evidence of a sinus.

(4) No radiographic evidence of periapical rarefaction, greater in extent than in the control radiograph recorded at the time of filling the canal. The area should have disappeared or contracted, but it is reasonable to accept an arrested lesion as 'healed', provided the other criteria are fulfilled, after a minimum period of two years.

Causes of failure

When a patient returns with a history of pain, swelling and loss of function, the following possibilities should

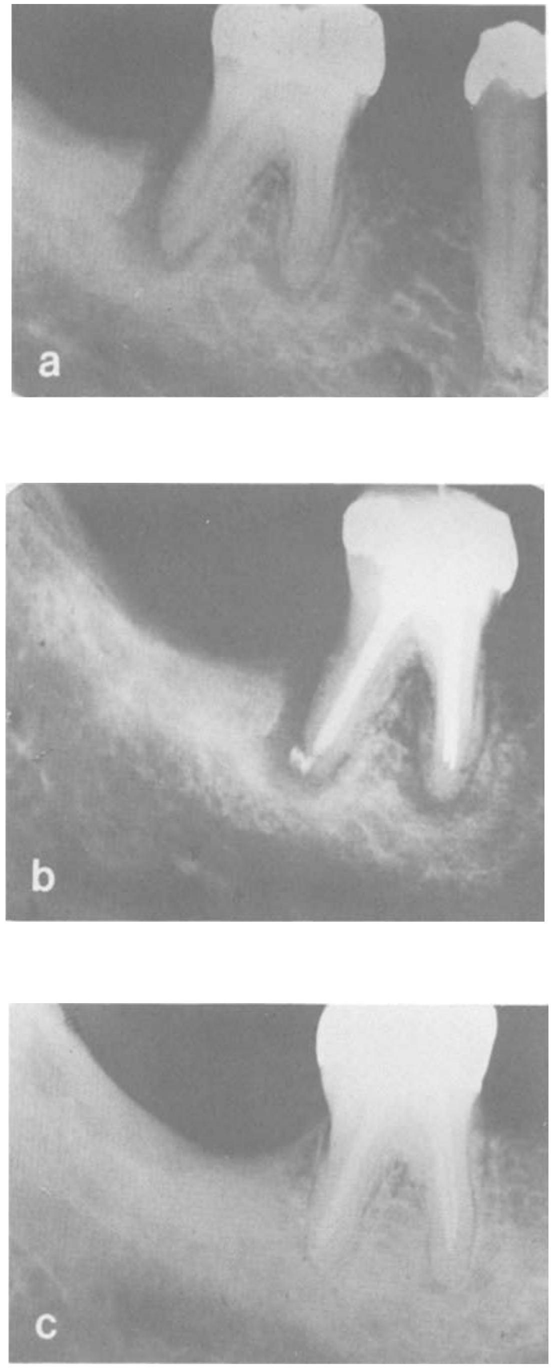


Fig. 25.92 Combined treatment of an endo-perio lesion. The endodontic treatment consisted of; (i) Biocalex dressing. (ii) Complete preparation of the canals and calcium hydroxide dressing. (iii) Root filling with a combination of silver cones, gutta percha and AH 26. Periodontal treatment was root planing, application of a periodontal pack and instruction in oral hygiene measures. (a) $\overline{7}|$ before treatment. (b) at conclusion of treatment. (c) after 2½ years.

