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INSTRUMENTATION OF THE ROOT CANAL SYSTEM

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МЕХАНИЧЕСКАЯ ОБРАБОТКА КОРНЕВЫХ КАНАЛОВ

INSTRUMENTATION OF THE ROOT CANAL SYSTEM

Учебно-методическое пособие

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Изложены базовые принципы механической обработки корневых каналов зубов при эндодонтическом лечении, описаны основные типы применяемых для этого инструментов, а также методики инструментальной обработки корневых каналов.

Предназначено для студентов 3-го курса медицинского факультета иностранных учащихся, обучающихся на английском языке.

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INTRODUCTION

Endodontics is the branch of clinical dentistry associated with the prevention, diagnosis and treatment of the pathosis of the dental pulp and their sequelae. That is, the main aim of the endodontic therapy involves to:

1. Maintain vitality of the pulp.
2. Preserve and restore the tooth with damaged and necrotic pulp.
3. Preserve and restore the teeth which have failed to the previous endodontic therapy, to allow the tooth to remain functional in the dental arch.

Thus we can say that the primary goal of endodontic therapy is to create an environment within the root canal system which allows the healing and continued maintenance of the health of the periradicular tissue. This can be achieved by elimination of microorganisms and their products from the root canal system and to shape it to receive an inert filling material.

> ***Endodontic therapy*** *or* ***root canal therapy*** *is a sequence of treatment for the infected pulp of a tooth which results in the elimination of infection and the protection of the decontaminated tooth from future microbial invasion*

Indications to endodontic treatment:

1. Irreversible pulpitis;
2. Pulp necrosis without or with clinical manifestations;
3. Orthopedic and orthodontic purpose;
4. Apical periodontitis.

True contraindications to endodontic treatment:

1. Insufficient periodontal support;
2. Inadequate crown-tooth ratio;
3. Root and bifurcation caries;
4. Internal resorption with perforation;
5. Vertical root fracture.

False contraindications to endodontic treatment:

1. The presence of broken instruments in the root canal;
2. The presence of calcifications;
3. Anatomical difficulties;
4. Difficulties of endodontic retreatment;
5. Big size of the periapical lesion.

Basic steps of endodontic treatment:

Diagnostic phase.

Preparatory phase.

Filling phase.

This textbook contains the basic principles of preparatory phase, that's mechanical instrumentation of root canals in endodontic treatment, the main types of instruments used for this purpose, as well as working length canals determination and instrumental techniques of root canal treatment.

PREPARATORY PHASE STEPS

Preparatory phase steps:
1) isolation from saliva;
2) access to the root canals;
3) evacuation of infected tissue from the root canal;
4) root canal preparation;
5) root canal irrigation;
6) root canal length determination.

ISOLATION FROM SALIVA

Cofferdam is a thin sheet of natural rubber used for isolating teeth during dental procedures (fig. 1).

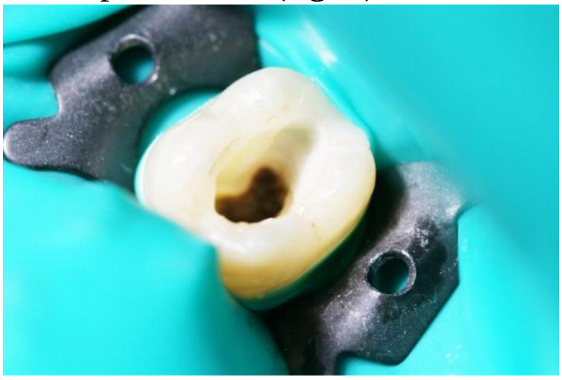

Fig. 1. Adequate isolation of the tooth with the cofferdam system within endodontic treatment

One must remember that the oral cavity is a habitat for millions of bacteria, while saliva and moisture are the biggest enemies of dentistry. Therefore, by isolating teeth with cofferdam, we prevent bacteria from getting into the procedure site.

No Cofferdam – No Endodontics!

The advantages of cofferdam and its recommended use:

1. Protects the patients' and medical staff's health against infection.

2. Prevents the swallowing of an instrument by the patient, as well as mechanical or chemical injuries of the mucous membrane of the oral cavity.

3. It also prevents mechanical injuries of the mucous membrane and, during endodontic treatment, it protects against chemical injury as well.

4. Isolates the operative field from moisture, which has a decisive impact on the final result of the treatment.

ACCESS TO THE ROOT CANALS

Adequate access is essential for successful endodontic treatment. Knowledge of pulp chamber morphology, along with an examination of preoperative radiographs, should be integrated when designing the access cavity to a tooth for nonsurgical root canal treatment. Once the coronal cavity has been adequately prepared, including the removal of carious dentin and defective restorations, a variety of instruments can be used in the process itself. Great variance in overall tooth size, morphology, and arch position means that no two access openings are identical, although common access guidelines have been established depending on the location of the tooth.

Access is the most important phase of nonsurgical root canal treatment. A well-designed access preparation is essential for an optimum endodontic result. Without adequate access, instruments and materials become difficult to handle properly in the highly complex and variable root canal system. The objectives of access cavity preparation consist of the following:

1. To achieve straight-line access to the apical foramen or to the initial curvature of the canal (fig. 2);
2. To locate all root canal orifices;
3. To conserve sound tooth structure.

Fig. 2. This diagram illustrates the importance of straight line access and correctly designed access cavities

The ideal access cavity creates a smooth, straight-line path to the canal system and ultimately to the apex. When prepared correctly, the access cavity allows complete irrigation, shaping, cleaning, and quality obturation. Optimal access results in straight entry into the canal orifice, with the line angles forming a funnel that drops smoothly into the canal(s). Projection of the canal center line to the occlusal surface of the tooth indicates the location of the cavosurface line angles. Connection of the line angles creates the outline form.

Endodontic Coronal Cavity Preparation Principles

1. *Outline Form*
2. *Convenience Form*
3. *Removal of the Remaining Carious Dentin and Defective Restorations*
4. *Cleansing of the Cavity*

The direction and extent of drilling endodontic access cavity preparation should be guided by knowledge of anatomy and radiographic information. To achieve optimal preparation, three factors of internal anatomy must be considered:

- size of pulp chamber;
- shape of pulp chamber;
- the number of individual root canals, their curvature, and their position.

Green V. Black's principles of cavity preparation, including outline, convenience, retention, and resistance forms, should be applied while thinking of an endodontic preparation as a continuum from enamel surface to apex (fig. 3). The entire length of the preparation is the full outline form. Sometimes, this outline may have to be modified for the convenience of a canal anatomy, radicular dilacerations, or insertion of endodontic instruments.

Regardless of the tooth, there are three phases in the preparation of the access cavity:

1. Penetration;
2. Enlargement;
3. Finishing.

Penetration phase. For initial entrance through the enamel surface or restoration the ideal cutting instrument is the round end carbide fissure bur or endo-access diamond stone mounted in a contra-angle handpiece operating at accelerated speed (fig. 4).

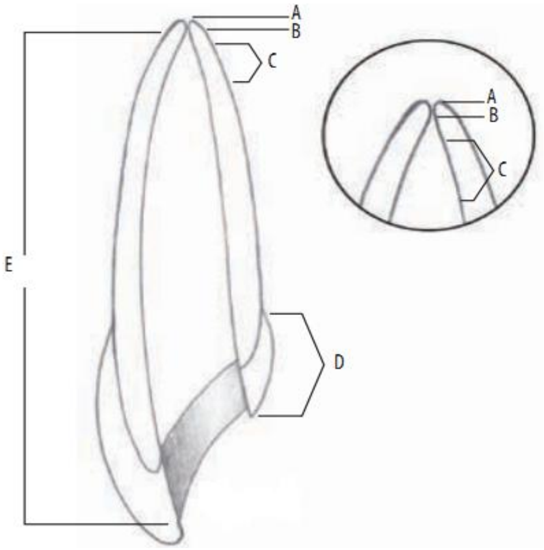

Fig. 3. Black's principles of cavity preparation in relation to endodontic access

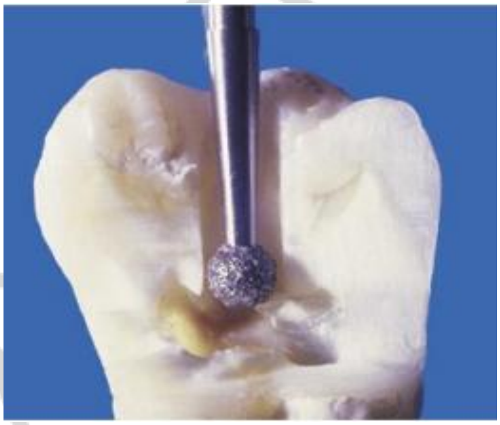

Fig. 4. Penetration phase

Enlargement phase. Includes complete removal of the roof of pulp chamber. Working from inside of the pulp chamber to the outside, the round bur is used to remove the lingual and labial walls of the pulp chamber; the lingual shoulder is removed to give a continuous, smooth flowing preparation (fig. 5). Long-shafted round bur mounted on a low-speed handpiece. It is used for the enlargement phase. The diameter of the bur is always smaller than that of the round, diamond bur used in the preceding phase.

Finishing and flaring phase. This phase requires a non-end-cutting diamond bur, also called self-guiding bur, or Batt's bur mounted on a high-speed handpiece. It is used to finish off the work performed during the preceding two phases and to smoothen the walls of the access cavity, so that the transition between the access cavity and the pulp chamber walls will be imperceptible to probing. With an appropriate angulation, the same bur is also useful for slightly flaring the most occlusal portion of the access cavity externally, so that it meets the requirements listed above (fig. 6).

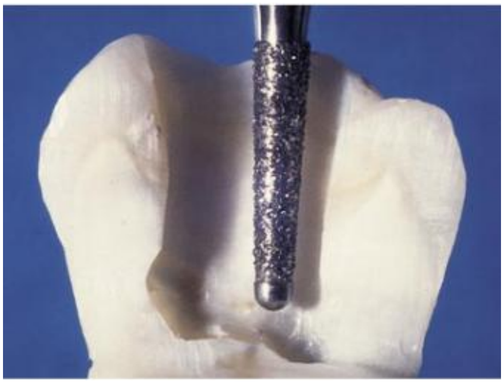

Fig. 5. Enlargement phase

Fig. 6. Finishing and flaring phase

COMMON ACCESS

Maxillary Central Incisors. The morphology of the chamber is triangular in design with high pulp horns on mesial and distal aspects of the chamber. The access opening is triangular in shape. The outline form of the access cavity changes to a more oval shape as the tooth matures and the pulp horns recede because the mesial and distal pulp horns are less prominent. A lingual ledge or lingual bulge is often present (fig. 7 *a*).

