Technical Endodontics

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This book is the work of Professor Dr. Hossam Tawfik and is *not* my creation. I would like to thank him for this book and for his knowledge which he has made available to everyone…

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2009

Pulp Space Morphology and Coronal Access Cavity Preparation

The dental pulp occupies a central cavity within each tooth. This space differs from tooth to another and a lot of variations can occur within the same tooth. Studies by Green, Vertucci and others demonstrated that anatomic complexities such as multiple foramina, deltas, and furcation accessory canals are common in most teeth. The student and the clinician must approach the teeth to be treated assuming that these deviations occur so often that they must now be considered normal anatomy.

Terminology:

Pulp Cavity “Space”:

This is the central cavity within a tooth, which is entirely enclosed by dentin except at the apical foramen. The pulp cavity may be divided into coronal portion “pulp chamber” and a ridiculer portion “root canal”. In anterior teeth the pulp chamber gradually merges into the root canal, and this division becomes indistinct.

Pulp chamber:

This is the pulp space that lies in the crown of the tooth. The shape of the pulp chamber usually reflects the external form of the crown. By aging and deposition of secondary dentin the size of the pulp chamber may be reduced.

Pulp Horn:

This is an accentuation of the roof of the pulp chamber directly under a cusp or developmental lobe.

Root Canal:

This is the pulp space in the root of the tooth starting by the root canal orifice and ending by the apical foramen.

Apical Foramen:

An aperture at or near the apex of a root through which the blood vessels and nerves of the pulp enter or leave the pulp cavity. The apical foramen is not always located in the center of the root apex. It may exist on the mesial, distal, labial or lingual surfaces. Anatomic studies have shown that the apical foramen is located within the anatomic apex in only 17 to 46% of cases and it located an average of 0.4 – 0.7 mm away from the anatomic apex.

Accessory or Lateral Canals:

These are lateral branches of the main root canal communicating the pulp space with the periodontal ligament. Accessory canals may be found at any level but the majority is found in the apical half of the root or in the furcation area of multirooted teeth.

Lateral canals and accessory foramina have been found with enough regularity to prove that they are integral parts of a normal pulp cavity rather than exceptions. They can occur due to:

1. The periodontal vessels curve around the root apex of a developing tooth and often become entrapped in Hertwig's epithelial root sheath, frequently occurs in the apical third of the root.

2. Disintegration of an area of the Hertwig's epithelial root sheath before induction of dentin formation so neither dentin nor cementum is formed.

3. Failure of fusion of the tongue like projections of the diaphragm in multi-rooted teeth resulting in accessory canals in the furcation areas.

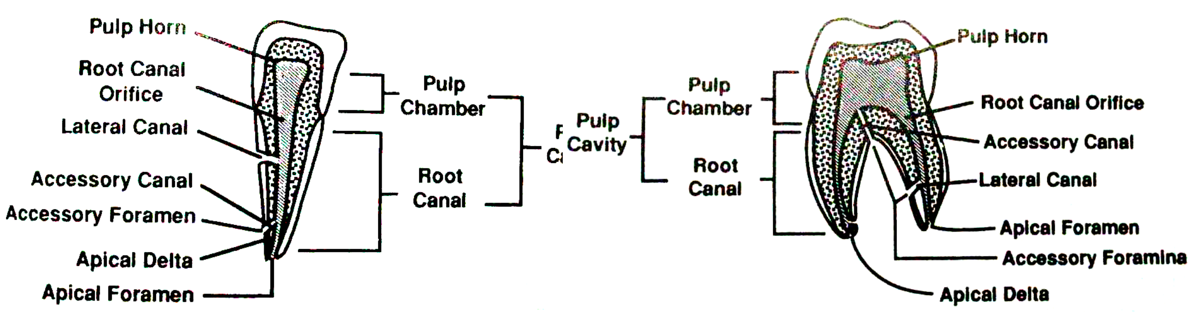


Fig (1): Components of root canal systems.

Common Canal Configurations:

Despite the many combinations of canals that are present in the roots of human permanent dentition, most of these root canal systems in any one root can be categorized in six different types. These six types are:

Type I : Single canal from pulp chamber to the apex.
Type II : Two separate canals leaving the chamber but merging short of the apex to form only one canal.
Type III : Two separate canals leaving the chamber and existing the root in separate apical foramina.
Type IV : One canal leaving the pulp chamber but dividing short of the apex into two separate canals with two separate apical foramina.
Type V : One canal that divides into two in the body of the root but returns to exist as one apical foramen.
Type VI : Two canals that merge in the body of the root but re-divide to exist into two apical foramina.

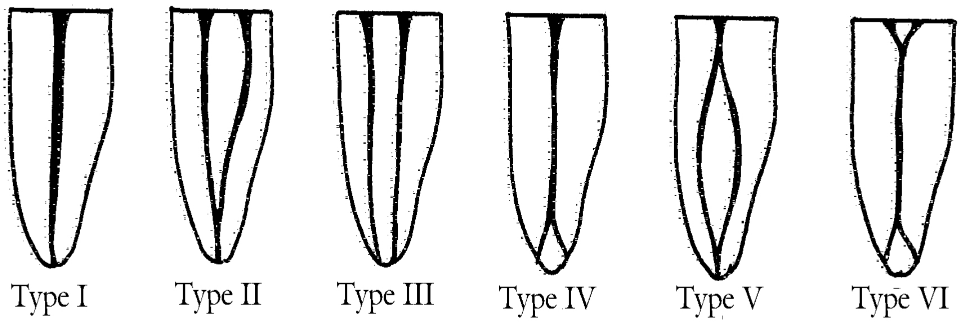


Fig (2): Types of root canal systems.

Root Canal Classes:

Another classification has been developed to describe the completion of root canal formation and curvature.

Class I : Mature straight root canal.
Class II : Mature but complicated root canal having-severe curvature, S-shaped course, dilacerations or bayonet curve.
Class III : Immature root canal either tubular or blunder bass.

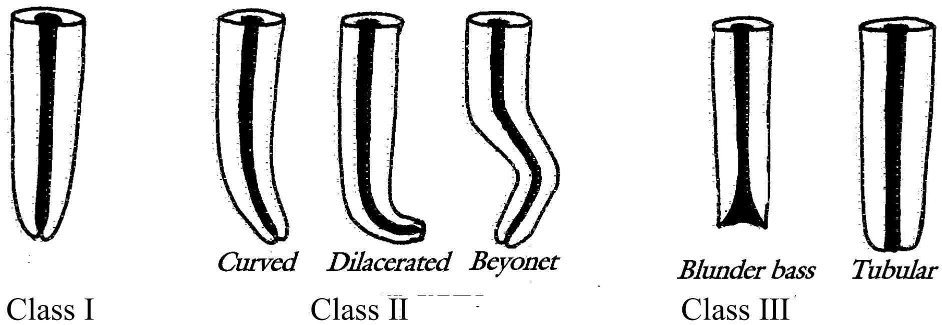


Fig (3): Root canal classes.

Principles of Coronal Access Cavity Preparation:

Principles of cavity preparation established by G.V. Black have been modified by John Ingle to suite endodontic cavity preparation. It has been divided into coronal and radicular cavity preparations. In this chapter, only coronal cavity preparation will be dealt with.

Endodontic coronal cavity preparation has been divided into:

I. Outline form.
II. Convenience form.
III. Removal of carious dentin and defective restorations.
IV. Toilet of the cavity.

I. **Outline form**:

The external outline form evolves from the internal anatomy of the tooth established by the pulp. That is to say, external outline form is established by projecting the internal anatomy of the pulp onto the external surface. This can be accomplished by drilling into the open space of the pulp chamber and then working with the bur from the inside of the tooth to the outside, cutting away the dentin of the pulpal roof and the walls overhanging the roof of the pulp chamber.
To achieve proper outline form, three factors must be considered.

1. **Size of the pulp chamber**:

Larger pulp chambers require more extensive outline form than in smaller pulp chambers. Size of pulp chamber is affected by age where pulp is receded in old age. Other factors include trauma, decay, and medications “e.g. calcium hydroxide”.

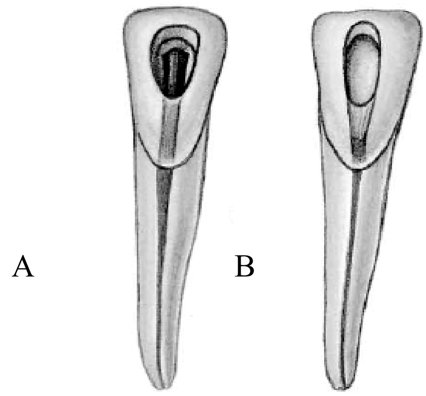
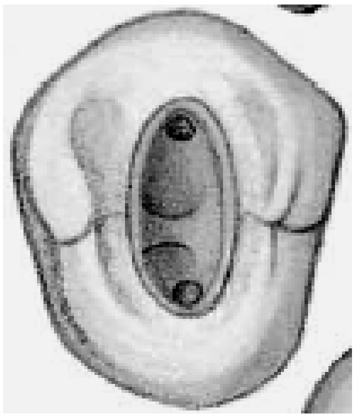


Fig (4): Effect of age on the size of pulp chamber; A: large triangular outline form in young age. B: smaller oval outline form in old age.

2. **Shape of the pulp chamber**:

The finished outline form should accurately reflect the shape of the pulp chamber. For example, the shape of the pulp chamber of maxillary first premolar is oval. This oval shape is extended up the walls of the cavity and out onto the lingual surface; hence, the final outline form is oval.

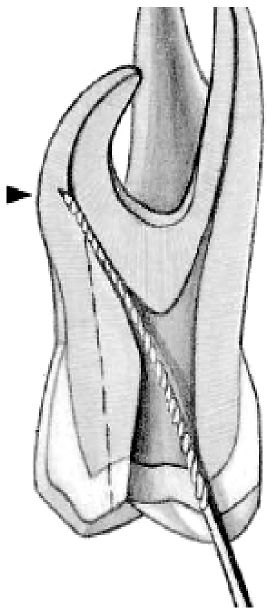
Fig (5).



3. **Number, position and curvatures of root canals**:

The access cavity walls should be extended enough to facilitate convenient approach to each root canal without interference. Hence, convenience form partly regulates outline form.

Fig (6): Dentin interference should be removed To allow proper preparation of curved canals.



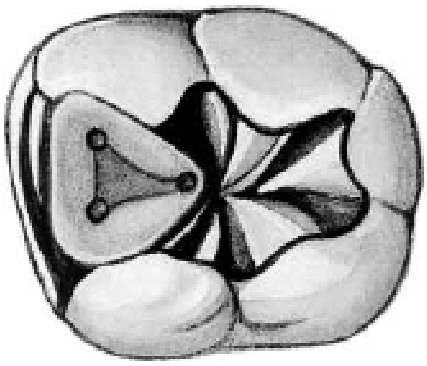
II-Convenience form:

This is the form given to the access cavity to improve visibility, instrumentation and obturation of the root canal. Four important benefits are gained through convenience form modifications.

1. Unobstructed access to the canal orifice:

Enough tooth structure must be removed to allow instruments to be placed easily into orifices of each canal without interference from overhanging walls.

Fig (7).



2. Direct access to the apical curvature:

Enough tooth structure must be removed to allow the endodontic instruments freedom within the coronal cavity. So, they can extend down the canal in an unstrained state.

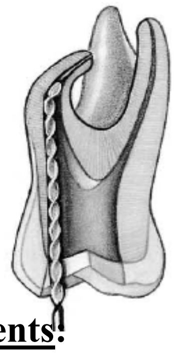


Fig (8): Endodontic instruments should have enough freedom to reach apical area without strain.

3. Complete authority over the enlarging instruments:

If the instrument is impinged at the canal orifice by tooth structure, the dentist will lose control of the direction of the tip of the instrument. On the other hand, if the tooth structure around the orifice is removed, the instrument will then be controlled by two factors only: the clinician's fingers holding the instrument and the walls of the canal touching tip of the instrument.

4. Extension to accommodate filling techniques:

To make certain that obturation instruments and procedures can be worked at ease.

Fig (9): Enough tooth structure should be removed to permit easy access during filling.

III Removal of carious dentin and defective restorations:

Caries and defective restorations must be removed for three reasons: (1) to eliminate mechanically as many bacteria as possible, (2) to eliminate the discolored tooth structure, and (3) to eliminate the possibility of any bacteria laden saliva leaking into the prepared cavity.

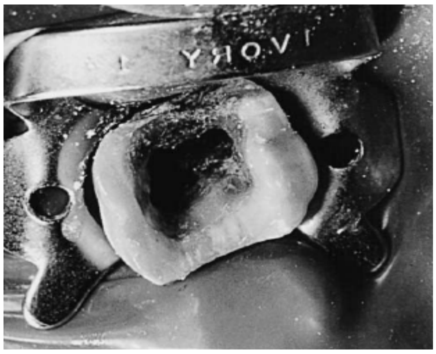


Fig (10): all carious dentin and defective restorations should be removed to allow placement of rubber dam sheet on sound tooth structure

IV Toilet of the cavity:

All of the caries, debris, and necrotic material must be removed from the pulp chamber before the radicular preparation is begun. If the calcified or metallic debris is left in the chamber and carried into the canal, it may obstruct the canal and increase bacterial population.

Pulp Space Morphology of Anterior Teeth

Maxillary Central Incisor:

Average Length: 23 mm.

Root Number and Form: One and Bulky

Canal Type: Type I

Labiolingual Section: Narrow near the incisal edge then widen as it approaches the cervical line and then narrow to the apex. The apical foramen frequently exits short of the apex to the labial. Lingual shoulder is present cervically.

Mesiodistal Section: Wide incisally with pulp horns and gradually taper to the apex.

Cross Sections: Cervical: nearly triangular in shape with apex lingually and base labially.
Mid root: oval Mesiodistally.
Apical: Round.

Outline Form: Triangular in the middle middle third of lingual surface.

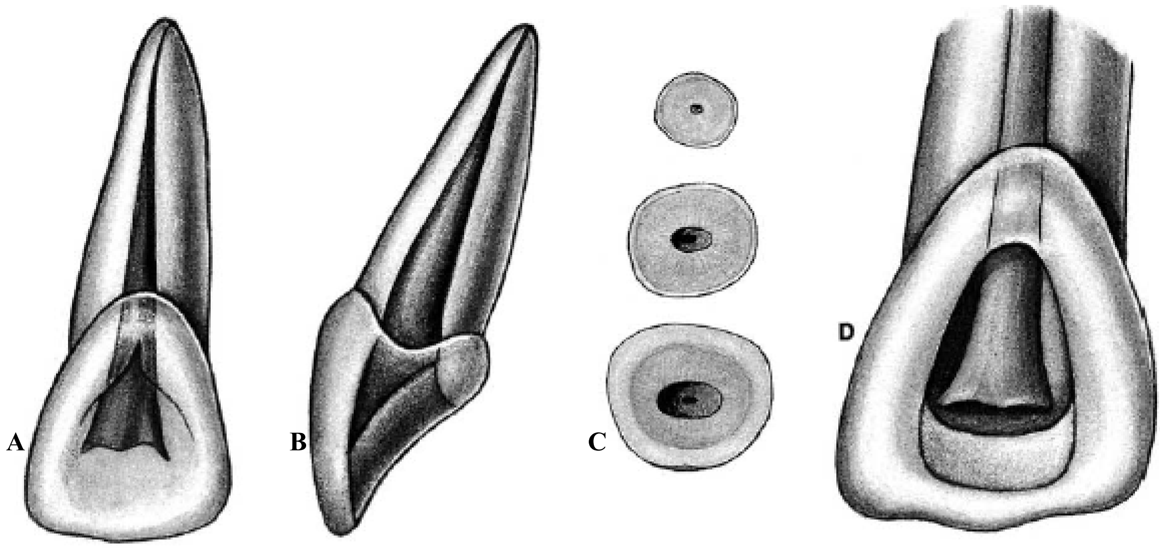


Fig (11): Maxillary Central Incisor; A: Mesiodistal section, B: labiolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Maxillary Lateral Incisor:

Average Length:	22.5 mm.
Root Number and Form:	one "slender" frequently with distal or lingual curvature or dilaceration
Canal Type:	Type I
Labiolingual Section:	Like maxillary central Incisor. Lingual shoulder is present at a point where chamber and canal join.
Mesiodistal Section:	Like maxillary central incisor.
Cross Sections:	Cervical: oval in labiolingual direction. Mid Root: ovoid Apical: round
Outline Form:	Triangular in the middle middle third of lingual surface.

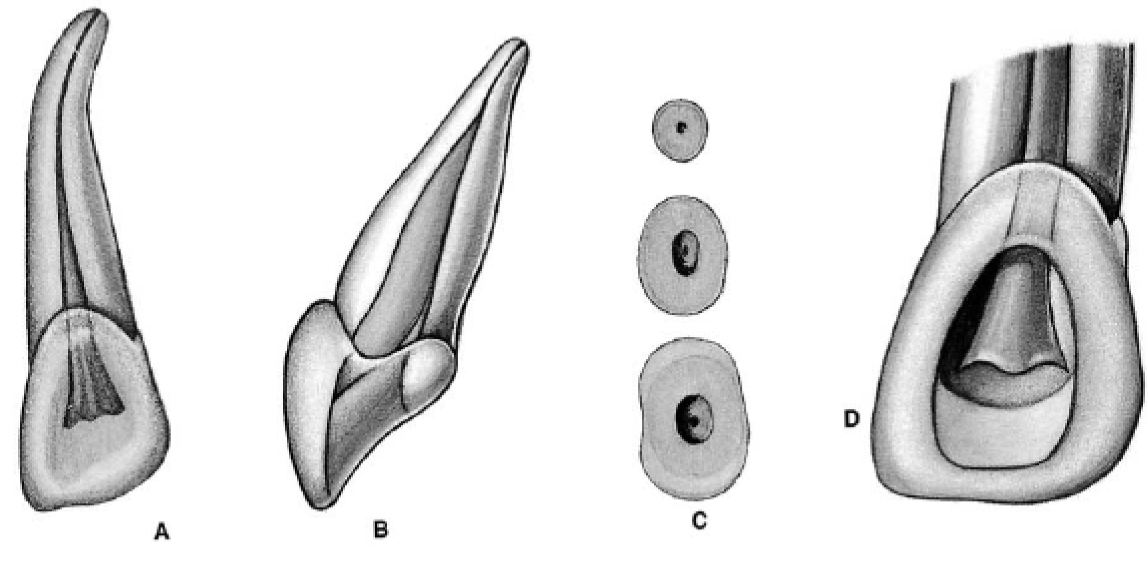


Fig (12): Maxillary Lateral Incisor; A: Mesiodistal section, B: labiolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Maxillary Canine:

Average Length:	26 mm.
Root Number and Form:	One, slender labially but bulky proximally. Distal apical curvature may be found.
Canal Type:	Type I
Labiolingual Section:	Begins as a point incisally and widens at the cervical and midroot regions then narrows in the apical one third to the apical foramen.
Mesiodistal Section:	Much narrow than in labiolingual section with nearly uniform taper to the apex.
Cross Sections:	Cervical: oval in labiolingual direction. Mid Root: oval Apical: Round
Outline Form:	Oval in the middle middle third of lingual surface.

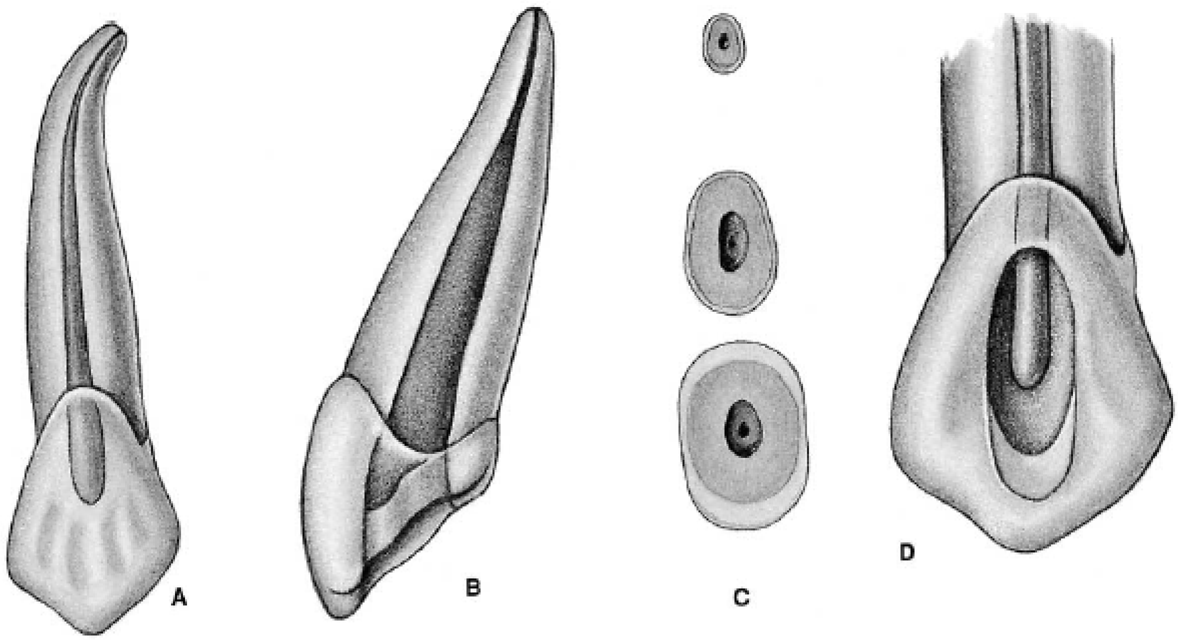


Fig (13): Maxillary Canine; A: Mesiodistal section, B: labiolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Mandibular Central and Lateral Incisors:

Average Length: 21 mm.

Root Number and Form: One narrow mesiodistally but relatively broad labiolingually. It has distal and/or lingual curvature. Sometimes, two roots have been reported.

Canal Type:
Type I. 60%.
Type II. 30%.
Type III. 10%.

Labiolingual Section: Wide broad canal can be found or two canals either join near the apex (type II) or remain separate (type III) lingual shoulder is present.

Mesiodistal Section: Quite narrow canal following curve of the root "distal and/or lingual".

Cross Sections:
Cervical: long oval in L.L direction and narrow in M.D direction.
Mid root: ribbon shaped due to flatness of the root.
Apical: round

Outline Form: Triangular in the middle middle third of lingual surface.

