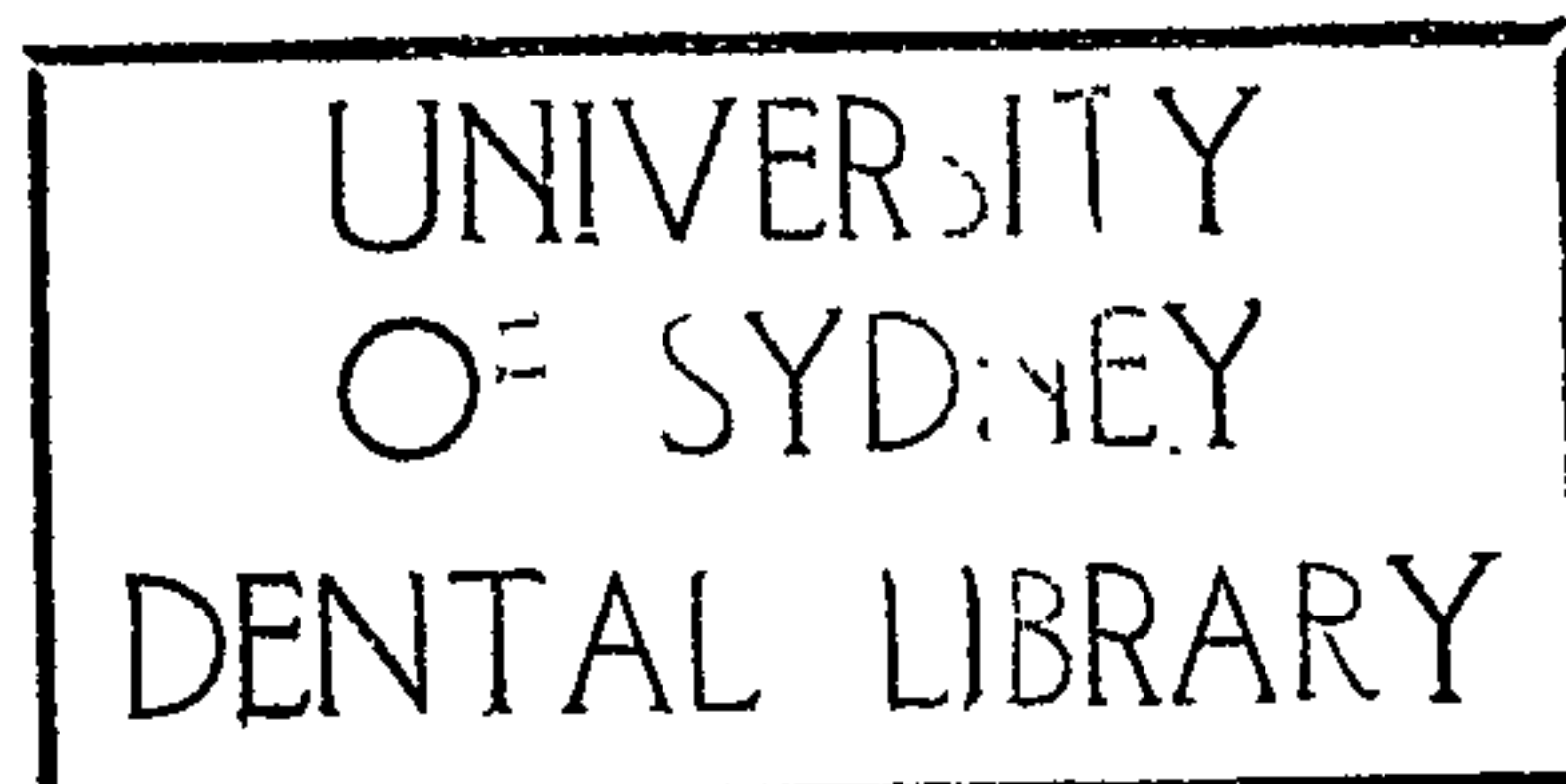


RESTORATION OF ENDODONTICALLY-TREATED TEETH



Treatise submitted as partial fulfillment  
of the requirements for the degree of  
Master of Dental Surgery to the  
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by

Richard Wainin Chan  
B.D.S. (University of Sydney)

Department of Operative Dentistry  
University of Sydney

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A handwritten signature in cursive script, reading "Richard Wainin Chan", with a horizontal line underneath.

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ABSTRACT

The principles guiding the clinical use of post-core foundations are considered and the large number of materials and methods that have been advocated and used in the restoration of endodontically-treated teeth are examined. Many of the prefabricated post systems readily available to the clinician are described and evaluated.

Other aspects related to the restoration of pulpless teeth such as the use of retentive pins, the construction of the core foundation and the coronal restoration are also considered in detail.

## PREFACE

The aims of this treatise are to consider the principles guiding the clinical use of post-core foundations, to examine the large number of materials and methods that have been advocated and used in the restoration of endodontically-treated anterior and posterior teeth, and to describe and evaluate the many prefabricated post systems readily available to the clinician.

The treatise is presented in one volume. A synopsis of the main topics discussed in each of the fifteen chapters is found at the beginning of the chapter; the tables and figures (and corresponding legends) pertaining to a particular chapter are located together at the end of each chapter.

In this treatise, the various topics related to the restoration of pulpless teeth are considered in basically the same chronological sequence as one would consider them clinically. Chapters 1 and 2 briefly introduce the historical aspects of the restoration of pulpless teeth and the characteristics of endodontically-treated teeth. Before a decision is made to perform root canal therapy on a particular tooth, the clinician should assess the periodontal condition of the tooth as well as the factors which might influence the ultimate success or failure of the endodontic treatment. These topics are reviewed in Chapters 3 and 4.

In Chapter 5, the functions, the indications for, and the design of post-core foundations are considered; Chapter 5 and Chapter 6 (materials for the restoration of endodontically-treated teeth) form the basis for the evaluation of the commonly available, prefabricated post systems in Chapters 10, 11 and 12. Although the use of posts is preferred, whenever possible, in the restoration of pulpless teeth, there are situations where the use of retentive pins is more practical; the different pin systems and their use in endodontically-treated teeth are considered in Chapter 13.

The important laboratory properties and clinical performance of the commonly used core materials are investigated in Chapter 14. In Chapter 15, the criteria for evaluating the result of the endodontic treatment and the timing of the restoration of the endodontically-treated tooth are reviewed. The different types of coronal restorations which have been advocated by clinicians for restoring pulpless teeth are considered according to the condition of the endodontically-treated tooth.

The preparation of the root canal for the insertion of a post is a relatively simple procedure. However, if it is not carried out carefully, serious complications may result. The timing and methods of post hole preparation are therefore discussed in Chapter 7, followed by a brief discussion on the methods of obtaining a post hole impression in Chapter 8.

Within this treatise, to avoid confusion, certain terms have been preferred to alternatives that may be commonly used in the literature. For example, the terms "endodontically-treated tooth" and "pulpless tooth" have been used synonymously and instead of "non-vital tooth" for reasons discussed in 2.4. The term "post" is used throughout the treatise although other authors often refer to them as "dowels". Since it is doubtful whether a post actually reinforces a pulpless tooth against fracture (5.3), the term "reinforcement" may be misleading and its use has been minimized.

The use of a standardized numerical system to identify sections of the text throughout the treatise has enabled considerable cross-referencing to be incorporated. Within each *chapter*, *sections* have been identified by their separation from the chapter number by a single full stop (for example, 6.2, 6.9 and 6.14). Within each of these sections, *sub-sections* have been identified by their separation from the section number by a second full stop (for example, 5.4.1, 5.4.2 and 5.4.3). *Parts* to these sub-sections have

been identified by additional numbers after the sub-section number without the use of further full stops (for example, 5.4.11, 5.4.12 and 5.4.13 identify the three subjects discussed within the sub-section, 5.4.1; furthermore, 5.4.211 and 5.4.212 identify the two subjects discussed within 5.4.21).

A *List of Tables* and a *List of Figures* are placed immediately after the *Table of Contents*. These lists detail the page number on which a specific table or figure is found. The tables and figures are placed together at the end of the appropriate chapters. Both the tables and figures are identified by two numbers (for example, Table 10.1, Fig. 14.2) — the first number denotes the chapter in which the table or figure is placed and the second number, the chronological order in which they occur at the end of the chapter. A small letter is used to refer to a particular diagram or photograph within a figure (for example, Fig. 6.2,a or Fig. 10.2,d).

Bibliographic details of published articles, textbooks, lectures and presentations, and other sources to which reference has been made in this treatise can be found at the end of the treatise in the section entitled *Bibliography*. Abbreviations used are consistent with those found in the *Index of Dental Literature* (1981) and, where possible, the format follows that used by the Australian Dental Journal in 1981.

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CHAPTER 1A BRIEF HISTORY OF THE RESTORATION OF ENDODONTICALLY-TREATED TEETH

The post-crown is one of the oldest devices used to restore lost tooth structure and was already known to the Assyrians and the ancient Egyptians (Cendres & Métaux, 1978). In the late nineteenth century and the early part of the twentieth century, techniques that utilized the pulp chamber for retention in the restoration of teeth with badly-broken down or missing crowns became increasingly popular (Johnson et al, 1976).

In 1869, G. V. Black advocated the use of gold foil to fill the coronal two-thirds of the root canal before a gold bolt was used to screw a porcelain-gold crown onto the root (Fig. 1.1). In the 1870's, T. W. Richmond introduced a post-crown technique for endodontically-treated teeth (Johnson et al, 1976); this was followed by other post-crown techniques such as the Davis and the Logan crowns (Goslee, 1903). The construction and clinical usage of some of these post-crowns have also been described by Barker (1963). Refer to Fig. 1.2.

Unfortunately, all these techniques entailed pulp removal whether or not the tooth was pulpally-involved. Undoubtedly, some of these teeth could have been restored by the more conservative methods available today. However, up until the early 1900's, the deliberate devitalization of teeth for crown and bridge procedures had been considered quite routine. Land (1903) criticized the post-crown techniques used in those days and stated that "pulp destruction should always be the last resort". In 1918, Billings claimed that non-vital teeth were foci of infection for systemic diseases and were responsible for most of the infection present in the oral cavity (Sommer et al, 1966, p.1). Because of this theory, the use of endodontic procedures declined rapidly during this period and, for almost three decades, there was little progress in the treatment of pulpally-involved teeth (Johnson et al, 1976).

Since then, the standardization of endodontic instruments, the development of the "aseptic technique" and modern pharmacologic agents (Sommer et al, 1966, p.2-3), and the refinement of root canal obturation techniques and materials (Milas, 1976, p.619-634) have led to a success rate reported by Ingle (1976, p.34) of 95 per cent for all endodontic procedures. Multi-rooted teeth as well as single-rooted teeth may be treated endodontically with predictable results and the general acceptance of endodontics by the profession and patients is evidenced by the number of endodontic procedures performed by dentists in the U.S.A. during the years 1970-1974 — an estimated 36,800,000 root canals were filled in this period (Ingle, 1976). With this large number of teeth being treated endodontically, it is imperative for the dentist to be capable of restoring endodontically-treated teeth effectively so that they can remain as integral functioning members of the dental arch.

Associated with the increase in the number of teeth being treated endodontically in the last two decades, there has been a gradual change in the method and materials used for the restoration of these pulpless teeth. Over the years, many prefabricated post systems have been developed to simplify the traditional cast gold post-core technique.

Today, methods that are more conservative than post-crowns are available for the restoration of badly broken-down teeth which are not pulpally-involved. Intentional devitalization of a broken-down tooth, merely to provide retention for the coronal restoration, should be avoided.

Fig. 1.1; 1.2

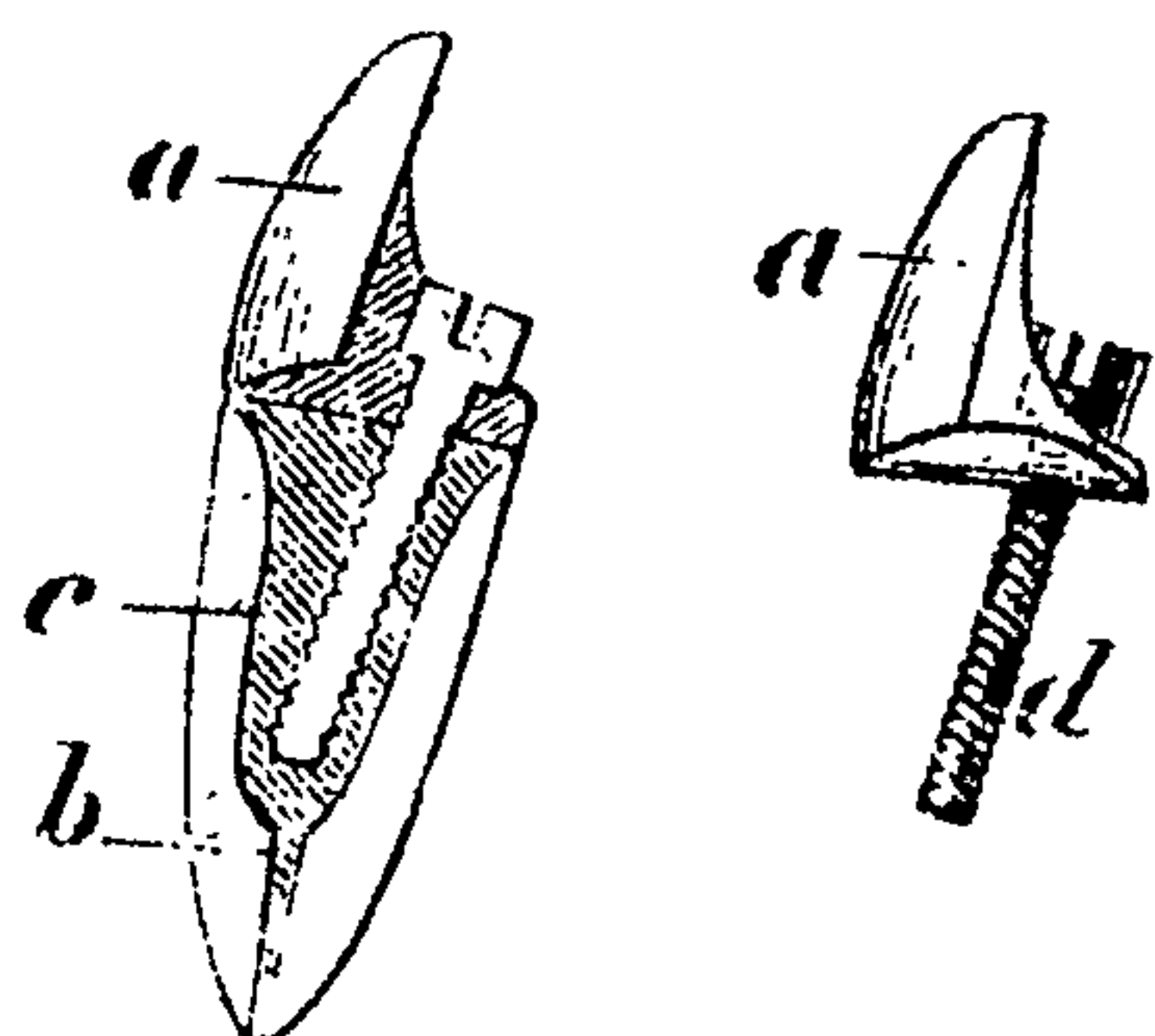
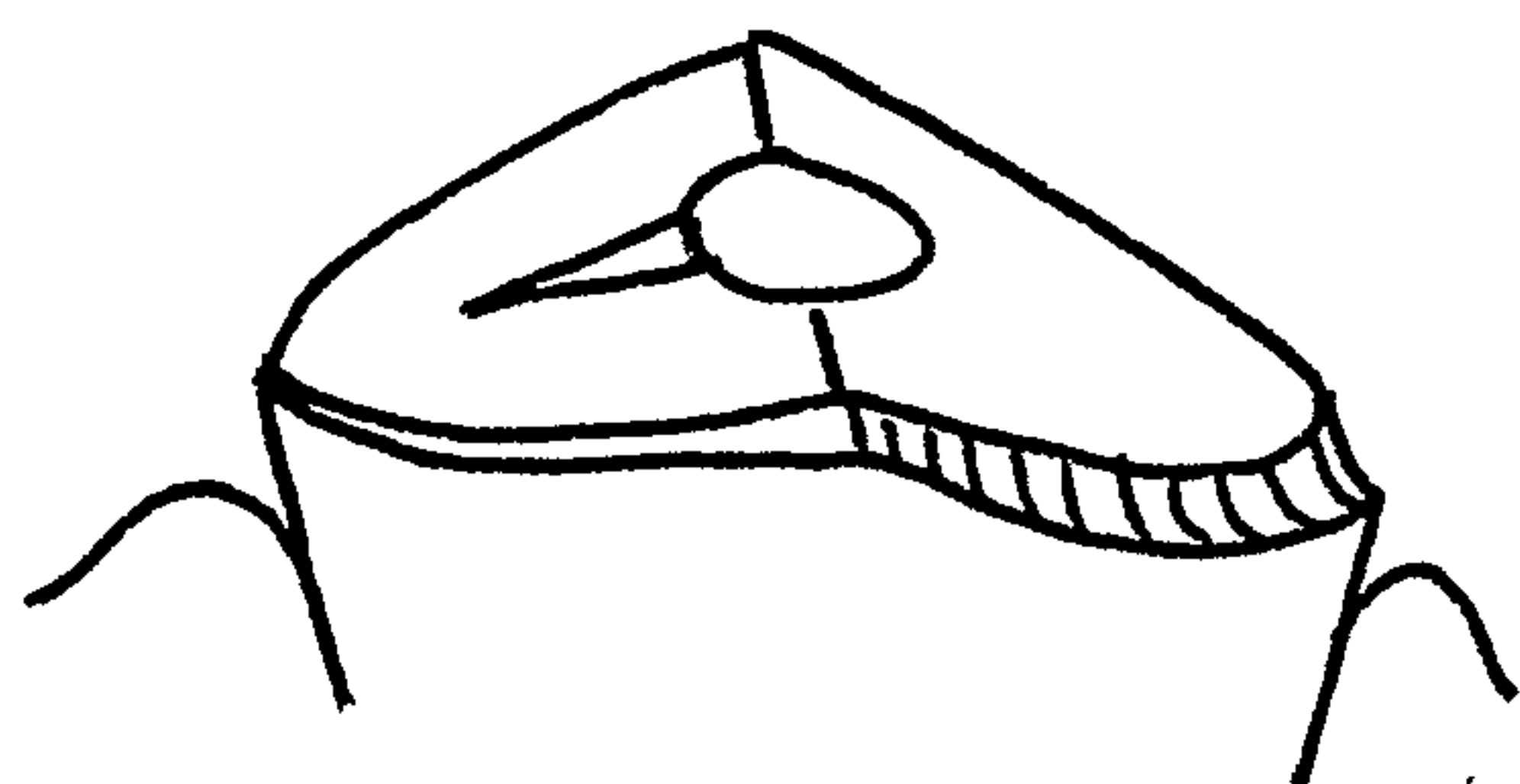
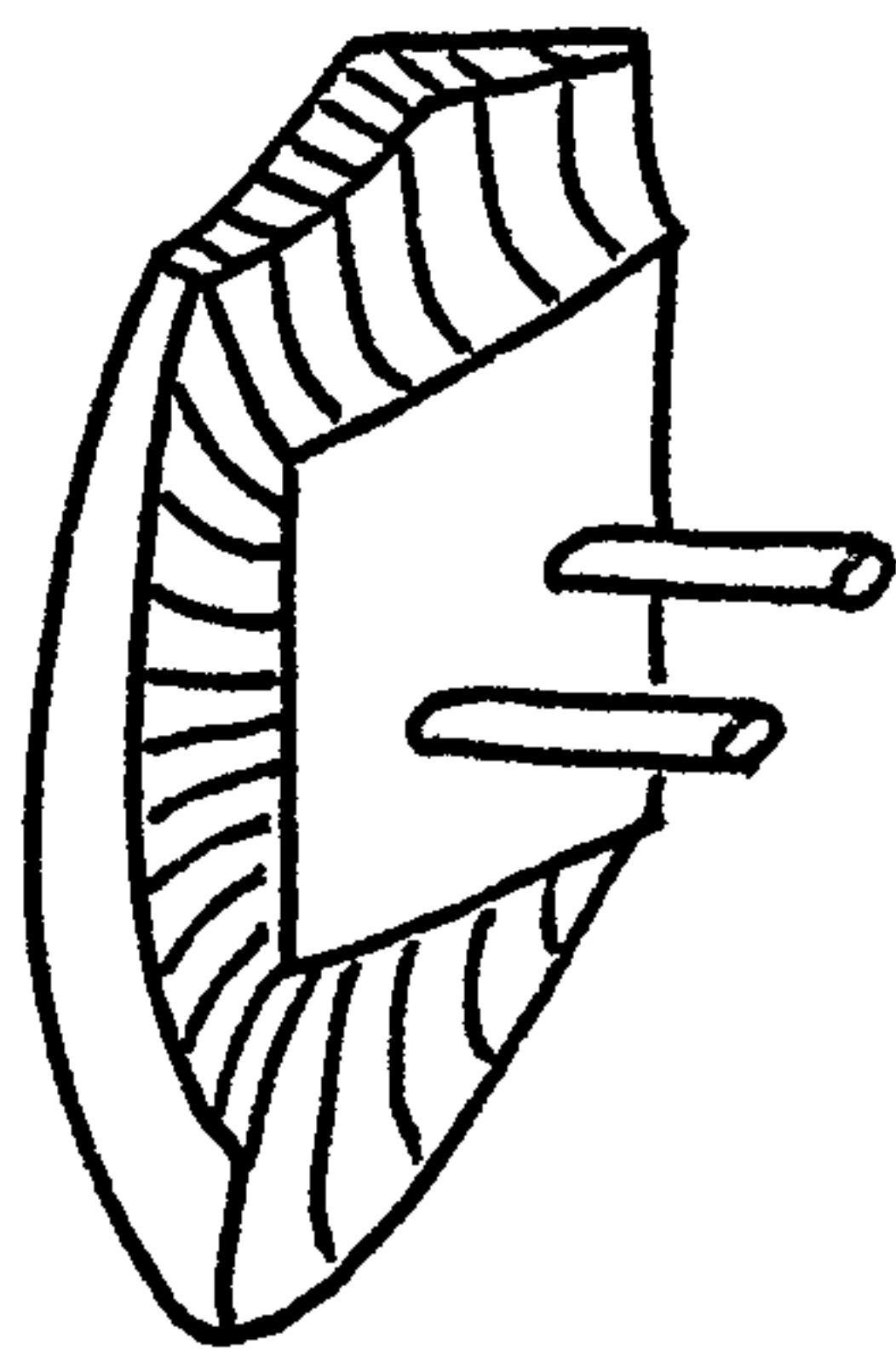


Fig.1.1 A method of grafting artificial crowns on the roots of teeth (Black,1869).

- a. a.** Artificial crown with gold backing.  
**b.** Canal in apex of root, filled.  
**c.** Canal in root, enlarged and filled.  
**d.** Gold bolt.



root face preparation



ground porcelain facing with long platinum pins

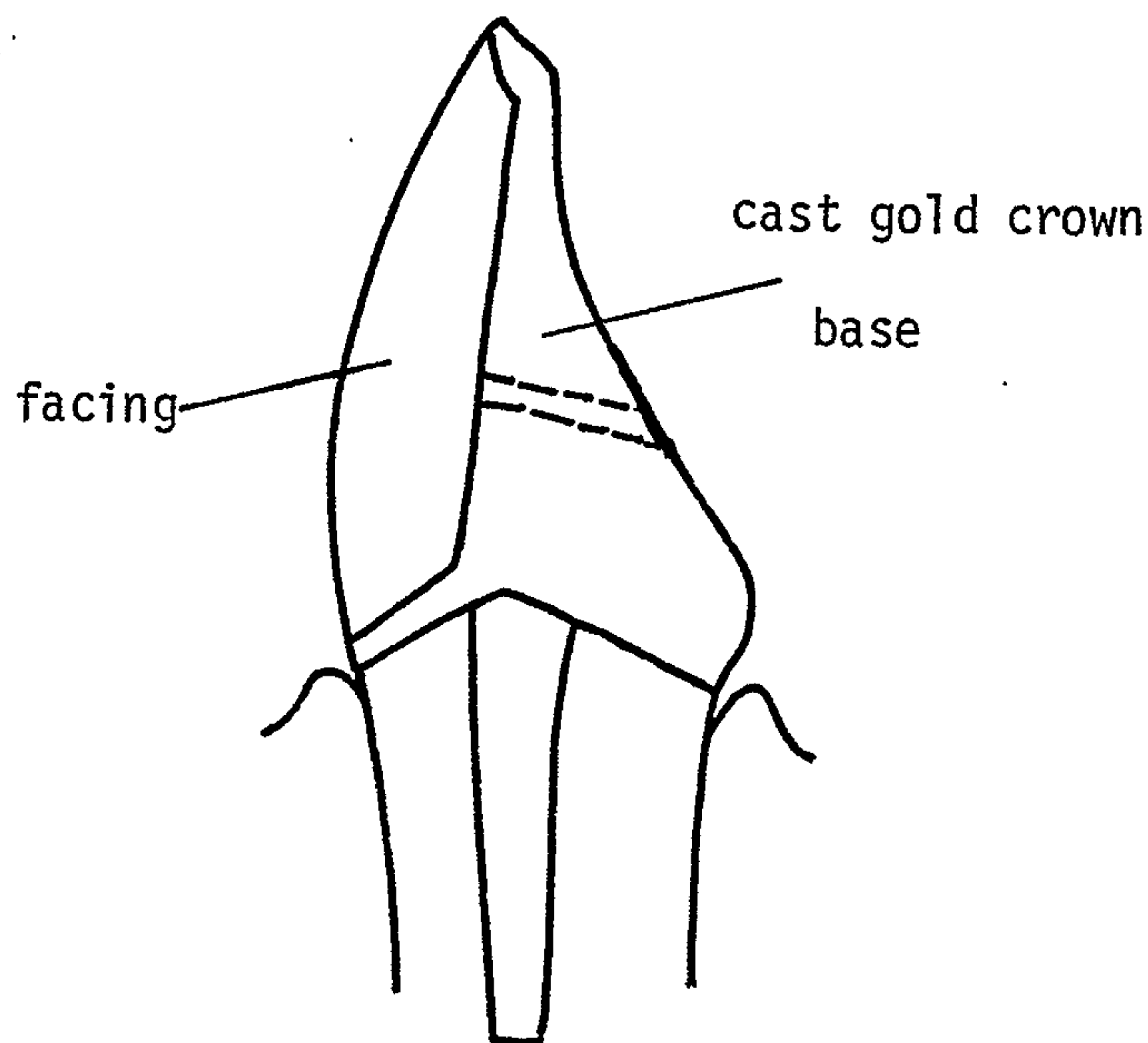


Fig.1.2 Modified Richmond Crown

( from Barker,1963 )

## CHAPTER 2

### THE ENDODONTICALLY-TREATED TOOTH

- 2.1 Introduction
- 2.2 Resistance of endodontically-treated teeth to fracture
- 2.3 Loss of internal and external tooth structure
- 2.4 Lowered rate of metabolism
- 2.5 Discolouration of the remaining tooth structure

#### 2.1 Introduction

Before considering the many aspects related to the actual restoration of an endodontically-treated tooth, the clinician should recognize the inherent differences between a vital and a pulpless tooth (Rosen, 1961). A form of treatment which might be considered sound for a vital tooth might be inadequate for an endodontically-treated tooth (Baum et al, 1981, p.522). Although the clinical crowns of these pulpless teeth are sometimes "badly broken down" due to extensive caries, restorations or fractures (Shillingburg et al, 1970; Weine et al, 1973; Waliszewski and Sabala, 1978), there are also cases where the clinical crown of the endodontically-treated tooth is relatively intact except for the endodontic access cavity.

Regardless of the condition of their clinical crowns, pulpless teeth have several features in common which may influence the method of their restoration (Rosen, 1961; Baum et al, 1981, p.522).

- i. The absence of vital pulp tissues places fewer restrictions on the restorative procedures.
- ii. The dentine in a pulpless tooth has a lowered moisture content and is likely to be more brittle and more susceptible to fracture than the dentine in a vital tooth (2.2).

- iii. In addition to the presence of caries or existing restorations, the pulpless tooth is further weakened by the endodontic access cavity and the removal of dentine internally during root canal therapy (2.3).
- iv. There is a lowered rate of metabolism in the dentine of pulpless teeth (2.4).
- v. Tooth discolouration is frequently observed following pulp degeneration and root canal therapy. The discolouration may be so marked that sound tooth structure has to be removed to enable the placement of a crown to create a more acceptable appearance (2.5).
- vi. A pulpless tooth has lost the ability to indicate to the patient the presence of a developing carious lesion by means of a pain response.

## 2.2 Resistance of endodontically-treated teeth to fracture

It has been generally recognized that a pulpless tooth is more brittle than one with a vital pulp (Silverstein, 1964; Baraban, 1967; Hirshfeld and Stern, 1972; Frank et al, 1976, p.774). Although Healey (1957) suggested that the loss of pulp vitality would result in a partial or even complete disappearance of dentinal moisture, research-based evidence, of a lowered moisture content in the substance of a pulpless tooth, was not available until 1972. In their investigation, Helfer et al (1972) compared the moisture content of vital and pulpless teeth. They extirpated pulps from dogs' teeth and subsequently extracted the teeth after pre-determined time intervals in order to monitor the loss of water content as a function of time. They found that there was nine per cent less moisture in the calcified tissues of pulpless teeth than in the calcified tissues of vital teeth.

It has been commonly considered that, in a vital tooth, secondary dentine formation and dehydration of dentinal tubules result in an increasing

loss of dentine resiliency. Tidmarsh (1976) commented that, as teeth aged, more peritubular dentine was laid down within the odontoblastic tubules; as a result, less space remained for organic material and tissue fluid, each of which was known to increase the flexibility of living tissue. This was in agreement with the suggestions by Sheets (1970) that dentine hardened with age and attrition, and that it was clinically more susceptible to fracture in older teeth.

Seltzer and Bender (1975, p.292) listed the age changes which had been reported to occur in the pulp and dentine; among these was dentinal sclerosis. In addition to time-dependent aging of the pulp, retrogressive and atrophic changes may frequently be induced in the pulps of teeth that have been subjected to extensive caries, abrasion, attrition, erosion or operative procedures, such as cavity or crown preparation and restoration. The presence of chronic pulpal inflammation and periodontal lesions may also contribute to the aging of the pulps of the involved teeth (Seltzer and Bender, 1975, p.298-311).

Ross (1980) questioned the validity of the common belief that teeth of an older individual were more likely to fracture than the teeth of a younger person. Both Lau (1976) and Baum et al (1981, p.522) have emphasized the similarity between an endodontically-treated tooth and a chronologically old tooth in which a cusp, root or entire clinical crown was more susceptible to fracture because of either the lowered moisture content or the loss of coronal dentine. The conclusion drawn by Ross (1980) that the age of an individual did not affect the tendency of a vital or pulpless tooth to fracture was based on his observations that tooth fracture had not occurred in any of the patients involved in his study although there were differences in age, ranging from 21 to 83 years. It is necessary, however, to question the validity of this assumption by Ross because the entire population of patients involved in the study was drawn from a practice limited to periodontics. Except in

cases of subgingival fractures which require periodontal therapy, the specialist periodontist is rarely the member of the dental team confronted with the problem of a fractured tooth. It would be wise, therefore, to treat Ross' conclusion with caution.

It is interesting to note that Stanford and his co-workers (1960), in their investigation of the compressive properties of hard tooth tissues and some restorative materials, also compared the compressive properties of the root dentine of vital and pulpless incisor teeth. They found no significant differences in corresponding physical properties between the two latter groups. Since the time intervals between pulpal death and extraction of the teeth were not available, it was suggested that this period may have been too short for physical changes, sufficient to be revealed by these tests, to have taken place. A similar reason might assist explanation of the findings of a laboratory study by Trabert et al (1978), in which no significant differences in resistance to fracture were demonstrated between untreated and endodontically-treated teeth.

Although authors have frequently attributed the increased brittleness of a pulpless tooth to its lowered moisture content (Rosen, 1961; Baraban, 1967; Hirschfeld and Stern, 1972; Gilmore and Lund, 1973, p.259-267; Morse, 1974, p.516-523; Tidmarsh, 1976), as evidenced by the preceding discussion, there is a relative lack of scientific evidence to verify the relationship between these two characteristics. Further research is required to verify the findings of Helfer et al (1972).

### 2.3 Loss of internal and external tooth structure

It is a clinical fact that frequently the condition of an endodontically-treated tooth, at the time of presentation for restoration, is one in which a significant amount of tooth structure has been lost as a result of extensive caries, previous restorative procedures, abrasion, erosion, fracture and endodontic access. It is therefore not surprising

that such a tooth may be susceptible to vertical and horizontal fracture under occlusal loading.

In addition to the apparent brittleness of a pulpless tooth (2.2) compared with the elasticity of a tooth with a vital pulp, a major factor in the lowered resistance to fracture of endodontically-treated teeth has been considered to be the removal of tooth substance for endodontic access and biomechanical preparation of the root canals (Spasser, 1963; Skurnik, 1965; Harper and Lund, 1976; Johnson et al, 1976; Gilmore et al, 1977, p.358-366).

Herschman, Weine and Strauss (1976, p.444) suggested that alteration to the pulp chamber morphology was most responsible for the weakness of a treated tooth. They pointed out that the roof of the pulp chamber has the configuration of an arch - a shape extremely resistant to pressures and stresses, and that it is the removal of this part of the tooth, for endodontic access, which contributes most to the resultant weakening of the pulpless tooth. During endodontic treatment, the required mechanical instrumentation of the root canal results in the removal of more dentine from the internal surface of the root; the canal filling, regardless of the material used, does not in any way restore strength in this region.

Tidmarsh (1976), in his article on the restoration of endodontically-treated posterior teeth, commented on the research of Grimaldi (1971), who found that there was a direct relationship between the amount of "central" tooth structure lost in cavity preparation and the deformations that occurred under load. It was postulated that an intact tooth was like a hollow, laminated structure which deformed under load. Although complete elastic recovery took place under physiologic loads, permanent deformation might follow the application of very high or sustained loads. In agreement with Grimaldi, Malcolm (1973) was reported by Tidmarsh (1976) to have found that the intact tooth appeared to behave as a pre-stressed

laminate. It is characteristic of such a structure to have the ability to withstand greater loads in the pre-stressed rather than the unstressed state. The significance of this phenomenon is that any cavity preparation, however small, will destroy the pre-stressed state and release the stresses; as a result, the tooth deforms to a much greater extent under applied loads. Since access cavities for endodontic treatment require the removal of a very substantial quantity of coronal dentine, it was suggested that even relatively low loads can subsequently cause significant deformation or even fracture.

#### 2.4 Lowered rate of metabolism

Although the term "non-vital" is commonly used to describe endodontically-treated teeth, the endodontically-treated tooth is not devoid of metabolism.

The role of the vital pulp as the main source of nutrition for the dentine is well established. With the aid of radio-phosphorus, several investigators (Wasserman et al, 1941, a and b; Volker et al, 1942), demonstrated that pulpless teeth have a lower rate of metabolism than vital teeth. The results of their experiments confirmed that the cemento-enamel junction was permeable to minerals; although the pulp was undoubtedly the main source of supply to the dentine, the intake of minerals by way of the cementum was significant.

Grossman (1950) summarized the position well: "The complete life of the tooth is not solely dependent upon the integrity of the pulp but also upon the integrity of the periodontal structures."

#### 2.5 Discolouration of the remaining tooth structure

Although discolouration of the crown and the root of a tooth is frequently observed following pulp death and root canal therapy, this can often be prevented, or at least minimized, by proper attention to the tooth during endodontic treatment. The aetiology, the prevention and the clinical treatment of tooth discolouration are discussed in 15.4.12.

CHAPTER 3PRE-ENDODONTIC TREATMENT CONSIDERATIONS

- 3.1 Introduction
- 3.2 Case selection
- 3.3 Can the tooth be treated successfully?
- 3.4 Should the tooth be treated?
- 3.5 Does the patient desire the treatment?
- 3.6 Access cavity
- 3.7 Root canal filling material and technique
- 3.8 Pulpless teeth with inadequate root length to accommodate a post of adequate length and a satisfactory apical seal

3.1 Introduction

Before discussing the restoration of endodontically-treated teeth, it is necessary to consider briefly some of the factors that influence the earlier decision to attempt endodontic treatment for a pulpally-involved tooth. These pre-endodontic considerations will, at times, result in a reduction in the number of teeth in which endodontics is attempted and which, therefore, need restoration.

Endodontic treatment involves the removal of a vital or necrotic pulp from the root canal and its replacement with a filling. The aim is to prevent the extension of disease from the pulp to the periapical tissues, or, where this has already occurred and periapical pathology exists, to encourage resolution and the return of the periapical tissues to a healthy state (Nicholls, 1977, p.64). Before endodontic treatment is commenced, the clinician should evaluate each case carefully before coming to a conclusion that treatment is needed and warranted. Several questions related to the treatment should be answered.

1. Does the tooth need to be treated endodontically? — Case selection
2. Can the tooth be treated successfully?
3. Should the tooth be treated?
4. Does the patient desire the treatment?

Once the decision to perform root canal therapy has been made, the clinician should also consider some aspects of the treatment which may influence the subsequent restoration of the endodontically-treated tooth.

- a. access cavity
- b. root canal filling material and technique

The evaluation of the success of endodontic treatment is discussed in 15.2.2.

### 3.2 Case selection

Eissmann and Radke (1976, p.537) listed the following indications for root canal therapy.

- i. Presence of irreversible damage to the pulp.
- ii. The loss of retentive coronal tooth structure due to caries, trauma, or abrasion which cannot be substituted by a pin-retained core addition.
- iii. The need for occlusal or axial re-alignment of malposed teeth where full crowns are likely to endanger the integrity of the pulp.
- iv. Grossly defective teeth with a guarded pulpal prognosis which would pose difficulties in post-restorative endodontic intervention.
- v. Overdenture techniques which require the retention of roots as anchors for bar and stud attachments.
- vi. The crown-root ratio of teeth in which inadequate periodontal support is to be improved by the use of endodontic-endosseous stabilizers.

### 3.3 Can the tooth be treated successfully?

Once it has been determined that endodontic treatment is necessary, the clinician must consider if this can be performed successfully. The accessibility of the tooth to endodontic treatment due to its position and alignment in the oral cavity can be a limiting factor. The anatomy of the

root canal system and the condition of the involved tooth should be considered before treatment is initiated. Certain conditions may make the location, the negotiation, the proper debridement and obturation of all the root canals very difficult, and, in some cases, impossible (Wakai, 1976, p.28-44; Scharwatt, 1979).

- a. abrupt curvature of the root canal
- b. excessive calcification of pulp chamber and/or root canal
- c. foreign body lodged in canal (for example, broken instrument, restorative materials, and re-treatment of root canals filled with gutta percha or silver points)
- d. Dens invaginatus
- e. Dens evaginatus
- f. Taurodontism
- g. inaccessible bifurcated canal
- h. immature apex in vital and non-vital teeth
- i. C-shaped canal most commonly encountered in mandibular first and second molars
- j. extensive fracture of the crown or root
- k. root perforations (pathologic or iatrogenic)
- l. rampant carious lesions
- m. internal, or gross periapical external resorptions
- n. an entirely or partially luxated tooth
- o. lateral or accessory canal lesions

Although these and other conditions frequently encountered do not necessarily render the tooth untreatable, they may be beyond the experience and capabilities of the general practitioner and a consultation with an endodontist may be required.

### 3.4 Should the tooth be treated?

Having determined that root canal therapy is necessary and that there is a reasonable chance that the endodontics can be performed successfully,

the clinician should decide whether the endodontic treatment is warranted for the patient. It should be determined whether the retention of the pulpally-involved tooth is of practical and functional value (Baraban, 1967).

*i. Unrestorable tooth*

Extensive crown/root fractures or carious destruction of the pulp chamber, the root canal or the furcation area often makes it extremely difficult, if not impossible, to restore the tooth to proper functional and aesthetic requirements. Moreover, such a tooth often cannot be satisfactorily isolated, and endodontic treatment is contraindicated.

That is, the possibility of successfully carrying out the necessary restorative procedures should be determined *prior to* the commencement of root canal therapy (Baum et al, 1981, p.522).

*ii. Strategic importance of the pulpally-involved tooth*

The long-term strategic importance of a tooth should be considered. If the pulpally involved tooth is currently not in function, has no opponent, and there is no possibility of the tooth developing strategic importance in conjunction with a prosthetic appliance, extraction may be the most appropriate treatment.

If the patient is already wearing a partial appliance, consideration may be given to the extraction of the pulpally-involved tooth and its replacement by adding a tooth to the denture. However, if there are only a few teeth remaining and the stability of the prosthesis is likely to be compromised by the loss of the tooth, then every effort should be made to save the tooth.