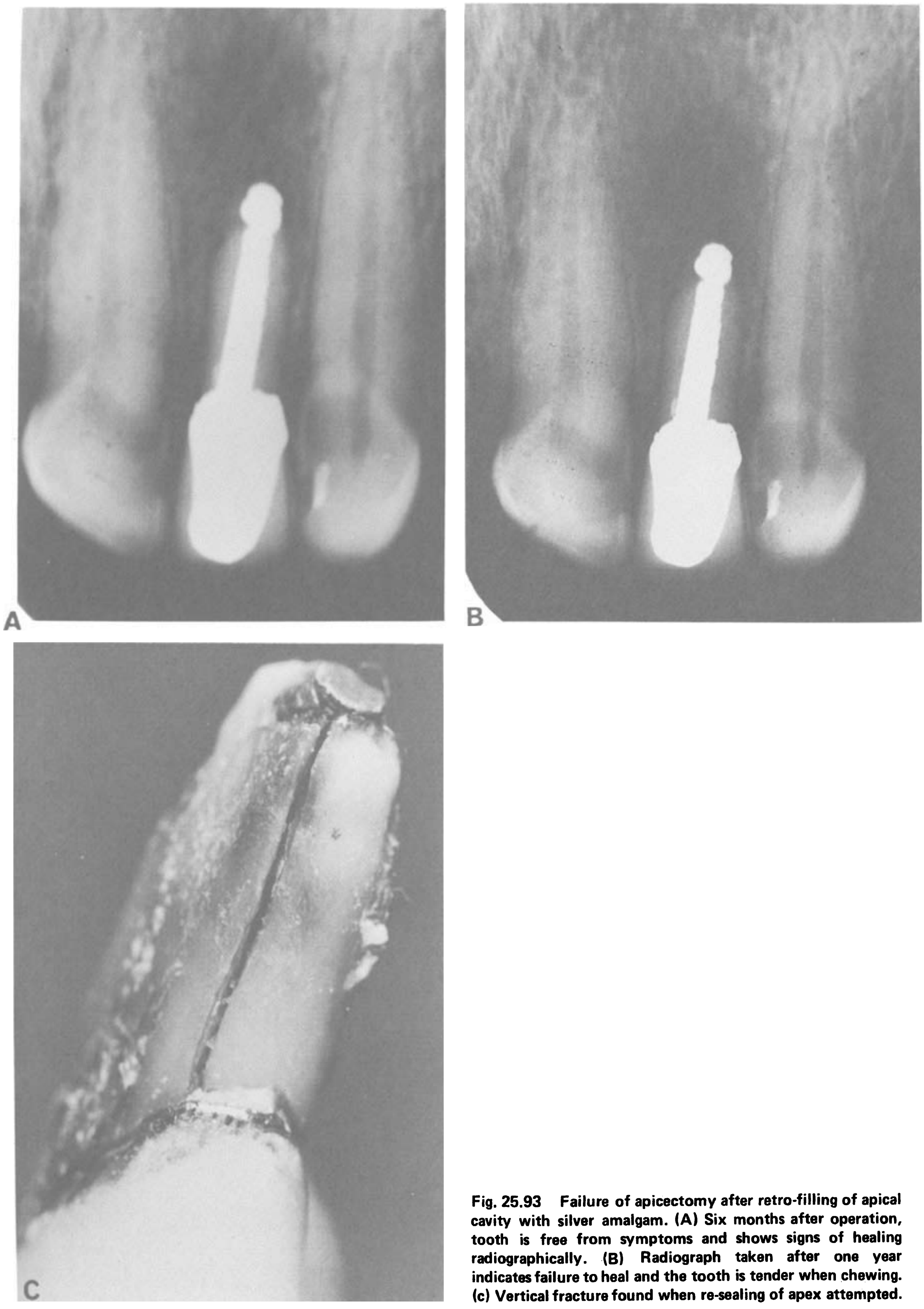


Fig. 25.93 Failure of apicectomy after retro-filling of apical cavity with silver amalgam. (A) Six months after operation, tooth is free from symptoms and shows signs of healing radiographically. (B) Radiograph taken after one year indicates failure to heal and the tooth is tender when chewing. (c) Vertical fracture found when re-sealing of apex attempted.

be considered:

(1) The root filling is deficient or has been extruded through the apical foramen or through a lateral perforation.

(2) A canal has been missed or has not been filled, or a lateral canal of some magnitude is infected and unfilled.

(3) Traumatogenic occlusion may be causing a chronic periodontitis, not directly connected with the root treatment, but due to a high spot on the restoration, or there might be a periodontitis resulting from a tight denture clasp, or an inadequate contact area which allows food impaction, or a fractured restoration, or fracture through the tooth.

(4) There may be continued discharge from a sinus, resulting from a periodontal abscess or from infection of the original apical lesion by a contiguous tooth with a necrotic pulp.

(5) Chronic tenderness which deters the patient from biting on that side may be due to fracture of the tooth (figure 25.93). This may occur if the weakened tooth, composed of brittle dentine and enamel, is not protected by a suitable gold inlay (e.g. maxillary premolars frequently develop a crack through the bifurcation). If there is no obvious movement of the two parts, the restoration should be removed and the dentine stained with liquor iodi mitis, so that a crack may be seen if present.

