THE SEALING PROPERTIES OF FOUR ROOT FILLING TECHNIQUES

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by

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ABSTRACT

The sealing properties of four root filling techniques were assessed by using electrochemical leakage (ECL) and linear dye penetration (LDP) techniques. The obturated teeth were also assessed radiographically for adaptation and length of root filling.

Fifteen teeth were used per root filling technique. The teeth were chemomechanically prepared by hand instrumentation and then obturated by one of the following techniques: Lateral condensation with sealer, Ultrafil thermoplasticized gutta-percha without sealer, McSpadden compaction with sealer, and Enac ultrasonically plasticized gutta-percha and sealer.

The teeth were exposed to 30 days of electrochemical leakage, and the degree of current flow was recorded daily for each tooth. At the end of the electrochemical leakage experiment, the teeth were immersed in 2% methylene blue dye for 48 hours and then sectioned vertically to assess the degree of linear dye penetration.

It was found that the ECL results for the four obturation techniques were very similar. Although differences were not statistically significant, teeth obturated by the lateral condensation technique tended to leak less than those obturated by the McSpadden technique, which generally had the highest leakage.

When open apex teeth were excluded, there was no significant difference in mean LDP between the lateral condensation, McSpadden compaction and the Enac obturation techniques. Teeth obturated by Ultrafil exhibited relatively high mean LDP, probably because no sealer was used.

Teeth obturated by lateral condensation and sealer exhibited good radiographic adaptation and length control while teeth obturated by Ultrafil exhibited relatively poor radiographic adaptation and length control.

PREFACE

Endodontics is a relatively new field of dentistry, having a truly scientific beginning as recently as the third decade of this century (Grossman, 1976). Many advances have been made in root canal instrumentation and obturation techniques in the past fifty years.

This investigation has two aims:

1) To test the apical seal of four obturation techniques, by assessing dye penetration and electrochemical leakage.
2) To relate the quality of the apical seal to the quality of the radiographic adaptation of the root filling to the root canal.

The thesis is divided into two parts. Part one contains the Review of Literature and part two contains the Original Research.

Part one is divided into five chapters. It was the aim of this section to provide some information on the field of Endodontics. Chapter 1 deals with the history of root canal filling materials and techniques. Chapter 2 discusses the rationale for endodontic therapy and Chapter 3, the preparation of the root canal. Chapter 4 deals with the obturation materials and techniques currently available. Chapter 5 deals with the techniques which have been used to assess the seal of root fillings.

Part two is divided into six chapters. The experimental method is described and discussed in chapter 6. Method A deals with electrochemical leakage, Method B deals with linear dye penetration and Method C deals with the radiographic assessment of the root filling

Chapter 7 deals with the results of the pilot study and Method A (electrochemical leakage). The results of the linear dye penetration experiment, (Method B) are presented in Chapter 8. Chapter 9 is concerned with the results of the radiographic assessment of adaptation and length of root canal fillings. The results of any additional experiments are presented in Chapter 10.

The discussion of the results is presented in Chapter 11. The final chapter in the thesis, Chapter 12 is labelled "Conclusion" and is a summary of the more significant findings.

The use of a standardized numerical system to identify sections of the text throughout the thesis has enabled 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, 7.1). Within each of these sections, subsections have been identified by their separation from the section number by a second full stop (for example, 8.2.1)

A list of Tables and a list of Figures are placed immediately after the Table of Contents. These lists present the page number on which a specific table or figure is found. Both the tables and the figures are identified by two numbers (for example, Table 7.1) - 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 in the chapter.

Bibliographic details of published articles, textbooks, lectures and presentations, and other reference sources in this thesis can be found at the end of the thesis in the section entitled Bibliography. Abbreviations used are consistent with those found in the Index of Dental Literature (1990) and the format follows that used by the Australian Dental Journal (1990).

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CHAPTER 1

HISTORY OF OBTURATION MATERIALS AND TECHNIQUES.

"Literature on the early history of endodontics is as sparse and as undocumented as that on the early history of dentistry itself. The scientific development of endodontics dates from the third decade of this century; this means that endodontics did not keep step with the development of the science of dentistry." Grossman (1976).

Many substances or materials have been used to fill root canals in the past. "A partial list arranged alphabetically, would include amalgam, asbestos, balsam, bamboo, calcium hydroxide,"Cavit", cement, copper, cotton, crystalizable substances, dentin chips,"Dycal", fiberglass, gold, gutta percha, indium, ivory, lead, paper, paraffin, pastes, pitch, polymerized acrylic resin, rubber, spunk, thistles, wax, wood." Grossman (1981,p 278).

In earlier times root canal filling actually preceded removal of the entire pulp. Once the pulp died and the canal was empty enough to receive a filling, some foreign substance (often gold foil) was inserted into it. As early as 1802 Longbotham, B.T. urged the filling of root canals as a means of saving teeth, instead of the usual alternative of extraction (Grossman, 1976).

Edward Hudson plugged root canals with gold foil in 1809. In 1850 Elisha Townsend of Philadelphia made the art of "stuffing" root canals with gold foil a little easier by suggesting that the gold foil should be heated to eliminate moisture, thereby improving the cohesive properties of the material (Grossman, 1976).

Those who could, filled canals with gold foil, others turned to more adaptable materials such as tin foil, lead foil, cotton, wood, spunk and plaster of Paris, while some dentists did not fill root canals at all.

Around 1876 some dentists removed the pulp and left the canal unfilled, simply placing Hill's stopping in the cavity as a restoration, then cutting a small hole in the labial or buccal surface of the tooth near the pulp chamber for the escape of "mephitic exhalation" if pain or swelling occurred (Grossman, 1976).

A common method of filling root canals in the mid 19th century was by saturation of a thread or wisp of cotton with creosote, phenol or coating the cotton with a paste made of these antiseptics and Iodoform. If a solid substance was used for filling, the canal was first wiped with a small amount of creosote. This method was continued into the 20th century (Grossman, 1976).

In 1856 the first cement was used and was composed of zinc oxide and a solution of zinc chloride.

"Oxychloride of zinc, as it was known, was replaced by oxyphosphate of zinc in 1879. Both oxychloride and oxyphoshate cements are still being used for filling root canals in some countries; however these cements cannot be removed should the teeth need re-treatment (which they often do) because the cement sometimes hardens before it can be carried to the apical foramen, or is partially withdrawn from the canal as the instrument bearing it into the canal is removed." Grossman (1976).

In 1867, G.A. Bowman introduced gutta percha points for filling root canals. "Gutta percha is derived from the coagulated sap of certain tropical trees." Phillips (1973). It is a soft, unvulcanized rubber, which has been used for some 120 years as the main root

filling material, with only slight changes in its composition, mainly to improve its properties.

In 1891 O.Walkhoff introduced Camphorated monochlorophenol as an intracanal medicament or as a base for resorbable paste for obturating root canals. Walkhoff's paste is still used today by many dentists, especially in the endodontic treatment of deciduous teeth (Grossman, 1987).

In 1911 J.Callahan recommended the use of rosin dissolved in chloroform for sealing dentinal tubules so as to incarcerate micro-organisms that had not been removed by mechanical means or destroyed by chemical agents. This concept was sound, but what Callahan was not aware of was that when the chloroform evaporated, it left an open latticework. These spaces between the varnish left many tubules uncoated, from which micro-organisms could grow out and reach the periapical tissues unless sealed with gutta-percha (Grossman 1987).

Callahan later used the rosin chloroform solution as a solvent for gutta percha cones which is essentially similar to the chloropercha method, used today. Around 1915, M.L. Rhein used the chloropercha method of filling root canals and attempted to seal the apical foramen with a small button-like overfill of gutta percha.

In 1929, J.R. Blayney did a histological study of 250 pulpless teeth of known history and found that better results followed when root canals were slightly underfilled (Grossman, 1976).

In 1930, B.W. Hermann recommended the use of calcium hydroxide for pulpotomy of vital teeth and root canal obturation (Grossman, 1987). Today, calcium hydroxide is a constituent of root canal cements, for example, Sealapex*. In the early 1930s silver cones were

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* Sealapex (Kerr/Sybron, Romulus MI, USA)

introduced by H.Trebitsch and later by B.Jasper for filling root canals (Grossman, 1976).

The obturation of root canals has undergone some changes, one of which is the availability of gutta percha cones that correspond fairly closely to the size and taper of the root canal instruments. The sectional silver cone technique and the chloropercha method have given way to the lateral and vertical condensation methods of filling root canals.

In the last ten years efforts have been made to plasticize gutta percha by means of heat, either with a hot instrument (vertical condensation, Endotec*), an instrument creating heat by frictional rotation (McSpadden@) or by preheating and injecting the gutta percha into the root canal (Obtura£ , Ultrafil¦) or by ultrasonic plasticization of gutta percha (Enac+). Pastes which are used to obturate root canals such as Hydron** have been used with mixed results. N2@@ is still being used in Europe even though it has been shown to be toxic to tissue. The greatest number of developments has been in the manufacture of new sealers which contain calcium hydroxide and those which bond to dentine.

A large variety of root canal filling materials has been advocated throughout the years. Many of these materials have been rejected by the profession as impractical, irrational or biologically unacceptable.

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* Endotec Thermal Endodontic Condensor (L.D. Caulk, Milford, DE USA)
@ McSpadden J.T. (Self study course of the thermatic condensation of gutta-percha. Toledo, OH R & R, Denstply 1980 USA.
£ Obtura technique (Unitek Corp. Monrovia, CA USA)
¦ Ultrafil system (Hygenic Corp., Akron, OH, USA)
\+ Enac ultrasonic device (Osada Electric Co. Ltd. Japan)
** Hydron (NPO Dental Systems, Inc., New Brunswick NJ, USA)
@@ N2 (AGSA, Zurich Switzerland)

CHAPTER 2

RATIONALE OF ENDODONTIC TREATMENT

Endodontics is the field of dentistry concerned with the pulp cavity and its cellular contents (Ingle 1976, p. 13). The pulp cavity consists of the pulp chamber and the root canal(s) (Figure 2.1). The pulp receives a vascular, lymphatic and nervous supply through the apical foramen and is composed of cellular and fibrous elements.

"Root canal treatment denotes the removal of a vital or necrotic pulp from a root canal and its replacement by a filling. Its object is to prevent the extension of disease from the pulp to the periapical tissue, or, where this has already occurred and periapical disease exists, to encourage resolution and return of the periapical tissues to normal" (Nicholls, 1977, p.64).

Nicholls (1977, p.64) stated that, ".... the immediate aim of root canal treatment is to eliminate the cause of periapical irritation." The irritants contained within the root canal are protein degradation products and, in most cases, micro-organisms living and growing in the decomposed tissue (Penick et al, 1970).

CAUSES OF PULP DISEASE "GROSSMAN 1981, P.49"

I. PHYSICAL

A. Mechanical

1. Trauma
   (a) accidental
   (b) iatrogenic
2. Pathologic Wear
3. Crack through body of tooth
4. Barometric changes (barodontalgia)

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

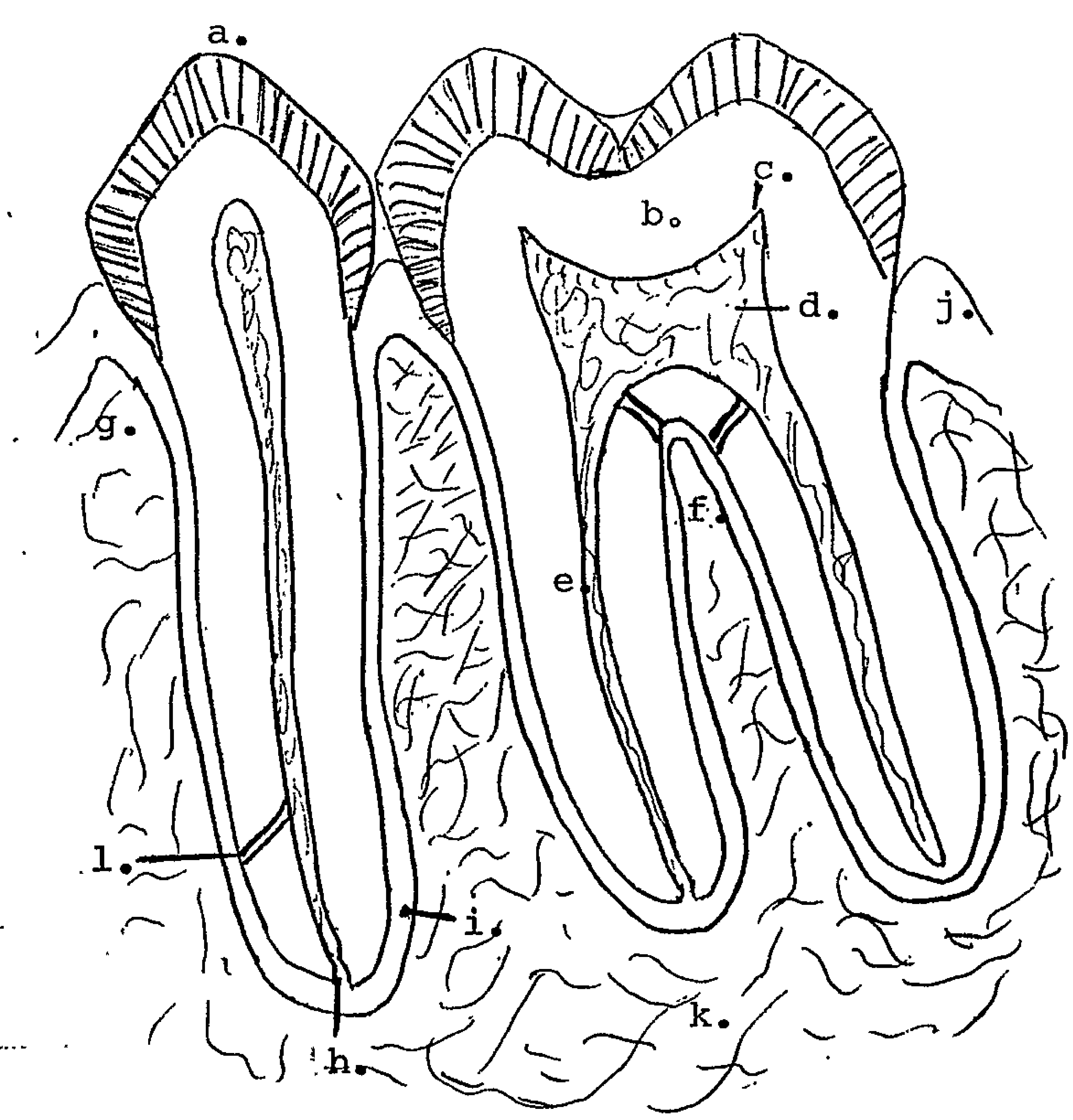

Fig. 2.1 Schematic diagram of the anatomy of human teeth.

a. Enamel
b. Dentine
c. Pulp horn
d. Pulp chamber
e. Root canal
f. Furcation region with accessory canals
g. Alveolar crest
h. Apical foramen
i. Periodontal ligament
j. Gingiva
k. Cancellous bone
l. Lateral canal.

B. Thermal

1. Heat from cavity preparation
2. Setting cement
3. Deep filling, no base
4. Polishing a restoration

C. Electrical

1. Dissimilar metallic fillings

II. CHEMICAL

1. Phosphoric acid
2. Erosion by acids

III. BACTERIAL

1. Toxins associated with carious process
2. Direct invasion of pulp
3. Systemic (Anachoresis)

The effect of these causes may be reversible or irreversible pulpitis. The treatment of irreversible pulpitis is pulpectomy. "Pulpectomy, or pulp extirpation, is the complete removal of a normal or pathologic vital pulp from the pulp cavity of a tooth." (Grossman 1981, p.128).