Maxillary Lateral Incisors. The chamber is similar to central incisors but proportionately smaller. The access opening is triangular, similar to maxillary central incisors, and proportionately smaller in the middle third of the lingual surface of the tooth. A lingual ledge may also be present but is usually not clinically significant. If a lingual shoulder of dentin is present, it must be removed before instruments can be used to explore the canal (fig. 7 *b*).

Maxillary Canine. The chamber shape is usually elliptical or oval. The access opening is oval on the lingual surface and should be in the middle third of the tooth, both mesio-distally and incisoapically. Because of its shape, the clinician must take care to circumferentially file the access opening labially and palatally to shape and clean the canal properly. A lingual ledge may be present but is usually not clinically significant (fig. 7 *c*).

a ***b*** ***c***

Fig. 7. Common access to the maxillary central incisors, lateral incisors and canine

Maxillary First Premolar. The chamber is usually oval and maintains a similar width from the occlusal level to the floor, which is located just apical to the cervical line. The palatal orifice is slightly larger than the buccal orifice. In cross section at the CEJ, the palatal orifice is wider buccolingually and kidney-shaped because of its mesial concavity. The access opening is oval on the occlusal surface and should be in the middle third of the tooth, both mesiodistally and buccolingually. Buccal and lingual cusps should not be undermined during access opening preparation. The buccal pulp horn usually is larger. There are often ledges of calcification on the buccal and/or lingual walls just coronal to the orifice that may inhibit straight-line access to the canal system (fig. 8 *a*).

Maxillary Second Premolar. The chamber morphology is usually oval. A buccal and a palatal pulp horn are present; the buccal pulp horn is larger. The access opening is oval on the occlusal surface and should be in the middle third of the tooth, both mesiodistally and buccolingually. The buccal and lingual cusps should not be undermined during access opening preparation. The single root is oval and wider buccolingually than mesiodistally, so the canal(s) remains oval from the pulp chamber floor and tapers rapidly to the apex (fig. 8 *b*).

a ***b***

Fig. 8. Common access to the maxillary premolars

Maxillary First Molar. The chamber is usually triangular or square, and the access opening is triangular to slightly square on the occlusal surface. Preparation of the access should be distal to the mesial marginal ridge, within the middle one third buccolingually, and mesial to the transverse ridge. Care should be taken not to undermine the transverse ridge during preparation or to extend the access opening so far mesially as to undermine the mesial marginal ridge. The palatal canal orifice is centered palatally, the distobuccal orifice is near the obtuse angle of the pulp chamber floor, and the main mesiobuccal canal orifice (MB-1) is buccal and mesial to the distobuccal orifice positioned within the acute angle of the pulp chamber. The second mesiobuccal canal orifice (MB-2) is located palatal and mesial to the MB-1. A line drawn to connect the three main canal orifices — MB orifice, distobuccal (DB) orifice, and palatal (P) orifice — forms a triangle known as the molar triangle (fig. 9 *a*).

Maxillary Second Molar. This shape of this chamber is usually less triangular and more oval than the maxillary first molar. The access opening is triangular, but becomes more straightened in a mesiobuccopalatal direction. Preparation of the access should be distal to the mesial marginal ridge, within the middle one-third buccolingually, and mesial to the transverse ridge. Care should be taken not to undermine the transverse ridge during preparation. The opening begins slightly more distally than in the first molar because of the location of the canal and root structure. When four canals are present, the access cavity preparation of the maxillary second molar has a rhomboid shape and is a smaller version of the access cavity for the maxillary first molar. If only three canals are present, the access cavity is a rounded triangle with the base to the buccal. As with the maxillary first molar, the mesial marginal ridge need not be invaded. Because the tendency in maxillary second molars is for the distobuccal orifice to move closer to a line connecting the MB and P orifices, the triangle becomes more obtuse and the oblique ridge is normally not invaded. If only two canals are present, the access outline form is oval and widest in the buccolingual dimension. Its width corresponds to the mesiodistal width of the pulp chamber, and the oval is usually centered between the mesial pit and the mesial edge of the oblique ridge (fig. 9 *b*).

Maxillary Third Molar. The chamber is usually less triangular and more oval in shape than the maxillary second molar. The access opening is somewhat triangular, but tends to rotate as the DB canal orifice becomes more aligned with the palatal canal. Preparation can begin in the central fossae and proceed in a buccopalatal direction. The access cavity form for the third molar can vary greatly, because the tooth typically has one to three canals that would require the access preparation to be anything from an oval that is widest in the buccolingual dimension to a rounded triangle similar to that used for the maxillary second molar. The MB, DB, and P orifices often lie nearly in a straight line. The resultant access cavity is an oval or a very obtuse triangle (fig. 9 *c*).

a ***b*** ***c***

Fig. 9. Common access to the maxillary molars

Mandibular Central and Lateral Incisors. The chamber shape is triangular to oval in design, with high pulp horns on mesial and distal aspects of the chamber in younger patients. A lingual ledge or lingual bulge may be present, which restricts visualization of the canal orifice and prevents straight-line access of the canal system. Often, the access opening must be extended more lingually in order to obtain straight-line access to the lingual orifice and the canal system. In addition, all working length films taken of mandibular incisors should be exposed at a slight mesial or distal angle to confirm the presence or absence of a second canal. Due to their small size and internal anatomy, the mandibular incisors may be the most difficult access cavities to prepare. The external outline form may be triangular or oval, depending on the prominence of the mesial and distal pulp horns. When the form is triangular, the incisal base is short and the mesial and distal legs are long incisogingivally, creating a long, compressed triangle. Without prominent mesial and distal pulp horns, the oval external outline form also is narrow mesiodistally and long incisogingivally. Complete removal of the lingual shoulder is critical, because this tooth often has two canals that are buccolingually oriented, and the lingual canal is most often missed. To avoid this, the clinician should extend the access preparation well into the cingulum gingivally. Because the lingual surface of this tooth is not involved with occlusal function, butt joint junctions between the internal walls and the lingual surface are not required (fig. 10 *a*).

Mandibular Canine. The morphology of the chamber is usually elliptical or oval, and a lingual ledge may be present. The access opening is oval on the lingual surface and should be in the middle one-third of the tooth, both mesiodistally and incisoapically. Preparation of the access cavity for the mandibular canine is oval or slot-shaped. The mesiodistal width corresponds to the mesiodistal width of the pulp chamber. The incisal extension can approach the incisal edge of the tooth for straight-line access, and the gingival extension must penetrate the cingulum to allow a search for a possible lingual canal. As with the mandibular incisors, butt joint relationships between internal walls and the lingual surface are not necessary (fig. 10 *b*).

a ***b***

Fig. 10. Common access to the mandibular central and lateral incisors and canine

Mandibular First Premolar. The chamber shape is usually oval or rounded, as is the access opening on the occlusal surface. As in many other circumstances, above, the access opening should be in the middle third of the tooth, both mesiodistally and buccolingually. Whenever possible, the buccal cusp should be preserved without being undermined during access opening preparation. The oval external outline form of the mandibular first premolar is typically wider mesiodistally than its maxillary counterpart, making it more oval and less slot-shaped. Because of the lingual inclination of the crown, buccal extension can nearly approach the tip of the buccal cusp to achieve straight-line access. Lingual extension barely invades the poorly developed lingual cusp incline. Mesiodistally, the access preparation is centered between the cusp tips. Often the preparation must be modified to allow access to the complex root canal anatomy frequently seen in the apical half of the tooth root (fig. 11 *a*).

Mandibular Second Premolar. As with the mandibular first premolar, the chamber morphology is usually oval or rounded, as is the access opening on the occlusal surface. Additionally, the access opening should be in the middle third of the tooth, both mesiodistally and buccolingually, and the buccal and lingual cusps should not be undermined during access opening preparation. There are at least two variations in the external anatomy that affect the access cavity form of the mandibular second premolar. First, because the crown typically has a smaller lingual inclination, less extension up the buccal cusp incline is required to achieve straight-line access. Second, the lingual half of the tooth is more fully developed. Consequently, the lingual access extension is typically halfway up the lingual cusp incline. The mandibular second premolar can have two lingual cusps, sometimes of equal size. When this occurs, the access preparation is centered mesiodistally on a line connecting the buccal cusp and the lingual groove between the lingual cusp tips. When the mesiolingual cusp is larger than the distolingual cusp, the lingual extension of the oval outline form is just distal to the tip of the mesiolingual cusp (fig. 11 *b*).

a ***b***

Fig. 11. Common access to the mandibular premolars

Mandibular First Molar. The chamber is usually triangular to square in shape. The access opening is triangular to slightly square on the occlusal surface, and its preparation should be distal to the mesial marginal ridge and primarily within the mesial half of the occlusal surface, keeping in mind that the distal extension of the access opening should extend into the distal half of the tooth. The access cavity for the mandibular first molar is typically trapezoid or rhomboid regardless of the number of canals present. When four or more canals are present, the corners of the trapezoid or rhombus should correspond to the positions of the main orifices. Mesially, the access should not invade the marginal ridge. Distal extension must allow straight-line access to the distal canal(s). The buccal wall forms a straight connection between the MB and DB orifices, and the lingual wall connects the ML and DL orifices without bowing (fig. 12 *a*).