(6) If a post-crown has been constructed subsequent to the root filling, it is possible that the apical seal has been disturbed, or that the post has perforated the root.

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Appendix

E.B.A. Cement (Formula according to G. M. Brauer)

	(Zinc oxide 64%)	*Liquid*
Powder	(Aluminium oxide (5μ particle size) – 30%)	Ortho-ethoxy benzoic acid 62.5%
	(Hydrogenated resin – 6%)	Eugenol 37.5%

Root Canal Sealers

Rickert's Paste Mixed in a powder/liquid ratio of 1.7 g to 0.2 ml of liquid

Powder	(Zinc oxide	41.2 G.
	(Precipitated silver	30.0 G.
	(White rosin	16.0 G.
	(Thymol iodide	12.8 G.
Liquid	(Clove oil	78.0 G.
	(Canada balsam	22.0 G.

Grossman's sealer

Powder	(Zinc oxide	40 parts)	
	(Staybelite rosin	30 parts)	Pass through
	(Bismuth subcarbonate	15 parts)	100-mesh sieve
	(Barium sulphate	15 parts)	
Liquid	(Eugenol	5 parts)	
	(Oil of Sweet Almond	1 part)	

Constituents of AH 26 root canal sealer (De Trey)

(Bisphenol glycidyl ether
(Bismuth dioxide
(Silver powder
(Titanium dioxide
(Hexamethylene tetramine

Irrigating solution for root canals

(Cetrimide 0.5%
(Chlorhexidine diacetate 0.05% in distilled water

Savlodil (I.C.I.)
(Available in sterile sachets for irrigation of root canals)

Chlorhexidine gluconate	1.5 % w/v
Cetrimide Ph. Eur.	0.15% w/v

Constituents of antibiotic/corticosteroid dressing for root canals
(Septomixine-Septodont)

Dexamethasone
Polymyxine B sulphate
Tyrothricin
Neomycin sulphate
Chloro-2. p-diethylamino ethoxy-phenyl-benzthiazole tartrate

Horsley's Bone Wax

(Yellow Beeswax	210 g
(01. Arachis	60 g
(Phenol	30 g

Formo-cresol (Buckley's formula)

Liquor formaldehyde	1 oz.
Cresol	1 oz.

Plus sufficient alcohol to make a clear solution.

Formula of Cavit: zinc oxide, calcium sulphate, zinc sulphate, glycolacetate, polyvinyl-chloride acetate, triethanolamine, red pigments.

E.D.T.A.C. chelating solution (Östby's formula)

Ethylenediamine tetra acetic acid	143 g
Cetyl trimethyl ammonium bromide	0.84 g
Distilled water	to 1000 ml

Contents of Tubliseal (Kerr modification of Grossman's sealer)

	accelerator
zinc oxide	
Oleoresins	
bismuth trioxide	eugenol
thymol iodide	polymerised resin
oils and waxes	amidolin

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The Bleaching of Pulpless Teeth

Varying degrees of discolouration can develop in teeth as a result of systemic and local causes. In congenital porphyria and hereditary opalescent dentine the enamel is purple to violet in colour, whereas if tetracycline is administered during the period when enamel is being laid down, the teeth erupt with yellow striae or with a grey colour, and in endemic fluorosis, yellowish-brown mottling is seen.

Local factors produce discolouration of single teeth and the colour changes vary from grey to brown and from purple to black. The causative agents may be: (1) chemicals used in cavities and root canals, such as silver nitrate and iodoform; (2) restorative materials, such as silver and copper amalgam and copper cement; (3) decomposition of pulp tissue and passage of the breakdown products into the tubules, and (4) trauma to the pulp allowing escape of blood into the dentinal tubules.

The only satisfactory method of improving the appearance of teeth discoloured by systemic agents is by crowning. This applies also to teeth which have undergone colour changes as a result of chemical contamination by medicaments.

This leaves those teeth, which have discoloured as a result of trauma to the pulp and haemorrhage into dentinal tubules, or the breakdown of dead pulp tissue, as candidates for bleaching, but only those teeth which are sound labially and incisally should be included.