Penick et al (1970) stated that success in root canal therapy was achieved by thorough debridement and meticulous microbial control, followed by total obturation of the root canal spaces. "Ultimate repair can be effected only by adjacent vital tissues." (Penick et al, 1970). Endodontic therapy simply contributes to this process of repair by eliminating irritants.

Grossman (1981, p.200) stated that endodontic treatment may be divided arbitrarily into five phases: 1) biomechanical preparation; 2) chemical preparation; 3) disinfection; 4) bacteriologic control; 5) root canal obturation.

In summary then, the rationale of endodontic treatment is:

(a) To remove all organic matter in the root canal that is capable of either supporting bacterial growth itself or of decomposing into tissue destructive by-products.

(b) To remove or destroy micro-organisms from the root canal.

(c) To mechanically shape the root canal, so that it can be obturated effectively in three dimensions.

(d) To obturate the root canal system apically and laterally with a biologically acceptable, unresorbable and well sealing material.

CHAPTER 3.

PREPARATION OF THE ROOT CANAL.

3.1 INTRODUCTION

This chapter is concerned with the procedures, instruments and techniques which are used to eliminate necrotic or vital organic debris and micro-organisms from the root canal, and with procedures which shape the root canal to receive a root filling material.

Grossman (1981, p.200) stated that preparation of the root canal consists of biomechanical preparation and chemical preparation. The objectives of biomechanical preparation are 1) to cleanse the pulp chamber and root canals of pulp remnants, foreign debris, infected or softened dentine, 2) to remove obstructions, 3) to enlarge the canal to receive a maximum amount of intracanal medicament or antibiotic for disinfection, and 4) to prepare the canal walls so as to facilitate eventual filling of the root canal space.

3.2 PREPARATION OF THE ACCESS CAVITY.

Initial cutting of the enamel for the access cavity can be performed using an air-turbine handpiece and a round-ended carbide fissure bur (Ingle 1976, p.101). The use of the air-turbine should be discontinued when the dentino enamel junction is reached and rubber dam applied to the tooth for isolation. A round-ended carbide bur in a slow speed handpiece should be used to cut through dentine until entrance is made into the pulp chamber. The round bur is used to remove the roof of the pulp chamber and to clean the side walls using a withdrawing movement out of the pulp chamber. Care should be taken not to perforate the floor of the pulp chamber, or to obliterate the root canal orifices.

"Once the canal orifice is located using an endodontic explorer, the canal can be entered using a file curved close to the tip as a pathfinder." (Ingle, 1976, p.182). With a complex rolling-rotating motion, termed "vaiven" by Ingle (1976, p.182), the operator can determine, whether or not the canal is patent over its entire length, and the direction and degree of curvature of the root canal.

3.3 LENGTH DETERMINATION

The length of the tooth from the incisal surface or from an occlusal cusp should be accurately determined, so that instruments can be confined within the root canal to avoid injury to the periapical tissue (Grossman 1981, p.212). "Failure to determine accurately the length of the tooth may also lead to incomplete instrumentation and underfilling of the canal which can result in persistent pain and discomfort from inflamed shreds of retained pulp tissue; vital or non-vital pulp tissue, debris and bacteria not removed from the canal can also act as a "nidus" for periapical inflammation.

In addition, mechanical preparation short of the dentino-cemental junction may result in ledge formation, which can make re-treatment of the canal very difficult, if not impossible." (Blackler,1983, p.40).

The working length of the tooth is the length from the incisal edge(reference point) to a point within the canal and just short of the apical foramen (about one millimetre from the root apex). The working length is most commonly determined radiographically, either by the Proportion method (Bryant et al, 1981, p.175), or by the Direct observation method (Bryant et al, 1981, p.176), by using a file set to a known length and positioned to within three millimetres of the root apex.

Another method of determining working length is the "electronic method". It essentially consists of a reamer or file which is inserted into the canal until an electric balance is attained with the periodontal ligament. At that point the instrument has reached the apex and its length measured. The theory behind the electrical measurements is that the periapical tissue and gingiva have the same electrical resistance (Grossman 1981, p.212).

Electronic measurement of tooth length is an effective method in from eighty to ninety percent of cases compared with the radiographic method. Inaccuracies can occur where there are tags of necrotic tissue, when the instrument in the canal comes into contact with a metallic filling, where a pulp stone is present, and when a foreign substance is present in the root canal (Grossman 1981, p.213). The apical limit of canal instrumentation is usually determined to be the dentino-cemental junction.

3.4 IRRIGATION OF THE ROOT CANAL

Chemical debridement of the root canal is always needed because even following "meticulous instrumentation" there are usually small irregularities which are not eliminated and which harbour micro-organisms in the debris they contain" (Masterton, 1965). Chemical debridement is a necessary adjunct to ensure complete eradication of necrotic tissue and debris (Heuer, 1963; Masterton, 1965). Irrigation greatly facilitates the removal of organic debris, dentinal filings and other foreign material from the root canal and lubricates the root canal instruments during mechanical preparation (Heuer 1963). Instrumentation of the root canal should always be achieved with copious irrigation. This will prevent packing dentine chips in the apical one-third of the canal (Weine 1976, p.199).

The ideal irrigating solution should perform the following functions (Blackler, 1983):

1) it should remove all debris (pulpal and dentinal) from the entire canal including the pulp chamber,
2) it should be an organic tissue solvent, acting to remove vital and necrotic pulpal tissue, predentine and bacteria, "out of reach" of instrumentation,
3) it should be bacteriocidal,
4) it should act as a "lubricant" to increase the cutting efficiency of endodontic instruments and to reduce the possibility of instrument breakage,
5) it should be a demineralizing agent and, as a result of this demineralizing action,"soften" the dentine wall of the root canal to facilitate instrument enlargement of the canal space. By virtue of its demineralizing action the

irrigating solution should completely remove the smeared layer and open and enlarge the dentine tubule orifices to allow for "chemical sterilization" of the tubule space and also provide a clean, smooth surface so that the root canal filling material may adapt better to the canal wall.

3.4.1 SOLUTIONS

Sodium Hypochlorite

Sodium hypochlorite, in varying concentrations, is the most widely used irrigant in endodontics (Weine 1976, p.288). It has been used as a 0.5 per cent to six per cent solution but is mostly used in a five per cent solution which yields approximately one per cent available chlorine (Luebke, 1967; Penick, et al, 1970). Weine (1976, p. 114) stated that a one per cent solution of sodium hypochlorite was the most frequently used concentration.

Weak hypochlorite solutions digest organic debris while having little effect on adjacent viable tissues (Schilder 1984, p. 178).

Sodium hypochlorite is a necrotic tissue solvent and an effective disinfectant, due to the halogen (Chlorine) content, and it also acts as a mild bleaching and deodorizing solution for dentine (Ingle 1976, p. 177). Grossman (1981, p. 239), prefers the use of five per cent sodium hypochlorite and three per cent hydrogen peroxide solutions, used alternately to produce a greater cleansing effect by effervescence as oxygen is liberated. Alternate use of these solutions not only washes out shavings, filings and bacteria but, since both solutions are antimicrobial, they help destroy micro-organisms (Grossman, 1981).

Spangberg (1973) found that five per cent sodium hypochlorite (which had the strongest antimicrobial effect) was much more concentrated than was necessary to kill bacteria in the root canal;

in this concentration the solution was very "toxic"- dissolving both vital and necrotic tissue. Spanberg suggested that a 0.5 per cent solution would dissolve necrotic tissue without breaking down vital tissue, and still retain its antimicrobial effect. Nicholls (1977, p. 138) also advocated using a more dilute sodium hypochlorite solution, the one per cent (1%) solution known as "Milton".

Many endodontists perform all cleaning and shaping procedures in canals flooded with sodium hypochlorite solution. The solution is rejuvenated constantly so the digesting action continues on tissue remnants throughout the cleaning and shaping procedures. In the Department of Operative Dentistry, of the University of Sydney, the recommended irrigant is Milton's (1%) sodium hypochlorite solution (Hewitt in Bryant et al, 1981).

Hydrogen Peroxide

Grossman has popularised the use of 3% hydrogen peroxide irrigation, alternating with 5% sodium hypochlorite irrigation. Both irrigants are bacteriocidal and the effervescent release of oxygen has a desirable debriding action.

Although nascent oxygen imparts some degree of germicidal activity, this activity is brief and for most part ineffective (Penick et al, 1970). Weine, (1976, p.209) however suggested that the rapid release of oxygen within the root canal would destroy organisms which are obligate anaerobes. Hydrogen peroxide has no ability to dissolve necrotic or any other debris (Penick et al, 1970).

Hydrogen peroxide should not be the last solution used in the root canal. Hydrogen peroxide may react with tissue fluid and liberate oxygen within the sealed root canal. The resultant pressure built up at the apex may cause post-operative pain. The oxygen can also force micro-organisms and debris into the periapical tissues (Nicholls, 1977, p. 139). Therefore the hydrogen peroxide should be neutralized by employing sodium hypochlorite as a following irrigant. Hewitt (in Bryant et al, 1981) recommends the use of hydrogen peroxide in the control of heamorrhage from an inflamed pulp.

Several studies (Thé, 1979 b; Abou-Rass, 1984) have shown that the use of 3% hydrogen peroxide had no effect as an irrigant in root canal therapy. Penick et al, (1970) showed that hydrogen peroxide had no ability to dissolve necrotic debris. In endodontic practice the use of hydrogen peroxide has decreased markedly in recent years (Blackler, 1987; Mayne, 1987).

Urea Peroxide

Urea peroxide is composed of urea and hydrogen peroxide. Urea is generally non-toxic, well tolerated by vital tissue and in a thirty percent solution, is a mild necrotic tissue solvent and antiseptic (Penick et al, 1970). It is claimed that ten percent urea peroxide in a glycerol base possesses a greater germicidal activity than aqueous hydrogen peroxide- it also acts as a lubricant for canal instrumentation (Stewart et al, 1961).

Chloramine-T

This chemical solution is composed of chloramine, sodium chloride and water and is used in a four percent aqueous solution (Attala et al, 1969). Chloramine-T exhibits reduced tissue solvent capacity and antimicrobial activity when compared to sodium hypochlorite (Penick et al, 1970).

Saline

Normal physiological saline is usually defined as a 0.86% solution of sodium chloride (Wayman et al, 1979). Curson (1966) suggested using sterile saline as the final irrigant, following irrigation with hydrogen peroxide and sodium hypochlorite, to reduce the possibility of irritation from residual hydrogen peroxide and sodium hypochlorite. Physiological saline is not a necrotic tissue solvent and has no antimicrobial capacity but is well tolerated by the periapical tissues.

Citric Acid

Research has shown that fifty percent Citric acid is an effective debriding agent which removes not only residual debris but the smeared layer from the root canal wall as well as acting as a lubricant for instrumentation (Tidmarsh, 1978). Citric acid acts as a chelating agent and, since it is found naturally in the body, it has been suggested that citric acid is well tolerated by the periapical tissues (Loel, 1975).

EDTA

Ethylene-diamine tetra acetic acid (EDTA) is a chelating agent which produces the cleanest canal walls (McComb et al, 1976). McComb used 6% EDTA of pH 8 and an antibacterial agent called Cetrimide. Grossman (1969) suggested using EDTA in place of sodium hypochlorite as the irrigant of choice in narrow canals where considerable difficulty was encountered in reaching the apical foramen; once the canal had been instrumented to the apex, sodium hypochlorite could then be used for its "proteolytic effect" on organic material left within the canal.

EDTA was first suggested as a root canal irrigant by Nygaard Ostby in 1957. The composition of fifteen per cent solution at pH 7.3, recommended by Nygaard Ostby (1957) was as follows:-

Disodium salt of EDTA	17 gm
Distilled water	100 ml
5N Sodium hydroxide	9.25 ml

Ostby stated that this solution inhibited the growth of, and would eventually destroy, bacteria by the process of starvation.

Nygaard Ostby (1961) suggested adding 0.84 grams of the quaternary ammonium compound, Cetavlon (hexadecyl trimethylene ammonium bromide), to the above solution in order to render it bacteriocidal, to lower its surface tension and to enhance its penetration ability. EDTA and EDTA-C (EDTA plus Cetavlon), are distinctly self-limiting; that is, a certain amount of each solution dissolved only a certain amount of dentine according to a definite equilibrium reaction which limits further decalcification once all receptor sites on the chelating agent have been occupied by calcium ions (Nygaard Ostby 1961).

3.4.2 LUBRICATING PASTES

<u>RC Prep*</u>

This product developed by Stewart et al (1969) is composed of 15 per cent EDTA and 10 per cent urea peroxide and a water soluble carbowax base.

RC Prep appears to combine the chelating action of EDTA with the effervescent and antimicrobial activity of urea peroxide. Cooke et al (1976) observed a definite increase in dentine permeability associated with the use of RC Prep. Mayne (1986) suggested using a one per cent sodium hypochlorite solution in combination with RC Prep during canal instrumentation.

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* RC Prep (Premier Dental Products Philadelphia USA)

Because RC Prep contains urea peroxide, it should not remain in the canal following instrumentation (Gurney, 1974) as it will react with tissue fluids and continue to release oxygen which may then cause post-operative discomfort.

Cook et al (1976), studied the permeability of dentine following the use of RC Prep. They reported twice as much apical leakage in canals cleaned and shaped with RC Prep and sodium hypochlorite than with sodium hypochlorite alone. The authours suggested that the residual carbowax may interact with the root canal sealers.

Other chemical solutions have been recommended for use as root canal irrigants, but, because of the success of the more commonly available solutions, they have not been used routinely.

3.4.3 IRRIGATION TECHNIQUE

Endodontic solutions are generally deposited into the root canal by a small syringe and a fine needle tip. Grossman (1981, p.241), using 5 per cent sodium hypochlorite and 3 per cent hydrogen peroxide solutions, described the irrigating technique using two separate syringes (glass or disposable plastic) and needle tips (no gauge was specified) that were bent at an obtuse angle so as to reach more readily the canals of the posterior as well the anterior teeth. The bevel of the needle was removed with a disc to make the needle tip blunt to prevent it from catching on the wall of the canal. The needle tip was inserted into the canal but never so far that it was forced to bind, to allow clearance between the canal and the needle for return flow of the solution.

The object of the technique is to wash out the canal rather than to force the solution in under pressure which might result in the solution passing into periapical tissue spaces.

Initially, Grossman (1981, p.243) recommended alternate irrigations of sodium hypochlorite and hydrogen peroxide solutions, which were repeated until no debris emerged from the canal. More recently, Grossman (1988, p.189) recommended the use of 5% sodium hypochlorite without the use of hydrogen peroxide. Irrigation should then be followed by thorough drying of the canal either by the use of paper absorbent points or suction apparatus. Several studies (The, 1979 b; Abou-Rass, 1984) have shown that the use of 3% hydrogen peroxide had no effect as an irrigant in root canal therapy. Penick et al (1970), found that hydrogen peroxide had no ability to dissolve necrotic debris.

Grossman (1981, p.222) stated that all instrumentation should be carried out in a wet or moist canal and that frequent irrigation avoided packing debris ahead of the instrument.

3.5 INSTRUMENTS

Root canal instruments are needed to clean the root canals of pulp remnants, debris, infected or softened dentine on the canal surface; to remove obstructions; to enlarge the canal to receive the maximum amount of intracanal medicament; to smooth the canal wall in order to improve contact of the medicament with the infected canal surface; and also to prepare the canal walls to facilitate eventual obturation of the root canal (Grossman 1981, p.201). Curved root canals tend to be straightened out during the process of enlarging with instruments.