Mandibular Second Molar. The chamber morphology is usually triangular. The opening of the access is triangular, but tends to straighten in a mesiodistal direction if two separate orifices are not present in the mesial root. Preparation should be distal to the mesial marginal ridge and primarily within the mesial half of the occlusal surface, although the distal extension of the access opening should extend into the distal half of the tooth. When three canals are present, the access cavity is very similar to that for the mandibular first molar, although perhaps a bit more triangular and less rhomboid. The distal orifice is less often ribbon-shaped buccolingually; therefore, the buccal and lingual walls converge more aggressively distally to form a triangle. The second molar may have only two canals, one mesial and one distal, in which case the orifices are nearly equal in size and line up in the buccolingual center of the tooth. The access cavity for a two-canal second molar is rectangular, wide mesiodistally and narrow buccolingually. The access cavity for a single-canal mandibular second molar is oval and is lined up in the center of the occlusal surface (fig. 12 *b*).

a ***b***

Fig. 12. Common access to the mandibular molars

Mandibular Third Molar. The morphology of the chamber is usually less triangular and more oval than the mandibular second molar. The access opening is also triangular to oval, with a pulp chamber that tends to be very large and very deep. The anatomy of the mandibular third molar is very unpredictable, and the access cavity can take any of several shapes. When three or more canals are present, a traditional rounded triangle or rhombus is typical. When two canals are present, a rectangle is used, and for single-canal molars, an oval. Significant ethnic variation can be seen in the incidence of C-shaped root canal systems. The access cavity for teeth with a C-shaped root canal system varies considerably and depends on the pulp morphology of the specific tooth. These teeth pose a considerable technical challenge; however, use of sonic and ultrasonic instrumentation, and plasticized obturation techniques greatly increase the likelihood of a successful treatment.

Adequate access is essential for successful non-surgical endodontic treatment. A straight line to the canal system that ultimately leads to the apex may achieve optimal results when it is based on knowledge of the internal morphology and observance of the principles of cavity preparation.

«Access is Success!»

ENDODONTIC INSTRUMENTS

Although variety of instruments used in general dentistry, are applicable in endodontics, yet some special instruments are unique to endodontic purpose.

Classification of endodontic instruments

ISO – FDI (Federation Dentaire International) grouped root canal instruments according to their method of use (table 1).

Table 1

Classification of endodontic instruments, ISO – FDI

Group I	Hand use only, for example, K and H-files, reamers, broaches, etc.
Group II	Latch type engine driven: same design as group I but can be attached to handpiece
Group III	Drills or reamers latch type engine driven, for example, Gates-Glidden, Peeso reamers
Group IV	Root canal points like gutta-percha, silver point, paper point

Grossman‘s Classification grouped root canal instruments according to their function and purpose (table 2).

Table 2

Classification of endodontic instruments, Grossman

Function	Instruments
Exploring	Smooth broaches and endodontic explorers (To locate canal orifices and determine patency of root canal)
Dibriding or extirpating	Barbed broaches (To extirpate the pulp and other foreign materials from the root canal)
Cleaning and shaping	Reamers and files (used to shape the canal space)
Obturating	Pluggers, spreaders and lentulospirals (To pack gutta-percha points into the root canal space)

STANDARDIZATION OF ENDODONTIC INSTRUMENTS

For decades, instrumentation of root canals was solely performed using stainless steel (and nickel–titanium) hand files in various forms. All these files have cutting flutes 16 mm long, and for each millimeter of shaft, the diameter increases by 0.02 mm (2 % taper), so the final cutting part of the instrument (known as D16) is 0.32 mm wider than the first part of the tip (known as D1) (fig. 13). Hand files series are color-coded and increase in diameter in set increments, the smallest diameter being 0.06 mm (at D1), and increasing to 1.40 mm (table 3). The D1/D16 distance is also constant (16 mm), so that the working portion of the instruments is always the same, despite the variability of the lengths of the available instruments: short (21 mm) for the molars of patients with small mouths, standard (25 mm), and long (31 mm) for the canines and any particularly long roots.

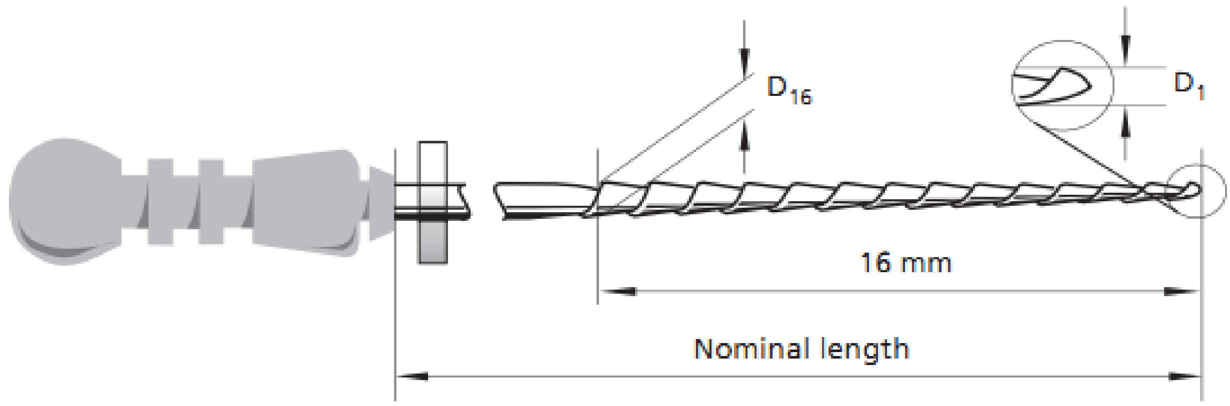

Fig. 13. Drawing showing a hand file (ISO-sized; 2 % taper) with the distances D1 and D16 marked

Table 3

Standardization of endodontic instruments, ISO

color	Color code	New number	diameter	
			At tip	At 16mm
	Pink	6	0.06	0.38
	Gray	8	0.08	0.40
	Purple	10	0.10	0.42
	White	15	0.15	0.47
	Yellow	20	0.20	0.52
	Red	25	0.25	0.57
	Blue	30	0.30	0.62
	Green	35	0.35	0.67
	Black	40	0.40	0.72

Continuance tabl. 3.

color	Color code	New number	diameter	
			At tip	At 16mm
	White	45	0.45	0.77
	Yellow	50	0.50	0.82
	Red	55	0.55	0.87
	Blue	60	0.60	0.92
	Green	70	0.70	1.02
	Black	80	0.80	1.12
	White	90	0.90	1.22
	Yellow	100	1.00	1.32
	Red	110	1.10	1.42
	Blue	120	1.20	1.52
	Green	130	1.30	1.62
	Black	140	1.40	1.72
	White	150	1.50	1.82

To determine the type of instrument, the ISO-symbols are also used (fig. 14). They are represented on the instrument handle

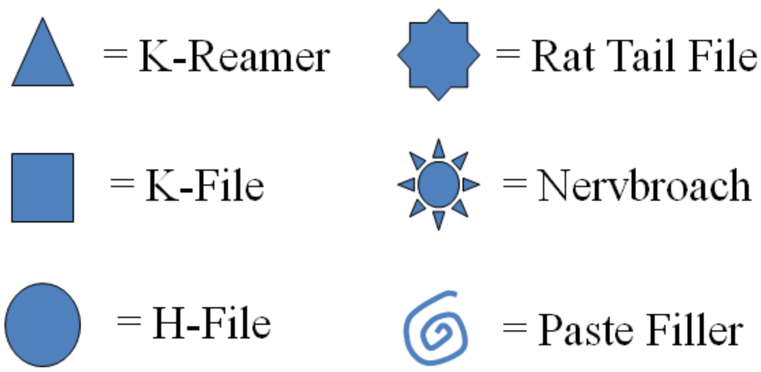

Fig. 14. ISO-symbols in endodontic instruments standardization

The obturating materials were also standardized, so that the manufacturers produce gutta-percha cones and paper points whose size and taper correspond to those of the instruments.

TYPES OF PREPARATION ENDODONTIC INSTRUMENTS

Conventional standardized instruments made of steel may wear quickly in dentin, and small size files may be regarded as disposable. Although some hand files are now available in a nickel-titanium alloy, which is more resistant to wear than ordinary steel, the increased cost and inability to pre-curve has not led to their widespread use. The majority of these modern files are manufactured with a modified non-aggressive tip to prevent iatrogenic damage to the canal system, and improve performance of the instrument. Figure 15 shows the different appearance of the principal types of these instruments.

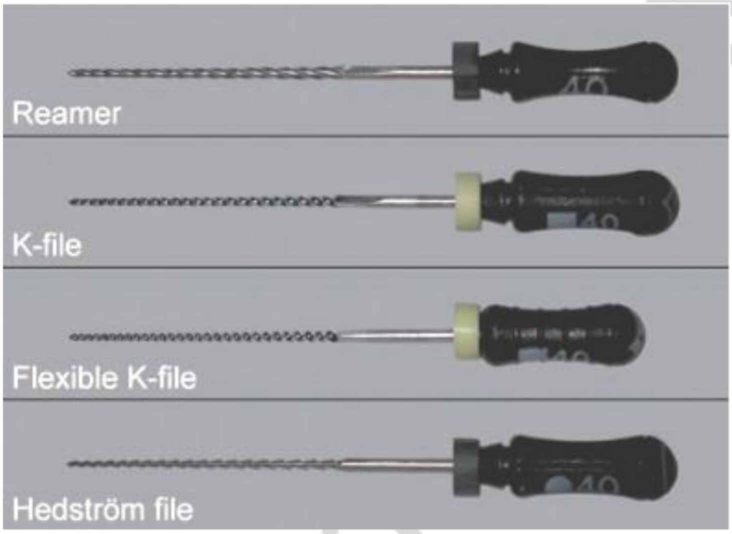

Fig. 15. Various stainless steel hand files (size 40)

Barbed broach. This instrument has sharp rasps pointing towards the handle. They may be used to remove the contents of the root canal before commencing shaping procedures (fig. 16). A vital pulp may be extirpated when carrying out elective endodontic procedures, or when treating a tooth with irreversible pulpitis, by introducing the barbed broach deep into the canal, twisting it a quarter to a half turn, and withdrawing.