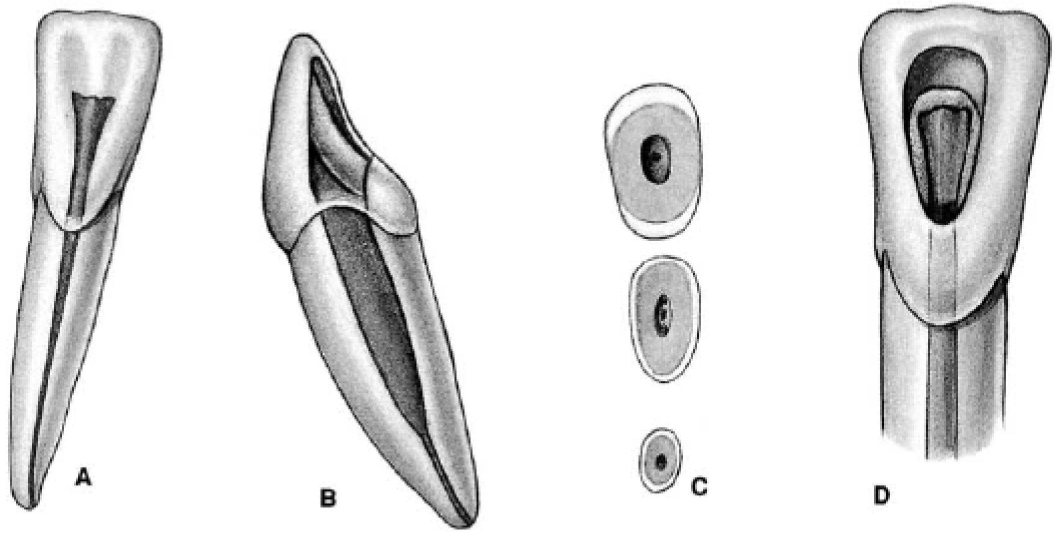


Fig (14): Mandibular Central and Lateral Incisor; A: Mesiodistal section, B: labiolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Mandibular Canine:

Average Length:	25 mm.
Root Number and Form:	One narrow mesiodistally but broad labiolingually. Rarely, two roots can be found, buccal and lingual.
Canal Type:	Type I. 94%. Type II or type III. 6%
Labiolingual Section:	Broad like mandibular Incisors.
Mesiodistal Section:	Much narrow than in labiolingual section with nearly uniform taper to the apex.
Cross Sections:	Cervical: oval in Labiolingual direction. Mid root: ovoid. Apical: round
Outline Form:	Oval in the middle middle third of lingual surface.

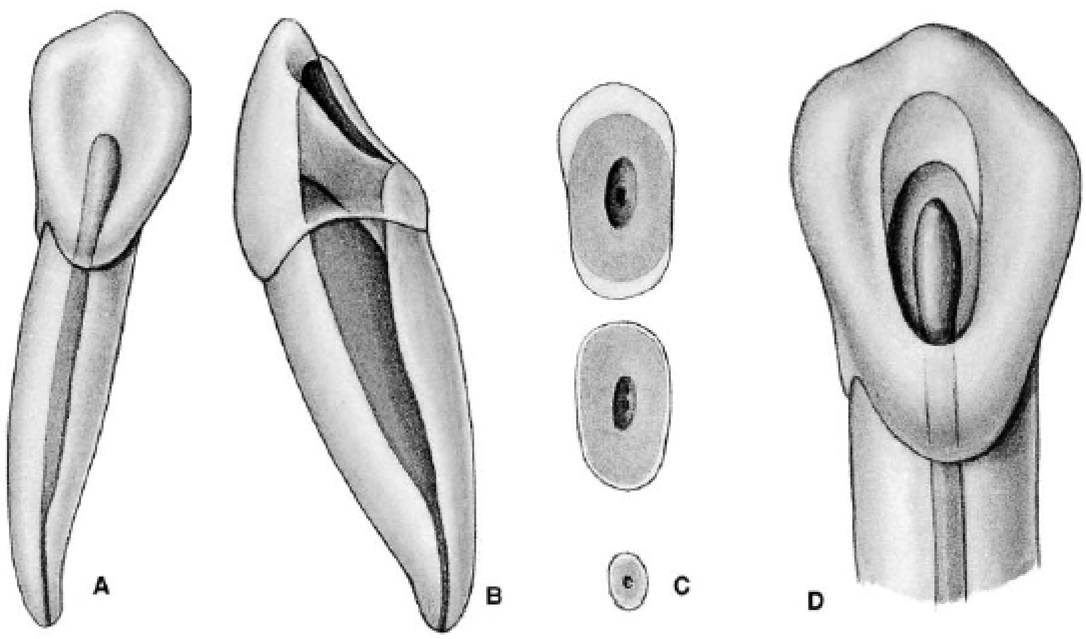


Fig (15): Mandibular Canine; A: Mesiodistal section, B: labiolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Endodontic coronal cavity preparation of maxillary and mandibular anterior teeth:

The access preparation is always on the lingual surface. For incisors the outline form is triangular in shape with the apex toward the cingulum and base toward the incisal edge. For canines the outline form is oval in shape in the B-L plane.

The lingual surface is divided into thirds and the initial penetration is made in the middle third. Penetration is done using a round carbide bur # 2 being directed parallel to the long axis of the tooth. Note that when the bur is parallel to the long axis of the tooth, it will be slightly lingually inclined relative to the labial surface of the crown. The operator should have the sensation of dropping into an open area. Now the roof of the pulp chamber is removed by cutting on the withdrawal with round bur #3.

Irrigate the pulp chamber with sodium hypochlorite 2.5% to remove surface debris and the outline form is probed for any binding. If the probe binds against any wall of the access preparation this area should be enlarged until probe can be freely placed into the canal. A lingual projection of dentin is always present at this stage, which should be removed using the round bur on withdrawal. This provides a smooth transition between the pulp chamber and the canal.

Final smoothness of the dentin walls is best achieved using the tapered fissure diamond stone.

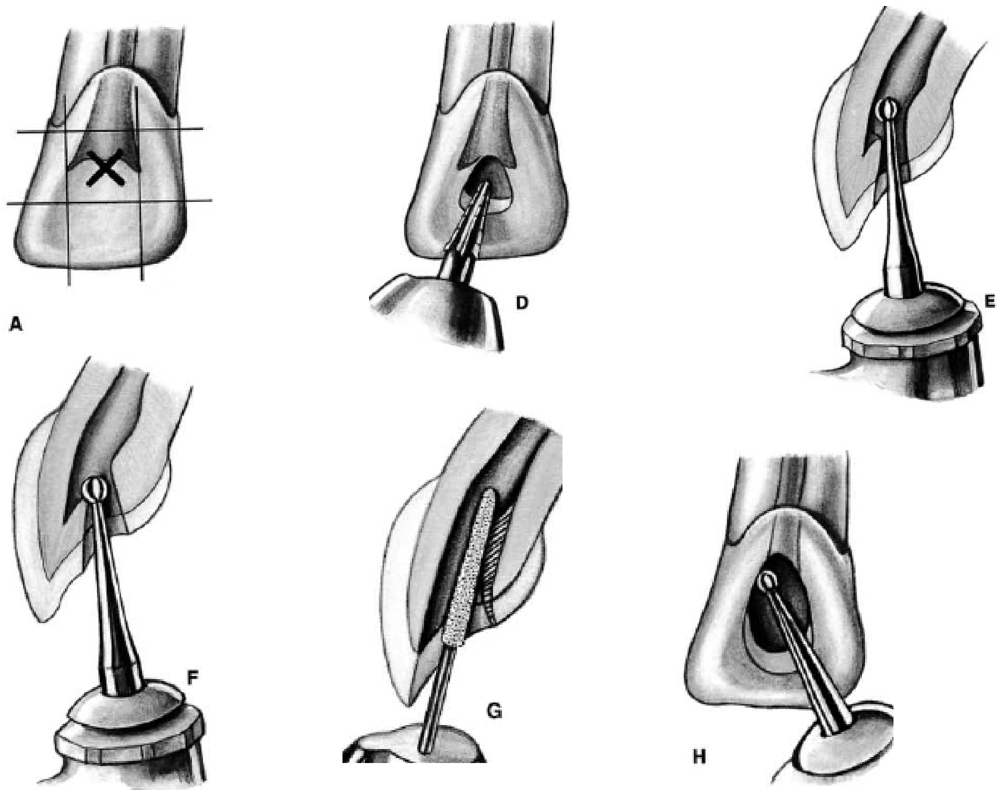


Fig (16): Steps of coronal cavity preparation

Errors during Endodontic Cavity Preparation:

1. Gouging the labial wall caused by failure to notice the lingual axial inclination of anterior teeth.
2. Gouging of the distal wall caused by failure to notice the mesial axial inclination of anterior teeth.
3. Labiocervical perforation caused by failure to complete convenience extension toward the incisal prior to the entrance of the shaft of the bur.
4. Discoloration of the crown caused by failure to remove pulp debris due to incisally under extended cavity.
5. Errors in intraradicular cavity preparation (e.g. ledge and perforation) caused by incomplete authority over enlarging instruments due to failure to complete the convenience extension.

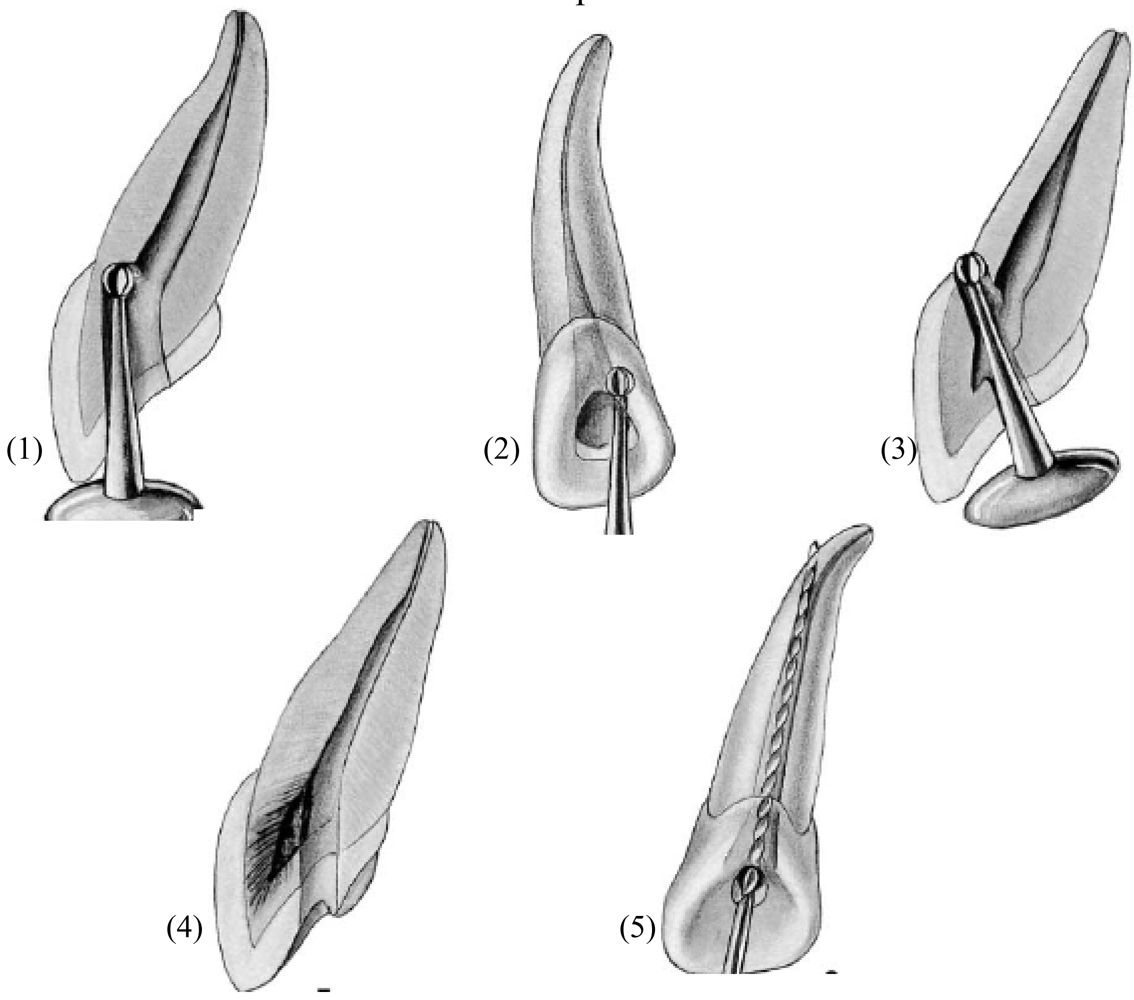


Fig (17): Errors during Endodontic coronal cavity preparation

Pulp Space Morphology of Premolars

Maxillary First Premolar:

Average Length: 21 mm.

Root Number and Form: Two roots in about 60% of the cases, buccal and palatal.
One root in 38% of the cases.
Three roots in less than 2% of cases. Two buccal and one palatal

Canal Type:

Two roots:	Each has type I	
One root:	Type III	70%.
	Type II	20%.
	Type I	10%.
Three roots:	Each has type I.	

Buccolingual Section: Wide, two pulp horns under each cusp. Buccal is more prominent in young teeth. Roof of pulp chamber is coronal to the cervical line. The floor is convex, with two orifices buccal and palatal. The floor lies deep in the coronal one third of the root below cervical line.

Mesiodistal Section: Narrow resembling upper canine.

Cross Sections: Cervical: ribbon shaped or figure "8".
Mid root: almost round "each canal".
Apical: round.

Outline Form: Oval buccolingual in the center of occlusal surface.

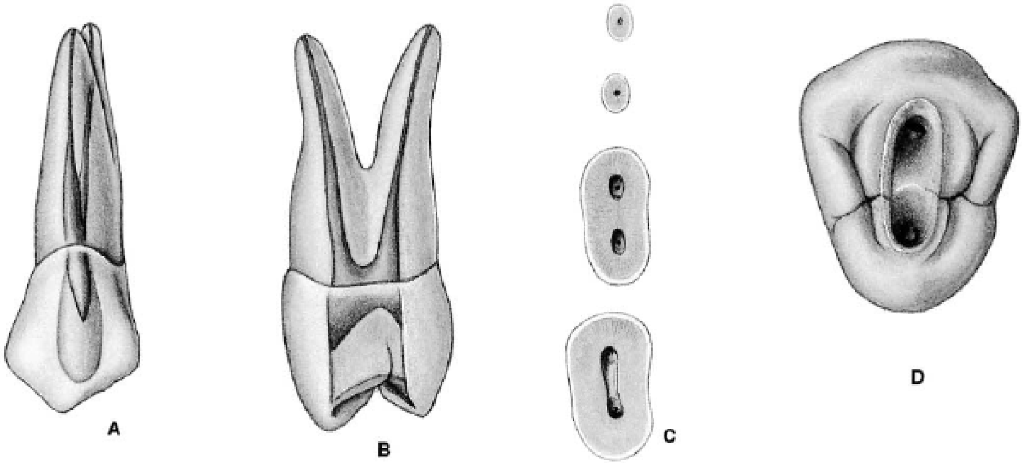


Fig (18): Maxillary First Premolar; A: Mesiodistal section, B: buccolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Maxillary Second Premolar:

Average Length: 21 mm.

Root Number and Form: one root in 85% of cases.
two roots in 15% of cases.

Canal Type: One root: Type I 70%.
Type II 20%.
Type III 10%.

Two roots: Each root type I

Buccolingual Section: It is similar to the maxillary first premolar except that the floor is deeper if two canals are present. Single canal is large and centered inside the root.

Mesiodistal Section: Narrow resembling maxillary first premolar.

Cross Sections: Cervical: one canal: oval.
Two canals: ribbon or figure 8
Mid root: one canal: ovoid
Two canals: round
Apical: round

Outline Form: Ovoid Buccolingual in the center of occlusal surface.

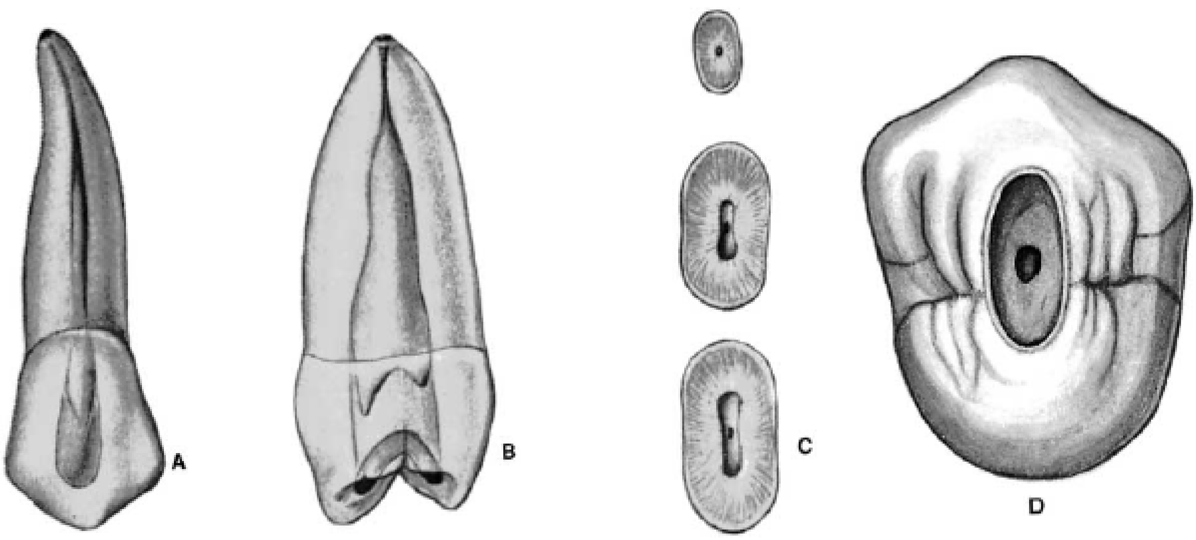


Fig (19): Maxillary Second Premolar; A: Mesiodistal section, B: buccolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Mandibular First Premolar:

Average Length: 22 mm.

Root Number and Form: One root. Relatively bulky crown in relation to the more slender root. Rarely, two roots can exist, Buccal and lingual.

Canal Type: Type I 85%.
Type II or III 15%
In case of two roots, one canal in every root is present (type I).

Buccolingual Section: Wide, with prominent buccal pulp horn. In young teeth, a small lingual pulp horn is present which may disappear by age giving the pulp the appearance of mandibular canine. The crown has a lingual inclination of 30° to the long axis of the root.

Mesiodistal Section: Narrow and simulate mandibular canine.

Cross Sections: Cervical: slightly oval
Midroot: ovoid
Apical: round

Outline Form: Ovoid Buccolingual. The access cavity is Located toward Buccal cusp.

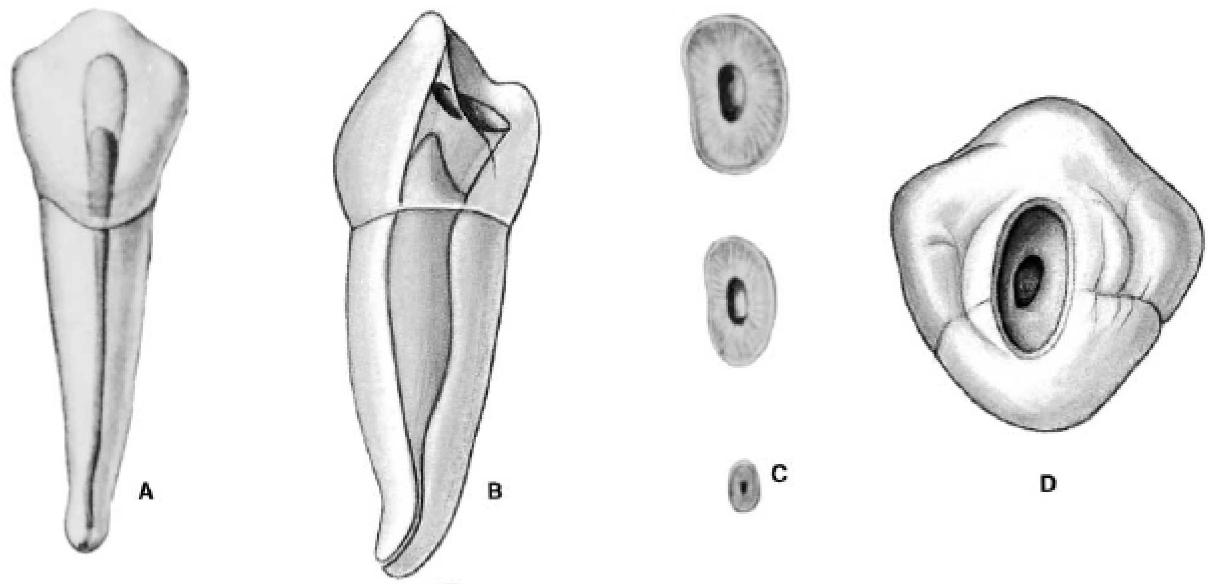


Fig (20): Mandibular First Premolar; A: Mesiodistal section, B: buccolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Mandibular Second Premolar:

Average Length:	21.5 mm.
Root Number and Form:	One root. Two roots can occur very rare (Buccal and lingual). Three roots can occur extremely rare (two buccal and one lingual)
Canal Type:	Type I. 85%. Type II, III. 15%. In case of more than one root, each has type I
Buccolingual Section:	Similar to the Mandibular first premolar except the Lingual pulp horn which is more prominent under well developed lingual cusp
Mesiodistal Section:	Similar to Mandibular first premolar.
Cross Sections:	Cervical: oval Mid root: ovoid Apical: round
Outline Form:	Ovoid Buccolingual in the center of the occlusal surface.