*iii. The periodontal condition*

When uncontrolled periodontal disease is present, endodontic treatment of the pulpally-involved tooth is contraindicated until the long-term periodontal status is determined. However, many associated periodontal defects have been found to heal following satisfactory

endodontic treatment. Ingle (1976, p.15-16) suggested a criterion for case selection (4.1) based on the origin of the periodontal pocket. If the periodontal lesion is a primary lesion that has advanced to involve the periapical region, the chance for successive therapy is slim. If, however, the periodontal lesion is secondary to the periapical lesion, the prognosis is greatly enhanced. Since the prognosis following the treatment of a periodontally-involved pulpless tooth is somewhat doubtful, these procedures should be reserved for cases in which it is vitally important to save the tooth.

*iv. Root morphology*

A lingual developmental groove extending the length of the tooth is most commonly seen in maxillary central and lateral incisors (Simon, 1976, p.455). This may lead to the formation of a periodontal pocket which is not amenable to treatment. The pulp may become necrotic as a result of direct communication with the apex through the gingival sulcus and root canal therapy in these cases is contraindicated.

*v. Extensive pathological resorption of the root*

In cases where severe internal or external resorption has resulted in extensive destruction of the root, endodontic treatment may be impractical. Even if the resorption can be arrested and adequate endodontic treatment carried out, the prognosis may still be poor due to inadequate alveolar support and the lack of tooth structure to resist fracture (Wakai, 1976, p.28-44).

*vi. Systemic condition*

Poor health is often mistaken as a contraindication for root canal therapy. In fact, in the presence of severe illness endodontic treatment is preferred to extraction because it places fewer demands on an already weakened system than alternative methods of treatment. There are almost no medical contraindications to root canal therapy (Wakai, 1976, p.42).

However, before commencing endodontic treatment, several factors should be considered.

1. The patient's present physical condition
2. Patient's current medical treatment and medication
3. Past medical history
4. Past dental history related to success or failure of treatment procedures.

### 3.5 Does the patient desire the treatment?

The patient's reasons for seeking treatment should be considered. Does he or she desire complete treatment or merely alleviation of pain. If the attitude of the patient has been one of long-term neglect, with poor oral hygiene and an overall low value placed on oral health, unless this attitude can be improved and the patient motivated towards better oral hygiene, the overall, long-term prognosis of the endodontically-treated tooth is poor (Scharwatt, 1979).

The patient should be informed in advance about the time required and the financial cost of the endodontic treatment and the final restoration of the pulpless tooth (Johnson et al, 1976).

### 3.6 Access cavity

The endodontic access cavity is a cavity, prepared in the crown of a tooth, through which root canal therapy is performed. The establishment of direct access to the apical portion of the root canal(s) is the first step in the mechanical phase of endodontic treatment. Certain aspects of this procedure may influence the subsequent restoration of the pulpless tooth.

Pickard (1964) stated that access to the pulp chamber in maxillary incisors was often gained through a point "too low on the cingulum of the palatal surface". This may lead to the unnecessary removal of more dentine from the palatal aspect of the root canal and, subsequently, may result in a post which is lingually inclined and "close on the bite".

In a discussion on the location of endodontic access cavities for pulpally-involved anterior teeth that are to be restored by full veneered crowns, Dadmanesh (1974) suggested that the occlusal relationship of the maxillary and mandibular teeth be taken into consideration. In certain situations, for example, in an edge-to-edge or a Class III relationship, he suggested a labial approach for endodontic access in maxillary anterior teeth. As a general rule, Dadmanesh (1974) recommended the establishment of endodontic access from the unarticulated surface — this, he claimed, would "preserve more tooth tissue and provide greater retention in the restorations" and there would be "little or no possibility for fracture of the coronal portion of the prepared teeth".

Behrend (1980) also suggested a variation in the design of conventional access cavities for maxillary anterior teeth which were to be restored with full crowns. In order to gain straight-line access to the apical portion of the root canal, part of the incisal edge of the tooth (which would subsequently have been removed during post-core and crown preparation anyway) was removed during the initial stage of the endodontic treatment. It was suggested that this procedure was more conservative of the lingual tooth structure (Fig. 3.1).

Since the long-term prognosis of the endodontically-treated tooth depends so much on the success of the root canal therapy, every effort should be made to ensure endodontic success even though this may have to be achieved at the expense of some sound coronal tooth structure in order to establish proper access (Levin, 1967; Perel and Muroff, 1972). However, one should be cautious not to remove any more tooth structure than that necessary for the proper mechanical preparation of the root canal. Only very rarely is the removal of the entire crown for endodontic access (as suggested by Perel and Muroff, 1972) indicated.

### 3.7 Root canal filling material and technique

Over the years, many materials and techniques have been advocated and used for the obturation of the root canal. The significance of the choice of the root filling material and obturation technique in relation to the subsequent restoration of the root-filled tooth with a post-core foundation and coronal restoration is discussed in 7.3.

### 3.8 Pulpless teeth with inadequate root length to accommodate a post of adequate length and a satisfactory apical seal

On occasions, teeth with short roots, either as a result of apical resorption or injudicious apicectomy, present a difficult problem when a post-core foundation has to be constructed; there is simply insufficient tooth structure to accommodate both an adequate root filling and a post of adequate length. In addition to the shortness of the root, an injudicious apicectomy creates two major treatment problems (Ehrmann and Feiglin, 1980). First, the diameter of the canal at the new apex of the tooth is so wide that it is difficult to condense a root filling and obtain an effective apical seal. Even if this can be achieved, it is quite possible that such an apical seal will be dislodged during the process of post-hole preparation.

To overcome these problems, several clinicians (Metrick, 1961; Ehrmann and Feiglin, 1980) have suggested the use of an "immediate post crown" (Fig. 3.2). This consisted of a well-fitting post that obturated the entire root canal space; it extended to the apical termination of the root and no other root filling was present except the cement. Coronally, a conventional core was attached to the post which provided support for the overlying restoration. Since the maintenance of a sterile canal during the impression and cementation procedures was extremely difficult, the insertion was often combined with periapical curettage. This form of treatment is in need of further clinical investigation.

Fig. 3.1; 3.2

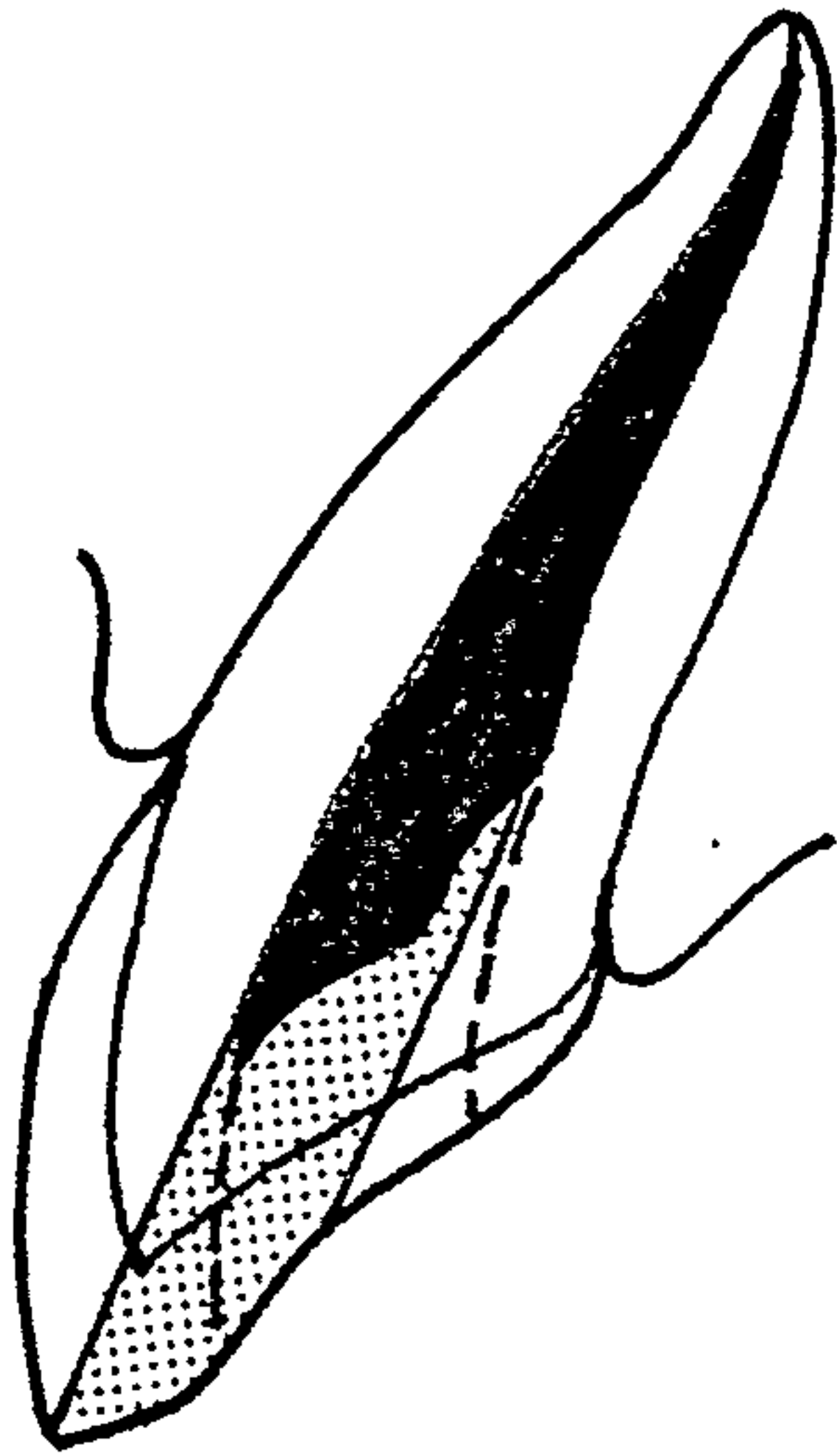
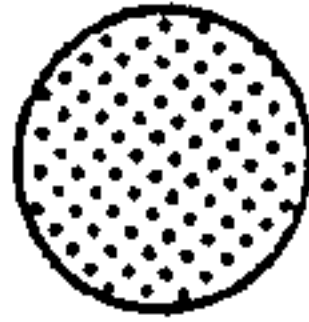


Fig. 3.1 Endodontic access cavity design

-  Outline of endodontic access as suggested by Behrend (1980) for teeth to be restored with a post-core foundation and full crown  
 Conventional access cavity outline

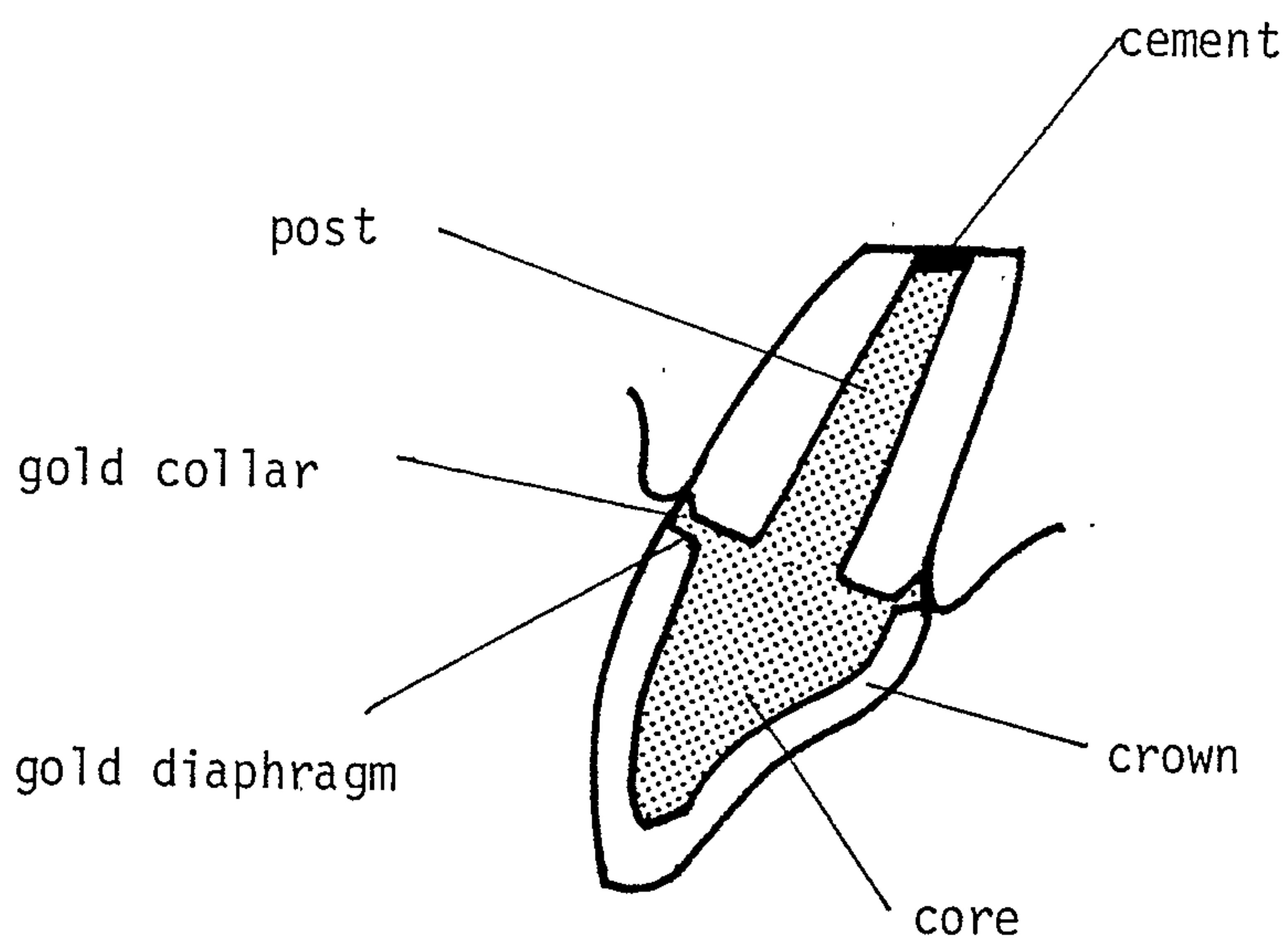


Fig. 3.2 "Immediate post crown"  
 ( adapted from Ehrmann and Feiglin,1980)

## CHAPTER 4

### PRE-ENDODONTIC CLINICAL ASSESSMENT OF THE PERIODONTIUM

- 4.1 Introduction
- 4.2 Effect of pulpal inflammation on the periodontium
- 4.3 Prognosis of the periodontal-endodontic lesion
- 4.4 Loss of tooth structure at the gingival margin or below the crest of the alveolar bone
- 4.5 Untreatable condition in a portion of a multi-rooted tooth
- 4.6 Teeth with inadequate alveolar bone support

#### 4.1 Introduction

The influence of the periodontal condition on the prognosis of a tooth cannot be over-emphasized. Before the decision is made to treat a tooth endodontically, the clinician should carefully assess "the quality and the quantity of its periodontal support" (Baraban, 1967) since the function of a tooth is dependent on the health of the periodontium — the gingival unit, cementum, periodontal ligament, and the alveolar bone (Simon, 1976, p.442).

According to Bower and Henry (1976) and Johnson et al (1976), before commencing endodontic treatment, the periodontal condition of the tooth should be assessed; these findings may influence the decision to undertake endodontic treatment. The periodontal assessment should examine:

1. the superficial tissues for signs of inflammation and altered architecture such as crater formation and hyperplasia
2. the position of the epithelial attachment relative to the cemento-enamel junction and gingival margin
3. the quantity and condition of the attached gingiva
4. the depth of any periodontal pockets and involvement of the furcation area in multi-rooted teeth
5. the amount of alveolar bone support
6. the degree of mobility (if present)

7. the presence of any long-standing cracks or vertical fractures, and
8. the presence of any developmental grooves that extend the entire length of the root.

#### 4.2 Effect of pulpal inflammation on the periodontium (Simon, 1976, p.442)

Periodontal disease may result either from the apical progression of gingival inflammation which can affect the cementum, periodontal ligament and alveolar bone in its course or from the direct extension of pulpal disease.

Pulpal pathology can progress beyond the apical foramen and involve the periodontal ligament. The inflammatory process results in replacement of the periodontal ligament by inflammatory tissue, usually with accompanying resorption of the alveolar bone, cementum or dentine. Lateral canals are a normal anatomic component of many teeth, especially in the apical one-third of the root and in the furcation areas of molars. Together with the apical foramen and the dentinal tubules, these openings provide a route for the spread of the inflammatory process. Examples of iatrogenic involvement of the periodontium include root perforations caused by overzealous endodontic instrumentation or lateral perforation of the root by a bur during post preparation.

#### 4.3 Prognosis of the periodontal-endodontic lesion

Although the effect of periodontal disease on the pulp does not appear to be as clear-cut or as prevalent as the effect of pulpal disease on the periodontium, periodontal inflammation can, nevertheless, exert a direct effect on the pulp via the same anatomic pathways (Simon, 1976, p.448-468).

Figure 4.1 illustrates the theoretical pathways of osseous lesion formation. An understanding of the interaction between pulpal and

periodontal disease enables the clinician to evaluate more accurately the severity of the clinical condition, and the prognosis for the periodontal and/or endodontic treatment (Simon, 1976, p.448-468).

The healing potential of osseous lesions varies according to their origin. Bony destruction primarily of endodontic origin can usually be expected to heal completely (Simon, 1976, p.455). However, this is not always the case with bony destruction of periodontal disease.

With endodontic lesions that are secondarily involved by periodontal disease, healing of the portion not affected by periodontal disease can occur following endodontic treatment. Thus, the prognosis of lesions with secondary periodontal involvement usually depends on the efficacy of the periodontal therapy. Generally, it may be stated that the greater the periodontal involvement, the poorer the prognosis.

Certain conditions of the periodontium are sometimes encountered when restoring endodontically-treated teeth (4.4 to 4.6).

#### 4.4 Loss of tooth structure at the gingival margin or below the crest of the alveolar bone

Aetiologic factors that may contribute to the loss of tooth structure in this part of the tooth include caries, traumatic injuries and fracture (in vital and pulpless teeth), large restorations, internal-external resorption or root perforation. In these situations, exposure of sound tooth structure is paramount if the following are to be achieved (Ingber, 1976):

- i. placement of margins of restorations on sound tooth structure
- ii. maintenance of the "biologic width" (Fig. 4.2)
- iii. access for impression procedures
- iv. control of haemorrhage
- v. maintenance of periodontal health

- vi. restoration of function
- vii. aesthetics

To help maintain healthy periodontal tissues, margins of the restorations should be sited coronal to the free gingival margin (Palamo and Kopczyk, 1978). Several clinical procedures have been advocated to achieve this.

a. A full thickness periodontal flap raised just before the impression procedure. This technique is not recommended because there is lack of evidence of connective tissue attachment to crown materials indicating that a periodontal pocket will continue to exist adjacent to the restoration (Bower and Henry, 1976). In addition, it is possible for impression materials to penetrate the alveolar process during impression taking procedures causing subsequent severe breakdown of the alveolar bone (Price and Whitehead, 1972; O'Leary et al, 1973).

b. The gingivectomy-gingivoplasty technique consists of the removal of adequate gingival tissues to expose sound tooth structures apical to the root surface defect. However, this mode of treatment cannot be used unless an adequate zone of attached gingiva exists, such as in the palate (Barkmeier and Williams, 1978). Although it is a simple and direct technique, it is of little use elsewhere unless it can be used with minimal excision.

c. The entire gingival complex may be apically repositioned by employing a full thickness mucoperiosteal flap procedure (Fig. 4.3). This procedure increases the clinical crown length, reduces pocket depth, maintains adequate keratinized gingiva and provides access to the underlying osseous structures and the fracture margin (Bower and Henry, 1976). Osseous surgery may be carried out in conjunction with apically positioned flaps to achieve physiologic bony contour if the root surface defect has extended apically to the margin of the alveolar process. Unfortunately, the results of this surgical technique are often only a

compromise especially in the anterior region where aesthetic considerations are important. Gingival and osseous surgery cannot be limited to the involved tooth and must be extended to adjacent teeth in order to blend the gingival and osseous contours. The ultimate result is a sacrifice of supporting bone on several teeth, root sensitivity, and aesthetic deformities in the form of long clinical crowns and open embrasures (Ingber, 1976).

d. Vertical movement of the root. Generally, this method is used only on teeth or roots that are considered unrestorable or at best extremely difficult to restore properly by other methods because of various problems involving the coronal one-third of the root (Fig. 4.4).

In 1973, Heithersay demonstrated the vertical extrusion of roots for the treatment of teeth with transverse root fractures near the gingival crevice. The extrusion was accomplished by vertical orthodontic movement that elevated the defect above the alveolar bone and gingival epithelial level, providing access for the proper restoration of the tooth (Fig. 4.5 and 4.6). He also suggested that this method may be of value in treating teeth or roots with perforations, caries or resorptive defects in a position close to the gingival crevice.

Formerly, teeth that had perforations in the coronal one-third of the root, whether caused by iatrogenic or resorptive causes, were treated in one of two ways depending on their size (Simon, 1976, p.448-468). The relatively small defect was filled from within the canal with gutta percha or amalgam, while a larger defect usually necessitated a surgical repair with amalgam. Interproximal defects presented special surgical problems interfering with preparation and filling. If accessible, defects within bone could be treated. The major problem is the creation of a self-maintained periodontal pocket that communicates with the oral environment. Because there is no attachment of the periodontal ligament to the amalgam in these cases, there is no bone occlusal to the amalgam; thus the entire

defect is open to plaque, calculus and periodontitis (Fig. 4.7). By using the Heithersay approach these problems can be minimized or eliminated. A defect that began subgingivally can now be elevated above the gingiva and the alveolar bone, and gingivoplasty carried out when indicated. The rationale of the forced eruption therapy and the tissue changes associated with the extrusion have been covered in articles by Ingber (1976), Cooke and Scheer (1980), Stern and Becker (1980) and Shiloah (1981).

A simpler, but probably less predictable method of achieving vertical movement of the tooth (Fig. 4.8) involves the reduction of the occlusal portion of the involved tooth to allow eruption (Palomo and Kopezyk, 1978).

#### 4.5 Untreatable condition in a portion of a multi-rooted tooth

In the past, many teeth were extracted because of the hopeless periodontal or endodontic involvement of one root. Although a method for the retention of roots and portions of teeth was described as early as 1886 by G.V. Black, and further described by Sharp in the 1920's (Weine, 1976, p.352-373), these techniques have only become more widely used since the early 1960's.

Several commonly employed procedures have been defined by Appleton (1980).

Root amputation — the removal of the root apical to the furcation without alteration of the crown.

Hemisection — surgical separation of a multi-rooted tooth through the furcation area in such a way that the blocked, defective, or periodontally involved root or roots may be surgically removed along with the associated portion of the crown (Fig. 4.9 and 4.10).

Root resection — removal of the root without reference to how the crown is treated. Indications for root resection include the following conditions (Abrams and Trachtenberg, 1974; Weine, 1976, p.352-356; Appleton, 1980).

- a. Severe bone loss about an isolated root which threatens adjacent healthier root support either by direct extension of the periodontal lesion or by the extent of its osseous surgical correction.
- b. A root which cannot be treated effectively with conventional endodontic therapy, and surgical intervention is contraindicated. It may be removed so that the residual segment can be treated.
- c. Elimination of problem furcation areas of molar teeth which are not correctable with odontoplasty. These include untreatable carious and/or endodontic lesions, and bucco-lingual fractures through the furcation. If both roots can be treated effectively with endodontic therapy and are restorable, root separation or "bicuspidization" (Appleton, 1980) may be the treatment of choice.
- d. Severe root exposure due to dehiscence.
- e. Control of compromised embrasure due to the tight proximity of adjacent roots. Roots in tight proximity to each other that do not permit access for cleaning usually do not allow for normal gingival form. Removal of selected roots may enable the re-establishment of proper embrasure space.
- f. Severe destructive processes may render one segment of a tooth non-restorable, removal of the involved root allows for retention of the remainder of the tooth. Examples include furcation and gingival caries, traumatic injuries, vertical fractures and large lateral perforation of the root.
- g. Failure of an abutment tooth within an extensive splint due to severe loss of supporting structures, vertical root fracture or endodontic failure.

Contraindications for root resection and root separation include the following.

- a. fused roots
- b. roots in very close proximity
- c. inability to restore the retained segment of the tooth properly
- d. endodontically untreatable canals in the root or roots to be retained
- e. inadequate bone support in residual root(s) to resist occlusal forces exerted by the planned prosthesis
- f. when strong adjacent teeth are available for bridge abutments
- g. deeply located furcations where there is inadequate gingival architecture.

#### 4.6 Teeth with inadequate alveolar bone support

The importance of adequate alveolar bone support has already been emphasized; as Sapone (1976, p.518) stated: "A tooth is as sound as the bone that supports it". Several aetiological factors may be responsible for the loss of alveolar bone support. These include apical root resorption, injudicious apicectomy, root fracture and the apical extension of periodontal disease. In order to improve the stability of these mobile teeth, the use of metallic endodontic-endosseous implant posts has been suggested by many clinicians (Strock and Strock, 1943; Orlay, 1964; Frank, 1967; Judy and Weiss, 1975; Vadja, 1978 and 1979). This technique is basically "an extension of the endodontic technique in situations where the stabilization of a mobile tooth is desired" (Vadja, 1978). The rigid implant post usually occupies only the apical portion of the root canal and extends apically into the alveolar bone in order to gain stability. However, the extension of the endodontic-endosseous implant post to become the post portion of a post-core foundation has also been reported (Sapone, 1973; Erickson and Vande Voorde, 1975; Vadja, 1978).

For success with this technique, it is important that the clinician selects the cases carefully, observes the principles of endodontics and carries out any necessary periodontal treatment. Weine (1972, p.389-399)

emphasized that the use of endodontic-endosseous implants (or "endodontic stabilizer" — Weine, 1972, p.390) only eliminated the problem of mobility. If periodontal disease was the initial cause of the loss of alveolar support, this must be treated. Because of the proximity of certain vital structures such as the inferior alveolar canal, the mental foramen or the maxillary sinus, and the lack of sufficient bone to support the intra-osseous portion of the implant post in the posterior region of the mouth, endodontic-endosseous implants are mainly used for the stabilization of anterior teeth. Since it is not the purpose of this discussion to present the criteria for case selection and step by step details of the techniques, the reader is referred to certain textbooks and publications for more information (Orlay, 1964; Frank, 1967; Weine, 1972, p.389-399).

- Fig. 4.1 A Endodontic lesions. The pathway of fistulation is evident through the periodontal ligament from the apex or a lateral canal.
- B Fistulation through the apex or a lateral canal, causing bifurcation involvement.
- C Primary endodontic lesion with secondary periodontal involvement. The existing pathway, as in A, is shown; with the passage of time, however, periodontitis with plaque and calculus formation begins at the cervical area.
- D Periodontal lesions. This is the progression of periodontitis to apical involvement. Note the vital pulp.
- E Primary periodontal lesion with secondary endodontic involvement. The primary periodontal involvement at the cervical margin and the resultant pulpal necrosis once the lateral canal is exposed to the oral environment result in this picture.
- F "True" combined lesions. The two separate lesions are heading to a coalescence, which forms the "true" combined lesion.

(From Simon, 1976, p.454)

- Fig. 4.2 A restored tooth in which the "biologic width" has been maintained.  
(From Ingber, 1977)

- Fig. 4.3 Apical repositioning of the gingival complex to allow access to fracture margin and alveolar bone after subgingival root fracture. Stage 1: preoperative; stage 2: sutured; stage 3: restoration placed. (A, Releasing incisions; B, reverse bevel incision; C, apical repositioning; F, fracture line; O, alveolar bone.)  
(From Bower and Henry, 1976)

Fig. 4.1; 4.2; 4.3

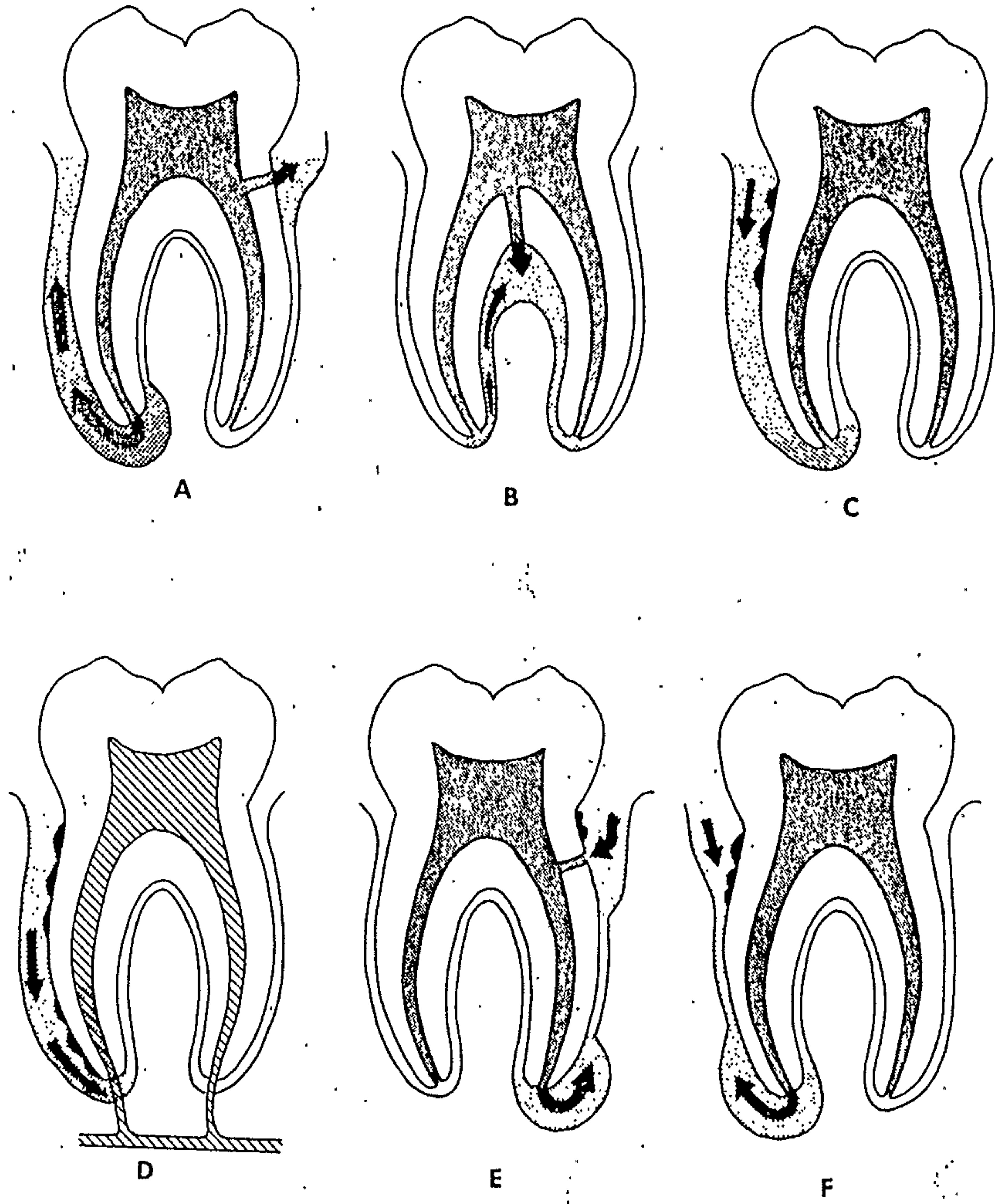


Fig. 4.1

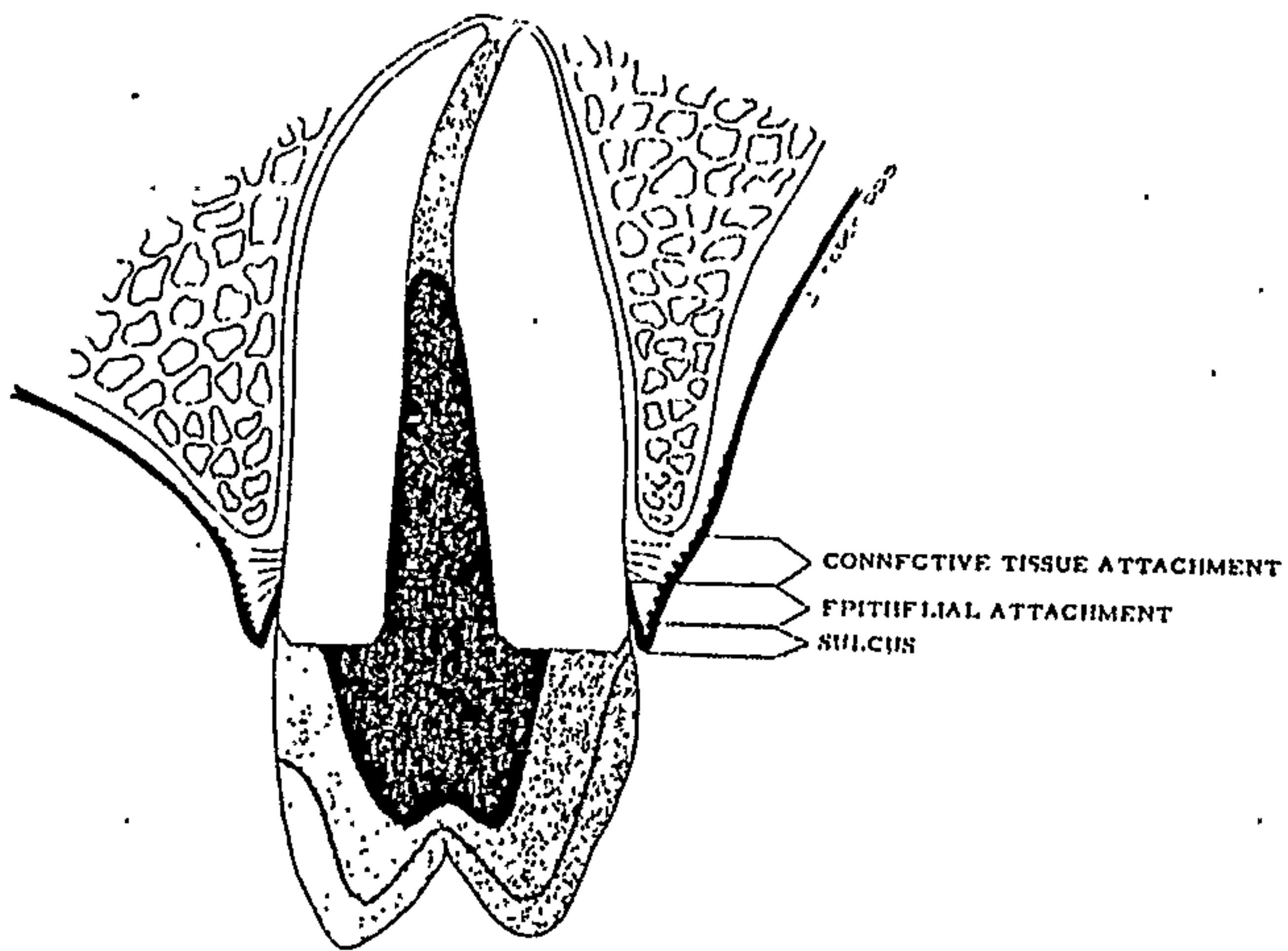


Fig. 4.2

Fig. 4.3

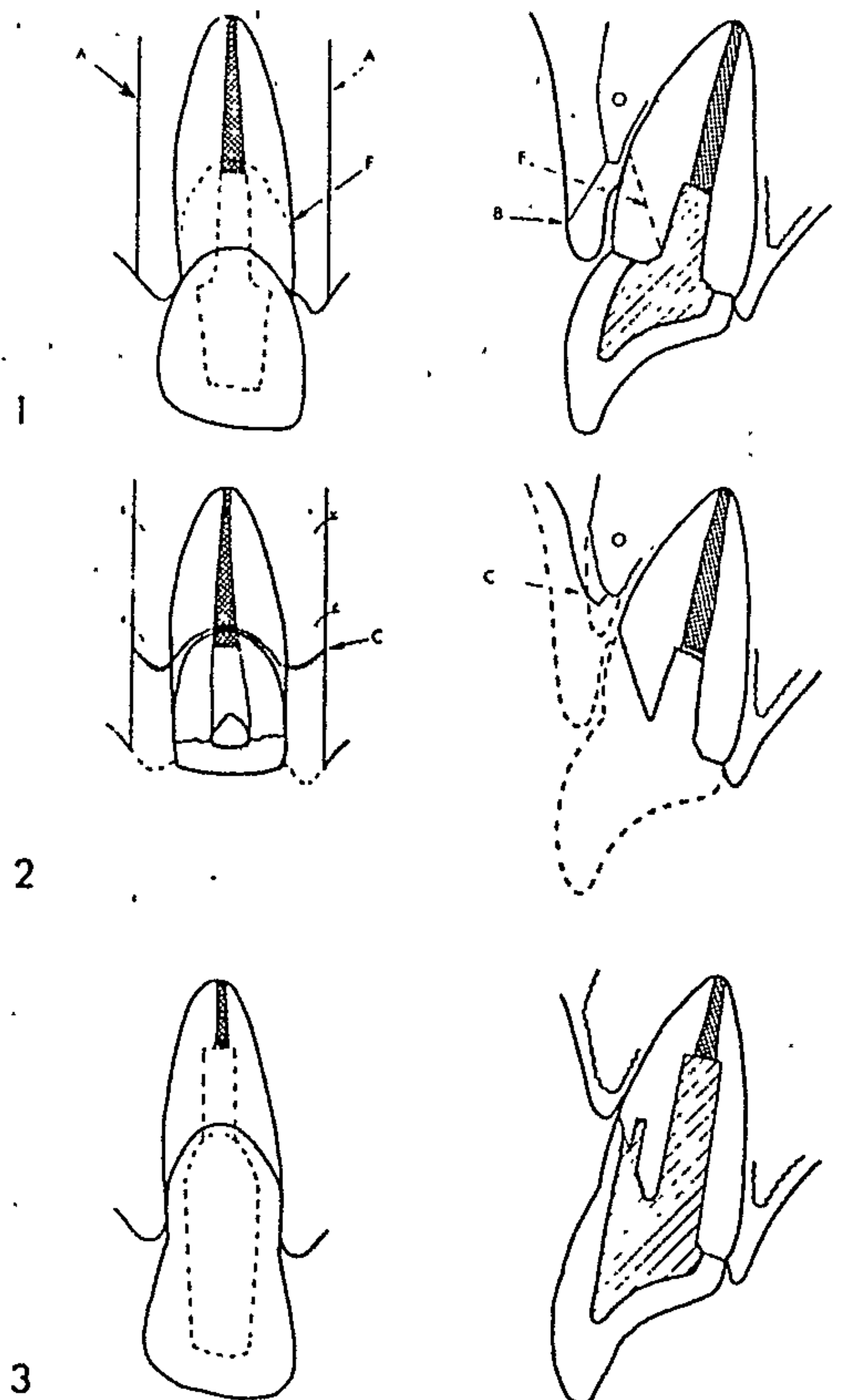


Fig. 4.4 Indications for root extrusion.

(From Simon, 1976, p.521)

Fig. 4.5 Diagrammatic representation of the clinical procedures involved in the combined endodontic-orthodontic treatment of transverse root fractures in the region of the alveolar crest. Method 1: A, Pulpectomy is carried out through the fracture site and the canal root is filled with gutta-percha and a sealer. B, A rectangular segment is removed from the crown, and a post (shank of bur) is inserted through the coronal segment into the apical segment. C, Orthodontic bands are applied to adjacent teeth and a spring attached to the post. Controlled orthodontic movement moves the apical segment to a satisfactory vertical position. Incisal and palatal surfaces are ground to allow incisal movement. D, Crown and post are removed. E, Post-retained crown is constructed.

Method 2: Procedures corresponding to Method 1, except that the coronal segment is removed at the initial stage or after placement of the root filling.

(From Heithersay, 1973)

Fig. 4.6 a and b — for legend see next page.

