Endodontics Modern Endodontic Principles Part 3: Preparation

Article *in* Dental update · November 2015

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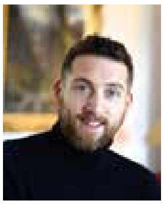

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Modern Endodontic Principles Part 3: Preparation

Abstract: The purpose of instrumentation is to facilitate irrigation and allow controlled obturation. This article will revisit methods of instrumentation of the root canal system with consideration given to length determination, apical preparation and the concept of patency filing. It will discuss hand instrumentation and rotary preparation looking at emerging technology such as reciprocating systems and the self-adjusting file.

CPD/Clinical Relevance: Mechanical preparation of the root canal system is of fundamental importance in achieving success, creating a more easily managed environment from a biological perspective.

Dental Update 2015; 42: 810–822

The objectives of mechanical preparation are two-fold:

1. To facilitate irrigation

Conventional radiography does not enlighten the clinician about the true complexity of the root canal system. Lateral canals, fins, anastomoses and ramifications are invariably present, with some canals being joined by narrow isthmi. The main canal is rarely round, but often oval, ribbon-like or even 'C'-shaped, depending upon the tooth. One seminal study has demonstrated up to 53% of the canal will remain unreached by instrumentation following preparation.[1] Therefore, mechanical preparation facilitates penetration of irrigants into these complex anatomical spaces. Although some dentine-containing micro-organisms will be removed during mechanical preparation, research suggests that a considerable amount of the canal will not be contacted by a file, therefore irrigants play a crucial role in destroying micro-organisms, neutralizing endotoxin and removing organic tissue components.[2]

2. To facilitate obturation

As cleaning and shaping does not remove all micro-organisms from the canal, obturation aims to entomb any residual pathogens and limit recolonization by preventing the passage of nutrients from both coronal and apical aspects. Mechanical preparation facilitates obturation. Schilder's principles of canal preparation (Table 1) still hold true today.[3] The idea of creating a continuously tapering preparation, free from mechanical errors, allows the best chance of a well-condensed obturation, with the absence of voids.

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The crown down approach

The majority of micro-organisms are in the coronal portion of the canal and pulp chamber.[4] Thus, whatever instruments are used, a crown down approach and only initial scouting of the canal prior to working length determination is sensible. This technique involves shaping the canal from the coronal aspect first and progressively working more apically with smaller diameter instruments[5] (Figure 1). Such an approach:

- Minimizes the transportation of pathogens further into the canal system;
- Allows a greater amount of irrigant to be held in the canal, facilitating debris removal and disinfection;
- Removes coronal curvatures and facilitates straight-line access;
- Improves accuracy of working length determination as reduction of curvature after working length determination may alter the working length and result in a tendency to transport the canal and

■ Continuous taper from apex to crown
■ Cross-section should narrow at every point apically
■ Preparation should follow the canal
■ Apical foramen should be maintained
■ The apex should be kept as small as possible

Table 1. Schilder's mechanical objectives of canal preparation.[3]

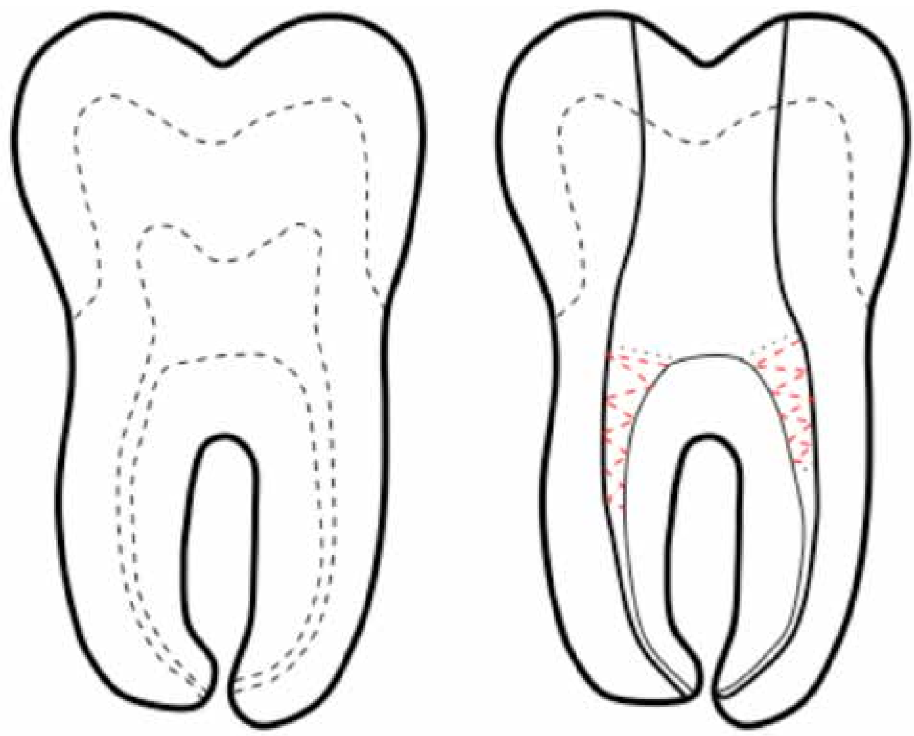

Figure 1. The crown down approach: the coronal third of the canal system is enlarged using GG or orifice-shaping files. The enlargement is directed away from the furcation and has the simultaneous benefit of removing dentine overhanging the orifices to allow optimal straight-line access.

over-enlarge the apical foramen;

- Reduces file binding in the coronal portion of the canal, facilitating working length assessment and further reducing the risk of instrument separation through torsional failure.