3.5.1 BROACHES

Broaches can be either smooth or barbed. Smooth broaches, can be used for exploring and locating the canal orifice and for determining or assisting in obtaining the patency of the root canal. Smooth broaches may be round, pentagonal or square in cross-section and have a pointed end (Nicolls 1977, p.127). The smooth broach will pierce or displace the pulp tissue so as to make room for a rough instrument, such as a barbed broach, reamer, or file (Grossman 1981, p.211). The barbed broach (Fig. 3.1) is manufactured from blanks of soft steel wire of various diameters; small angular cuts are made in the shaft of the blank at an acute angle and the small "spur" of metal is then forced away from the shaft of the instrument forming a "barb" with the tip pointed toward the handle of the instrument (Sampeck, 1967).

A barbed broach, can be used to extirpate (remove) the entire pulp, debris, absorbent points and other fragments (Grossman 1981, p.202). Success in withdrawing the pulp in one piece without shredding depends very much on the proper selection of the broach and on the adequacy of the access opening. One cannot expect to deliver a diseased pulp intact through an access opening that is narrower than the pulp itself (Schilder et al 1984, p.177).

Two principles guide the selection of broaches for pulp extirpation: 1) The broach chosen should be wide enough to engage the pulp effectively (without touching the walls of the canal). Very narrow broaches tend to stab the pulp without securing enough grip to fully remove the pulp in one piece and thus shreds the pulp: 2) The broach should not be so wide as to make contact with the walls of the canal. Barbed broaches are not made to cut dentinal walls, and may break if wedged carelessly into a canal. Barbed broaches should be used sparingly around curves and never more than two thirds the length of the canal (Schilder et al 1984, p.177). If a proper grip on the pulp tissue is obtained by the barbs along two thirds of its length, the apical third of the pulp will usually become dislodged

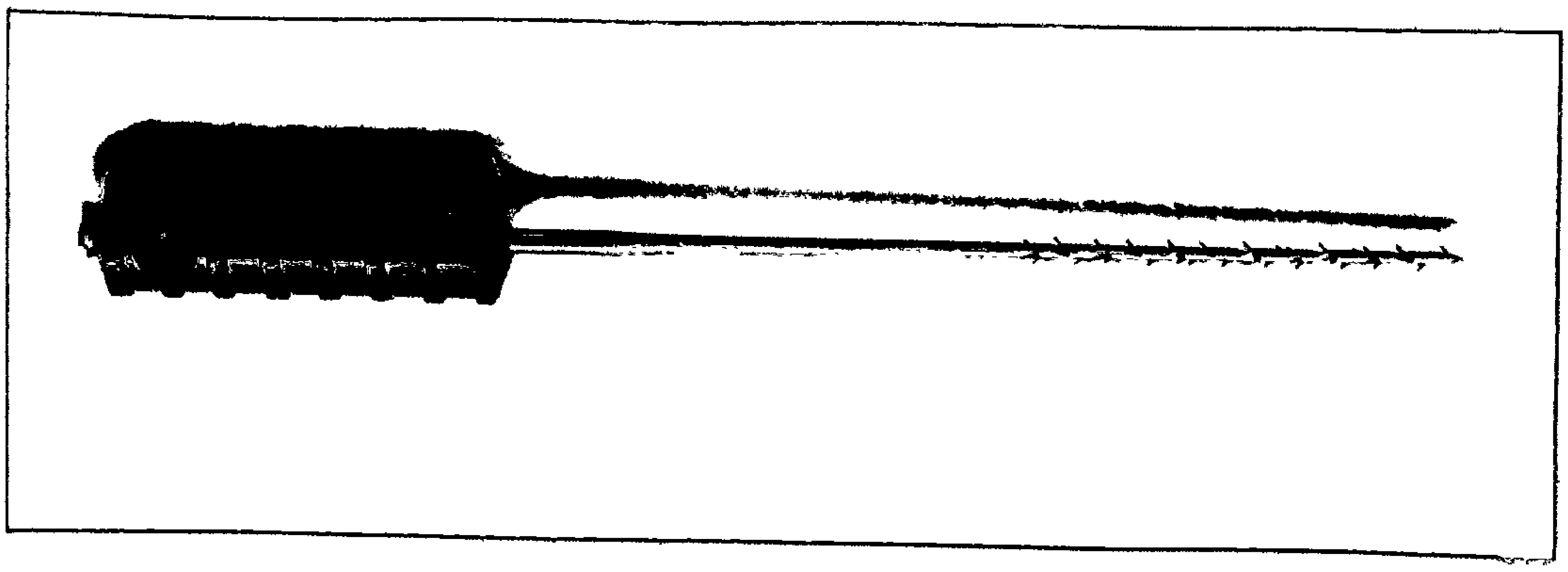

Figure 3.1 Barbed broach

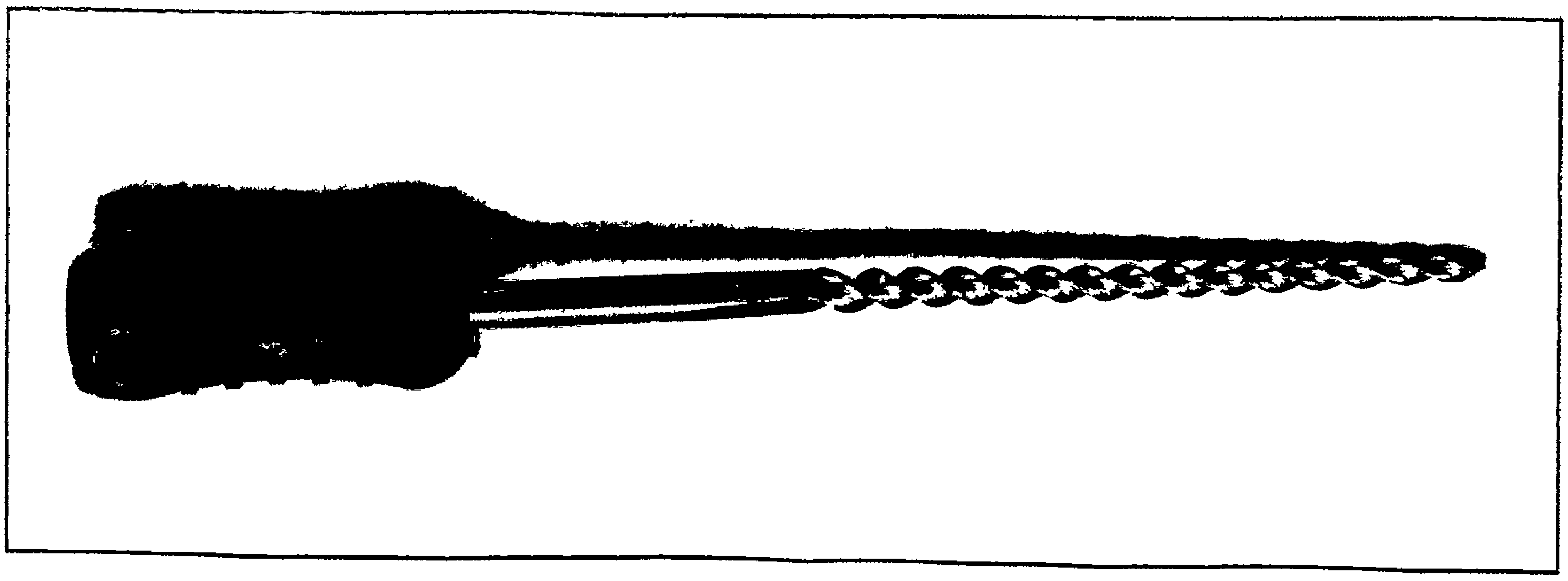

Figure 3.2 K File

effectively without the necessity of dangerously inserting the instrument to the apex.

The barbed broach is used by inserting it into the root canal without binding, rotating it 180 degrees clockwise and withdrawing out. If the access cavity and the broach are of appropriate size the pulp will be entangled into the barbs and will be removed in one piece without shredding. Short handled barbed broaches are available in a variety of sizes from XXX fine to extra course. Extreme care is needed in using the finer sizes of broaches as they break all too readily.

3.5.2 REAMERS

Most reamers are manufactured by pulling and twisting a triangular wire into a sharpened tapered instrument of gradual spirals (Ingle 1976, p.170). Oliet and Sorin (1973) found that triangular instruments cut more efficiently than square instruments and that, during testing, the fracture rate of the triangular instruments was higher than that of the square instruments. The smaller reamers have a square cross-section.

Reamers are delicate twist drills which cut by being rotated. The very nature of their design predisposes them to breakage. Should the end of the reamer bind while the instrument is being rotated, breakage may occur. They should be used with great care (Bryant et al 1981, p.177).

3.5.3 FILES

Files are divided into (a) K files (b) Hedstroem files (c) New breed of files. Each is manufactured differently and each is used for different functions.

3.5.3a K files

K files are produced by twisting square wire into a tapered pointed instrument of much tighter spirals than the reamer (Figure 3.2). The smaller K files have a triangular cross-section. Reamers can only be used for reaming, but files can be used for both reaming and filing. Many dentists use K files only. The reaming action from files is accomplished by three motions (1) Penetration, (2) Rotation, and (3) Retraction (Ingle 1976, p.170). Penetration is accomplished by carefully advancing and gradually rotating the instrument apically until it is tightly in place at the full depth at which it is to be used. For rotation, the instrument is set in the dentine by rotating the handle clockwise one-quarter to one-half turn. While under this tension the instrument is then forcibly withdrawn. This is the retraction stage, when the cutting blades, locked in the dentine wall, remove the dentine. Since debris will be caught between the blades of the instrument a K file may be used to facilitate removal of debris from the root canal without running much risk of forcing the debris through the apical foramen. A K file should not be rotated more than a quarter turn at a time. The instrument should then be moved back a little, re-inserted and given another quarter turn. Repeated removal and re-insertion of the instrument , and care not to give it more than a quarter turn at a time , will prevent binding, ledging or loss of length. From time to time, debris clinging to the instrument should be removed by mechanical cleansing with gauze (Bryant et al 1981, p.178). Because of the design and method of usage, K files have displaced the routine use of reamers and Hedstroem files. Most dentists use only the K file for the mechanical preparation of the root canal.

3.5.3b Hedstroem Files

Hedstroem files (Fig. 3.3, p. 25) are manufactured using a rotary cutter to gouge triangular segments out of a round blank metal shaft in the same manner that wood screws are made (Weine 1976, p.163). The instrument is weakened at each position of gouging and, as a result, the instrument may fracture when the flutes bind into dentine and the handle rotated. Hedstroem files should be used with a pull stroke. If used improperly they may force debris through the apical foramen. A loosely fitting file should be inserted into the root canal and be withdrawn laterally against the wall in such a manner as to file one surface of the canal at a time (Bryant et al 1981, p.177).

3.5.3c New breed of files

'Unifile' is similar to the Hedstroem file. In cross-section the Unifile has two blades while the Hedstroem file has only one. The Unifile is stiff and less prone to fracture in the coronal and middle thirds of the shank and is flexible in the apical third which corresponds to the position of the curve in root canals (Stock 1985).

'Helifile' is manufactured similar to the Hedstroem and Unifile except in cross-section there are three blades. The appearance of the instrument resembles a reamer rather than a Hedstroem file (Stock 1985).

'K-flex files' are similar to K files except that the K-flex files have a diamond-shaped cross-section. The acute angle of the diamond shape provides the instrument with two sharp blades and the narrower diameter allows greater flexibility in the shaft than a conventional K file. Manufacturers claim that more debris is collected in between the blades and therefore removed from the canal (Stock 1985).

'Flex-o-file' is manufactured in the same way as a K file but using a more flexible type of steel. It does not fracture easily and is so flexible that it is possible to tie a knot in the shank of the

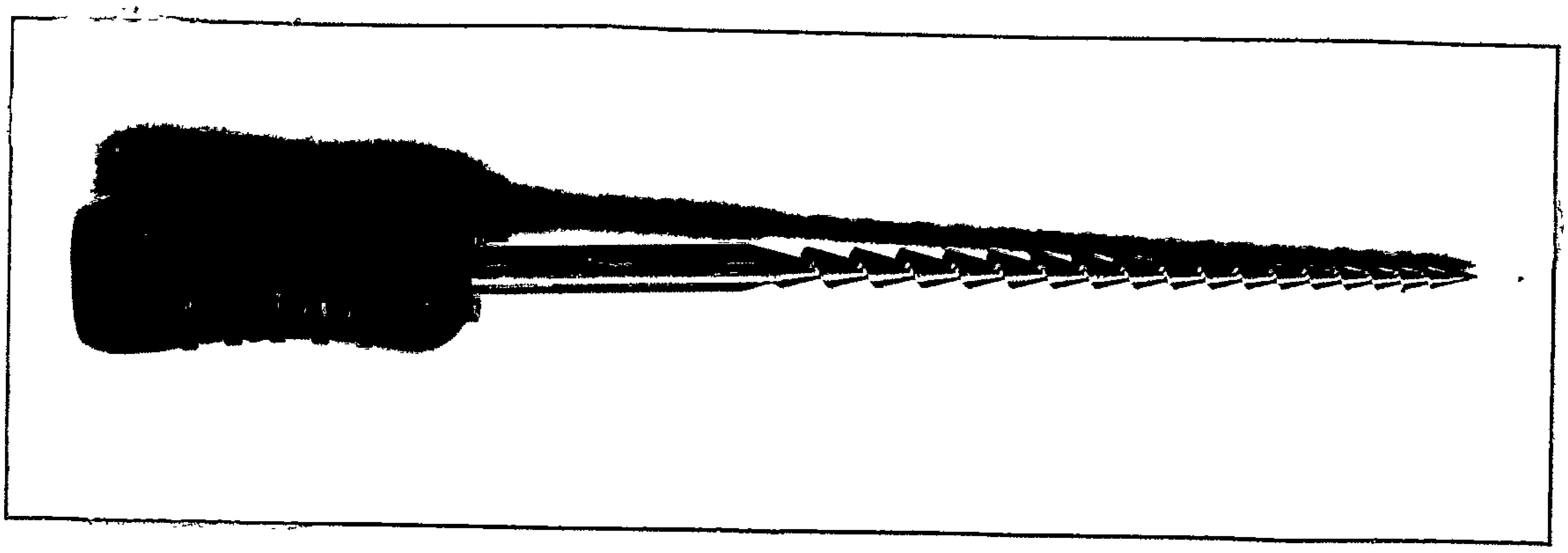

Figure 3.3 Hedstroem file

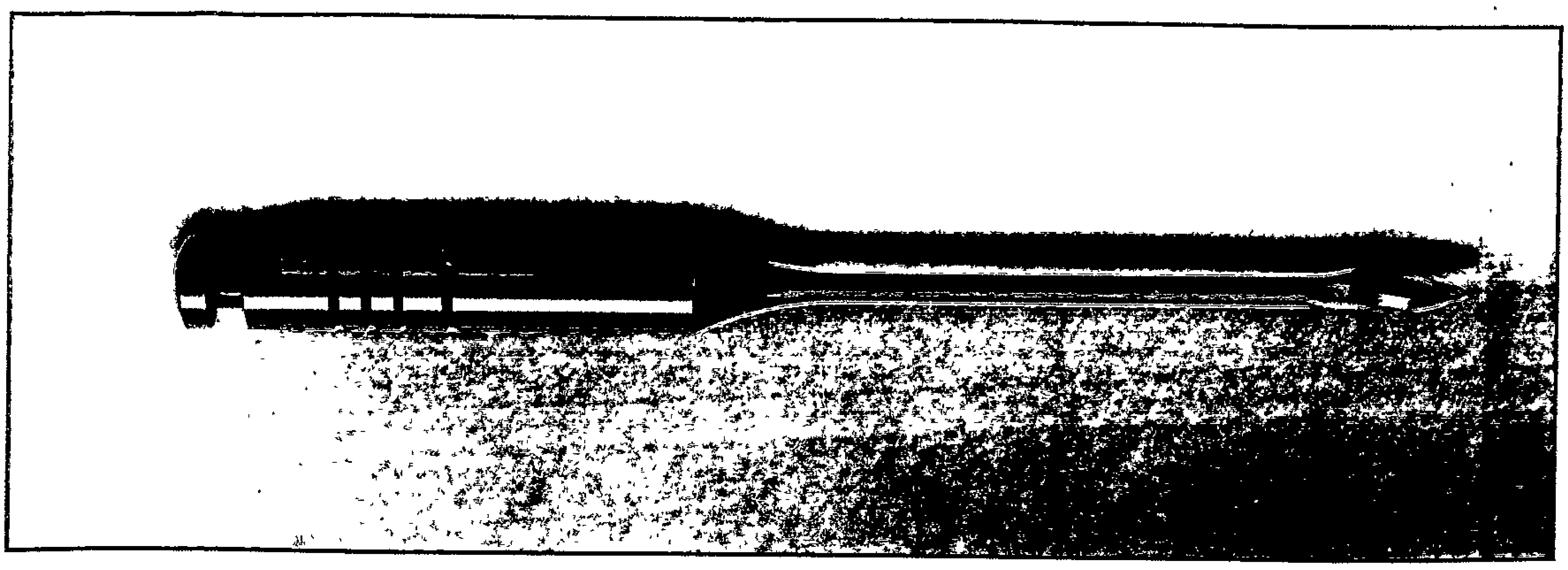

Figure 3.4 Gates glidden bur

smaller sizes (Stock 1985).