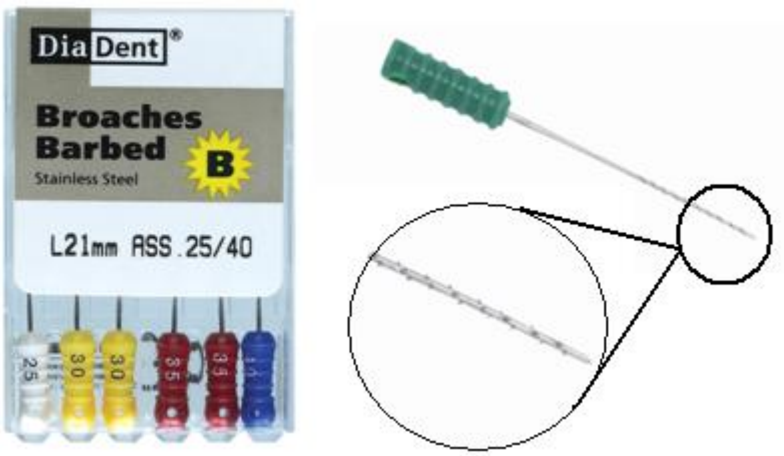

Fig. 16. Barbed broach

Uses of Broach:
- to extirpate pulp tissues (fig. 17);
- to remove cotton or paper points lodged in the canal;
- to loosen the necrotic debris from canal.

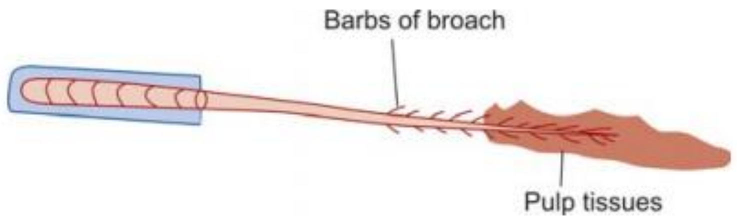

Fig. 17. Pulp extirpation using broach

K-type file (fig. 18). These instruments were originally made from a square or triangular blank, machine twisted to form a tight spiral. The angle of the blades or flutes is consequently near a right-angle to the shank, so that either a reaming or a filing action may be used. The K-type file has been subject to continuous development.

Fig. 18. K-file (size 30)

K-flex Files (fig 19). They were introduced by Kerr manufacturing company in 1982. It was realized that a square blank of file results in total decrease in the instrument flexibility. To maintain shape and flexibility of these files, K-flex files were introduced. K-flex files are rhombus in cross section having two acute angles and two obtuse angles. Two acute angles increase sharpness and cutting efficiency of the instrument. Two obtuse angles provide more space for debris removal. Also, the decrease in contact of instrument with canal walls provide more space for irrigation. They are used in filing and rasping motion.

Fig. 19. K-flex file (size 30)

Flexo Files (Fig. 20). These are similar to the K-Flex files except that they have triangular cross section. This feature provides them more flexibility and thus ability to resist fracture. The tip of file is modified to non-cutting type. They are made up to NiTi. Flexo files have more flexibility but less cutting efficiency.

Fig. 20. Flexo File (size 25)

Hedstroem file (H-file) (fig. 21). The Hedstroem file is machined from a round tapered blank. A spiral groove is cut into the shank, producing a sharp blade. Only a true filing action should be used with this instrument because of the angle of the blade. There is a strong possibility of fracture if a reaming action is used and the blades are engaged in dentin. The Hedstroem file is useful for removing gutta-percha root fillings.

Fig. 21. H-file (size 30)

Safety Hedstrom File. This file has non-cutting safety side along the length of the blade which reduces the chances of perforations. The non-cutting side is directed to the side of the canal where cutting is not required. The non-cutting side of safety file prevents lodging of the canals.

S-file. It is called «S» file because of its cross-sectional shape. S-File is produced by grinding, which makes it stiffer than Hedstrom file. This file is designed with two spirals for cutting blades, forming double helix design (fig. 22). S-file has good cutting efficiency in either filling or reaming action, thus this file can also be classified as a hybrid design. ***C+Files*** are used for complicated and calcified canals. They have better buckling resistance than K-files. They are available in size 8, 10 and 15 of length 18, 21 and 25 mm.

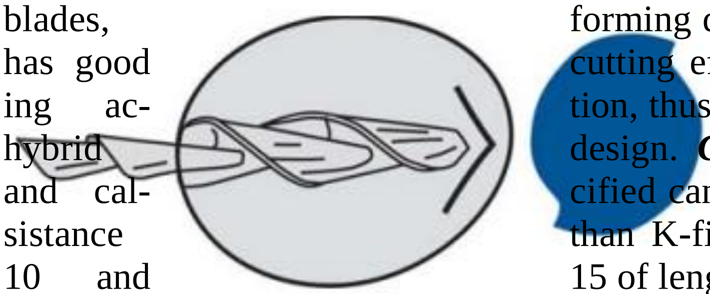

Fig. 22. S-file

Golden Medium Files. These files were described by Weine. They come under intermediate files provided with half sizes between conventional instruments. They are available in sizes from 12-37 like 12, 17, 22, 27, 32 and 37. They are used for narrow canals. They are formed by cutting 1 mm from the tip of the instrument. In this way # 10 file can be converted to # 12, and 15 to # 17, and so on.

Reamer (fig. 23). The reamer is constructed from a square or triangular blank, machine twisted into a spiral but with fewer cutting flutes than a file. The reamer will only cut dentin when it is rotated in the canal; the mode of action described for its use is a quarter to a half turn to cut dentin, and withdrawal to remove the debris. The stiffness of an instrument increases with each larger size, so that larger reamers in curved canals will tend to cut a wider channel near the apical end of the root canal (apical zipping). Considerable damage may be caused to a root canal by an incorrect use of a reamer, and their routine use is no longer

Fig. 23. Reamer

recommended.

Comparative characteristics of files and reamers is shown in Table 4.

Table 4

Difference between files and reamers

Characteristic	Files	Reamers
Cross-section	Square	Triangular
Area of cross-section	More	Less
Flutes	More (1½–2/mm)	Less (½–1 mm)
Flexibility	Less	More (because of less work hardening)
Cutting motion	Rasping	Rotation and penetration, retraction (push and pull)
Preparation shape	Usually avoid	Round
Transport of debris	Poor, because of tighter flutes	Better, because of space present in flutes

ENGINE DRIVEN INSTRUMENTS

Gates-Glidden Burs (fig. 24). Traditional engine driven instruments include Gates-Glidden drills which have flame-shaped cutting point mounted on long thin shaft attached to a latch type shank. Gates-Glidden are available in a set from 1 to 6 with the diameters from 0.5 to 1.5 mm. Due to their design Gates-Glidden drills are side cutting instruments with safety tips. They should be used at the speed of 750-1500 rpm in brushing strokes. Safety design of Gates-Glidden is that its weakest part lies at the junction of shank and shaft of the instrument. If its cutting tip jams against the canal wall, fracture occurs at the junction of shank and the shaft but not at the tip of the instrument. This makes an easy removal of the fractured drill from the canal. They can be used both in crown down as well as step back fashion.

Uses of Gates-Glidden Drills

1. For coronal flaring during root canal preparation;

2. During retreatment cases or post space preparation for removal of gutta-percha;

3. During instrument removal, if used incorrectly for example using at high rpm, incorrect angle of insertion, forceful drilling, the use of Gates-Glidden can result in procedural accidents like perforations, instrument separation, etc.

Flexogates. Flexogates are modified Gates-Glidden. They are made up of NiTi and have non-cutting tip. They are more flexible and used for apical preparation. Flexogates can be rotated continuously in a handpiece through 360°. These instruments have many advantages over the traditional instruments in that they allow increased debris removal because of continuous rotation, smoother and faster canal preparation with less clinician fatigue.

Advantages of Flexogates

1. Safe non-cutting guiding tip.

2. Safety design, i.e. its breakage point is 16 mm from the tip, so once fractured, it can be easily retrieved.

3. Flexible, so used in curved canals.

Fig. 25. Peeso Reamers

Peeso Reamers (fig. 25). They are rotary instruments used mainly for post space preparations. They have safe ended non-cutting tip. Their tip diameter varies from 0.7 to 1.7 mm, and they should be used in brushing motion.

Disadvantages of using peeso reamers:

1. They do not follow the canal curvature and may cause perforation by cutting laterally.

2. They are stiff instruments.

3. They have to be used very carefully to avoid iatrogenic errors.

NICKEL TITANIUM (NITI) ENDODONTIC INSTRUMENTS

The latest developments in file design have seen a move away from the ISO standard 2 % taper to files with increasing tapers of up to 12 %, made in a nickel-titanium alloy. Although most of these new developments are used with an electric motor, hand files of greater taper are available.

When using the stainless steel files, occurrence of procedural errors cannot be avoided especially in case of curved canals. Deviation from the original shape, ledge formation, zipping, stripping and perforations are the common problems which are seen in curved canals. But the superelasticity of NiTi alloy allows these instruments to flex more than the stainless steel instruments before exceeding their elastic limit, thereby allowing canal preparation with minimal procedural errors. NiTi was developed by Buchler 40 years ago. NiTi is also known as the NiTinol (NiTi Navol Ordinance Laboratory in US). In endodontics commonly used NiTi alloys are called 55 NiTinol (55 % weight Ni and 45 % Ti) and 60 NiTinol (60 % weight of Ni, 40 % Ti). First use of NiTi in endodontics was reported in 1988, by Walia et al when a #15 NiTi file was made from orthodontic wire and it showed superior flexibility and resistance to torsional fracture. This suggested the use of NiTi files in curved canals.

Advantages of NiTi Alloys:

1. Shape memory.
2. Superelasticity.
3. Low modulus of elasticity.
4. Good resiliency.
5. Corrosion resistance.
6. Softer than stainless steel.

Disadvantages of NiTi Files:

1. Poor cutting efficiency.
2. NiTi files do not show signs of fatigue before they fracture.
3. Poor resistance to fracture as compared to stainless steel.

NiTi rotary instrumentation should always be performed with slow-speed, low-torque or «right-torque» electric motors (fig. 26). A variety of motors exist from varying manufacturers including the Tecnika ATR and Aseptico ITR both of which were designed specifically for endodontics and are supplied by Tulsa Densply. These types of electronic motors have preprogrammed speed and torque values preset by the manufacturer for their recommended instruments. The units also allow the operator to adjust the manufacturers' settings to the specific needs of the user. An additional benefit to the electric motors is the auto-reverse feature which is activated prior to reaching the elastic torque limit of the file, potentially reducing the possibility of instrument separation. Also available are air driven motors that connect to a slow-speed attachment on the dental unit. The air driven motors are less expensive than the electric motors. However, they are unable to control torque and do not have an auto-reverse feature.