Traditionally, Gates Glidden (GG) instruments would be used for the crown down procedure but many rotary filing systems now have orifice shapers to begin the preparation (Figure 2). If clinicians elect to use GGs it is wise to remember a Size 6 GG has an apical diameter of 1.5 mm (ISO 150), with sizes stepping down in 0.2 mm increments to a Size 1 GG at 0.50 mm (ISO 50). As such, even the smallest of GGs can be very destructive if used carelessly. Avoid using sizes above GG 3 (0.90 mm: ISO 90). Whatever instruments are used, caution must be taken with regard to the furcation region, the instruments being used away from the furcation (anti-curvature filing[6]). Despite the aforementioned advantages, it is easier to create blockages and ledges with an aggressive or careless crown down approach, thus highlighting the importance of recapitulation.

Working length determination

The apical extent of preparation should be kept within the canal system: over extension can reduce success up to 62% and, for every mm short of the apex, underextension reduces success by 12%.[7] Methods used to estimate the maximum working length for instrumentation include apical gauging by tactile sensation, instrumentation without local anaesthetic, using pre-operative radiographs alone, the paper point technique, working length radiographs (WLRs) with files *in situ* and, most recently, the use of electronic apex locators (EALs). Historically, the most widely accepted method is by placing a file to the estimated length, then taking a confirmatory radiograph, but the radiographic apex rarely corresponds with the anatomical apex.[8] It follows that WLRs can only give an estimation of the correct termination of preparation.

Modern impedance-based multifrequency EALs are reliable and accurate >90% of the time.[9] These devices are only accurate at a ZERO reading (Figure 3). Any reading given other than ZERO should not be used as a marker of apical extent. The ZERO reading is reached when the file contacts the periodontal ligament. Thus, by definition this is over extended and, to calculate the working length, one must subtract 0.5 mm from the ZERO reading length.[10] For more information readers are referred to other papers on the subject of EALs.[11,12]

The 2013 Faculty of General Dental Practitioners Selection Criteria for Dental Radiography states '*Unless there is confidence about working length(s) derived from an electronic apex locator, at least one good-quality radiograph is necessary to confirm working length(s)*'.[13] From this one could extrapolate that WLRs are no longer always necessary. We recommend that a combination of techniques is used. Figure 4 gives an algorithm for determining working length. If there is any doubt about final working length, consider a cone-fit radiograph before obturation.

Size of apical preparation

There is equivocal evidence regarding the effect of the size of apical preparation on the success of endodontic treatment.[14,15] Smaller apical preparation has the advantage of minimizing the risk of transportation and extrusion of debris and irrigant. Conversely, a more aggressive apical preparation will remove more infected dentine and allow greater access to irrigants but may increase the risk of perforation and extrusion of debris and irrigants. Traditional teaching advocated using a master apical file which was three sizes larger than the first file to bind.[16] Subsequent work has shown this method to be inaccurate.[17] In addition, most

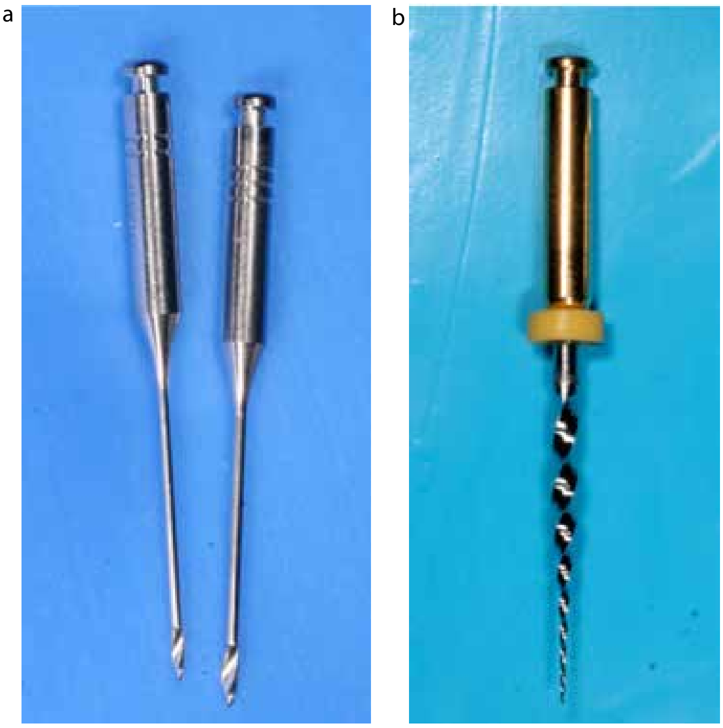

Figure 2. (a) A Gates Glidden Sizes 2 and 3. Apical diameter: 70 mm and 90 mm. **(b)** The *ProTaper SX* orifice-shaping file (Dentsply, Tulsa, USA).