The younger the patient, when the tooth is traumatised, the larger is the pulp and consequently the greater the haemorrhage with resultant extravasation of blood into the dentinal tubules. The tooth is pink or violet to purple at first, but slowly the colour changes to brown and finally to dark grey or blue-black. Such extreme colour changes in teeth prove to be extremely difficult to bleach, although a moderate degree of improvement can be achieved as an alternative to crowning, if the patient is considered to be too young for crown preparation and the discolouration is causing embarrassment.

There is a tendency to consider bleaching to be a waste of time because of the tendency in some cases for the teeth to darken again after a variable period of time. Undoubtedly, by making a porcelain jacket crown the ultimate aesthetic result may be assured; however, in many cases the patient is delighted to have an improvement in aesthetics without the trouble and expense of crowning. Moreover, even if the tooth darkens after a few years, it is a relatively simple task to repeat the bleaching.

The patient must be warned that there can be no guarantee of permanence, but it should also be stressed that the treatment in no way precludes the possibility of subsequent construction of a crown.

Undoubtedly, prevention of those causes of discolouration that are avoidable should receive constant attention. Blood or dead pulp should never be left in the cornua of a pulp chamber; this will not occur if the whole pulp chamber is opened up and cleaned when access is gained to the pulp. Similarly after extirpation of a pulp, haemorrhage from the amputated apical stump should be controlled prior to dressing the canal. If silver amalgam is used in anterior teeth, it must be used over a lining and a layer of copal-ether varnish applied to the dentine as a barrier to the formation of metallic interaction products which would cause staining. It is preferable, however, to avoid the use of amalgam where a problem of aesthetics might arise. When root canal sealers which contain silver or silver salts, iodine, or red lead are used, all traces should be dissolved out of the coronal part of the canal before the cavity is restored. For this purpose, acetone or chloroform may be used.

The technique of bleaching

Before deciding to bleach a tooth, the presence of a perfect apical seal of the root canal must be assured, because otherwise there is a risk that the irritant bleaching fluid could reach the periapical bone and cause a severe reaction. If there is any doubt, the root filling should be replaced or, if it has been satisfactory over a long period, it may be covered with a small barrier of phosphate cement.

All old restorations are removed from the crown and the root filling is cut back to a point approximately 2.0 mm apical to the neck of the tooth. Heavily stained dentine may be ground out, provided that its removal does not weaken the crown excessively.

The rubber dam is applied to the affected tooth alone, provided it is retentive enough to hold a clamp (figure 26.1), but first the gingival margins are coated with vaseline to protect them from the caustic bleaching agent in the event that leakage might occur around the rubber dam. If the tooth to be bleached has a well-developed cingulum, it may be possible to secure the rubber dam with a clove hitch ligature alone, after everting the edges of the dam into the gingival crevice.

The bleaching agents which are commonly used are Pyrozone, which is a 25% solution of hydrogen peroxide in ether, or Superoxol, a 30% solution of hydrogen peroxide in distilled water. The former is very caustic and irritating to the tissues and has poor keeping properties, while the latter, which is caustic, is less so than Pyrozone, but it should be stored in a tightly stoppered, coloured bottle in a refrigerator and kept away from heat, because of the risk that the bottle may explode when stored in a hot environment.

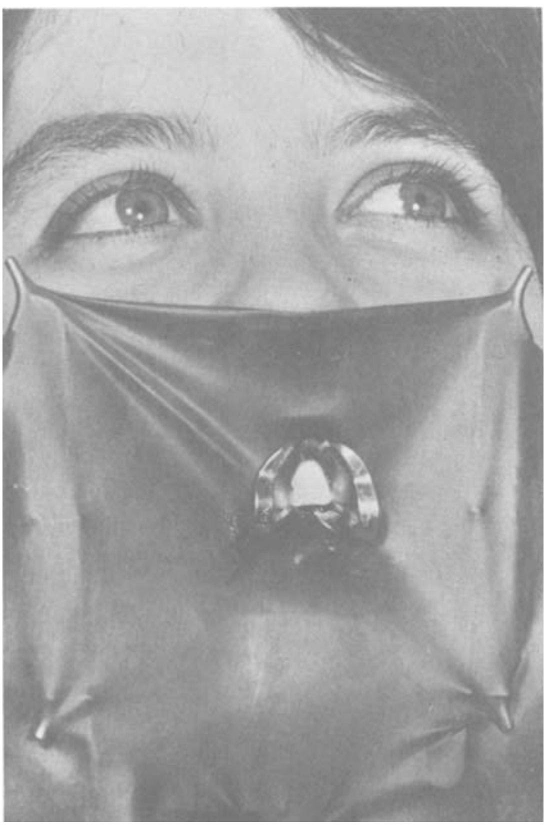

Fig. 26.1 Rubber dam *in situ* for bleaching.