Fig. 4.4; 4.5; 4.6,a and b

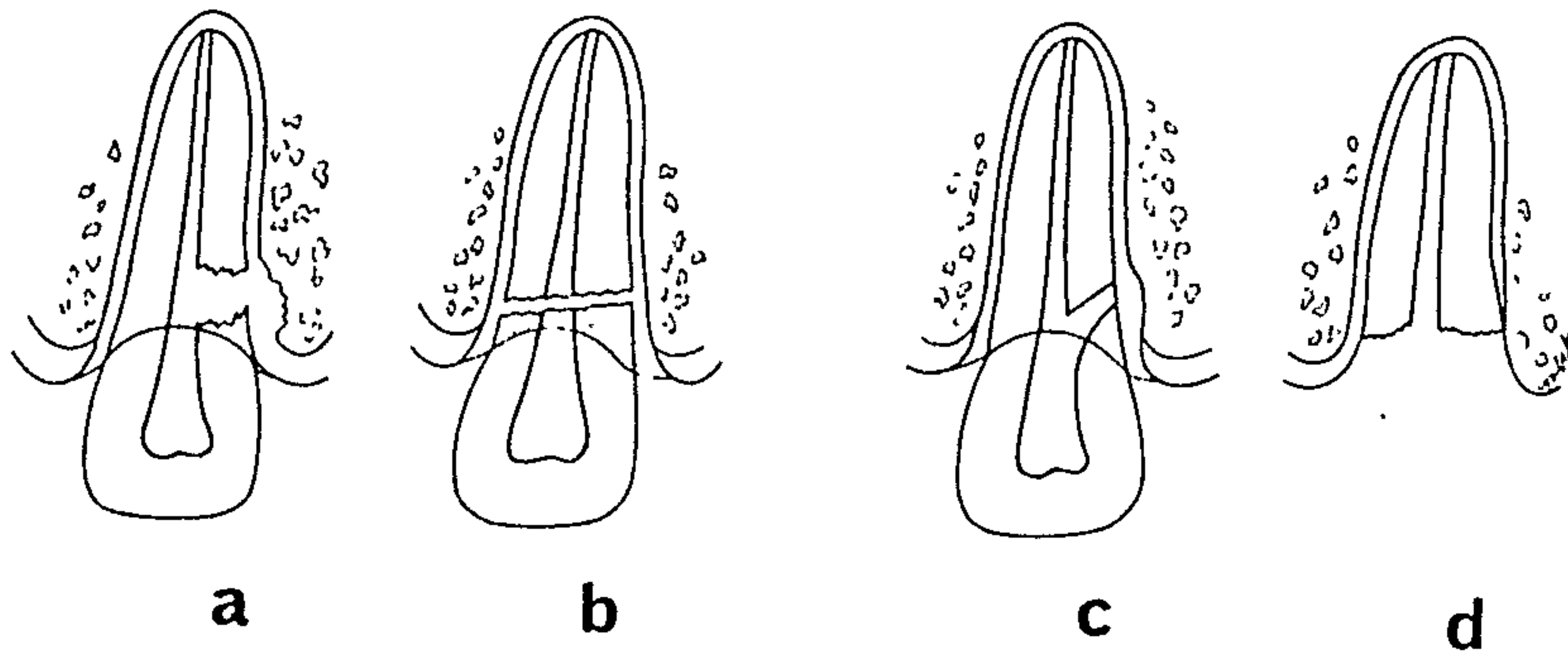


Fig. 4.4

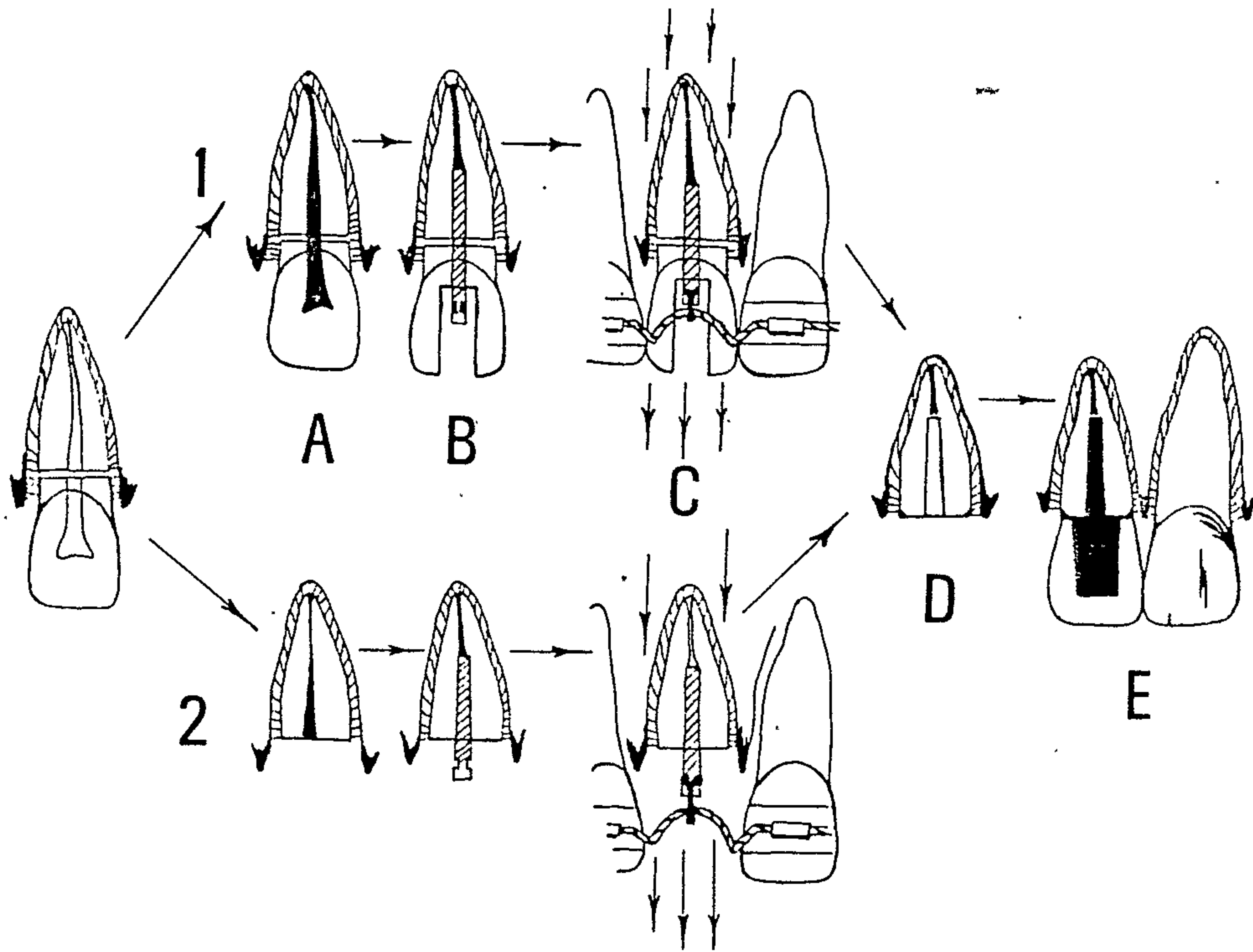


Fig. 4.5

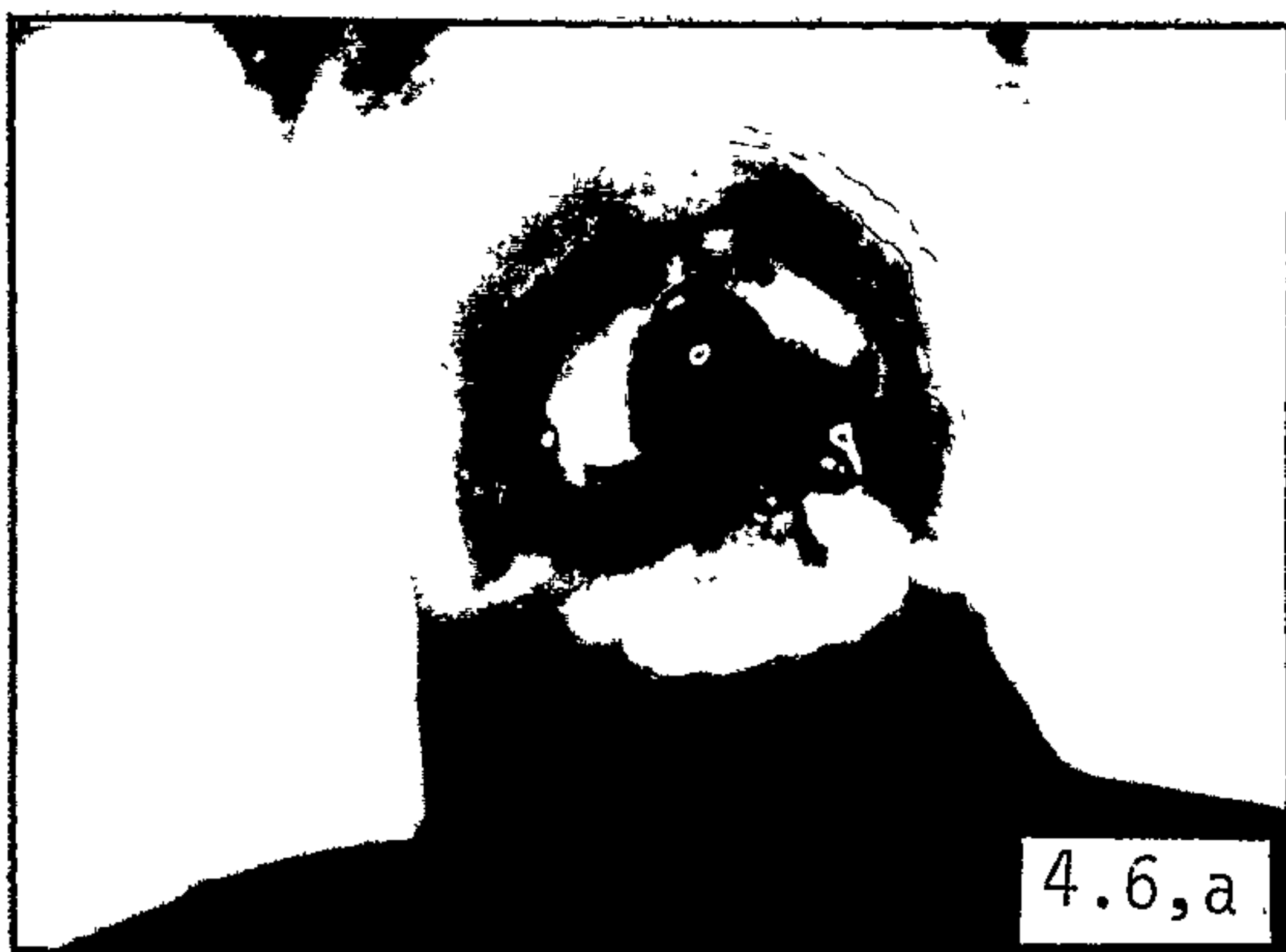


Fig. 4.6 Subgingival fracture of a restored pulpless tooth as a result of trauma.

a and b, Pre-operative clinical condition following removal of the post-core foundation and crown. The fracture extended 3-4 mm below the level of the alveolar bone in the palatal.

c, Post-core and crown re-cemented. The crown was reduced to allow incisal movement of the root.

d, Note the amount of incisal movement in a period of three weeks.

e, Compare the positions of the apices of the central incisors. The outline of the socket of the extruded root is still vaguely visible. The elastic was replaced by a ligature wire and a composite resin splint during the period of stabilization.

f, The inadequate apical seal was removed and replaced with a more substantial root filling of gutta percha and root canal sealer. Periodontal surgery was performed prior to the construction of the coronal restoration.

g and h, Radiographic and clinical appearance of the treated tooth one year after the placement of a post-retained composite resin core and a ceramo-metal crown.

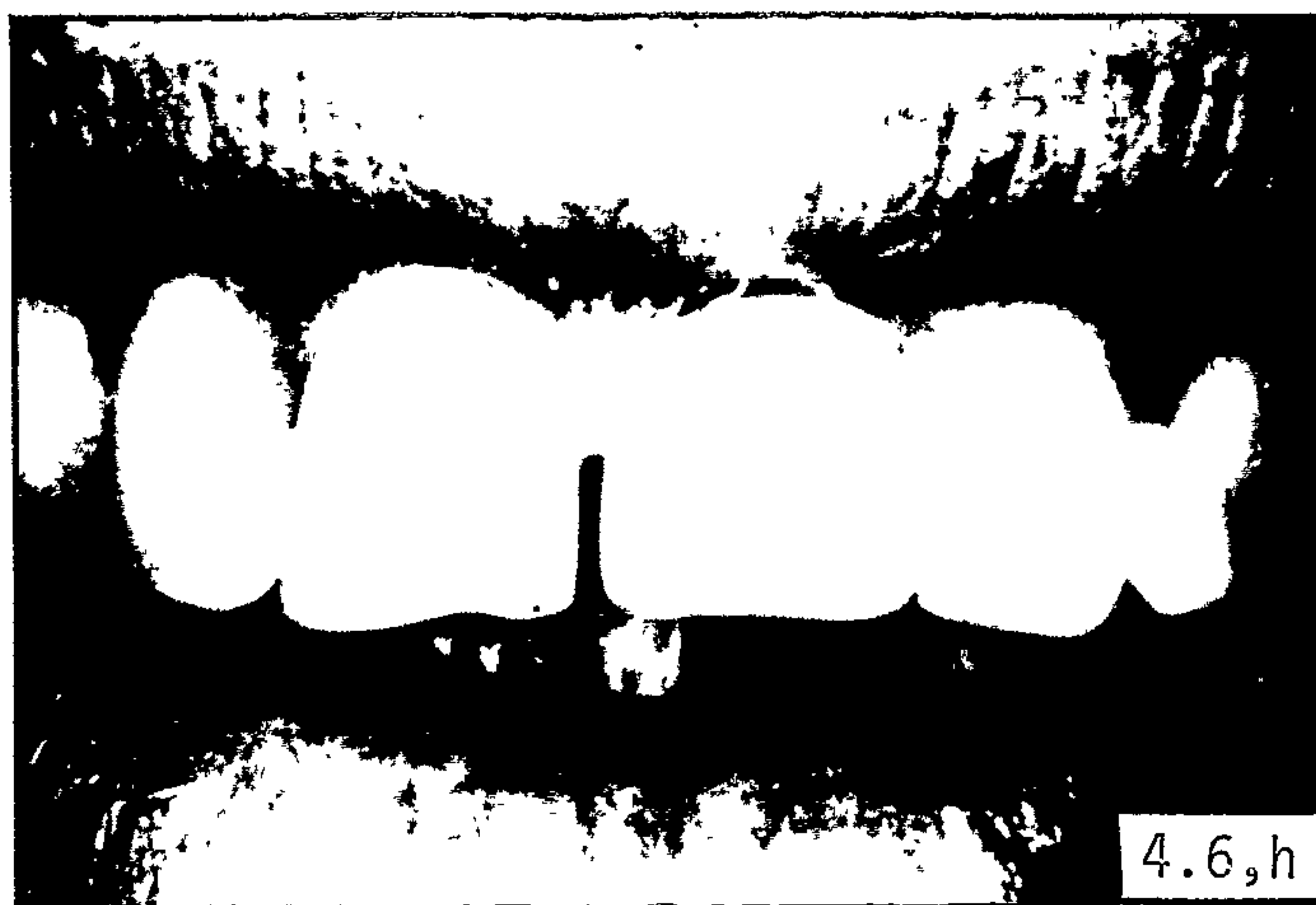
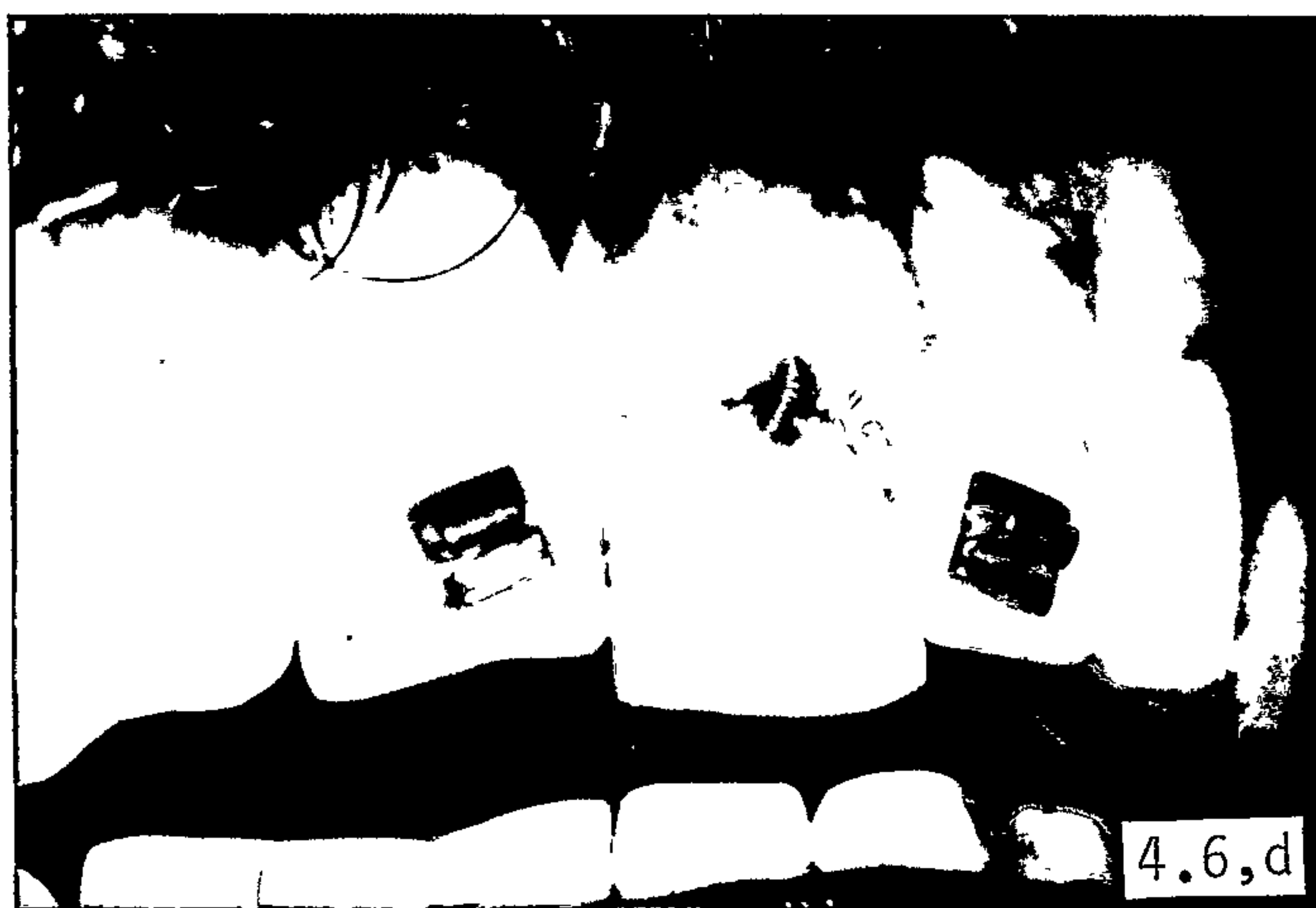
Fig. 4.6,c to h

Fig. 4.7 Failure of an attempt to repair a root perforation.

For further explanation, refer to 4.4,d.

(From Colman, 1979)

Fig. 4.8 a. Occlusal surface of the tooth with osseous lesion is reduced to allow eruption.

b. Same tooth allowed to erupt or extrude orthodontically; compare final position of cemento-enamel junctions, apices and bone levels.

(From Palamo and Kopczyk, 1978)

Fig. 4.9 Treatment of a combined periodontal-endodontic lesion.

a. The first molar tooth has a combined periodontal-endodontic lesion. The pulp was necrotic and there was furcation involvement. The bicuspid tooth also had a necrotic pulp.

b and c. Periodontal lesion persisted following endodontic treatment.

d and e. The palatal and the disto-buccal roots were removed leaving only the mesio-buccal root and a portion of the post-retained amalgam core in place.

Fig. 4.7; 4.8; 4.9,a to e

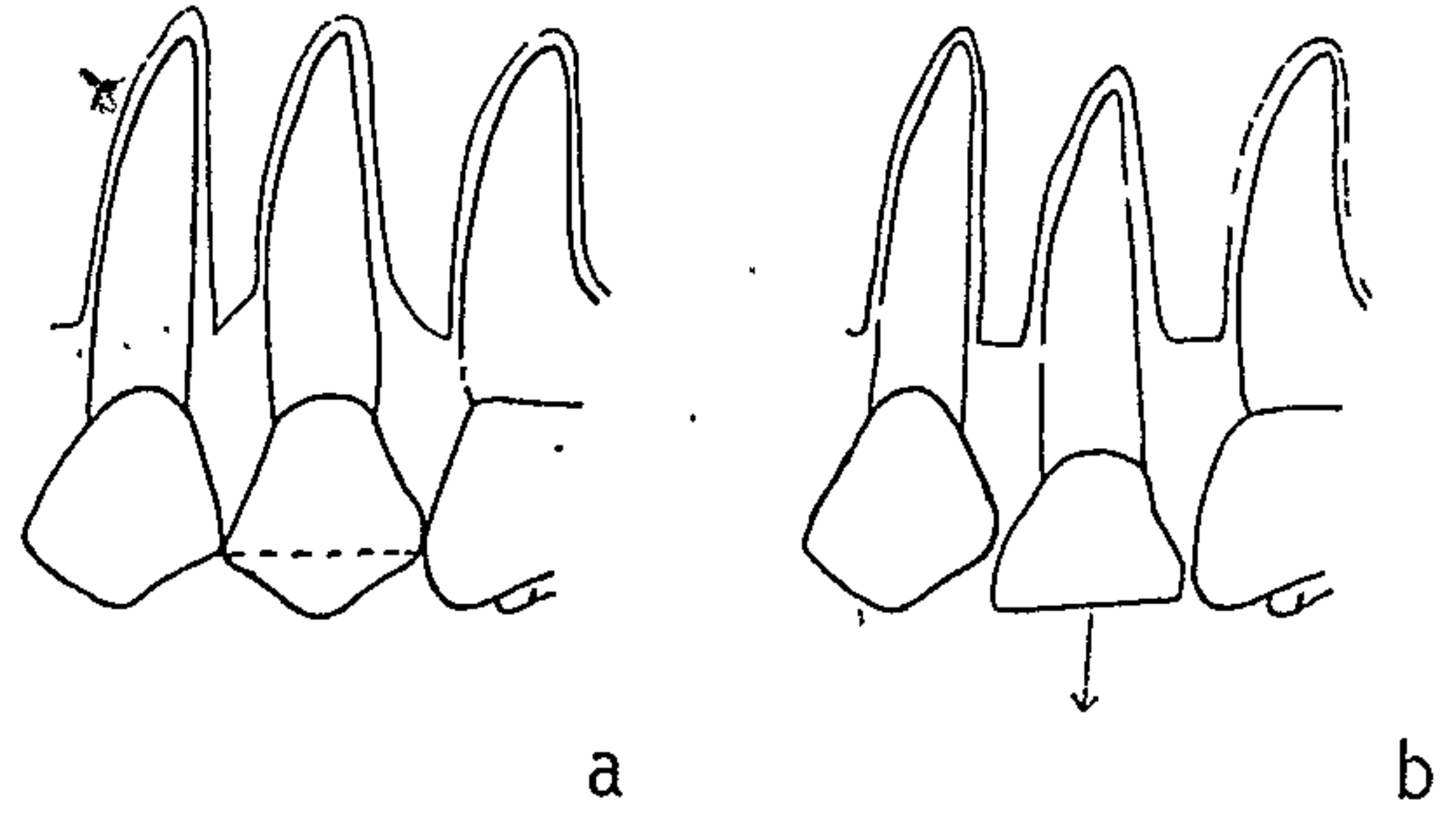


Fig. 4.8

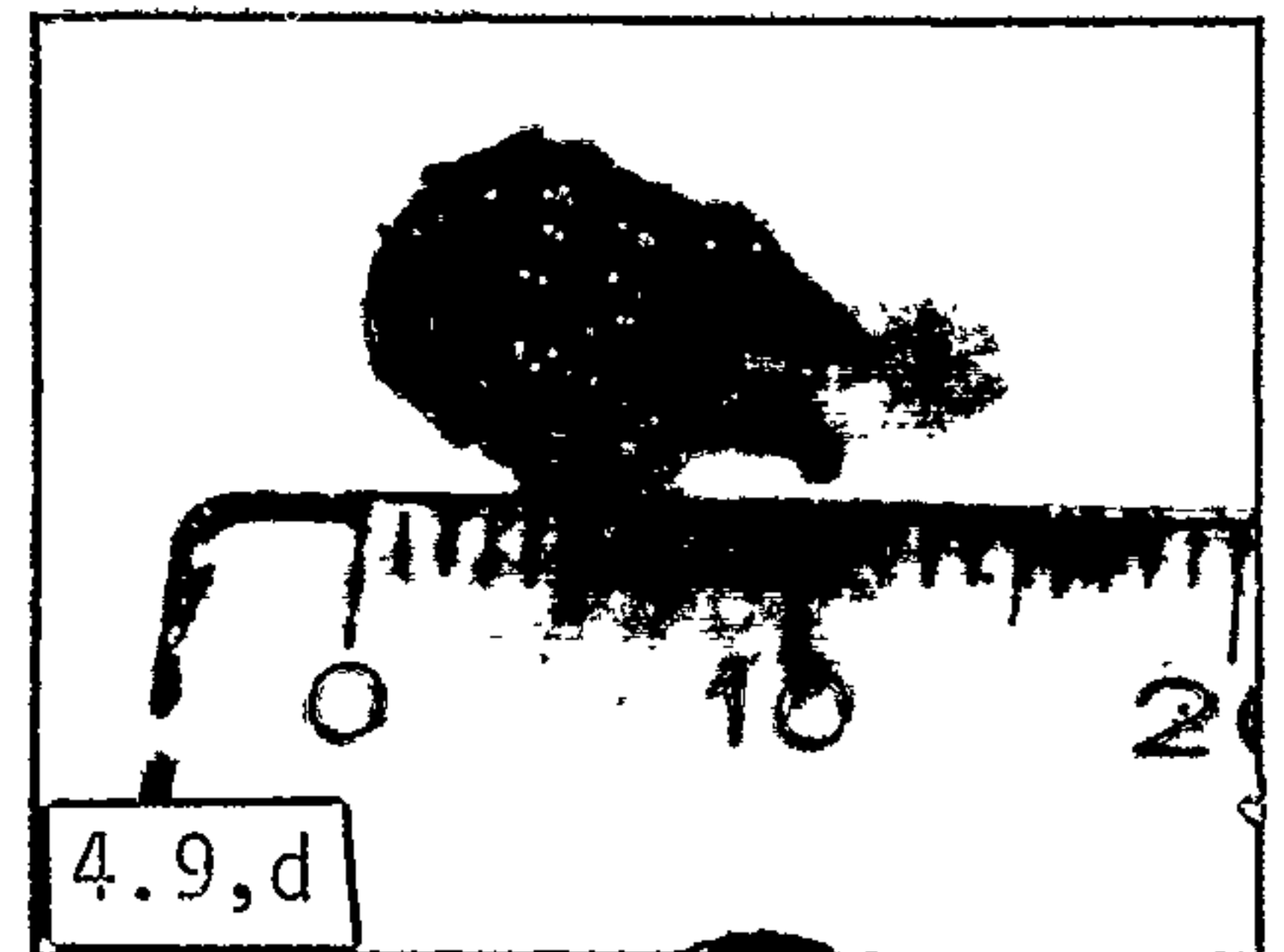
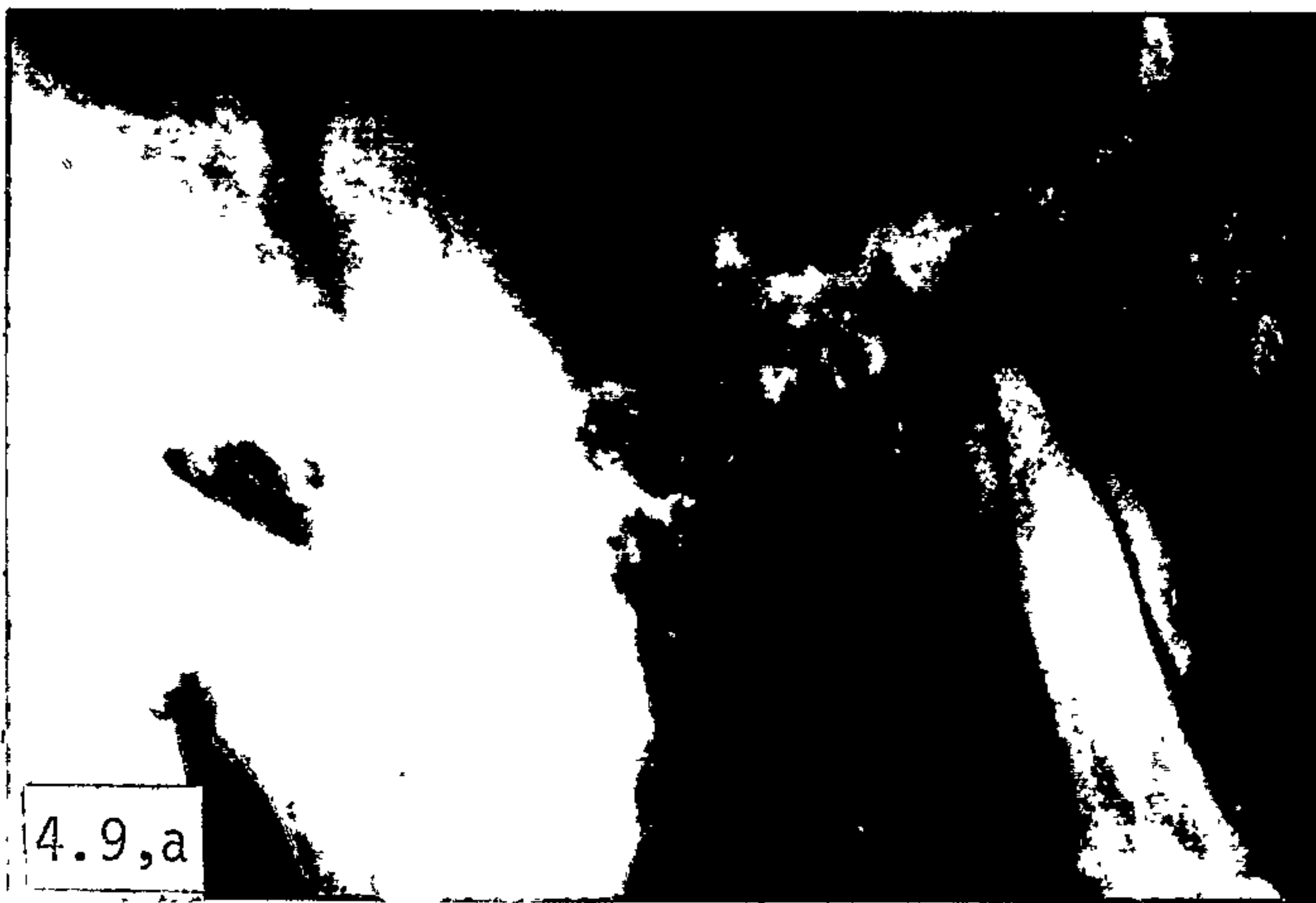


Fig. 4.9 f. Clinical appearance of the resected tooth three months post-operatively. The bicuspid tooth was restored with a cast gold, 2-unit post-core foundation.

g and h. The teeth were subsequently restored with a semi-fixed bridge. The photographs were taken 2 years after the periodontal surgery.

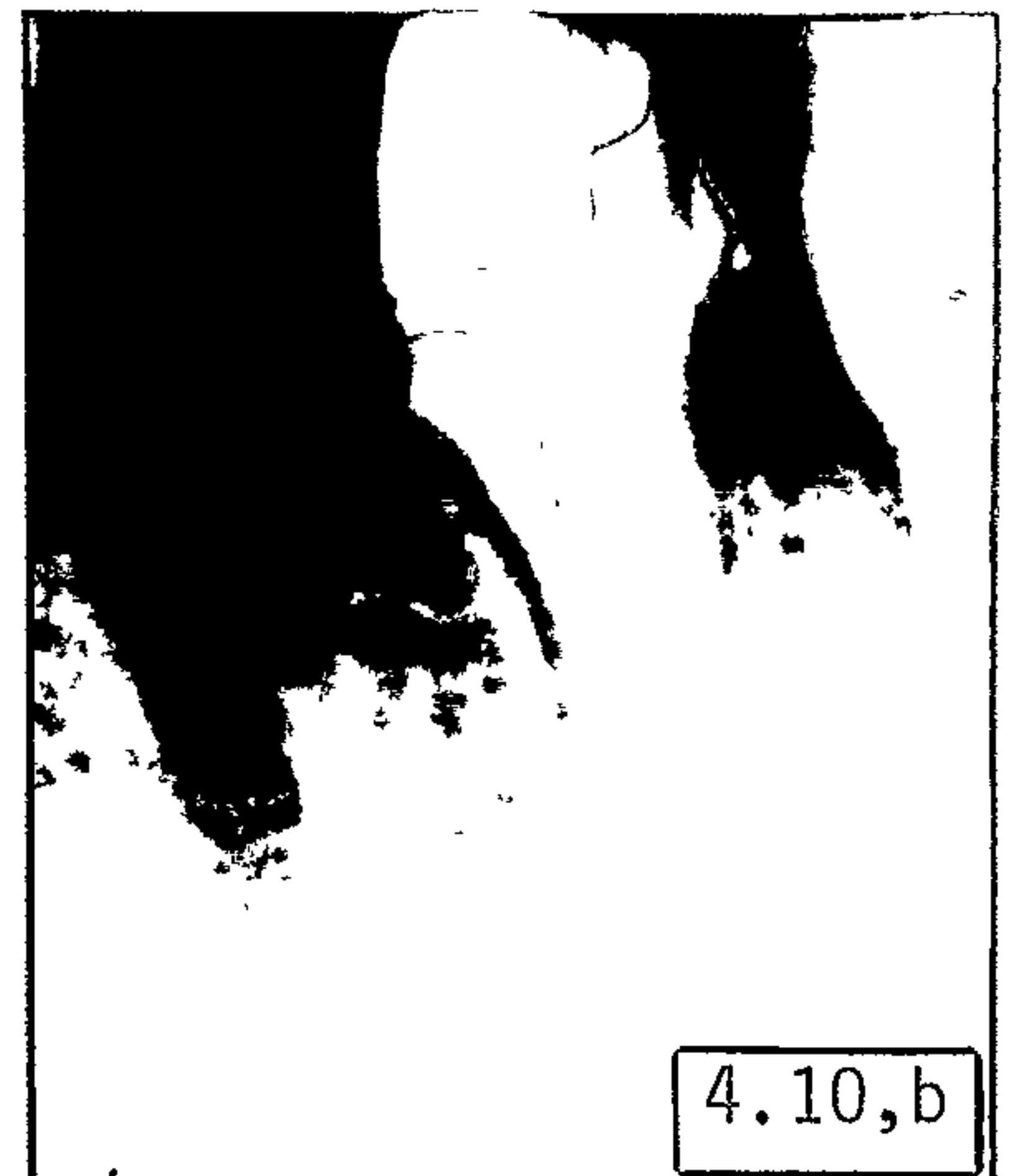
(Periodontal surgery was performed by C. Daly, Sydney)

Fig. 4.10 a. Bucco-lingual crown-root fracture through bifurcation area and pulp became necrotic.

b. Mesial root was removed after the distal root was endodontically-treated.

c. Distal root was ready for the final coronal restoration after the insertion of a post-retained amalgam core foundation.

Fig. 4.9,f to h; 4.10



## CHAPTER 5

### THE POST-CORE FOUNDATION — DESIGN PRINCIPLES

- 5.1 Introduction
- 5.2 Components of the post-core foundation
- 5.3 Indications for the use of a post
  - 5.3.1 Introduction
  - 5.3.2 Indications for the use of a post in the restoration of anterior pulpless teeth
  - 5.3.3 Indications for the use of a post in the restoration of posterior pulpless teeth
- 5.4 The post
  - 5.4.1 Stress distribution by the post
  - 5.4.2 Retention of the post
  - 5.4.3 Obturation of the root canal
- 5.5 The core
  - 5.5.1 Conservation of coronal tooth structure
  - 5.5.2 The core and tooth preparation for the final restoration
  - 5.5.3 The sequence of preparation
  - 5.5.4 Retention form
  - 5.5.5 The fabrication of the post-core foundation and the final restoration

#### 5.1 Introduction

The restoration of an endodontically-treated tooth is achieved in two stages, namely, the construction of a post-core foundation and, secondly, the placement of the final restoration. The post-core foundation forms an integral part of the preparation for the final restoration (Eissmann and Radke, 1976, p.538).

The purpose of this chapter is to consider the principles governing the use, the design and the construction of post-core foundations. These principles are based on the findings of laboratory studies and clinical observations and form the basis for the assessment of the different post systems and methods of core construction in the later chapters.

#### 5.2 Components of the post-core foundation

The *post* (or dowel) is the part of a post-core foundation which extends into the root of an endodontically-treated tooth. It has three basic functions. First, it is used to increase the resistance of the

endodontically-treated tooth to root fracture by the distribution of the forces placed on the crown over a large area of dentine in the root (Locke, 1977). Some authors (Gerstein and Burnell, 1964; Silverstein, 1964; Lau, 1976; Henry and Bower, 1977) have used the term, "reinforcement", presumably to describe this function of stress distribution. Since it is uncertain at this stage, whether a root canal post actually increases the resistance of an endodontically-treated tooth to fracture, particularly when the pulpless tooth is relatively intact (5.3.21), this term may be a little misleading and its use is avoided. Secondly, it may be used to retain the "core", over which a final restoration will be placed (Herschman et al, 1976, p.444-466); in the case of a post-crown, it provides direct retention to the coronal restoration (Frank, 1959; Sommer et al, 1966, p.520-524). Thirdly, the cementation of the post serves to complete the obturation of the root canal (Kayser, 1969).

The *core* is an addition to the preparation for the coronal restoration so that optimal resistance and retention form are provided for the final restoration (Eissmann and Radke, 1976, p.538). The size of the core is determined by the amount of remaining non-carious, well-supported coronal tooth structure. If adequate coronal tooth structure is present, the core may be only a small coronal extension of the post (Fig. 5.1,a); if, however, a large portion of the clinical crown is missing, the core may make up the entire coronal preparation for the final restoration (Fig. 5.1,b). In most instances, the final preparation for the coronal restoration is a combination of the remaining sound tooth structure and a core of cast alloy, amalgam or composite resin, with or without the aid of retentive pins or posts.

The *coping* is a band 2 mm or more in occluso-gingival width which surrounds the clinical crown at the margin with a ferrule effect (Eissmann and Radke, 1976, p.538). It may be part of the core or formed by the final restoration (Fig. 5.1 and 5.2).

### 5.3 Indications for the use of a post

#### 5.3.1 *Introduction*

Before examining, in subsequent sections, the various aspects of the design and construction of post-core foundations, an attempt is made to answer the following question; "When restoring an endodontically-treated tooth, is a post necessary in all cases?"

As mentioned previously (2.1), the condition of a tooth following root canal therapy may vary considerably. Although these pulpless teeth commonly have substantial loss of the clinical crowns, there are cases where the clinical crown of the endodontically-treated tooth has remained relatively intact except for the endodontic access.

Although it is generally recognized that a post-core foundation is the ideal method for the restoration of an endodontically-treated tooth with little remaining coronal tooth structure, pin-retained foundations are also widely used as an alternative method of reconstruction.

Opinions appear to be divided over the use of posts in endodontically-treated teeth with relatively intact crowns. It has been suggested that the placement of a prefabricated metal post into the root canal of such a pulpless tooth is necessary to "reinforce" the tooth against fracture (Lau, 1976; Colman, 1979). However, the findings of several laboratory studies attempting to demonstrate the claimed benefits of this clinical procedure were somewhat inconsistent. The findings of these investigations are evaluated and an attempt is made to present guidelines for the use of posts in the light of this research.

Because of the different restorative problems encountered, the discussion on the use of posts in the restoration of pulpless teeth is divided into two sections - anterior (5.3.2) and posterior (5.3.3) teeth. Within each section, separate consideration is given to pulpless teeth with relatively intact clinical crowns and to those with substantial loss of coronal tooth structure.

### 5.3.2 *Indications for the use of a post in the restoration of anterior pulpless teeth*

#### 5.3.21 Anterior teeth with relatively intact clinical crowns

These are pulpless teeth which may have, apart from the endodontic access cavity, relatively small lesions or restorations which only involve one or both of the proximal surfaces. A review of the literature has indicated that, in the past, the use of the post was largely empirical. In recent years, evidence has become available as a result of laboratory research.

##### a. Opinions expressed in the literature

Many authors have offered opinions concerning the need for a post in relatively intact anterior teeth. There is a divergence of opinion on this subject and the lists of indications for the use of posts in these teeth may vary considerably from one author to another.

Several authors (Perel and Muroff, 1972; Henry and Bower, 1977) stated that "all root filled anterior teeth require reinforcement by a post and core". Others (Lau, 1976; Waliszewski and Sabala, 1978) suggested that the placement of a preformed metal post into the root canal was usually adequate to "reinforce" the pulpless tooth against subsequent fracture and that this should be carried out routinely. Colman (1979) recommended the placement of a post as a means of preventing cervical fracture following endodontic treatment. He described a technique, which is illustrated in Fig. 5.3 and considered that, in most cases, this amounted to "minimal" treatment. However, if the tooth to be treated was out of the range of functional occlusal relationships, he suggested that the use of a post may be eliminated.

Although Baraban (1967) recognized that the insertion of either a cast gold post or a prefabricated metal post into the root canal was an effective means of reinforcement, he suggested that the placement of a simple restoration to seal the endodontic access cavity was "adequate" in

most instances. He pointed out that the main disadvantage of placing a post at this stage was associated with the complications that might arise should it be deemed necessary, subsequently, to place a post-core foundation and crown restoration because of caries or tooth discolouration.

Locke (1977) discussed whether or not, all endodontically-treated anterior teeth should be protected with a post-core foundation and full crown. He emphasized the need to consider the forces to which the particular tooth was likely to be subjected, and for a clinical judgement to be made concerning the ability of the remaining tooth structure to withstand such forces without fracturing. Factors to be considered should include (Locke, 1977; Baum et al, 1981, p.523):

- i. the nature of the opposing tooth — whether it is a natural tooth, a denture or an open bite situation
- ii. the presence of bruxing habits — severe wear indicating high forces, and
- iii. the condition of the endodontically-treated tooth itself.