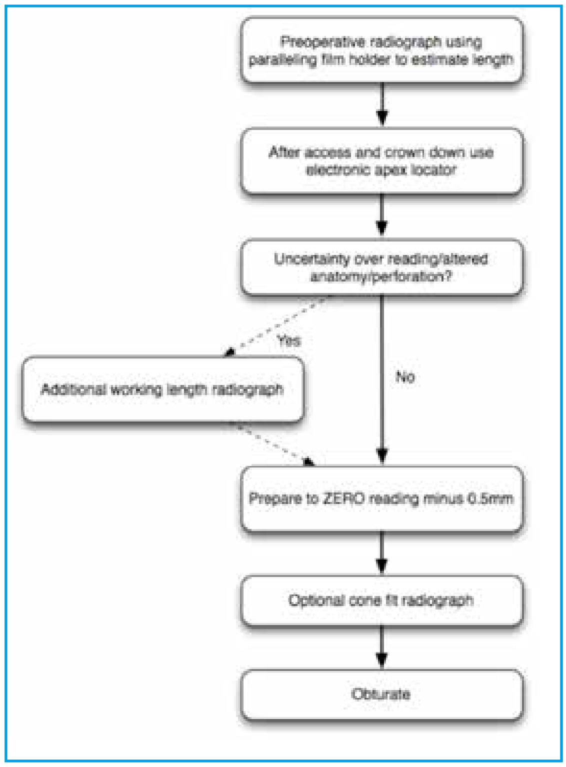

Figure 4. An algorithm for determining working length.

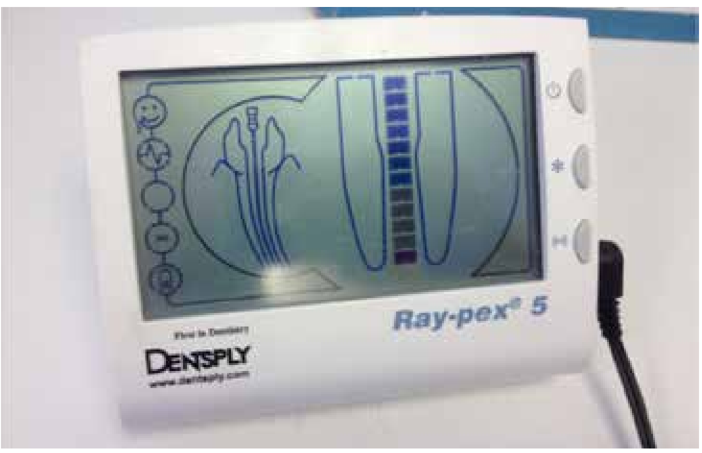

Figure 3. Apex locators are only accurate at ZERO. From ZERO 0.5–1 mm must be subtracted to determine the working length.

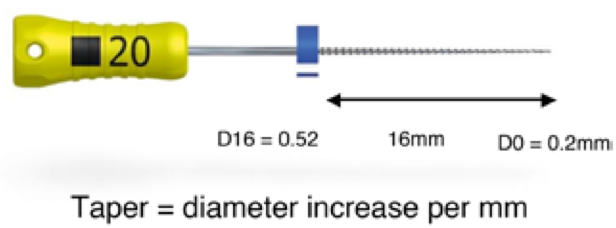

Figure 5. Features of a size 0.02 tapered file: an ISO 20 file is 0.20 mm at the apex. The fluted portion of the file is 16 mm long. A size 0.02 taper increases 0.02 mm ever mm, therefore this file is 0.52 mm at 16 mm.

apical foramina are not round but ovoid in shape and it is questionable whether infected dentine needs to be removed as appropriate irrigation penetrates dentine and kills micro-organisms.[18]

A modern approach to apical enlargement focuses on irrigation. Irrigant must reach the apical 1 mm of the canal.[19] Evidence suggests that irrigants do not flow greater than 1–2 mm past the syringe tip. Ideally, the irrigating syringe tip must be placed within 1–2 mm of the apex.[20] A conventional 30 gauge needle corresponds to the tip of an ISO 30 file, therefore an apical preparation smaller than this may result in the inability to place the needle tip within the apical 2 mm and thus there may be inadequate irrigation in this area. We suggest that an apical preparation of 0.25–0.30 mm (ISO 25–30) should be considered a good target. In addition, it has been demonstrated that larger taper preparations enhance cleaning and irrigation and subsequently reduce bacterial load.[21] One study has shown only modest increases in irrigation with taper increases beyond 0.04.[22] The clinician must therefore be aware that increasing taper carelessly may also increase the risk of excessive tooth structure removal and perforation without added benefit.