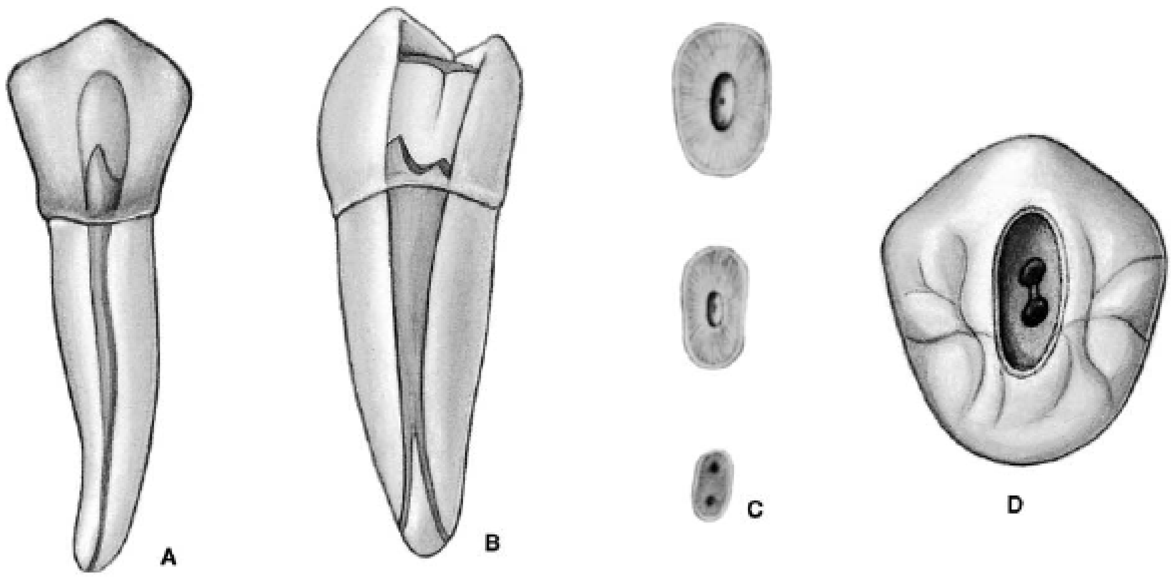


Fig (21): Mandibular Second Premolar; A: Mesiodistal section, B: buccolingual section, C: cross sections (cervical, mid-root, apical), D: outline form.

Endodontic coronal cavity preparation of maxillary and mandibular premolar teeth:

The access preparation is always on the occlusal surface. The outline form is ovoid with the largest dimension bucco-lingual. The access preparation is made using round bur # 2. The initial penetration is made in the center of the central groove with the bur being aligned parallel to the long axis of the tooth.

Reaching the pulp chamber, the operator will experience the sensation of dropping into an empty space. The roof of the pulp chamber is completely removed by the same bur on the withdrawal. The taper of the preparation is enhanced by using the tapered fissure diamond stone while keeping the M-D dimension narrow. This is necessary because premolars are narrow mesio-distally in the cervical area and can be easily perforated. The access preparation is irrigated and dried. The canal (s) are located using explorer and the access is to be modified so that the explorer can freely be introduced inside the orifice.

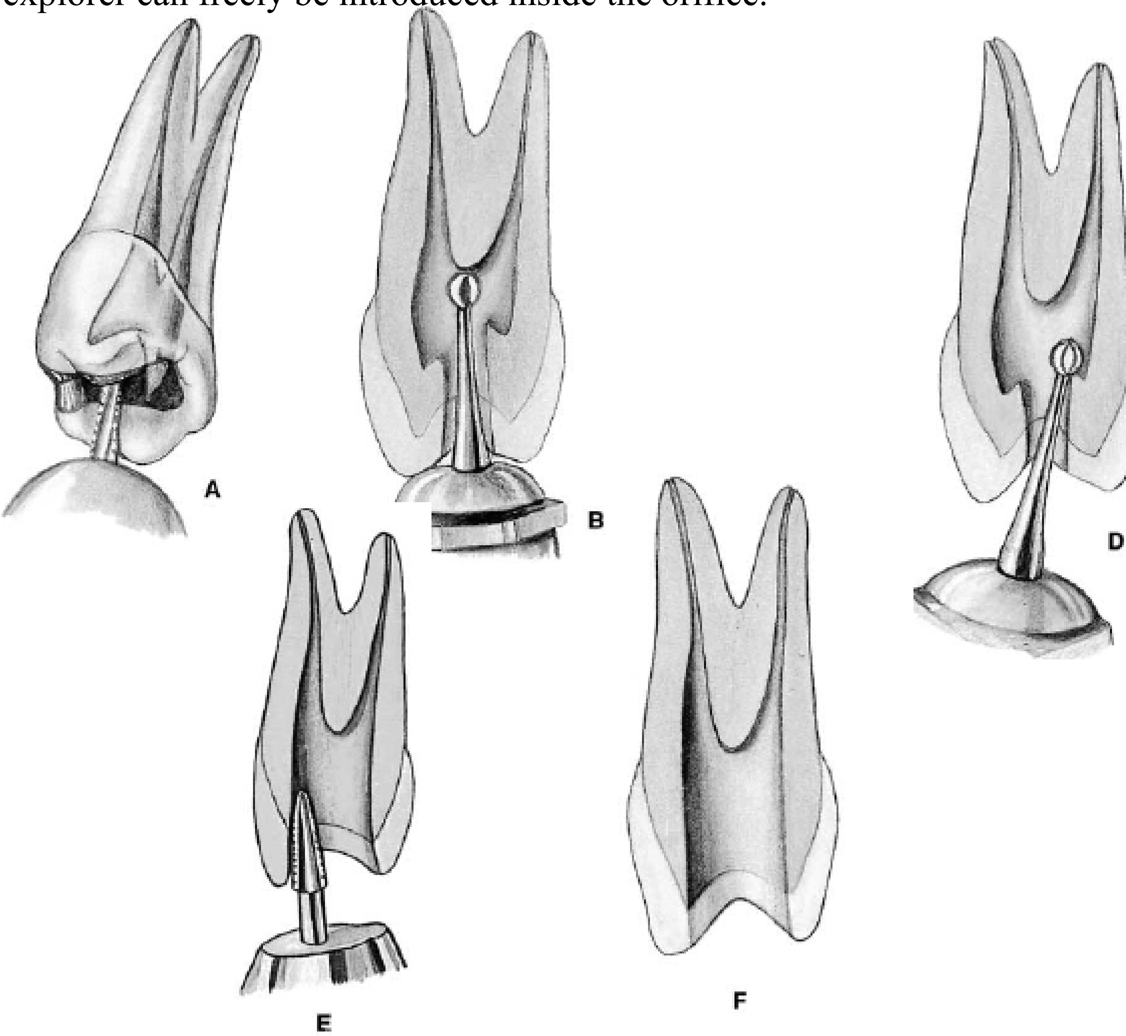


Fig (22): Steps of Endodontic coronal cavity preparation of maxillary and mandibular premolar teeth.

Errors During Endodontic Cavity Preparation:

1. Under extended preparation exposing only pulp horns due to lack of knowledge about position of the floor of pulp chamber in premolars. The lighter color of dentin is a clue to a shallow cavity.
2. Over extended preparation occurred during searching for root canal orifices. This is caused by failure to notice the recessed pulp in pre-operative radiograph.
3. Perforation at the mesiocervical area due to failure to recognize the distal axial inclination of the tooth.
4. Failure to explore, debride and obturate a second canal due to under extended cavity.

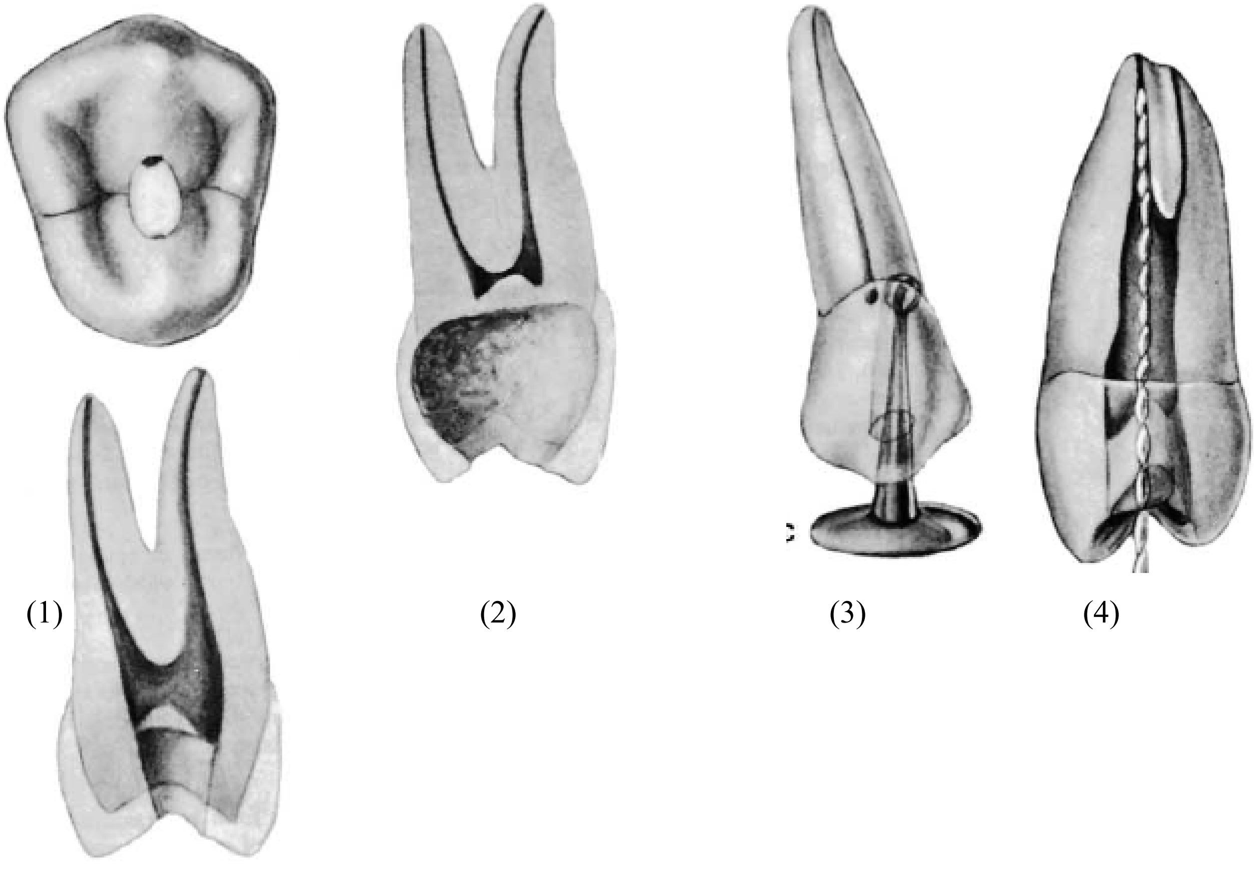


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Fig (23): Errors during Endodontic Coronal Cavity Preparation of Premolars

Pulp Space Morphology of Molars

Maxillary first molar:

Average Length: 20.5 mm

Root Number and Form: Three roots, two buccal and one palatal.
Mesiobuccal (MB): first curves to Mesial and nearly at the mid root region curves to distal.
Distobuccal (DB) curvature is less than MB and usually to mesial "cow horn appearance"
Palatal (P): most broad one. Diverge palataly but it might have a buccal curvature at the apex.

Canal Type: MB root: Type I 60%.
Type II 30%.
Type III 10%.
DB root: Type I "narrow"
P root: Type I "wide and broad" on rare occasions DB and P roots may have 2 root canals each.

Buccolingual Section: The floor of the pulp chamber is in the cervical one third of the root and the roof is in the cervical one third of the crown. Pulp horn extends under each cusp. Palatal canal is wider and may have a buccal curvature.

Mesiodistal Section: Buccal canals are thin and well centered in their respective roots but with both orifices on the mesial 3/5 of the crown.

Cross Section: Cervical: floor of pulp chamber appears quadrilateral with canal orifices at each corner.
MB is ribbon shaped or 2 separate canals.
DB is small and round.
P. is wide and oval in M-D direction.

Outline Form: Triangular outline form, with the base toward the buccal and the apex toward the palatal, reflects the anatomy of the pulp chamber, with the orifices positioned at each angle of the triangle. Both buccal and lingual walls slope buccally. Mesial and distal walls funnel slightly outward**.** The cavity is entirely within the mesial 2/3 of the tooth and should be extensive enough to allow positioning of instruments and filling materials needed to enlarge and fill canals. The orifice to the second mesiobuccal canal (MB2) may be found in the groove near the mesiobuccal canal (MB1).

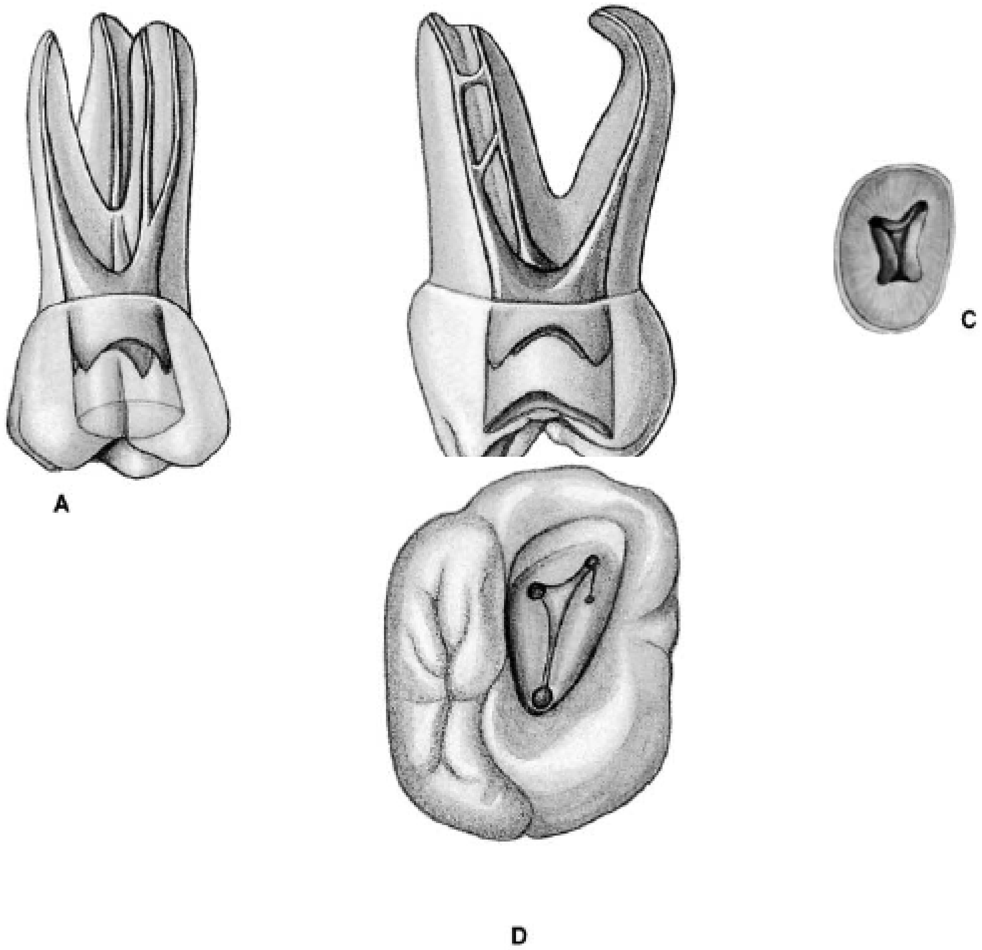


Fig (24): Maxillary First Molar; A: Mesiodistal section, B: Buccolingual section, C: Cross section (cervical), D: Outline form.

Maxillary second Molar:

Average Length:	20 mm
Root Number and Form:	Three roots, two buccal and one palatal (90%) Two roots, one buccal and one palatal (10%)
Canal type:	Three roots: same as maxillary first molar. Two roots: Each root has type I most freq. Buccal root may have type II or III infrequently.
Buccolingual Section:	Same as maxillary first molar.
Mesiodistal Section:	Same as maxillary first molar.
Cross Section:	Cervical: like maxillary first molar but in crowns compressed M.D, DB orifice may be located toward center.
Outline Form:	Triangular like maxillary first molar, but flattened due to the position of the DB canal (near center of cavity floor).

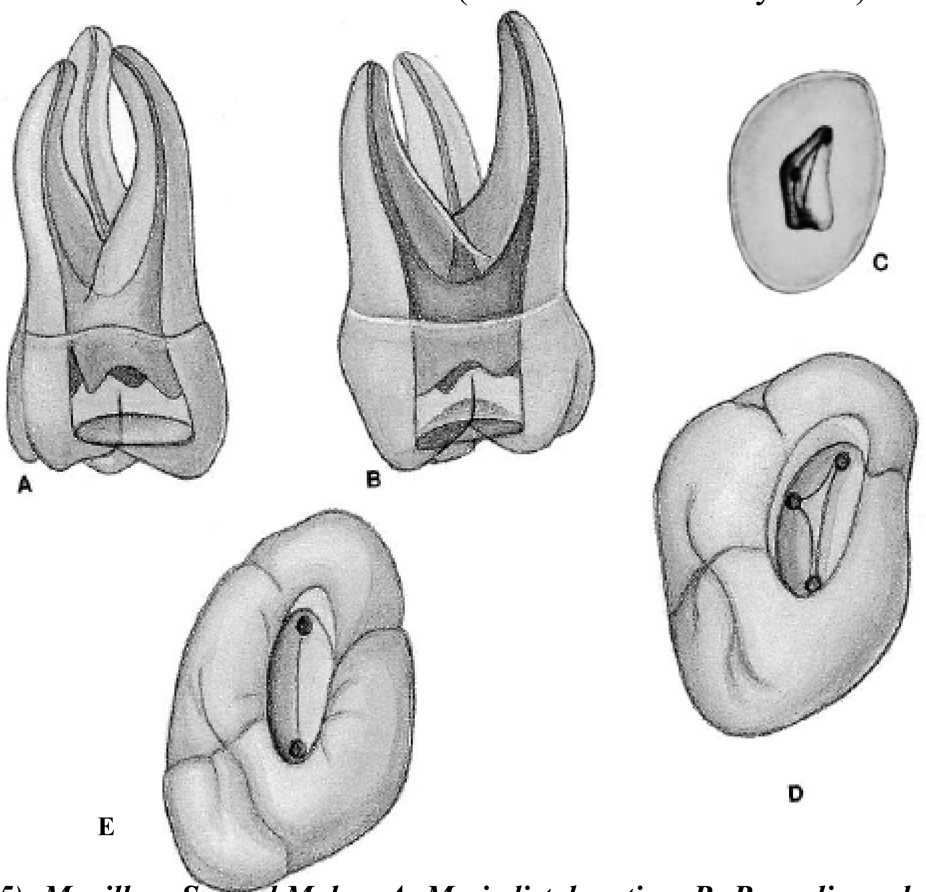


Fig (25): Maxillary Second Molar; A: Mesiodistal section, B: Buccolingual section, C: cross section (cervical), D: Outline form (three canals), E: Outline form (two canals).

Mandibular first molar:

Average Length: 21 mm

Root Number and Form: Two roots, one mesial and one distal.
Mesial root usually curves distally, broad B-L narrow M-D.
Distal root either straight or have mesial curvature. It is narrower than the mesial root B-L but wider M-D.

Canal Type:
Mesial root Type III (90%)
Type II (10%)
Distal root Type I (60%), large and kidney shaped canal.
Type II or III (40%)

Buccolingual Section: Pulp chamber is in the center of the crown. Distal canal is wide and ribbon shaped whereas the mesial canals are thin.

Mesiodistal Section: Orifices of both mesial and distal canals lie in the mesial 2/3 of the crown. The canals are will centered in their roots.

Cross Section: Cervical: trapezoidal with canal orifices at each corner. Distal canal is wide ribbon shaped or kidney shaped.

Outline Form: Triangular outline form reflects the anatomy of the pulp chamber. Both mesial and distal walls slope mesially. The cavity is primarily within the mesial 2/3 of the tooth but is extensive enough to allow positioning of instruments and filling materials. Further exploration should determine whether a fourth canal could be found in the distal.

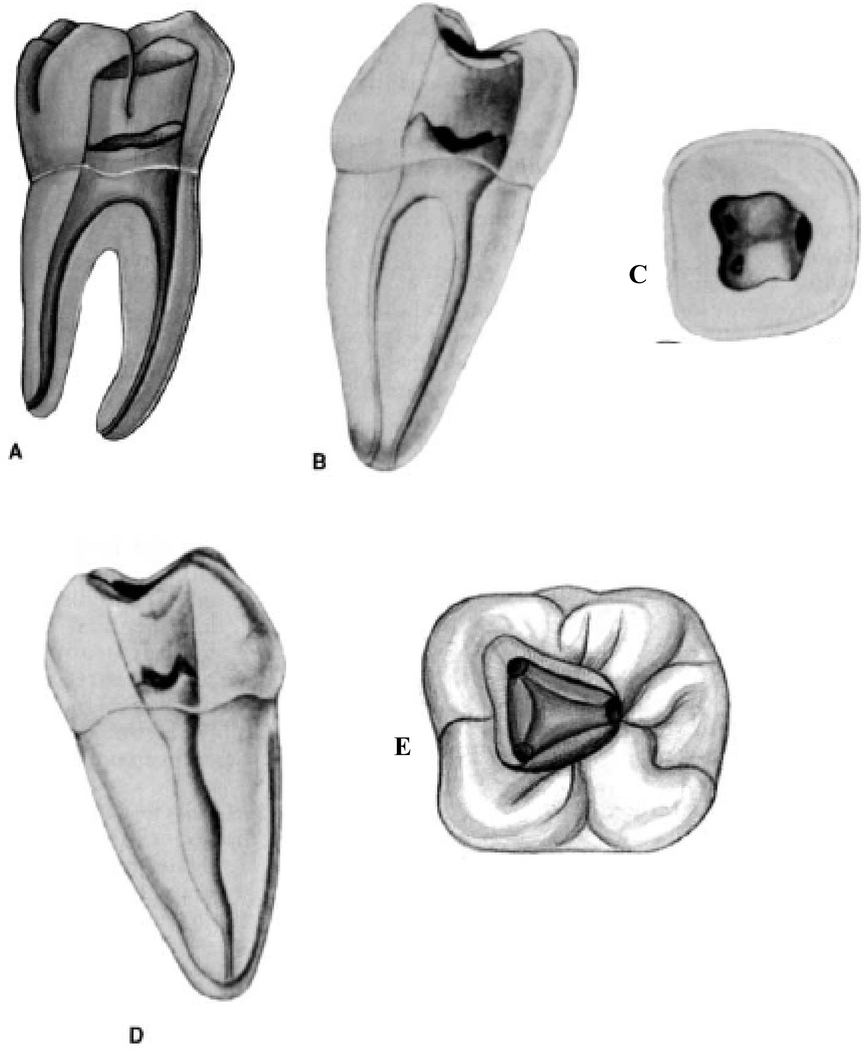


Fig (26): Mandibular First Molar; A: Mesiodistal section, B: Buccolingual section (Mesial view), C: cross sections (cervical), D: Buccolingual section (Distal view), E: outline form.

Mandibular Second Molar:

Average Length: 20 mm

Root Number and Form: It may have:
Two roots, mesial and distal.
Three roots two mesial and one distal.
One root.