In an attempt to clarify the use of posts in the restoration of endodontically-treated teeth, Courtade and Timmermans (1971, p.145) listed the following indications:

- 1. when previous restorations or caries leave insufficient coronal dentine to support the restoration
- 2. when the cervical circumference of the tooth is small, so that, even if the root canal diameter is small, insufficient dentine remains to resist fracture
- 3. when the realignment of an endodontically-treated tooth is indicated. The restoration may then be placed in the ideal position for aesthetics and function.

It was the opinion of a number of authors (Spasser, 1963; Sommer et al, 1966, p.518; Gilmore and Lund, 1973, p.258; Abdullah et al, 1974; Harper and Lund, 1976; Nicholls, 1977, p.326) that a post was not needed

in the restoration of a pulpless anterior tooth with a relatively intact crown. Most of these authors recommended the use of tooth-coloured restorative materials for the sealing of the endodontic access cavity as the final restoration.

b. Evidence from laboratory research

In 1976, Bravin reported the findings of a study into the effectiveness of tooth reinforcement by several commonly used post systems. Extracted maxillary lateral incisors were used for testing. It was found that the insertion of a post for the support of a restored incisor might, in fact, weaken a relatively sound tooth and enhance the possibility of its fracture. He suggested, however, that reinforcement by means of a post was necessary if the incisor was badly broken down.

In a laboratory investigation, Guzy and Nicholls (1979) compared the loads at failure of intact endodontically-treated teeth with and without "reinforcement" by Kerr\* Endo-Posts. The specimens used for testing included freshly extracted maxillary central incisors and maxillary and mandibular canines. They concluded that no statistically significant reinforcement was achieved by the cementation of a Kerr Endo-Post into a sound endodontically-treated tooth.

An *in vitro* comparative study of several commonly used restorative techniques for pulpless teeth was conducted by Kantor and Pines (1977). Extracted single-rooted teeth were used for testing. It was not specified whether they were anterior or premolar teeth; nor was it mentioned whether endodontic treatment, or at least mechanical preparation of the root canal was performed in the test specimens, before the restorative procedures were carried out. The Whaledent<sup>@</sup> Para-Post System was used throughout the

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\*Sybron/Kerr Mfg. Co., Romulus, Mich., U.S.A.

<sup>@</sup>Whaledent International, New York, N.Y., U.S.A.

experiment and all the posts used were 0.050 inch (1.25 mm) in diameter.

There were four test groups:

1. Control. Untreated, non-reinforced teeth were prepared to a "standardized form" used for all other specimens.
2. Endodontically-treated teeth, reinforced with cemented stainless steel posts, were prepared in the same manner.
3. Cast gold post-core foundations.
4. Cemented stainless steel posts with composite resin cores.

Polycarboxylate cement was used for the cementation of the posts.

The cast gold post-core and the steel post-composite resin core foundations were constructed on specimens with minimal intact coronal tooth structure.

Force was applied at 45 degrees to the long axis of the tooth in an attempt to approximate the combination of forces on teeth as opposed to purely compressive or shear forces. In contrast with the results of the previously mentioned investigations, Kantor and Pines reported that the mean load required to produce tooth fracture in the group of specimens reinforced by the stainless steel posts was significantly ( $P < 0.02$ ) higher than the control group. They concluded that "when a pulpless tooth with intact coronal dentine has had conservative endodontic therapy and is to be reinforced before restoration, a single reinforcing post cemented into a pre-drilled hole is the treatment of choice. Such a procedure can approximately double the strength of the tooth".

These findings were consistent with those of Trabert and co-workers (1978), who investigated the impact resistance of maxillary central incisors to simulated trauma. Untreated teeth, teeth treated endodontically, and teeth "reinforced" by the use of Whaledent parallel-sided, stainless steel posts were subjected to identical impacts. No significant difference in resistance to fracture was demonstrated between the untreated and endodontically-treated teeth. However, it was found that the endodontically-

treated incisors reinforced with the stainless steel posts showed significantly higher resistance to fracture during impact. In addition, it was found that over-preparation of the root canal and the use of larger posts did not provide additional reinforcement but, instead, decreased the ability of the endodontically-treated tooth to withstand the simulated trauma.

c. Evidence from clinical studies

From a review of the literature, Ross (1980) noted the lack of clinical evidence concerning the incidence of fracture of endodontically-treated teeth with or without root canal posts; this reviewer has had the same experience. There is also a lack of evidence on the clinical fracture rates of vital teeth as compared to pulpless teeth although it has been implied by many authors that pulpless teeth are more susceptible to fracture. Ross suggested that conclusions drawn from laboratory studies should be considered with caution as the forces exerted against the test specimens may have exceeded forces exerted in the mouth during masticatory and non-masticatory functions. He suggested that the tendency of an endodontically-treated tooth to fracture should be evaluated in relation to the amount, direction and duration of the forces on the tooth. The principal advantage of a long-term clinical study compared with a laboratory study is that evaluation would be carried out after the teeth had been subjected to actual masticatory forces for many years rather than to forces generated under laboratory conditions.

It is obvious that long-term clinical studies are needed before there can be resolution of this controversy. Until then, it is necessary to rely on the findings of laboratory studies but to temper this reliance with caution because of their obvious limitations. It is worth noting that although it is a method of "reinforcement" advocated by Lau (1976), Waliszewski and Sabala (1978) and Colman (1979), and has been used in some laboratory investigations (Kantor and Pines, 1977; Trabert et al,

1978; Guzy and Nicholls, 1979), evidence has suggested that prefabricated posts seldom fit the prepared root canal accurately along their entire length. Insertion of an accurately-fitting, individually fabricated cast metal post might prove to be a more effective means of "reinforcing" the endodontically-treated tooth. There is however, an almost complete absence of clinical evidence in the literature, to confirm that this technique assists a relatively intact, endodontically-treated tooth to resist fracture.

In laboratory studies, the age of the extracted teeth and the length of time between endodontic treatment and testing have received little attention. Since older teeth, in general, are more brittle, and pulpless teeth have been shown to have a lower moisture content following endodontic treatment (Helfer et al, 1972), a comparison of pulpless tooth specimens that have been aged for a period of time, say two to three years, with freshly prepared specimens may assist the future interpretation of laboratory data.

Currently there is quite inadequate evidence in the literature to provide a sound basis for decisions concerning the need for a post in relatively intact endodontically-treated teeth. Although the placement of a post in these teeth may satisfy the dentist's sense of responsibility, there is virtually no clinical evidence to support it. It is surprising that there has been no clinical data on this. Endodontically-treated teeth *do* fracture but these events may have been too infrequent or too variable in aetiology to enable the collection of adequate data. A survey of the experience of a large number of dentists may provide valuable information.

It is undoubtedly true, clinically, that many relatively intact anterior teeth that are restored without a post, remain unfractured for many years. It is possible, based on some reported laboratory research,

that the placement of a post may, at times, further weaken the tooth by the removal of a quantity of sound tooth structure.

Until further evidence is available, the dentist should continue to exercise "clinical judgement" and place posts, with care, only where reasonable doubt exists about the ability of the tooth to resist loads placed on it. Where a post is placed, it should be, with minor modification, adequate for the support of any subsequent crown that is required without the need for its future removal and replacement. (This hazardous and, at times, difficult procedure should be avoided.)

Therefore, there does appear to be some justification for not placing a post in most anterior pulpless teeth that are relatively intact, particularly those in which immediate crowning, for aesthetic reasons, is not required. However, the patient should be advised of the greater risk of future fracture of the pulpless anterior tooth.

#### 5.3.22 Anterior teeth with substantial loss of coronal tooth structure

When a major portion of the clinical crown of a pulpless anterior tooth has been lost, a full veneer crown is often required as the final restoration. The post-core foundation is probably the most widely accepted method of providing retention and resistance form for the final restoration in such cases (Baraban, 1967; Courtade and Timmermans, 1971, p.145; Herschman et al, 1976, p.444-455; Nicholls, 1977, p.328-336). The use of a post-core foundation has also been advocated (Kafalias, 1969; Colman, 1979) for a pulpless tooth that was to become a fixed or removable partial denture abutment.

Several other alternative methods of core retention have been suggested:

- a. cast metal, amalgam or composite resin cores retained by a post as well as one or more pins for additional stabilization (Baraban, 1967 and 1970; Courtade and Timmermans, 1971, p.145-172)

- b. cast metal core retained by retentive pins incorporated in the casting (Baraban, 1967; Courtade and Timmermans, 1971, p.164)
- c. amalgam (Markley, 1958, 1966; Watson, 1968) and composite resin cores (Spalten, 1971; Janis and Lugassy, 1972; Rose, 1973) retained by cemented or self-threading pins
- d. all-composite resin post-core foundations retained by the material placed into the root canal (Landwerlen and Berry, 1972).

Baraban (1967) listed several situations where the use of the canal for retention of a post-core foundation was neither favourable nor practical and suggested the cast core with retentive pins as a possible solution:

- i. when the canal was short, curved or tortuous
- ii. when the canal had been filled previously with a silver point which could not be removed
- iii. when, because of tilting, a multi-rooted tooth did not have a path of insertion for a cast post-core foundation
- iv. when a post had been previously cemented and either could not or should not be removed.

Markley (1966) stated that "pin amalgam foundations better splint the root against splitting". He suggested that a circle of cemented pins placed at varying depths into the root, when bound together by amalgam or amalgam plus a final restoration, would substantially strengthen the tooth while the traditional post and core casting would actually tend to split the root. Figure 5.4 depicts, in theory, the difference between excessive forces applied to an amalgam core retained by cemented pins and to a cast post-core foundation. Watson (1968) suggested that the amalgam core retained by cemented pins is a safer method because the occlusal load is "divided between tensile forces on the pins nearest to it and compressive forces on the pins farther away." These forces

tend to cancel each other resulting in less shearing force being exerted on the root.

In a laboratory study by Lovdahl and Nicholls (1977), the physical properties of endodontically-prepared intact teeth were compared with those of teeth restored by pin-retained amalgam cores or cast post-core foundations. Upon loading, the cast, tapered post-core foundations uniformly failed by dislodgement from the prepared canal. Root fracture in the coronal 2-3 mm was observed in ten of the thirty specimens. Three self-threading pins were used to retain the amalgam core in each of thirty-five specimens — two pins in the labial and one in the palatal aspect of the root face. Failure of the specimens appeared to be related to the failure of the pin system. Since the force was applied to the lingual surface of the specimens towards the labial, the performance of the pin-retained cores might have been improved if the two pins were placed in the lingual aspect of the root. Although the failure loads presented clearly showed that the pin-retained amalgam cores were significantly more retentive than the cast post-core foundations, root fracture occurred in twenty-five of the thirty-five pin-amalgam specimens. The incidence of root fracture was comparatively lower in the cast gold post-cores — only 10 of the 30 cast gold post-core specimens fractured.

A similar study was reported by Moll and co-workers (1978); cast gold post-core foundations and pin-retained composite resin cores were compared. The composite resin was inserted around the self-threading pins and into the prepared root canals. A complete cast metal crown was cemented to each specimen before testing. Consistent with the findings of Lovdahl and Nicholls (1977), all the cast gold post-core foundations were displaced from the root canals and showed evidence of bending under the force of the testing device. However, there was no evidence of tooth fracture in any of the cast gold post-core specimens. Although the results suggested that the pin-retained composite resin cores were up to four times

more retentive than the cast gold post-core foundations under the conditions of the experiment, Moll and his co-workers (1978) reported that in 93 per cent of the pin-retained composite resin specimens, fracture was produced in the dentine beneath the apical ends of the pins.

Since self-threading pins are much more retentive than cemented pins (13.4.2), had these researchers used cemented pins in their experiments, the difference in the retention of the two types of foundations is likely to have been less. Self-threading pins are inserted into undersized pin channels and have been shown to cause stress concentration in the supporting dentine (13.5). It is probable, therefore, that the incidence of root fracture would also have been lower if cemented pins had been used instead of self-threading pins. Guzy and Nicholls (1977) stated that "if failure does occur in the oral environment, the least amount of damage to the tooth structure is desirable". Any fracture of the root may potentially result in the loss of the tooth. It is necessary, therefore, to exercise care in deciding upon the type of support required for a core. If a post of adequate length can be accommodated in the root canal, the post-retained foundation is the preferred method since occlusal forces may be distributed over a much wider area. However, if, for the reasons outlined earlier, the use of a post is impractical, or if retention of the core is a problem, then it may be necessary to accept the additional risk of root fracture associated with the use of a core retained by self-threading pins.

### 5.3.3 *Indications for the use of a post in the restoration of posterior pulpless teeth*

#### 5.3.31 Posterior teeth with relatively intact clinical crowns

Although pulpal involvement in posterior teeth is usually the result of extensive caries and repeated restorative procedures, occasionally, endodontic treatment becomes necessary even in teeth with relatively intact

clinical crowns. These may include teeth with an occlusal or proximal lesion that is very deep pulpally, but otherwise, relatively small.

A review of the literature has indicated that little research has been done on the use of posts in these posterior teeth. Colman (1979) pointed out that since occlusal forces are more vertically oriented in the posterior areas of the mouth, the coronal restoration probably plays a more significant role in the prevention of longitudinal and transverse fracture of an endodontically-treated posterior tooth. Harper and Lund (1976) emphasized the need for the placement of "vertical support" — in the form of a post — in premolar (and anterior) teeth in order to prevent transverse fracture of the pulpless tooth. They suggested that the potential for fracture was more evident in these more anteriorly placed teeth due to the intensified transverse stresses placed upon the teeth in the anterior part of the mouth. This was supported by Henry and Bower (1977,a) who stated that "bicuspid teeth invariably require post support". Eissmann and Radke (1976, p.538-539) considered that the amount of remaining coronal tooth structure and the tooth circumference at the cervical region were the main factors determining the need for posts in posterior teeth. They suggested that, although, in most cases, bicuspid teeth required a post, the necessity for a post could be eliminated for most molar teeth because of their large circumference. Henry and Bower (1977) considered that the elimination of posts was advisable only if the treated molar tooth had considerable residual coronal tooth structure and if it was subjected to low functional loading. However, experiments conducted by Craig and Peyton (1975, p.110) on adults have demonstrated a definite increase in biting forces from the incisor region to the molar region. Early measurements of biting force with a gnathodynamometer by Black (1948, p.207-213), in 134 patients with an average age of approximately 25 years, yielded mean biting force values of 665, 453 and 222 N (150, 102 and 50 lb) on molars, bicuspid teeth and incisors, respectively. In contrast to the

suggestions of Eissmann and Radke (1976, p.538-539) and Henry and Bower, this evidence from clinical research indicated that similar principles of restoration should be applied to molars as to bicuspid.

In the restoration of a pulpless posterior tooth with a relatively intact crown, some authors (Spasser, 1963; Shillingburg et al, 1970; Abdullah et al, 1974; Nicholls, 1977, p.327-328) have placed little importance on the use of posts. Although the selection of the final restoration is discussed in Chapter 15, it is of interest to note here that, although cuspal protection is generally acknowledged as an essential feature in the coronal restoration of an endodontically-treated posterior tooth, the attitude towards the need for post support is more flexible.

In clinical cases where a restored, endodontically-treated tooth would be subjected to additional occlusal forces — for example, as a result of its function as an abutment for a fixed or removable partial denture — Colman (1979) recommended the use of a post to provide resistance against fracture (Fig. 5.5). Kafalias (1969) stated that "root filled teeth that are to receive a crown or bridge should have some form of post and core".

#### 5.3.32 Posterior teeth with substantial loss of coronal tooth structure

The restoration of endodontically-treated posterior teeth with little or no residual coronal tooth structure can often be a difficult problem. These cases may be the result of the loss of coronal tooth structure associated with endodontic treatment, previous restorations, caries or fracture. As Baraban (1967) pointed out, the aim, in these situations, is to design and construct a restoration which does not only restore the coronal form, but also has good retention and enhances the strength of the remaining tooth structure.

There appears to be a lack of clinical or research-based evidence in the literature either advocating or denying the need for the use of posts in multi-rooted posterior teeth. Many authors (Rosen, 1961;

Burnell, 1964; Skurnik, 1965; Herschman et al, 1976, p.449-466; Tidmarsh, 1976; Colman, 1979), based on clinical experience, have described or advocated the use of post-retained core foundations in these teeth. It is generally acknowledged that a post-retained core is the preferred method of restoration, although a pin-retained core is also considered by many (Baraban, 1967; Markley, 1968; Shillingburg et al, 1970; Brown et al, 1979) as an acceptable alternative.

One of the functions of a post is to distribute occlusal forces over as wide an area as possible. Since posts cemented into the root canals contact a much wider area of the root than the cemented or threaded pins, post retention may be a more efficient method of distributing occlusal stresses to the supporting tooth structure. Leggett (1979) considered that the use of pins, whether self-threaded or cemented, inevitably further weaken the remaining tooth structure and render it more susceptible to fracture. He suggested that, where possible, posts cemented into the root canals should be used to provide retention for the core foundation and the coronal restoration. This is consistent with the opinions of several other authors (Perel and Muroff, 1972; Nicholls, 1977, p.337; Caruso et al, 1978, p.488-500) that, when a large portion of the clinical crown has been destroyed, the post-core foundation is the preferred method for the reconstruction of the pulpless tooth.

Nicholls (1977, p.336-337) considered that the choice between peripheral pins and an intra-radicular post depends on the amount of coronal tooth structure remaining and the accessibility of the individual root to periapical surgery should periapical disease develop later. Where a root is inaccessible to periapical surgery, he advocated the use of pin-retained core foundations so that re-treatment of the root canal would still be possible by way of the pulp chamber.

Eissmann and Radke (1976, p.538-539) maintained that the large circumference of multi-rooted posterior teeth usually eliminates the

necessity for posts. They suggested that the core foundation may be retained by the existing coronal tooth structure and cemented pins. The walls of the prepared pulp chamber may also be used to provide retention for the core. Johnson et al (1976) noted that, although pin build-up is an accepted, routine technique for vital teeth, its use in pulpless teeth is a debatable issue. They suggested that pins were often used principally because of their greater convenience. The insertion of self-threading and friction-locked pins have been shown to cause minute fracture lines and crazing of the dentine (13.5). The length of time the tooth has been non-vital should be a factor when the use of pins is being considered. The greater the time since pulp death, the less elastic the dentine is likely to be and the greater the possibility of initiation of fracture lines as a result of the placement of self-threading and friction-locked pins, which rely on the resiliency of the dentine for retention. The use of cemented pins may eliminate the dependence on the resiliency of the dentine for retention but, generally, longer pins have to be used to compensate for their lower retentive properties.

Newburg and Pameijer (1976) investigated the retentive properties of cast post-core foundations, post-retained composite resin foundations and pin-retained composite resin foundations in single-rooted premolar teeth. Although the retention of composite resin cores retained by four self-threading pins was reported to be favourable compared to the post-retained foundations, there were also cases of tooth fracture in these specimens. Unfortunately, these authors did not discuss this very important issue in any detail and no mention was made of the incidence of root fracture in the post-retained core foundations.

In summary, except in clinical situations such as those listed in 5.3.22, where the use of posts may be impractical, it would appear that there are good theoretical reasons as well as some evidence from laboratory research to indicate that a post should be used in the restoration of posterior teeth with substantial loss of coronal tooth structure. Posts are preferred to self-threading or cemented pins.

#### 5.4 The post

The post serves three principal functions (5.2). It distributes forces exerted on the coronal restoration and core foundation to the supporting structures. It provides retention for the core portion of the coronal preparation, and in the case of a post-crown, it provides direct retention for the crown. The post also completes the obturation of the root canal.

When forces are applied to the coronal restoration and the core, they are transmitted to the root by the post. The aim is to distribute these forces as evenly and over as wide an area as possible. Any undue concentration of stress may increase the possibility of root fracture. Since the use of a post is not the only method available for retaining the core and since a post does not necessarily provide the greatest amount of retention, the widespread use of posts in the restoration of endodontically-treated teeth appears to reflect, at least to some extent, the opinion of the clinicians on the considerable importance of stress distribution. In order to achieve stress distribution and to provide retention for the core, the post itself must have sufficient retention to remain within the root canal. The ability of a post to distribute stresses evenly to the supporting structures and the retention of the post within the root canal are of fundamental importance and are discussed in detail in 5.4.1 and 5.4.2, respectively. Provided that the post is satisfactorily retained in the root canal, the use of a post is then able to provide retention for the core and to assist indirectly in the retention

of a final coronal restoration. The third function — completion of the obturation of the root canal — is discussed briefly in 5.4.3.

Broadly speaking, a post may be one of two types — custom or prefabricated.

1. Custom posts are individually fabricated posts to fit the particular root canal. Because each post is prepared for its own canal, the variation in size and shape of these posts is as great as the number of teeth that are restored. Because of their individual variation they have rarely been used in laboratory research. Although custom posts are popular clinically, there is, unfortunately, an absence of scientific, clinical data on this form of post. Because of this, it is necessary to extrapolate from the findings of laboratory research on prefabricated posts in order to understand custom posts. Any conclusions drawn from this extrapolation of data require substantiation and should be viewed with caution until more information is available.
2. Prefabricated post systems have become increasingly popular in recent years for clinical use. This increased popularity can be attributed partly to the increased demand for some form of prefabricated post system to meet the increased popularity of endodontics and more costly crown restorations, partly to the greater expertise in the manufacture of these precision materials, and partly to the increased understanding, of the principles involved in the design and clinical use of different forms of posts, resulting from laboratory research and clinical experience.

#### 5.4.1 *Stress distribution by the post*

The ability of a post to distribute occlusal stresses to the supporting structures may be influenced by one or more of the following factors:

- a. post design (5.4.11)
- b. post length and diameter (5.4.12)
- c. insertion and cementation of the post (5.4.13)
- d. accuracy of fit of the post (5.4.14)

#### 5.4.11 Post design

In the context of this discussion, "post design" refers to the overall shape of the post as well as its surface characteristics. Custom posts are most commonly made of cast metal and have the same degree of taper as the root canal of the pulpless tooth. Prefabricated posts are usually marketed in kits, as post "systems", containing posts of different sizes and materials for different purposes, instruments to prepare the canal precisely and come with appropriate sizes of wrench to assist in the placement of the posts. These post "systems" can be classified into two basic types — the cylindrical or parallel-sided posts, and the conical or tapered posts. Within these types, a post can have one or more of several surface characteristics (Fig. 5.6). It may have one or more venting channels to allow the escape of trapped air and excess cement during cementation. The surface of the post may be smooth, sandblasted, serrated, grooved or threaded. Depending on their surface design, some of the posts are cemented passively into a prepared root canal, while others are screwed into threaded channels prepared in the root canal walls.

In a laboratory study by Standlee and co-workers (1972), posts of three different designs — smooth-sided parallel posts, smooth-sided tapered posts, and threaded, parallel posts — were cemented into epoxy resin testing blocks with zinc phosphate cement. Stress-free channels were prepared on a Unimat drill press to depths of 4, 7 and 10 mm for each post type. Cylindrical cast silver crowns were cemented over the 4 mm lengths of protruding posts to provide a simulated crown length of 10 mm which was, according to Wheeler (1969, p.24), considered to be typical for maxillary central incisors. Two models were prepared for each type of post

at each length. Loading of the specimens was performed on a vertical straining frame in conjunction with a 500-pound load cell. Photographic data yielding x3 magnification were recorded while the specimens were loaded in a field of circularly polarized, mercury green, monochromatic light. Different loads were applied to the specimens:

- i. 30 pounds at 26 degrees from the long axis of the post
- ii. a 27 pound compressive load
- iii. a 13.5 pound shear load

i. For the purpose of description, Standlee et al (1972) used the term "lingual" to describe the side of the post to which the load was applied and "labial" to describe the side opposite to "lingual".

When the load was applied from a lingual direction at 26 degrees to the long axis of the tooth, there was very little evidence of lingual stress in contrast with the concentration of labial stresses. The smooth-sided parallel posts showed the least evidence of stress concentration on the labial side, the threaded posts showed intermediate stress levels in the shoulder and counter seat regions, and the tapered posts exhibited the greatest evidence of labial stress patterns. The smooth-sided parallel posts showed slightly higher stress concentration apically than the other two types of posts tested.

ii. When subjected to compressive loading, by the application of a load along the long axis of the post, stress concentrations were apparent at the shoulder region of the crown and adjacent to the apical end of the post with the smooth-sided parallel posts. The tapered posts showed the greatest evidence of stress at the shoulder, and also evidence of "low-order fringes" along the length of the post which was considered to be indicative of a tendency for "wedging" to have occurred. The threaded parallel posts showed evidence of high stress adjacent to the counter-seat.

These results confirmed the opinions of Charlton (1965) who suggested that a parallel-sided post would transmit axial forces in line with the

long axis of the tooth, but that a tapered post would also transmit forces to the walls of the root canal (Fig. 5.7). He warned that if the shoulder of the core did not fit closely to the root face, the wedging effect observed with tapered posts would tend to split the root.

iii. When shear loads were applied, Standlee et al (1972) reported that the tapered posts and the smooth-sided, parallel posts generated moderate stress in the shoulder region but only low levels of stress along the shafts of the posts; the threaded parallel posts appeared to generate high stress levels which were concentrated about the counter-seat.

Standlee et al concluded that the design of the post — its overall shape and surface characteristics — has a definite influence upon the distribution of stress. It was suggested that sharp angles and counter-seats should be avoided in the root face preparation because of the greater likelihood of concentration of functional stresses.

In a similar study by Henry (1977), experimental replicas of a maxillary central incisor were made using a photoelastic plastic and, into these experimental teeth, posts of several different designs were inserted; some of these posts were attached to a core foundation. Each specimen was subjected to a simulated functional loading condition. A straining device was used to apply the load to the area of the central fossa of the core section, tangentially to the long axis of the post. Information on the number of specimens, the angle of load application, and the amount of force applied was not available. The resulting isochromatic fringe patterns were recorded photographically for analysis. The post designs investigated were:

- i. smooth-sided, tapered post
- ii. serrated, vented, parallel post (Para-Post\*)

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\*Whaledent International, New York, N.Y., U.S.A.

- iii. threaded, parallel post (Kurer\*)
- iv. threaded, tapered post (Dentatus<sup>@</sup>)

Prior to loading, the specimens with the smooth-sided, tapered post and the serrated, parallel post with cast cores were all observed to be stress free. However, both the threaded, tapered and the threaded, parallel posts caused high stress concentration, particularly in the apical one third of the walls of the prepared root canal.

Upon loading, the serrated, parallel post provided even stress distribution to the root canal walls along the length of the post. The tapered cast post showed relatively greater stress concentration on opposite sides of the root canal walls. The threaded tapered posts developed high stress concentration when subjected to the simulated functional loading condition. However, out of the systems studied, the threaded parallel post was reported to have developed, upon loading, the highest stress concentration in the specimens.

The results of the studies by Standlee et al (1972) and Henry (1977) were in conflict with the findings of a study by Durney and Rosen (1977) who investigated the relationship between the incidence of root fracture, post design and technique of insertion; this study has been discussed further in 5.4.13. Durney and Rosen concluded that the two systems studied — the self-threading, tapered post (Dentatus), and the threaded, parallel post (Kurer Crown Saver) — were relatively safe and simple to use as long as the technique were understood and performed with care. Of the post systems investigated by Standlee et al (1972) and Henry (1977), however, these two systems were found to generate the greatest stress concentrations.

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\*Cottrell & Co., London, England

<sup>@</sup>Dentatus, Hägersten, Sweden

### *Summary*

Posts that are passively cemented into the prepared root canals — non-threaded posts — do not cause any undue stress concentration in the supporting structures in the unloaded state. However, threaded posts which rely on the resiliency of the tooth structure for additional retention, result in areas of stress concentration even in the unloaded condition. When loaded, parallel-sided posts distribute stresses relatively evenly along their length and stress distribution tends to concentrate in the shoulder and the apical region. Tapered posts exhibit a tendency for wedging because stresses are distributed to the walls of the root canal. This is especially true if the shoulder of the core does not fit closely to the root face. Threaded parallel and tapered posts developed high stress concentrations when subjected to occlusal loads.

#### 5.4.12 Post length and diameter

In the study by Standlee et al (1972), three types of post design were investigated (5.4.11). For each design — the smooth-sided parallel post, the smooth-sided tapered post and the threaded parallel post — it was found that the longer posts (7 mm and 10 mm) distributed stresses more evenly than the 4 mm posts to surrounding structure when the posts were subjected to either shear or compressive loading.

Consistent with these results, Henry (1977) found that, with serrated parallel posts, increased post length resulted in more even stress distribution over a greater area of root surface. Certain details of the experiment — the length of the posts, the diameter of the posts and the number of specimens tested — were not available; this information might have assisted in the determination of the minimum post length necessary to achieve adequate stress distribution.

Although the minimum length of a post required to provide adequate stress distribution and to ensure retention of the post has been a subject of discussion for many years, there appears to be a relative lack of

research on this topic. Many guidelines for post length have been suggested, commonly on the basis of clinical observations.

A length of post equal to one half the length of the root was advocated by Pickard (1964), Baraban (1967), and Christy and Pipko (1967); Courtade and Timmermans (1971, p.145) suggested that the post should be two-thirds of the root length. Other authors (Shillingburg et al, 1970; Whiteside, 1970), recommended that the post should be equal to, or exceed, three-quarters of the root length; however, they advised that at least 3 mm of intact root canal filling should remain to provide an apical seal.

The occluso-gingival height of the clinical crown has also been used by some clinicians as a guide to the length of the post. Many authors (Rosen, 1961; Tylman, 1965, p.722; Kafalias, 1969; Goldrich, 1970; Sheets, 1970; Standlee et al, 1972; Caputo and Standlee, 1976; Locke, 1977) suggested that the length of the post should be at least equal to the occluso-gingival height of the clinical crown of the final restoration. Herschman et al (1976, p.446) went further by recommending that the length of the post should be equal to one and one half times the height of the clinical crown.

Emphasizing the importance of considering the level of alveolar support for the root when determining the length of post to be used, Hirschfeld and Stern (1972) and Perel and Muroff (1972) recommended that the post should extend at least to one half of the length of the root contained in bone.

In summary, several authors (Kantorowicz, 1970, p.92; Gilmore et al, 1977, p.359-360; Waliszewski and Sabala, 1978) suggested that, clinically, posts should be made as long as possible, to within 3 mm to 5 mm of the apex; an effective apical seal must be maintained. Locke (1977) described the action of a post as a lever arm. Forces applied to the crown, or the

core, are transmitted down the post where they must be resisted by the root; the longer the post, the greater the mechanical advantage the root has for resisting the lever arm force on it and the greater the area of tooth for distribution of the forces. Therefore, the weaker the root or the greater the force on it, the longer the post should be to prevent the root from fracturing.

It is interesting to note that the effect of post diameter on stress distribution did not receive any attention from these researchers. Presumably, the clinician should only increase the diameter of the post sufficiently to achieve adequate internal adaptation for stress distribution and retention. Increasing the diameter of the post beyond that necessary for proper internal adaptation usually results in the removal of more tooth structure and further weakening of the root. This procedure is not recommended even if the stresses may be distributed evenly over a wider area.

#### 5.4.13 Insertion and cementation of the post

Stresses are generated in surrounding structures during the insertion of posts; these stresses were found by Standlee et al (1972) to vary with different post designs and lengths. The smooth-sided tapered posts were found to cause the least stress during insertion; the induced stress did not increase as post length increased. The amount of stress associated with the insertion of the smooth-sided parallel posts was dependent on the length of the post; high apical stresses were observed with post lengths of 7 mm and 10 mm and low apical stresses were generated adjacent to the apical end of posts of 4 mm length. It was considered that these apical stresses were probably caused by the constant application of pressure required during cementation in order to overcome the hydrostatic back pressure of the cement. Provision of vents in the design of parallel posts was therefore recommended.

Examination of stresses generated during the insertion of threaded, parallel posts emphasized the importance of careful execution of the tapping operation; high stresses were generated adjacent to the threads and at the apical seat. Standlee et al (1972) reported that, if the tap was not completely withdrawn for cleaning after each two turns, high stress concentrations, cracking of specimens and fracture of taps were likely to occur; correct use of the tap, however, was found to produce no significant residual stress.

A laboratory study by Durney and Rosen (1977) investigated the relationship between the incidence of root fracture, post design and the technique of insertion. Two systems of threaded post were tested:

1. self-threading, tapered posts (Dentatus\*)
2. threaded, parallel posts inserted into a tapped root canal (Kurer Crown Saver<sup>@</sup>)

These researchers measured the amount of torque required to seat the Dentatus posts and that required to tap threads into the root to receive the Kurer post. The amount of torque required to fracture the root was also determined for both systems.

Sixty extracted teeth mounted in stone were used for the testing of Dentatus posts. After initial enlargement with the Gates-Glidden drills<sup>#</sup>, the root canals were prepared with the corresponding reamers to receive the respective posts. Three posts of each size were used in the experiment. A torque wrench<sup>+</sup>, which was capable of increasing the torque in increments of 2 ozf in (0.014 Nm), was used to measure the amount of torque required to fully seat each Dentatus screw post.

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\*Dentatus, Hägersten, Sweden

<sup>@</sup>Cottrell & Co., London, England

<sup>#</sup>Union Broach Co., Long Island City, N.Y., U.S.A.

<sup>+</sup>Torque Control Inc., Orangeburg, S.C., U.S.A.

They reported that the amount of torque required to seat the Dentatus posts increased as the diameter of the posts increased. However, the length of the posts appeared to have no influence on the torque.

The amount of torque required to tap threads into the root canal was studied using 20 extracted teeth — ten teeth for each method of tapping. A torque wrench set at 2 ozf in (0.014 Nm), was used to drive the tap into the root canal with a drop of water as lubricant. It was given one backward turn after every two turns forward. Each time more torque was needed it was increased in amounts of 2 ozf in until the thread was cut into the whole length of the prepared root canal. The second method was similar except that after two turns forward the tap was removed and the debris of dentine was cleaned from the flutes of the tap as well as from the root canal.

Their findings indicated that the method of tapping had a definite influence on the amount of torque required to cut threads in the root canal. Significantly less torque was required to cut the threads when the tap was removed for the cleaning of the dentine debris from the flutes of the tap and the root canal. This result was in agreement with the findings of Standlee et al (1972) who, also found, in their photoelastic stress analysis of several post systems, that high stresses, cracking of the specimens, and fracture of the taps occurred if the taps were not removed and cleaned after two turns.

In the study by Durney and Rosen (1977) the extra-long Dentatus posts (No. 15) and the smaller Kurer Crown Saver posts were inserted into a total of 120 maxillary lateral incisors in order to determine the amount of torque required to cause root fracture. After the Dentatus post and the Kurer tap had been fully seated, the torque was increased by increments of 2 ozf in until a torque of 30 ozf in was reached in an attempt to provoke a fracture of the root.

Of the sixty roots used for the fracture test by the Dentatus post system, five roots fractured at slightly under the maximum torque, ten roots withstood the maximum torque, and the remainder failed because the post fractured, the threads were stripped, or the root was dislodged from the stone. It is interesting to note that sixty per cent of the Dentatus posts used in this particular test failed because of post fracture. The amount of torque required to fracture the roots was almost seven times that required to seat the posts; the amount of torque required to strip the threads was five times greater than that required to seat the post.

Application of a torque up to 30 ozf in did not result in any root fractures when the Kurer tap was used; however, the tap failed in four instances by fracture or twisting.

Although it was not known if micro-fractures were formed in the dentine, Durney and Rosen (1977) concluded that the technique for both types of threaded posts were simple and relatively safe provided that they were understood and correctly performed. The findings of this study have been compared with other research in 5.4.11.

#### 5.4.14 Accuracy of fit of the post

The importance of proper internal adaptation of the post has been emphasized by Perel and Muroff (1972) and Johnson et al (1976). An accurately fitting post ensures even distribution of the stresses to the root without the application of undue stress at any one point and allows for a thin, even layer of cement seal. This compensates for the weaknesses inherent in the cementing medium.

#### *Summary*

Accurate internal adaptation is essential for effective distribution of stresses to the supporting tooth structure.

Parallel-sided posts distribute stresses more evenly than tapered posts. Tapered posts may exhibit a tendency for wedging of the root.

Threaded posts screwed into pre-tapped canals cause areas of stress concentration even in the unloaded state. Longer posts distribute stresses more evenly. The diameter of the post should only be increased sufficiently to achieve adequate internal adaptation for stress distribution and retention and to provide adequate strength to resist occlusal stresses.

#### 5.4.2 *Retention of the post*

The post, if it is to distribute stress and retain the core (and the coronal restoration) satisfactorily, must itself be retained in the root canal. The following discussion is concerned primarily with the retention of the different types of posts in the root canal. The significance, and the influence of several factors which are normally within the control of the dentist will be evaluated. These factors are:

1. post design (5.4.21)
2. post length (5.4.22)
3. post diameter (5.4.23)
4. luting agent and technique of cementation (5.4.24)

##### 5.4.21 Post design

Post design was described by Standlee et al (1978) as "the greatest single factor influencing the retention of posts". The effect of the overall shape of the post is examined first (5.4.211) and is followed by an examination of the influence of the different surface characteristics on the retention of the post (5.4.212).

##### 5.4.211 Effect of the overall shape of the post

As mentioned in 5.4.11, all the currently available prefabricated post systems generally conform to one of two overall shapes — tapered or parallel-sided.

A study by Colley and co-workers (1968) compared the retentive properties of parallel-sided posts and tapered posts with various "angles of convergence" — a term employed by Jørgensen (1955) to describe the

extent to which a truncated cone gradually becomes smaller towards one end. The root canals which were to receive parallel-sided posts were prepared with round burs, as described by Tylman (1965, p.651-652).

The Mooser\* posts and the P.D.<sup>@</sup> posts were the two tapered post systems tested, and zinc phosphate cement was used to cement the posts into the specimens. Retention was examined only in the axial direction by direct pull. Posts of lengths ranging from 3.5 mm to 8.0 mm, and with angles of convergence of 0°, 3.5° and 4.0° were compared. When these smooth posts were used, they reported that the degree of taper (up to 4°) did not appear to have a significant influence on the retention of the posts.

The experiment was then repeated with serrated posts of the same shape. However, when the posts were serrated, the effect of the angle of convergence on the retention of the posts became obvious. An increase in the angle of convergence from 0° to 3.5° resulted in a significant reduction in retention and at post lengths of above 6.5 mm, a further increase of 0.5° in the angle of convergence (to 4.0°) resulted in further significant loss of retention. The authors recommended the limiting of the angle of convergence in tapered posts to a maximum of 4°.

In a more recent study, Ruemping et al (1979) also investigated the retentive properties of parallel and tapered posts cemented with zinc phosphate into root canals prepared with matching reamers. A total of 64 specimens, comprising smooth, parallel-sided Para-Posts<sup>#</sup> and smooth, tapered Endowels<sup>+</sup>, were subjected to tensile and torsional forces; two different lengths — 5 mm and 8 mm — of each type of post were tested.

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\*Cendres & Métaux, S.A., Biel-Bienne, Switzerland

<sup>@</sup>Produits Dentaires, S.A., Vevey, Switzerland

<sup>#</sup>Whaledent International, New York, N.Y., U.S.A.

<sup>+</sup>Star Dental Mfg. Co., Conshohocken, PA., U.S.A.

Tensile forces were applied in an axial direction. At a post length of 5 mm, the mean tensile load required to separate the post from the prepared canal was 28.7 lb for the smooth tapered posts and 38.8 lb for the smooth parallel posts; results obtained with the 8 mm posts were 34.9 lb and 44.3 lb, respectively. The torsional tests were conducted with a specially built machine and the torque was measured in ounce-inches (applied load x lever arm length). With posts of both 5 mm and 8 mm length, the smooth-sided parallel posts were found to have superior retention against displacement by a torsional load; this was consistent with their superiority when a tensile load was applied.

The retentive properties of tapered and parallel posts against tensile forces were also investigated by Johnson and Sakumura (1978). Smooth-sided, Endo-Posts\* which have an endodontically-standardized taper, and serrated, parallel-sided Para-Post<sup>@</sup> were inserted into prepared roots with zinc phosphate cement. A tensile load was applied to each specimen. An average of 4.5 times as much tensile force was required to remove the serrated, parallel posts as the tapered posts of similar diameter from the specimens. Although the authors acknowledged the added advantage given to the parallel-sided posts by their being serrated rather than smooth-sided, they still concluded that the shape of a post has a significant influence on its retention in the prepared canal.

The task of reviewing the influence of the shape of the post on its retention is made more difficult by some researchers having compared the smooth version of one type of post with the serrated version of another. For example, Standlee et al (1978) found that serrated, parallel posts were significantly more retentive than smooth, tapered posts; this result

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\*Sybron/Kerr Mfg. Co., Romulus, Mich., U.S.A.

<sup>@</sup>Whaledent International, New York, N.Y., U.S.A.

was in agreement with the findings of Johnson and Sakumura (1978) and Ruemping et al (1979).

During the last decade, "precision" has become an important consideration in post construction. Prefabricated posts of different sizes and materials have become available. Reamers, either hand-held or engine-driven, have been designed for the preparation of a matching root canal for the prefabricated post. This improved precision may, in part, explain the discrepancy between the findings of Colley et al (1968) and those of Johnson and Sakumura (1978), Standlee et al (1978) and Ruemping et al (1979). Since the three recent studies all used a precisely-matched prefabricated parallel post system, it is likely that the angle of convergence of a smooth-sided post does have more influence on its retention than that shown by Colley et al (1968).