If canals are sclerosed or very curved such large preparation may not be possible. In these circumstances, the focus should shift towards improving irrigation. The next paper in this series will discuss methods for improving the activity and exchange of irrigants.

Preparation techniques

New endodontic filing systems are being continually introduced on to the market, allowing clinicians to complete endodontic treatment with simpler protocols, faster. Accordingly, there has been a paradigm shift towards nickel titanium rotary file systems. Nonetheless the clinician must understand the importance of hand filing: the clinician that cannot hand file is handicapped in the 'art of endodontics'.

Hand filing

Hand files afford the clinician greater tactile feedback than rotary instruments and are often invaluable in determining the direction and magnitude of curvatures and canal configurations. There are two main types of files: Hedstrom and K files. The former are machined stainless steel cylinders that cut aggressively. The latter are twisted stainless steel that are more flexible and less aggressive. The cross-section varies depending on the type of file. All have 16 mm fluted portions and follow ISO dimensions (Figures 5 and 6). New instruments are available in nickel titanium. These instruments are flexible and potentially safer but cannot be pre-curved and negate some of the benefit of hand filing in the early stages, especially in curved canals.

Shaping the canal with hand files can be undertaken in numerous ways, depending upon the canal anatomy (Table 2). Techniques for total canal preparation with hand files includes 'step-back', 'crown-down', 'double flare' and 'anticurvature filing'.[5,6,23,24] Techniques for manipulation of the files during preparation include circumferential filing, 'balanced force',[25] watch-winding and push-pull. Thus the former describe the strategy and the latter describes the method of achieving that.

'Step-back' and 'double flare' techniques both involve determining the working length and choosing a master apical file size, then using progressively larger files at shorter lengths in order to create a continuous taper. Stainless steel hand files are all standard 2% ISO taper. The operator can choose the degree of taper created by adjusting the lengths to which progressively larger files are inserted. Traditional step back, using increments of 1 mm creates a canal with a 5% taper. If the clinician wishes to develop a larger taper, then reducing the increments to 0.5 mm will result in a canal with a 10% taper. One common pitfall with both these techniques is under preparation of the middle third of the canal. This poses problems when obturating using cold lateral compaction techniques, as accessory points cannot penetrate past the coronal third, resulting in an obturation which resembles an 'inverted wine bottle' (Figure 7).

The 'balanced force' technique involves turning the file clockwise up to 90° followed by an anti-clockwise movement of 180° or more whilst maintaining apical pressure.[25] The first movement engages the dentine, whilst the second movement releases and cuts the canal wall. This permits predictable, centred dentine removal. Though 'balanced force' may be used in all canals, it is an especially effective and safe technique for hand filing curved canals. Circumferential and push-pull filing techniques are more suitable for straight, wide canals, C-shaped or ovoid canals: the walls of the canal are reamed with an oscillating apico-coronal movement. As a rule, the use of stainless steel endodontic instruments should be avoided in rotary hand-pieces as they can be aggressive and are prone to breakage.

Irrespective of which technique is adopted, there are a few useful guidelines to follow when using hand files, which are presented in Table 3. Stainless steel files may be pre-curved to the estimated shape of the canal, preferably with a designated instrument to avoid contamination (Figure 8). It is useful to indicate the direction of the curve by marking it with the pointer on the rubber stop. After using each successive file, always irrigate and recapitulate with a fine file, such as #10, to disrupt and to agitate the plug of 'dentine mud' which builds up apically which can result in loss of working length.

Patency filing

Patency filing is the process of placing an ISO 10 file (or smaller) 0.5 mm passively beyond the apex.[26] It is imperative that the file is not excessively rotated, as this can enlarge the apical foramen. This removes dentine plugs that can be compacted in the apical region. These can harbour bacteria and may result in deviation of the instrument tip if not cleared. Ensuring patency of canals improves the success of RCT[7] (Figure 9).

The era of nickel titanium

The most notable development in endodontics in the last 25 years is the introduction of nickel titanium (NiTi) instruments.[27] This alloy, composed of 55% nickel and 45% titanium has several properties which are desirable for endodontics; most notably, NiTi has super elasticity and shape memory. This helps to keep the file centred in the canal and reduces the risk of procedural errors. Although NiTi instruments are commonly associated with rotary techniques, many manufacturers also produce hand file versions of their rotary systems, which are designed to be used in the same sequence (Figure 10). The super elasticity of nickel titanium does, however, prevent these files being pre-curved.