3.5.3d ENGINE DRIVEN ENDODONTIC INSTRUMENTS

(i) Rotary (ii) Non-rotary

(i) Rotary engine driven endodontic instruments such as Gates-Glidden burs (Fig. 3.4, p. 25) in a contra-angle low speed handpiece can be used to gain more access to the apical portion of the root canal. They are flame-shaped long-shaft cutting instruments, which are intented to cut without pressure and are designed to break near the contra-angle handpiece if too much force is used during cutting. Gates-Glidden drills are available in sizes one to six and are used to widen the orifices of the root canals extending from the floor of the pulp chamber. Peeso reamers are engine-driven twist drills designed to enlarge the root canal orifice. Weine (1976, p.227) stated that both Gates-Glidden drills and Peeso reamers must only be used, with a withdrawal motion, to remove tooth structure at very low speeds with irrigation. The Gates-Glidden drill is advanced very carefully into the canal orifice while it is slowly rotating and then withdrawn against the canal walls.

There are currently four new designs for power assisted cutting instruments: The Rispi, which is similar to a barbed broach, the Heli Girofile, which is an engine mounted Helifile, the Dynatrak, which is a Unifile with a non-end-cutting tip, and a diamond coated file available for the ultrasound handpiece (Stock 1985).

(ii) Ultrasonic instruments have been used recently for canal debridement. K files, in an ultrasonic handpiece with sodium hypochlorite irrigation, have been used with great success in obtaining very clean dentinal walls, with no smeared layer and open dentinal tubules (Martin et al, 1980; Cameron, 1988).

3.6 STANDARDIZATION OF INSTRUMENTS

In recent years manufacturers have endeavoured to standardise endodontic instruments and root filling points so that there will be uniformity of size, taper and length. The instruments are numbered from 6 to 140, based on the diameter of the instrument in hundredths of a millimetre at the tip, a point labelled D1. The distance between D1 and D2, the point up the blade, at the end of the cutting edge of the instrument is sixteen millimetres. The increase in diameter between D1 to D2 is 0.3 mm. Every instrument therefore has a standardised taper. The diameter at point D1 increases 0.05 millimetres from size 10 to 60 file, while there is an increase of 0.10 millimetres from size 60 to 140 (Grossman 1981, p.204).

3.7 MECHANICAL PREPARATION OF THE ROOT CANAL

Schilder et al (1984, p. 181) has listed five objectives in the mechanical preparation of the root canal.

1) To develop a continuously tapering conical form in the root canal preparation.

2) To make the canal narrow apically, with the narrowest cross-sectional diameter at its terminus. This is essential, in gutta-percha techniques, to facilitate the obturation of the canal.

3) The preparation should follow the natural curves of the root canal, it should "flow" with the contour.

4) To leave the apical foramen in its original position. External transportation (known more commonly as apical perforation) may occur when instrumentation is carried to or beyond the terminus of the root canal. Internal transportation is more commonly known as ledging, zipping, or lateral perforation.

5) To keep the apical foramen as small as is practical. There is no biologic or mechanical advantage in enlarging the apical foramen.

Ingle (1976, p.192) stated that the apical seat of the canal can be developed using either a reamer or K file with a reaming action in a straight canal. Hewitt (in Bryant et. al. 1981) suggested the use of K files to prepare the apical seat and then using H files 3 mm short of the apical stop to clean and funnel the middle and coronal portions of the root canal.

Grossman (1981, p. 218) named the serial preparation technique of root canal preparation the "step-back" method. Ingle (1976, p. 199) also named serial preparation of the root canal the telescoping method. Serial preparation is a technique in which each consecutive larger root canal instrument is placed short of the apex in 1 mm increments. This technique produces the required preparation of the root canal. (Grossman 1981, p. 218) The advantages of the step back technique over conventional techniques are "1) ability to condense the root filling more adequately, 2) the step back technique is less likely to cause periapical trauma from instrumentation, 3) the narrower apical foramen prevents overfilling of the root canal, 4) greater pressure can be exerted, which tends to fill lateral canals with the sealer." (Grossman, 1981, p. 219).

Recent studies (Stock, 1985; Powell et al, 1986; Spyropoulos et al, 1987) discuss the use of engine driven instrumentation as compared to hand instrumentation. Powell et al (1986) found that K files, with a modified tip, cut without ledging while Dynatrak files tend to be destructive of tooth structure. Spyropoulos et.al. (1987) found that there was no difference in the instrumentation time or in the smoothness of canal walls between the use of hand files and Giromatic files. The Giromatic files produced wider apical preparations but hand files produced more flared preparations.

Mayne, (1988) found that excessive flaring of molar root canals either by hand files or by engine driven instruments could lead to extremely thin furcation surface walls 2-4 mm apical to the bi-or-trifurcation. This creates the potential for root-stripping and post perforation, especially in the young patient.

3.8 DISINFECTION OF THE ROOT CANAL.

Disinfection of pulpless teeth may be accomplished by 1) chemical means, 2) physical means, or 3) a combination of both. Chemical means alone (topical or intracanal medication) are employed most commonly (Grossman 1981, p.252). The need for intracanal disinfection has been questioned in recent years. Holland et al (1979) have shown that intracanal medication is an important part of endodontic treatment in that it reduces the microbial flora.

The requirements of a root canal disinfectant have been tested by Grossman and he claims that such medicaments should:

1) be an effective germicide and fungicide;
2) be non irritating;
3) remain stable in solution;
4) have a prolonged antibacterial effect;
5) be active in the presence of blood, serum, and protein derivatives of tissue;
6) be capable of penetrating the tissues deeply;
7) not interfere with repair of periapical tissues;
8) not stain tooth structure;
9) be easily introduced into the root canal;
10) be capable of being inactivated or neutralized by culture medium.

Root canal disinfectants may be grouped arbitarily as essential oils, phenolic compounds, salts of heavy metals, halogens, sulphonamides, and antibiotics.

Three root canal disinfectants are used in the Department of Operative Dentistry, University of Sydney. These are * Ledermix Paste, Camphorated para-chlorophenol (Kri-3)@ and calcium hydroxide paste (Pulpdent)+. Ledermix paste contains one per cent Triamcinolone Acetonide, and three per cent Demethylchlortetracycline Calcium. The Demethylchlortetracycline is a broad spectrum antibiotic with a bacteriostatic action, while the Triamcinalone Acetonide is a corticosteroid anti-inflammatory agent which reduces oedema and therefore reduces the pain associated with acute and subacute pulpitis and apical periodontitis.

Camphorated p-chlorophenol@ is composed of two parts p-chlorophenol and three parts gum camphor. It is a transparent, oily, light amber-coloured liquid having a characteristic aromatic odour. The camphor serves as a vehicle and diluent, and reduces the irritating effect of pure p-chlorophenol (Grossman 1981, p. 254). Penick et al (1970) stated that camphorated p-chlorophenol provided marked germicidal activity "against all types of bacteria as well as fungi". One paper (Schilder & Yee 1984, p.180) reported that camphorated p-chlorophenol was the recommended medicament in cases of root canal necrosis.

Calcium hydroxide has also been used as an intracanal medicament. A brief study in cat's teeth by Stevens and Grossman, (1983) did not find calcium hydroxide to be as effective as camphorated p-chlorophenol. Its antiseptic action probably relates to its high pH and its dehydrating action on necrotic pulp tissue (Nicholls 1984, p.152). Tronstad et al (1981) have shown that calcium hydroxide causes a significant increase in the pH of circumpulpal dentine when the

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* Ledermix paste (Lederle Pharmaceuticals, Aldwych, Lond Eng)
@ Kri-3, camphorated p-chlorophenol (Pharmache AG Zurich Switzerland)
+ Pulpdent paste (P.C.A. Corp. Brookline, MA, USA)

compound is placed in the root canal. Bystrom and Sundqvist (1981), in a clinical study of more than 100 periapically involved teeth, found that calcium hydroxide was a very effective intracanal disinfectant.

3.9 SUMMARY

This chapter has briefly discussed the most relevant instrumentation techniques available at present to prepare the root canal to biological acceptibility. Instrumentation of root canals has improved greatly with the standardization of instruments and with the accompanying use of sonic, ultrasonic and slow handpiece instruments. Irrigation materials and techniques which form one of the most important phases of root canal treatment have been reviewed with emphasis placed on the most popular irrigant solutions. Properties of the ideal disinfectant have been presented, together with three commonly used root canal medicaments.

CHAPTER 4

OBTURATION OF THE ROOT CANAL

4.1 INTRODUCTION

The final stage in root canal treatment is the obturation of the entire root canal system with a biologically acceptable material. The aim of this chapter is to discuss the rationale behind root filling, and to introduce the wide number of root filling materials and techniques currently available.

Why Fill the Root Canal?

As an undergraduate the author wondered why the root canal had to be filled. It was understood that the root canal had to be enlarged, and disinfected to eliminate all the microbes, but why after negative cultures and thorough debridement was it necessary to fill the canal? Grossman (1981, p.277) gives two reasons why the root canal has to be obturated. 1) To prevent any micro-organisms, that might be transported to the periapical tissue during a transient bacteremia, from lodging in the unfilled portion of the canal where they might establish themselves and irritate the periapical tissue. 2) If the canal was completely obliterated apically and laterally, micro-organisms would be "bottled up" in the dentinal tubules between the cementum and canal filling where they could not survive. To these two reasons for obturating canals we can add

3) to prevent recontamination from the oral cavity (Schilder 1967). 4) To prevent percolation of tissue fluids (exudate) from the periapical tissue into the root canal where it can subsequently stagnate and produce products which might irritate the periapical tissues (Nguyen 1987, p.183). 5) Obturation of the canal creates a favourable environment for periapical healing to take place. Dow and Ingle (1955) have shown that approximately sixty per cent of endodontic failures are apparently caused by incomplete obliteration of the canal space. Therefore the clinician should make every effort to achieve a dense, well adapted root filling with good apical seal.

Requirements of an ideal obturation material

The requirements of the ideal root canal filling material are listed below, as stipulated by Grossman (1981, p.279). The ideal material should:

1) be introduced easily into the root canal;
2) seal the canal laterally as well as apically;
3) not shrink after being inserted;
4) be impervious to moisture;
5) be bacteriostatic , or at least not encourage bacterial growth;
6) be radio-opaque;
7) not stain tooth structure;
8) not irritate periapical tissue;
9) be sterile, or easily and quickly sterilized immediately before insertion;
10) be easily removed from the root canal, if necessary.

There is no known material which has all the ideal properties listed above. The aim of the next section is to review some materials currently available and to evaluate them according to Grossman's ideal criteria.

4.2 OBTURATION MATERIALS

Obturation materials can be divided into (a) Pastes, (b) Semisolid materials, and (c) Solids.

(a) Paste-type filling materials include zinc oxide-eugenol cements, zinc oxide and epoxy resins (AH-26)*, acrylic resin (Hydron)** , polyethylene, polyvinyl resins (Diaket)***, polycarboxylate cements, and Silastic materials.

Zinc oxide-eugenol root canal sealers

The most commonly used pastes are based on the zinc oxide-eugenol formulations and come in powder and liquid forms. These include Kerr sealer (Rickert's formula)[@], ProcoSol sealer[@@], Grossman's sealer[@@@], and Wach's[a] paste. Kerr have introduced a zinc oxide-eugenol based two paste sealer called Tubliseal[b].

The setting of these cements involves the sorption of eugenol into the zinc oxide powder producing a mass of unreacted zinc oxide embedded in a matrix of zinc eugenolate. Heavy metal salts such as barium sulphate are present in the powder to make the set cement more radio-opaque.

It is now appropriate to present the chemical compositions and properties of the commonly available zinc oxide-eugenol sealer cements.

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* AH-26 (DeTrey Freres S.A., Switzerland)
** Hydron (NPO Dental Systems, Inc., New Brunswick, NJ. USA)
*** Diaket (Espe GMBH, West Germany)
@ Kerr sealer (Kerr Mfg. Co. USA)
@@ ProcoSol sealer (Star Dental Co. Valley Forge PA. USA)
@@@ Grossman sealer (ProcoSol Chem Co. USA)
a Wach's paste (Sargent's Drugs Chicago Ill. USA)
b Tubliseal (Kerr Mfg. Co. USA)

Kerr sealer (Rickert, 1931)
Kerr Mfg. Co., U.S.A.

The sealer is germicidal due to its thymol iodide content. It also has excellent lubricating and adhesive qualities, and sets in approximately thirty minutes. The main disadvantage of this sealer is its silver content, which may discolour tooth structure, and therefore must be removed from the coronal pulp chamber with xylol (Nguyen 1987, p. 236).

ProcoSol radiopaque silver cement (Grossman 1936)
ProcoSol Chem. Co. U.S.A.

The main disadvantage of this sealer is the tendency for the crown of the tooth to become stained because of the silver content (Nguyen 1987, p. 236).

ProcoSol non-staining cement (Grossman 1958)
ProcoSol Chem. Co. USA

Grossman´s sealer (Grossman 1974)

Grossman´s sealer meets most of Grossman´s own requirements for an ideal sealer. It shows minimum tissue irritation, it has antimicrobial activity, it can be mixed into a creamy consistency and can therefore be easily inserted into the canal. The sealer does not set on the slab for six to eight hours and therefore can be used for several hours. The cement begins to set approximately thirty minutes after it is placed into the canal, accelerated by the moisture which is present in the dentinal tubules. The sealer has good lubricating properties, it has a good sealing potential, there is only a small volumetric contraction on setting, and it has been found that it is absorbable by tissue, which is an advantage if paste overfill occurs (Nguyen 1987, p. 237).

The main disadvantage of this sealer is that it can be decomposed by water, through continuous loss of eugenol, and therefore should not be used as a sole canal filling material, but in combination with a semi-solid (gutta-percha) or solid material (Weine 1990, p. 214).

Tubliseal (Kerr 1961)
Kerr Mfg. Co., U.S.A.

Tubliseal comes in two tubes, one being the catalyst and the other the base. The material mixes well, it has excellent lubricating properties and does not stain tooth stucture. Its main disadvantage is its rapid setting time especially in the presence of moisture (Nguyen 1987, p. 237).

Wach's paste (Wach 1955)

The sealer is germicidal, it has low tissue irritation and an adequate setting time. Its main disadvantage is in its limited lubrication of the master cone.

Roth root canal cement

Roth Drug Co., Chicago, IL. U.S.