Despite their superior retention, a major drawback of cylindrical (parallel) posts is the necessity to remove more dentine apically, in order that the post is supported by tooth structure along most of its length. Clinically, there is less risk in the preparation of the root canal for a tapered post; because the tapered post preparation follows the outer contours of the root more closely, the chance of perforation is reduced (Brunell, 1979).

#### 5.4.212 Effect of the surface characteristics of the post

There are three principal types of surface design available — namely, smooth, serrated or grooved, and threaded. It is of some importance to note Roush's (1941) explanation of how zinc phosphate cement assists the retention of restorations: "zinc phosphate cements set by crystals forming in the microscopic scratches or undercuts made in the cavity preparation by burs or cutting instruments. This crystal formation between the tooth and the inlay acts in the manner of a lock causing adhesion". Tylman (1965, p.394-396) also pointed out that the increased retention resulting from the cementation of two roughened approximating surfaces is due to the

many rods and projections of cement that are formed in the cement junction; the resistance to displacement "is proportional to the compressive and shear strength and thickness of the cement rods and cones".

Colley et al (1968) investigated the effect of the angle of convergence of the posts on their retention in the root canal. In doing so, they also demonstrated the influence of surface serrations on the retentive properties of the posts. With the parallel posts, a serrated or roughened surface was found to provide as much as two to three times more retention as a smooth post of the same length and diameter. Although the increase in retention resulting from the roughening of the post surface was less marked when the angle of convergence was increased to  $3.5^{\circ}$  and  $4.0^{\circ}$ , the retention of these tapered posts was improved significantly.

In a study by Kurer et al (1977), parallel posts with five different surface characteristics were tested to provide information on the effects of these variables on the retention of the posts. The posts used in the experiments were either smooth-sided, sandblasted, had sharp-edged or round-edged grooves, or were threaded. A total of sixty-eight measurements were made of stainless steel posts with the first four above-mentioned surface configurations. The posts were 10 mm in length, had a diameter of 1.52 mm and were cemented into matching channels prepared in whalebone with polycarboxylate cement mixed with a cement powder/liquid ratio of 1.5:1 (by mass). They reported that modifications to the smooth surfaces of the stainless steel posts, produced either by sandblasting or by the placement of four sharp or four rounded grooves on the surface, approximately doubled the retention of the posts.

The difference in the retention between smooth-sided, parallel posts and serrated parallel posts was studied by Ruemping et al (1979). They reported that, with both the 5 mm and 8 mm post lengths, significantly higher loads were required for the removal of the serrated posts from the

specimens when the force was applied in an axial direction. When torque was applied to the two types of posts, the serrated posts again proved to be more retentive. Although the difference in the retention of the two types of posts was not as great as that reported by Colley et al (1968), their findings confirmed the conclusions of Colley and his co-workers that the nature of the surface of the post has a significant effect on its retention in the root canal.

In order to improve the retention of post-core foundations in endodontically-treated teeth, P. F. Kurer (1967) suggested the use of a threaded, parallel post, which was screwed and cemented into a tapped root canal. Since its introduction, the Kurer\* post has been included in several studies which investigated the factors influencing post retention. H. G. Kurer et al (1977) compared the retention in an axial direction of the threaded posts with that of serrated and roughened parallel posts of the same length and diameter. They reported that significantly higher axial loads were required to remove the threaded posts.

These findings were consistent with those of subsequent studies by Standlee et al (1978) and Ruemping et al (1979). The three types of posts tested by Standlee and co-workers were 8 mm long, 1.75 mm in diameter and cemented into the prepared canal with zinc phosphate cement. The threaded, tapped Kurer posts recorded a mean load of 193 pounds before being dislodged from the root canal. The serrated, cylindrical Para-Posts<sup>@</sup> showed intermediate retention — mean dislodgement force of 95 pounds — and the smooth Unitek<sup>#</sup> tapered posts (with endodontically standardized taper) were the least retentive, exhibiting a mean load at failure of 28 pounds.

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\*Kurer Post System, Cottrell & Co., London, U.K.

<sup>@</sup>Whaledent International, New York, N.Y., U.S.A.

<sup>#</sup>Unitek Corp., Monrovia, Ca., U.S.A.

Results of the experiment by Ruemping et al (1979) again confirmed the superior retention, in an axial direction, of the screw-in, threaded, parallel posts. However, when subjected to torque, little difference in retention was demonstrated between the serrated, parallel posts and the threaded, screw-in posts.

#### 5.4.22 Post length

A second factor influencing the retention of posts is the depth of post embedment in the dentine — that is, the length of the post that is supported by the walls of the root canal.

It has been demonstrated in several studies that the amount of retention is directly related to the effective length of the post; an increase in the depth of post embedment into the root canal is usually associated with increased retention (Colley et al, 1968; Kurer et al, 1977; Johnson and Sakumura, 1978; Standlee et al, 1978; Krupp et al, 1979; Ruemping et al, 1979). The surface area of posts was stated to be important in relation to retention because an increase in the diameter or length of the post increases the surface area available for the formation of the retentive cement bond between the surface of the post and the root canal walls. When the retention of the posts in an axial direction was tested, all the above-mentioned authors reported a general trend towards increased retention with increased post length. A similar finding was also reported by Ruemping et al (1979) when a torsional load was applied to the four different types of posts tested — the 8 mm long posts were, on the average, 1.23 times as retentive as the 5 mm long posts.

Johnson and Sakumura (1978) found that although post lengths of 7 mm and 9 mm provided a similar level of retention in an axial direction, a post of 11 mm length provided significantly increased retention. It was suggested therefore, that, where other conditions permitted, a post with a length equal to three-fourths, or more, of the remaining root was indicated to ensure maximum retention. They noted, however, that in some

multi-rooted teeth, preparation of the root canal to receive a post of 11 mm was impractical and that, in such cases, a post of 7 mm may provide adequate retention.

Although a post of length equivalent to the height of the clinical crown of the restored tooth is usually sufficient to meet the requirements of stress distribution and retention against axially-directed displacement, Locke (1977) indicated that there were certain situations where the length of the post should be increased. These included roots that were weak due to the presence of a large canal and situations where the forces subsequently transmitted by the post might be greater than normal, such as in a pulpless tooth that was being used as a bridge abutment. In such circumstances, the principal aim of increasing the length of the post was to enable the even distribution of the occlusal forces over as wide an area as possible.

#### 5.4.23 Post diameter

As stated previously (5.4.22), the retention of the post is influenced by both the length and the diameter of the post because each of these factors influences the quantity of surface contact made by the post with the walls of the root canal.

Although the findings of Johnson and Sakumura (1978) indicated that an increase in either the length or the diameter of a post could provide a relative gain in retention of 24 to 30 per cent, they suggested that, where possible, increasing the length was the preferred method of achieving greater retention. Lengthening the post to achieve the same increase in retention was found to result in less removal of dentine from the treated root. In contrast, increasing the diameter beyond that required to produce intimate contact between the post and the dentine walls resulted in unnecessary removal of dentine, weakening of the roots and, possibly, perforation or fracture of the root. On the other hand, Perel and Muroff (1972) pointed out that the diameter of the post should be adequate to

resist bending or fracture. Cases of post fracture have been reported by Samani and Harris (1978).

The influence of the diameter of the post on retention has been investigated by Kurer et al (1977), Standlee et al (1978) and Krupp et al (1979). In an experiment in which the depth of embedment was kept constant, Krupp et al (1979) found a significant increase in retention between 1.25 mm diameter and 1.50 mm diameter serrated, parallel posts. No increase in retention between 1.50 mm and 1.75 mm diameter posts was found, however, by Standlee et al (1978) and Krupp et al (1979). Their results were in agreement with the findings of Kurer and co-workers (1977) who assessed the retention, in an axial direction, of threaded parallel posts of different diameters and lengths. They found an increase in the resistance to axial displacement with increasing post length; increasing the diameter of the post, however, did not have any significant effect on the retentive property of the post.

Caputo and Standlee (1976), recommended the use of parallel posts but emphasized the importance of preserving adequate sound dentine in the root. They noted that, following the removal of the coronal root canal filling to the desired level, care should be taken to keep the coronal canal opening to minimal diameter and flare, in order to avoid unnecessary weakening of the root. It was suggested that, after preparation, at least one millimetre of sound dentine should remain around the entire circumference of the prepared canal.

#### 5.4.24 Luting agent and technique of cementation

##### a. Luting agent

Because, in most instances, the insertion of posts into endodontically-treated teeth involves the use of a dental cement, it is evident that the type of cement used may also have an influence on the retention of the post in the root canal.

The importance of proper internal adaptation of the post-core foundation cannot be over-emphasized. As Standlee et al (1978) stated: "the less the mismatch between dowel and channel, the greater the retention that is achieved". The aim of the cementing procedure, therefore, is to provide a strong, uncontaminated, cement film of optimal thickness.

Hanson and Caputo (1974) compared the influence of three types of luting agent — polycarboxylate, zinc phosphate and ethyl cyanoacrylate — on the retentive properties of serrated, vented, parallel stainless steel posts of the Para-Post System\*. For all post diameters, the cyanoacrylate cement provided the greatest retention when testing was carried out ninety minutes after cementation. However, long-term (30 days) tests did not reveal any significant difference in retention between the three types of cements.

Experiments by Standlee and co-workers (1978) also concluded that the effect of cement type was statistically insignificant for two of the three types of posts that they tested — namely, the serrated, vented, parallel post cemented in a matched canal and the threaded, parallel posts, screwed into a tapped canal. In the third type of canal, which used an endodontically standardized, smooth-sided tapered post, zinc phosphate cement was found to provide superior retention to polycarboxylate cement; an epoxy cement proved to be the least retentive.

A study by Krupp et al (1979) on post retention, which investigated the use of a glass ionomer cement, was inspired by the reported high strength properties and adhesive characteristics of the cement. The anticipated increase in retention was not realized; no significant increase in retention was noted when results were compared with findings previously reported for zinc phosphate, polycarboxylate and the epoxy resin cements. No suggestion was made to account for this somewhat unexpected finding.

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\*Whaledent International, New York, N.Y., U.S.A.

In an investigation on the factors influencing the retention of posts (Kurer et al, 1977), cast gold posts of different lengths were cemented with zinc polycarboxylate cement of two different powder/liquid ratios. It was noted that, as a general trend, the lower powder/liquid ratio (1.5:1) gave superior results. With a thicker mix (2:1 ratio) difficulty was experienced during attempts to seat the post completely. It was also found that the polycarboxylate cement provided better retention than a "Bowen's resin-based adhesive cement" (Epox)\* when used to cement ten millimetre long posts that were tapered and grooved.

On the evidence currently available, it would appear that, when used properly, the differences in retention afforded by the commonly available cements are clinically insignificant. The choice of the luting agent may, instead, depend on other factors such as cost, setting time, ease of manipulation, and the effect of moisture contamination on its physical properties. Therefore, of the commonly used luting agents, zinc phosphate cement probably remains as the most suitable in most situations. Glass ionomer cement may offer slight advantages in terms of increased strength properties particularly in cases where the root canal is of an irregular shape.

#### b. Technique of cementation

The technique used in the cementation of a relatively long cylindrical or tapered post into a precisely prepared canal is considered because of the potential difficulties that might influence the quality of stress distribution and retention afforded by the post to the final post-core foundation.

Several authors (Perel and Muroff, 1972; Johnson et al, 1976) have stressed the importance of proper internal adaptation of the post-core foundation. This will allow for only a thin, even layer of cement seal

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\*American Consolidated Mfg. Co. Inc., Philadelphia, Pa., U.S.A.

because, in most situations, the cementing medium is the weakest component of the restoration for the endodontically-treated tooth.

Courtade and Timmermans (1971, p.145) suggested that venting the post, by means of a groove or channel, allowed the excess cement to escape, resulting in complete seating during cementation and a more closely fitting post in the root canal. Abdullah et al (1974) recommended that the apical end of a post should be rounded or bevelled with a 45 degree angle to reduce the "plunger action" which prevents the cement from escaping to the sides during cementation.

The cement should be mixed to a correct consistency and in a manner that will provide a slow set. The post should be seated slowly with digital pressure to allow the outflow of excess cement. Too rapid seating of the post-core restoration will lead to a build-up of hydraulic pressure within the root canal and can result in root fracture (Baraban, 1967; Harper and Lund, 1976; Herschman et al, 1976, p.444-475). The use of excessive pressure during placement of posts has also been reported to cause root fractures (Wechsler et al, 1978).

If a post which fits the root canal exactly before cementation is cemented, an unacceptable layer of cement may result between the post and the root. Brunell (1979) suggested a method of avoiding this by slightly widening the root canal immediately before cementation or by the preparation of a vent along the length of the post to reduce the build-up of hydraulic pressure. Because of this, he recommended that "one should not make both the post-core and the crown for simultaneous cementation from the same root canal - root surface impression" since the fit of the crown may be adversely affected by the cementation of the post-core foundation.

#### *Summary*

Parallel-sided posts are more retentive than tapered posts. The angle of convergence of a post should be limited to  $4^{\circ}$ . Serrations or roughening of the post surface increases the retention of the post.

Threaded posts, whether parallel-sided or tapered, which are inserted into pre-tapped root canals are more retentive even though they generate large areas of stress concentration in the root. Increasing the length of the post normally increases the retention of the post; increasing the diameter of the post may lead to some increase in the retention. The type of luting agent used for cementation apparently has little effect on retention of the post. Correct cementation technique is important.

#### 5.4.3 *Obturation of the root canal*

As previously stated (5.2), one of the functions of the post is to complete the obturation of the root canal. Ideally, the post should fit the prepared canal accurately and only a minimal space, occupied by cement, should exist between the apical root filling and the post. It was suggested by Johnson et al (1976) that, if a space existed between the post and the remaining root canal filling, and this space was not completely filled with cement and, if a lateral canal opened into the area, a lateral abscess might develop (Fig. 5.8). Although the likelihood of this set of circumstances existing is slight, it is probably sufficient justification for attempting to complete the obturation of the canal space during placement of the post. This may require that the prepared canal is first filled with the luting agent using a Lentulo spiral, before the insertion of the post into the root canal.

#### 5.5 The core

The function of the core is to replace the missing portion of the coronal tooth structure so that optimal resistance and retention form may be provided for the final restoration. As mentioned in 5.2, the proportion of the coronal preparation occupied by the core is related to the amount of remaining sound, coronal tooth structure. The need for conservation of sound tooth structure is discussed (5.5.1). Other factors pertinent to the core which may influence the quality of the final restoration are discussed in 5.5.2 to 5.5.5.

### 5.5.1 *Conservation of coronal tooth structure*

The primary goal of all restorative procedures should be the conservation of sound tooth structure. It is important to remember that it is the tooth structure remaining in the root that ultimately resists the occlusal loads placed on the coronal restoration and the post-core foundation. Any unnecessary removal of sound, well-supported, coronal dentine further weakens the restored pulpless tooth. There are situations, however, where non-carious, well-supported dentine has to be removed; these include discoloured tooth structure which has failed to respond to bleaching and teeth which have to be realigned in order to achieve satisfactory aesthetics and function.

Traditionally, two methods of root face preparation have been advocated. One, the so-called "roof top" preparation (Charlton, 1965), involved the removal of the remaining tooth substance coronal to the interdental gingival crest (Nicholls, 1963; Charlton, 1965; Kurer, 1967; Kantorowicz, 1970, p.96; Sheets, 1970; Department of Operative Dentistry, University of Sydney, 1972). Principles of this technique have been illustrated in Fig. 5.9. The second method advocates the retention of as much non-carious, well-supported coronal dentine as possible (Baraban, 1967; Perel and Muroff, 1972).

It is neither essential nor desirable to reduce routinely the coronal tooth structure to the height of the gingival margin (Baraban, 1967). The core should replace only that amount of tooth structure that is missing because of caries, fracture, inherent weakness or other restorative reasons; the core, therefore may have a wide variety of shapes, depending upon the amount of remaining sound, coronal dentine. The retention of this sound, coronal dentine has been acknowledged to enhance the resistance and retention form of the post-core foundation (Kafalias, 1969; Perel and Muroff, 1972).

Henry (1977) made use of photoelastic plastic replicas to examine stress distribution. He reported that the type of post-core preparation, which retained coronal tooth structure and thereby possessed a cast core of minimal dimensions, showed the most evenly distributed pattern of stress concentration; there was little, if any, evidence of stress concentration at the level of the shoulder.

Herschman et al (1976, p.452) and Locke (1977) outlined the sequence of steps in the construction of a crown based on a conservative post-core foundation (Fig. 5.10). The first step is the preparation of the endodontically-treated tooth to the approximate form required for the final crown restoration; any carious and unsupported tooth structure and old restorations are then removed. Any minor undercuts are either removed or eliminated by the placement of luting cement, glass ionomer cement or amalgam. A bevel is placed on the occlusal or incisal portion of the preparation to protect the preparation against fracture from the lateral forces of mastication.

#### 5.5.2 *The core and tooth preparation for the final restoration*

Regardless of the method of preparation for the core, it is important that each post-core foundation should on completion, provide optimal retention and resistance form, and a path of insertion for the final restoration. Minimum preparation of either tooth or core should be required following insertion of the post-core foundation (Baraban, 1967; Colman, 1979).

Where possible, the margins of the final coronal restoration should be extended into sound tooth structure at least 2 mm apical to the margin of the post-core foundation. This apical extension allows the crown restoration to act as a "ferrule" and protect the underlying root from longitudinal fracture (Eissmann and Radke, 1976, p.538; Johnson et al, 1976; Baum et al, 1981, p.526), and enhances the retention of the crown

(Colman, 1979) and the resistance form of the crown to rotational forces (Kurer, 1967).

The importance of preparing the abutments to "classical form" was emphasized by Baraban (1967), Kafalias (1969; 1975) and Perel and Muroff (1972). Kafalias suggested that, "when the cast of the prepared arch is examined, it should not be apparent whether the preparations were carried out on non-carious teeth, built-up vital teeth or built-up non-vital teeth".

#### 5.5.3 *The sequence of preparation*

Locke (1977) stated that all teeth being prepared for cast post-core foundations should have the crown preparation carried out before the preparation for the post unless the post hole has already been prepared during the root filling appointment. This sequence of preparation not only removes all tooth material that will not subsequently be required for the crown preparation, enabling the operator to assess more accurately, and remove any weakened sections of dentine in this portion of the core, but it also provides better access to the root canal for the preparation of the canal for post insertion. Having done this, a post-core foundation may be constructed to replace the missing portion of the final crown preparation.

#### 5.5.4 *Retention form*

Occlusal forces may be applied to a post-core foundation from different directions and dislodge it from the root canal. Although the retention of posts is frequently tested in an axial direction, loss of retention caused by tipping and rotational forces probably also has an important role in the clinical failure of post-core foundations. Clinically, the loss of retention under torsional forces often results in an almost imperceptible movement as compared to the more marked withdrawal of a post under tension. This slight, frequently undetected movement can be the beginning of the failure of the post. Since the

resistance to displacement of the eccentric-type posts to torsional forces is much smaller than the resistance to tensile forces applied in an axial direction (Ruemping et al, 1979), the provision of resistance form against torque has become a major consideration in the design of the root face preparation.

Kafalias (1969) suggested that resistance to displacement by tipping or vertical forces is provided principally by a post of adequate length. Resistance to displacement by rotational forces may be provided in one of several ways; these are illustrated in Fig. 5.11:

- a. Sound coronal dentine is retained as part of the post-core foundation (Fig. 5.11,a)
- b. The labial and lingual planes of the root face may be prepared at an angle and a groove included to minimize rotation of the post-core foundation (Fig. 5.11,b)
- c. If the root canal is oval in cross section, maintenance of this shape provides resistance to rotational forces (Fig. 5.11,c)
- d. A square box preparation sunk into the root face at the entrance to the root canal to a depth of two millimetres provides excellent retention. Care should be taken not to weaken the sides of the root (Kafalias, 1969) (Fig. 5.11,d)
- e. Short auxiliary pins attached to the lingual aspect of the post-core foundation may be used to provide a guide to seating, to prevent rotation of the post-core foundation in the root canal, and to increase retention and lateral stability (Courtade and Timmermans, 1971, p.145-146) (Fig. 5.11,e).

It was suggested by Charlton (1965) that rotational forces should, ideally, be resisted by a vertical plane, in line with the "radius" of the root face, which is parallel to the long axis of the root (Fig. 5.12). Charlton compared this method with some of those described previously and illustrated in Fig. 5.11. The inclined planes and the V-shaped groove

Fig. 5.11,b) used in the conventional "roof top" preparation was considered likely to lift the post out of the root canal. Because of the mechanical advantage which force  $F$  has over resistance  $R$  (Fig. 5.12,c), an oval post, like the one shown in Fig. 5.11,c was considered likely to provide inadequate resistance against torsional forces.

#### 5.5.5 *The fabrication of the post-core foundation and the final restoration*

A number of authors (Rosen, 1961; Nicholls, 1963; Skurnik, 1965; Kafalias, 1969; Perel and Muroff, 1972; Brunell, 1979; Colman, 1979) have advocated that the post-core foundation and the final restoration should be prepared, fabricated and cemented in two distinct steps. Many reasons have been given to support this suggestion:

- i. If wear, fracture, recurrent caries, excessive recession of the gingiva or periodontal surgical operation necessitates remaking of a crown, the procedure is much simplified by not having to remove and replace the post-core foundation. In addition, the risk of root fracture or of perforation associated with attempts at removal of the post are avoided.
- ii. If, in the future, the restored tooth is required as an abutment for a fixed or removable partial denture, or a splint, the coronal portion may be prepared without endangering the root.
- iii. The alignment of abutment preparations for a fixed bridge is simplified, without the need to consider also the direction of the proposed post canal in one or more of the abutment teeth. Perel and Muroff (1972) stressed that the post should lie in the direction of the long axis of the tooth even if the core may have to deviate from this because of the design of the retainer.

- iv. The retention and stability of the post can be tested critically and improved, if necessary, prior to the construction of the crown or other prosthesis.
- v. The crown preparation can be made more easily and more precisely with a core present to provide a frame of reference during the preparation of shoulder, chamfer or other finishing line.
- vi. Separate post-core foundations and crowns result in reduction in the size of the castings and may reduce the tendency for porosity exhibited by large castings.
- vii. It is more difficult to obtain a positive seating of the post-core foundation and the cast crown simultaneously. If the post-core foundation is constructed by the indirect method, the crown restoration should not be made from the same root canal-root face impression (suggested by Wax in Herschman et al, 1976, p.462; Gilmore et al, 1977, p.358-366). Brunell (1979) warned that any inaccuracy in the fit of the post-core foundation often results in an exaggerated marginal discrepancy in the coronal restoration. Even if optimal film thickness is obtained during the cementation of the post-core foundation, the thickness of the cement around the margin of the crown is increased by the same amount. Therefore, the post-core foundation should be cemented first; routine impression procedures may then be employed for the fabrication of the final coronal restoration.

Fig. 5.1 Components of a post-core foundation.

Fig. 5.2 a. "Splitting" of a wooden tent pole is prevented by the addition of a metal ferrule (f).  
b. A pulpless tooth requires similar ferrule-like protection against fracture.

(From Eissmann and Radke, 1976, p.540)

Fig. 5.3 Prophylactic "reinforcement" with a prefabricated metal post. The post is only supported by the luting cement in the coronal portion (arrowed).

(From Colman, 1979)

Fig. 5.1; 5.2; 5.3

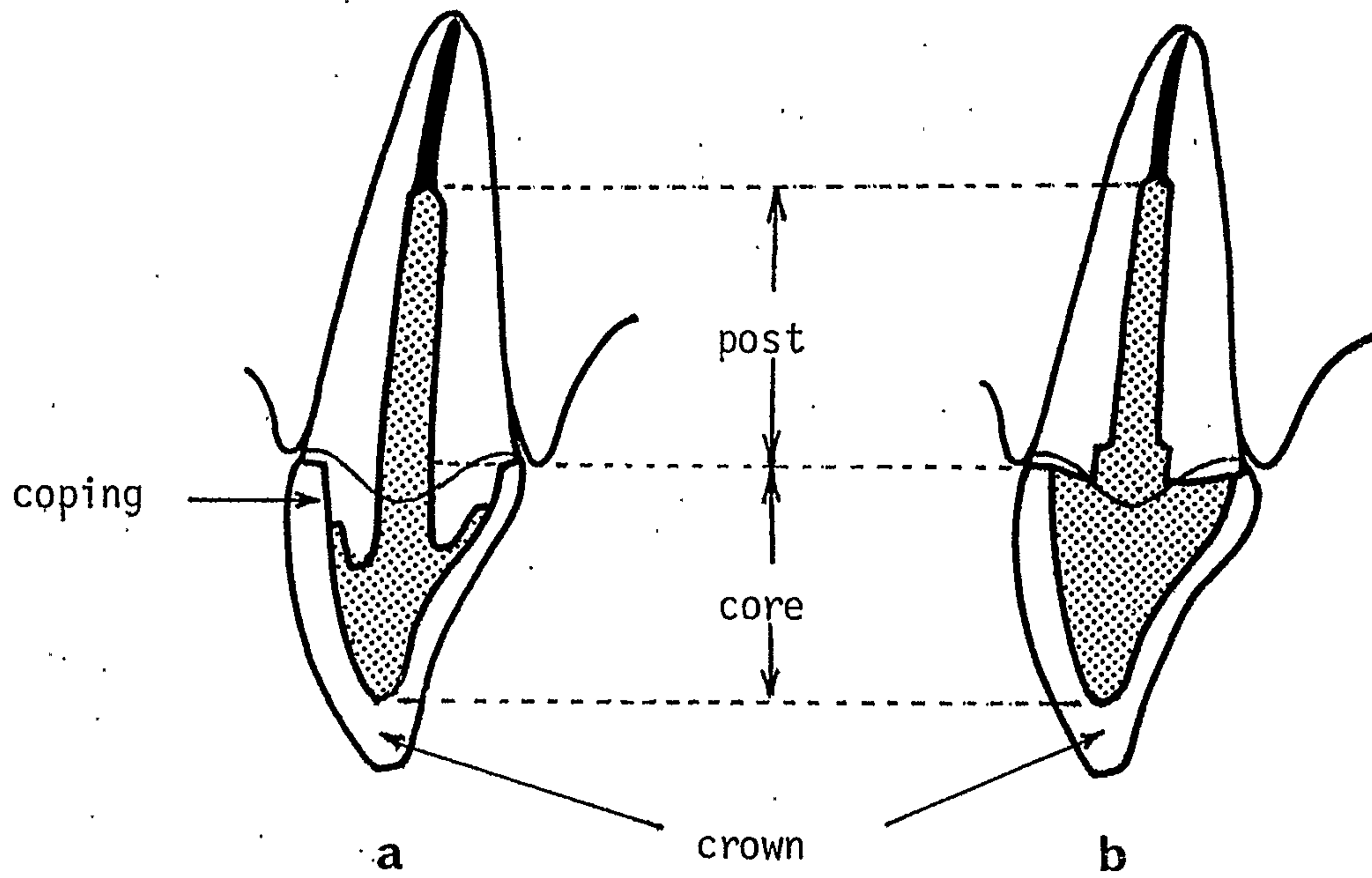


Fig. 5.1

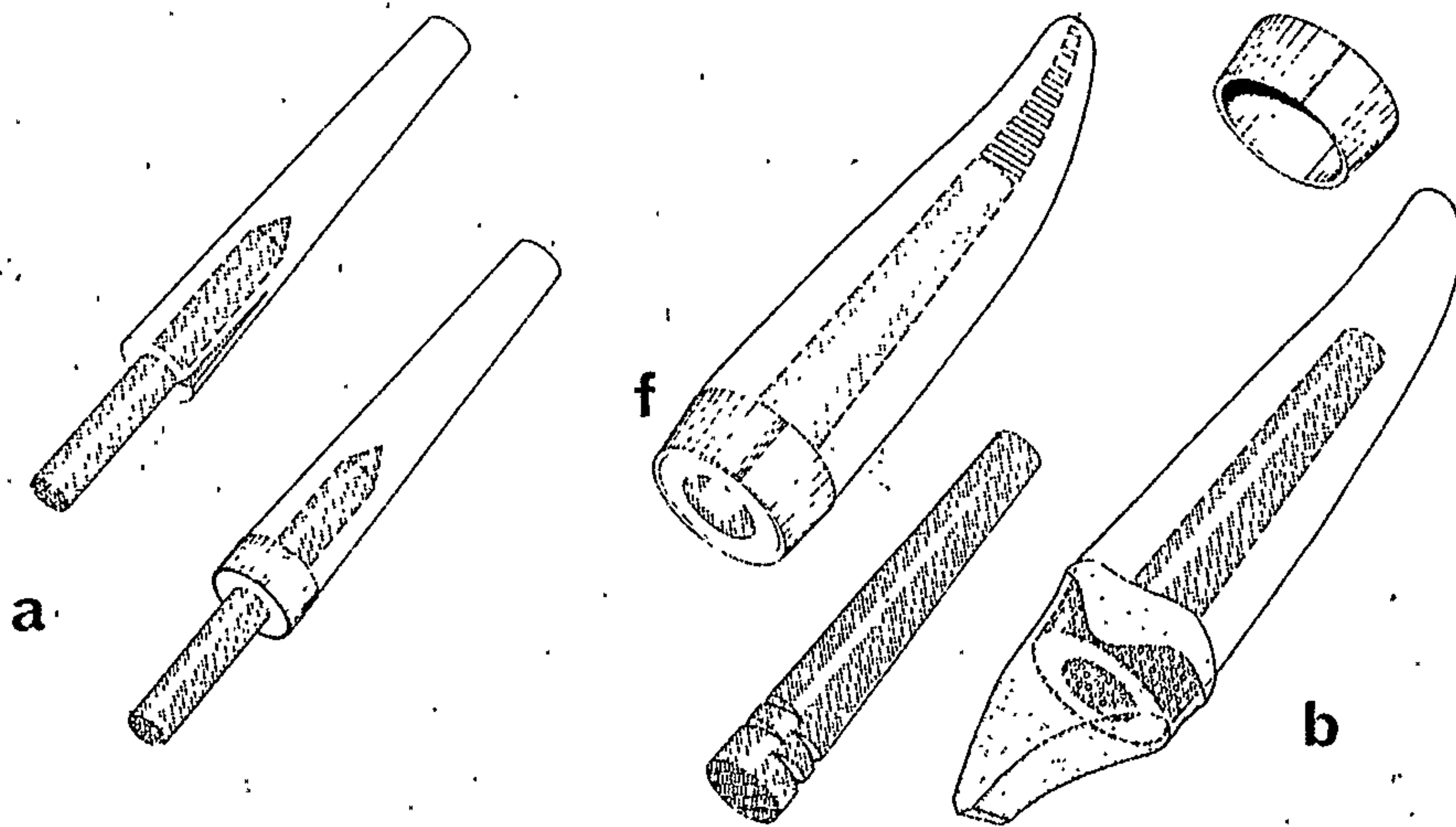


Fig. 5.2

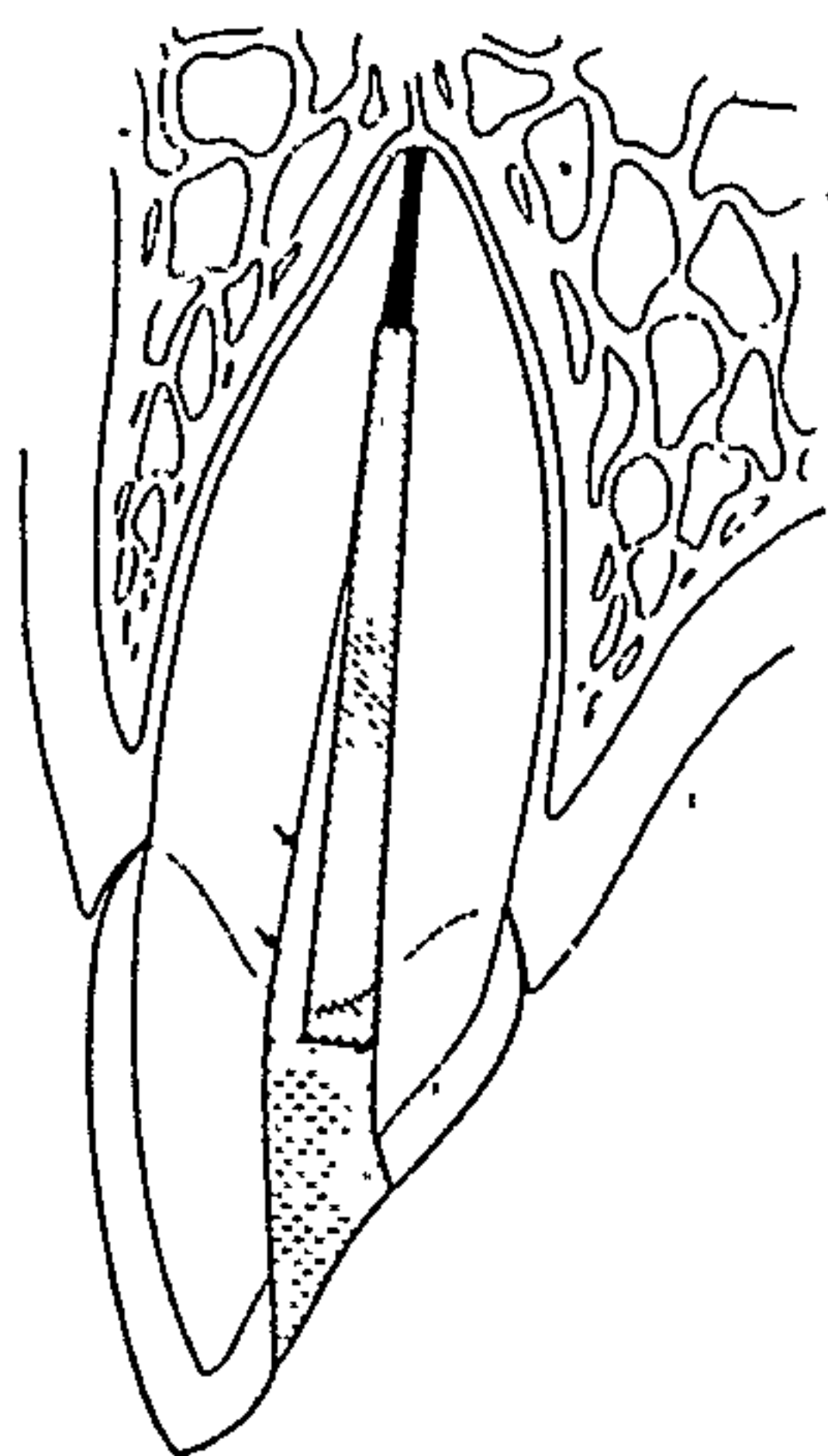


Fig. 5.3

Fig. 5.4 For legend refer to 5.3.22.

Fig. 5.5 Placement of a post-core foundation prior to the construction of the fixed bridges may have prevented the fracture of these pulpless abutment teeth.

(From Colman, 1979)

Fig. 5.6 Diagram illustrating some variations in the design of prefabricated posts.

- a. tapered (vented)
- b. parallel (serrated)
- c. threaded, tapered
- d. threaded, parallel.

(From Caputo and Standlee, 1976)

Fig. 5.4; 5.5; 5.6

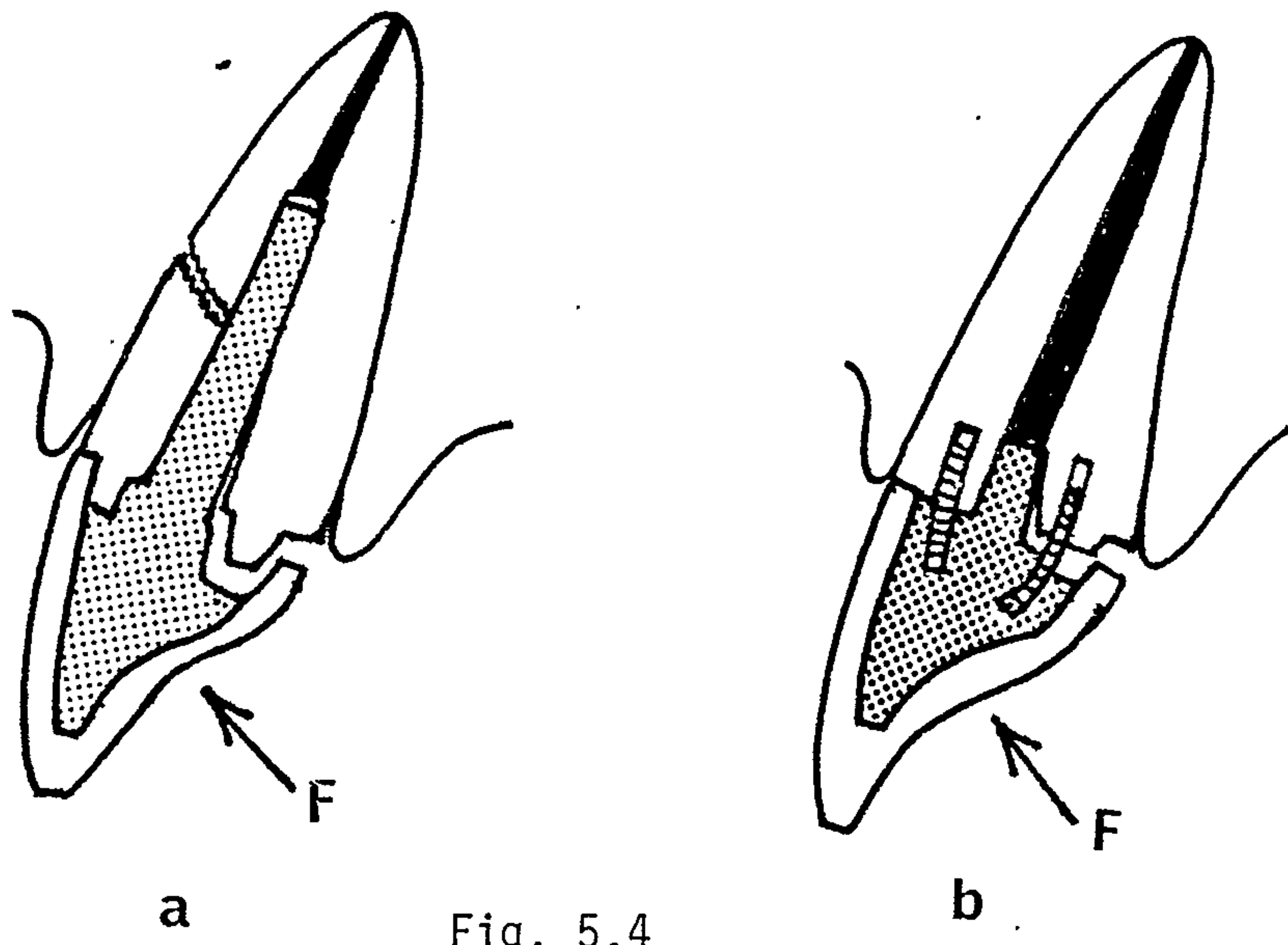


Fig. 5.4

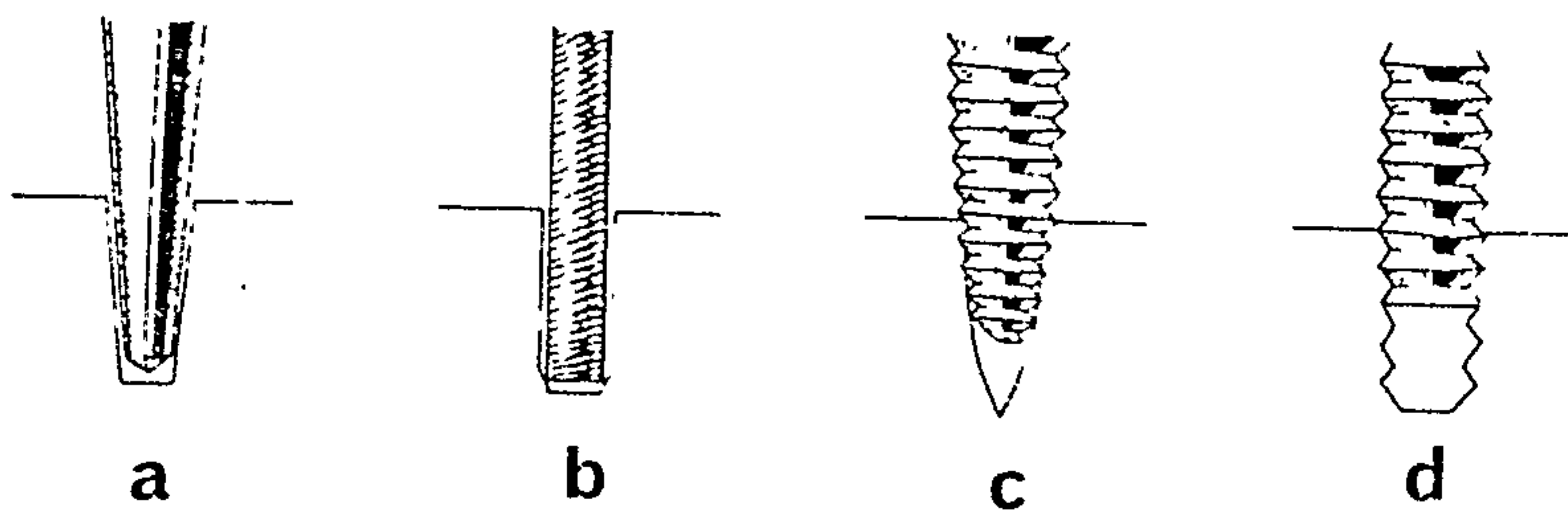
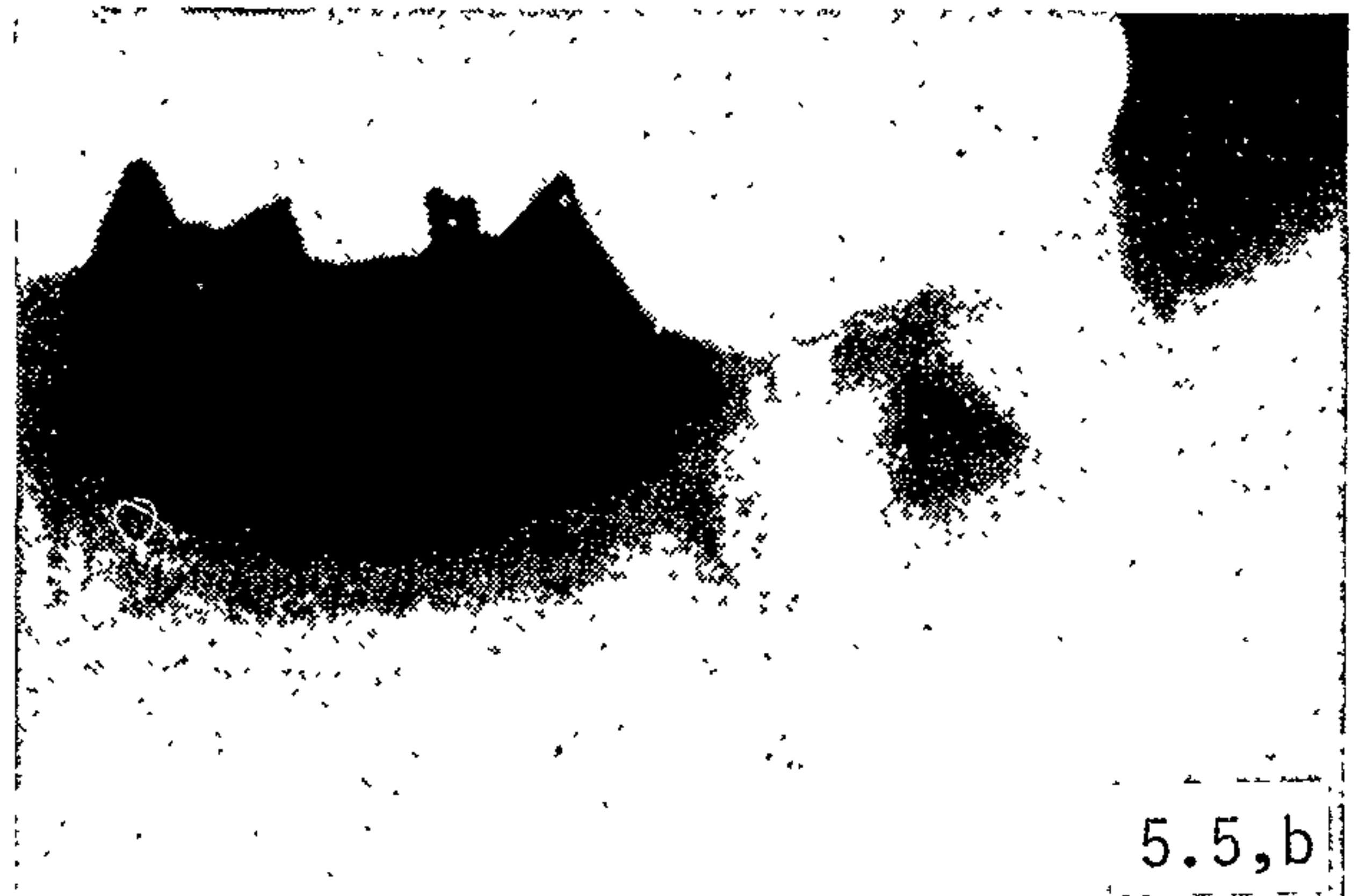


Fig. 5.6

Fig. 5.7 For legend refer to 5.4.11.