Recent advances in material technology now afford greater flexibility and cyclic fatigue resistance.[28] These include *M-wire* (Dentsply, Tulsa) and *HyFlex CM* or *Controlled Memory* (Coltene/Whaledent, Germany). *M-wire* is now used in the production of single file systems (see below). *HyFlex CM* instruments can also be pre-bent, reducing the risk of ledging, transportation or perforation (Figure 11). This may potentially revolutionize nickel-titanium technology.

Rotary file systems

Since the introduction of nickel titanium it has been possible to prepare root canals using a motor safely and predictably. Rotary instrumentation increases cutting efficiency. Although speed reducing motor hand-pieces can be coupled to existing units, the use of dedicated electric endodontic motors is recommended. The torque and speed can be adjusted to match the instrument

Filing Technique	Indication
Anti-curvature filing (filing away from the furcation)	Molar teeth. Improves straight line access and protects the furcal region
Circumferential filing	Ribbon and 'C'-shaped canals; very large canals
Balanced force	Curved canals to prevent procedural errors

Table 2. Common hand filing techniques and their indications.

Figure 6. Hedstrom files are round in cross-section; K files, square; K-Flex, rhomboid and K-Flexo files, triangular. The triangular cross-section improves flexibility.

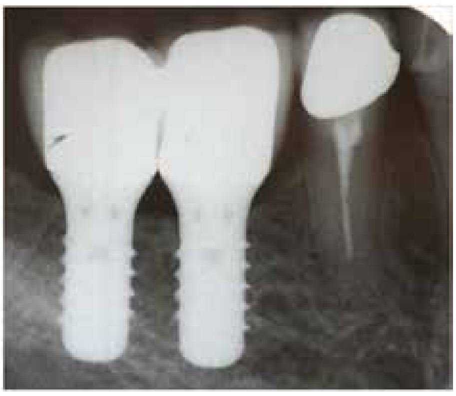

Figure 7. Under preparation of the middle third results in a 'wine bottle' appearance. The aim should be a smooth taper from apex to pulp.

manufacturers' specifications precisely and many have auto reverse to prevent files binding in the canal and exceeding the torque limit (Figure 12). Rotary files usually create preparations of greater taper than the conventional ISO 2%, with some systems exhibiting variable taper throughout the length of the file. Although most practitioners will be familiar with the manufacturers' protocol for such instruments, Table 4 offers a list of guidelines relevant to all using rotary instrumentation[29] (Figure 13).

Most manufacturers would recommend the use of a 'glide path' to ensure safe and efficient passage of the instruments to full working length. By taking an ISO 20 hand file to the length to which a NiTi instrument is to go will significantly reduce the risk of instrument fracture, as covered below. There are ranges of NiTi instruments that are advocated for developing a glide path (eg *Pathfile* (Dentsply, Tulsa, USA) (Figure 14). The manufacturers indicate these for use in sclerosed or difficult to negotiate canals. These should be used at slow speeds and with caution. It remains sensible to create a glide path with hand instruments first.

The finer details of file design and shape will not be covered in this paper but the clinician should be aware that many of the properties of an instrument are not simply governed by the material but the shape of the instrument. It is important to know the cutting efficiency, the taper size, and the instrument diameters at the tip (Figure 15).

Although rotary NiTi file systems can be advantageous for preserving the original canal anatomy, they have limitations:

- When straight files are placed into curved roots the instrument can straighten the canal, resulting in a 'zip' apically where the apex is expanded. This is virtually impossible to fill. Rotary instruments should not be left rotating for more than 3–4 pecks of the apex to prevent such zipping and the ensuing difficulties this presents for obturation (Figure 16).
- Rotary preparations are circular, thus they are less useful in ribbon and 'C'-shaped canals, which are better prepared with hand files using circumferential techniques.
- Rotary files have a propensity to separate by two mechanisms.[30] First, torsional failure can occur by the file continuing to rotate whilst one part of it is bound against the canal. Secondly, continuous rotation of the file in a curved canal can result in cyclical failure. The move to single use instruments reduces the risk of instrument separation but this will never mitigate the risks of poor technique. Always inspect the tips of instruments during use: if the threads are unwinding there is a risk of separation, so discard them. Nonetheless, NiTi rotary instrumentation is safe and effective if care is taken and manufacturer's instructions are followed.[31]

Reciprocating systems

Reciprocation involves the file rotating in both anti-clockwise and clockwise directions: essentially a form of mechanized 'balanced force'. The anti-clockwise movement engages dentine following which the clockwise turn releases the file from the canal before re-engaging the canal wall, shearing dentine and creating the preparation. The reciprocating motion and single file system has several important benefits:

- Decreased risk of cyclical failure as the files are rotating at a lower RPM;
- Decreased risk of torsional failure as the filing motion repeatedly disengages the dentine, thus preventing binding and instrument fracture;
- More cost-effective endodontic treatment as the current reciprocating systems are 'single file'.
- A simplified protocol with only three choices of instrument for small, regular or large canals.