Canal Type: Mesial root: Two canals type II or III most freq.
Type I least freq.
Distal root: almost always type I
One root: Two canals "mesial and distal"type III or II
One canal "large""rare" C-shaped

Buccolingual Section: Same as Mandibular first molar.

Mesiolingual Section: Same as Mandibular first molar.

Cross Sections: Same as Mandibular first molar.

Outline Form: Triangular like Mandibular first molar. However, mesial canals can be closer to each other. Sometimes having the same orifice.

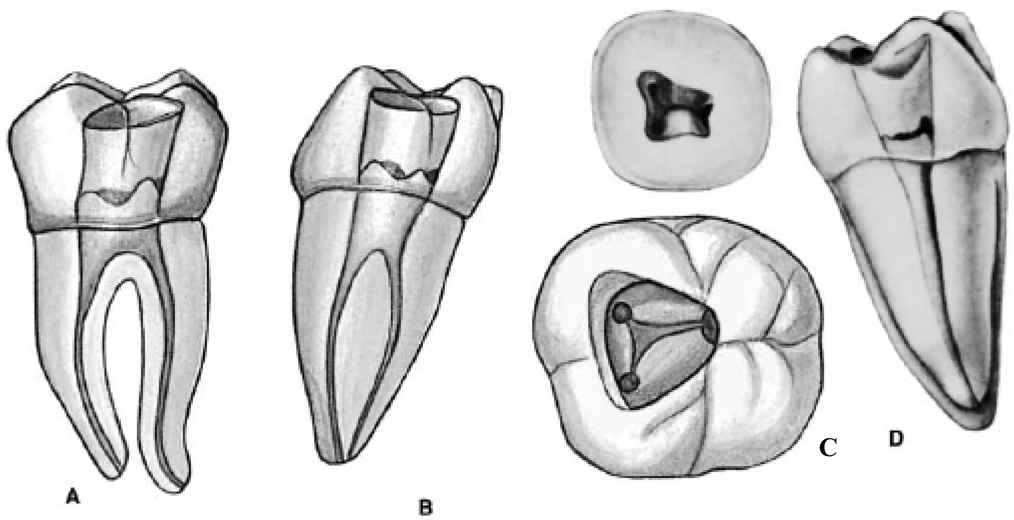


Fig (27): Mandibular Second Molar; A: Mesiodistal section, B: Buccolingual section (Mesial view), C: cross sections (cervical), D: Buccolingual section (Distal view), E: outline form.

Endodontic coronal cavity preparation of maxillary molar teeth:

The access preparation is always on the occlusal surface. The outline form is triangular in shape with the base toward the buccal surface and the apex toward the palatal. The entire preparation is located within the mesial half of the tooth without or slightly crossing the oblique ridge. The access preparation is made using round bur # 3. The initial penetration is made in the exact center of the mesial pit (midway between the mesial ridge and the oblique ridge). The bur is slightly directed toward the palatal where the greatest space in the pulp chamber exists. Once the pulp chamber is penetrated, the operator will have the sensation of dropping into an empty space. The roof of the pulp chamber is completely removed on withdrawal.

Irrigate the pulp chamber, dry it and start locating the orifices. The orifice of the MB canal should be present beneath the MB cusp tip. The DB canal orifice is located 2-3 mm to the distal and slightly palatal to the MB orifice. The orifice of the palatal canal is located beneath the MP cusp. The access preparation is to be enlarged where necessary so that the explorer can be freely inserted into each canal orifice. Planning, flaring and smoothening of the cavity walls should be achieved using tapered fissure bur.

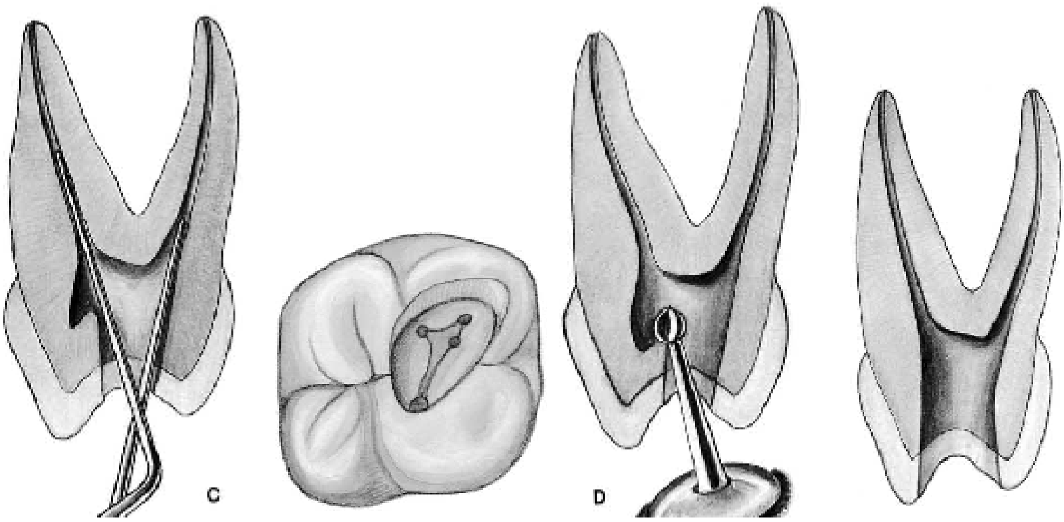


Fig (28): Steps of Endodontic coronal cavity preparation of mandibular molar teeth.

Endodontic coronal cavity preparation of mandibular molar teeth:

The access preparation is always on the occlusal surface. The outline form is triangular or rectangular in shape with the base toward the mesial surface and the apex toward the distal. The entire preparation is located within the mesial two-thirds of the tooth. The access preparation is made using round bur # 3. The initial penetration is made in the central pit. The bur is slightly directed toward the distal where the greatest space in the pulp chamber exists. Once the pulp chamber is penetrated, the operator will have the sensation of dropping into an empty space. The roof of the pulp chamber is completely removed on withdrawal.

Irrigate the pulp chamber, dry it and start to locate the orifices. The orifice of the MB canal should be present beneath the MB cusp tip. The ML canal orifice is located 2-3 mm to the lingual to the MB orifice. The orifice of the distal canal is located slightly distal to the central pit. The access preparation is to be enlarged where necessary so that the explorer can be freely inserted into each canal orifice. Planning, flaring and smoothening of the cavity walls should be achieved using tapered fissure bur.

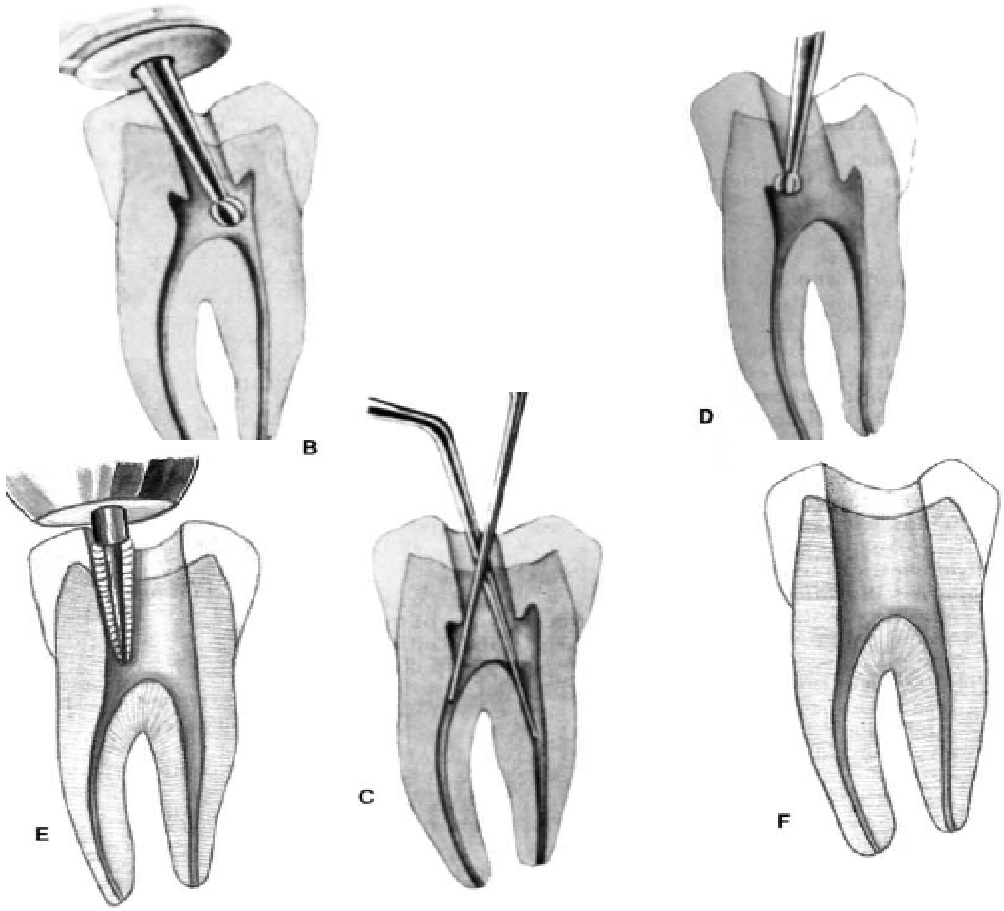


Fig (29): Steps of Endodontic coronal cavity preparation of mandibular molar teeth.

Errors during endodontic cavity preparation:

1. Under extended preparation. Only pulp horns have been exposed. The entire roof of pulp chamber remains. This is due to luck of knowledge of the position of the floor of pulp chamber. The lighter color of dentin is a clue to shallow cavity.
2. Overextended preparation and badly gauging the crown due to failure to observe pulp recession in pre-operative radiograph.
3. Perforation into the furcation area resulting from failure to notice that the narrow pulp chamber had been passed. A preventive measure is to mark length of bur needed to reach pulpal floor on preoperative radiograph.
4. Perforation at the mesial-cervical in lower molars caused by failure to orient the bur with the long axis of the molar severely tipped to mesial.
5. Failure to find all canals due to under extended endodontic cavity preparation leaving part of pulpal roof un-removed.

6. Disoriented occlusal outline form exposing only one canal. A faulty cavity has been prepared in full crown, which was placed to straighten up a lingually tipped molar.

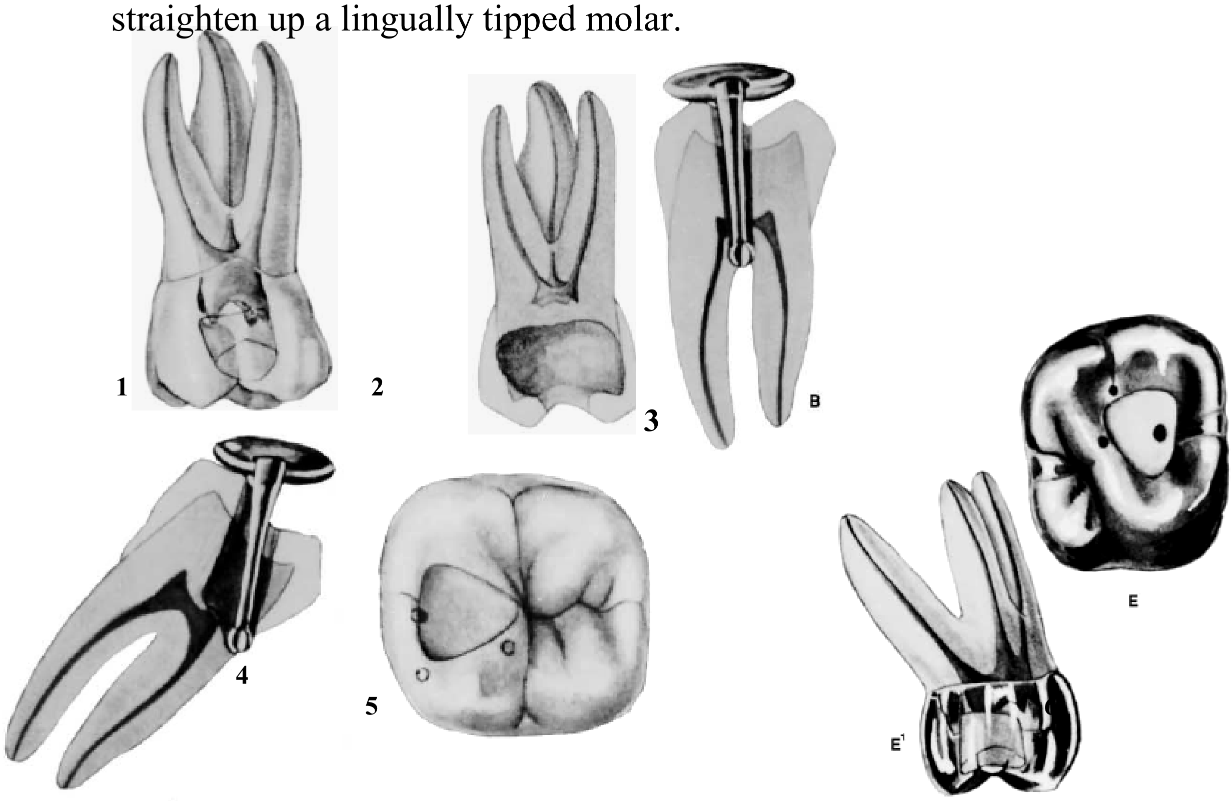


Fig (30 C Errors occurring during endodontic coronal cavity preparation of maxillary and mandibular molars.

Endodontic Instruments

The technical demands and level of precision required for successful performance of Endodontic procedures is achieved by careful manipulation of instruments and by strict adherence to biological and mechanical principles. Although the armamentarium of endodontics has grown in complexity over the past 30 years, yet, the basic instruments used today are not much different from those used at the turn of the century.

Classification of endodontic instruments

Different classifications for endodontic instruments have been proposed, however, the easiest would be to classify the instruments according to their sequence of usage during performing root canal procedure.

I- Diagnostic instruments

II- Extirpating instruments

III- Enlarging instruments

IV- Obturating instruments

V- Miscellaneous

I- Diagnostic instruments

In addition to basic examination instruments (mirror, explorer and twizer) a number of specialized devices are necessary for evaluating the status of the teeth and the surrounding tissues.

(1) Visual aids

Recently, magnifying elements have been incorporated in the endodontic practice to enhance vision in the operative site. These could be as simple as magnifying loops being attached to ordinary eye glasses giving a magnification of 2.5X. Surgical microscopes have recently been adopted in the dental operatories. They offer a wide range of magnification from 2.5-20X together with fiber optic illumination. Operator can work through the eyepiece or a monitor.

(2) Vitality testing

Clinical assessment of pulp vitality is considered an important aspect in reaching proper diagnosis. This can be achieved by stimulating the neural element or by measuring the vascular conductance.

Neural Tests:

This is the most popular method for measuring the pulp vitality through thermal or electrical stimulation of the peripheral nerve endings.

Thermal testing: This includes a group of testing agents either cold or hot.

Cold testing:

Ice -------------- 0^oC
Ethyl chloride -------------- -7^oC
CO_2 snow -------------- -78^oC

Hot testing :

Rubber wheel
Hot instrument
Gutta percha stopping

Electrical Testing: This includes a group of devices that deliver a very low electrical current to the enamel surface through the presence of an electrolyte.

These devices are called the ***Electric pulp tester (EPT).***

Vascular Tests

Although the thermal and the electric pulp testers are very popular and widely used, yet, it is the testing of the vascular element, which reflects the true vitality of any tissue rather than its neural supply. Recently, few devices were introduced in the market, which have the capability of measuring the pulpal blood flow. These include

- Laser doppler flowmetry
- Pulse oximetry

(3) Radiographs

Radiograph is an essential tool during all phases of root canal therapy (diagnosis, treatment and prognosis). Because root canal therapy relies on accurate radiographs and focuses on minimizing the amount of radiation the patient is subjected to, different radiographic devices were introduced in the specialty, which includes:

- Plain radiography
- Xeroradiography
- CT-Scan / MRI
- Radiovisiography (RVG)

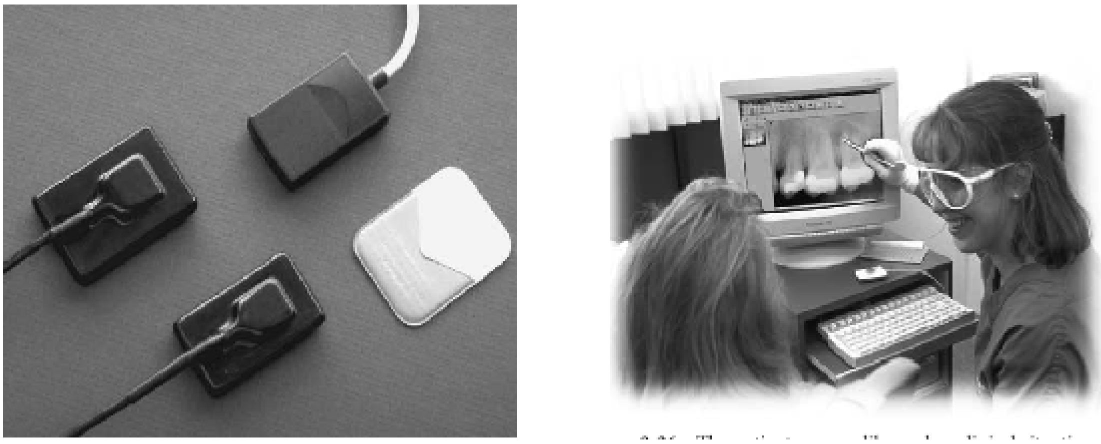


Fig 1: Radiovisiography sensor (left) and the soft ware.

II- Extirpating instruments

Barbed (nerve) Broaches

This instrument is manufactured from soft steel by placement of a series of extrusive incisions along the shaft (parallel to the shaft). These incisions are then elevated forming sharp projections. Barbed broaches are used for the removal of intact pulp tissue being slowly introduced into the canal, rotated full turn to entangle the pulp tissue then withdrawn. Because of its weak design (sharp projections), this instrument is limited for usage in large size canals to avoid fracture. In small sized canals any of the enlarging instruments (H-file) can be used for pulp extirpation.

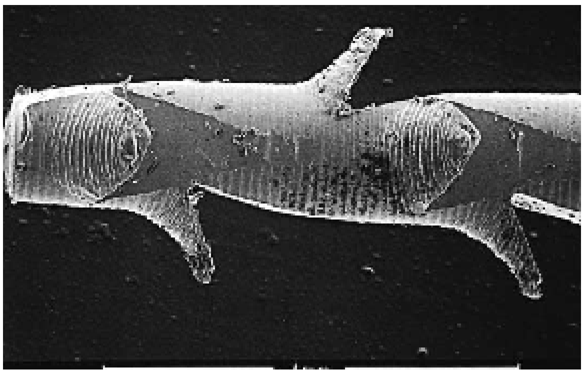


Fig 2: The barbed broach

III- Enlarging instruments

Cleaning and shaping of the pulpal space can be achieved by either Hand-driven instruments or a combination of Hand-driven and Engine-driven instruments.

(1) Hand-driven enlarging instruments

a- Basic enlarging instruments

These instruments were introduced by the beginning of the last century (1904) and are considered by far the most commonly used intracanal instruments. These include four basic instruments, which are:

(i) K-file

Fabrication of a K-file starts as a round St.St wire that is cut to form a tapered instrument ending by a pointed tip with square cross-section. This wire is then twisted in a counter clock wise direction to form spirals (flutes), which are 1.5 – 2.5 flute/mm. This instrument can be used in filing action (push - pull motion) or reaming action (insertion - clockwise rotation - withdrawal). When K-file is locked inside the root canal, the continuous clockwise rotation results in unwinding and ends by ductile type fracture. On the other hand, counter clockwise rotation leads to "Sudden" brittle type fracture.

(ii) K-reamer

Similar to K-file, the K-reamer starts as a round St.St wire cut to form a tapered instrument ending by a pointed tip with triangular cross section. This wire is then twisted in counter clock wise direction to form flutes, which are not as tight as the K-file. The number of flutes on the shaft of the reamer are 0.5 – 1 flute/mm. Reamers can be used in reaming action only.

	K- File	**K - Reamer**
Cross - section	Square	Triangle
Flute number	1.5-2.5/mm	0.5-1/mm
Cutting angle	90^{o}	60^{o}
Clearance Space	Less	More
Flexibility	Less	More

N.B: Although the square cross-section of the K-file have a cutting angle of 90^o which is considered to be less efficient than the cutting angle of K-reamer (60^o), yet, this is compensated by the greater number of flutes the K-file have.

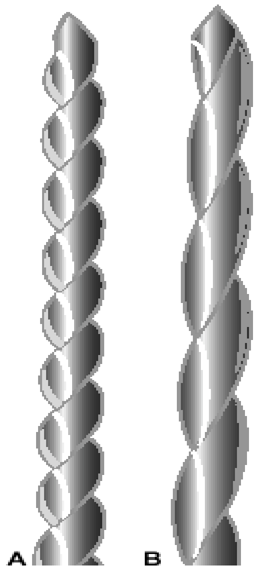


Fig 3: (A) K-file, (B) K-reamer

<u>(iii) H-file (Hedstrom file)</u>

This file is constructed from round St. St. wire by machine grinding forming a series of intersecting cones. This design produces sharp edges at the base of each cone, which cuts tooth structure on pulling only. The cross-section of this instrument shows that it is coma shaped (tear drop) with one cutting edge.

At the junction between each two cones, the shaft of the instrument is weak facilitating its breakage if used in any form of rotation (reaming action). Therefore, H-files are to be used in filing action only.

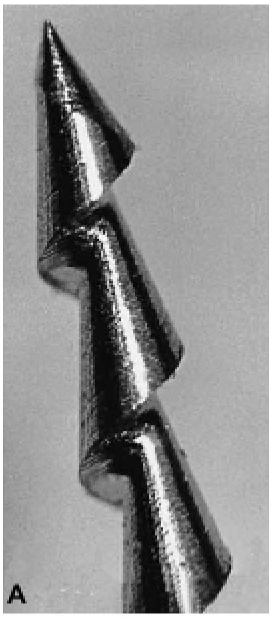


Fig 4: H-file

(iv) R-file (Rat-tail file)

This instrument is very similar to the barbed broach having metal projections perpendicular to the instrument shaft with an eight pointed polyhydron cross section. R-file is easily fractured inside the root canal and therefore, is not very commonly seen on the market nowadays

Standardization of endodontic basic instruments

Before 1958, endodontic enlarging instruments were manufactured without any established criteria where an instrument of one company rarely coincided with a comparable instrument of another company. The standardization included the following items:

Standardization of size:

The sizing system goes as follows:
6,8,10----15,20,25,30,35,40,45,50,55,60----
70,80,90,100,110,120,130,140.