Fig. 26. Electric endomotor with speed and torque control handpiece

The past few years have seen a dramatic increase in the number of manufacturers producing NiTi rotary files. The most popular systems are marketed by Tulsa Dental and Sybron Endo (formally Analytic Technologies). Tulsa markets both the ProSystem GT and ProTaper lines of rotary instruments, where Sybron Endo markets K3 (the successor of the Quantec line of files).

Greater taper files (GT FILES) (fig. 27). The GT rotary instruments possess a U-shaped file design with ISO tip sizes of 20, 30 and 40 and tapers of 0.04, 0.06, 0.08, 0.10 and 0.12. Accessory GT files for use as orifice openers of 0.12 taper in ISO sizes of 35, 50, 70 and 90 are also available. The maximum diameter of these instruments is 1.50 mm. Recommended rotational speed for GT files is 350 rpm. Negative rake angle of these files makes them scrape the dentin rather than cut it.

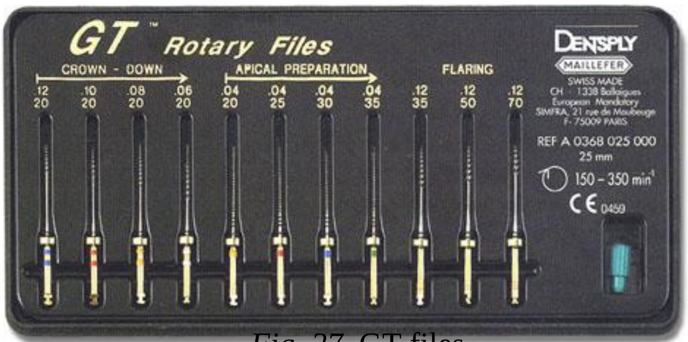

Fig. 27. GT files

ProSystem GT™. ProSystem GT is the next evolution of the Greater Taper series (GT) Profile instruments. The file has traditional U-shaped flutes to lift debris coronally, safe-ended tips that reduce the risk of apical transportation, ledging, or perforation, and varied pitch and sharpness along flutes to reduce the potential for threading into the canal (4). Files are available in three different ISO tip sizes #20, #30, and #40 corresponding to small, medium, and large canals respectively with varying tapers from 0.10 to 0.04 in 0.02 increments. The manufacturer recommends crowning down beginning with the 0.10 taper instrument and continuing with the 0.08, 0.06, and 0.04. Once the working length has been reached with the 0.04 taper instrument, the operator can either choose to increase the taper by using the previous instrument to the full working length (i.e. the 0.06 taper instrument), increase the apical preparation size by selecting the next larger apical tip size with the same taper as the last instrument to reach the working length, or terminate the preparation.

ProTaper™ (fig. 28, 29). ProTaper files are marketed to instrument difficult, highly calcified, and severely curved root canals. They are available as rotary and manual types. The progressive taper and advanced flute design reportedly provide the flexibility and efficiency to achieve consistent, successful cleaning and shaping when faced with these challenges. A unique feature of the ProTaper instrument is the convex triangular cross-section which reduces the contact area between the file and dentin (fig. 30). The greater cutting efficiency has been purportedly safely incorporated through balancing the pitch and helical angles. These instruments also have a partially active tip which cuts as it moves apically (5). The system consists of six files beginning with the SX, or Shaping X file, which is used to optimally shape canals in shorter roots, relocate canals away from external root concavities, and to produce more shape, as desired, in the coronal aspects of canals in longer roots. The shaping 1 (S-1), and shaping 2 (S-2) files have increasingly larger tapers over the length of their cutting blades allowing each instrument to engage, cut and prepare a specific area of the canal. S-1 is designed to prepare the coronal one-third of a canal, whereas, S-2 enlarges and prepares the middle one-third. Although both instruments optimally prepare the coronal two thirds of a canal, they do progressively enlarge its apical one-third. The finishing files, or F1, F2 and F3 instruments, reportedly optimally finish the apical one-third, while progressively and subtly expanding the shape in the middle one-third of the canal. The manufacturer states that generally only one finishing instrument is required to prepare the apical one-third of a canal and the one selected is based on the canal's curvature and cross-sectional diameter.

Fig. 28. Handle ProTaper

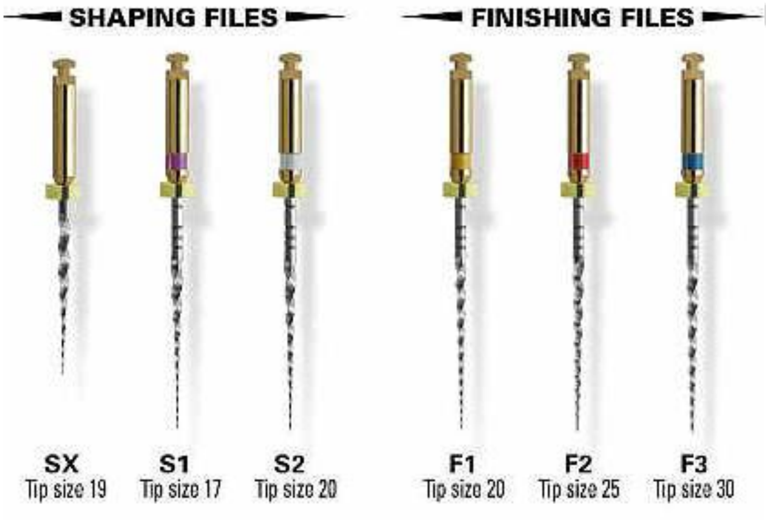

Fig. 29. Rotary ProTaper files

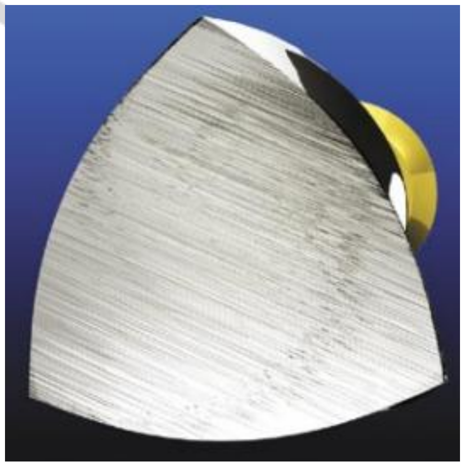

Fig. 30. Convex triangular cross-section of the ProTaper

WAVE ONE™ File System WaveOne instruments are single file technique with reciprocation. The 3 WaveOne instruments are termed small (yellow 21/06), primary (red 25/08), and large (black 40/08). The small 21/06 file has a fixed taper of 6 % over its active portion. The primary 25/08 and the large 40/08 WaveOne files have fixed tapers of 8 % from D1 to D3, whereas from D4 to D16, they have a unique progressively decreasing percentage tapered design. This design serves to improve flexibility and conserve remaining dentin in the coronal two thirds of the finished preparation.

Another unique design feature of the WaveOne files is that they have a reverse helix and 2 distinct cross-sections along the length of their active portions (fig. 31). From D1 to D8, the WaveOne files have a modified convex triangular cross section, whereas from D9 to D16, these files have a convex triangular cross section. The WaveOne files have non-cutting modified guiding tips, which enables these files to safely progress through virtually any secured canal. Together, these design features enhance safety and efficiency when shaping canals that have a confirmed, smooth, and reproducible glide path. The files are manufactured with M-wire technology which significantly improves the resistance to cyclic fatigue by almost 400 %.

Fig. 31. WAVE ONE™ File System and X Smart Plus endomotor with reciprocation function

The advantages of the reciprocating technique are numerous:

- It makes it possible to shape most root canals using only one single file.
- It decreases total shaping time up to 40 % versus a traditional rotary technique in continuous motion.
- Optimized reciprocating angles reduce the risk of a screwing effect and file breakage.
- It has a geometry conceived specifically to provide maximum user benefits from the reciprocating movement of the e3® torque control motor.

ProTaper NEXT™ (fig 32, 33) is the newest innovation to the ProTaper® system. It is innovative off-centred rectangular cross section gives the file a snake like «swaggering» movement as it moves through the root canal. The rotation of the off-centered cross section generates enlarged space for debris hauling. Optimization of canal tracking is also achieved due to the «swaggering effect». The M-WIRE® NiTi material improves file flexibility, while still retaining cutting efficiency M-WIRE® NiTi also provides greater resistance to cyclic fatigue, the leading cause of file separation.

Fig. 32. ProTaper NEXT cross-section

Endodontic files exhibit signs of wear during normal use. They are also subject to cyclic fatigue, which is the main cause of file breakage during the patient's treatment. This increases dramatically with multiple use. Single use therefore reduces the risk of file breakage and thus increases the patient's safety.

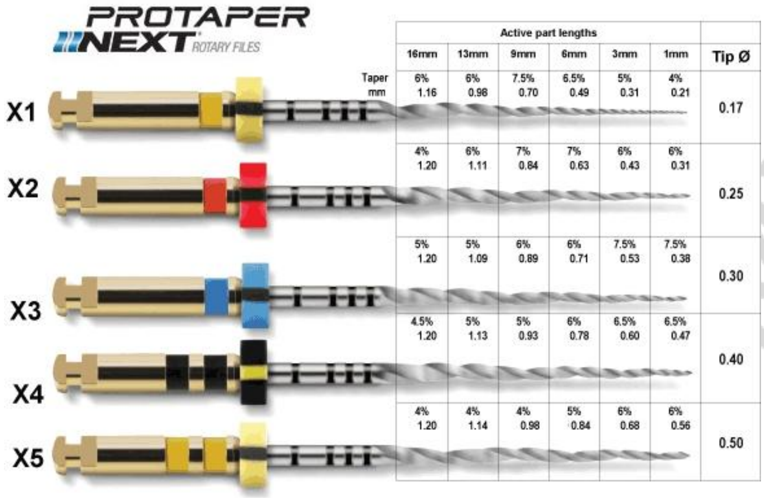

Fig. 33. ProTaper NEXT files

PathFile™ — Mechanical Glide Path Files (fig. 34). PathFiles are rotary NiTi files that are used to create a mechanical glide path and preflare the canal, a task that is normally carried out with stainless steel hand files. Because of the relative stiffness of stainless steel instruments, it can be difficult to avoid the risk of canal transportation, ledges and apical zipping. Flexible and resistant to cyclic fatigue, PathFiles can offer a number of advantages compared to manual solutions.