This root canal sealer is a zinc oxide eugenol containing cement with its exact composition not disclosed by the manufacturers.

Non Eugenol Containing Sealers

Chloropercha and Eucapercha are made by dissolving gutta-percha in chloroform or eucalyptol respectively. These are used by some clinicians as the sole canal filling material, but more often are used in combination with gutta-percha cones. The main advantage of the chloropercha technique is its ability to fill unusual curvatures in the root canal. In cases of perforation or ledge formation the two methods are useful in getting a good fit of the master cone. The main disadvantage of these techniques is the large amount of shrinkage that occurs when the solvent evaporates (Nguyen, 1987; Weine, 1990).

Chloroform is an irritant of the periapical tissues while eucalyptol appears to be well tolerated (Morse & Wilcko 1978).

Diaket (Schmitt 1951)
Espe GMBH, West Germany

Diaket is an organic polyketone compound introduced in Europe in 1951. It comes as a fine powder and viscous liquid. It has a high resistance to absorption and sticks to tooth structure, but because it has a tacky texture it is difficult to manipulate (Nguyen 1987, p. 238)

AH-26 (Schroeder 1957)
DeTrey Freres S.A., Switzerland

AH-26 is an epoxy resin with low solubility. It has good adhesive and antibacterial properties, it has low toxicity and is well tolerated by periapical tissues. Warming the material decreases its viscosity and increases the setting time. The early AH-26 powder contained silver powder, which stained the crown if excess sealer was left in the coronal pulp chamber. The modern AH-26 has silver-free powder (Weine 1990, p. 215).

Therapeutic and Medicated Sealers

Therapeutic and medicated sealer-cements are usually used without the core materials. They are introduced into the canal by lentulo spiral or by some type of injection device. The composition and properties of these pastes will be discussed in this section.

Riebler's Paste (Riebler)

The set cement is probably composed of unreacted zinc oxide in a matrix of zinc sulphate. The barium sulphate makes the material radiopaque while the formaldehyde fixes microbial and pulpal cells. Extrusion of the sealer through the apex can cause tissue damage (Nguyen 1987, p. 238).

Iodoform Paste (Wolkhoff, 1928)
Pharmachemie AG Switzerland

Iodoform paste is radiopaque and resorbable. Overfilling can cause great discomfort to the patient, until the paste is resorbed. It is difficult to obtain a consistently dense, nonporous filling using a creamy paste. Air voids can occur anywhere in the paste but if they occur near the apical foramen, both leakage and percolation of exudate into the canal space may occur. Also, in the absence of positive pressure, pastes cannot effectively fill accessory canals (Nguyen, 1987 p. 238).

Endomethasone
Specialites-Septodent, France

Paraformaldehyde is a very toxic chemical, and can cause irreversible tissue damage through the apex. There have been cases where paraformaldehyde containing cements injected into the canal with force have caused paraesthesia of the inferior dental nerve. There has been increasing concern about safety because of the paraformaldehyde in these cements. Paraformaldehyde has been shown to have mutagenic ability (Murphy, 1988) and therefore the routine use of paraformaldehyde containing cements as a permanent root canal filling is not recommended.

N-2 (Sargenti 1970)
AGSA, Switzerland

N-2 and Endomethasone are similar in that they contain paraformaldehyde and corticosteroids in an attempt to alleviate the severe postoperative complications. N-2 contains lead as an oxide. Lead tetroxide increases the radiopacity of the cement and appears to contribute to the extreme hardness and slow solubility of N-2 (Heuer & Miserendino, 1987 p. 420). The lead content of N-2 is very toxic to tissue which is its main contraindication (Murphy, 1988).

Calcium Hydroxide Pastes

Laws (1962) combined calcium hydroxide powder with propylene glycol liquid to create a paste which does not set but can be used as a temporary root filling. Of the calcium hydroxide pastes available, Pulpdent paste* is preferred as it has a methyl cellulose base which decreases the solubility of calcium hydroxide in tissue fluids and

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* Pulpdent paste (P.C.A. Corp. Brookline, MA, USA)

because of its physical consistency allows easy introduction into the root canal. The paste has a pH of 12.2 (Heithersay, 1977).

The following discussion on the use of "Pulpdent" paste is based on Heithersay's article. Calcium hydroxide paste is usually placed after an initial dressing of Ledermix paste®. The paste is introduced into the prepared and dried root canal using a lentulo spiral at low speed, keeping it approximately 3-5 mm from the apex. Pressure is gently applied to the paste in the pulp chamber with a cotton wool pellet so that the material fills the apical region of the root canal. The cavity is sealed with I.R.M.!, zinc oxide-eugenol cement (Kalsogen)+, or Cavit£.

Clinical indications for the use of calcium hydroxide include:

1) Control of periapical exudation;
2) Temporary root filling in teeth with large periapical lesions;
3) Dressing agent in routine endodontic therapy;
4) Temporary root filling where time does not permit completion of normal endodontic treatment;
5) Control of apical resorption resulting from chronic periapical lesion;
6) Arrest of external inflammatory root resorption due to trauma;
7) Control of internal resorption in the apical region;
8) Control of internal or external resorptive defects;
9) Management of perforations;
10) Treatment of transverse root fractures;
11) Apex formation in the pulpless incompletely developed teeth.

@ Ledermix paste (Lederle Pharmaceuticals, Aldwich. London, England)
! I.R.M. Temporary material (L.D.Caulk, Dentsply, Milford, Del. USA)
+ Kalsogen (De Trey Div. Dentsply, Surrey, England)
£ Cavit temporary material (Espe, Seefeld, Oberlay, West Germany)

Schroeder (1973) showed that a combination with equal proportions (50:50) of Ledermix paste and Pulpdent paste, increased success in the resolution of large periapical lesions. Other studies have not supported Schroeder's findings and it seems that the removal of the micro-organisms by instrumentation and irrigation of the root canal is what causes resolution of periapical lesions (Nehammer and Stock, 1985).

Recently, sealers which can stimulate hard tissue formation and biological closure of the root apex have been formulated. It is well established that calcium hydroxide can induce hard tissue formation across pulp exposures (Granath, 1982), on root perforations and at root apices (Leornado & Filho, 1980; Holland et al, 1979). Most calcium hydroxide cements are used as cavity liners and set too rapidly for general use as root canal sealers. Recently, a calcium hydroxide root canal sealer, Sealapex (Kerr, Romulus, MI), with bench setting time of forty minutes became commercially available.

Sealapex (Kerr)

One study (Hovland & Dumsha, 1985) found that the leakage associated with Sealapex, using the silver stain technique over thirty days, was not significantly different from Tubli-Seal (Kerr), or Procosol (Star Dental Manufacturing Co, Conshohocken, PA). Lim & Tidmarsh (1986) showed that there was no significant difference between the sealing ability of Sealapex and AH-26 over a thirty day period using the electrochemical method of determining apical leakage. Madison (1987) showed that root canals filled with Sealapex and gutta-percha exhibited significantly less coronal leakage than those filled with AH-26 and gutta-percha.

The calcium hydroxide content in Sealapex has made it a highly acceptable root canal sealer in the dental profession. Rothier et al (1987) showed that Sealapex* and CRCS@ exhibited less linear dye penetration than ProcoSol sealer while Zmener (1987) found that there was no significant difference in linear dye penetration between Sealapex, CRCS and Tubliseal.

It has been shown by many authors that calcium hydroxide can stimulate hard tissue formation around the immature apex (Schroeder 1973). It may be assumed that the calcium hydroxide in Sealapex would offer the same calcific repair potential as other non-setting calcium hydroxide pastes. However, many clinicians who have used Sealapex report that it has a granular consistency which they find makes accurate placement of the master cone unreliable.

Non-Therapeutic Pastes

Although the use of pastes as the sole obturating material has not been adopted widely in clinical practice, it does have its proponents. Why are pastes used in practice? The reason for the use of a paste as the sole root canal filling material is that there is only one interface where microleakage could occur between the dentine and the sealer. On the other hand, when a core material like gutta-percha is used in combination with a sealer, there are two types of interfaces where microleakage could occur. Although root canal sealers alone may be easier to use than gutta-percha and sealer, the use of sealer alone to fill the root canal may create problems. One problem

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* Sealapex (Kerr/Sybron, Romulus, MI. USA)
@ Calciobiotic Root Canal Sealer (Hygenic Corp., Akron, OH. USA)

is that when a sealer sets, it undergoes shrinkage away from the canal walls which enables microleakage to occur (Stock, 1985). The ammount of shrinkage can be reduced by using a stable core material such as gutta-percha and reducing the ammount of sealer used (Stock, 1985; Nguyen 1987, p 238).

Hydron*

Hydron (Poly-2-hydroxyethylmethacrylate), a hydrophilic gel with barium sulphate added for radiopacity, was introduced as a root canal filling material in 1976 by Benkel et al (1976).

When injected into a root canal system by a specially designed device, Hydron polymerizes and expands, especially in the presence of any residual moisture.

Initially Hydron was reported by some authors (Rising et al, 1975; Benkel et al, 1976) to be inert, nontoxic, biocompatible, nonabsorbable, and non-inflammatory and was said to fulfill the criteria for an ideal root canal material. Subsequent studies (Kronman et al, 1977; Goldberg & Massone, 1980; Langeland et al, 1981) however, showed different results with regard to the physical, chemical, and biologic properties of Hydron. Hydron´s radiopacity is very low, much less than gutta-percha. This appears to make it difficult to assess the quality of the root filling, as seen radiographically (Heuer & Miserendino, 1987 p. 410).

The syringe method used in Hydron filling makes it difficult to control the placement of the plastic gel accurately and to control the formation of voids within its structure. The working time of six to eight minutes may prove insufficient for the correction of procedural

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* Hydron (NPO Dental Systems, Inc., New Brunswick, NJ. USA)

difficulties, such as voids and underfilling (Heuer & Miserendino, 1987 p. 410).

Hydron has been shown to be capable of penetrating fins, spurs, instrument marks, and dentinal tubules (Nguyen, 1987 p.239). Other investigators (Kronman et al, 1977; Goldberg & Massone, 1980) did not find that the material penetrated the dentinal tubules.

In regard to the inert property and tissue tolerance of Hydron, the opinions are controversial. Rising et al (1975) and Benkel et al (1976) have reported excellent biocompatibility of Hydron. Spangberg & Langeland (1973) and Langeland et al (1981) have reported long-term inflammation, material absorption by phagocytes and poor sealing ability associated with Hydron.

It has been shown by Spangberg & Langeland (1973), Kronman et al (1977) and Langeland et al (1981) that overfillings with Hydron cause long-term, severe periapical inflammation, with the activation of large numbers of macrophages containing particles of Hydron. Lymphocytes were observed but to a lesser degree.

Once the Hydron has hardened by polymerization, its removal from the canal for post preparation or re-treatment can only be accomplished by drilling with burs such as Peeso reamers.

One study (Murrin et al, 1985) found that Hydron sealed the apical 2 mm of the root canal very well when viewed in cross section under a microscope. The same study found that teeth filled with Hydron exhibited more dye leakage than teeth obturated with laterally condensed gutta-percha and Grossman's sealer.

Endo-fill

The Endo-fill* is an injectable silicone resin endodontic sealant. The manufacturer claims it can be used as a sealer in conjunction with a core like gutta-percha or as a sole sealant and filling material to be injected in the canal with a pressure syringe.

Endo-fill consists of a silicone monomer and a silicone-based catalyst plus bismuth subnitrate filler. The mixed silicone resin has a low viscosity with adaptation to tooth structure and good penetration into accessory canals. It cures to a pale pink rubbery solid. Silicone elastomers are low in toxicity and inert to tissues (Nguyen 1987, p. 239).

<u>Dentine Bonding Agents</u> In spite of the technique used for obturation, and considering that most of the root canal sealers traditionally used do not provide adhesion to tooth structure, a microscopic space is likely to exist between the sealer and the tooth structure, preventing the establishment of an hermetic seal. Recently, dentinal bonding agents capable of primary bonding to dentine have been introduced to bond resin materials to dentine. The advent of dental adhesive materials provides a potential solution to the problem of microleakage after obturation of the root canal.

Zidan & ElDeeb (1985) found that canals obturated with gutta-percha and Scotchbond@ leaked significantly less than when gutta-percha with Tubliseal was used in one other technique.

The dentine bonding agents have to be chemically cured.

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* Endofill (Lee Pharmaceutical Co. Calif.USA)
@ Scotchbond (3M Co., St Paul, MN USA)

These materials are very soluble in the first thirty minutes and therefore the root canal has to be absolutely free of all moisture. Because they are chemically cured one cannot be sure if the material has undergone complete set in the canal.

Gee (1987) found that teeth obturated by lateral condensation of gutta-percha with sealer showed a better seal than teeth obturated by dentine bonding agents, using Concise* composite and a single gutta-percha cone. The main problem of the chemically cured bis-GMA resins is the rapid setting time, which does not allow the introduction of accessory gutta-percha cones in the apical third of the canal. Zidan et.al. (1987) found that teeth obturated using the single cone gutta-percha technique with Scotchbond exhibited less linear dye penetration than other root filling techniques.

The main disadvantage of the dentine bonding agents is their resistance to removal when they have set. If Scotchbond is used it should be used with a dissolvable core material such as gutta-percha which is soluble in chloroform. The most promising dentine bonding agent at present is Glass Ionomer Cement (GIC). Some GIC are available which are radiopaque and theoretically can be used as root canal filling materials. These cements have three main problems. They are hard to manipulate because they stick to metal instruments, they have a very short setting time, and most importantly, they can only be removed by drilling out the material.

<u>Semi-solid Materials</u>

<u>Gutta-Percha</u> is a purified coagulated exudate from mazer wood

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* Concise (3M Co., St.Paul, MN USA)

trees, and has been used in dentistry since the nineteenth century. Gutta-percha in its pure form was found to be useless in dentistry. It was after the addition of zinc oxide, zinc sulphate, alumina, whiting, precipitated chalk, lime or silex in various combinations that the material was used for temporary restorative purposes (Heuer & Miserendino 1987, p. 412).

In 1867, G.A. Bowman introduced gutta-percha points for filling root canals. Before the addition of waxes, fillers, and opacifiers, gutta-percha is a red-tinged, grey translucent material, rigid and solid at room temperature. It becomes pliable at thirty degrees centigrade, it is a soft mass at sixty degrees centigrade, and it melts, partially decomposing, at one hundred degrees centigrade. Exposed to light and air, gutta-percha changes crystalline form and may oxidize, becoming a brittle resinous material. Gutta-percha is 60% crystalline at room temperature; the remainder of the mass is amorphous. It exhibits viscoelasticity which is common to polymers.

Natural rubber and gutta-percha are isomers, composed of the same building block, isoprene. Natural rubber is cis-polyisoprene while gutta-percha is trans-polyisoprene. Two crystalline forms of trans-polyisoprene exist. If the naturally occurring alpha gutta-percha is heated above sixty five degrees centigrade, it becomes amorphous and melts. Room temperature cooling of the gutta-percha results in crystallization of the beta form found in most commercial gutta-percha. The reversion of the beta crystalline to the alpha crystalline form, which is more brittle, is the primary reason why gutta-percha cones used in endodontics become brittle with age (Oliet & Sorin, 1977; Sorin & Oliet, 1979). Gutta-percha aging can be delayed by storage under refrigerated conditions or can be reversed by tempering the brittle cones in hot tap water for a few minutes. Gutta-percha points have been reported to contain 19-22% gutta-percha, 59-75% zinc oxide, 1-17% heavy metal sulphates and 1-4% waxes and resins.

In spite of the secrecy surrounding the composition of the material, it is reasonable to assume that gutta-percha points are composed of approximately 20% gutta-percha, 66% filler, 11% radiopacifier, and 3% plasticizer (Heuer & Miserendino, 1987 p. 414).