Fig. 5.8 Clinical failure associated with the incomplete obturation of the root canal space.

a. Cast post-core foundation and crown had been placed seven years previously. Clinical symptoms resembled that of an acute periapical abscess.

(courtesy of E. H. Jones)

b. Cast gold post-cores and crowns had been in place for three years when patient presented with a draining sinus in the labial mucosa. Apical seal in the right maxillary lateral incisor had been disturbed. Although there was an area of radiolucency around the apex of the lateral incisor, a gutta percha exploratory point located the origin of the sinus tract — the space between the apical seal and the apical end of the cast gold post in the central incisor.

Fig. 5.9 "Roof-top" post-core preparation.

a. Removal of all tooth structure coronal to the interdental gingival crest.

b. Mesio-distal cross-sectional view of the preparation.

c. Incisal view of post-core preparation.

A. anti-rotational notch on the labial surface of the root canal wall.

B. the angle between the labial and palatal incline planes is rounded.

Fig. 5.7; 5.8; 5.9

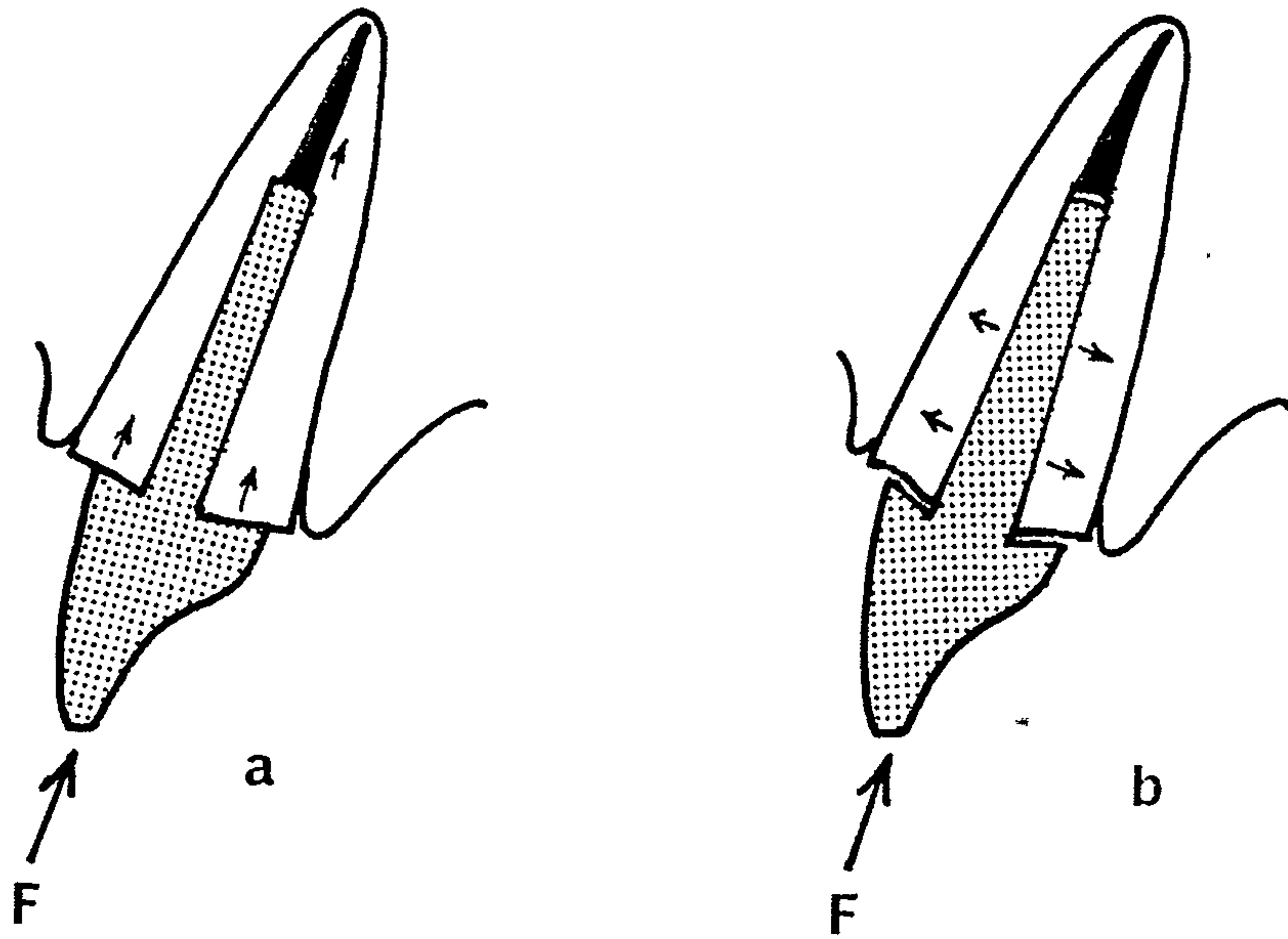


Fig. 5.7

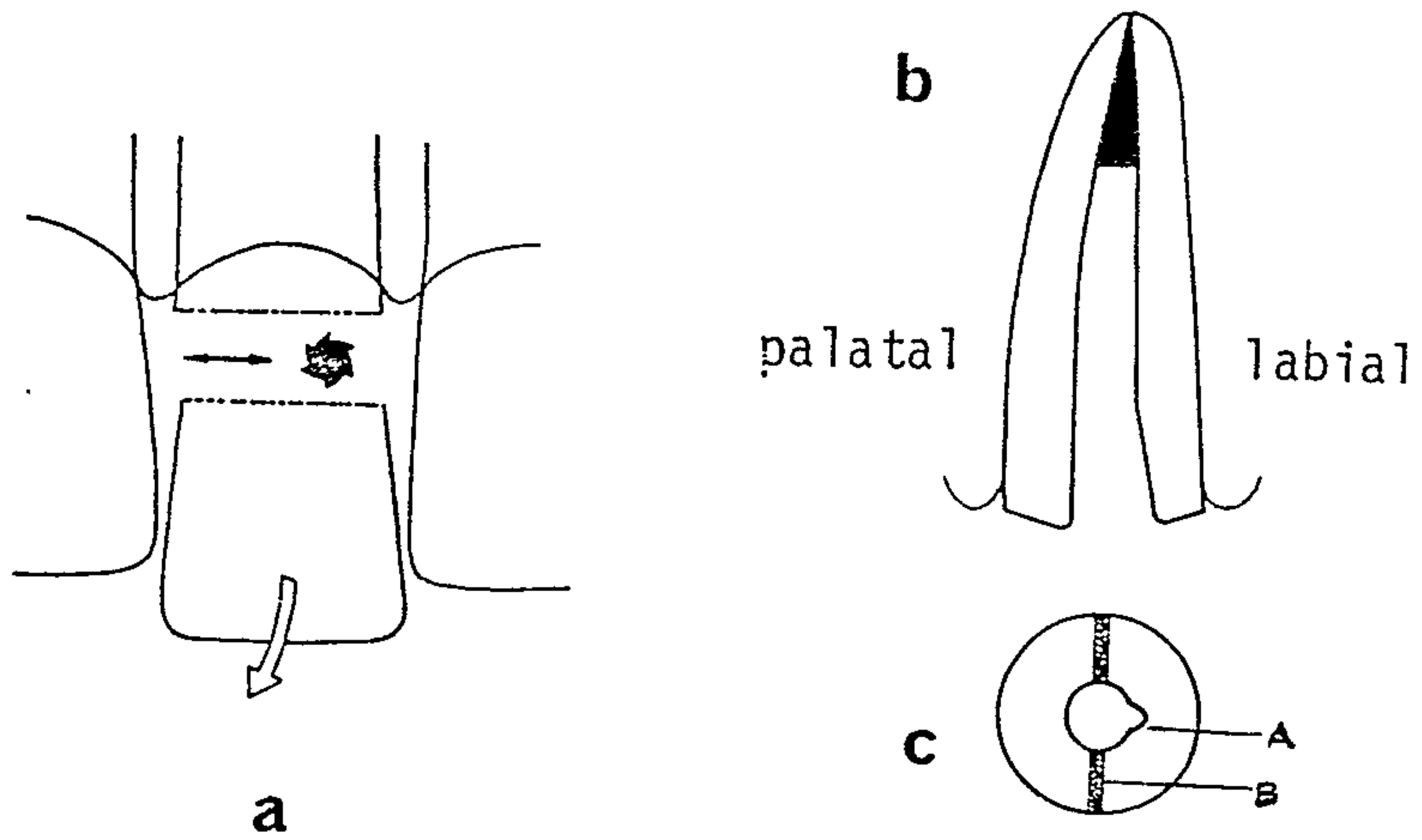
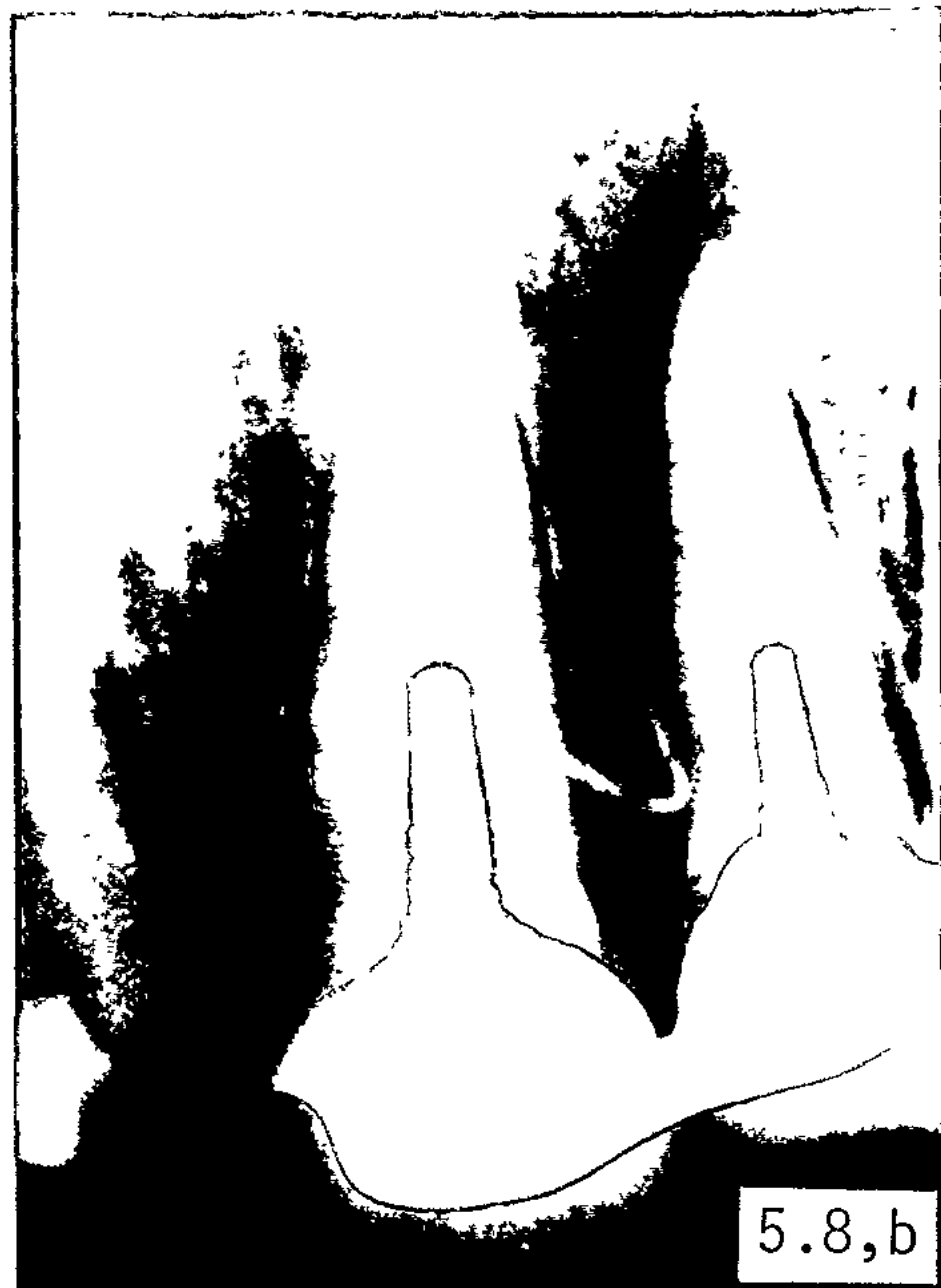
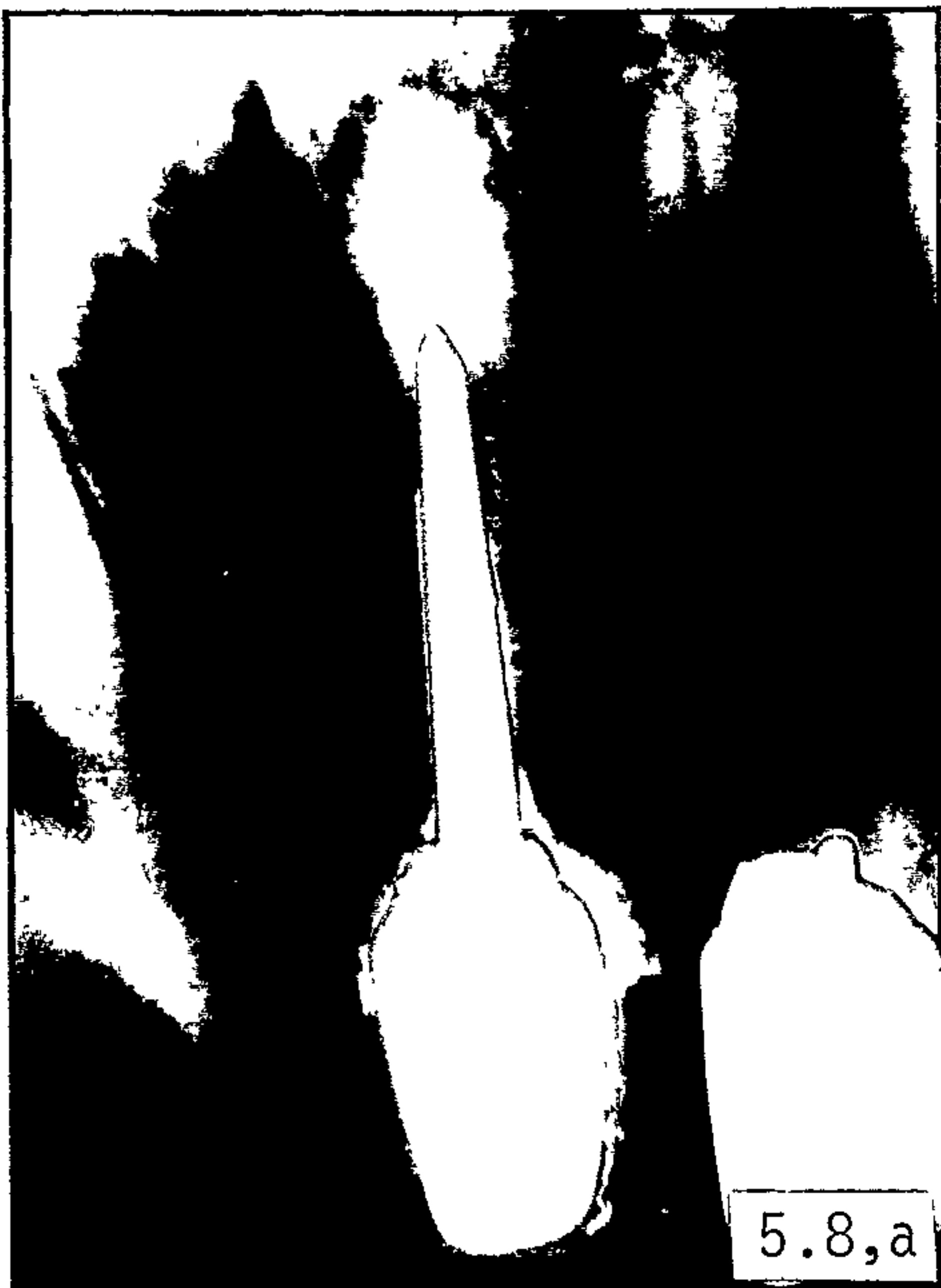


Fig. 5.9

Fig. 5.10 For legend refer to 5.5.1.

Fig. 5.11 For legend refer to 5.5.4.

Fig. 5.12 Resistance to displacement by rotational forces.

(Charlton, 1965)

a. Rotational forces should be resisted by a flat plane in line with the "radius" of the root face and parallel with the long axis of the root.

b. An inclined plane, as used in the "roof top" preparations for post-core foundations, will tend to lift the post out of the root canal.

c. Because of the mechanical advantage which force  $F$  has over resistance  $R$ , an oval post was considered likely to provide inadequate resistance against torsional forces. In addition, if the post is tapered, rotational forces will tend to lift the post out of the root canal.

Fig. 5.10; 5.11; 5.12

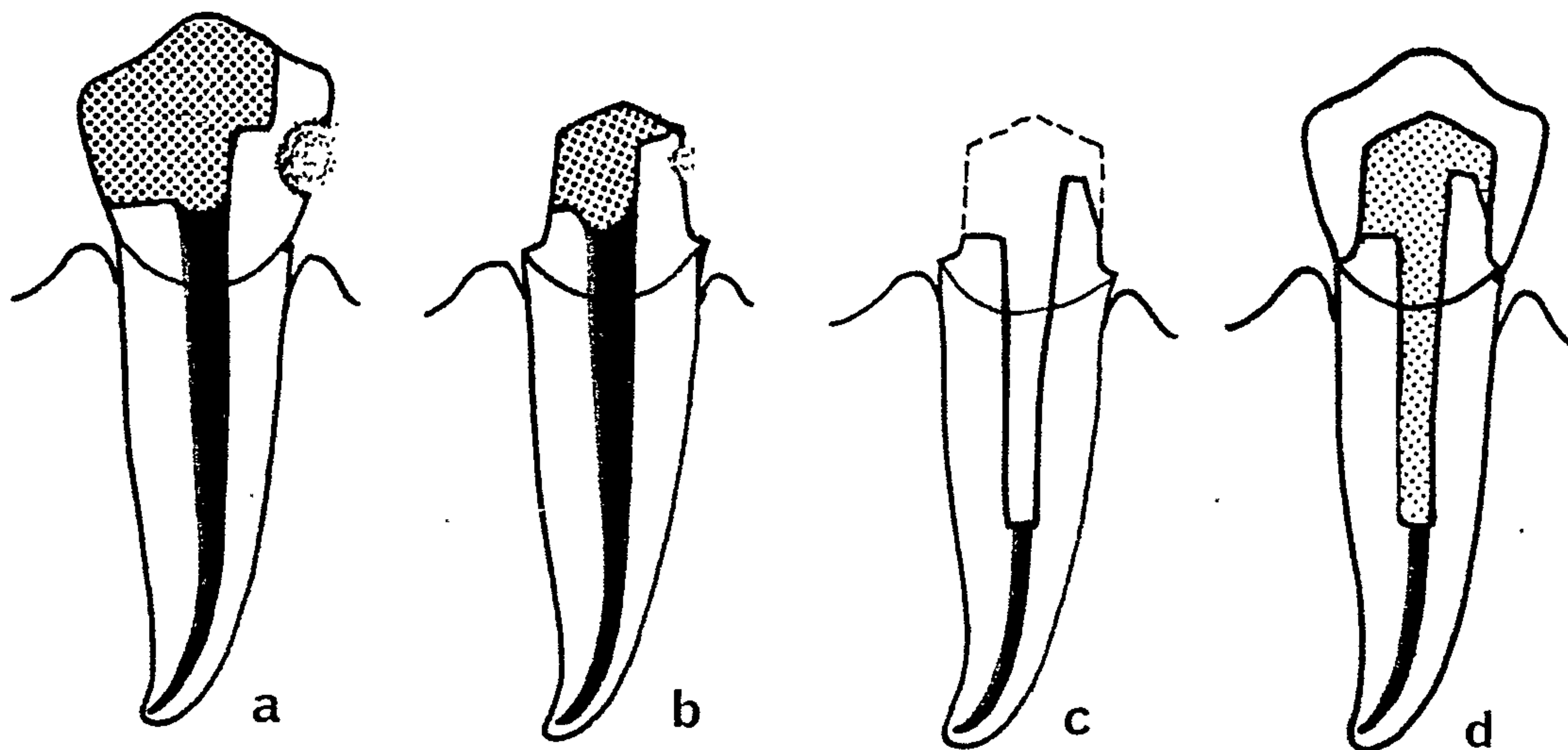


Fig. 5.10

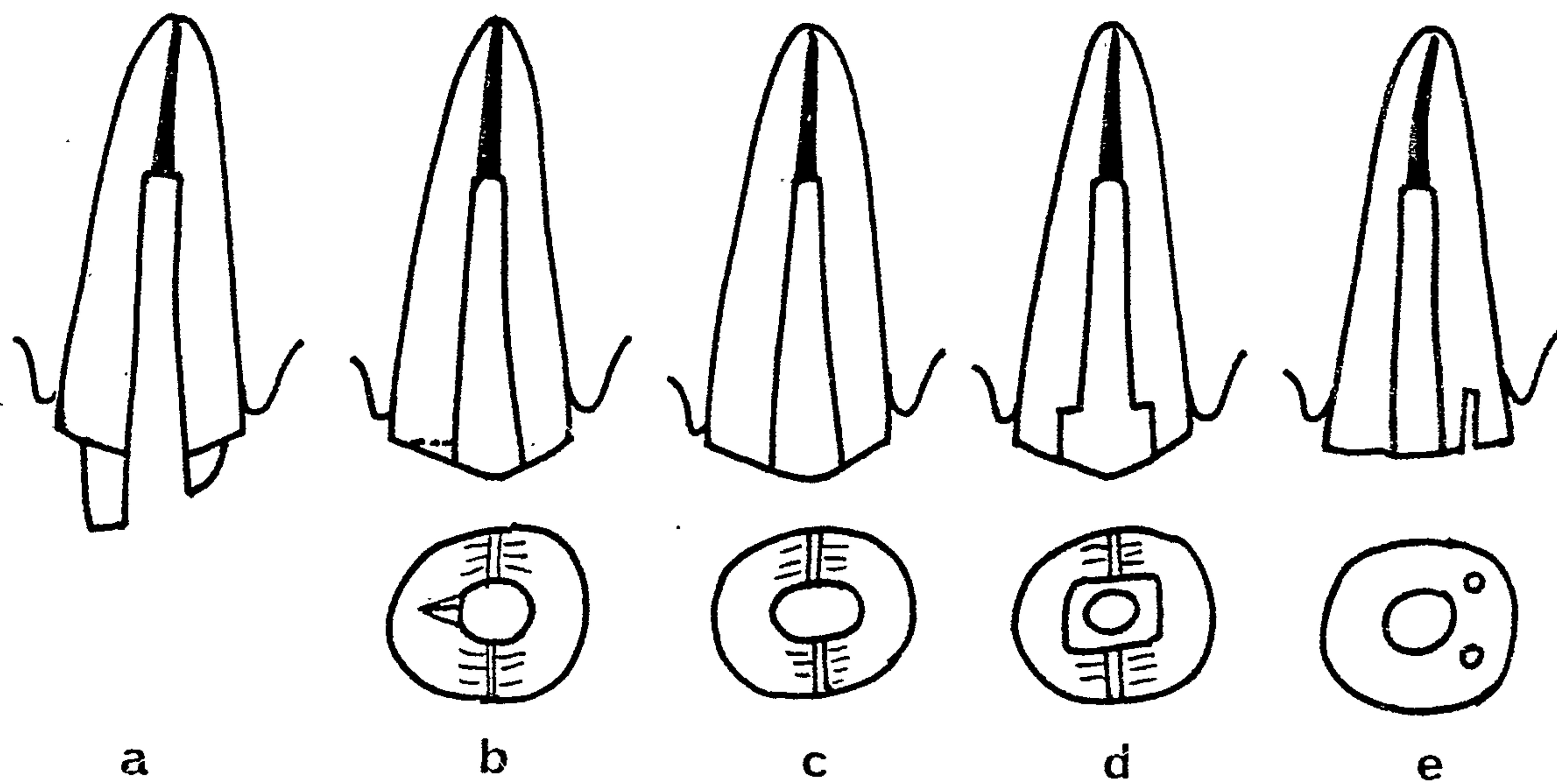


Fig. 5.11

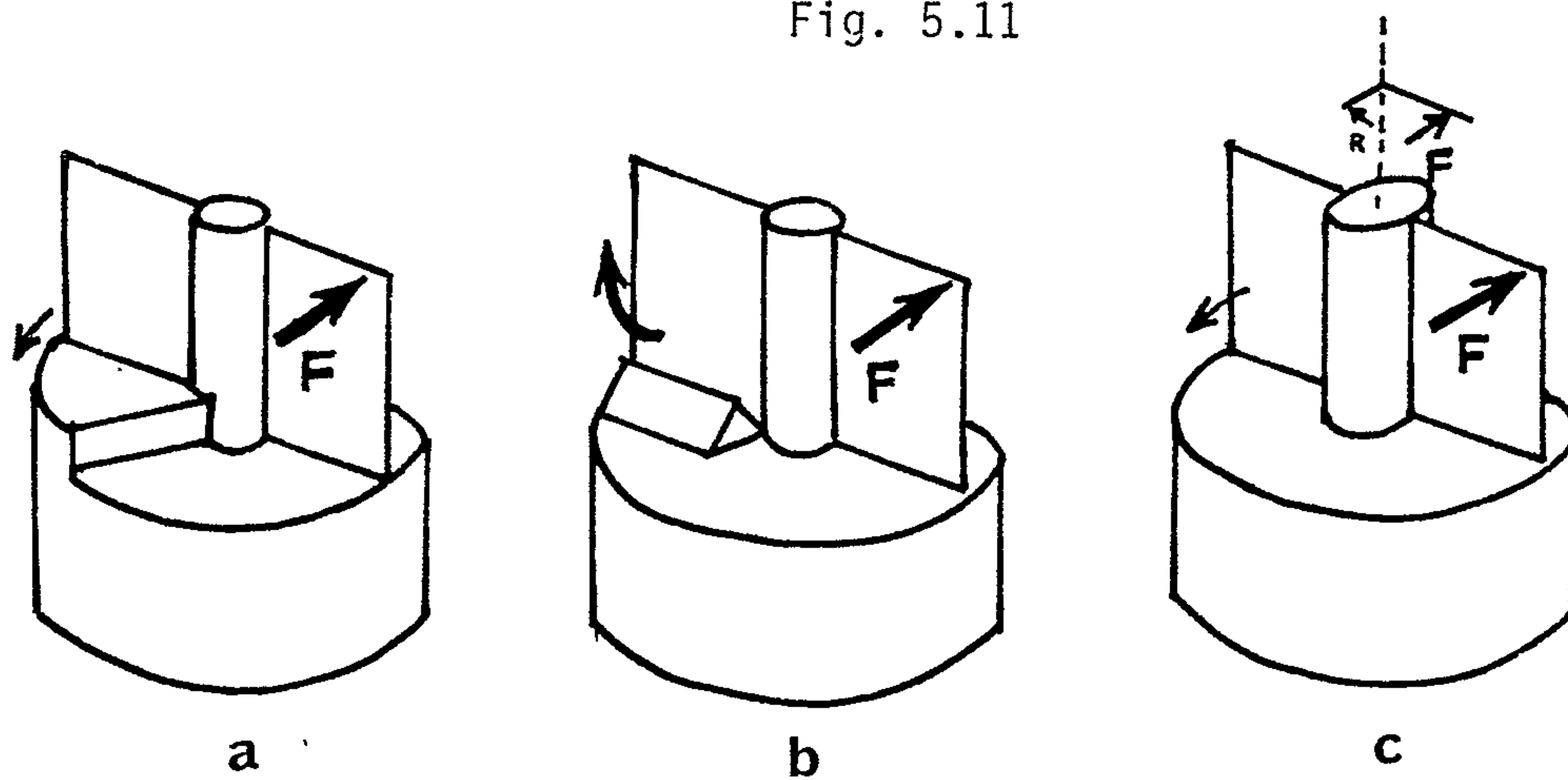


Fig. 5.12

CHAPTER 6MATERIALS FOR THE RESTORATION OF ENDODONTICALLY-TREATED TEETH

- 6.1 Introduction
- 6.2 Materials for use as posts
- 6.3 Materials for use as core and/or restoration
- 6.4 Gold alloys
  - 6.4.1 Conventional casting gold alloys
  - 6.4.2 High-fusing ceramic gold alloys
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- 6.6 Nickel-chromium alloys
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### 6.1 Introduction

Before an assessment is made of the different post systems, pin systems and methods of core construction, it is appropriate to examine the materials that might be used for the restoration of an endodontically-treated tooth. The choice of material may affect many aspects of the techniques associated with restoring the tooth, the cost of the treatment, the quality of the final restoration and, ultimately, the prognosis of the treated tooth.

A detailed consideration of every material that could be used for the restoration of an endodontically-treated tooth would be an enormous task, and is beyond the scope of this treatise. An attempt is made to consider only those factors that are considered particularly relevant to

the restoration of endodontically-treated teeth. The properties of the materials, that may be either desirable or essential for the construction of the post, the core and the restoration, are discussed. These properties are used as criteria to assess the suitability of the different materials that have been used, or suggested, for the various restorative purposes.

For many years, the dental profession has made extensive use of the noble metal alloys for the construction of posts, cores and restorations for pulpless teeth. Although these materials possess many of the desirable qualities and have been clinically successful, the clinical and laboratory procedures involved can be complicated and time-consuming, especially for multi-rooted teeth in the posterior region of the mouth. Consequently, materials suitable for direct application have been advocated for the restoration of endodontically-treated teeth because of the ease of their use and the saving in chairside and/or laboratory time. Amalgam was first advocated for this purpose in the late 1950's; more recently, composite resin was recommended. Although new techniques and materials for direct application have been introduced, the time-proven cast gold post-core foundation has remained the standard by which others have been measured. Because of the substantial increase in the price of noble metals in recent years, there is an increasing interest among the profession in the search for a low-cost alloy as a satisfactory substitute for gold. The use of semi-precious alloys and base metal alloys for the construction of posts and cores has also been suggested.

The individual materials are discussed in 6.4 to 6.14; as stated previously, this discussion is limited to the properties and qualities of the materials considered to be particularly relevant to the restoration of an endodontically-treated tooth.

Some materials are commonly used for one purpose — for example, for the post or for the core — others are frequently used in several parts of the restoration. Although most materials are stable on their own, some, when combined, or in contact with another material, may react unfavourably or even break down rapidly in the oral environment. In addition, certain procedures in the construction of a post-core foundation may have detrimental effects on the properties of an otherwise satisfactory material. For these reasons, the materials available for the construction of the post, the core and the restoration, and the relatively large number of possible combinations of these materials are considered.

## 6.2 Materials for use as posts

As defined in the previous chapter (5.1), the functions of a post include the distribution of functional and non-functional stresses to the supporting tooth structure, retention of the core foundation and the restoration, and the obturation of the root canal space. If the post is to perform these functions satisfactorily in the oral cavity, the materials used for its construction must possess certain physical and mechanical properties.

The material or combination of materials used must adequately withstand the applied loads. The four main types of stresses present on restorative components in the oral cavity are illustrated in Fig. 6.1. Although the strength of the materials is often expressed in terms of their resistance to compressive or tensile forces, their resistance to shear stresses and torque can, to a certain extent, be predicted from their compressive or tensile strength values (Mahler and Mitchem, 1964; Phillips, 1973, p.326). It is evident, if the post is to distribute occlusal stresses to the root, that the post itself must be sufficiently strong to withstand these stresses without any appreciable deformation

or fracture (Harty and Leggett, 1972). Compressive strength values are useful for comparing materials that are brittle and generally weak in tension. The tensile strength, however, gives a better indication of the ability of a ductile material to withstand a relatively heavy load. The ultimate tensile strength, however, may not be the most useful guide because, before failure, permanent deformation will have taken place; permanent deformation is generally unacceptable in a dental restoration. During mastication, a combination of shear stresses and torque, in addition to compressive and tensile stresses, is often exerted on the restoration, the core and the post; this is acknowledged in the design of anti-rotational preparations for the core foundation. Threaded posts, which have insufficient strength, have been known to fracture during insertion (Durney and Rosen, 1977) and during function in the oral cavity (Messing and Wills, 1973). Although some materials may be able to resist a static load adequately, their abilities to withstand an impact force could be somewhat different. If the jaws were to close suddenly upon a hard object such as a piece of metal or bone that was introduced accidentally with a mouthful of food, the stresses applied to the restoration would be much greater than that normally present during mastication. A similar heavy blow to an endodontically-treated anterior tooth could clearly have serious consequences. Ideally, therefore, the impact strength of all materials used for the restoration of endodontically-treated teeth should be sufficiently high to prevent failure in these circumstances.

The modulus of elasticity of an alloy is an indication of the degree of rigidity or flexibility that might be expected in the cast structure; the higher the value for the modulus of elasticity, the more rigid the structure. In order to support the final restoration, the post and the core foundation must also be rigid enough to resist bending

under load. A material with a reasonably high modulus of elasticity is therefore desirable. For the same reasons, if a material distorts readily under stress, it is generally not suitable for use in a permanent restoration.

It was shown in a previous chapter (2.4) that an endodontically-treated tooth is not entirely devoid of metabolism, although the rate of ionic exchange between the periodontal ligament and the root canal tends to be somewhat less than that of a vital tooth. Consistent with all restorative dental materials, the materials used for post construction should be readily tolerated by the oral tissues. It is desirable, therefore, that materials used as posts should be resistant to tarnish and corrosion. Tarnish is a surface discolouration or even a slight loss or alteration of the surface finish or lustre on a metal (Phillips, 1973, p.289-290). It is often the forerunner of the more serious condition of corrosion which is an actual deterioration of the metal by reaction with its environment. The exact phenomenon of corrosion is often complex and not completely understood (Phillips, 1973, p.290). Corrosion may not only effect the appearance of a restoration, the physical properties of the alloy may be altered to such an extent that the appliance may be weakened or may fail. The accumulation of corrosion products from a cemented post in the root canal may cause undesirable reactions in adjacent soft tissues (Arvidson and Wróblewski, 1978); furthermore, root fractures resulting from corrosion of the posts have been reported and have led to the ultimate loss of pulpless teeth (Angmar-Månsson et al, 1969; Rud and Omnell, 1970; Dérand, 1971; Petersen, 1971).

An important feature of biocompatibility that should be considered is hypersensitivity since many metals, including nickel and cobalt, are known sensitizers (Williams and Cunningham, 1979, p.253 and 281). Some

alloys may contain small quantities of toxic metals such as beryllium. The danger to the patients of using these alloys is probably minimal but care should be exercised in the handling of these materials during the different stages of fabrication of the post-core foundation and the restoration.

Tooth structure and restorative materials in the mouth expand when warmed by hot foods and beverages and contract when exposed to cold substances. Such expansions and contractions may result in the breaking of the marginal seal of a restoration particularly if the difference in the rate of thermal expansion or contraction between the tooth and the restoration is great. The coefficient of thermal expansion of materials used for the post, the core and the restoration, should, ideally, be as close to that of tooth structure as possible.

Sometimes it is difficult to carry out dental procedures within the restricted space of the oral cavity. Visibility and access to the teeth may be restricted by the lips, cheek and tongue and the presence of moisture can further complicate the procedures. If optimal properties of a material are to be achieved consistently, the technique should be relatively simple to carry out and applicable in the mouth. For example, a material with a very slow setting rate or one which is highly susceptible to moisture contamination during setting will frequently be unsuitable for direct clinical use. Alloys with very high melting points require special equipment and investment materials for their handling; their use may be impractical for this reason. The materials for post construction should be relatively inexpensive and readily available. Any material that is expensive, or involves complicated clinical and laboratory procedures or expensive equipment increases the total cost of the treatment; this may limit the use of the material or technique.

### 6.3 Materials for use as core and/or restoration

The function of the core is to rebuild the clinical crown of the tooth sufficiently to provide retention form and resistance form for the final restoration; it also serves to distribute occlusal stresses to the root through its connection with the post. The restoration completes the reconstruction of the clinical crown and protects the remaining tooth structure from fracture.

Ideally, the margins of the final restoration should be established in sound tooth structure, gingival to the margin of the post-core foundation. In these cases, although it is desirable for the core foundation to adapt closely to the root face preparation, some clinicians (Pinkley and Morris, 1974; De Domenico, 1977) have stated that, provided the coronal restoration fits the prepared tooth accurately, the marginal adaptation of the core foundation is not as critical. However, in certain clinical situations, it may be more practical or more conservative of overall tooth structure for part or all of the margin of the coronal restoration to be prepared in the core foundation material rather than tooth structure (Herschman et al, 1976, p.451-455; Colman, 1979). Sometimes, because of the high cost of the complete course of treatment — the root canal therapy, the post-core foundation and the final restoration — the core foundation has to be left in a form where it functions as a "semi-permanent" restoration. For these reasons, the properties that are normally considered important to the clinical performance of a material as the final restoration may also be applicable for a material used as a core in the restoration of the endodontically-treated tooth. The requirements of materials that are used for the core foundation or for the final restoration are therefore considered together in this discussion.