Fig. 34. PathFile™

A significant risk during NiTi rotary instrumentation is instrument separation. When the instruments are stressed over time, the crystalline structure can change or deform making the files weaker and more prone to reaching their elastic limit. When this occurs, the instrument undergoes plastic deformation and if the stress is not relieved, instrument failure will result. Current studies show that these instruments can be used safely in up to a maximum of 10 canals; however, a single use in a very difficult canal should warrant disposal of the file. The use of a labeling system to keep track of file usage is highly recommended. A major advantage to NiTi rotary systems is the use of the crown down technique. Crowning down has been shown to effectively pull debris and pulpal remnants out of the canal rather than push them into the periradicular tissues. In addition, early coronal flaring makes instrumentation easier and increases the efficiency of electronic apex locators.

EVACUATION OF INFECTED TISSUE FROM THE ROOT CANAL

As far as the main aim of the endodontic treatment is elimination of microorganisms and their products from the root canal system and to shape it to receive an inert filling material, the first stage of the preparatory phase is evacuation of infected pulp from the root canal.

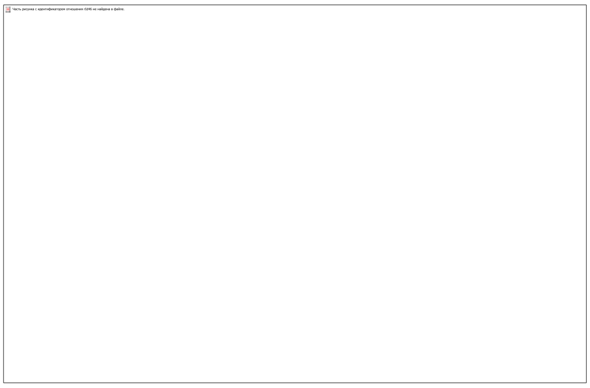

Fig. 35. Removing the infected pulp with the barbed broach

Technique of pulp extirpation (Healey, 1984)

Penetrate the barbed broach along the canal wall towards the apex.
As it reaches the apical constriction, move it into the center of mass of pulp tissue

Rotate the broach several times in a watch winding manner to entrap the pulp which is then withdrawn from the canal (fig. 35).

Broach should not be forced apically into the canal, as its barbs get compressed by the canal wall. While removing this embedded instrument, barbs get embedded into dentin and broach may break on applying pressure.

ROOT CANAL PREPARATION

Mechanical preparation refers to controlled removal of dentin by manipulating root canal instruments. Factors influencing the amount and pattern of dentin removal are:

- design and sharpness of the cutting edge;
- the manner in which it is manipulated;
- the force applied, and the operator's skill.

The operator's skill is influenced by the ability to discriminate tactile feedback from the instrument and the ability to manipulate the instruments in a controlled way according to the mental image of a three dimensional shape of the root canal system.

The mechanics of cleaning and shaping may be viewed as an extension of the principles of coronal cavity preparation to the full length of the root canal system. Schilder gave five mechanical objectives for successful cleaning and shaping 30 years ago. The objectives taught the clinicians to think and operate in three dimensions.

The objectives given by Schilder are:

1. The root canal preparation should develop a continuously tapering cone: This shape mimics the natural canal shape. Funnel shaped preparation of canal

should merge with the access cavity so that instruments will slide into the canal. Thus access cavity and root canal preparation should form a continuous channel.

2. Making the preparation in multiple planes which introduces the concept of «flow»: This objective preserves the natural curve of the canal.

3. Making the canal narrower apically and wider coronally: To create continuous tapers up to apical third which creates the resistance form to hold gutta-percha in the canal.

4. Avoid transportation of the foramen: There should be gentle and minute enlargement of the foramen while maintaining its position.

5. Keep the apical opening as small as possible: The foramen size should be kept as small as possible as overlapping of foramen contributes to a number of iatrogenic problems.

DIFFERENT MOVEMENTS OF INSTRUMENTS

Reaming. Ream indicates use of sharp edged tool for enlarging holes. In endodontic practice, reaming is commonly done by use of reamers , though files can also be used. It involves clockwise rotation of an instrument. The instrument may be controlled from insertion to generate a cutting.

Filing. The term filing indicates push-pull motion with the instrument. This method is commonly used for canal preparation.

Combination of Reaming and Filing. In this technique, the file is inserted with a quarter turn clockwise and apically directed pressure (i.e. reaming) and then is subsequently withdrawn (i.e. filing).

Balanced Force Technique. This technique involves oscillation of instrument right and left with different arcs in either direction. Instrument is first inserted into the canal by moving it clockwise with one quarter turn. Then cut dentin; the file is rotated counter clockwise and simultaneously pushed apically to prevent it from backing out of the canal. Finally, the file is removed by rotating file clockwise simultaneously pulling the instrument out of the canal.

This technique offers most efficient dentin cutting but care should be taken not to apply excessive force with this technique because it may lock the instrument into the canal.

Watch Winding. It is back and forth oscillation of the endodontic instrument (file or reamer) right and left as it is advanced into the canal. The angle of rotation is usually 30 to 60 degrees. This technique is efficient with K-type instruments.

Basically, there are two approaches used for biomechanical preparation, either starting at the apex with fine instruments and working up to the orifice with progressively larger instruments, — this is ***Step back*** technique, or starting at the orifice with larger instruments and working up to apex with larger instruments, — this is ***Crown down*** technique.

STEP BACK TECHNIQUE

Step back technique is also known as Telescopic canal preparation or serial root canal preparation (fig. 36). Step back technique emphasizes keeping the apical preparation small, in its original position and producing a gradual taper coronally.

This technique was first described in 1960 by Mullaney. Basically this technique involves the canal preparation into two phases; phase I involves the preparation of apical constriction and phase II involves the preparation of the remaining canal.

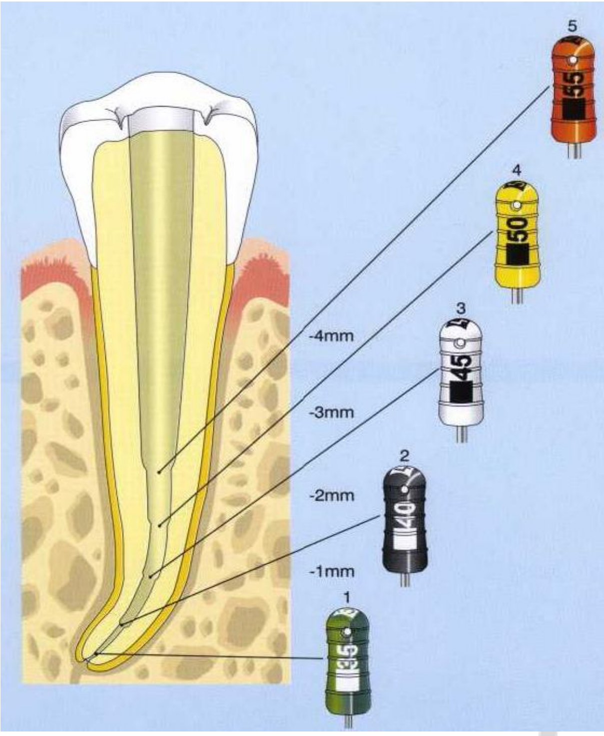

Fig. 36. Step back technique

Phase I

1. Evaluate the carious tooth before initiating endodontic treatment.
2. Initially prepare the access cavity, and locate the canal orifices.
3. Establish the working length of the tooth using pathfinder.
4. Now insert the first instrument into the canal with watch winding motion. In watch winding motion, a gentle clockwise and anticlockwise rotation of file with minimal apical pressure is given.
5. Remove the instrument and irrigate the canal.
6. Don't forget to lubricate the instrument for use in apical area because it is shown that lubricant emulsifies the fibrous pulp tissue allowing the instrument to remove it whereas irrigants may not reach the apical area to dissolve the tissues.
7. Place the next larger size files to the working length in similar manner and again irrigate the canal.
8. Don't forget to recapitulate the canal with previous smaller number instrument. This breaks up apical debris which are washed away with the irrigant.
9. Repeat the process until a size 25 K-file reaches the working length. Recapitulate between the files by placing a small file to the working length.

Phase II

1. Place next file in the series to a length 1 mm short of working length. Insert the instrument into the canal with watch winding motion, remove it after circumferential filing, irrigate and recapitulate.
2. Repeat the same procedure with successively larger files at 1 mm increments from the previously used file.
3. Similarly mid canal area and coronal part of the canal is prepared and shaped with larger number files.
4. Finally, refining of the root canal is done by master apical file with push-pull strokes to achieve a smooth taper form of the root canal.

Advantage of Step Back Technique. More flare at coronal part of root canal with proper apical stop.

Disadvantages of Step Back Technique:

1. Difficult to irrigate apical region
2. More chances of pushing debris periapically.
3. Time consuming.
4. Increased chances of iatrogenic errors for example ledge formation in curved canals.
5. Difficult to penetrate instruments in canal.
6. More chances of instrument fracture.

CROWN DOWN TECHNIQUE

In the crown down technique, the dentist prepares the canal from crown of the tooth, shaping the canal as the instrument moves towards the apical portion of the canal (fig. 37). Morgan and Montgomery found that this «crown down pressureless» techniques resulted in a rounder canal shape when compared to usual step back technique. Moreover, many studies have shown that greater apical enlargement without causing apical transportation can be achieved if coronal obstructions are eliminated.

Technique of Crown Down Preparation

1. The first step in the crown down technique is the access cavity preparation with no pulp chamber obstructions. Locate the canal orifices with sharp explorer, which shows binding in the pulp chamber.

2. Now fill the access cavity with an irrigant and start preflaring of the canal orifices. Preflaring of the coronal third of the canal can be done by using hand instruments, Gates-Glidden drills or the nickle-titanium rotary instruments.