Gutta-percha appears to be the core material of choice in all the endodontic obturation techniques. It is radiopaque, it is easily removed from the pulp chamber with a heated instrument, it is insoluble in tissue fluids, it is non-irritant, and can be easily removed from the root canal if dowel space is needed, or if the root canal therapy has failed (Nehammer & Stock, 1985; Weine 1989, p. 376). Gutta-percha can be injected into the root canal in the fluid state which enables it to conform to the anatomy of the root canal (Marlin, 1986).

The main shortcoming with gutta-percha is its lack of stiffness. Because gutta-percha is soft and easily deformed it makes it very difficult to seat at the correct working length in very curved, narrow canals (Weine 1989, p. 376).

Solid Materials

Silver Points

Metals have been used as root canal filling materials just as long and perhaps longer than gutta-percha. Gold and lead were used as early as 1757 for filling the root canals of extracted teeth prior to replantation. In the nineteenth century, gold wire and gold foil were common root canal filling materials. Tinfoil, lead wire and cones, silver and copper amalgam, and gold-tin alloys have been recommended at one time or another.

Aside from its availability and physical properties, one of the reasons silver was selected in preference to other metals was its bactericidal effect, referred to as its oligodynamic property. Oligodynamic refers to the toxic effect on living cells of releasing small quantities of a substance in solution. In the 1920s and 1930s silver, with its oligodynamic property, was widely recommended. The mechanism of oligodynamic activity was thought to be related to the surface area of the soluble silver salts. The bactericidal effects were due to the affinity of silver ions for sulfhydryl enzymes, which ultimately caused protein denaturation (Heuer & Miserendino 1987, p. 416).

Several brands of silver cones are commercially available (Kerr, Premier). Most silver cones are machined to the same sizes and taper as the root canal instruments. Therefore the silver cones are standardized to the K files used for mechanical preparation of the root canal.

While silver cones are machined to precise measurements, they do not always correspond completely with the diameter and taper of the root canal instruments, so that there could be a good fit of the cone in some cases and a rather loose fit in others predisposing the cone to slight underfilling or overfilling.

Silver cones have many shortcomings. If they do not fit well in the canal after cementation, corrosion products such as silver sulphide, sulphate, and carbonate can form as a result of contact with tissue fluids. Preparing dowel space once a silver cone is cemented is dangerous because of the risk of perforating the root or breaking the apical seal. In cases of re-treatment it is sometimes extremely difficult to remove a silver point (Grossman 1981, p. 303).

4.3 OBTURATION TECHNIQUES

Today there are many methods of obturating the root canal. Some methods employ cements, solutions or pastes in conjunction with a single cone of gutta-percha while others employ several cones (lateral condensation, vertical condensation, compaction) or sections of gutta-percha cones (sectional) or thermoplasticized gutta-percha which can be injected in the canal in a softened (fluid) state. In modern day endodontic practice, gutta-percha in combination with a sealer are the materials most commonly used to obturate the root canal.

Single Gutta-Percha Cone Method (Nguyen 1987)

This technique essentially uses a standardized gutta-percha point which is the same size as the last instrument used at the working length. The cone is fitted in the canal at the pre-determined length and then cut at the incisal or occlusal level of the crown. The cone should exhibit "tug back", that is, resistance to withdrawl in the apical third of the canal. A radiograph is taken to ensure that the gutta-percha cone is at the apical stop and to check the adaptation in the apical four millimetres of the canal. If the cone appears too long then it should be shortened by the appropriate amount. If the cone is short then the canal should be reinstrumented to the correct length and the gutta-percha point re-fitted.

Once the correct fit is obtained, the root canal cement is mixed to the proper consistency and the canal walls are coated by using a K file, paper point or lentulo spiral. The apical 4-5 mm of the gutta-percha point is coated with the sealer and then seated to the working length. The coronal part of the cone is then cut off by using a hot instrument. All excess cement is removed at this stage.

It has been suggested that the single cone method may be used when the canal walls are reasonably parallel and the master cone fits well in the apical third of the canal (Nguyen 1987, p. 202).

Lateral Condensation (Grossman 1981)

The Lateral Condensation technique involves using a master cone to seal the apical three millimeters of the canal and then accessory gutta-percha cones are condensed laterally against the master cone using a spreader (plugger). The lateral condensation method is well suited to filling oval-, hourglass-, and funnel-shaped root canals. These canals are found in upper incisors of young people, maxillary and mandibular premolars, lower canines, and distal root canals of lower molars (Grossman 1981, p 284).

Lateral condensation not only obliterates spaces between the canal wall and the master cone but also, because of the pressure used, tends to seal accessory canals in the apical and middle one-third of the root (Grossman 1981, p. 286). Lateral condensation is preferable to the single cone method (Grossman 1981, p. 286).

The technique involves fitting a standardized master gutta-percha cone at the predetermined length, taking a radiograph to ensure proper adaptation to the apical one-third of the canal and then coating the canal wall with sealer. The master cone is seated at the correct length and then a finger spreader is inserted with pressure between the canal wall and the master cone to create space for accessory gutta-percha cones. The finger spreader is then rotated and withdrawn taking care not to dislocate the master cone. One accessory cone is inserted in the space created by the spreader. This process of inserting the spreader and then an accessory cone is repeated until no additional accessory cones can be added to the apical or middle portions of the canal. The protruding gutta-percha cones are cut off with a hot instrument, the pulp chamber is cleared of gutta-percha and cement and a temporary restoration is placed in the access cavity. A radiograph is then taken to check the quality of the completed root canal filling.

Vertical Condensation (Weine 1989)

This method is also known as the "warm gutta-percha method" and was introduced by Schilder with the object of filling accessory canals as well as the main root canal. The preparation of the root canal and the actual technique for vertical condensation are as follows.

A widely flaring endodontic cavity is prepared much the same as for lateral condensation technique. Proper resistance form must be created to permit the application of vertical pressure against the gutta-percha, which is to be softened with heat and packed into the apical preparation.

The convenience form may need to be extended to allow for the larger rigid plugger to be placed. The extension may require enlarging the access cavity and the telescoping of the body of the canal to create a greater flare from the apical preparation to the access cavity.

This extension is necessary because condensation is done with a series of root canal pluggers, which are more rigid and which have a greater diameter than the number 3 spreader or the finger spreaders used for lateral condensation.

Standardized gutta-percha points are not used in this technique for two reasons: (1) the canal has been prepared by telescoping (flaring) and the gutta-percha points made to match the instrument size do not match the canal shape; (2) The non-standardized gutta-percha points are manufactured with a greater flare from the tip to the butt end, providing a greater mass of gutta-percha to absorb the heat and vertical pressure (Ingle & Beveridge, 1976 p. 249).

The objective of the technique is to obliterate the canal with a filling material softened by heat and packed with sufficient vertical pressure to force it to flow into the root canal system.

<u>The Vertical Condensation Technique</u> (Schilder 1967)

The tip of the primary (master) point is cut until it reaches a diameter that fits to within 2-3 mm of the working length without "tug back" or resistance to withdrawl of the point. Root canal sealer is mixed and placed into the canal as described previously. The primary point is covered with sealer and inserted to the full depth, where it should come to a definite stop; i.e. 2-3 mm short of the working length.

The coronal end of the primary cone is cut off with a hot instrument. A cold root canal plugger is used to apply vertical pressure against the cut end of gutta-percha within the canal.

A number 3 spreader is then heated cherry red and carried quickly into the cold mass of gutta-percha and withdrawn immediately, to prevent the gutta-percha from sticking to it. A cold plugger of suitable size is then forced against the warmed gutta-percha and vertical pressure is created. The cold plugger should be dipped in zinc oxyphosphate cement powder to prevent sticking to the gutta-percha (Ingle & Beveridge, 1976 p. 249).

The initial heating and plugging acts to soften and unite the mass of gutta-percha in the canal. As the procedure is repeated the spreader penetrates and the heat is carried to the apical end of the gutta-percha, causing it to move apically as the vertical force is applied. Tremendous pressure is built up in the apical mass of gutta-percha. One study (Wollard et.al., 1976 p. 98) observed that canals that were filled by the vertical condensation method exhibited more cracks in the dentine than teeth that were filled by the lateral condensation method.

The heat-softened gutta-percha and sealer are forced to flow around irregularities of the root canal system. The heating and condensation are repeated until the gutta-percha is packed to the desired length which should be checked radiographically (Ingle & Beveridge, 1976 p. 249).

The rest of the canal can be filled in increments by softening up one end of a gutta-percha segment and inserting it into the canal against the apical gutta-percha. The newly introduced gutta-percha should adhere to the apical gutta-percha while it is being condensed with a cold plugger. The convenience of the vertical condensation method is that if dowel space is required, the coronal half of the root canal does not have to be filled.

Vertical condensation is very useful in obturating the entire root canal system, especially curved canals and any lateral or accessory canals (Schilder 1967). In the hands of the experienced operator it works very well. It is of utmost importance that a stable apical stop is created. The apical stop is required to prevent any apical extrusion of gutta-percha.

Three factors would make the vertical condensation method unfavourable to general practitioners. 1) The technique may be difficult to perfect and appears to be time-consuming. 2) There are eight root canal pluggers required which to some practitioners may not be economically viable. 3) To ensure proper condensation several radiographs may need to be taken, which exposes the patient to additional radiation.

<u>Combined Lateral and Vertical Condensation</u> (Nguyen 1987)

This technique uses the best of both lateral and vertical condensation techniques to produce a very satisfactory root canal filling.

The primary gutta-percha point is fitted to the apical stop until it exhibits tug back and a radiograph is taken to ensure good adaptation in the apical region. The canal is coated with sealer and then the primary cone is dipped in the sealer and seated to the apical stop. A finger spreader is then used to create space laterally for accessory gutta-percha points until the spreader cannot be pushed to within 5 mm of the apical stop (Nguyen 1987, p. 204).

A red hot instrument is now used to remove the gutta-percha in the coronal half of the canal. While the gutta-percha is still warm, a plugger of suitable size (one that does not bind against the walls of the canal) is used to condense the gutta-percha vertically. If dowel space is required the root canal filling is complete at this stage and a radiograph should be taken to assess the quality of the obturation. If no dowel space is required, the coronal half of the root canal can be filled by either lateral condensation or by vertical condensation (Nguyen 1987, p. 205).

The combination of these two techniques produces a well condensed root filling which is easily controlled, without the problem of overfill, and without the need to take several radiographs during obturation. The filling of root canals by this combined method is usually a matter of habit when one is preparing dowel space immediately after root filling (Nicholls 1977, p.189). A good clinician is conscious of the fact that when heating out gutta-percha the hot instrument has to be used quickly to prevent it from cooling and sticking to the gutta-percha mass. By withdrawing a cool instrument from the canal the gutta-percha mass could be inadvertently pulled coronally away from the apical seat. With this in mind, one uses the plugger, with vertical pressure to enable the gutta-percha mass to move hard against the apical seat while the gutta-percha is still soft (Nguyen 1987, p. 204).

<u>Inverted Cone Method</u> (Grossman 1981)

This method is mainly suited for teeth with incompletely formed apices where the apical foramen is wide open such as in upper anterior teeth of young people. In this method, a gutta-percha point of suitable size is inserted butt end first and a radiograph is taken to ensure an adequate fit apically. Any necessary adjustments are now made and the canal is coated with sealer. The gutta-percha cone is coated with sealer and inserted to the working length and then addition cones are packed around it by lateral condensation. With teeth having very thin dentinal walls apically, care must be taken not to exert too much force while condensing due to the possibility of fracture (Grossman 1981, p. 287).

Rolled Cone Method (Nguyen 1987)

When the root canal is wide but the walls of the canal are parallel, the tapered gutta-percha points will be too thin to fit the root canal. In such a case it may be necessary to roll three or more gutta-percha points together on a warm glass slab or to roll the gutta-percha points on a cold slab using a warm broad spatula. By rolling the gutta-percha cones together, a thick homogeneous mass of even diameter is produced.

The rolled gutta-percha cone is allowed to cool to a rigid state and then it is disinfected in alcohol. The gutta-percha cone should be tried in a moist root canal to prevent the cone from binding on the canal walls. The tip of the cone is softened in chloroform for a few seconds and then inserted to the predetermined length and a radiograph taken. If the cone is short of the working length it may need to be rolled narrower or if it is not thick enough extra gutta-percha cones can be rolled together. When the custom made gutta-percha cone is ready, the canal walls are coated with sealer the cone is dipped in sealer and inserted to the working length. If a calcific bridge is present gentle lateral condensation can be attempted or a red hot spreader may be pushed into the centre of the cone to within 3 mm of the working length and withdrawn quickly to avoid sticking to the gutta-percha. A wide plugger is then used to condense the gutta-percha apically using minimum vertical pressure.

In both the inverted and the rolled cone methods it is assumed that some apexification procedure has been carried out before-hand.

Calcium hydroxide paste is the material used to stimulate calcific bridge formation across the open apex. This apexification procedure may need to be carried out over six to eighteen months, with the calcium hydroxide paste having to be replaced every three months. Three months appears to be a good interval to change the calcium hydroxide because it has been shown to be absorbed by phagocytes beyond the three month period (Heithersay, 1977).

Sectional Method (Thé 1979 a)

The sectional method uses 3-4 mm sections of gutta-percha to obturate the canal. A plugger is selected which can reach to within 4 mm of the apical stop and this length is marked using a rubber stopper. A gutta-percha point is selected which fits the canal accurately and is cut up into 3-4 mm sections. The canal walls can then be coated with a minimum amount of sealer. The apical section of gutta-percha is picked up by the plugger (which has been warmed in a flame or in a hot salt sterilizer) , dipped in eucalyptol and inserted to the working length. The plugger is swung back and forth through an arc and is released from the cone. A radiograph is then taken to assess the fit of the apical section and any alterations are made (Nguyen 1987, p. 210).

If the canal is needed for post (dowel) space, then no more gutta-percha compaction is necessary. If no dowel space is needed the rest of the sections of gutta percha can be condensed sequencially until the canal is fully obturated.

Chloropercha Method

Chloropercha is a paste made by dissolving gutta-percha in chloroform and is usually used in conjunction with a gutta-percha cone. The chloropercha method has been used by some clinicians as the sole canal filling material (Nguyen 1987, p. 216). The use of only chloropercha paste as the filling material is not recommended because of the excessive shrinkage which the material undergoes as the chloroform evaporates. Used in conjunction with a primary gutta-percha cone, it has been reported by some authors (Callahan, 1914; Johnston, 1927) that the technique can fill accessory canals as well as the main root canal.

Chloropercha may be made by dissolving base-plate gutta-percha in chloroform to make a creamy solution. Chloropercha paste may also be prepared by placing a few drops of chloroform in a sterile dappen dish and dipping a gutta-percha point into the solution. When the surface of the gutta-percha point has become softened, the point is carried into the canal and the chloropercha formed on its surface is used to coat the canal. The gutta-percha point is removed and discarded, and a new gutta-percha point is used to fill the canal. This method of application is suitable for relatively wide canals only (Grossman 1981, p.294).

The chloropercha technique is useful in perforation cases and in filling unusually curved canals that cannot be negotiated or canals with ledge formation (Nguyen 1987, p.216).

There are two modifications of the chloropercha method.

The Johnston-Callahan diffusion technique.

The canal is flooded first with 95 per cent alcohol which is absorbed on paper points, and then the canal is flooded with Callahan's rosin-chloroform solution for three minutes. A suitable gutta-percha cone is then inserted, with a stirring motion of the plugger, and the cone is compressed laterally, against the wall of the canal. Additional cones are packed into the canal and compressed in the same manner to fill the canal completely. Care must be taken to prevent the filling material from being forced through the apical foramen because freshly prepared chloropercha is toxic before evaporation of chloroform (Spangberg & Langeland, 1973).