Currently, there are two systems on the market, *Wave One* (Dentsply-Maillefer, Ballaigues, Switzerland) and *Reciproc* (VDW, Munich, Germany) (Figure 17). *Wave One* utilizes an 170°:50° anti-clockwise:clockwise movement and *Reciproc* 150°:30°. This means that it will take three reciprocating movements for both file systems to rotate 360°. Although marketed as a single file system, the

■ Pre-curve files based on the estimated geometry of the canal from pre-operative radiographs
■ Use the pointer on the rubber stopper to indicate the direction of the file curvature
■ Patency file to prevent apical blockage
■ Recapitulate and irrigate after each successive file to prevent loss of working length

Table 3. Tips for using hand files.

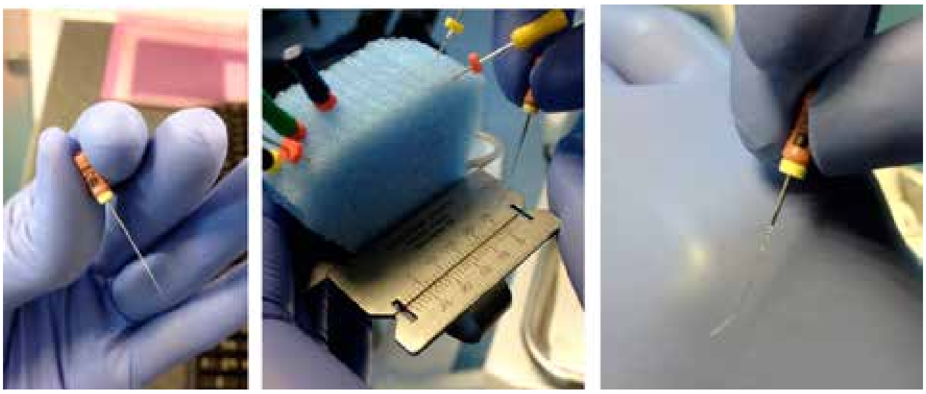

Figure 8. Pre-curving files helps follow the curve. In this case, a size 0.06 file is gently pressed against a metal surface until there is gentle curve. Note the use of the *EndoRing* (Sybron Endo, USA): very useful for measuring, storing and cleaning the flutes of files safely.

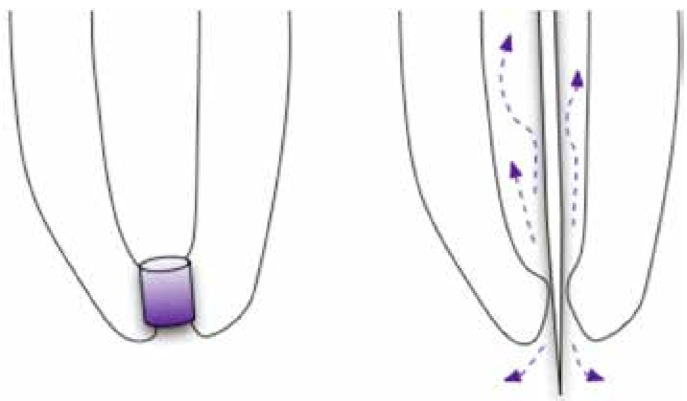

Figure 9. During instrumentation, plugs of dentine chips and debris can accumulate apically, which may prevent adequate shaping, irrigation and potentially deviate instrument tips, resulting in ledges. Taking a size ISO 8 or 10 file regularly 0.5 mm beyond the apex helps prevent this.

Figure 10. *ProTaper* hand files (Dentsply, Tulsa, USA) offer the control of hand filing with the benefits of NiTi.

recommended protocol for *Wave One* still involves the initial use of hand files.[32] The manufacturers of *Reciproc* advocate that production of a glide path with hand files is not required in most cases.[33] It remains good practice to establish a glide path with 0.20 ISO files before any NiTi instrument is used to working length. These instruments surpass conventional rotary instruments in resisting cyclical and torsion fatigue and, although similar in concept, *Wave One* has greater resistance to torsional fatigue than *Reciproc* and *Reciproc* has greater resistance to cyclical fatigue than *Wave One*.[34] This means that *Reciproc* is more suited to curved canals and *Wave One* to narrow or sclerosed canals.

The self-adjusting file concept

All current rotary file systems rotate during function and thus create round preparations. In uncomplicated canal configurations, such preparations are adequate. Unfortunately, most root canals are not circular in cross-section and often contain complex curvatures. Creating round preparations in ovoid-shaped canals can result in either a significant proportion of the canal remaining un-instrumented or, if the preparation is enlarged, then strip perforations can become a real risk.