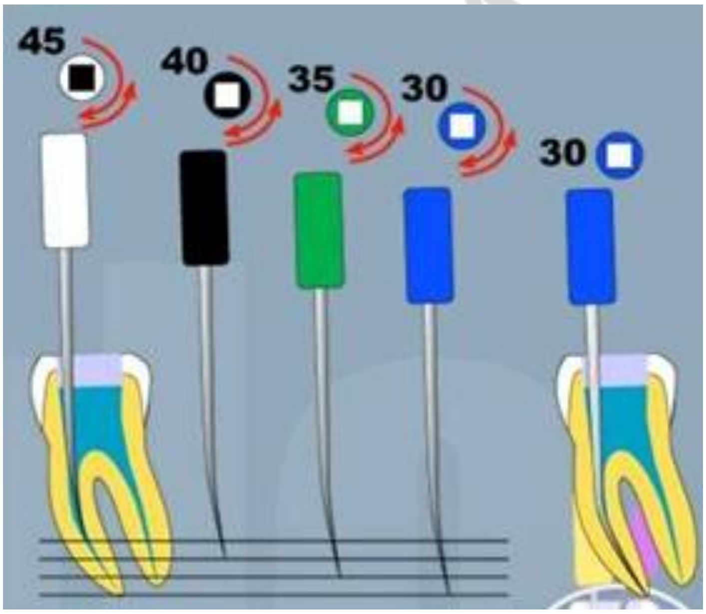

Fig. 37. Crown Down technique

3. Gates-Glidden drills can be used after scouting the canal orifices with # 10 or 15 files. The crown down approach begins with larger Gates-Glidden first. After using this subsequent, smaller diameter, Gates-Glidden are introduced into the canal with additional mm to complete coronal flaring. One should take care to avoid carrying all the Gates-Glidden drills to the same level, which may lead to excessive cutting of the dentin, weakening of the roots and thereby «Coke Bottle Appearance» in the radiographs.

4. Frequent irrigation with sodium hypochlorite and recapitulation with a smaller file (usually # 10 file) to prevent canal blockage.

5. After establishing coronal and mid root enlargement, explore the canal and establish the working length with small instruments.

6. Introduce larger files to coronal part of the canal and prepare it. Subsequently introduce progressively smaller number files deeper into the canal in sequential order and prepare the apical part of the canal.

7. Final apical preparation is prepared and finished along with frequent irrigation of the canal system. The classical apical third preparation should have a tapered shape which has been enlarged to at least size 20 at apex and each successive instrument should move away from the foramen by 1/2 mm increments.

Biological Benefits of Crown Down Technique

1. Removal of tissue debris coronally, thus minimizing the extrusion of debris periapically.

2. Reduction of postoperative sensitivity which could result from periapical extrusion of debris.

3. Greater volumes of irrigants can reach irregularities in the canal in early stages of canal preparation because of coronal flaring.

4. Better dissolution of tissue with increased penetration of the irrigants.

5. Rapid removal of contaminated and infected tissues from the root canal system.

Clinical Advantages of the Crown Down Technique

1. Enhanced tactile sensation with instruments because of coronal interferences removal.

2. Flexible (smaller) files are used in apical portion of the canal; whereas larger (stiffer) files need not be forced but kept short of the apex.

3. In curved canals, after doing coronal flaring, files can go up to the apex more effectively due to decreased deviation of instruments in the canal curvature.

4. Provides more space for irrigants.

5. Straight line access to root curves and canal junctions.

6. Enhanced movement of debris coronally.

7. Desired shape of canal can be obtained that is narrow at apex, wider coronally.

8. Predictable quality of canal cleaning and shaping.

9. Decreased frequency of canal blockages.

The crown down is often suggested as a basic approach using nickel-titanium rotary instruments.

BALANCED FORCE TECHNIQUE

This technique was developed by Roane and Sabala in 1985. It involves the use of instrument with noncutting tip. Since the K-type files have pyramidal tips with cutting angles which can be quite aggressive with clockwise rotation. For this technique, use of triangular cross sectioned instruments should be done. The decreased mass of the instrument and deeper cutting flutes improve the flexibility of instrument and decrease the restoring force of the instrument when placed in curved canals. Use of Flex-R files is recommended for this technique. This file has «safe tip design» with a guiding land area behind the tip which allows the file to follow the canal curvature without binding in the outside wall of the curved canal.

Technique:

1. In balanced force technique, first file which binds short of working length is inserted into the canal and rotated clockwise a quarter of a turn. This movement causes flutes to engage a small amount of dentin.

2. Now, file is rotated counterclockwise with apical pressure at least one third of a revolution. It is the counterclockwise rotation with apical pressure which actually provides the cutting action by shearing off small amount of dentin engaged during clockwise rotation.

3. If there is little curvature or if instrument does not bind, only one or two counterclockwise motions are given. It should not be forced to give the counterclockwise rotation because it may lead to fracture of the instrument.

4. Then a final clockwise rotation is given to the instrument which loads the flutes of file with loosened debris and the file is withdrawn.

Advantages of Balanced Force Technique:

- with the help of this technique, there are lesser chances of canal transportation;
- one can manipulate the files at any point in the canal without creating a ledge or blockage;
- file cutting occurs only at apical extent of the file.

ENGINE DRIVEN PREPARATION WITH NITI INSTRUMENTS

These instruments were introduced in early 1990s, and since then they have become indispensable tools for canal enlargement. Before using these instruments one should take care to have a straight line access to the canal system. Canals should be thoroughly explored and passively enlarged before using rotary instrument. Instruments should be constantly moving and speed of rotation of each instrument should be known.

All of these NiTi rotary systems incorporate:

1. Crown down preparation.
2. Apical preparation as finale.
3. Increasing taper instruments.

PROTAPER FILES

As we have seen ProTaper files have a triangular cross-section and are variably tapered across their cutting length. The progressively tapered design improves flexibility, cutting efficiency and the safety of these files.

The ProTaper system consists of three shaping and three finishing files.

1. Shaping files are termed as Sx, S1 and S2.

Sx these are files of shorter length of 19 mm with D1 diameter of 0.19 mm and D14 diameter of 1.20 mm. The increase of taper up to D9 and then taper decrease up to D14 increases its flexibility.

S1 has D1 diameter of 0.17 mm and D14 of 1.20 mm; it is used to prepare coronal part of the root.

S2 has D1 diameter of 0.20 mm and D14 of 1.20 mm; it is used to prepare middle third of the canal.

2. Finishing files F1, F2, F3 are used to prepare and finish apical part of the root canal.

F1 D1 diameter and apical taper is 20 and 0.07.

F2 D1 diameter and taper is 25 and 0.08.

F3 D1 diameter and taper is 30 and 0.09.

Clinical Technique (fig. 38):

1. The foremost step is gaining straight line access to the canal orifices.
2. Establish a smooth glide path before doing any instrumentation with ProTaper system.
3. Now prepare the coronal third of the canal by inserting S1 into the canal using passive pressure. Don’t go more than third fourth of the estimated canal length.
4. Irrigate and recapitulate the canal using #10 file.
5. In shorter teeth, use of Sx is recommended.
6. After this, S2 is worked up to the estimated canal length.
7. Now confirm the working length using small stainless steel K- files up to size 15 by electronic apex locators and/or with radiographic confirmation.
8. Use F1, F2 and F3 (if necessary) finishing files up to established working length and complete the apical preparation. Then refine the apical preparation using corresponding stainless steel file to gauge the apical foramen and to smoothen the canal walls.

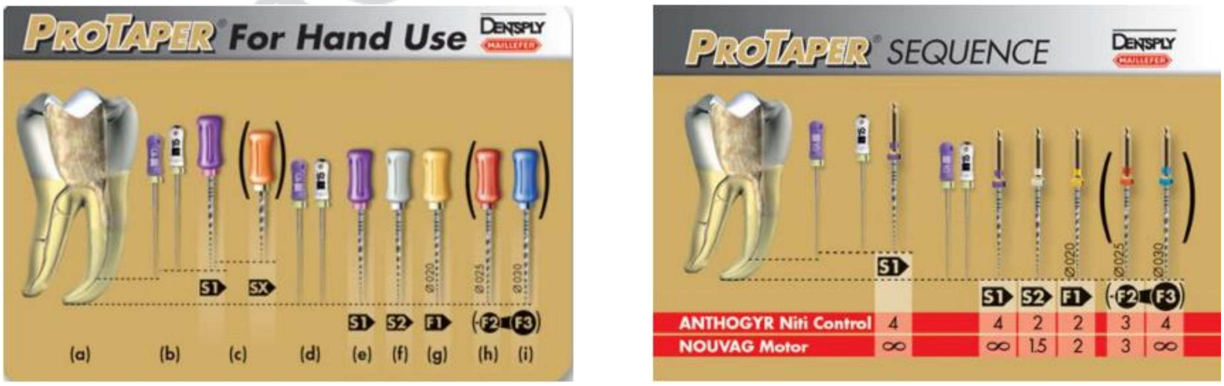

Fig. 38. ProTaper technique

Advantages of ProTaper Files:

1. ProTaper files have modified guiding tip, which allows them to follow the canal better.
2. Variable tip diameters of ProTaper files allow them to have specific cutting action in defined area of canal without stressing instrument in other sections.
3. Changing helical angle and pitch over the cutting blades of ProTaper files reduce the instruments from screwing into the canal and allow better removal of debris.
4. ProTaper files act in active motion, this further increases its efficiency and reduces torsional strain.
5. Length of file handle is reduced from 15 to 17.5 mm, which allows better access in posterior areas.

ROOT CANAL LENGTH DETERMINATION

Determination of an accurate working length is one of the most critical steps of endodontic therapy. The cleaning, shaping and obturation of root canal system cannot be accomplished accurately unless working length is determined precisely.

DEFINITIONS

According to endodontic glossary, ***working length*** is defined as *«the distance from a coronal reference point to a point at which canal preparation and obturation should terminate».*

Reference point: Reference point is that site on the occlusal or incisal surface from which measurements are made. A reference point is chosen; it should be stable and easily visualized during preparation. Usually, this is the highest point on incisal edge of anterior teeth and buccal cusp of posterior teeth (fig. 39). Reference point should not change between the appointments.

Anatomic apex is «tip or end of root determined morphologically».

Radiographic apex is «tip or end of root determined radiographically».

Apical foramen is main apical opening of the root canal which may be located away from anatomic or radiographic apex.