Before applying the bleaching agent the enamel is polished and the shade of the teeth is recorded as a reference, to measure the degree of improvement without removal of the dam.

The author has achieved satisfactory results through the use of Superoxol in the following ways. The tooth is desiccated by swabbing the canal with a mixture of ethyl alcohol and ether and dried with blasts of hot air. A pledget of cotton-wool is soaked in Superoxol, to 2.0 ml of which one drop of Teepol has been added to lower its surface tension. It is placed in the pulp chamber, while a film of the liquid is flooded over the labial enamel, so that it can perfuse through microscopic cracks in the surface. The breakdown of the hydrogen peroxide to nascent oxygen and water may be accelerated through the use of a source of ultra-violet light, such as a No. 1 photoflood lamp in a reflector, with a shield to protect the patient from the heat and light, while the rays are concentrated on the tooth through a cylindrical tube (figure 26.2). The enamel surface and the pulp chamber are kept moist by frequent renewal of the Superoxol over a period of 15–30 min. The incisal part of the tooth tends to bleach more rapidly than the gingival part, and it is often necessary to repeat the bleaching after a few days. The effect of the ultra-

Fig. 26.2 Application of Superoxol to tooth under photoflood bulb in shielded reflector.

violet rays on the unstable Superoxol is expressed in the formula:

$$H_2O_2 \xrightarrow{\text{u.v. light}} H_2O + (O)$$

and the nascent oxygen reacts with iron sulphide in the tubules (which is derived from haemoglobin in the blood, thus: Hb + H_2S = FeS) oxidising it to Fe_2O_3 (ferric oxide). The black iron sulphide is oxidised to white ferric oxide and this reaction forms the basis of bleaching.

If the operator has no bleaching lamp, equally satisfactory results can be obtained by the slightly more tedious process of flooding the pulp chamber and labial enamel alternately with Superoxol and sodium hypochlorite:

$$NaOCl + H_2O_2 \rightarrow NaCl + H_2O + O_2$$

If this is continued for approximately 20 min, a definite lightening in colour of the tooth should be apparent. The heavy frothing which accompanies the reaction between peroxide and hypochlorite indicates the liberation of oxygen.

Bleaching may be continued between visits by sealing into the pulp chamber a suspension of sodium perborate in Superoxol. The mixture continues to liberate oxygen slowly and the colour of the crown is seen to have lightened further by the next visit (figures 26.3, 26.4).

Fig. 26.3 |1 prior to bleaching.

Fig. 26.4 Immediately after bleaching. The marginal gingivitis was aggravated by the presence of the clamp but responded to periodontal therapy.

The second visit

At the second visit, the additional bleaching which has ensued, as a result of sealing the perborate/Superoxol mixture in the tooth, may be found to have produced a satisfactory colour. The neck of the tooth, however, sometimes tends to require more time for the eradication of stain, hence a repetition of the bleaching procedure employed at the first visit may be indicated.

When a shade slightly lighter than the adjacent teeth has been achieved, the canal is irrigated thoroughly with water and a pledget of cotton-wool, soaked in an aqueous solution of sodium fluoride, is sealed in the dried pulp chamber for one week. This step is advocated by Dietz to reduce the permeability of the enamel and dentine and so, in turn, to reduce 'fall-back' and make the bleach more permanent.

The final visit

After removal of the fluoride dressing, the translucency of the tooth may be restored by the use of a 10% solution of clear methyl methacrylate polymer in chloroform, or an 80% solution of chloral hydrate in water. The pulp chamber is first dried and then painted with the solution, after which it is dried again and filled with a light shade of silicate or composite material.

If, after these treatments, there has not been an appreciable improvement in the colour of the tooth, crowning should be considered.

It cannot be stressed too much that the use of rubber dam is obligatory, because of the causticity of Superoxol. If contamination of the fingers or of the patient's face or gingivae with Superoxol should occur, it must be washed away immediately. The skin or mucous membrane becomes white and itches and burns, but this manifestation tends to disappear after an hour or two.

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