The 'Self Adjusting File' (SAF, ReDent Nova, Ra'anana, Israel) is a novel system which has been developed to overcome such problems. Rather than twisting or using a machine on a solid piece of metal, the files are composed of a NiTi lattice with a hollow centre (Figure 18). This allows the file to be compressed at any point along the lattice, hence it can adapt to any canal shape. The surface of the file is roughened by sandblasting and dentine removal occurs as the file operates in a hand-piece utilizing a vertical, rather than a rotating motion. Due to the fragility of the lattice structure, all files are single use but, despite this, there have still been reports of lattice separation.[35]

The hand-piece system also provides continuous irrigation during shaping by attaching an irrigation tube to the shank of the file. As the file is moving during irrigation, this also acts to activate the irrigant and transport it throughout the canal system. As the lattice is hollow, it would be expected that this would facilitate debris removal and reduce the incidence of blockages.

The files are produced in two diameters and three lengths. As such, they are not recommended for canals greater than 21 mm in length, or teeth with immature apices (greater than ISO 60). Canal preparation still requires the use of Gates Glidden burs to provide enlargement of the coronal third and creation of a glide path to up to a size 20 (ISO) hand file.

Create straight line access to the coronal or middle third of the root before using a hand or rotary instrument
Create a glide path up to a #20 hand file to the apex before using hand or rotary instruments in that part of the canal
Fine files frequently: after 3–4 pecks of a rotary instrument, remove, irrigate and recapitulate with fine files
Thoroughly clean the flutes of the instrument after removal from the canal
Maintain patency throughout by taking a small (ISO 8 or 10) file 0.5 mm beyond the working length
Never force a rotary instrument. If resistance is met; stop, increase the amount of coronal flaring, irrigate and recapitulate
If challenging anatomy is present, always prepare the canal with hand files before introducing rotary instruments
Don't try to bypass ledges with rotary instruments; always use hand files for this
Prepare sufficient coronal flaring to ensure that the minimum amount of the file is contacting the canal walls
Always introduce the file into the canal whilst it is rotating. Do not stop and start the motor once the file is in the canal
Make sure that you have an accurate working length before using rotary files in the apical area. Aggressive enlargement and transportation can occur if a rotary file goes beyond the apex
Any time saved in preparation should be used in irrigation

Table 4. Tips for using rotary NiTi file systems modified from the AAEs Guidelines.

Figure 11. *HyFlex Controlled Memory* files (Coltene, Feldwiesenstrasse, Switzerland) are NiTi and can be pre-shaped.

Figure 12. Torque controlled molars can be programmed for multiple file systems. Both the *X-Smart* (Dentsply, Tulsa, USA) and *Reciproc* (VDW, Munich, Germany) also offer reciprocation.

Unlike conventional rotary file techniques, it is recommended to leave the instrument in each canal for four minutes, unless resistance is felt.[36]

The SAF system claims to preserve the original canal anatomy and to allow effective cleaning and shaping of canal irregularities. Some research comparing the SAF to conventional rotary systems does seem to support this.[37] Although it is unarguably an advantage to preserve original canal anatomy, this does pose a significant challenge to achieving adequate obturation in complex canal configurations.

File-less systems

Gentle Wave (Sonendo, California, USA) is a new endodontic system. It is based on the philosophy that traditional endodontic treatment is crude, time-consuming and unpredictable. Furthermore, the anatomy of the root canal system is not sufficiently respected. The company have developed a technology that uses disposable sonic hand-pieces to create a 'fluid loop' within the canal system. It has been named a 'Multisonic Ultracleaning System'. The next paper on irrigation will look into this technology further but for more information visit **www.sonendo.com**.

Time

The time saved in preparation using rotary instruments should be used wisely. The clinician should aim to prepare canals and dedicate the remaining time to irrigation, not shorten the overall appointment time.[38]

Which system is best?

The method of instrumentation used (hand or rotary) does not appear to influence success rates,[7] although one study found better success rates with rotary instruments amongst general practitioners.[39] Although manufacturers are becoming more aware of the importance of robust supporting evidence, clinicians must not be duped by the marketing and should research the systems independently, if possible. We recommend practitioners remain open-minded about using differing