As chloroform evaporates, it causes a significanat dimensional change of the filling and a possible loss of the apical seal (Wong et.al., 1982). Sufficient time should be allowed for the chloroform to become dissipated in the course of the filling operation and the guttta-percha should be compressed to form a homogeneous filling and to compensate for the shrinkage.

McElroy (1955) has shown that, even when additional gutta-percha cones are added to chloropercha, there is still about 7.5 per cent loss in volume owing to shrinkage.

Nygaard-Ostby (Kloroperka) Technique.

The technique involves adding a preparation made of finely ground gutta-percha, Canada balsam, colophonium, and zinc oxide powder mixed with chloroform in a dappen dish. The canal walls are coated with Kloroperka and then the primary cone is dipped in sealer and is inserted apically by pushing the partially dissolved tip of the cone to its apical seat. Additional cones are packed into the canal to obtain a compact filling.

Nygaard-Ostby (1971) suggests additional lateral condensation, but to avoid overfilling the use of a spreader is delayed until the subsequent appointment. The Kloroperka technique is reported to greatly reduce both apical extrusions and shrinkage of the filling.

One study (Goldman 1975) compared chloropercha, Kloroperka, and lateral condensation methods of obturation. It was found that chloropercha replicated the canal irregularities better than lateral condensation or Kloroperka but is subject to porosity and volume change, while Kloroperka demonstrated superior homogeneity.

Gutta-Percha-Eucapercha Technique (Nguyen 1987)

Eucalyptol is derived from eucalyptus trees and is reported to have antibacterial action and anti-inflammatory properties (Morse & Wilcko, 1978 p.58). Eucalyptol has much less tissue toxicity than does chloroform but its main shortcomming is that it takes a few minutes to dissolve the gutta-percha compared with chloroform which takes only a few seconds.

This technique can be used when a sound apical stop is present. The primary cone should exhibit "tug back" and fit to within one millimeter of the apex. A Dappen dish is half filled with eucalyptol and then small segments of gutta-percha are placed in the liquid. The Dappen dish is held over a bunsen for twenty seconds to warm the eucalyptol which increases its ability to dissolve the gutta-percha. The contents of the Dappen dish are stirred with a spatula until the segments of gutta-percha are dissolved forming a cloudy mixture of eucapercha.

The apical half of the primary cone is dipped into the warm eucapercha solution and rotated for thirty to forty seconds and then inserted into the canal at the predetermined length. A radiograph is taken to determine the fit of the eucapercha coated primary cone. Vertical and lateral condensation is then performed to complete the filling procedure. A few drops of warm eucalyptol can sometimes be placed in the pulp chamber to help soften the filling mass and move the gutta-percha-eucapercha mass apically (Nguyen 1987 p. 217).

The gutta-percha-eucapercha technique can effectively fill lateral and accessory canals but the fine canals will not appear as radiopaque as when gutta-percha is used in conjunction with a sealer containing barium sulphate (Nguyen 1987, p. 218).

Thermomechanical Compaction of Gutta-Percha

This technique was introduced in 1978 by McSpadden and consists of creating sufficient heat by means of a rotating instrument to plasticize gutta-percha. The working shaft of the compactor instrument is similar to a Hedstroem file with blades reversed (Figure 4.1). The McSpadden kit* comes with a self study course, and includes a radio cassette explaining the technique, a clear perspex root canal simulator, gutta-percha cones, and the compactors. (Figure 4.2)

McSpadden Technique.

After the preparation of the root canal a gutta-percha point is selected so the tip cannot pass through the apical foramen. The canal is coated with sealer, the gutta-percha is dipped in the sealer and inserted in the canal. A compactor with the same diameter as the last K file used is selected and placed in a contra-angled handpiece.

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* McSpadden J.T. Self study course for the thermatic condensation of gutta percha. Toledo: Ranson and Randolph, 1980.

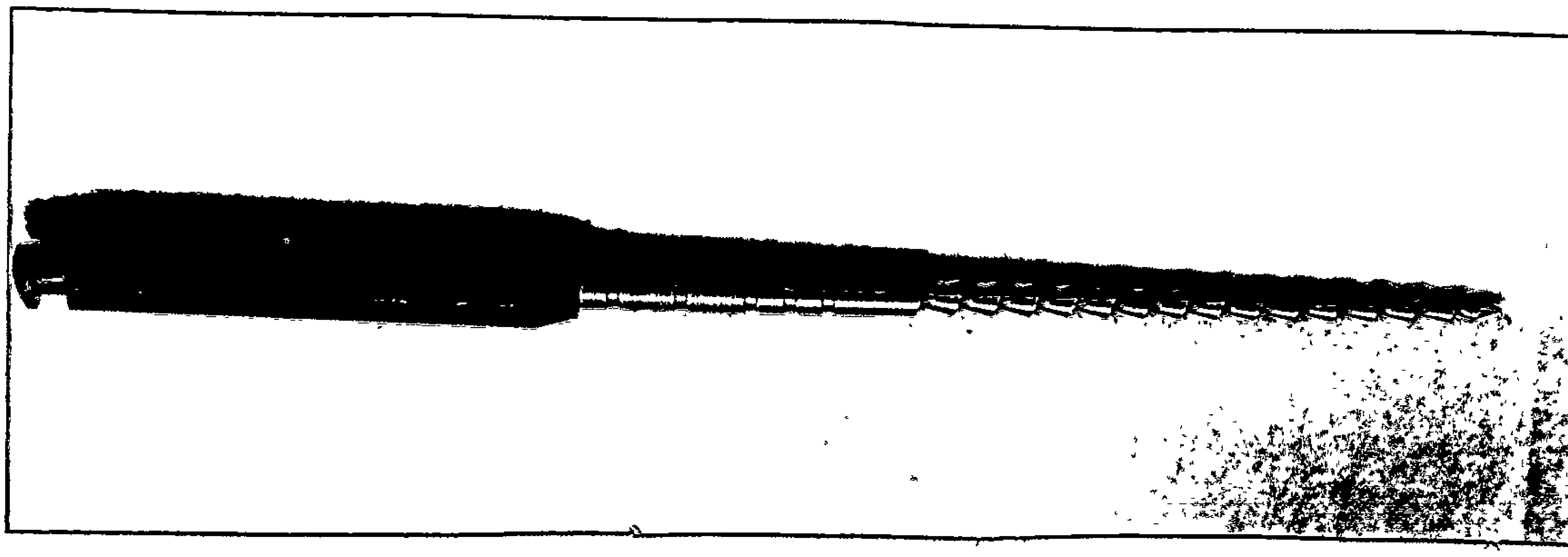

Figure 4.1 McSpadden compactor

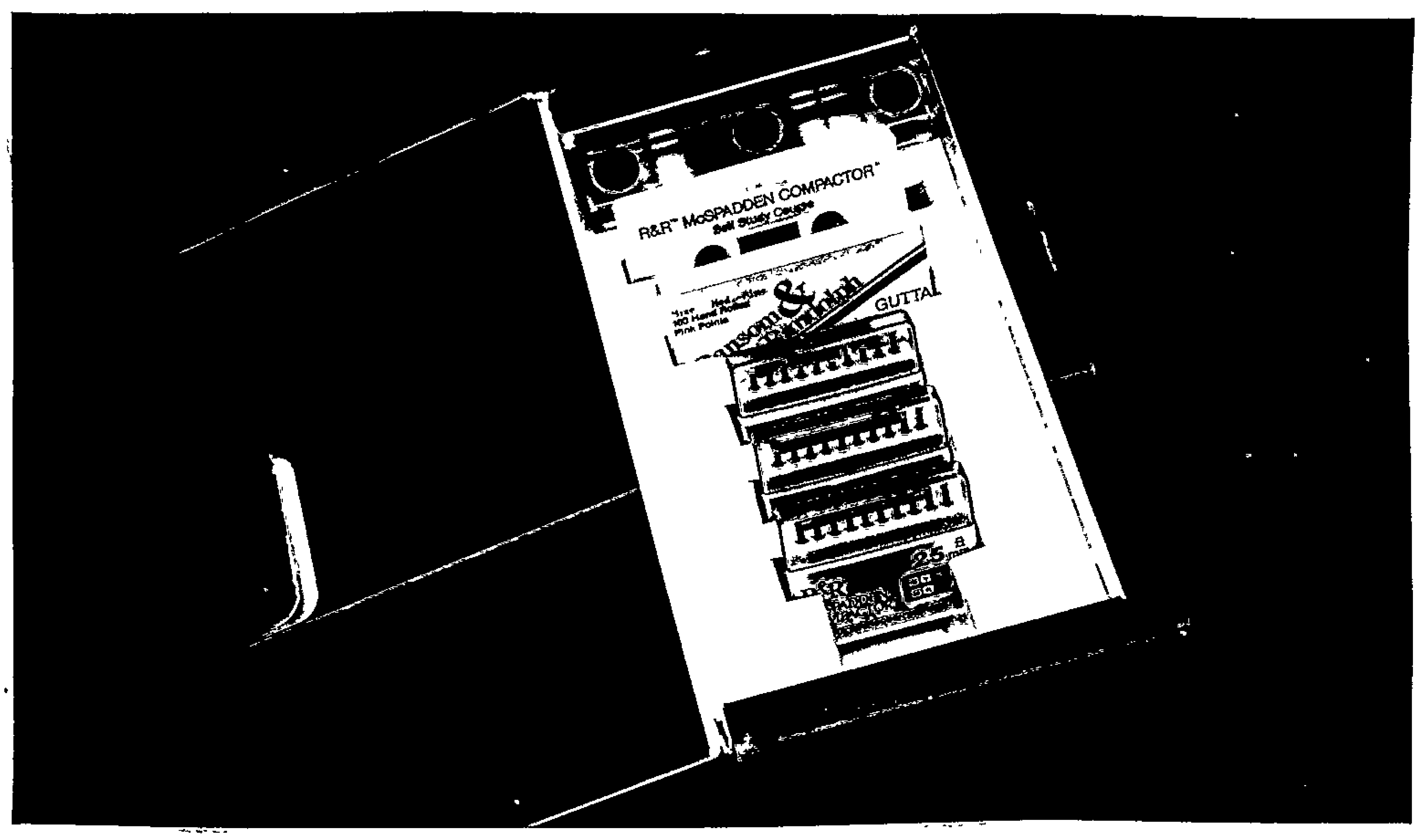

Figure 4.2 McSpadden kit

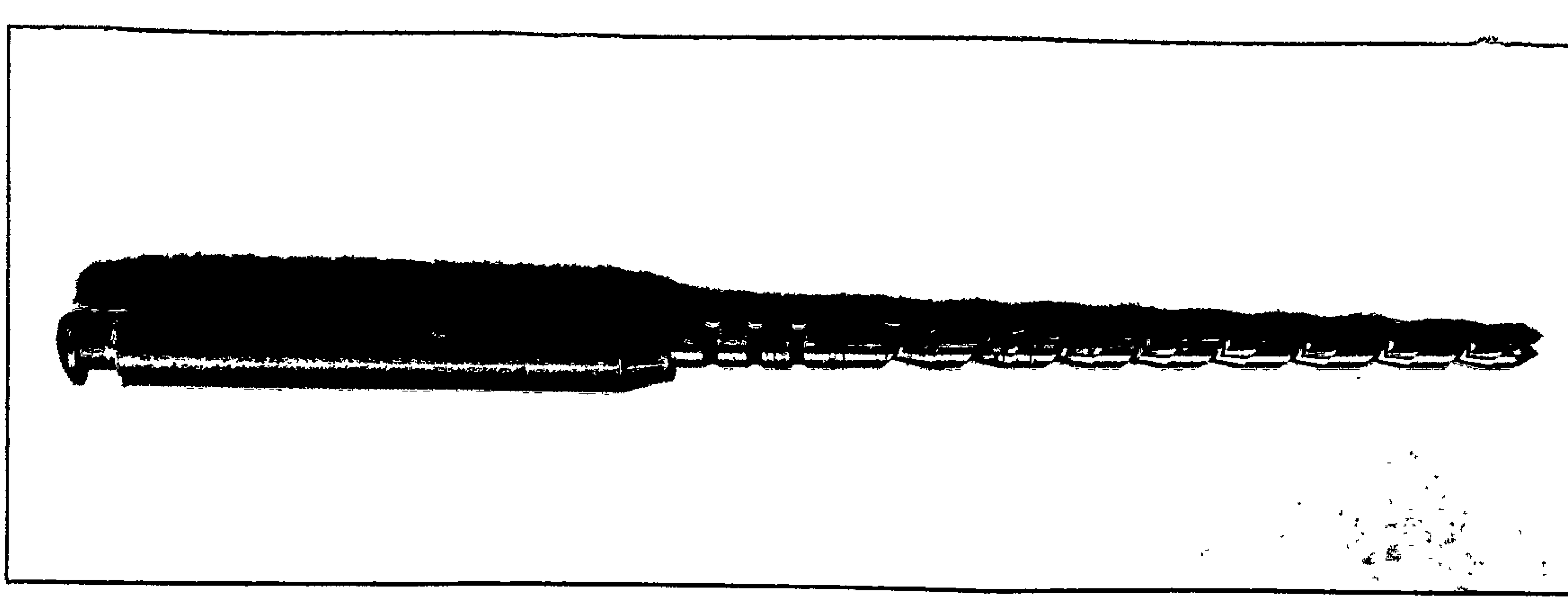

Figure 4.3 The Brasseler compactor

The handpiece is checked to ensure a clockwise rotation. The compactor is activated at full speed, (8,000-10,000 r.p.m.) against the gutta-percha but without any apical pressure. The frictional heat will plasticize the gutta-percha in one second. The compactor is then inserted to the predetermined depth and withdrawn in a fluent motion while the compactor is rotating at full speed. A radiograph should be taken to check the condensation of the apical portion of the canal. When satisfied with the condensation of the apical portion of the root filling, a larger cmpactor may be needed to fill the flared coronal portion of the canal.

The McSpadden technique is technique sensitive and this can produce many problems to the inexperienced operator. The major problems found by most studies (Tagger et al, 1984; Hopkins et al, 1986; Hardie, 1987) are:

1) Fracture of the compactor,
2) Extrusion of gutta-percha through apical foramen,
3) Incompletely condensed gutta-percha,
4) Vertical root fracture.

The problems mentioned above can be avoided by the experienced operator. With its proper use, thermomechanical compaction has been shown by several studies (Wong et al, 1981; Egushi et al, 1985; ElDeeb et al, 1985; Kersten et al, 1986 a&b; Peters, 1986) to have an excellent adaptation and condensation to the root canal, both radiographically and stereomicroscopically. Ishley & ElDeeb (1983) found that there was no difference in linear dye penetration between teeth obturated by McSpadden compaction or by lateral condensation providing sealer was used. Without sealer the same study found that teeth obturated by McSpadden showed a 5 to 20 fold increase in linear dye penetration. Hopkins et al (1986) found that teeth obturated by McSpadden and sealer showed more radioisotope leakage than teeth obturated by lateral condensation and sealer.

Brasseler TLC (Thermal Lateral Condensation) (Brasseler's Description)

Designed by J. McSpadden, the Brasseler TLC* overcomes the disadvantages of Thermatic Compaction by using the same technique of hand or finger spreaders that is used in lateral condensation to make space for the condensor. Manufacturers claim that it combines the best of all gutta-percha condensing techniques without any of the disadvantages.

The TLC instrument (Figure 4.3) looks like a McSpadden compactor except it has a decreased number of spirals per unit length.

There are seven sizes standardized to the cutting tips of K-files. They are 25, 30, 35, 40, 50, 70, 90. In using the TLC, it is best to think of the instrument as a spreader that is capable of plasticizing and introducing gutta-percha into the canal. The mechanical spreader is used in a low speed handpiece.