This sizing system is not arbitrary but is based on the diameter of the instrument in hundredths of a millimeter at the tip of the instrument

(Do). As an example, an instrument size 60 means that the diameter of the instrument at Do = 60/100 = 0.6 mm.

Standardization of length

The first standard in length is the full extent of the shaft up to the instrument handle and this comes in three lengths: 25 mm (standard), 31 mm (long) and 21 mm (short).

The second standard in length is the length of the instrument blade (working or cutting area). This length is standard to be 16mm starting at Do and ending at D16.

Standardization of taper

The file diameter increases at a standard rate of 0.02mm/mm starting at Do ending at D16. This means that the difference in diameter between Do and D16 regardless the instrument size is always 0.32mm (0.02x16=0.32).

Standardization of tip angle

The angle formed between the instrument tip and the long axis of the instrument shaft is standardized to be $75^o + 15^o$.

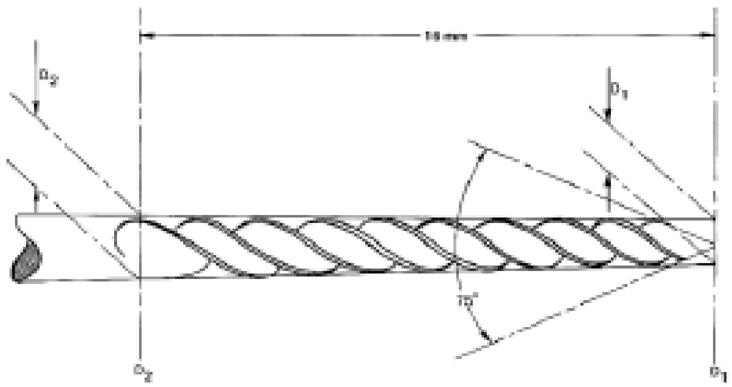


Fig 5: Standardization of basic enlarging instruments.

b- Hybrid enlarging instruments

To debride the root canal space, the enlarging instrument must contact and plane all the walls. Despite the simplicity of that concept there is no instrument that can efficiently clean and shape the entire root canal space while retaining the preoperative shape of the canal. This difficulty is due to the complex pulpal anatomy. Continuous development and improvement in
instrument design and physical properties is aiming to fulfill this goal.
Modifications include:

- **A- Modification in instrument design.**
- **B- Modification in method of manufacturing.**
- **C- Modification in instrument material.**

A- Modification in instrument design:

(i) Modification in instrument cross-section:

Flex-R-file:

The square cross-section of K-file was modified to triangle cross-section **(Flex-R-file)**. This modification led to the following advantages:
- Increase in cutting ability.
- Increase of carrier effect (hold more debris).
- Increase in flexibility (less metal mass).

K-flex file:

Again, the square cross-section of the K-file was changed to rhomboid cross-section **(K-flex file).** The cutting edge of the K-flex file is formed of two acute angles (high flutes), which present increased sharpness while the two obtuse angles (low flutes) provide more space for debris removal. In addition, this change in design increased instrument flexibility.

S-file / Uni-file:

The modification in the single blade of the H-file (tear drop) by adding second blade (S-file & Uni-file) or by adding third blade (Helifile) did significantly increase the cutting ability of the tool.

U-file:

The U-file first appeared in 1988 and its design have been being adopted in most of the recent rotary enlarging instruments (Profile system, Light speed system, and the profile GT system). The U design has two 90^o cutting edges at each of the three points of the blade. The flat cutting surfaces act as a planning instrument and are referred to as "Radial Lands". The radial lands allows the instrument to be used in 360^o motion (rotary).

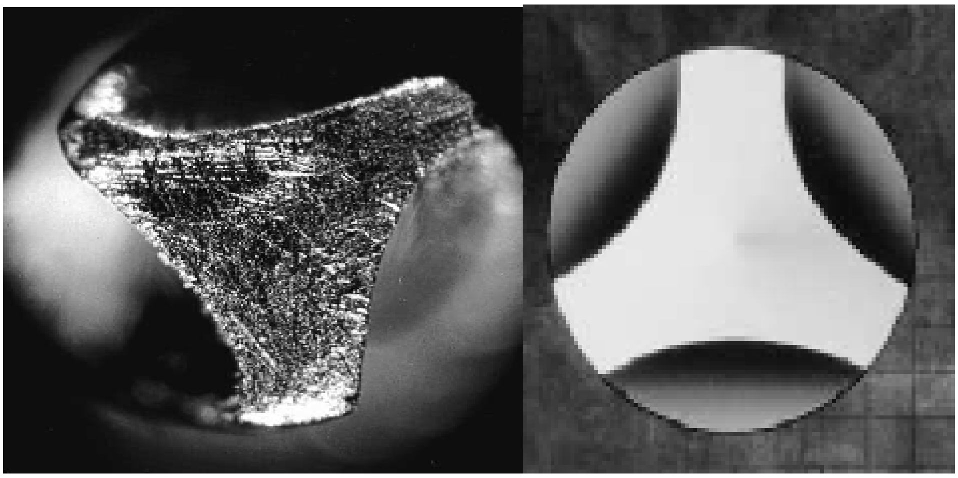


Fig 6: Cross-sectional view of the U-file.

(ii) Modification of depth and angle of blades:

To overcome the inherent weakness of H-file present at the junction of different intersecting cone, a decrease in the depth of the blades introduced by the Uni-file and the S-file significantly decreased the tendency of these tools to break inside the root canal.

(iii) Modification in length of cutting blade:

Canal Master file:

The canal master was introduced in 1989 by Senia and Wiley where the cutting segment of the instrument was reduced from 16mm to 1-3mm. They claimed that this modification should reduce the chance of canal transportation and ledging during enlargement of the curved canals.

Profile Great taper system (GT):

This is a rotary enlarging tool having a cutting blade of 6-8 mm instead of 16mm.

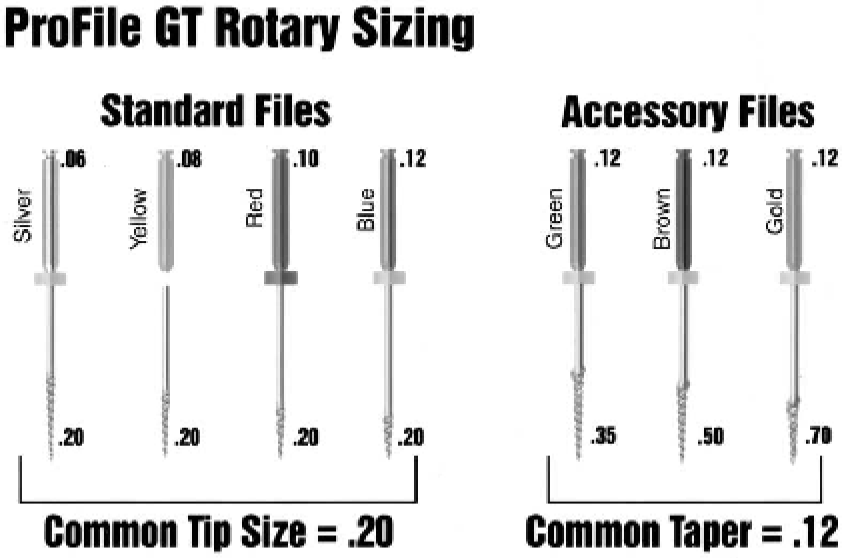


Fig 7: The profile GT system showing limited cutting blade.

Light speed system:

Again, the light speed system is a rotary enlarging tool that exhibits a reduction in the length of the cutting blade starting from 0.25 mm for smaller sizes up to 1.75 mm for larger sizes.

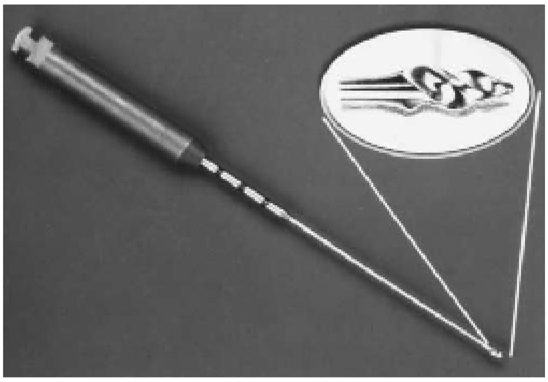


Fig 8: The light speed cutting tool.

(iv) Modification in taper

Instruments with increased taper recently appeared on the market where the standard taper of 0.02mm was replaced by either 0.04, 0.06 or 0.08 mm taper. It is important here to mention that instruments with increased taper are all fabricated from NiTi.

(v) Modification in tip design:

Again the Flex-R-file was the first file introduced in the market in which the angle of the instrument tip being flattened i.e. non-cutting tip. Nowadays all newly produced instruments have a non-cutting tip which was shown to decrease the chances for canal transportation and ledging during enlarging curved canals.

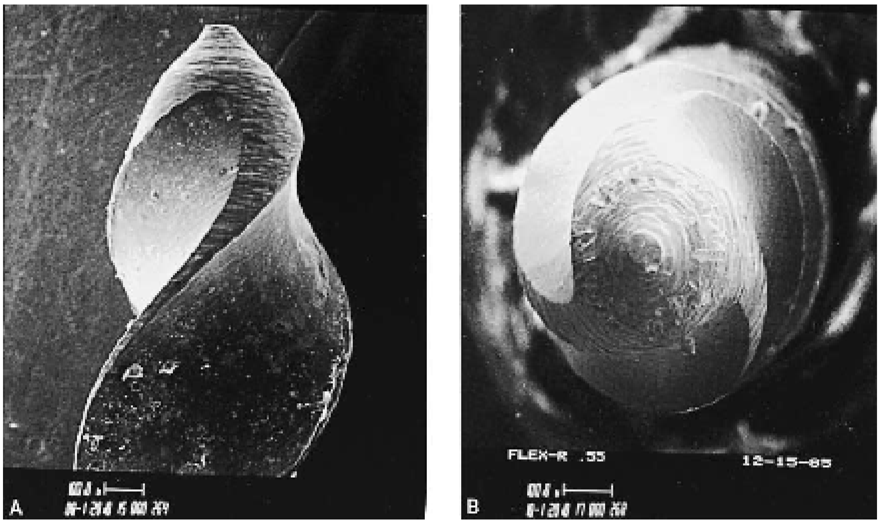


Fig 9: Front (A) and top view (B) of an instrument with non-cutting tip.

(vi) Modification in numbering system

Golden mediums:

These are instrument sets with intermediate sizes (12.5, 17.5, 22.5, 27.5, 32.5, …..). These sizes were suggested to decrease the big transition in diameter between small size instruments.

Profile Series 29:

In 1992, Schilder introduced a new numbering system known as the Profile series 29. This new system presents instrument sizes that progress by a constant percentage increase (29%) from one instrument size to the next. Profiles comes in sizes 00,0,1-----------11. This system offers two advantages; First, it provides constant increase in instrument diameter

(29%) and second, it provides fewer number of instruments compared to the ISO system.

B- Modification in method of manufacturing

The Flex-R-file (modified K-file) was the first St. St.file to appear on the market with a new concept in the method of fabrication. Instead of instrument twisting, the flutes were created by grinding or milling to decrease the internal stresses induced inside the instrument during the twisting process. Grinding is totally necessary for instruments made of Nickel-Titanium because their super elasticity prevents their twisting.

C- Modification in instrument Material:

When basic instruments first appeared they were fabricated from carbon steel, however, due to decreased flexibility and low corrosion resistance of carbon steel, instruments were fabricated from stainless steel. The only intra canal instrument that is still manufactured from carbon steel is the path finder which is used to negotiate calcified narrow canals.

Inspite of the reasonable flexibility of St. St., it was not very satisfactory in preparation of curved canals. This led to the appearance of super elastic instruments fabricated from Nickel-Titanium (NiTi). NiTi instruments do offer better flexibility however, its cutting ability could be questionable.

Nickel Titanium (NiTi):

NiTi alloy was first introduced in 1960 for orthodontic wires. In 1988, Walia and associates introduced NiTi to be used in fabrication of endodontic files.

	NiTi	**St.St.**
Super elasticity	Very high	Lower than NiTi
Resistance to fracture (Torque strength)	Lower than St.St.	High
Wear resistance	Higher than St. St.	Low
Cutting ability	60% that of St.St.	Higher

(2) Engine-driven enlarging instruments

The popularity of using engine driven instruments for preparing and enlarging root canals is increasing aiming to increase speed and efficiency. Engine driven enlarging instruments can be classified according to the type of motion employed into :

A- Devices utilizing vibratory motion (sonics and ultrasonics)

B- Devices utilizing rotary motion (low speed contra-angle)

A- Vibratory instruments

These instruments depends on the vibratory action of enlarging tool inside the canal. Generally, two categories of devices have been developed based on the frequency of vibration.

	Sonics	**Ultrasonics**
Frequency	Less than 20KHz	20- 50 KHz
Power	Compressed air	Electric current
Irrigant	Water	NaOcl
Cutting tool	Rispi and Shaper files	K-files and D-files
Brands	Endosonic 3000	Cavi Endo

The main debriding action of Sonics/ultrasonics was initially thought to be by "Cavitation", a process by which bubbles formed from the action of the file become unstable and collapse causing vacum-like action. Nowadays, it is believed that a different physical phenomenon occurs called "Acoustic Streaming" which is responsible for the debridment.

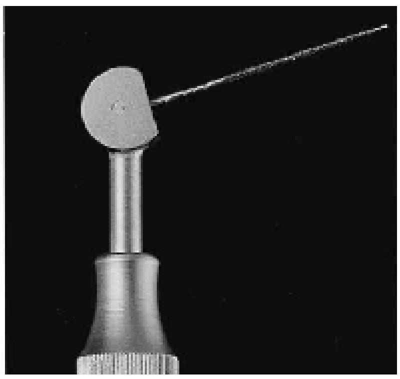


Fig 10: An ultra sonic unit (left) and the ultrasonic tip (right)

B- Rotary instruments:

These are formed of two parts, a part which supplies the motion and in this group it is a rotary motion supplied by three types of low speed contra-angles. These three hand pieces are: a full rotary hand piece, a reciprocating quarter turn hand piece and a reciprocating hand piece with vertical stroke. The second part is the enlarging tool which differs according to the type of contra-angle used. Different systems are present on the market among which:

Type of contra-angle	Enlarging tool	Usage
Ordinary low speed contra-angle (360^o)	Gates Glidden drill and Pesso drill	Coronal 2/3 of the canal
Giromatic (Quarter turn 90^o)	St. St. files with latch	Full length prep
Canal Finder (Quarter turn+vertical stroke)	St. St. files with latch	Full length prep

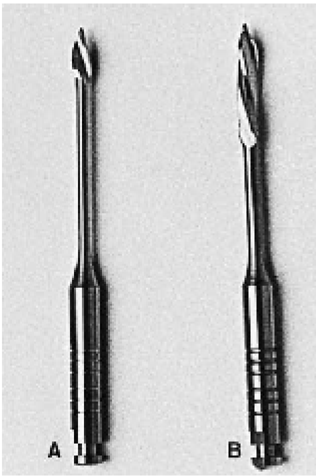


Fig 11: Gates Glidden drill (A) and the pesso drill (B)

Attempts to use conventional St. St. files with rotary hand pieces for root canal enlargement was not so successful over the years due to the decreased flexibility of st. st. which caused instrument breakage and changes in root canal configuration (ledging and perforation). However, the introduction of NiTi metal as a substitute for St.St. in manufacturing of endodontic enlarging instruments led to the development of new rotary enlarging instruments. These new systems include:

1- Profile and Profile GT systems.
2- Light speed system.
3- Quantec system.
4- Pow-R system.
5- Protaper system
6- Hero 642 system.

All these systems have the same basic features with some differences. They all share the following:

Hand pieces:
- Reduced Gear (300-1200 rpm)
- High Torque

Enlarging tool:
- Nickel Titanium
- Increased taper

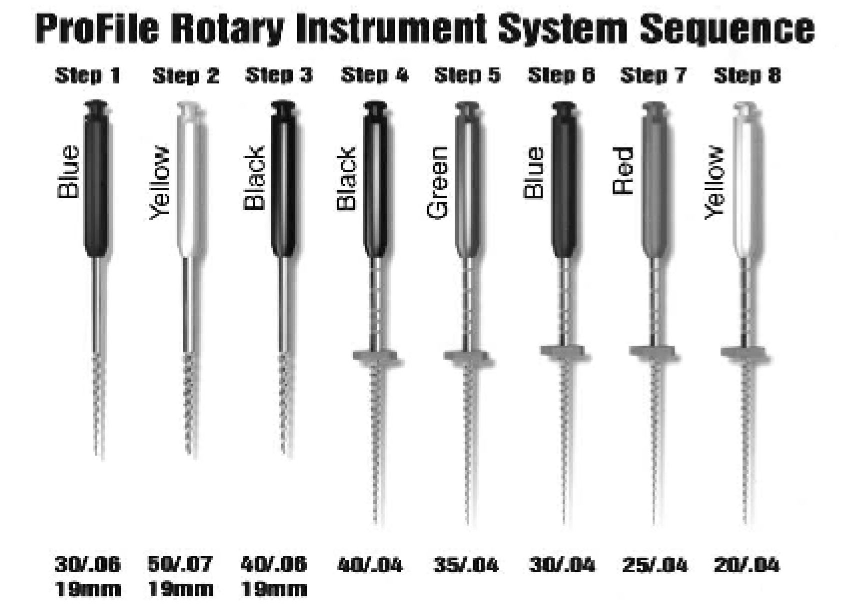


Fig 12: The profile system.

IV- Obturating instruments

Obturation of the root canal system involves the introduction of a biologically compatible filling material inside the root canal. This material should provide three dimensional sealing of the root canal space thus preventing the egress of microorganisms or toxic products into the vital periapical tissues.

Gutta percha, considered to be the most popular filling material for decades have been the focus of development over years. Recent developments have been directed toward the introduction of delivery systems and devices for the placement of thermoplasticized gutta percha inside the root canal forming a homogenous mass which seals the space three dimensionally. This is highly desirable so as to accurately conform to the anatomic irregularities and complexities of the root canal system. To summarize, gutta percha can be introduced inside the canal either in a non softened state or in a softened state.

1- Non-softened techniques:

Spreaders and Pluggers:

Endodontic spreaders and pluggers are smooth tapered metal instruments used to compress and compact gutta percha within the root canal space. Pluggers have blunted or flat ended tips whereas, spreaders are more tapered with pointed tips. Both spreaders and pluggers are supplied in either of two forms: Finger spreaders/pluggers (finger held instruments similar in design to files but with smooth non-cutting shaft) or Hand spreaders/pluggers (Palm held instruments).

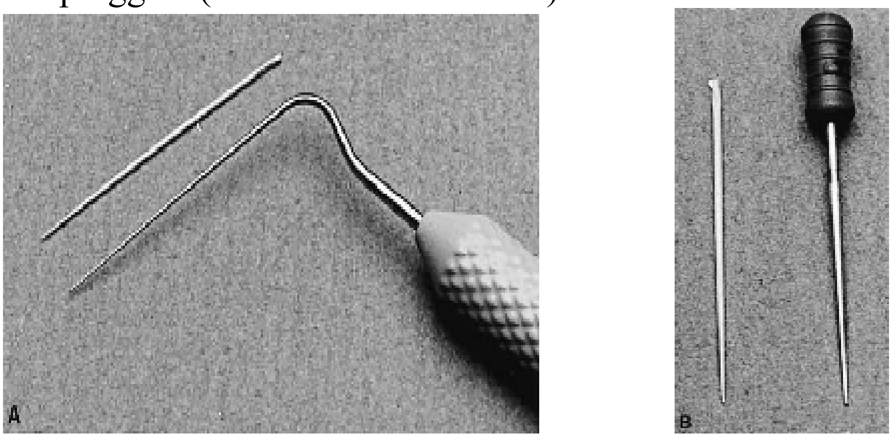


Fig 13: Hand spreader (A) and finger spreader (B)

Lentulo Spiral:

This is a St. St. wire twisted into a spiral used to carry root canal sealer into the root canal.

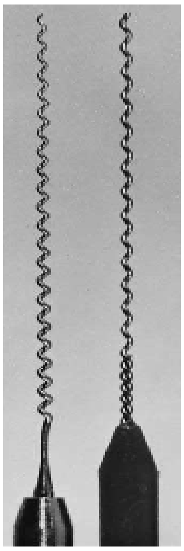


Fig 14: The lentulo spiral

2- Softened techniques:

These are instruments or devices introduced to soften gutta percha either directly inside the canal or soften the gutta percha outside the patient's mouth then carry it inside the canal. These include the following:

Thermal applicators:

Two electric devices are available for softening the gutta percha inside the canal during condensation. These devices are similar to hand spreaders or pluggers, however, their tips becomes warm when the unit becomes activated.

- ***Touch'N'Heat***
- ***System B***

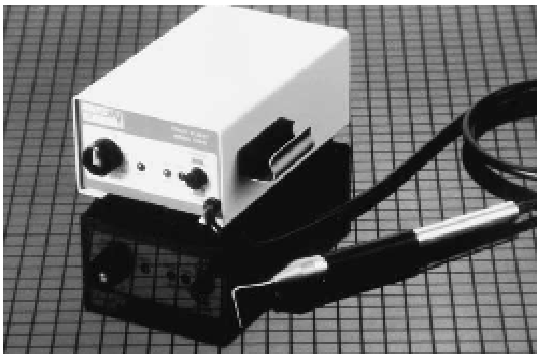


Fig 15: The touch N' heat unit

Thermomechanical compactors:

This system consists of a low speed contra-angle attached to it a compactor which resembles a H-file. The compactor is introduced inside the root canal with the gutta percha master cone in place. The friction produced warms and plasticizes the gutta percha while the instrument flutes force the material apically and laterally.

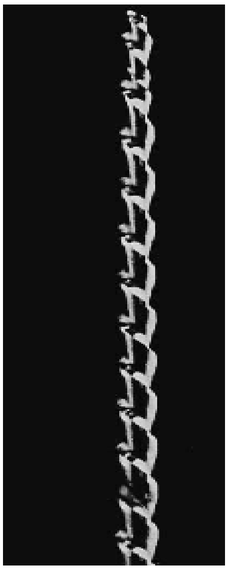


Fig 16: The thermomechanical compactor

Injection systems:

These include two syringe systems for injection of gutta percha

i-Obtura: Device consists of pistol-like delivery unit for introduction of gutta percha through 23 gauge silver injection tip. The delivery unit is connected to an electric unit which warms the gutta percha to the desired temperature (max temp 204ºC).