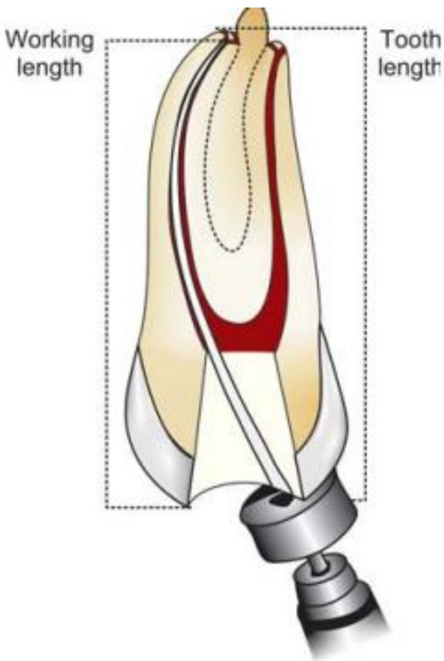

Fig. 39. Working length distance is defined as the distance from coronal referencer point to a point where canal preparation and obturation should terminate

Apical constriction (minor apical diameter) is apical portion of root canal having narrowest diameter. It is usually 0.5–1 mm short of apical foramen (fig. 40). The minor diameter widens apically to foramen, i.e. major diameter.

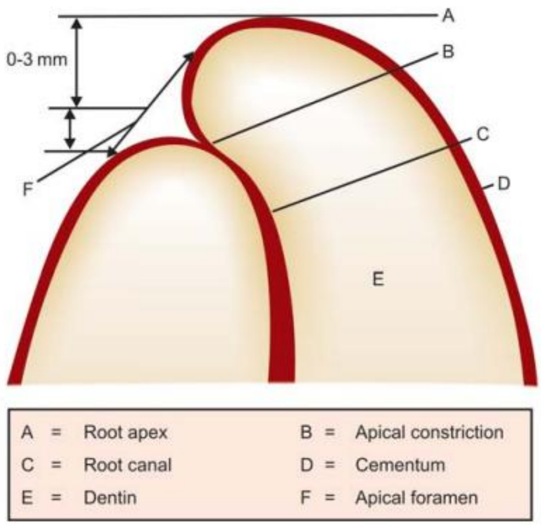

Fig. 40. Anatomy of root apex

Significance of working length

Working length determines how far into canal, instruments can be placed and worked.

It affects degree of pain and discomfort which the patient will experience following appointment by virtue of over and under instrumentation.

If placed within correct limits, it plays an important role in determining the success of treatment.

Before determining a definite working length, there should be straight line access for the canal orifice for unobstructed penetration of instrument into apical constriction.

Once apical stop is calculated, monitor the working length periodically because working length may change as curved canal is straightened.

Failure to accurately determine and maintain working length may result in length being over normal, which will lead to postoperative pain, prolonged healing time and lower success rate because of incomplete regeneration of cementum, periodontal ligament and alveolar bone.

When working length is made short of apical constriction it may cause persistent discomfort because of incomplete cleaning and underfilling. Apical leakage may occur into uncleaned and unfilled space short of apical constriction. It may support continued existence of viable bacteria and contributes to the periradicular lesion and thus poor success rate.

Consequences of overextended working length:

- Perforation through apical construction
- Overinstrumentation
- Overfilling of root canal
- Increased incidence of postoperative pain
- Prolonged healing period
- Lower success rate due to incomplete regeneration of cementum, periodontal ligament and alveolar bone.

Consequences of working short of actual working length

- Incomplete cleaning and instrumentation of the canal
- Persistent discomfort due to presence of pulpal remnants
- Underfilling of the root canal
- Incomplete apical seal

– Apical leakage which supports existence of viable bacteria, this further leads to poor healing and periradicular lesion.

– Causes of loss of working length
– Presence of debris in apical 2–3 of canal
– Failure to maintain apical patency
– Skipping instrument sizes
– Ledge formation
– Inadequate irrigation
– Instrument separation
– Canal blockage.

Different methods of working length determination

Various methods for determining working length include using average root lengths from anatomic studies, preoperative radiographs, tactile sensation, etc. Other common methods include use of paper point, working length radiograph, electronic apex locators or any combination of the above.

Directional Stop Attachments

Most commonly stoppers used for endodontic instruments are silicon rubber stops (fig. 41), though stop attachments can be made up of metal, plastic or silicon rubber. Stop attachments can be available in two shapes tear drop or round.

Fig. 41. Flexo File (size 25) with silicon rubber stop

Radiographic method of length determination (fig. 42):

1. Measure the estimated working length from preoperative periapical radiograph.

2. Adjust stopper of instrument to this estimated working length and place it in the canal up to the adjusted stopper.

3. Take the radiograph.

4. On the radiograph, measure the difference between the tip of the instrument and root apex. Add or subtract this length to the estimated working length to get the new working length.

5. Correct working length is finally calculated by subtracting 1 mm from this new length.

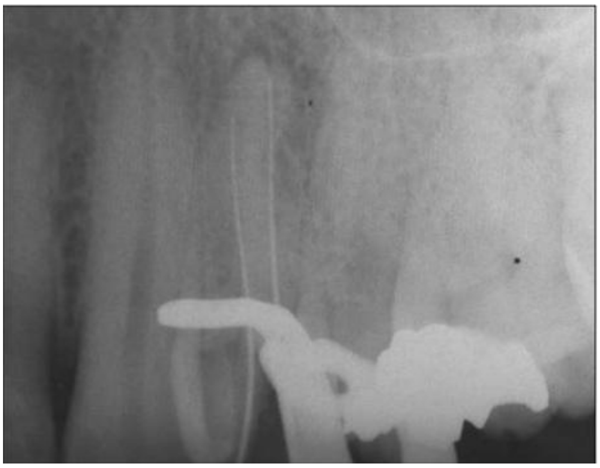

Fig. 42. Working length radiograph

Advantages of radiographic methods of working length determination:
1. One can see the anatomy of the tooth
2. One can find out curvature of the root canal
3. We can see the relationship between the adjacent teeth and anatomic structures.

Disadvantages of radiographic methods of working length determination:
1. Varies with different observers
2. Superimposition of anatomical structures
3. Two-dimensional view of three-dimensional object
4. Cannot interpret if apical foramen has buccal or lingual exit
5. Risk of radiation exposure
6. Time consuming
7. Limited accuracy

Non-radiographic Methods:

1. Digital tactile sense: In this method the clinician may see an increase in resistance as file reaches the apical 2-3 mm.

Advantages:
- time saving;
- no radiation exposure.

Disadvantages:
- does not always provide the accurate readings
- in case of narrow canals, one may feel increased resistance as file approaches apical 2–3 mm.
- in case of teeth with immature apex, instrument can go periapically.

2. *Periodontal sensitivity test*: This method is based on the patient's response to pain. But this method does not always provide accurate readings; for example, in case of narrow canals, instrument may feel increased resistance as file approaches apical 2–3 mm; in case of teeth with immature apex, instrument can go beyond apex. In cases of canal with necrotic pulp, instrument can pass beyond apical constriction; in case of vital or inflamed pulp, pain may occur several mm before periapex is crossed by the instrument.

3. *Paper point measurement method*: In this method, paper point is gently passed in the root canal to estimate the working length. It is most reliable in cases of open apex where apical constriction is lost because of perforation or resorption. Moisture or blood present on apical part of paper point indicates that paper point has passed beyond estimated working length.

All this methods are used as supplementary technique.

Electronic apex locators (EAL) are used for determining working length as an adjunct to radiography. They are basically used to locate the apical constriction or cementodentinal junction or the apical foramen, but not the radiographic apex.

All of apex locators function by using human body to complete an electrical circuit. One side of apex locator circuit is connected to endodontic instrument and the other side is connected to the patient's body. Circuit is completed when endodontic instrument is advanced into root canal until it touches the periodontal tissue (fig. 43).

Components of Electronic Apex Locators (fig. 44):
– lip clip;
– file clip;
– electronic device;
– cord which connects above three parts.

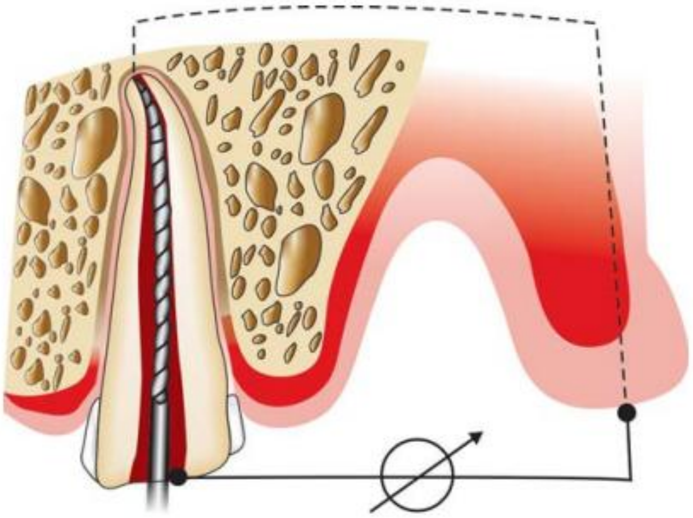

Fig. 43. Diagrammatic representation of working of resistance type of apex locator

Fig. 44. Electronic Apex Locators

Advantages of Apex Locators:
1. Provide objective information with high degree of accuracy.
2. Accurate in reading (90–98 % accuracy)
3. Some apex locators are also available in combination with pulp tester, so they can be used to test pulp vitality.

Disadvantages:
a). Can provide inaccurate readings in the following cases:
– presence of pulp tissue in canal
– too wet or too dry canal
– use of narrow file
– blockage of canal
– incomplete circuit
– low battery
b. Chances of overestimation
c. May pose problem in teeth with immature apex.

Basic conditions for accuracy of EAL

- canal should be free from debris;
- canal should be relatively dry;
- no cervical leakage;
- proper contact of file with canal walls and periapex;
- no blockages or calcifications in canal.

The most important thing to understand when determining working length is morphology of apical one-third of the canal. The consideration should be given to adopt the parameters of 0.5–0.0 mm (from the apical constriction) as most ideal terminating point in canal. One should use as many techniques as possible during the course of treatment. First of all, there should be a stable coronal reference point. Next step is to estimate working length from average anatomical length and preoperative radiograph. Finally, calculate the correct working length using combination of various mentioned techniques, i. e. tactile sense, radiography, electronic apex locators, etc. Multiple measurements should be taken to determine accurate readings of working length. With so many advances coming up in the branch of endodontics, we expect the future of apex locators to provide accurate readings in all the conditions of root canal without the need of calibrations.

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