In order to support the coronal restoration, the materials for the core foundation must have good mechanical properties. The distribution

of forces within the oral cavity is highly complex, including compressive, tensile and shear components, and these forces can be large in magnitude (refer 6.2). The materials used for the core foundations and restorations should be strong enough to resist these stresses without deformation or fracture. The volume of material required for a core foundation is usually large compared to the dimension of a post. Thus, materials that are weak in thin sections and are not suitable for post construction may be useful as a core material. The impact resistance, the hardness and abrasion resistance of a material may also effect the clinical performance of a restoration. Although certain parts of a restoration may not need to be very rigid, it is usual to assume that a material with a higher elastic modulus is preferable (Williams and Cunningham, 1979, p.238-239).

The general condition within the oral cavity to which the material is subjected is influenced by a number of factors such as saliva, diet, general physiology, temperature changes and the activity of the oral flora; localised changes may also arise from the deposition and accumulation of plaque and calculus. As Von Fraunhofer (1975, p.332) pointed out, "the oral cavity constitutes an aggressive environment, containing some 1000ppm of chloride, which can vary widely with the individual and through many intrinsic and extraneous factors". Furthermore, any restorations or appliances placed in the oral cavity are subjected to masticatory and other functional forces. The restorative material should be insoluble in oral fluids. Metallic restorative materials used for permanent restoration should be resistant to tarnish and corrosion. Corrosion may not only affect the appearance and possibly the mechanical properties of the restoration, but the corrosion products may also elicit an undesirable reaction in the adjacent soft tissues. The ability of a material to take and retain a

highly polished surface is considered important to the comfort and the periodontal health of the patient.

The importance of biocompatibility, with particular reference to hypersensitivity and toxicity has already been discussed in 6.2. Since the margins of the restoration, and sometimes the margins of the core, are exposed to oral fluids, the ability of the restorative material to adapt closely to the tooth structure plays a significant role in the clinical success of the restoration. Marginal leakage at the tooth/restoration interface in a tooth with a vital pulp may be responsible for a number of clinical conditions including recurrent caries, post-operative pain, tooth discolouration, hypersensitivity, and pathosis of the pulp (Phillips, 1973, p.52). A pulpless tooth is more vulnerable to recurrent caries because of its inability to detect a developing carious lesion (Rosen, 1961; Schilder, 1976, p.638). Different factors may influence the tendency for marginal leakage around different restorative materials; these factors are considered in the following discussion as they relate to the use of the particular material.

The setting rate of a restorative material has significant effect on its practical application. One of the claimed advantages of using composite resin as a core material is that the preparation of the coronal restoration may be carried out at the same appointment, soon after its placement (Baraban, 1972). However, there is doubt whether the same procedure should be used with an amalgam core foundation because of its slower setting rate. Because, most commonly, the aim of restoring an endodontically-treated tooth is to render it a functional and aesthetic member of the dental arch, the aesthetic properties of a restorative material may be of great importance, particularly in the anterior region of the mouth. To many patients, this is undeniably the most important consideration in the choice of a restorative material.

Ideally, a restorative material should be capable of matching tooth structure in colour, texture and translucency.

The use of the different types of materials in the restoration of endodontically-treated teeth are discussed individually in sections 6.4 to 6.14. The potential of these materials for use as posts, cores or final restorations is considered by comparing their properties with those required of a material for use in the particular parts of the restoration.

Since it is not uncommon to find that the post, the core foundation and the final restoration; are of different materials, the possible effects of combining different materials is considered in 6.15.

#### 6.4 Gold alloys

Several types of gold alloys are commonly used in restorative dentistry:

- i. Conventional casting gold alloys — Types I to IV\* (6.4.1)
- ii. High-fusing ceramic gold alloys (6.4.2)
- iii. Wrought gold alloys (6.4.3)

##### 6.4.1 *Conventional casting gold alloys*

There are four types of conventional casting gold alloys. Of these, the type I (soft) and the type II (medium hardness) alloys are generally not recommended for restorations which are likely to be subjected to heavy occlusal loads during mastication (Phillips, 1973, p.389). The tensile strength and the hardness of the type III (hard) casting gold alloys are higher than those of the type I and type II alloys. The type III alloys are amenable to age hardening, although a marked decrease in ductility usually takes place. Although this loss in ductility may not be desirable in a restoration because "burnishing" of the margins is

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\*Also referred to as Types A - D.

sometimes needed to optimize the final marginal adaptation, hand-finishing or burnishing procedures are seldom performed on a post-core foundation. Heat treatment alters the hardness, the proportional limit and the percentage elongation of an alloy. However, the elastic modulus, or the rigidity of the cast alloy, remains basically constant (Craig and Peyton, 1975, p.317). Because the strength and the ductility of the type III alloys can be modified to a certain extent, by simple heat treatment procedures, to suit the requirements of the particular case, they have largely replaced the type I and type II alloys for general usage. The type III alloys are indicated for crowns or bridge abutments which are subjected to high stresses during mastication. Their high noble metal content (above 78 per cent) imparts excellent tarnish and corrosion resistance to these alloys.

The type IV (extra hard) gold alloys are the hardest and the strongest of the casting gold alloys and have been recommended for use as posts and cores because of their mechanical properties (Burnell, 1964; Shillingburg et al, 1970; Welsh and Priddy, 1978; Williams and Cunningham, 1979, p.250). All the alloys in this group can be age hardened and their ductility is, in general, comparatively low. They are not indicated for restorations and appliances that require hand-working or "burnishing" procedures. It is generally considered that a minimum of 4 to 6 per cent elongation is necessary to prevent a condition of excessive brittleness in service; for this reason, care must be taken not to subject these alloys to severe heat treatment. It is possible for the strength of this type of alloy to be doubled (approximately) during a hardening heat treatment. This property may be considered advantageous when selecting a gold alloy for the casting of a post with a small diameter. Because these alloys are commonly used for casting large appliances such as partial dentures or precision-cast fixed bridges,

the fusion temperature should not be too high because a considerable amount of the alloy must be fused at any one time. Consequently, this type of alloy usually has a fusion temperature lower than that of the other types — ranging between  $871^{\circ}$  and  $982^{\circ}\text{C}$ . This may be achieved by the introduction of more copper, at the expense of the gold content, with a resultant slight decrease in tarnish and corrosion resistance (Phillips, 1973, p.389-390).

The average modulus of elasticity for the various types of alloys is approximately  $9 \times 10^4$  MPa. Although this is not as high as those of some base metal alloys such as stainless steel or cobalt-chromium, which are approximately double that of gold, the type III and IV gold alloys appear to be sufficiently rigid to withstand functional and non-functional stresses present in the oral cavity. The increased hardness of the type III and type IV alloys may make adjustment and subsequent finishing of a cast restoration a little more difficult; however, if a preformed, matching plastic post is used for pattern fabrication, often only minor adjustment is necessary for complete seating of the post-core foundation in the prepared pulpless tooth.

The use of casting gold alloys for post and core construction has been described by numerous authors (Baraban, 1967; Abdullah and Bjorndal, 1970; Herschman et al, 1976, p.444-475). The excellent tarnish and corrosion resistance, the ability of the alloy to cast accurately into restorations of various shapes and sizes, and the strength of the material even in relatively thin sections are probably amongst the reasons that the gold alloys are so widely accepted as a post and core material. Even in situations where the margins of the core foundation are exposed to oral fluids, a cast gold core foundation can be made to fit the prepared tooth accurately (Frank et al, 1976, p.773-796; Herschman et al, 1976, p.444-475). Nitkin and Asgar (1976) conducted a

study to evaluate the fit and completeness of castings made from commercially available semi-precious alloys and base metal alloys; they used a type III gold alloy as control. As expected, the castings made from the type III gold alloy were judged excellent in terms of fit and marginal completeness. The linear coefficient of thermal expansion for the cast gold alloys is approximately  $12-16 \text{ mm/mm/}^{\circ}\text{C} \times 10^{-6}$  (Anderson, 1972, p.24). Although this is slightly higher than that of tooth structure ( $11.4 \text{ mm/mm/}^{\circ}\text{C} \times 10^{-6}$ ), it is generally considered that the difference is sufficiently small not to have any deleterious effect on the marginal seal of the cast restoration. The role of the cementing medium and the types of luting agents available are considered in a later section (6.16).

It is generally acknowledged that, in contrast with composite resin and inadequately polished amalgam, a well-fitting, highly polished gold restoration, like highly glazed ceramics, does not irritate the gingiva (Massler, 1978, p.44).

The marked increase in the world price of the noble metals in recent years was probably responsible for the interest shown by the profession in the search for a satisfactory low cost substitute for type III gold for use in fixed prosthodontics. The amount of gold alloy required for the construction of a post-core foundation in an anterior tooth is usually relatively small. However, in a large, multi-rooted, posterior, endodontically-treated tooth, the cost of the gold and, in particular, the technical difficulties of producing an interlocking, two or three-piece cast post-core foundation, may become a major consideration when selecting the materials and methods of post-core construction.

#### 6.4.2 *High fusing ceramic gold alloys*

Although cast gold alloy is one of the most useful restorative dental materials available, many patients object to the appearance of a

gold restoration, particularly in the anterior region of the mouth. During the last two decades, porcelain-fused-to-metal restorations have played an increasingly important role in the restoration of both vital and pulpless teeth. A variety of alloys including base metal alloys have been developed to which porcelain can be fused. These alloys have high melting points and do not discolour when combined with porcelain. Although it is not recommended that the post-core foundation and the crown are constructed as a single unit (5.5.5), this clinical practice is not uncommon. Consequently, preformed posts made from high-temperature casting gold alloys have become available commercially (for example, Endo-Post\* and Schenker post<sup>@</sup>). According to Craig and Peyton (1975,p.319) these ceramic gold alloys may have a slightly higher modulus of elasticity — that is, they may be more rigid — than conventional crown and bridge gold alloys. Their coefficient of thermal expansion is lower than that of the other gold alloys and is close to that of porcelain. The tensile strength and yield strength values for these alloys are comparable to many of the conventional crown and bridge gold alloys. The percentage elongation of these alloys is low, indicating that these alloys are not ductile in nature. However, if, as recommended, the post-core foundation and the final restoration are constructed separately, there is no real advantage in using the ceramic gold alloys in preference to the conventional type III or type IV casting gold alloys for the post-core foundation.

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\*High-fusing Endo-Post — melting range 1218-1246°C,

Regular Endo-Post — melting range 1002-1071°C,

Sybron/Kerr, Romulus, Michigan, U.S.A.

<sup>@</sup>Ceramicor Alloy Posts,

Cendres & Métaux S.A., Biel-Bienne, Switzerland

### 6.4.3 *Wrought gold alloys*

In general terms, metals and alloys used in dentistry are cast for two quite different purposes. In one instance the casting serves as the final structure, as in the case of an inlay or a crown. In the second, the casting serves as an object that is given further manipulation to form wires, sheets, posts, or similar structures. These castings are subjected to rolling, swaging or wire-drawing operations, which produce severe mechanical deformation of the metal. Such operations are described as hot or cold working of the metal, depending on the temperature at which the operation is performed, and the final product is often described as a wrought structure. Their characteristic properties are quite different from those of cast structures both in internal appearance and mechanical characteristics.

It is generally considered that many mechanical properties of the wrought structure are superior to those of a casting prepared from the same metal or alloy (Craig and Peyton, 1975, p.144). It is for this reason, as well as the practical convenience of using prefabricated posts in the construction of the post-core foundation, that several commercially manufactured posts are available in the wrought form (for example, Para-Post\* and Endo-Post<sup>®</sup>). Harty and Leggett (1972) pointed out that, although cast posts may have adequate strength when there is sufficient bulk, a long thin cast metal post in a narrow canal is liable to bend or fracture under stress. They suggested that, where the diameter of the apical portion of a post is 1.5 mm or less, a wrought metal post should be used. Charlton (1965) also criticized the use of cast metal alloys for posts and cores because of their inferior mechanical

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\*Whaledent International, New York, N.Y., U.S.A.

<sup>®</sup>Sybron/Kerr, Romulus, Michigan, U.S.A.

properties compared to the wrought alloys. Sickelmore (1959) described post fractures as "perhaps the most common of all failures". He considered that with most materials, it was virtually impossible to make a post sufficiently strong without weakening the root as a result of excessive enlargement of the canal; the use of an iridio-platinum alloy as a post material was therefore recommended. These gold-iridium-platinum alloys are used as pins and posts in crown and bridge restorations and, because of their high melting points, other alloys may be cast or soldered to the posts without damage (Craig and Peyton, 1975, p.304).

It is evident in Table 6.1 that the tensile strength of wrought gold alloy wires is considerably higher than the tensile strengths of the cast alloys; the modulus of elasticity is slightly higher and the percentage elongation of the wrought alloy is comparatively low.

It is a characteristic of metals or alloys that have been vigorously cold worked in the process of forming wires or posts, that there is a change in their internal structure and properties when heated or annealed. The characteristic fibrous structure of the wrought appliance is gradually lost, and a grain or crystalline structure reappears. This process is known as recrystallization or grain growth. The degree of recrystallization is related to the alloy composition, the mechanical treatment received during the fabrication of the post, as well as the temperature and duration of the heating operation. Generally, high temperatures or long heating periods produce the greatest amount of recrystallization. As recrystallization and grain growth occur, the strength properties are greatly reduced and the elongation and ductility are increased (Craig and Peyton, 1975, p.144-147).

During recent years, wrought metal posts have frequently been used with the "cast-on core" technique (Baraban, 1971; Courtade and Timmermans,

1971, p.145-172). This method involves the fabrication of a core pattern with inlay wax or burn-out acrylic resin around a wrought alloy post which has a higher melting point than the alloy intended for use as the core foundation. The pattern is then invested with the post and subsequently eliminated during the burn-out and casting procedures. The relationship between the post and the core is maintained by mechanical retention. While investments containing chloride have been reported to affect the strength of the posts (Behrend, 1980), it is surprising that the possible effects of the heating and casting operations on the mechanical properties of the wrought posts have not been investigated. If the strength properties of the wrought gold alloy posts are, in fact, greatly reduced as a result of the prolonged heating necessary for the casting of the core portion, the high strength values claimed by the manufacturer may not be present in the final post-core foundation. Therefore, it is advisable to keep the time and temperature of heating as low as possible consistent with the requirements of the particular casting gold alloy for the core foundation (Craig and Peyton, 1975, p.145).

It is possible that an alternative alloy type is more suitable for use as the preformed post in the "cast-on core" technique. A preformed cast post made from a different alloy from the core material, which has similar mechanical properties in the "as cast" condition as the wrought gold alloys, and which can withstand the heating operations without any undesirable effects might be ideal.

#### 6.5 Semi-precious alloys

This is a group of dental casting alloys which has a gold and platinum group metal content less than that required by the specification for cast gold alloys. The gold content of these alloys may vary considerably according to their cost. The development of these and the

base metal alloys as substitutes for gold alloys in dentistry was stimulated in recent years by the steep rises in the world-wide price of gold. Dental gold alloys have reached the stage of development where the clinician may rely on them to fulfill his requirements. Any substitutes should therefore demonstrate properties which are similar to, or better than, those achieved by gold alloys if they are to give satisfactory clinical performance.

The possibility of the use of the semi-precious alloys as substitutes for casting gold alloys for restorations and post-core foundations has been investigated (Nitkin and Asgar, 1976; Dale and Moser, 1977, a and b). Although these alloys are less expensive and their strength and hardness are generally at least comparable with those of type III casting gold alloys (Dale and Moser, 1977, a), Nitkin and Asgar (1976) stated that many other factors should be taken into consideration when evaluating a dental casting alloy; these factors should include corrosion resistance, biocompatibility, ease of manipulation, castability, accuracy of the fit of the casting, ease of polishing and finishing, and soldering. They stressed that the laboratory time, as well as the cost of the materials, would determine the total cost of producing a restoration. The difficulty of fabricating a restoration must therefore be taken into account when determining the actual saving in the cost of producing the restoration.

To study the possible corrosion behaviour of the semi-precious alloys in the oral cavity, Dale and Moser (1977, b) mounted specimens of these alloys in an acrylic resin base fitted with contact electrodes and placed them in Ringer's solution. Polarization was usually begun at a potential approximately equal to the open-circuit corrosion potential. The potential was increased by 50mV at intervals of 5 minutes. The data was compared with those from a typical non-precious metal alloy based on

the nickel-chromium system and a type III casting gold. The semi-precious alloys were found to exhibit potential-current relationships intermediate between those of base alloys and noble alloys. These researchers concluded that the semi-precious alloys should be "acceptably resistant to corrosion in the oral environment". In a clinical evaluation of the use of semi-precious alloys as post-core foundations, Dale and Moser (1977, a) found that the semi-precious alloys produced accurate and well-fitting posts that required minimal adjustment. Since the manipulation of these alloys is similar to that of type III gold alloys, and because the alloys are harder than type III gold alloys, they considered that the semi-precious alloys would be ideal for casting posts and cores.

In the study by Nitkin and Asgar (1976), it was found that castings made from a low (approximately 50 per cent) gold-content alloy were comparable with those made from a type III gold alloy in terms of fit and marginal completeness. The gold-silver-palladium alloys yielded castings nearly comparable with those made from type III gold. After consideration of the findings of this research and that of Dale and Moser (1977, a and b), and of the mechanical properties of these alloys, it is probably not unreasonable to expect these alloys to be quite suitable for clinical use as posts, cores and restorations. The manipulation and handling of these materials are similar to those of the type III gold alloys and enable them to be used conveniently as a substitute for these gold alloys.

#### 6.6 Nickel-chromium alloys

This is one of the two main types of base metal casting alloys commonly used in restorative dentistry. Cobalt-chromium alloys are extensively used for partial denture construction; their use in the restoration of pulpless teeth is discussed in 6.7.

In recent years, nickel-chromium alloys have gained some acceptance as gold alloy substitutes for crown and bridge work applications and their use for cast post-core foundations has also been advocated (Pinkley and Morris, 1974).

Because of the large number of nickel-chromium alloys available, it is difficult to specify a range of composition that covers all these products. The alloys usually contain 70-80 per cent nickel, 12-20 per cent chromium, small quantities (1-5 per cent) of molybdenum to refine grain size, and aluminium (approximately 3 per cent) to allow precipitation hardening to take place. In order to lower the fusion temperature and to refine the grain size, some manufacturers also add a small quantity (up to 2 per cent) of beryllium into the alloy.

A wide range of mechanical properties has been reported for these alloys. Average tensile strength values in the range of 600-900 MPa and a Vickers Hardness Number of 300 indicate that these alloys may be even stronger and more difficult to polish and adjust than the type IV casting gold alloys. Percentage elongation is comparatively low — usually approximately 5 per cent. The elastic modulus for these alloys is  $20-21 \times 10^4$  MPa, which is approximately twice the value for gold alloys.

The long-term corrosion resistance of these materials has not yet been established because of the relatively short period of their clinical use. Because they contain up to 20 per cent chromium and display passivity, these alloys should have good resistance to corrosion; they do, however, have a tendency to tarnish a little more than gold alloys. Because of the possibility of a hypersensitivity reaction to these alloys, they should not be used in patients who are known to be sensitive to nickel. As mentioned previously, the use of nickel-chromium alloys containing beryllium may be hazardous in the laboratory environment,

especially during melting and grinding operations when beryllium-bearing particles may be inhaled by the technician. If, nickel-chromium alloys containing beryllium are used for post-core construction, care should be exercised in the formation of the pattern so that polishing and adjustment of the post-core casting can be kept to a minimum (Williams and Cunningham, 1979, p.252-253).

The sprueing, burn-out temperature, casting temperature, and casting technique of these base-metal alloys are significantly different from those for gold alloys (American Dental Association, 1978, p.122-123). The melting range of 1250-1360<sup>0</sup>C for the nickel-chromium alloys is considerably higher than that for gold alloys. It is necessary to use phosphate-bonded investment materials for the moulds and melting cannot be achieved by the use of conventional gas-air torches. Because of the higher temperature involved, there is also a greater solidification and thermal contraction than with gold casting alloys. Critical attention to these technical differences is required to obtain correct fit of the restoration and clinically satisfactory margins (American Dental Association, 1978, p.123-124). Moffa (1977) suggested that certain aspects of these non-precious alloys might, after more research, be modified —

- i. decreased hardness, which would assist in chair-side finishing,
- ii. improved "burnishability", a property which may be important for the marginal seal of cast restorations (but is considered to be of less significance for cast post-core foundations since the margins of the coronal restoration are usually located in natural tooth structure gingival to the margin of the post-core foundation),
- iii. improved investment which would decrease casting roughness, and
- iv. a standardized test for bond strength to porcelain.

As Phillips (1977) pointed out, too little attention has been given to the development of a more suitable investing material for these base metal alloys, the refinement of their casting technique and other fabrication procedures. Past attempts at producing precision castings have been made using techniques originally designed for the handling of gold alloys. The differences in alloy density and melting ranges make the development of new handling techniques an urgent requirement. Nitkin and Asgar (1976) suggested that the development of a different type of investment material with easily controllable and adequate expansion may result in castings of non-precious alloys comparable with those of gold.

Despite some doubt on the long-term clinical performance of non-precious alloy cast restorations because of inadequate current evidence, there appears to be a growing demand for this material for post and core construction. Since the nickel-chromium alloys possess desirable mechanical and physical properties, there is little doubt that, with further development and refinement of the auxiliary materials and handling technique, their use as an alternative to gold alloys for cast restorations will increase in the future.

#### 6.7 Cobalt-chromium alloys

An alloy based on a composition of 70 per cent cobalt and 30 per cent chromium, with the addition of minor quantities of carbon, manganese, and silicon was first used in dentistry in 1929. The alloys used today vary a little from this original composition; small quantities of nickel and molybdenum replace some of the cobalt in order to increase ductility. As mentioned in 6.6 (nickel-chromium alloys), the cobalt-chromium alloys are extensively used for the construction of removable partial denture framework because of their strength, low cost and lower mass compared with type-IV gold alloys. According to Craig and Peyton (1975, p.362), it was estimated that, in the U.S.A., more than 80 per cent of all partial denture

appliances were cast from these alloys as early as 1949. With the increase in the price of gold in recent years and considering the amount of metal usually required, it is probably safe to assume that these alloys have almost replaced cast gold alloys for partial denture construction. Although the use of the cobalt-chromium alloys for cast restorations is limited, several clinicians (Harty and Leggett, 1972; Erickson and Vande Voorde, 1975; DeDomenico, 1977; Crocker, 1981) have advocated their use as substitutes for cast gold alloys for post and core construction.

The mechanical properties of these alloys are summarized in Table 6.1. It is evident that the tensile strength of the cobalt-chromium alloys is similar to that of the type IV casting gold alloys. However, there are some important differences between the two material types. The modulus of elasticity of the cobalt-chromium alloys is approximately twice the modulus of the gold alloys; while this greater rigidity may not be of great significance in inlays and crowns, it may be advantageous for post construction particularly when the diameter of the prepared canal is small. The percentage elongation of these alloys is generally low, 1.5-2.0 per cent, and they are usually brittle. The ductility of the cobalt-chromium alloys can be increased by the addition of nickel — usually at the expense of the cobalt — which is accompanied by a reduction in strength and hardness. Some of the newer compositions exhibit percentages of elongation similar to those of the type IV gold alloys (American Dental Association, 1978, p.125-128). The Vickers Hardness Number for a cobalt-chromium alloy is usually in the range of 370 to 400; this property makes the adjustment and finishing of a casting much more difficult compared to type IV gold which may have a BHN of approximately 220.

The excellent biocompatibility and the corrosion resistance of the cobalt-chromium alloys in the oral environment is indicated by their

common use for surgically-implanted prostheses. Although it is possible for some patients to display sensitivity to these alloys, usually due to the cobalt content, this is very rare (Williams and Cunningham, 1979, p.281). The main role of the chromium in these alloys is to impart corrosion and tarnish resistance; generally, the higher the chromium content, the better the corrosion resistance. Therefore, the use of these alloys as post-core foundations should not present any problems in terms of corrosion or biocompatibility.

Harty and Leggett (1972) described a post-core technique which used a wrought nickel-cobalt-chromium post with a cast-on core foundation. They claimed that the physical properties of these wrought alloy posts were unaffected by the high temperatures required to cast metal directly onto the surface. Using this technique, the anti-rotational device and the core are cast in a base metal alloy directly onto the post and are retained mechanically by the very close adaptation of the cast metal to the roughened post surface. Others have also suggested the use of cobalt-chromium alloys for cast post-core foundations. Erickson and Vande Voorde (1975) reported a case in which they used cobalt-chromium to construct a combined post, core and endodontic-endosseous implant for an anterior pulpless tooth which was left with a very short root after an apicectomy. De Domenico (1977) described a technique of casting a post-core foundation in cobalt-chromium together with the waxed framework of a removable partial denture. This appeared to be a convenient method of constructing a strong and inexpensive one-piece post-core foundation. Because of the increased hardness of these alloys compared to gold alloys, proper attention should be paid to the formation of the post-core pattern so that only very minor chair-side adjustment is required prior to cementation.

Because of the very limited "burnishability" and the greater casting shrinkage (2.0-2.5 per cent) of the cobalt-chromium alloys, compared to

cast gold alloys (1.25 per cent) and nickel-chromium alloys, the use of these alloys is generally restricted to clinical situations where the margins of the cemented post-core casting are protected from oral fluids.

Cobalt-chromium alloys, as cast, can be very coarse grained so that, in finer structures, such as a denture clasp or a post with a small diameter, they may only be two or three grains thick. Since the alloys work harden very rapidly, any attempt to bend the post may result in its fracture and should be avoided.

#### 6.8 Stainless steel

Steels, by definition, are alloys of iron and carbon with or without the addition of other elements. Steels that contain a minimum of approximately 12 per cent chromium possess good corrosion resistance because of the passivating effect of the surface layer of chromic oxide ( $\text{Cr}_2\text{O}_3$ ), and are generally known as stainless steels. There are several types of stainless steels depending on their composition; the one most important for dental purposes is the austenitic stainless steel which usually contains 17-19 per cent chromium, 8-19 per cent nickel, and less than 0.15 per cent carbon. It is commonly referred to as 18-8 stainless steel.

Because of their high melting points ( $1400^\circ\text{C}$ ), stainless steels are usually used in the wrought form. The typical values for the properties of an 18-8 austenitic type of stainless steel are included in Table 6.1. It is difficult to establish a specific value for the mechanical properties of stainless steel used in dentistry because certain factors of manipulation and technique of operation can have a significant influence on these properties (Craig and Peyton, 1975, p.377). Due to the work hardening effect, the strength and ductility of these alloys depend on the extent of prior deformation. In the "soft" state, where there has been little or no deformation, the alloy is relatively weak,

has a yield strength of less than 300 MPa, an ultimate tensile strength of approximately 600 MPa, and an exceptionally high percentage elongation of up to 55 per cent. However, in a fully work-hardened condition, the yield strength can approach 1500 MPa and the ultimate tensile strength 1700 MPa, with a corresponding reduction in ductility to less than 5 per cent (Williams and Cunningham, 1979, p.297). The modulus of elasticity of an 18-8 stainless steel is approximately  $20 \times 10^4$  MPa which is a little less than that of cobalt-chromium alloys. Despite the fairly high strength of these alloys, cases of fracture of stainless steel posts have been reported (Messing and Wills, 1973).

As previously mentioned, the corrosion-resistant qualities are dependent on the surface passivity resulting from a thin film of oxide or other compound on the surface of the metal. This film is stabilised by the presence of chromium in the alloy and the degree of passivity is influenced by a number of circumstances, such as alloy composition, heat treatment applied, surface condition, stress in the appliance, and the environment in which the appliance is placed. In dental applications, the stainless qualities of the alloys can be altered or lost by excessive heating during certain procedures such as the casting of a metal against it or welding, the use of abrasives or reactive cleaning agents, and even by poor oral hygiene practiced over prolonged periods. The "cast-on core" technique using a wrought stainless steel post is not recommended because the exposure to high temperature necessary during the heating and casting procedures may result in the precipitation of chromium carbide and a severe reduction in the chromium content of the alloy. Such an alloy is said to be *sensitized* and usually there is permanent damage to the stainless qualities as well as to the mechanical properties of the alloy. Although used with less success than the cobalt-chromium alloys, the fact that stainless steels have been used for surgical implants probably

indicates that these alloys are also fairly well tolerated by the oral tissues.

For many years, wrought stainless steel posts have been used in combination with a different core material (such as amalgam or composite resin) for the construction of post-core foundations. Although the stainless steel post by itself has adequate corrosion and tarnish resistance in the oral environment, some laboratory and clinical studies (Angmar-Månsson et al, 1969; Rud and Omnell, 1970; Petersen, 1971) have found alarming evidence that the combination of a stainless steel post and a metallic core foundation may result in the accelerated corrosion and disintegration of the post-core foundation. This is discussed in 6.15.

Although wrought stainless steel posts are frequently used in the restoration of endodontically-treated teeth, the use of wrought stainless steel as a core material is fairly limited. In 1965, Charlton presented a post-core technique which involved the use of a prefabricated wrought stainless steel post-core foundation. This post-core foundation was turned to shape from a stainless steel rod. The flat surfaces were then produced by grinding or filing in a jig. Even though the wrought stainless steel is strong and has adequate corrosion resistance, its hardness makes it very difficult to adjust; because it is a prefabricated post-core foundation, a certain amount of adjustment is unavoidable. In any case, this type of technique entails the removal of all or most of the clinical crown and the accuracy of fit of the core portion is far from satisfactory.

#### 6.9 Brass

The brass that is commonly used in dentistry in the form of screw posts, is an alloy of approximately 60 per cent copper, 39 per cent zinc, and 1 per cent gold or silver as a protective layer (Dérand, 1971).

Brass is also used to make dowel pins for the orientation of dies in the working casts of fixed prostheses. As a core material in conjunction with a stainless steel post it was first introduced by Kurer (1967) in the form of the Kurer Crown Anchor System (12.1.1).

With the above composition, this brass is the strongest of the copper-zinc alloys. However, when the physical and mechanical properties of this alloy (Table 6.1) are compared with those of the alloys considered in the preceding discussion (6.4 to 6.8), it is obvious that the use of brass as a post material offers no real advantages. Brass of this composition has a low resistance to corrosion (Dérand, 1971) and screw posts made of this material are usually covered with a very thin layer of gold that is probably electrolytically precipitated. As this thin layer of gold is easily damaged during post insertion procedures, its ability to protect the brass post is questionable. In a laboratory study by Dérand (1971), the brass screw posts\* were found to corrode (with loss of superficial brass) in approximately 10 per cent of the specimens; the corrosion products were usually taken up by the dentine.

Despite these disadvantages, brass screw posts are fairly commonly used for the retention of amalgam or composite resin core foundations in endodontically-treated teeth particularly in the posterior region of the mouth (Nicholls, 1963; Kafalias, 1969 and 1975; Leggett, 1979). Scully (1972) described the use of a tapered brass dowel pin as a post-core foundation for single-rooted anterior pulpless teeth. Furthermore, the use of brass as a core material in the Kurer Crown Anchor System can hardly be considered satisfactory. Such a method of post-core construction necessitates the removal of most or all of the clinical crown and a great deal of adjustment of the metal core is usually required to complete the coronal preparation. As Henry and Bower (1977,a)

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\*Dentatus, Hägersten, Sweden

stated "materials such as brass do not conform to the biologic standards required of dental restorative materials".

#### 6.10 Aluminium

The use of aluminium in the restoration of endodontically-treated teeth is very limited. Even the once commonly used aluminium temporary crowns for posterior teeth are gradually being replaced by the newer temporary restorative materials. One commercial post system\* incorporates a range of aluminium posts, of similar dimensions as the stainless steel and the gold alloy posts, for the retention of temporary acrylic resin crowns between appointments. However, if these aluminium posts are inadvertently used in the construction of a post-amalgam core foundation, the result can be a very rapid breakdown of the entire aluminium post/amalgam core foundation and fracture of the treated root (refer 6.15.2).

#### 6.11 Titanium alloys

Titanium-containing base alloys are relatively new in dentistry and until recently, their use has been restricted to direct implant materials (Greener et al, 1972, p.365). In 1981, a range of titanium alloy root canal posts were introduced for use with amalgam or composite resin core foundations. The alloy passivates spontaneously over a wide range of potential and has excellent corrosion resistance. It is well tolerated by the tissues and has had extensive orthopaedic application (Greener et al, 1972, p.366). The tensile strength of this material is comparable to those of wrought stainless steel and wrought cobalt-chromium (Von Fraunhofer, 1975, p.335). It is likely that there will be increased use of this material for root canal posts in the future (Henry, 1982).

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\*Para-Post System, Whaledent International, New York, N.Y., U.S.A.

## 6.12 Amalgam

For over a century, dental amalgam has been widely used for the restoration of lost tooth structure. Today, although other more aesthetic restorative materials, such as composite resin, are available for the restoration of anterior teeth, amalgam is still the most widely used material for the restoration of lost tooth structure (Phillips, 1973, p.301) particularly in stress-bearing areas and areas where tooth-coloured aesthetics are not of importance.

Dental amalgam has been extensively investigated and discussed in the dental literature. Several types of amalgam alloys are currently available. To the conventional alloys, based on lathe-cut or spherical particles of  $\text{Ag}_3\text{Sn}$ , have been added the dispersion modified alloys (for example, Dispersalloy\* and Luxalloy<sup>@</sup>) in which spheres of silver-copper eutectic are included with the lathe-cut  $\text{Ag}_3\text{Sn}$  particles. More recently, a number of single melt high copper alloys (examples include Tytin<sup>#</sup>, Sybraloy<sup>+</sup> and Indiloy<sup>¶</sup>) have been introduced in which the original alloy particles contain a reduced silver content and a copper content of between 12 and 30 per cent (Bryant, 1979). It is intended that only those aspects of amalgam directly related to the restoration of endodontically-treated teeth should be considered in this brief discussion.

It is generally acknowledged that, when handled properly, amalgam is one of the most satisfactory restorative materials available in terms of marginal adaptation, bio-compatibility, dimensional stability,

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\*Johnson and Johnson Dental Products Co., East Windsor, N.J., U.S.A.

<sup>@</sup>Degussa, Frankfurt, West Germany

<sup>#</sup>S.S. White Dental Products International, Philadelphia, PA., U.S.A.

<sup>+</sup>Sybron/Kerr, Romulus, Michigan, U.S.A.

<sup>¶</sup>Shofu Dental Corporation, Menlo Park, Calif., U.S.A.

abrasion resistance, ease of manipulation and cost. As a post material, however, cast and wrought gold alloys possess many physical and mechanical properties which make them almost ideal for the purpose. These gold alloys are usually the "standards" by which other post materials are evaluated.

A lack of adequate strength to resist masticatory forces has long been recognised as one of the inherent weaknesses of the amalgam restoration (Phillips, 1973, p.325). It is well known that amalgam in thin sections possesses relatively low strength (Wing, 1971) and a failure to provide a sufficient bulk of the material reduces the overall strength of the restoration. For these reasons, the use of amalgam is indicated only in situations where it may be present in adequate bulk rather than in thin sections having low resistance to stresses (Wing, 1971); Gilmore et al (1977) suggested that a minimum thickness of 2.5 to 3.0 mm of amalgam was required for adequate resistance to occlusal forces.

The cross-sectional area of a root canal post is usually small even compared to that of a conservative amalgam restoration. Although the compressive strength of modern amalgams is generally regarded as satisfactory, it has been suggested that most forces in the oral cavity during mastication produce tensile forces (Wing, 1971). The tensile strength of amalgam (59-98 MPa) is very low compared to that of type III casting gold alloys (360(S) - 415(H) MPa). It is probably for this reason and because of the complex nature of stresses on the post that amalgam has had fairly limited use as a post material. However, as Nayyar et al (1980) pointed out, no scientific data exist on what constitutes adequate intracoronal support for endodontically-treated teeth. They described a technique which employed amalgam as a post and core material in multi-rooted posterior teeth in which the pulp

chamber and the prepared canals were used for retention of the material. This technique eliminated the need for the preparation, impression and cementation of a single- or multiple- unit cast metal post-core foundation; the use of prefabricated posts or pins was also eliminated. After restoring some 400 posterior teeth with this method over a period of four years, no failure attributable to the all-amalgam post-core foundation was reported by these clinicians.

More conventionally, amalgam has been used as a core material in combination with a prefabricated or custom-made post. In a laboratory study, Christian et al (1981) compared the resistance to horizontal forces of endodontically-treated mandibular molars restored with amalgam cores, with and without a prefabricated stainless steel post in the distal canal. They found that the stronger post-core foundation was one with a post and an amalgam core in which the amalgam was well condensed around the post. The mean load at failure for this group was 142 pounds; the all-amalgam cores demonstrated a lower resistance to fracture and failed under a mean load of 123 pounds. It was suggested that the resistance to occlusal forces of the all-amalgam post-core foundation, although inferior to the post-amalgam core, was probably adequate under most circumstances. These researchers also reported a lower incidence of tooth fracture with the all-amalgam post-core foundations. Of the ten specimens in each of the two types of core foundations, root fracture occurred in seven of the metal post-retained amalgam core specimens and only in four of the ten all-amalgam core specimens. This may be an advantage of the all-amalgam core technique; that is, clinical failure may involve the root less frequently and the tooth may be re-treated. Because of the relatively sparse information in the dental literature, on the clinical failure (by root fracture) of endodontically-treated teeth which have been adequately restored with post-core foundations,

the use of amalgam as a post material, in certain clinical situations, may deserve further investigation.

In the last two decades, the use of an amalgam core in combination with prefabricated posts or retentive pins, has gained wide acceptance as an alternative to cast gold alloys as a method of supporting a cast restoration (Courtade, 1963; Nicholls, 1963; Watson, 1968; Shillingburg et al, 1970; Johnson et al, 1976; Gilmore et al, 1977, p.358-366; Henry and Bower,1977,a; Lovdahl and Nicholls, 1977; Reuter, 1977; Leggett, 1979). Benefits of this technique include the low cost of the material, the ease of application, the elimination of impression and laboratory procedures and the reduction in chair-side time. As a core foundation in posterior endodontically-treated teeth, there is usually a sufficient bulk of the amalgam in the amalgam core. Although the use of pin-retained amalgam build-up's for the support of a full crown restoration in vital anterior teeth had been described (Martin, 1966), sufficient space may not be available to provide an adequate bulk for the amalgam core foundation in a *small* anterior pulpless tooth (such as a maxillary lateral incisor or a mandibular incisor). The use of amalgam in these situations may be contra-indicated.

Henry and Bower(1977,a) expressed their preference for the use of amalgam as a core material to fit around pins and posts. It was observed that amalgam has a longer working time than composite resin materials and void elimination was not likely to be a problem.

There has been some controversy as to whether the preparation for the final restoration should be carried out soon after the initial set of the amalgam core foundation. Some clinicians have related the early strength of certain amalgam alloys to the ability to prepare an amalgam core foundation at this time, for a subsequent crown restoration. If a fast-setting amalgam alloy (for example, Tytin) is used (refer Table 6.2),

a number of clinicians (Shillingburg et al, 1970; Johnson et al, 1976; Reuter, 1977; Hormati and Denehy, 1980; Nayyar et al, 1980) have suggested that the amalgam core may be prepared for the final restoration, without any "harmful effects", immediately after the initial set of the amalgam has occurred. On the other hand, Baraban (1972), Henry and Bower (1977,a), and Wing (1981) have recommended that the amalgam be allowed to set for at least 24 hours, or 8 hours, respectively, before completion of the coronal preparation. This controversy is discussed further in 14.4.

Although amalgam has been extensively used with satisfactory results in the restoration of lost tooth structure in vital teeth, its role as a final coronal restoration in endodontically-treated teeth has been less certain. In the anterior region of the mouth, after root canal therapy, the pulpless tooth may, infrequently, require only a simple restoration to seal the access cavity. Even in these situations, the use of amalgam has gradually declined because of the possible effects on the colour and the translucency of the treated tooth (Grossman, 1978, p.323; Massler, 1978, p.40). In the posterior region, cuspal protection has been considered by many authors (Baraban, 1967; Blair, 1971; Herschman and Weine, 1972, p.385; Johnson et al, 1976) to be a feature of paramount importance in the restoration of an endodontically-treated tooth. Brown et al (1979) reviewed the several indications for a pin-retained amalgam restoration as an alternative to the cast restoration as the final restoration in the treatment of a posterior endodontically-treated tooth.

1. Questionable endodontic or periodontal prognosis — the treatment of some pathological conditions may have a less than ideal prognosis and healing may take months or longer. For financial reasons, cast gold restorations may not be indicated at this stage and a pin-retained amalgam restoration was suggested as an interim restoration which can later serve as a core for a complete crown when the endodontic or periodontal prognosis improves.

2. Economic factors. Economic considerations may be a deciding factor in determining the type of restoration proposed for the endodontically-treated tooth, even in a well-motivated patient. A pin-amalgam restoration may serve as a long-term restoration and subsequently as a foundation for a cast restoration when economic factors are more favourable.

3. Disabled, handicapped patients and/or the presence of medical conditions that preclude multiple visits to the dental surgery.