Fig 17: The obtura injection system

ii- Ultrafil: Device consists of preloaded gutta percha filled canules with 22 gauge stainless steel needles. These canules are warmed in a separate heating unit then loaded in a special injection syringe (max temp 70^{o}C).

Gutta percha carriers:

These devices consist of alpha phase gutta percha molded around a metal core resembling an endodontic file (carrier). These carriers were first made of St St, nowadays, they are available in plastic and titanium. Carriers come in sizes ranging from 20-140 with calibrated markings on the shaft to assist in length control. The gutta percha coating these carriers is softened by passing it over flame and then inserted inside the canal. The most popular type of these carriers is called **" Thermafil"**.

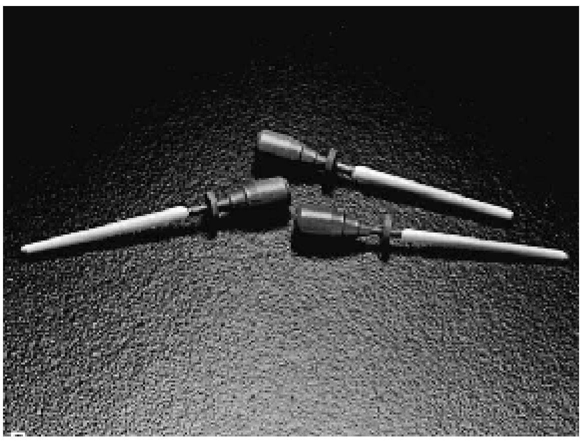


Fig 18: The gutta percha carrier "THERMAFIL"

V- Miscellaneous

1- Apex locators:

Electronic devices used to determine the tooth length before initiating the canal debridment. The first generation of these devices was introduced by Sunada in which the root canal length was determined by comparing the electrical potential difference between the periapical tissues and the oral mucosa.

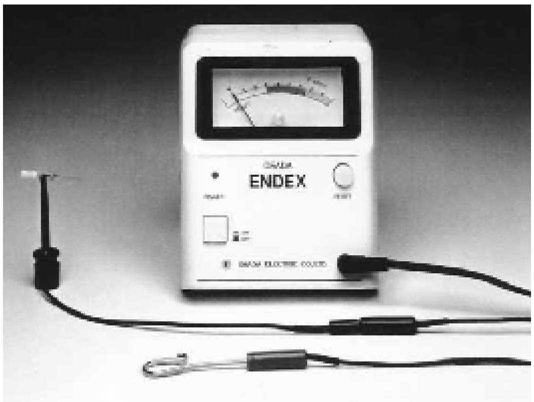


Fig 19: An apex locator device

2- Endobox:

An organizer for placement of endodontic files where instruments are sorted by sizes.

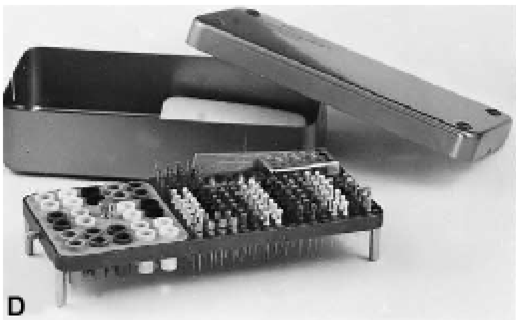


Fig 19: Endobox

3- Endometer:

Metal or plastic autoclavable rulers for measurements during enlargement and obturation.

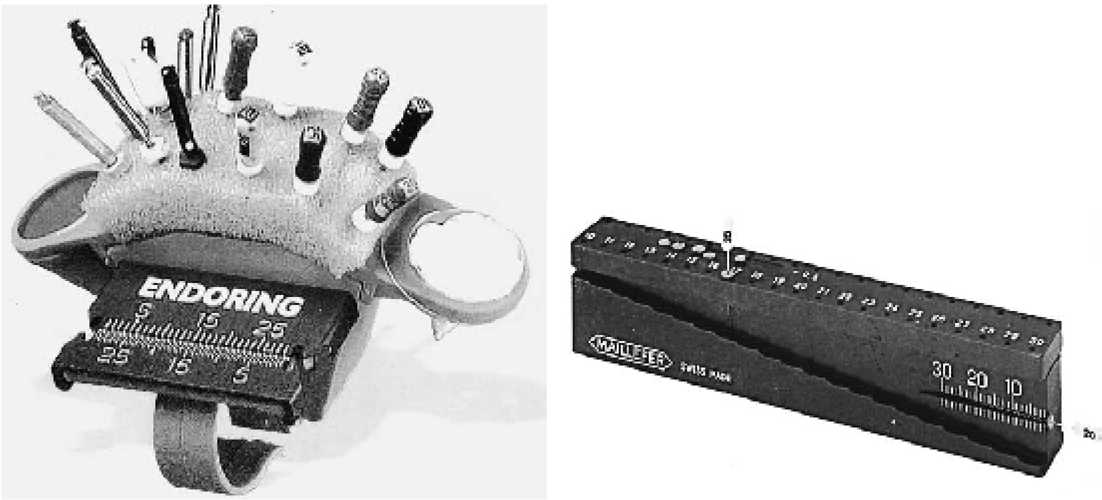


Fig 20: Transfer sponge with an endometer

4- Rubber dam:

Device utilized to isolate the tooth under treatment from the oral environment. Isolation is mandatory to prevent salivary contamination and aspiration of instruments into patients throat. Rubber dam is formed of five components:

- Rubber dam sheet to isolate the tooth
- Rubber dam punch to make a hole in the sheet
- Rubber dam clamp to stabilize the sheet in place
- Clamp Holder to position the clamp in place
- Rubber dam frame to stretch the rubber dam sheet

CLEANING AND SHAPING

Upon the completion of the coronal access cavity, intraradicular cavity preparation is initiated. Root canal system must be cleaned and shaped, cleaned of organic remnants and shaped to receive a three dimensional hermetic filling. Debridement is the terminology referring to the cleaning of the inside of the root canal system. The principle of debridement is simple, instruments should plane all the walls and loosen debris, irrigants then flush all the loosened and suspended debris from the canal space. The chemical action of the irrigant further dissolves organic remnants and destroys microorganisms in what we call chemicomechanical preparation of the canal. Proper cleaning and shaping ensures perfect seal of all portals of exist (fig.1).

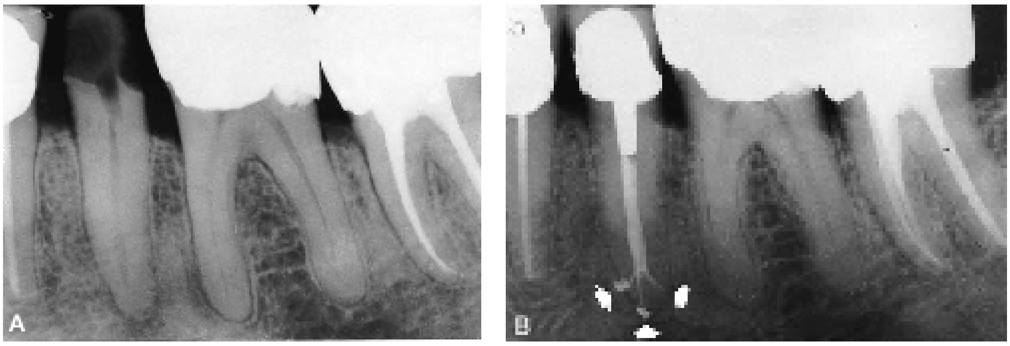


Fig. 1(A &B): Proper cleaning and shaping ensures perfect seal of all portals of exist.

Treatment objectives

For better understanding of the proper cleaning and shaping we should first review our treatment objectives. Herbert Schilder, a distinguished endodontists, introduced these mechanical objectives 25 years ago. Simply we need thorough debridement of the root canal system and specific shaping of the root canal space to receive a specific type of filling. These two objectives in details are:

(1) Mechanical objectives

1- Develop a continuously tapering conical form in the root canal preparation with the narrowest part apical and the widest part coronal.

2- Preserve the natural curve of the canal.

3- Preservation of the apical foramen (never transport the foramen).

4- Creation of an apical stop (seat) which help to confine root canal instruments and materials to the canal space and create a barrier against which gutta percha can be condensed.

To summarize, the goal is to produce a three-dimensional continuously tapering cone from access preparation to apical constriction while preserving apical foramen position and size.

(2) Biological objectives

1- Total removal of organic and inorganic debris in root canal system.

2- Sterilization of the root canal system.

3- Do not harm the tooth or the periodontium.

Principles for radicular cavity preparation (G.V. Black)

***Irrigation**: of the access preparation to eliminate as much debris as possible before introducing the enlarging instruments inside the canal.

***Resistance form**: This is achieved by enlarging the apical terminus of the canal while preserving the apical constriction. Violating the apical constriction by over instrumentation leads to irritation of the periapical tissues by instruments and filling materials. In addition, the absence of an apical stop due to violation of the apical constriction results in an inability to compact the root canal filling material.

***Retention form**: This is achieved by enlarging the apical terminus of the canal while retaining its round cross-section. This shape provides an intimate contact between the apical dentin walls and the gutta percha master cone thus preventing future leakage in the canal space. Coronal to this area of retention, the cavity walls are flared where the degree of flare depends on the filling technique to be used.

****Extension for prevention***: This last principle reflects the necessity for extension of the preparation throughout the entire length and breadth to ensure prevention of future problems.

Pulp anatomy in relation to root canal enlargement

To master the anatomic concepts of cavity preparation, the operator must develop a mental three dimensional image of the inside of the tooth from the pulp horn to the apical foramen.
In the past, we have been thinking vertically, many students were taught that the first concern in root canal preparation was "working length". We understand now that the critical issue is three dimensionality. Pulp space is a very difficult environment to work. Intracanal instruments (files) are designed to enlarge a straight uniform slightly tapered space, which is not the case in root canals. Knowledge of pulp space morphology shows that this space offers different levels of difficulty due to its complex anatomy.

This complex anatomy is reflected by:

* Pulp spaces are much wider in the bucco-lingual dimension than in mesio-distal dimension.(fig.2)

* Cross-sections of root canals are rarely round along the entire length of the canal but rather oval, ovoid, elliptical or kidney-shaped.

* Root canals exist in different types reflecting the presence of extra canals as second canal in mandibular incisors or second mesiobuccal canal in maxillary molars. (fig. 3)

* Root canals might exhibit lateral or accessory canals along their entire length or in the furcation area. (fig. 3)

* All root canals show a degree of curvature, which might be in one plane, or curvatures at different planes.

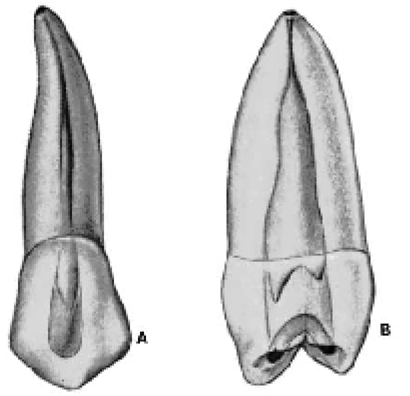


Fig. 2: Pulp spaces are much wider in the bucco-lingual dimension than in mesio-distal dimension.

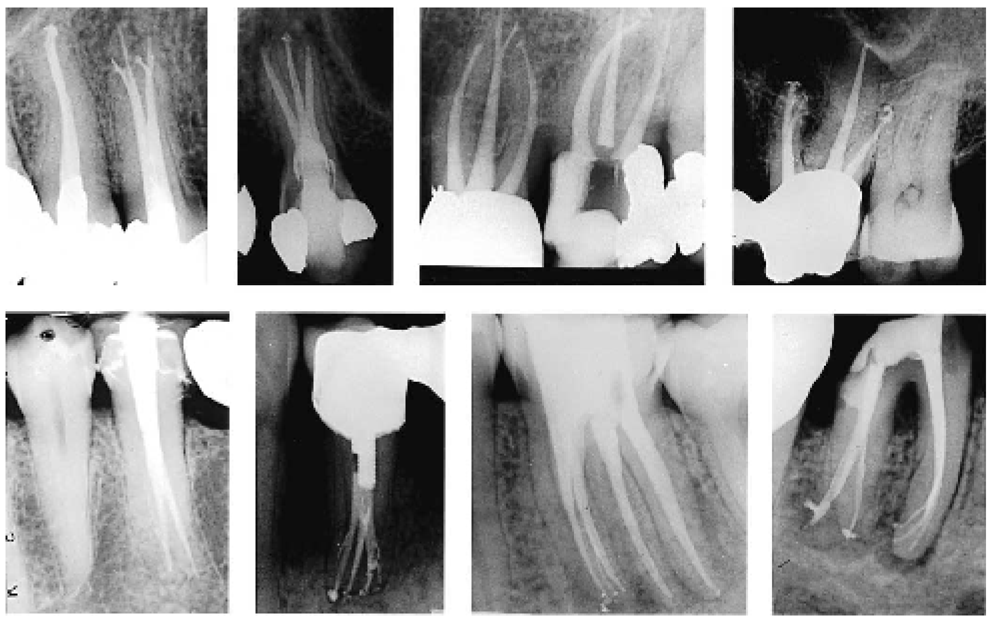


Fig. 3: Pulp spaces exhibit extra canals, lateral accessory canals and different curvatures.

Preparation for root canal enlargement

I. Intra-coronal preparation

A proper access preparation is mandatory prior to canal instrumentation. Straight-line access allows files to be introduced without binding through the pulp chamber and into the canal.

II. Tooth length determination

Prior to cleaning and shaping of the root canal, the length of the root canal should be accurately measured. This length is measured from a point on the tooth's coronal surface that is within the clinician's field of view and goes apical reaching the apical constriction, which is 0.5-1 mm short of the anatomical apex.

The apical constriction is the narrowest point of the canal beyond which the canal widens and develops a broad vascular supply. Therefore, from a biologic and mechanical perspective the constriction is the most rational point to end the canal preparation. (fig.4)

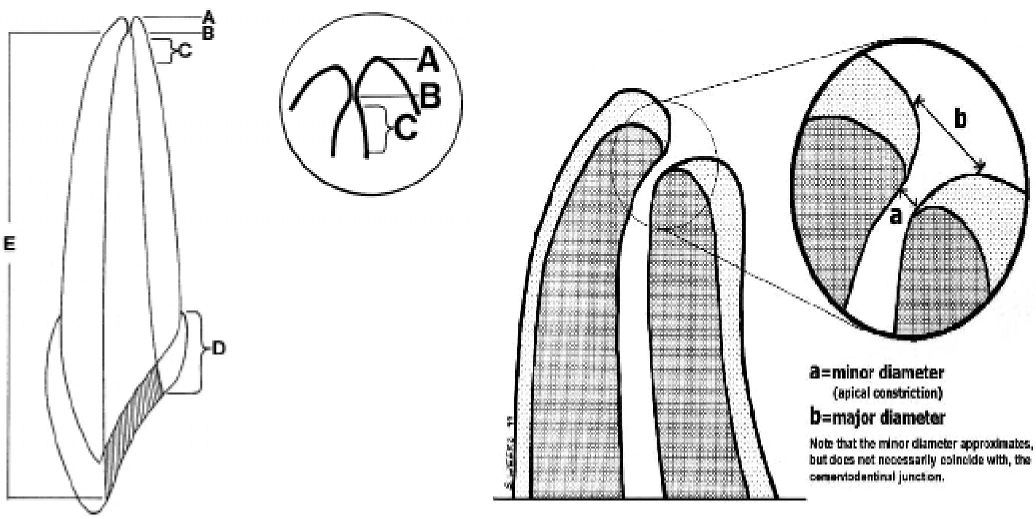


Fig.4: Tooth length measurement extending from coronal end to apical constriction.

Determination of the length of the canal can be done either by the **radiographic technique** (Ingle's method) or by **electronic devices** for tooth length measurement (apex locators).

(1) Radiographic method (Ingle's method) (Fig. 5)

The radiographic technique is considered the most widely used method. Based on the length of the tooth on the preoperative radiograph and the average tooth length, a pre-measured file is inserted inside the canal. The plastic stopper on the file should be resting on a sound reference point e.g. cusp tip, incisal or canine tip (fig. 6). A radiograph with the file inside the canal is exposed, processed and examined. Working length should be 0.5-1 mm from the root apex. Adjust the length of the file according to the tooth length radiograph (fig.7).

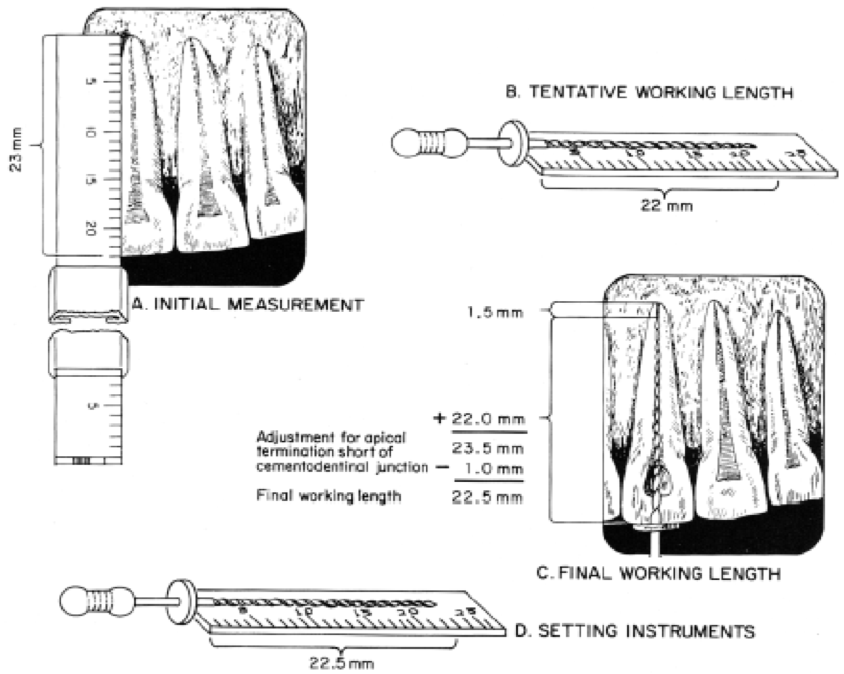


Fig. 5: Radiographic technique for tooth length measurement

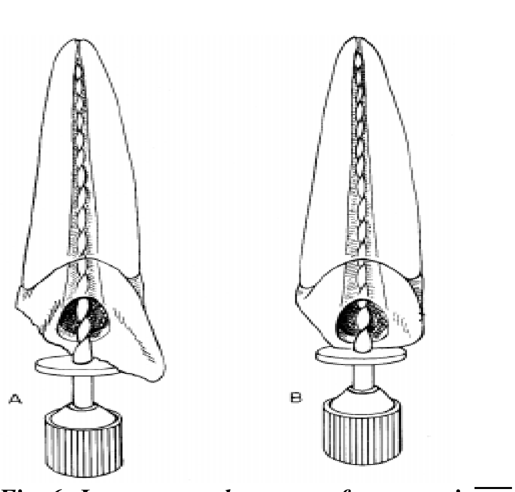


Fig. 6: Improper and proper reference point

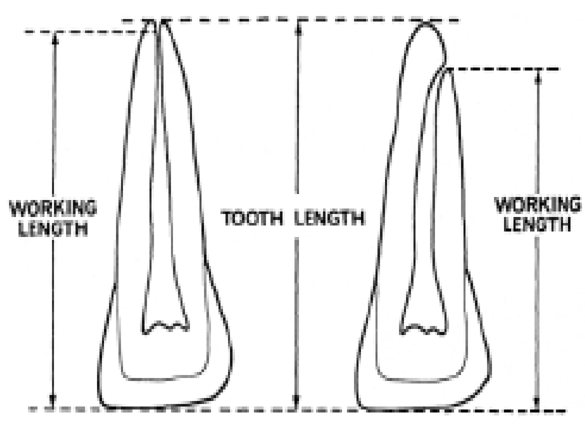


Fig. 7: Cleaning and shaping should be terminated at the apical constriction.