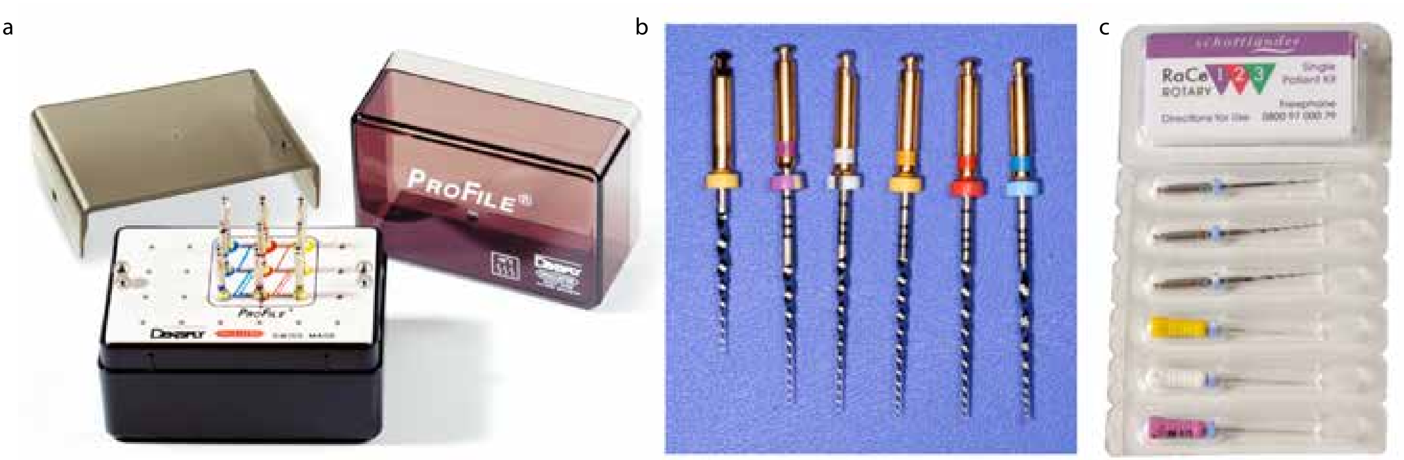

Figure 13. Since the introduction of rotary NiTi there has been a drive to simplify filing protocols. **(a)** *ProFile* (Dentsply, Tulsa, USA) may necessitate as many as 9 or 12 files if the manufacturer's instructions are followed, whereas **(b)** *ProTaper* (Dentsply, Tulsa, USA) may require as few as 3 files. **(c)** *RaCe 123* (Schottlander, Herts, UK) is a dedicated 3 file system designed for most root canals.

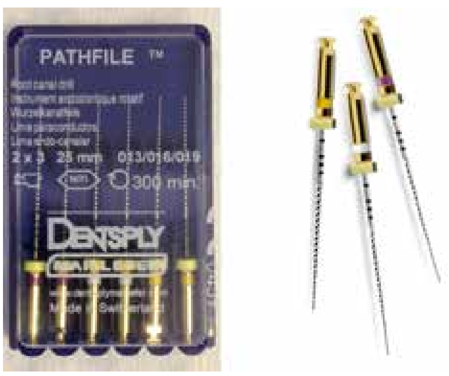

Figure 14. NiTi files designed for creating glide paths should be used with caution.

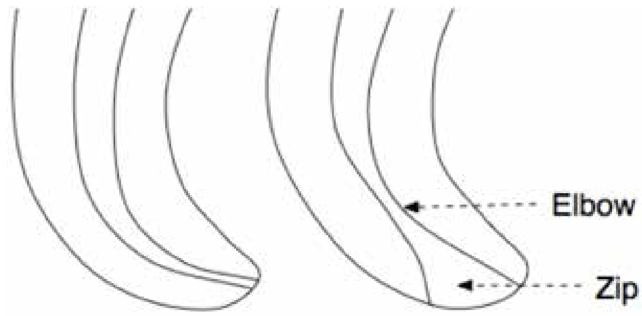

Figure 16. Rotation of straight instruments in curved canals can enlarge the apex creating a zip; often impossible to obturate.

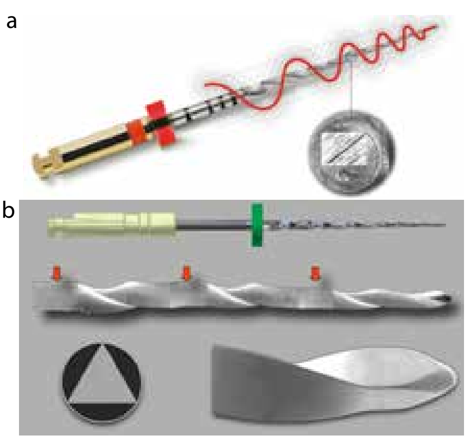

Figure 15. Modern file designs challenge the 'norm'. **(a)** the *ProTaper Next* (Dentsply, Tulsa, USA) has a rectangular cross-section and a 'swag-gered' file to cut more efficiently and facilitate debris removal whilst reducing dentine contact and dangerous torquing effects. **(b)** The *BioRace* system (FKG, La-Chaux-de-Fonds, Switzerland) has alternate cutting blades to minimize self-threading, a triangular cross-section to increase flexibility and cutting and a non end-cutting tip.

Figure 17. Both reciprocating instruments available use a simplified filing system with one principle file determined by the size of the root canal system.

Figure 18. The SAF attached to the hand-piece and irrigation tube. As the file is hollow, irrigant can be deposited inside the lattice. (Photograph courtesy of ReDent Nova, Israel.)

systems and practise, practise, practise. It is wise to use extracted teeth to trial new filing systems. Finally, always remember the mantra 'files shape and irrigants clean': no system of instrumentation renders the canal bacteria free.[40,41] Irrigation is the key to success in endodontics and will be discussed in the next paper.

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