4. High caries index. Amalgam restorations may have better resistance to recurrent caries in these "high-risk patients" than cast restorations retained by a cementing medium.

5. Teeth not receptive to posts. Pin-retained amalgam may be used as an alternative to the preferred post-amalgam foundation.

These authors (Brown et al, 1979) recommended the use of cemented pins and, in order to achieve complete cusp protection, all the cusps were reduced 2.5 to 3 mm to allow sufficient bulk for the amalgam and the placement of the retentive pins. They suggested that the proper condensation, carving and shaping of such an extensive amalgam restoration might be limited by the relatively short working time of the material.

One of the reasons for the extensive use of amalgam as a restorative material has been the ability of the amalgam restoration to minimise marginal leakage (Andrews and Hembree, 1978). The decrease in marginal leakage as the amalgam ages has been attributed to accumulation of corrosion products at the amalgam-tooth interface (Phillips, 1973, p.302; Massler, 1978, p.42; Hormati and Denehy, 1980). In the initial stages after placement of the amalgam restoration, when the amalgam is known to leak (Wing, 1971), the use of copal varnish has been shown (Wing and Lyell, 1966; Andrews and Hembree, 1978) to be

effective in reducing the marginal leakage before the amalgam becomes self-sealing. Although whenever possible, the amalgam core foundation should be completely protected from oral fluids by the coronal restoration, there are clinical situations where this procedure is not practical and part of the amalgam core foundation is left exposed to the oral fluids. It has been suggested (Hormati and Denehy, 1980) that, should leakage occur around the margins of the coronal restoration, the core should, ideally, serve to arrest this leakage.

With its unique self-sealing property and the ability of the material to resist wear and maintain satisfactory form, amalgam may serve as a core foundation or as a long-term interim restoration (Hormati and Denehy, 1980).

### 6.13 Composite Resin

#### 6.13.1 *Introduction*

Until the introduction of acrylic restorative resin in 1950, silicate cements had been, for over fifty years, the most commonly used restorative material in anterior teeth (Mannerberg, 1977). Composite resins were introduced in 1965 and, since then, have virtually replaced silicate cements and acrylic resins as the tooth-coloured restorative material of choice (Leinfelder et al, 1975; Massler, 1978, p.43).

The acrylic resins were deficient in hardness and had poor abrasion resistance that resulted in loss of surface contour. They had inferior compressive and tensile strengths compared to composite resins, high polymerization shrinkage that resulted in poor marginal adaptation, and a high coefficient of thermal expansion, that was associated with marginal failure with thermal cycling (Eames et al, 1974; Al-Hamadeni and Crabb, 1975; Stahl and O'Neal, 1975). Although Baraban suggested in 1967 that a fine grain acrylic resin such as Duralay might be used as a core material instead of amalgam, he later (1972) described a composite resin core

technique that made use of stainless steel posts and pins for retention. Self-curing acrylic resins remain useful materials, however, for the fabrication of temporary crowns during the different stages of restoring an endodontically-treated tooth.

The use of silicate cements in the restoration of endodontically-treated teeth was limited most commonly to small proximal lesions and the sealing of the lingual endodontic access cavity in cases in which the clinical crown of the treated anterior tooth was relatively intact (Gilmore and Lund, 1973, p.257-267). In recent years, composite resins have virtually replaced silicate cements.

#### 6.13.2 *Composite resin as a post and core material*

In an attempt to simplify the procedures of post-core construction, Landwerlen and Berry (1972) and Stahl and O'Neal (1975) described techniques in which composite resin was used as the material for both the *post and core*. The main benefits of these techniques were the reduction in chair-side time because the post-core foundation and the preparation and impression for the final restoration were able to be completed in the one appointment; in addition, the expense of the gold alloy and the laboratory fees associated with a cast gold post-core foundation was eliminated. It was also claimed that the colour and translucency of the composite resin might enhance the aesthetics of the final restoration if an acrylic resin or porcelain jacket crown was chosen (Landwerlen and Berry, 1972).

It has generally been acknowledged that the mechanical properties of composite resin are comparable with those of tooth structure, but somewhat inferior to those of amalgam (Lee et al, 1969; Spalten, 1971; Spanauf, 1972). The tensile strength of composite resin is much lower than that of the cast gold alloys and it has been considered doubtful whether a post of composite resin would have sufficient strength to resist

bending or fracture under stress. Stahl and O'Neal (1975) claimed that the composite resin post-core foundations appeared to be strong enough to withstand normal masticatory forces. Because, in several cases they reported, the composite resin tended to fracture before it was dislodged, it was claimed by these authors that the remaining root was protected against injury from traumatic forces. In addition, because retention of a composite resin post-core is more dependent on the close adaptation of the composite resin to the natural irregularities and undercuts placed in the root canal walls, it was considered that the length of the composite resin post need not be the same as that for a gold post; in this way, the risk of perforation was reduced (Stahl and O'Neal, 1975). However, these authors maintained that the post should be of "sufficient" length and design to distribute the forces of leverage and torque throughout the remaining portion of the pulpless tooth; the authors did not define "sufficient length". The technique described by these authors, for an all-composite resin post-core foundation, has not been widely accepted by other authors.

Composite resin has achieved popularity as a *core* material in recent years principally because of its rapid setting rate (near maximum strength — approximately 240 MPa — at this early time), which enables the preparation for the final restoration to be carried out immediately after polymerization (Baraban, 1972; Spanauf, 1972; Fujimoto et al, 1978; Hormati and Denehy, 1980; Behrend, 1981). The performance of composite resin as a core foundation material, has been the subject of a number of laboratory investigations (Newburg and Pameijer, 1976; Kantor and Pines, 1977; Fujimoto et al, 1978; Moll et al, 1978; Hormati and Denehy, 1980; Larson and Jensen, 1980; Chan and Bryant, 1982); its performance is discussed in Chapter 14. It has been the experience of a number of clinicians that the surface layer of the composite resin core was

plasticized by the eugenol when a zinc oxide-eugenol type temporary cement was used. Therefore, it may be advisable to use a quick-setting calcium hydroxide cement instead, for the cementation of temporary crowns during treatment and avoid eugenol-containing luting cements for the final cementation of the coronal restoration.

### 6.13.3 *Composite resin as a final restorative material*

Although much has been written on the use of composite resin for the restoration of vital teeth, there appears to be little in the literature on the use of composite resin as the final restorative material in endodontically-treated teeth except in anterior teeth in which the clinical crown of the pulpless tooth is relatively intact. Only relatively simple restorations are required in these cases. Because of the lack of adequate resistance to wear (Phillips et al, 1973; Osborne et al, 1973; Eames et al, 1974; Leinfelder et al, 1975 and 1980), and the inability to provide long-term cuspal protection, composite resin has limited use as a final restorative material in the posterior region of the mouth (apart from its use as a core material).

Early studies (Lee and Swartz, 1970; Brannstrom and Nyborg, 1971) on the marginal adaptation of composite resins, demonstrated the presence of microleakage under these materials. Since then, etching the enamel margins of the cavity preparation has been found in many laboratory investigations to reduce marginal leakage (Al-Hamadani and Crabb, 1975; Eriksen and Buonocore, 1976; Eliasson and Hill, 1977; Luscher et al, 1978; Hormati and Chan, 1980; Martin, 1980).

A coupling agent (a solution of acrylic compound dissolved in acetone), developed by Bowen (1982), has been found to produce adhesion between dentine and composite resin; Beech (1977) also suggested the use of an "intermediate adhesive" in order to achieve bonding to dentine. Research however has indicated that acid treatment of vital dentine may

have harmful effects on the pulp (Brannstrom and Nyborg, 1972; Dickey et al, 1974). As yet, no satisfactory agent has been developed whereby cementum or dentine can be routinely etched, with safety, in order to secure the required mechanical bonding of the resin to that surface (Phillips, 1982, p.242). However, in an endodontically-treated tooth, the nature of the dentine may be different; the absence of vital pulp tissues places less restriction on the biological properties of the resin. As Hormati and Denehy (1980) suggested, should leakage occur around the crown margins, the core should, ideally, serve to arrest the leakage. Since during crown preparation, most, if not all of any acid-etched enamel margins would be removed, methods of improving the bonding of composite resin to dentine in pulpless teeth deserves further investigation.

#### 6.13.4 *Composite resin materials*

There are three types of composite resin currently available — conventional, macrofilled composite resin, microfilled composite resin and the macro/micro-filled composite resins (Bryant, 1980). These materials have been broadly classified according to the size of their inorganic filler particles. Two systems of activation of their polymerization reaction are available. Chemical activation of the monomer is usually accomplished by means of the tertiary amine — benzoyl peroxide system; incandescent light and ultraviolet light have both been used to initiate polymerization in the light-cured composite resins. Based on clinical experience, certain advantages have been found for the use of the light-cured composite resin materials (Clinical Research Associates, 1981):

1. reduced chair time due to the fast set (10 to 20 seconds as compared to 3 to 4 minutes in the chemically-cured composite resins) and elimination of mixing,
2. extended working time and command set,

3. less finishing required because resin may be shaped before curing,
4. smoother surface since mixing, with resultant entrapped air, is eliminated, and
5. better shade control because exact shades can be seen as dispensed from syringes.

Because of the limit to the depth of penetration of the curing light, any composite resin restoration or core foundation of considerable bulk should be built up in stages; alternatively, the chemically-activated systems should be used to ensure proper setting of the material in every part of the preparation.

#### *Summary*

A decade ago, composite resin was generally considered as a restorative material suitable only for "semi-permanent aesthetic" intracoronal restorations (Ambrose et al, 1971) in the anterior region of the mouth. The material has been found to have other useful clinical applications such as the splinting of periodontally-involved or traumatized teeth and as core foundations (with stainless steel posts) for anterior and posterior endodontically-treated teeth (Baraban, 1972; Behrend, 1980). As a post material, it is very doubtful whether currently available composite resins possess sufficient strength and rigidity to withstand adequately the functional and para-functional stresses to which the pulpless tooth may be subjected. As a final restoration, the currently available composite resin materials can only provide restorations with intermediate longevity compared to other restorative materials such as gold or porcelain because of their inadequate long-term resistance to abrasion and loss of surface contour.

#### 6.14 Glass ionomer cements

The formulation of the glass ionomer cements by Wilson and his co-workers and their development for clinical use by McLean and Wilson

took place in the United Kingdom in the early 1970's (McLean and Wilson, 1977, a). It was the aim of these researchers to produce a material which possessed the most desirable qualities of the silicate cements, composite resins and polycarboxylate cements.

As a restorative material, the compressive and tensile strengths of glass ionomer cements are somewhat lower than those of silicate cements (Phillips, 1982, p.487). Their solubility in oral fluids is much lower than that of silicate and other conventional cements such as zinc phosphate or reinforced zinc oxide-eugenol. The cements are semi-translucent and have been claimed to be similar to polycarboxylate cements in having a "bland" effect on the pulp when applied on dentine in deep cavities (McLean and Wilson, 1977, a; Beech, 1980).

Currently, they (and polycarboxylate cements) are the only dental materials available that achieve true adhesion to enamel and dentine because they "adhere to substrates by means of polar and ionic attractions" — a process described as "physiochemical adhesion" (McLean and Wilson, 1977, a). McLean and Wilson (1977, a) reported the findings of Crisp, Wilson and Hotz that indicated that glass ionomer cements also adhered to stainless steel and tin or tin oxide-plated platinum and gold.

Amongst the suggested clinical applications for the glass ionomer cements (McLean and Wilson, 1977, b; Beech, 1981) are several which may be applicable to the restoration of an endodontically-treated tooth. Their potential as luting agents is discussed in 6.16.

Because of their ability to adhere to tooth structure (including dentine) and their superior strength to other base forming materials such as zinc phosphate or reinforced zinc oxide-eugenol cements, they have been suggested for the "building-up to classical form" of crown preparations even when a substantial portion of the crown preparation

has been lost (Beech, 1981). McLean and Wilson (1977, a) noted that a study by Hotz et al (1976) found that the adhesive bond to enamel, dentine and other tin-plated alloys was only approximately 4 MPa. It may therefore be advisable in pulpless teeth with substantial tooth loss, to build up the crown preparation using a stronger material (rather than glass ionomer cement) such as amalgam or composite resin, retained by posts or pins and the remaining tooth structure.

Glass ionomer cement is very sensitive to moisture contamination for 20 to 30 minutes after mixing (McLean and Wilson, 1977, c), and finishing with rotary instruments is not recommended until the material is fully set in 24 hours. For these reasons, it may be more appropriate to restrict the use of this material to relatively minor additions to crown preparations such as the elimination of undercuts.

Although glass ionomer cements have been used clinically with success, for some years in the restoration of vital teeth, there has been little research into the adhesion of the cements to the dentine of non-vital and endodontically-treated teeth. It is possible that, in the absence of some moisture from the dentine, the adhesive bond may be reduced. Beech (1981) suggested that the presence of a fine film of moisture on the tooth surface may in fact assist the retention of glass ionomer cements by enhancing the adhesive bond.

## 6.15 Combination of post and core materials

### 6.15.1 *General discussion*

The suitability of the various materials for use as posts, core foundations or final restorations has been considered. However, because of convenience in the technical procedures, and in order to be able to use the materials with the most desirable qualities for the particular parts of the restoration, techniques that make use of different materials for the post and the core foundation have been suggested. While some

combinations of post and core materials may be used without any apparent ill-effects on the physical or mechanical properties of the materials, others may lead to unfavourable reactions that affect the ultimate prognosis of the treated tooth.

"Cast-on" techniques, that employ gold casting alloys as a core material in combination with high-fusing wrought gold or iridio-platinum posts, have become popular in recent years (Baraban, 1971; Courtade and Timmermans, 1971, p.145-172) because of the improved mechanical properties of the wrought posts and the convenience of the technique. Wrought cobalt-chromium posts with cast gold or base metal alloy cores, fabricated by this technique, have also given satisfactory results (Harty and Leggett, 1972). However, the use of a wrought stainless steel post in combination with a cast metal core is contra-indicated because of the very real danger of the stainless steel alloy being sensitized during the heating and casting procedures (6.8). Angmar-Månsson et al (1969) noted that many cases of root fracture due to the corrosion of such posts have been reported in the literature.

Amalgam and composite resin core foundations retained by metal posts and/or pins have become popular methods of reconstructing endodontically-treated teeth in the last two decades. Posts of gold, stainless steel (Courtade and Timmermans, 1971, p.145-172), wrought cobalt-chromium (Leggett, 1979) and brass (Nicholls, 1963; Kafalias, 1969 and 1975) have been used in combination with two of the most popular core materials — amalgam and composite resin. The influence of the presence of retentive pins on the mechanical properties of amalgam and composite resin is discussed in 13.7. Although similar studies have not been carried out to determine the possible effects of root canal posts on the mechanical properties of these core materials, the effects of the posts are likely to be similar in type to those described for pins in Chapter 13.

Although, for many clinicians, the metal post-retained amalgam core has been a popular method of providing a foundation for the coronal restoration, there has been some controversy over the clinical significance of the galvanic reaction that takes place in the oral environment between the amalgam core and the metal post(s), and between the amalgam core and the coronal gold restoration.

Galvanic corrosion may occur when metals with different electrochemical potentials come into contact in the presence of an electrolyte with the consequent formation of an electric circuit. In the oral environment, the electrolyte is usually saliva or tissue fluid (Simonsen et al, 1973). In galvanic corrosion usually the less noble metal is attacked, while the more noble one with the higher electrochemical potential remains intact. The amount of corrosion may vary with the potential difference between the metals or alloys (Angmar-Månsson et al, 1969) and the electrochemical properties of the electrolyte (saliva); this depends upon its composition, concentration of its components, pH, surface tension and its buffering capacity (Phillips, 1982, p.294).

In vital teeth, evidence of a galvanic current was noted by Carter (1965) who reported a clinical case in which a sharp, painful response was elicited from the pulp when a cast gold crown was allowed to come in contact with an amalgam foundation. Phillips (1982, p.295) referred to this as a "galvanic shock". In pulpless teeth, many cases of root fracture, thought to be caused by the build-up of the products of galvanic corrosion, have been reported by Angmar-Månsson et al (1969), Rud and Omnell (1970) and Petersen (1971). In two papers, Angmar-Månsson et al (1969) and Rud and Omnell (1970) reported on the diagnostic aspects and the metallurgical analysis of some 460 cases of root fractures associated with the corrosion of the components of the post-core foundations. Amongst the 36 extracted teeth (selected at random) in

which the post, the core and the root were available for examination, several combinations of post and core materials were present. These included 20 cases of steel post-cast alloy core, 8 cases of German silver (Cu, Ni, Zn) post-cast alloy core, 2 cases of steel post-amalgam core, and other combinations such as steel post-silver core, brass post-amalgam core, gold post-cast alloy core and cast post-cores of gold or a tin-antimony-silver-zinc casting alloy. Although in a number of the cases, the stainless steel post was heated during the casting of the core foundation (and therefore, very likely to have a lowered corrosion resistance), Angmar-Månsson et al (1969) suggested that the corrosion mechanism responsible for the complications was most probably of the galvanic type because in cases where amalgam was the core material, the post would not have been heated; and in every case where corrosion had occurred, metals with different electrochemical potentials were present. While the fractures could have been caused by trauma and could have preceded the corrosion, it was also possible that the tissue fluid had come into contact with the metals through the root cementum and dentinal tubules. Lindén (1968) showed that root cementum and dentine of extracted teeth are permeable to both water and saline. Consequently, insoluble corrosion products build up inside the root canal and could have exerted considerable pressure on the inside wall of the root until root fracture occurred.

Although in galvanic corrosion, it is usually the less noble metal that is attacked, Parvinen et al (1976) found that two cast gold bridges, that were placed over amalgam cores retained by non-noble screw posts, corroded after only approximately 2½ years service. In this patient, the galvanic current became a chronic irritant to the mucosa which was, in fact, the principal complaint of the patient. The cast gold bridges were removed and eventually replaced by acrylic resin bridges and the

symptoms disappeared. Although these authors did not mention the condition of the amalgam core foundations, Phillips (1982, p.343-344) warned that whenever a gold restoration is placed in contact with an amalgam, one can expect corrosion of the amalgam to take place because of the large differences in the electrochemical potential of the two materials. The free mercury liberated by the corrosion process, may contaminate and weaken the gold restoration. The long-term clinical significance of this type of galvanic corrosion, particularly in cases where part of the amalgam core foundation supporting a gold crown is exposed to oral fluids, is currently unknown.

In order to determine whether non-noble screw posts corrode in the oral environment without showing radiographic signs of corrosion and whether the corrosion products penetrate into adjacent structures, Arvidson and Wróblewski (1978) examined ten extracted endodontically-treated teeth which had been restored with brass screw posts, amalgam cores and gold crowns 3 to 10 years prior to the extraction. X-ray microanalysis of the extracted teeth was carried out and biopsies were obtained from the discoloured gingiva adjacent to the extracted teeth. The copper and zinc from the brass screw posts were found to have migrated into the dentine and other surrounding tissues. In order to reduce the risk of galvanic corrosion, these authors suggested keeping the number of combinations of different restorative materials to a minimum and that as far as possible, only noble alloys should be used.

In contrast with the findings of the previous authors, a follow-up study, over a period of up to nine years, of post-retained or pin-retained amalgam restorations by Simonsen et al (1973), appeared to support the use of stainless steel pins and brass screw posts as an alternative to the cast gold post-core. During the period of investigation, the 150 post-retained or pin-retained amalgam

restorations did not show any clinical or radiographic signs of corrosion. However, as Arvidson and Wróblewski (1978) pointed out, corrosion, when it occurred, may be undetectable (both clinically and radiographically) in its early stages.

The use of brass as a core material in conjunction with a stainless steel post (Kurer, 1967) was discussed in 6.9. While the method is relatively economical and simple to use, the adaptation of the post-core foundation to the prepared pulpless tooth is generally unsatisfactory and has to rely on the cementing medium to compensate for the deficiency.

#### 6.15.2 *Case reports*

For some time now, the technique using amalgam core foundations retained by stainless posts has been a popular method of restoring endodontically-treated posterior teeth. Aluminium posts\*, although intended only for the retention of temporary acrylic resin crowns, have also been inadvertently used for retaining amalgam core foundations. Two cases of root fractures associated with the use of aluminium posts in conjunction with amalgam core foundations have been observed by the author.

##### *Case 1*

The patient, a female aged 35, had been attending the University Operative Dentistry Clinic of the United Dental Hospital, Sydney, since April, 1979. Treatment rendered included several amalgam and composite resin restorations and root canal therapy for three maxillary premolars. Endodontic treatment for the maxillary right first premolar (14) began in October, 1979. Although biomechanical preparation of the two root canals was completed, a permanent root filling was not placed due to

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\*Para-Post System, Whaledent International, New York, N.Y., U.S.A.

persistent drainage. The root canals were medicated\* and the tooth temporarily restored with a composite resin crown retained by five self-threading pins. The root canals were subsequently obturated with gutta percha and Proco-Sol<sup>@</sup> in February, 1980. Both the buccal and palatal canals were prepared to receive a 1.75 mm diameter, parallel-sided, stainless steel post<sup>#</sup>. Instead, a 1.75 mm diameter, aluminium post<sup>#</sup> was cemented into the buccal canal and an amalgam core foundation was placed over it. A porcelain fused to metal jacket crown was constructed and cemented seven weeks later.

In May, ten days after the insertion of the full crown, the patient presented at the Student Clinic complaining of a "continuous throbbing pain" in the tooth for the previous five days. On examination, there was an open contact in the distal causing food impaction and the buccal incline of the palatal cusp was over-contoured resulting in occlusal interference. However, radiographically, (Fig. 6.2,a) although there were no obvious signs of a root fracture, the post could not be seen. After occlusal adjustment, the tooth remained asymptomatic for four months. When the patient returned in September, 1980, there was pain and swelling in the area around the 14. A root fracture near the bifurcation was diagnosed after exploration through the porcelain-metal crown. Because of the extremely poor prognosis, the tooth was extracted (Fig. 6.2,b).

On examination of the extracted tooth, there was no evidence of either the amalgam or the cemented aluminium post except for the green paint which identified its size (Fig. 6.2,c).

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\*KRI-3, Pharmachemie AG, Zurich, Switzerland

<sup>@</sup>Star Dental Mfg. Co. Inc., Conshohocken, PA., U.S.A.

<sup>#</sup>Para-Post System, Whaledent International, New York, N.Y., U.S.A.

*Case 2*

The patient, a male aged 45, was also a patient at the University Operative Dentistry Clinic of the United Dental Hospital, Sydney. Following mechanical preparation and root filling with gutta percha and Proco-Sol (February, 1980) the palatal root canal of the maxillary right first premolar and the buccal root canal of the second premolar were prepared to receive a parallel-sided stainless steel post\* for the support of an amalgam core foundation. Instead, aluminium posts\* of the same diameter were cemented and amalgam was condensed around these posts. Crowns were subsequently placed over the amalgam foundations (July, 1980). It was approximately at this time that the inadvertent use of the aluminium posts was discovered. Unfortunately, no action was taken to remove the cemented aluminium posts and the patient presented in September complaining of pain and occlusal interference due to the gold crown on the 14. On examination, the bucco-gingival margin of the 3/4 veneer gold crown on the 15 has a similar discrepancy (Fig. 6.3,a). When the porcelain-metal crown on the 14 was removed, only a small amount of the amalgam core was present and there was no evidence of the aluminium post cemented some six months previously. Because of the presence of a deep, subgingival, diagonal fracture which would have required periodontal surgery prior to any attempt at restoring the tooth, extraction was determined to be the treatment of choice. Radiographically (Fig. 6.3,b), the aluminium post in the 15 could not be detected. On removal of the 3/4 veneer gold crown on the 15, it appeared that the aluminium post had completely corroded and that even part of the amalgam foundation was missing (Fig. 6.3,c). Apart from this, the root appeared intact and was subsequently restored with a

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\*Para-Post System, Whaledent International, New York, N.Y., U.S.A.

3/4 veneer gold crown placed on an amalgam foundation supported by two stainless steel posts.

### *Discussion*

Although the exact nature of the chemical reaction that took place in the oral environment in these cases is still uncertain, amalgam is known to react with aluminium on contact. While it cannot be proven conclusively that the reaction between the aluminium post and the amalgam core was the primary cause of the root fractures, in view of the serious nature of these complications, the author would strongly advise against the use of the aluminium posts in combination with amalgam — under any circumstances — not even in a temporary amalgam restoration. Until laboratory or clinical research provide more information on the use of aluminium posts with amalgam, the manufacturer should include, in the packaging of these posts, labels warning the users of the possible danger of the use of the aluminium posts with amalgam.

### 6.16 Cementing medium

The cementing medium plays an important but often "under-rated" role in the various stages of the restoration of an endodontically-treated tooth — from the cementation of posts, pins and cast metal post-core foundations, to the placement of the final coronal restoration. Although the retention of a cemented structure — whether it is an intra-coronal or an extra-coronal restoration — is dependent principally on its frictional fit and the resistance and retention forms given to the cavity preparation (Bryant and Wing, 1975), the cementing medium is the final component which completes the process of restoring the pulpless tooth.

For almost 150 years, cements resembling the modern zinc phosphate cement have been available in dentistry (Christensen, 1978, p.477).

Currently, there are at least six categories of dental cements in use for luting inlays, crowns, bridges and other structures to teeth. These are zinc phosphate, zinc polycarboxylate, zinc oxide-eugenol, zinc silicophosphate, resin and glass ionomer cements. A review of laboratory and clinical studies on the first five categories of dental cements was presented by Going and Mitchem (1975) soon after glass ionomer cement was first introduced and while it was undergoing clinical evaluation as an adhesive restorative material as well as a luting agent. Their report considered factors such as strength, solubility, bonding to tooth structure, manipulation and setting, film thickness and effects on the pulp. They acknowledged that, frequently, clinical success was difficult to predict from many of the laboratory tests used, and they emphasized the need for comprehensive clinical studies correlated with physical and biological testing in order to identify the properties that were clinically significant. For example, it was suggested that compressive and tensile strength values did not necessarily predict the relative retentive ability of cements that had different potentials for reacting with or on the tooth surface. Some of the properties of the six categories of cements are presented in Table 6.2.

Pulpal irritation is an undesirable property of cements that are to be used on teeth with vital pulps; in endodontically-treated teeth, other properties of dental cement assume greater importance. Although there are considerable differences in the compressive and tensile strength of the different cement types, the minimum strength required of a dental luting cement in clinical practice is not yet known (Going and Mitchem, 1975). While some of the cements currently available for luting purposes are considerably stronger, clinical studies by Myers (1968) indicated that cements with a compressive strength of 55 MPa might be adequate.

All the cements currently available are soluble in oral fluids to some extent, with the exception of the infrequently used composite resin cement (Christensen, 1978, p.483), which is insoluble in normal mouth fluids. The resistance of silicate and glass ionomer cements to attack by weak acids were compared (McLean and Wilson, 1977,a) in a laboratory investigation; the glass ionomer cements were found to be much less soluble in the acidic environment. The solubility of the reinforced zinc oxide-eugenol cements has been reported to be in the range of zinc phosphate cement (Phillips et al, 1968); however, some clinicians (for example, Wilson and Batchelor, 1970) have expressed concern over the continual loss of eugenol by leaching. Exposure of many to these cements to moisture during setting has detrimental effects on the strength and solubility of the set material. Therefore, in spite of its questionable (possibly high) film thickness and the possible harmful effects on the pulp when used in vital teeth, the composite resin cement (EpoxyLite CBA 9080\*), with its high strength properties and insolubility, has been suggested for the cementation of restorations in endodontically-treated teeth (Christensen, 1978, p.483).

Several factors are known to influence the thickness of the cement film between a prepared tooth surface and a restoration (Jørgensen, 1960 and 1963):

1. Effective grain size of the cement powder particles
2. Powder-liquid ratio of the cement
3. Amount and duration of the pressure applied during seating of the restoration
4. Presence of an occlusal venting channel
5. Degree of taper of the preparation.

Although the actual adhesion of zinc polycarboxylate and glass

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\*Lee Pharmaceuticals, South El Monte, Calif., U.S.A.

ionomer cements to enamel, and to a lesser extent to dentine, has been demonstrated (Smith, 1968 and 1971; McLean and Wilson, 1977,a), the clinical significance of this bonding has yet to be proved. According to Christensen (1978, p.480), there was no significant difference in the retention of inlays cemented with zinc phosphate or zinc polycarboxylate cement. Whether the potential bonding of the zinc polycarboxylate and glass ionomer cements to tooth structure will decrease future leakage at the margin of the restoration is not known. Since long-term clinical evaluations of glass ionomer cements as a luting agent have not been concluded, it is necessary to be cautious in accepting Beech's claim (1980) of this material as "the best luting cement currently available"; it does, however, possess qualities which enhance its potential as an ideal luting agent. According to Beech (1980), in addition to their ability to bond to tooth structure, the glass ionomer cements have very good resistance to breakdown by oral fluids and good handling characteristics and flow permitting satisfactory film thickness; although the rate of solubility and disintegration is low, the glass ionomer cements release fluoride for caries protection.

Going and Mitchem (1975) summarized their review by stating that: "until further studies demonstrate conclusively the superiority of a single luting system, the dentist can remain assured of maximum clinical longevity through his continued use of the zinc phosphate cement".

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Table 6.1

SOME PROPERTIES OF THE MATERIALS USED IN THE RESTORATION  
OF ENDODONTICALLY-TREATED TEETH

| MATERIAL               | COMPRESSIVE STRENGTH<br>(MPa) | TENSILE STRENGTH<br>(MPa)     | MODULUS ELASTICITY<br>( $\times 10^4$ MPa) | LINEAR COEFFICIENT<br>OF THERMAL EXPANSION<br>( $\times 10^{-6}$ mm/mm/ $^{\circ}$ C) | ELONGATION (%)             | HARDNESS (units)               | MELTING RANGE ( $^{\circ}$ C)           |
|------------------------|-------------------------------|-------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------|----------------------------|--------------------------------|-----------------------------------------|
| Gold alloy - Type I    |                               | 275 <sup>1</sup>              | 7.5 <sup>5</sup>                           |                                                                                       |                            |                                |                                         |
| - Type II              |                               | 310 <sup>1</sup>              | 9 - 10 <sup>5</sup>                        | 14 <sup>7</sup>                                                                       | 30 <sup>1</sup>            | 69 BHN <sup>1</sup>            | 1005 <sup>0</sup> - 1070 <sup>01</sup>  |
| - Type III             |                               |                               |                                            | 14 <sup>7</sup>                                                                       | 25 <sup>1</sup>            | 85 BHN <sup>1</sup>            | 900 <sup>0</sup> - 970 <sup>01</sup>    |
| - Type IV              |                               | 360(S) - 415(H) <sup>1</sup>  | 9 - 10 <sup>5</sup>                        | 14 <sup>7</sup>                                                                       | 20(S) - 12(H) <sup>1</sup> | 105(S)-115(H) BHN <sup>1</sup> | 930 <sup>0</sup> - 1000 <sup>02</sup>   |
| - wrought              |                               | 505(S) - 765(H) <sup>1</sup>  | 9 - 10 <sup>1</sup>                        | 14 <sup>7</sup>                                                                       | 20(S) - 4(H) <sup>1</sup>  | 140(S)-225(H) BHN <sup>1</sup> | 871 <sup>0</sup> - 982 <sup>04</sup>    |
| - high-fusing          |                               | 660(S) - 1300(H) <sup>1</sup> | 10.5 <sup>1</sup>                          | 14 <sup>7</sup>                                                                       | 15(S) - 4(H) <sup>1</sup>  | 175(S)-275(H) BHN <sup>1</sup> | 950 <sup>0</sup> - 1035 <sup>02</sup>   |
|                        |                               | 415 - 765 <sup>1</sup>        | 11 <sup>1</sup>                            | 14 <sup>7</sup>                                                                       | 4 <sup>1</sup>             | 225 BHN <sup>1</sup>           | 1400 <sup>02</sup>                      |
| Semi-precious          |                               | 448 <sup>6</sup>              |                                            |                                                                                       | 18 <sup>6</sup>            | 195 VHN <sup>6</sup>           | 977 <sup>0</sup> - 987 <sup>0</sup> 6   |
| Nickel-chromium        |                               | 600(S) - 900(H) <sup>5</sup>  | 20 - 21 <sup>5</sup>                       |                                                                                       | 5 - 10 <sup>5</sup>        | 300 VHN <sup>5</sup>           | 1250 <sup>0</sup> - 1360 <sup>0</sup> 5 |
| Cobalt-chromium (cast) |                               | 640 - 825 <sup>1</sup>        | 22.8 <sup>1</sup>                          | 9 - 12 <sup>7</sup>                                                                   | 1.5 - 10 <sup>1</sup>      | 370-400 VHN <sup>5</sup>       | 1250 <sup>0</sup> - 1480 <sup>0</sup> 5 |
| Stainless steel (18-8) |                               | 585(S) - 965(H) <sup>1</sup>  | 20 <sup>3</sup>                            | 11 - 13 <sup>7</sup>                                                                  | 55(S) - 25(H) <sup>1</sup> | 165(S)-275(H) BHN <sup>1</sup> | 1400 <sup>0</sup> 1                     |
| Brass                  |                               | 482 <sup>10</sup>             |                                            |                                                                                       | 15                         | 75 RHN <sup>10</sup>           |                                         |
| Aluminium              |                               | 179 <sup>10</sup>             |                                            |                                                                                       | 9                          | 60 RHN <sup>10</sup>           |                                         |
| Amalgam                | 415 - 550 <sup>9</sup>        | 59 - 98 <sup>11</sup>         | 2.1 <sup>5</sup>                           | 25 <sup>7</sup>                                                                       | 0 <sup>1</sup>             | 90 KHN <sup>2</sup>            |                                         |
| Composite resin        | 235 - 276 <sup>13</sup>       | 32 - 45 <sup>13</sup>         | 4.5 <sup>13</sup>                          | 35 <sup>13</sup>                                                                      |                            | 49 KHN <sup>2</sup>            |                                         |
| Acrylic resin          | 69 <sup>13</sup>              | 24 <sup>13</sup>              | 2.4 <sup>13</sup>                          | 81 <sup>13</sup>                                                                      |                            | 16-20 KHN <sup>13</sup>        |                                         |
| Glass ionomer          | 214 <sup>12</sup>             | 13 <sup>12</sup>              | 1.9 <sup>12</sup>                          |                                                                                       |                            |                                |                                         |
| Enamel                 | 400 <sup>8</sup>              | 69 <sup>3</sup>               | 4.8 <sup>3</sup>                           | 11.4 <sup>1</sup>                                                                     | 0 <sup>1</sup>             |                                |                                         |
| Dentine                | 297 <sup>8</sup>              | 41 <sup>3</sup>               | 1.4 <sup>3</sup>                           | 11.4 <sup>1</sup>                                                                     | 0 <sup>1</sup>             |                                |                                         |

TABLE 6.2

PROPERTIES OF LUTING CEMENTS

| CEMENT TYPE                                   | COMPRESSIVE STRENGTH (MPa) | TENSILE STRENGTH (MPa) | FILM THICKNESS (µm) | SETTING TIME (AT 37°C min.) | BONDING TO TOOTH OR RESTORATIVE MATERIALS                                                       | SOLUBILITY IN ORAL FLUIDS  | CARIES PROTECTION                        | PULPAL IRRITATION          |
|-----------------------------------------------|----------------------------|------------------------|---------------------|-----------------------------|-------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------|----------------------------|
| Zinc phosphate                                | 103.5 <sup>1</sup>         | 5.5 <sup>1</sup>       | 18 <sup>1</sup>     | 5.5 <sup>1</sup>            | none                                                                                            | moderate <sup>4</sup>      | none                                     | moderate <sup>1</sup>      |
| Reinforced zinc oxide-eugenol (EBA + Alumina) | 55.2 <sup>1</sup>          | 4.1 <sup>1</sup>       | 25 <sup>1</sup>     | 9.5 <sup>1</sup>            | none                                                                                            | moderate plus <sup>4</sup> | none                                     | mild <sup>1</sup>          |
| Zinc polycarboxylate                          | 55.2 <sup>1</sup>          | 6.2 <sup>1</sup>       | 21 <sup>1</sup>     | 5.5 <sup>1</sup>            | enamel, dentine <sup>3</sup>                                                                    | moderate <sup>4</sup>      | none                                     | mild <sup>1</sup>          |
| Zinc silicophosphate                          | 144.8 <sup>1</sup>         | 7.6 <sup>1</sup>       | 25 <sup>1</sup>     | 4 <sup>1</sup>              | none                                                                                            | moderate <sup>4</sup>      | contains <sup>3</sup> leachable fluoride | moderate <sup>1</sup>      |
| Resin cement                                  | 65.5 <sup>1</sup>          | not available          | 10-60 <sup>1</sup>  | 4-10 <sup>1</sup>           | none                                                                                            | insoluble <sup>4</sup>     | none                                     | moderate <sup>1</sup> plus |
| Glass ionomer                                 | 128 <sup>2</sup>           | 8 <sup>2</sup>         | 24 <sup>2</sup>     | 6.5 <sup>1</sup>            | enamel, dentine, <sup>2</sup> stainless steel, and to tin or tin oxide-plated platinum and gold | very low <sup>5</sup>      | contains <sup>5</sup> leachable fluoride | mild <sup>1</sup>          |

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5. Beech, D. R. (Aust. Dent. J., 25:3, p.185 (June) 1980)

Fig. 6.1; 6.2

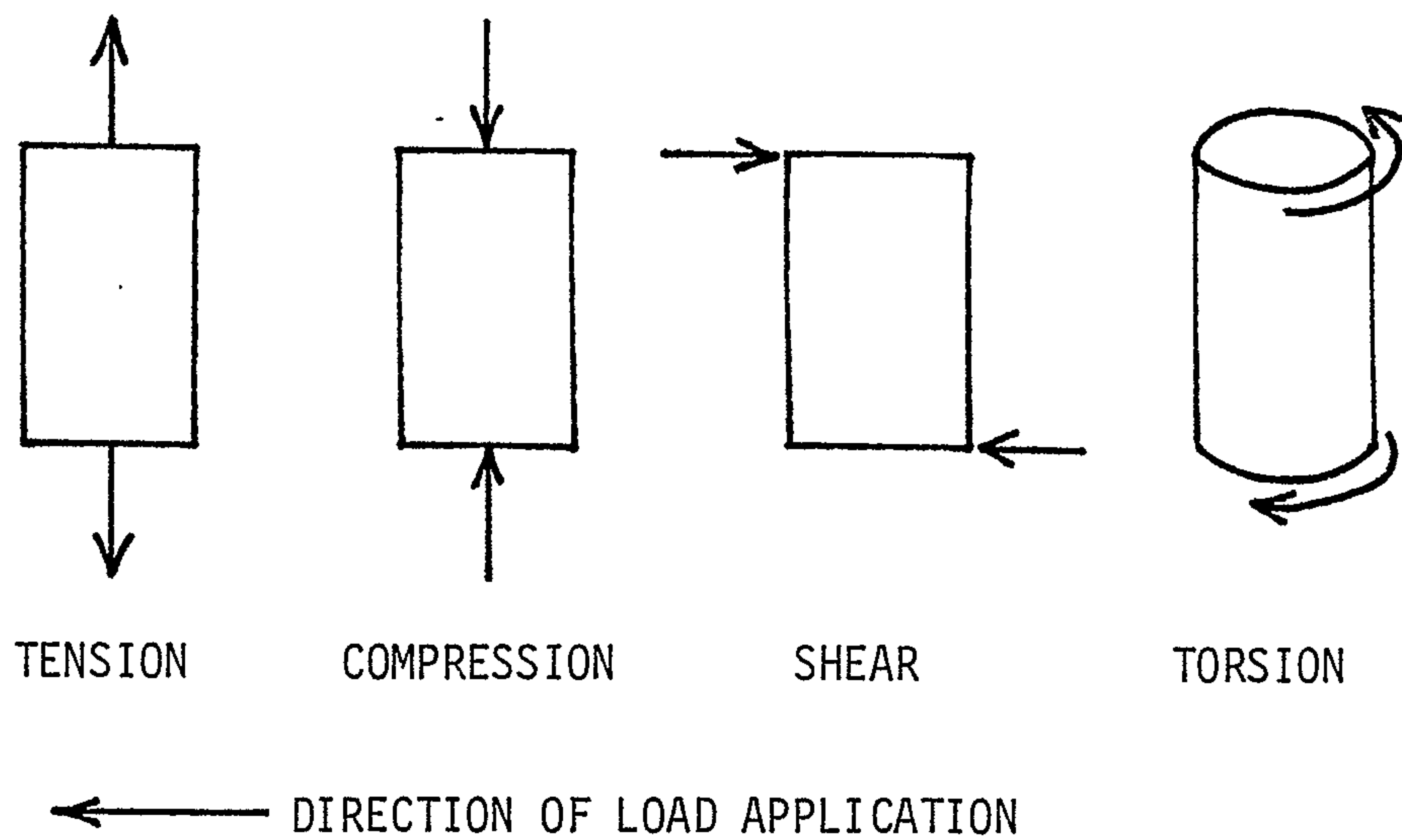


Fig. 6.1 Basic modes of load application in the oral cavity  
( from Greener et al, 1972, p.45)



Fig. 6.2 For legend refer to 6.15.2

Fig. 6.3

For legend refer to 6.15.2