The Buccal Object Rule:

When two root canals exist in the same bucco lingual plane, they appear on the radiograph superimposed on each other. Shifting the x-ray cone in the horizontal plane either mesial or distal will bring the image of the two canals beside each other on the radiograph. This is the called the buccal object rule or the shifting technique. To identify each canal on the radiograph apply the MLM rule. The MLM rule states that: When we shift the x-ray cone to the mesial (M), the lingual canal (L) will appear on the x-ray film on the mesial side (M). (fig. 8)

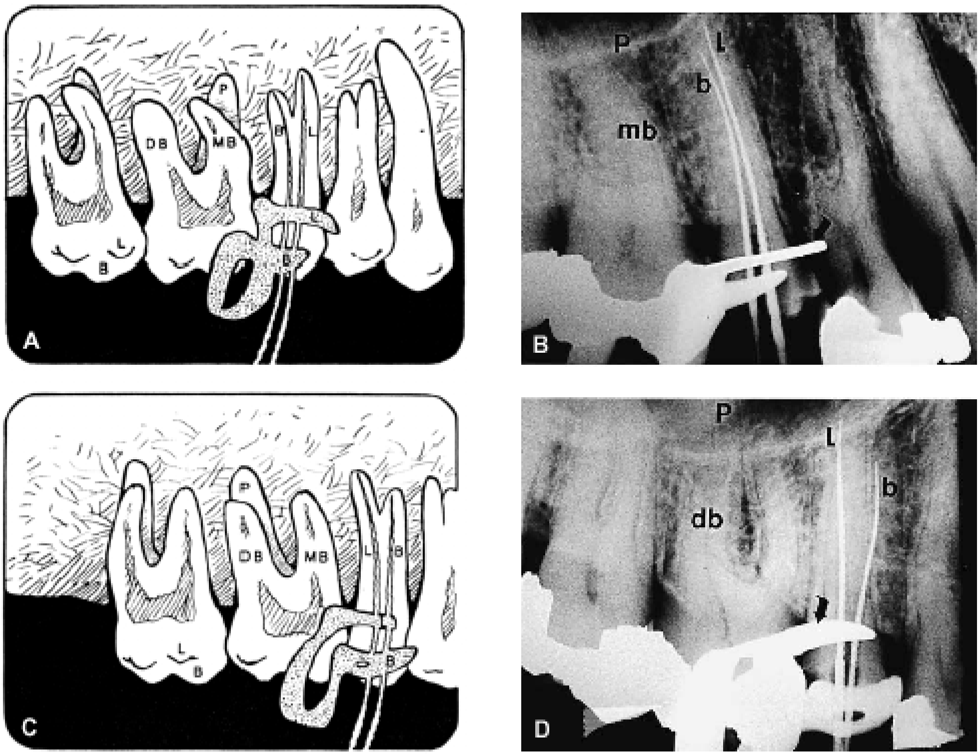
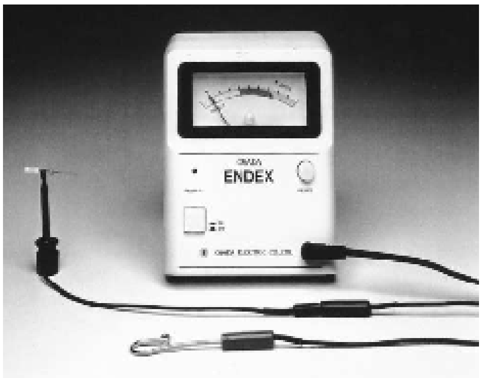


Fig. 8: The Shifting technique (Buccal object rule)

(2) Electronic method (Apex locators):

The idea behind these devices depends on the resistance of different tissues to electricity. Oral soft tissues conduct electricity easily while hard tissues act as an insulator. All apex locators in the market have two electrodes one touches the patient oral mucosa while the second is connected to a file which is introduced inside the canal (fig. 9). By passing the file inside the canal a very small current exists between the two electrodes i.e. a very high resistance exists. This electrical resistance is very high as the file enters the enamel and dentin and decreases as the instrument moves down the canal and finally dropping as the file approaches the periapical tissues. Digital reading, light or sound are the indicators for different devices when reaching the end of the canal. (Fig.10)



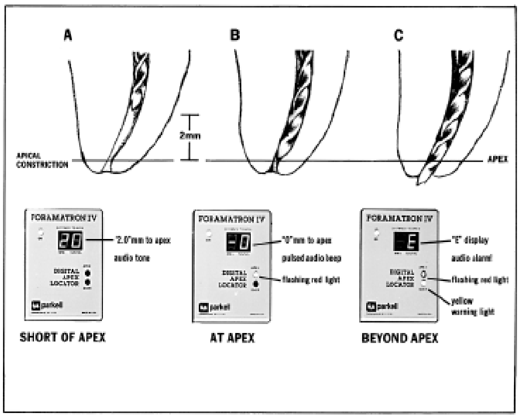


Fig. 9&10: Electronic device for tooth length measurement (apex locator)

Electronic apex locators have been tested for accuracy against radiographic technique and both were found to be 80-90% accurate. However, radiographs supply the clinician with important data about canal curvatures, number and the condition of the surrounding soft and hard tissues.

Improper tooth length determination will complicate the outcome of the treatment leading to failure of the case. This complication is reflected by either:

***(i) Internal transportation*:** a condition in which canal will be prepared short of its real length leading to improper cleaning, persistent infection, ledge formation with subsequent under filling ending by failure.

(ii) External transportation: a condition in which enlarging instruments are extended outside the canal irritating the surrounding tissues. This situation leads to severe postoperative pain, persistent chronic inflammation with subsequent over filling ending by failure of the case.

III. Pulp extirpation

Pulp extirpation is the complete removal of the pulp tissue from the pulp chamber and the root canal(s). Initial extirpation is performed using nerve broaches (barbed broaches) in large sized canals and files in small sized canals. However, complete removal of pulp tissue is not accomplished until working length is established and considerable canal preparation has been done.

IV. Irrigation

Before and during the course of cleaning and shaping root canals should be washed out or irrigated with a solution capable of disinfecting them and dissolving organic matter. Although instrumentation of the root canal is the primary method of canal debridement, irrigation is a critical adjunct. Irregularities in the root canal system prevent complete debridement by mechanical instrumentation alone. Irrigation serves as a physical flush to remove debris as well as serving as a bactericidal agent, tissue solvent and lubricant.

Properties of ideal irrigant

1- Tissue and debris dissolvent: The irrigant should have the ability to dissolve tissues either vital, necrotic or chemically fixed.

2- Lubricant: The irrigant should have a lubricating action to facilitate sliding of the instruments along the canal walls.

3- Antibacterial action: Ideal irrigant should have a bactericidal action against aerobic, anaerobic organisms and bacterial spores.

4- Removal of smear layer (if desirable): The smear layer is a microcrystalline layer of cutting debris covering the canal walls after canal preparation.

5- Low toxicity: An ideal irrigant should have minimal or no toxic effect of the periapical tissues.

6- Availability, reasonable cost and adequate shelf life.

***Types of irrigants*:**

Many types of solutions have been used, from distilled water to concentrated acids.

1- Sodium hypochlorite (NaOCL)

* The most popular and advocated irrigant is sodium hypochlorite (clorox). The full concentration of sodium hypochlorite (5.25%) can be

toxic to surrounding tissues, so it is recommended to be diluted by equal amount of water (2.6%), which decreases its toxicity, while it still retains its action.

* Sodium hypochlorite is an excellent tissue solvent where its action may be increased by warming the solution, however, warming the solution affects its stability.

* Combining solutions of NaOCL and hydrogen peroxide causes foaming action for better removal of debris, however, this combination inhibit the antibacterial action of both irrigants.

* Alternate use of NaOCL and EDTA is capable of removing the smear layer.

2- Chelating agents:

* The most common Chelating agent used as an irrigant is Ethylene diamine tetra acetic acid (EDTA). This irrigant have an excellent antibacterial action with no tissue solvent action.

* RC-Prep is a paste composed of EDTA and urea peroxide. This paste when used with NaOCL is capable of removing the smear layer and produce bubbling action due to interaction of urea peroxide and NaOCL. This bubbling help loosening and floating of dentinal debris.

* Dentin softening is an added property when using chelating agents which is advocated by some clinicians to facilitate root canal enlargement.

3- Hydrogen peroxide (3%):

Once was a very popular irrigant due its effervescence action, which is capable of removing cutting debris from inside of the canal. In addition the release of nascent oxygen works against anaerobic microorganisms.

4- Quaternary ammonium compounds:
The most popular irrigant of this group is the 9-amino acridine. This irrigant is an antiseptic with low toxicity with no tissue dissolving property.

5- Chlorohexidine Gluconate (0.2%):
This chemical was shown to have antibacterial action comparable to that of NaOCL but again it does not have tissue solvent action.

Method of irrigation:

The technique of irrigation is simple by using a plastic syringe and bending the needle to allow easier insertion inside the canal (fig. 11). It is strongly recommended that the needle lie passively inside the canal as forceful irrigation can push the irrigant into the periapical tissues leading to severe complications.

Goldman developed an irrigating needle which have sealed end with ten side perforations along its length.

Ultrasonic irrigation is considered the most effective method of root canal irrigation where the vibrational motion of the files inside the canal moves the irrigant in a vortex like motion cleaning areas which are cannot be reached by the files. In addition, this motion causes warming of the irrigant thus increasing its action.

To summarize, it appears that NaOCL 2.6% provides both excellent antimicrobial and tissue solvent action putting into consideration that proper technique of irrigation is followed to avoid its toxic properties. If it is desired to remove the smear layer before obturation, EDTA should be used in combination with NaOCL.

Fig. 11: Technique of root canal irrigation

Steps of root canal enlargement

Root canal enlargement (Intra radicular reparation) can be done manually (hand instruments) or by engine driven tools. A combination of the two methods is another alternative being preferred by some clinicians.

A. Root canal enlargement using hand instruments:

To fully understand the procedure of root canal enlargement, one need to learn first the motion of the enlarging tool (file) inside the root canal (basic instrumentation motion). Second, which part of the canal do we approach first (apical versus coronal).

Basic instrumentation motions (maneuvers)

Cleaning and shaping of the root canal is performed by endodontic instruments (files) being moved against the dentin walls either in a linear motion (up and down) or rotation motion. These motions are being referred to as ***"BASIC INSTRUMENTATION MOTIONS"***(Fig.12)

1- Linear motion:
Filing motion: This is a linear motion in the form of push and pull action. It is the most efficient motion in cutting dentin. All types of files can be used with this motion, however, the H-file is considered the best. This motion is recommended for enlarging the coronal 2/3 of the canal (circumferential filling)(fig.12A).

2- Rotation motions:
a. Reaming motion: This is a rotation motion. The term ream indicates clockwise or right-hand rotation of the instrument. It is assumed that this motion produces round cross-section of the root canal, however, chances of the instrument to fracture is increased. Reamers and K-files are very suitable for this motion (fig. 12B).

b. Turn and pull: This is a combination of reaming and filing where the instrument is inserted with a quarter turn clockwise (reaming) then the file is subsequently withdrawn (filing)(fig.12C).

c. Watch winding motion: This is a rotation motion. The instrument is being inserted in the canal with a gentle clockwise/counterclockwise motion (right and left). Reamers and K-files are suitable for this motion (fig.12D).

d. Balanced force: It is a rotation motion. It is identical to the watch winding in which the instrument is rotated right and left inside the canal until reaching the desired length. Now the instrument is rotated to the left (counter clockwise). This left rotation attempts to drive it out of the canal so, the clinician must apply apical pressure to prevent outward movement to obtain cutting. Simultaneous apical pressure and counter clockwise rotation of the file strikes a balance between the tooth structure and instrument. This balance keeps the instrument centralized inside the canal thus, minimizing the chances for canal transportation. Flex-R-file (modified K-file) is the instrument of choice to be used with this motion due to its triangular cross section (less metal mass = more flexibility) and for its non-cutting tip (fig.12 E).

N.B: All rotation motions are recommended to be used in enlarging the apical 1/3 of the canal due to their ability to offer a round preparation.

Fig.12: Basic instrumentation motions; A: filing, B: reaming, C: turn and pull, D: watch winding, E: balanced force

Techniques for Instrumentation (approach)

Over the years two different approaches to root canal cleaning and shaping have emerged. The ***step back*** and the ***step (crown) down*** preparations. The step back preparation begin the preparation at the apex and working back up the canal coronally with larger and larger instruments. The step down approach, on the other hand begins coronally and the preparation is advanced apically using smaller and smaller instruments.

Anyone or more of the previously mentioned basic instrumentation motions can be used with any of these techniques.

1. STEP-BACK TECHNIQUE (Telescopic preparation)(fig.13)

The step-back technique was first described by Clem 1969 and became popular as it creates smoother flow and a more tapered preparation.

Cleaning and shaping of the root canal by the step-back technique includes two phases. In phase one the motion used is a rotation motion (reaming, watch winding or turn and pull motion) and its aim is to prepare the apical portion of the canal (apical preparation phase). In phase two, the motion used is the filing motion along the circumference of the canal (circumferential filing). The aim of phase two is to enlarge and flare the coronal two thirds of the canal (flaring phase). The technique is described as follows:

Phase one (apical preparation)

* Based on the tooth length determination, select the ***INITIAL FILE*** to start your cleaning and shaping. The initial file should reach the working length with slight resistance at the apical third.

* The initial file is inserted inside the canal to the full working length using a watch winding motion (Back & forth motion).

* When reaching the full working length the initial file is given a quarter turn motion in a clockwise direction then withdrawn outward (***Turn and pull motion***).

* This action is repeated until the file is totally loose inside the canal, make sure that you irrigate frequently during preparation.

*This procedure is repeated until the apical area is prepared at least three sizes larger than the initial file. The largest file reaching the full working length is what we call "***MASTER APICAL FILE***" (MAF).

Remember: Always keep the canal flooded with the irrigant and never force an instrument inside the canal.

<u>Phase two (flaring)</u>

* The next step would be to step backward using the larger size files while shortening the working length to obtain a flared preparation.

* This step back preparation is done by inserting sequentially files larger than the MAF in a passive manner i.e. no pressure is applied to the file handle to push it deeper inside the canal. This size will mostly stop short of the working length. Move the file in a circumferential filing motion to smoothen the dentin walls.

* Irrigate the canal and go back again to the MAF placing it to the full working length and carry the collected debris outside the canal to avoid canal blockage. This is what we call "***RECAPITULATION***".

* Step backward again and recapitulate until canal appears to be funneling out smoothly.

<u>NB.</u> Engine driven tools (Gates Glidden drill) can be used in phase II to achieve fast and efficient cutting.

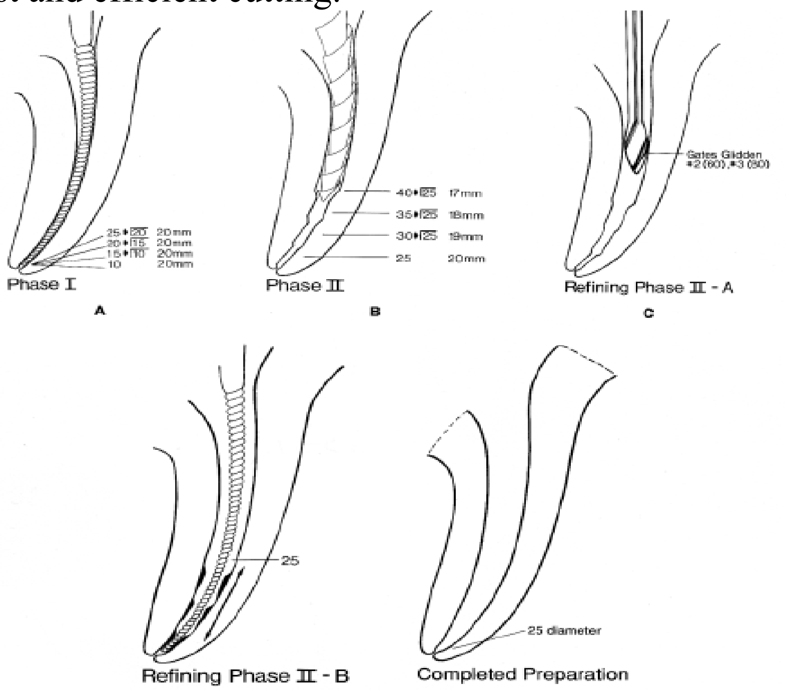


Fig. 13: The step back preparation (Phase I &II)

2- STEP (CROWN) DOWN TECHNIQUE (Fig, 14)

In the last few years the step down technique gained a lot of support from experienced endodontists. The technique involves cleaning and shaping the root canal from the coronal third down to the apical third. This technique is proposed to have the following benefits:

a- It eliminates cervical dentin constrictions giving the operator full tactile awareness in the apical third.
b- It allows deeper and earlier penetration of irrigants.
c- It removes the major portion of the pulp debris before the apical third is approached thus minimizing the risk of pushing such irritants into the periapical region.

The technique in brief is as follows:

- After proper access preparation, the root canal is negotiated for patency using k-file #15.
- Large H-files (#40-50) are passively inserted inside the root canal using watch-winding motion then the coronal 1/3 is enlarged using circumferential filling.
- Sequential usage of smaller sizes permits deeper penetration of the files until reaching the apical 1/3 of the root canal.
- Tooth length should be accurately determined before initiation of apical preparation.
- Apical terminus of the root canal is prepared using smaller k-files in rotation motion.

NB. Engine driven tools (Gates Glidden drill) can be used in the initial coronal enlargement to achieve fast and efficient cutting.

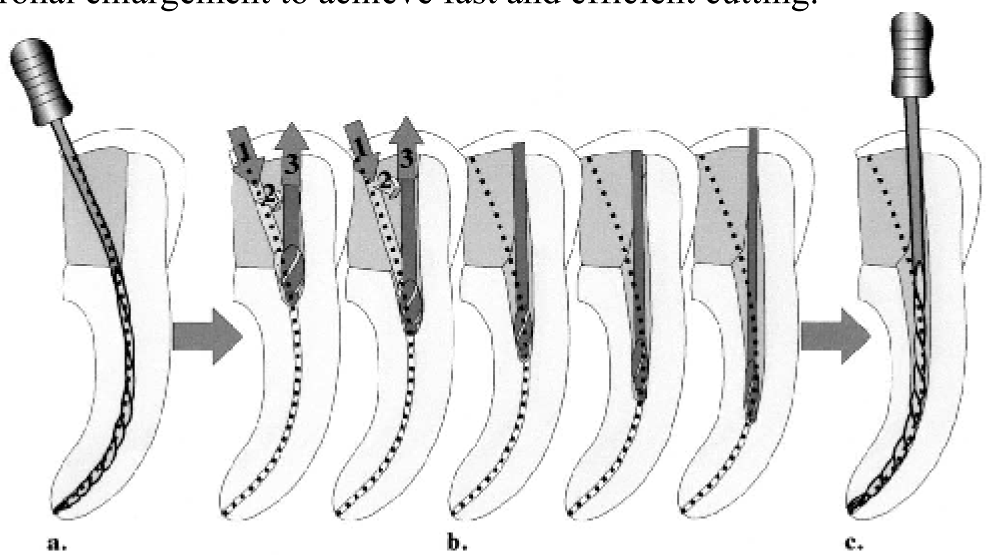


Fig. 14: Step (crown) down technique

B- Root canal enlargement using engine-driven devices

Manual root canal enlargement is considered by some clinicians somewhat difficult and time consuming. Recently, engine driven instruments for root canal enlargement have been suggested. Two types of motions are utilized either rotational motion or vibrational motion.

I- Engine driven instruments utilizing rotational motion:

These include large variety of special hand pieces that rotate back/forth or in a quarter turn or even up and down motion. Tips mounted on these hand pieces are files or reamers with latches instead of handles.

Rotational engine driven instruments were not widely accepted in the past due to problems that appeared when using them which included:

1- Less effective in canal debridement.
2- More tendency for canal packing with dentin debris.
3- More tendency for ledges and perforations
4- More tendency for canal straightening.
5- More tendency for instrument breakage.
6- Loss of operator sense of canal topography.

However, the new generation of engine driven instruments were greatly modified and nowadays are comparable to hand instrumentation techniques. Modifications included:

1st- Modification in the handpiece:

- High torque
- Very low speed (300-1200 RPM)
- Steady rotation

2nd- Modification in the cutting tool:

- Nickel-titanium files (flexible)
- Increased taper

These newer systems include:

a. The profile series 29 system.
b. The light speed system.
c. The POW-R system
d. The profile GT system
e. The protaper rotary system
f. The Hero 642 system.

NB:

- Most of these devices utilize a rotation motion either full rotation or back and forth motion.
- The step (crown) down approach is the technique advocated by most of the manufactures of these systems.
- Most of the clinicians recommend a combination of hand instrumentation with any of these systems.

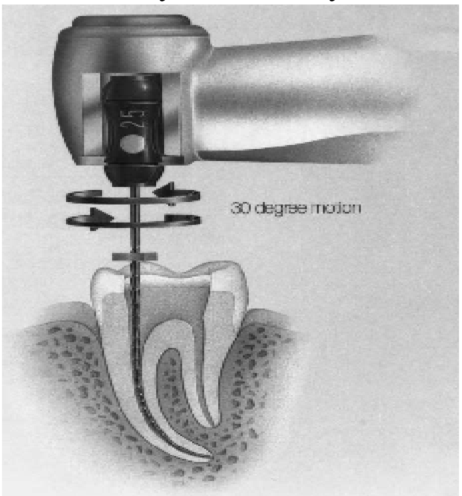


***Fig. 15*: Root canal Rotary system**

II- Engine driven instruments utilizing vibrational motion: (Sonics & ultrasonics)(Fig. 16)

The utilization of vibrational motion in endodontics was first introduced more than twenty years ago by Dr. Martin. The power source (electromagnetic or piezoelectric) is transferred to a special insert that hold a special instrument similar to a file. When the file is energized in a canal flooded with irrigant, the fluid motion helps loosening debris with better flushing of canal contents together with file scraping against the dentin wall.

The results of the studies have shown that canal enlargement using sonics and ultrasonics may not be efficient as hand instrumentation and is even less effective in small curved canals. However, flushing and disinfection appears to be very effective with the sonics or ultrasonics.

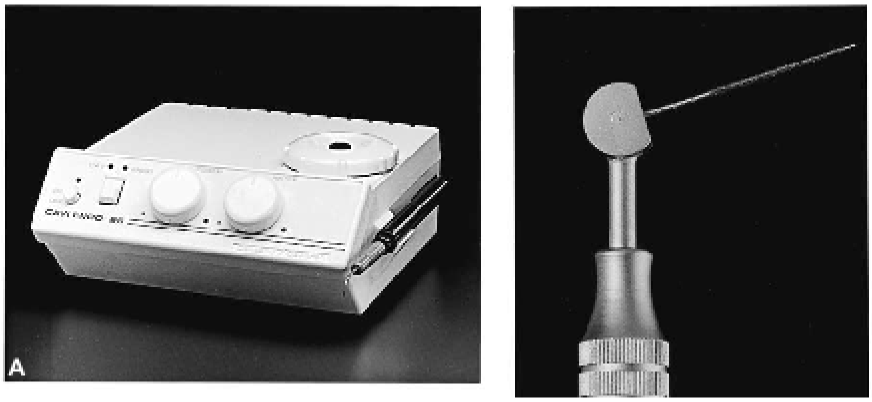


Fig. 16: Ultrasonic unit and insert with a file mounted for canal enlargement

Guidelines for instrumentation of curved canals

The ideal canal enlargement would be the one that enlarges the canal while retaining the canal pre-operative shape. In a straight large canal this rule is easy to apply, but studies have shown that straight canals are the exception and the majority of root canals show a degree of curvature.

When a file is inserted in a curved canal, elastic forces develop inside the instrument. These forces attempt to return the instrument to its original shape hence it is called **"Restoring forces".** These forces act on the canal wall during preparation and influence the amount of dentin cut by the instrument. The restoring force is not equally divided along the length of the instrument being maximum at the instrument tip (Fig. 17). This phenomenon is responsible for most of the procedural errors which occur during canal enlargement.

Fig. 17: The distribution of the restoring force along the length of the instrument

These guidelines should always be remembered regardless of the technique of instrumentation used:

1- Always work files in a canal filled with **irrigant.**

2- Never **skip** intermediate instrument size during preparation.

3- Never **force** files inside the canal to avoid instrument breakage or packing of debris in the apical region of the canal.

4- **Precurving** of instruments: a precurved file is a valuable tool for feeling canal passages and for moving around calcifications and ledges. In addition, a curved file helps alleviate the adverse effects of canal curvature.

5- **Anticurvature filing** concept: this concept describes the action of pulling the files against the outside wall of the canal. This directionally applied pressure prevents straightening of midroot curvatures, which can lead to strip perforation.