Size selection of the TLC is the same as for pluggers or spreaders and is always smaller than the canal at it's depth of insertion. After insertion of a master cone, the TLC is placed along side the master cone and vertical presssure is exerted as with a spreader. Rotation is initiated (optimal speed is 2000 r.p.m.) to plasticize the gutta-percha, condensing it laterally and forming a good apical plug. Additional accessory cones may be added, each being plasticized and condensed.

The manufacturers claim that the TLC offers the advantages of other thermoplasticized gutta-percha techniques with reduced threat of extrusion through the apex and root or instrument fracture (for safer, easy operation).

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* Brasseler USA, Inc. Savannah, Georgia, U.S.A.

Thermoplasticized Injection-Molded Gutta-Percha

The obturation of the root canal using injectable gutta-percha in conjuction with a pressure syringe was introduced by Yee et al in 1977. Heated gutta-percha was injected with and without sealer in vitro in teeth that were cleaned and shaped. The quality of the seal was assessed by dye penetration which showed that an effective root canal filling could be achieved. Yee et al (1977), in an in-vitro study, showed that injection molded gutta-percha seems to be capable of filling multiple foramina and lateral and accessory canals.

The claimed advantages of this technique are 1) the root canal can be filled in about twenty seconds, 2) the gutta-percha remains plastic for about two minutes thereby allowing vertical condensation to obliterate voids, 3) a scanning electron microscopic study (Torabinejad et al, 1978) has shown that the root canals that were obturated by thermoplasticized gutta-percha and sealer exhibited good adaptation to the canal wall, similar to those canals filled by lateral condensation or vertical condensation.

The disadvantages of the early delivery system were that it was too cumbersome and both patient and clinician had to be protected from a device utilizing a temperature of 160° C.

Obtura*

Marlin et al (1981) evaluated a simpler thermoplasticized injection delivery system called Obtura. Marlin stated that "The

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* Obtura (Unitek Co. Monrovia, CA. USA)

method shows promise because the success rate seems comparable with the rate achieved by conventional gutta-percha obturation techniques."

This system is composed of an electrical control unit with pistol-grip syringe (gun). Gutta-percha cylinders are loaded in a slot on the top of the gun and the piston is pushed in. When sufficient temperature is reached, approximately 160° C, the gutta-percha flows freely from the needle as the trigger is sqeezed. The gutta-percha remains plastic in the root canal enabling the clinician to vertically condense the gutta-percha. Continuous condensation is essential to prevent cooling shrinkage (Marlin et al 1981). Recently, however, Skinner & Himel (1987) found that whether or not vertical condensation was used in conjunction with the Obtura system, it did not make a significant difference in leakage, in large straight canals.

The sealing ability of the Obtura technique appears promising. Skinner and Himel (1987) using fluorescent dye found that teeth obturated with Obtura and sealer had less leakage than teeth that were obturated with the Obtura only. Mann and McWalter (1987), using methylene blue dye found that teeth filled with Obtura and sealer showed slightly more leakage than teeth that were filled with lateral condensation and sealer. More leakage occurred in teeth with curved canals. The significant finding was that 50% of the injection-molded thermoplasticized teeth showed underextension or overextension. Ritchie (1988) showed that in teeth with foramina 0.4 mm or larger, overextension of the thermoplasticized gutta-percha occurs. Teeth with wide foramina have to have a good apical stop, which is produced with dentinal filings.

Marlin (1986) found that the injectable thermoplasticized gutta-percha technique can produce complete endodontic obturation by obliterating many types of intraradicular irregularities.

Ultrafil*

The Ultrafil or low-temperature gutta-percha injection system was introduced by Michanowicz & Czonstkowsky (1984). The system consists of an injection syringe (Figure 4.4), gutta-percha cannulas with 22-gauge needles attached, and a portable heater (Figure 4.5).

The gutta-percha composition developed by the Hygienic Corporation allows the gutta-percha to flow at 70° C. The root canal has to be prepared to at least a size 70 K file, 6 mm from the apical stop.

The portable heater is preset at 90° C. The cannulas are placed in the heater for fifteen minutes before use. The gutta-percha will flow for about one minute after the cannula is removed from the heater. The cannula is loaded in the syringe, the needle of the cannula is then inserted in the canal without binding and the trigger of the syringe is sqeezed slowly and then released. This sqeeze-release action is continued until the back pressure of the gutta-percha lifts the needle out of the root canal.

The Ultrafil technique does not advocate manual compaction. In light of what we know about cooling shrinkage of gutta-percha, it would be favourable to minimize shrinkage by vertical compaction with pluggers.

The apical seal of Ultrafil has recently been tested. Michanowicz and Czonstkowsky 1984, using methylene blue dye to test for leakage, found that Ultrafil in conjunction with a sealer created a

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* Ultrafil injection system (Hygenic Corp., Akron OH USA)

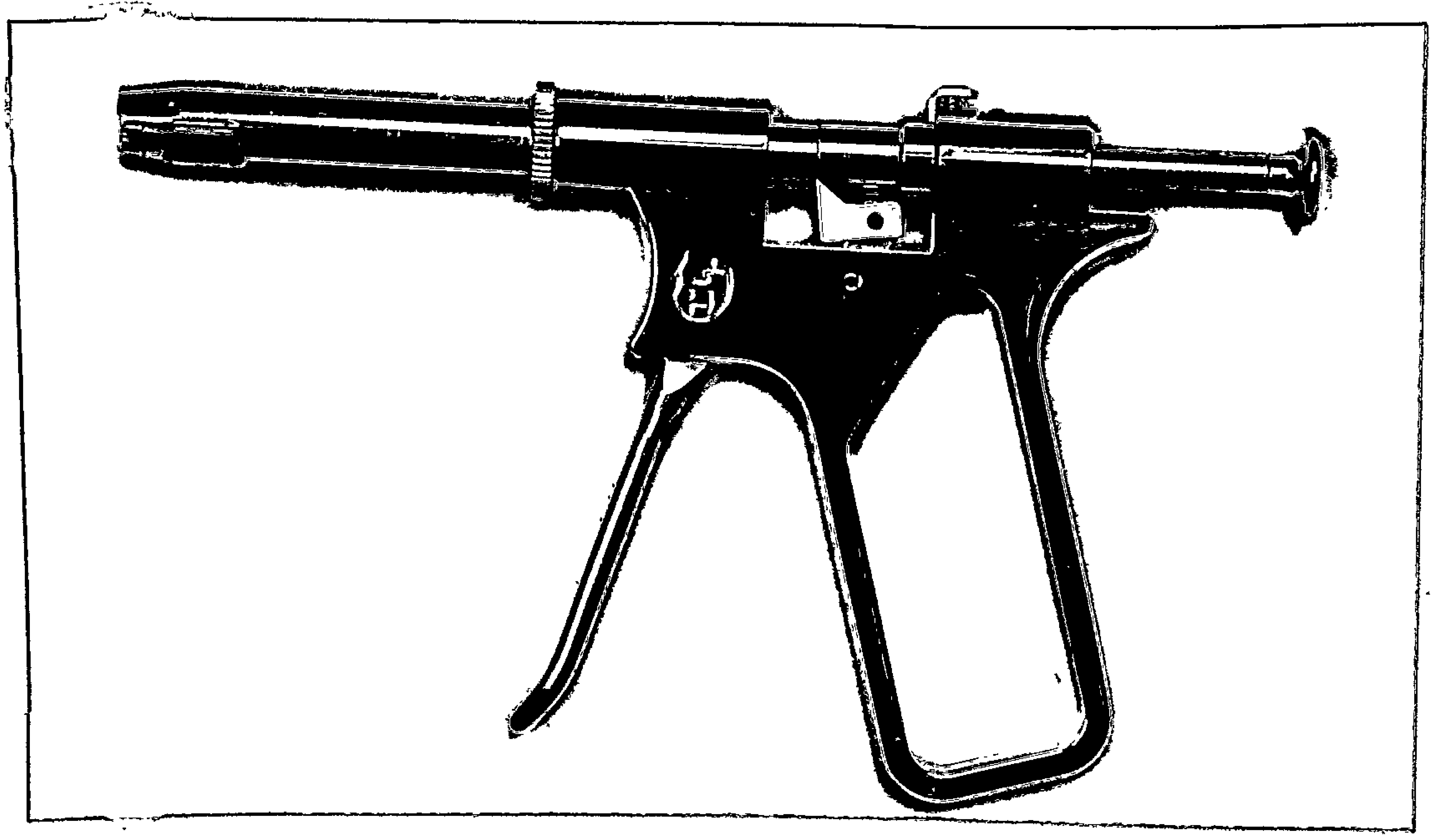

Figure 4.4 The Ultrafil injection syringe

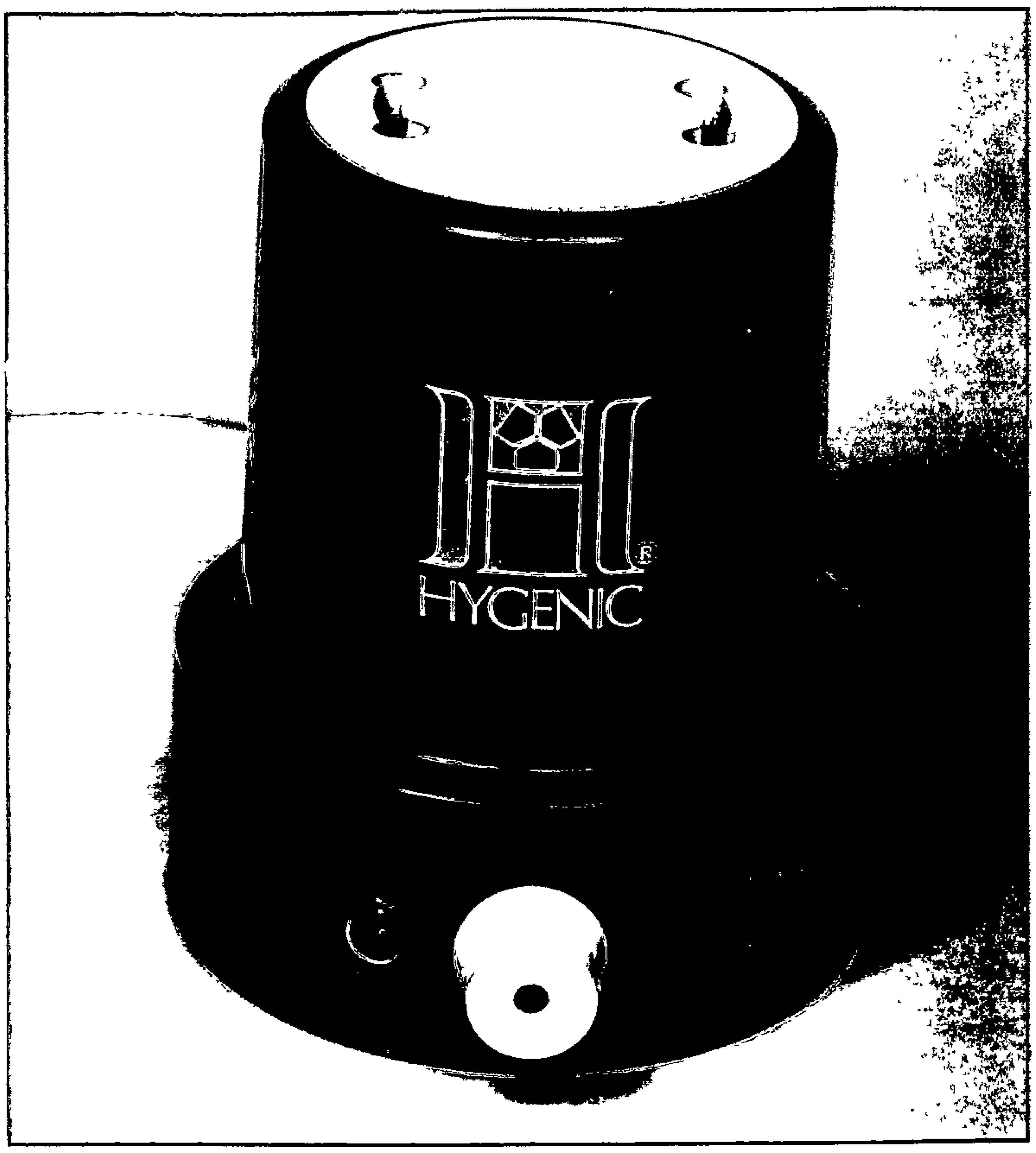

Figure 4.5 The Ultrafil portable heater

good apical seal, which was comparable to lateral condensation. Another study (Czonstkowsky and Michanowicz, 1985) utilizing radioactive isotopes to quantify the leakage, found that teeth filled with Ultrafil and sealer had slightly less leakage than teeth filled by lateral condensation with sealer.

Teeth filled with Ultrafil and without sealer had slightly more leakage than the lateral condensation group. Evans and Simon (1986) showed that both lateral condensation and Ultrafil techniques did not provide an apical seal to ink penetration when used without sealer, even with the smear layer removed. An effective seal was obtained in both techniques when used with sealer. The presence or absence of smear layer had no significant effect on apical leakage in vitro.

The Ultrafil technique is also advocated for use by the manufacturer in teeth with open apices by using either of the following methods.

1) Filing a dry canal to create a dentine chip plug at the working length; or

2) Fitting a master gutta-percha point at the working length, removing the coronal two thirds of the master point with a heated instrument, and obturating the coronal part of the root canal with thermoplasticized gutta-percha. The first method appears very hazardous and could easily lead to over-extension of the gutta-percha. The second method appears more reliable. George et al (1987) showed that to prevent over-extension of the thermoplasticized gutta-percha, an apical stop has to be created which produces resistance to a number 20 K file upon mild pressure.

Endotec*

The Endotec was developed by Martin (1986) and has been described as a "thermal endodontic condenser". The Endotec consists of 1) a cordless handpiece with quick-change tips (corresponding to size 30 and 45 root canal files), pushbutton-controlled heating element and rechargeable batteries, and 2) a battery charger base with AC current converter. The manufacturer claims that the Endotec combines lateral and vertical condensation techniques to produce a more dense and a more homogeneous root filling.

The manufacturer claims that the Endotec causes gutta-percha to coalesce and fuse into a dense homogeneous mass (Martin 1986). When thermo-softened, the gutta-percha can easily be condensed to the shape of the root canal wall. Weine (1989 p. 389) found that 1) the instrument can be used in a similar way to lateral condensation, as a spreader, which can soften the master gutta-percha to accommodate more accessory cones and 2) the instrument replaces the bunsen burner, and decreases patient apprehension and increases safety in the surgery.

The problems associated with using the Endotec include the following: 1) The Endotec has limited application in the posterior part of the mouth due to lack of access, 2) The tips tend to be bent out of shape, very easily, and 3) The position of the button, which has to be kept depressed while the Endotec is being used makes the instrument cumbersome (Weine 1989, p.389).

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* Endotec (L.D. Caulk Div. Dentsply, Milford, DE. USA)

Ultrasonic Activated Condensation (Moreno 1977)

This technique is a combination of both lateral and thermomechanical condensation. Moreno (1977) used a K-file which was cut off at the shaft and then inserted in an ultrasonic handpiece. The ultrasonically activated file was used essentially as a root canal spreader. The file was inserted next to the master gutta-percha point and ultrasonically activated. The heat produced by the vibrating file plasticized the gutta-percha into a more homogeneous mass (Moreno, 1977). The same author found in an in-vitro study that teeth obturated by ultrasonically activated gutta-perha and sealer exhibited less radioisotope leakage than teeth obturated by lateral condensation and sealer. The results of this study must be viewed with caution due to the small sample size. Other studies have not reported the use of this technique.

4.4 SUMMARY

There are a large number of materials and techniques available to Endodontists and General Dental Practitioners for the obturation of the root canal. The rapid and prolific release of new products allows little time for proper evaluation of the material or the technique before clinical usage begins.