6- **Radicular access**: This procedure is employed nowadays in most instrumentation techniques. It describes enlarging the coronal 1/3 of the canal before initiating the cleaning and shaping. This can be accomplished either by rotary instruments (gates Glidden drills) or by circumferential filing by H-files.

7- Files with higher **flexibility** (NiTi) exhibit less tendency for canal straightening.

Termination of canal preparation

How much should the root canal be enlarged ? The answer is simple, canals should be enlarged enough to permit adequate debridement as well as manipulation and control of obturating materials and instruments.

The end point for root canal preparation depends on several factors:

a. Initial size of the root canal (anterior versus posterior).

b. Nature of the disease (vital versus nonvital cases).

c. Method of obturation.

Clinical criteria for termination of canal preparation

1- Debridement: All walls should feel smooth along the whole length of the canal together with clean yellow dentin debris.

2- Apical preparation: An apical stop (apical control zone) should exist. This is tested by the failure of the master apical file to pass beyond the working length when a reasonable apical pressure is applied to it.

3- Adequate taper: Selected obturating instrument (spreader or plugger) can reach easily to within 1-2 mm of the working length.

Procedural errors during cleaning and shaping

Iatrogenic changes in root canal during cleaning and shaping do occur and especially in narrow curved canals. The majority of these complications are a result of improper control over the preparation instrument. These procedural errors include:

I- Canal blockage

This condition occurs when the operator feels that canal patency is lost during cleaning and shaping.

Diagnosis

* Full working length can not be reached.
* At area of blockage canal feels sticky.

Etiology

* Failure to maintain full working length during preparation.

* Insufficient irrigation.
* Failure to recapitulate during preparation.

Treatment

To solve this situation, the operator should irrigate the canal and start negotiating the canal at full working length using the initial file (smallest file reaching the working length).

II- Ledge formation

This condition occurs when the operator feels that full working length cannot be reached. (fig.18)

Diagnosis

* Loss of working length.
* End of canal feels as a solid wall (non-sticky).
* Radiographically file appears to leave the original path of the canal.

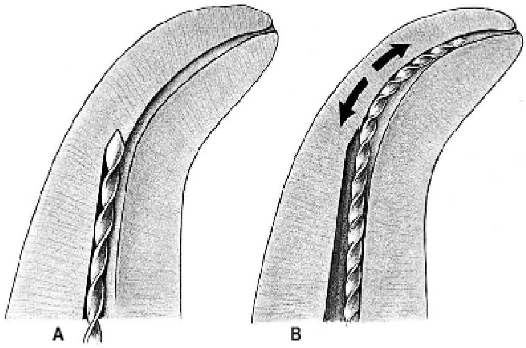


Fig. 18: File leaving main path of the canal (ledge formation)

Etiology

- Insufficient irrigation.

- Failure to recapitulate
- Using large-sized instruments in small curved canals.
- Skipping of instrument sizes during preparation.
- Improper access preparation that does not allow direct access to apical part of the canal.

Treatment

To solve this situation, operator should irrigate the canal and try to relocate the original canal. This is done by placing a sharp bend at the last 1-2 mm of a file # 15 (fig. 19). This tip is teased along the canal wall until the full working length can be re-established.

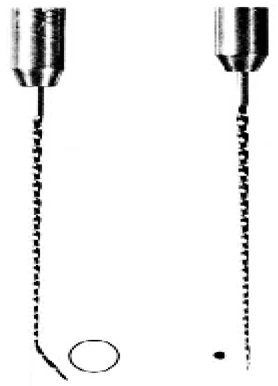


Fig. 19: A sharp bend at the file tip to negotiate a ledge

III- Perforation

This problem can occur anywhere along the length of the canal (coronal, mid-root or apical.

Diagnosis

* Sudden pain
* Sudden bleeding in a canal originally dry.
* Radigraphically file is seen projecting out of the canal.

Etiology

Coronal Perforation: (fig. 19)

- Over widening of canal orifice.

Bifurcation Perforation: (fig. 20)

- Failure to locate canal orifices.

Mid-root Perforation: (fig. 21)

- Boring through a ledge (side perforation).
- Over enlargement of small canal leads to longitudinal perforation (strip perforation).

Apical Perforation:

- Improper working length.

Treatment

* If perforation was apically, reestablish working length and create a new apical stop by enlarging the master apical file one or two sizes.

* If perforation was side perforation, try to relocate the original canal and complete the cleaning procedure. The perforation can then be sealed during canal obturation or an external seal can be performed surgically.

* Strip perforations are difficult to deal with. Obturate the canal and follow up the case.

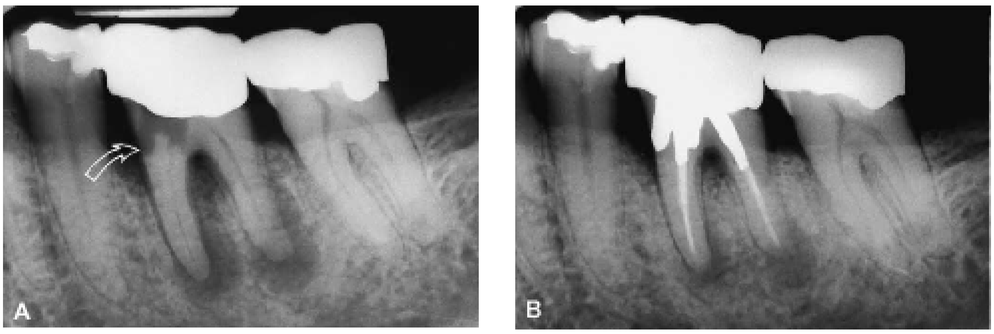


Fig. 19: Perforationof the coronal 1/3 of the root canal

Fig. 20: Bifurcation perforation

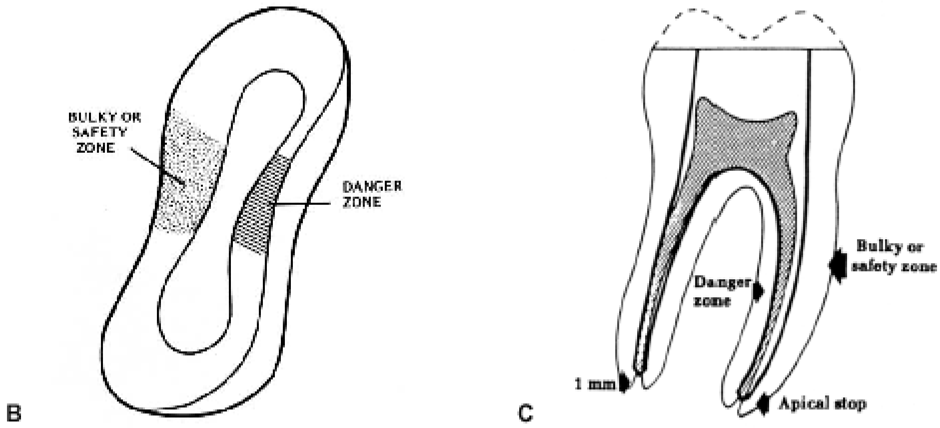


Fig. 21: Longitudinal Perforation(Strip perforation)

IV- Instrument breakage

During instrumentation, fragment of the instrument can break inside of the canal. This fragment blocks the canal thus preventing routine cleaning and shaping. This condition is diagnosed as follows:

Diagnosis

* Sudden loss of working length (canal blocked).

* Loss of a fragment of the instrument.

* Radiographically instrument fragment can be seen.

Etiology

* Using excessive force during instrumentation.

* Failure to inspect the instrument before use (fig. 22).

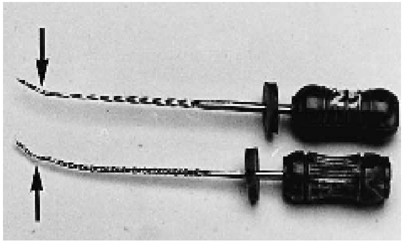


Fig. 22: Files with untwisted flutes

Treatment

- The best correction for this error is to try to remove this fragment. Ultra sonic fine instruments have proven to be the most effective where a tunnel is created around the instrument fragment then vibrated and dislodged.
- If impossible, try to bypass it using small size files then complete the instrumentation procedure (fig. 23).
- If also impossible, clean and obturate the canal to the level of the fragment and follow-up the case.

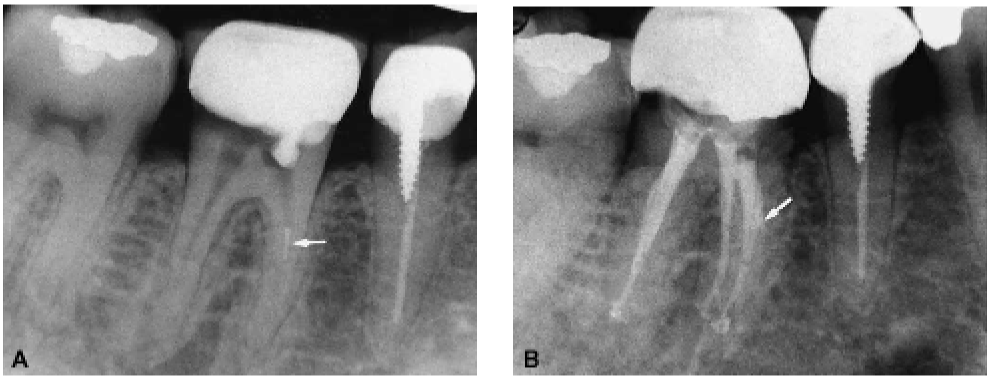


Fig. 23: Instrument bypassing

Prognosis

The prognosis of this condition depends on several factors:

- Location of instrument (apical, middle or coronal).
- Size of the instrument.
- How much cleaning was performed before instrument breakage.
- The nature of the pulp disease (vital or non-vital case).

OBTURATION

The final stage of endodontic treatment is to fill the entire root canal system and all its complex anatomic pathways with non-irritating hermetic
sealing agents. The success of canal obturation is dependent on the excellence of the endodontic cavity design and on thorough canal shaping and cleaning. To fully understand this terminal phase of root canal treatment four important questions have to be answered which are: why, when, what & how do we obturate root canals?

Objectives for Obturation (why)

1- To prevent microleakage of periapical exudate into the root canal space which prevent microorganisms from reinfecting canals during transient bacteremia.
2- To act as a barrier against coronal microleakage which can cause canal reinfection.
3- To create favorable biologic environment for healing of periapical tissues.

Time for Obturation (when)

1- When root canal (s) is cleaned and shaped to optimum size.
2- Tooth is asymptomatic (comfortable).
3- Absence of any sign of infection.

-Absence of foul odour.
-Absence of exudate (dry canal)
-Absence of sinus tact.

Materials used for Obturation (what)

A large variety of root canal filling materials have been advocated throughout the years. Many of these materials have been rejected by the profession being impractical, irritational, or biologically unacceptable.
Root canal filling materials currently in use are grouped into two categories: Pastes and semisolids (gutta percha – silver cones).

GUTTA PERCHA

Chemical Nature

Gutta percha is a high molecular weight polymer structured from isoprene monomer. Gutta Percha naturally occur in an alpha-form while most of commercially available gutta percha is in a beta-form. Both alpha and beta forms are chemically the same, however, they slightly differ in physical nature. To obtain alpha-phase, the material is heated above 65^{o}C it becomes amorphous and melts if it was allowed to cool extremely slowly (0.5^{o}C/hr), alpha form will recrystalise. However, if it was allowed to bench cool, beta form will recrystalise. Alpha is more brittle however, it is more tacky on heating and offers better adhesive properties than beta phase.

Physical Nature

- Gutta Percha expands slightly on heating therefore, condensation is recommended during heat techniques to compensate for cooling shrinkage.
- Gutta Percha can be compacted but no compressed.
- Gutta Percha gets brittle on aging which is assumed to be due to slow change to alpha phase.

Composition

Gutta percha	20%
Zinc oxide	60%
Metal sulphates	15%
Waxes / resins	5%

Availability

Standardized Cones (15-140)
Non standardized Cones (xx fine, fine, medium, coarse)

Advantages

1- Compactable and adapts to irregular contour of canal.
2- Can be softened by heat or chemically.
3- Inert and tissue tolerant.
4- Dimensionally stable.
5- Radio opaque.
6- Can be easily removed from canal when necessary.

Disadvantages

1- Lacks rigidity.
2- Lacks adhesive quality (does not adhere to canal walls).
3- Can be easily distorted (it deforms by stretching).

SILVER CONES

Silver cones (points), once favored as solid core filling material for their ease of manipulation in sealing of narrow curved canals, are no longer used due to:

1- Inability to conform to canal shape.
2- Corrosion.
3- Irritation to periapical tissues.
4- Lack of dissolvability.

PASTES

Paste-type filling materials have been proposed which include: zinc oxide eugenol cements with various additives, epoxy resins, polyvinyl resins, silicone rubber ….etc . Solvent altered gutta percha pastes has been also used (chloropercha - eucapercha).
However, due to several problems with the paste systems it is nowadays

accepted that pastes should not be used as a sole filling material but used in conjunction with solid core i.e. they act as sealers.

Root Canal Sealers

The current method for obturating root canal involves a semi solid (solid) cone or core cemented into the canal with a root canal cement (sealer).

Role of Root Canal Sealer

1- Close interface by filling irregularities and minor discrepancies between filling material and dentin.
2- Having an antibacterial property, it acts against organisms.
3- Act as a lubricant facilitating the seating of filling cones.
4- It can fill patent accessory canals and multiple foramina.

Types of Sealers

Several types of sealers have been formulated for use in endodontics
the most common ones are based on zinc-oxide-eugenol formulations.

1- Zinc-oxide- eugenol based sealers:

Rickert sealer.
Wach's sealer.
Grossman sealer.

2- Medicated Zinc-oxide eugenol sealers:

Endomethasone.
Sargentti formula (N2).
Spad.

3- Calcium hydroxide sealers:

CRCS
Seal apex

4 – Resin sealers:

Diaket.

AH26.

5-Glass ionomer sealers:

ketac-Endo.

NB: It is important here to mention that all sealers are highly irritant when

freshly mixed and their irritation decreases as it sets. Further more, most of sealers are soluble, these two important properties should be regarded in our obturation techniques such that:

(i) All filling materials should be limited to the confines of the root canal.

(ii) Serious effort should be made to maximize the volume of the dimensionally stable core material and to minimize the amount of soluble sealer .

Techniques of Obturation (How)

Preparation for obturation

1-Preparation of the root canal:

Root canal should be irrigated thoroughly and dried with paper points equivalent to size of master apical file and adjusted to the proper working length.

2-Preparation of the sealer (mixing):

Manufacturer instructions for mixing the sealer should be followed. To test for proper consistency two tests can be applied:

Drop test: After mixing, the cement is gathered onto the spatula and held edgewise. The cement should not drop off of the spatula edge in less than 10-12 seconds.

String out test: After mixing, the cement is touched with the flat surface of the spatula, the spatula is raised slowly up the cement should string out one inch (2.5 cm) before breaking.

3-Fitting of the master cone:

The size of the master cone should be equivalent to the size of the largest file reaching the full working length (master apical file). The length of the master cone should be equal to the pre-determined working length. Based on these two criteria the selected master cone is inserted inside the canal until reaching the full working length. For best fitness, the cone should:

* Fit tightly in the apical 1/3 of the canal (good tug-back)
* Fit the full working length.
* Cannot be forced beyond the apical foramen.

A radiograph is exposed to confirm the fitness of the master cone.

OBTURATION TECHNIQUES

Gutta percha is by far the most universally used solid core root canal filling material (solid core + sealer). However, over years the presentation of the material and techniques of handling have greatly changed. Gutta percha can be used in a non softened or softened form .

I- Non-softened techniques

The most popular technique for the use of gutta percha in a non-softened state is ***The lateral condensation technique.*** The technique in brief is as follows:

* Selection of master cone (previously mentioned).

* Selection of obturating instruments (spreaders):

A spreader of the same size of the master apical size is chosen so it can reach to within 1mm shorter than the working length.

* Mixing of sealer (previously mentioned).

* Application of sealer inside the canal :

The sealer can be carried inside the canal by coating the master cone itself and using it to coat the dentin walls. Instruments like files, reamers or lentulo spirals can be used.

* Obturation Procedure :
1- After placement of the master cone, a premeasured spreader is then introduced inside the canal alongside the primary point until it reaches maximum penetration (1mm short of working length).

2- The spreader is moved back and forth while withdrawing it from the canal to avoid disturbance of the master cone.

3- An auxiliary gutta percha cone equivalent to the size of the spreader is introduced inside the canal in the space created by the spreader.

4- The spreader is inserted again making room for another cone.

5- The spreading procedure is repeated several times until a spreader can no longer be introduced inside the canal.

6- Protruding points are severed at the level of the canal orifice with a hot instrument.

7- A plugger is used to vertically compact gutta percha to assure complete tightness of gutta percha mass.

8- Pulp chamber is cleaned from sealer and remnants of gutta percha to evaluate quality of obturation.

Modification in lateral condensation technique:

The previously described lateral condensation technique is used efficiently with mature canals however, in cases of immature canals where no apical constriction exists (tubular canals) or when canals diverge apically (blunder buss canals) a modification in the master cone has to be done.

A-The inverted cone technique:

This is recommended in cases of tubular canals when the largest gutta percha cone is loose in the canal. A coarse gutta percha cone is selected and the serrated butt end of the cone is removed, the cone is inverted and introduced inside the canal. If the selected inverted cone should reach the full working length, now the exact procedure previously described for lateral condensation is followed .

B-Tailor-made cone technique :

If the tubular canal is so large that the largest inverted cone is still loose in the canal, a tailor made cone is fabricated. This tailor made cone is prepared by heating a number of gutta percha cones and combining them to form a cone which can tightly fit the canal. This procedure is done on a glass slab where the gutta percha cones are rolled together using a hot spatula until they combine together. Again, after fitting this tailor made cone inside the canal, the previously described lateral condensation technique is followed.

II- softened techniques

Softening of gutta percha during the condensation inside the canal have always been proposed. Softened gutta percha can better adapt to aberrations in canal anatomy, in addition a coherent mass of gutta percha offers better sealing than compacted cones. Gutta percha can be softened either thermally or chemically.

(A) Chemically Softened techniques:

A number of chemicals have the ability to soften gutta percha. Perhaps, chloroform is considered the most popular one. However, chloroform have been proven to be highly irritant and exhibit carcinogenic and mutagenic properties which led to the appearance of other less irritating chemicals.

These Include:

- Eucalyptus
- Xylene
- Halothane
- Rectified White turpentine

Chloroform softened gutta percha (chloropercha)

Three techniques have been proposed for chloropercha:

1- Johnston-Callahan technique:
The root canal is flooded with chloroform then the gutta percha master cone is introduced and a regular lateral condensation technique is performed.

2- Placement of master cone in a dappen dish filled with chloroform for few seconds then introducing this softened cone inside the canal. The softened cone is assumed to attain the shape of the apical canal when soft, wait few seconds then withdraw the master cone from the canal coat it with sealer then perform regular lateral condensation technique

3- Nygard-Ostby technique :

A number of gutta percha cones are placed in a dappan dish full with chloroform for few minutes until all cones forms a creamy mix.
A prefitted master cone is dipped in this creamy Mix and a regular lateral condensation technique is performed i.e. the chloropercha mix is used as a sealer.

Disadvantages of chemically softened techniques:
* Chemicals are highly irritant to periapical tissues.
* Chemically softened gutta percha is dimensionally unstable where shrinkage occurs after the evaporation of the chemical used leaving voids.

(B) Heat softened techniques

<u>(1)Thermal applicators</u>

<u>(i) Warm lateral condensation technique :</u>
This technique is similar to the non-softened lateral condensation technique, however, the lateral condensation is done by hot spreaders. Two devices are present on the market:
A- Endotec.
b- Touch 'N' heat.

NB: regular spreaders may be also heated and used to perform warm lateral condensation technique.

<u>(ii) Warm vertical condensation technique:</u>

In this technique, a master cone is fitted similar to the lateral condensation technique but instead of spreaders, gutta percha is vertically condensed using pluggers. Pluggers should be fitted to reach 3 –4 mm from the apex. After the coronal half of the master cone is cut by a hot instrument, the prefitted plugger is used to vertically pack the thermosoftened apical mass of gutta percha. This procedure of thermosoftening and vertical Compaction is repeated several cycles to ensure full adaptation of softened gutta percha inside the canal. At the end of this stage the apical half of the canal is filled, now the coronal half of the canal is filled by any of the injection devices (obtura).

<u>(2) Injection systems</u>
<u>(i) High temperature thermoplasticzed injection technique (Obtura):</u>
The device consists of a pistol like delivery unit for introduction of gutta percha through a 23 gauge silver injection tips. The delivery unit is connected to an electric unit which warms the gutta percha to the desired temperature.
Injection technique : the canal is coated with sealer, the injection needle should be able to reach within 3-5 mm from the working length then injection starts. When the warm gutta percha fills the canal space, the back pressure gradually raises the needle out of the canal. The thermoplasticized gutta percha is then gently compacted with cold

pluggers. This compaction is to be continued until gutta percha cools so as to compensate for cooling shrinkage and minimize small voids due to air entrapment .

(ii) Low temperature thermoplasticzed injection technique (Ultrafill) :

The device consists of preloaded gutta percha filled canules with 22 gauge stainless steel needles. These canules are warmed in a separate heating unit then loaded in a special injection syringe. The injection technique is similar to the obtura.

NB: The success for the thermoplasticized obturation techniques (obtura-Ultrafil) depends on adequate canal preparation.
The canals should be flared more than usual to accommodate the needle size.
A well developed constriction is mandatory to minimize apical extrusion of the filling material.

(3) Thermomechanical compactors

The device resembles a reverse Hedstrom file fitting into a latch type contra angle rotating at 8000-20000 rpm, the heat generated by friction softens the gutta percha while the instrument flutes forces the gutta percha apically and laterally.

(4) Solid Core gutta percha Carriers

These devices consists of alpha-phase gutta percha molded around a metal core resembling an endodontic file (carrier). Initially the central carrier was made of stainless steel, recently, carriers are also made from titanium or plastic.
Carriers are supplied in sizes from 20-140#.
The proposed technique is as follows :

The canal is coated with sealer.
*A gutta percha carrier is selected where its size is equivalent to the size of the master apical file.
*The carrier is heated either in an open flame or in a special oven.
*Now the carrier is introduced slowly inside the canal to the full working length.
*The shaft of the carrier is cut 2 mm above the level of the canal orifice with a bur.
*A cold plugger is used to compact the gutta percha around the carrier.
que (Obtura):