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ProTaper NT system

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During the last decade, endodontic therapy went through a fascinating development. The introduction of operating microscopes, rotating nickel-titanium instruments, and other new features has enabled the practitioner to better shape the root canal. The ProTaper system (Dentsply/Maillefer, Ballaigues, Switzerland) represents a new generation of NiTi instruments currently available. The system was developed by a group of well-respected endodontists (Prof. Pierre Machtou, Université Paris, France; Dr. Clifford Ruddle, Santa Barbara, California, USA; and Prof. John West, University of Washington, Seattle, Washington and Boston University, Boston, Massachusetts, USA) in cooperation with Dentsply/Maillefer. Compared with other systems, the files demonstrate completely new design features. The progressively tapered instruments with their new flute design and their clinical use are described below in detail [1].

Proper biomechanic cleaning and shaping of the root canal system is the basis of endodontic therapy and three-dimensional obturation. Since the introduction of the first rotating nickel-titanium files for the preparation of root canal systems in endodontics, a wide range of new file systems have been established in the market. The benefits of the new systems are apparent in their near-perfect preparation of the root canal system. Properly used, NiTi systems enable the user to finish a more predictable root canal instrumentation and limit procedural errors at the same time. The latest research [2,3] seems to confirm the fact that NiTi files are easing the preparation with no or very little transportation.

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Originally, NiTi ProTaper instruments were developed to facilitate instrumentation of difficult, constricted, and severely curved canals (Fig. 1). A revolutionary new file geometry was designed to allow for high efficiency and safety. Since the introduction of the system, the continuing application has allowed for the safe and efficient management of even ''standard-cases'' (Fig. 2). The ProTaper instruments were designed ''to cover the whole range of treatment with only a few files, which incorporate superior flexibility, unmatched efficiency and improved safety'' [1]. The number of files with a progressive taper (ProTaper) was decreased to a set of six instruments (Fig. 3): three shaping files for the crown-down procedure and three finishing files for apical shaping and creating a smooth transition from the middle one third of the canal providing the preparation deep shape. The three shaping files are characterized by increasing tapers over the whole length of their cutting blades, allowing for a controlled cutting performance in special sections of the instrumented root canal. The finishing files are dominated by different diameters, #20, #25, #30 and a fixed taper over 3 mm to finish apical preparation.

Fig. 1. Radiograph showing a severely curved upper premolar with two joining canals. (Courtesy of Thomas Clauder, DDS.)

Fig. 2. This tooth was cleaned and shaped with ProTaper files. (Courtesy of Thomas Clauder, DDS.)

The following innovations characterize the ProTaper system:

Progressive taper
Modified guiding tip
Varying tip diameters
New cross-section of the instruments
Varying helical angel and pitches
New shorter handle of the file

One of the most outstanding innovations is the varying taper within one file. Comparing the ProTaper NT system with other systems, one can note that other file systems focus on one taper within a file and tend to combine a series of files to achieve the necessary effect. In contrast, ProTaper has varying tapers within one file ranging from 3.5% to 19%, which makes it possible to shape specific sections of a root canal with one file. Other new design features are the modified guiding tip (Figs. 4 and 5) and varying tip diameters. The modified guiding tip allows one to follow the canal better and the variable tip diameters allow the files specific cutting action in defined areas of the canal, without stressing the instrument in other sections. In

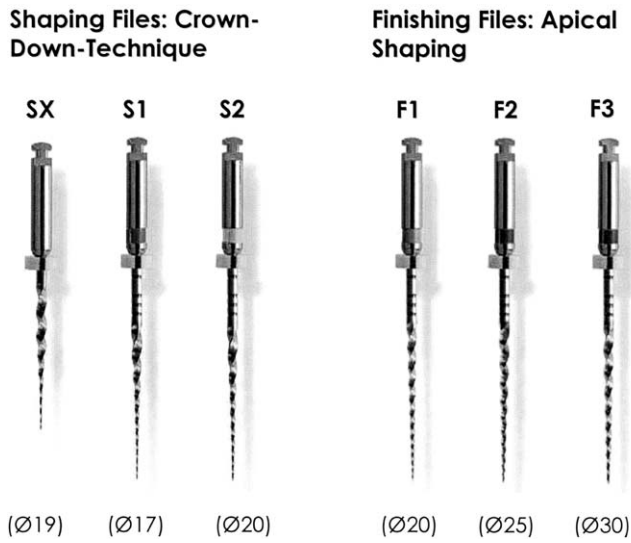

Fig. 3. The set of six ProTaper files includes three shaping files and three finishing files.

comparison with other file systems manufactured by Dentsply/Maillefer (Profile and System GT) as well as other file systems with radial lands and a U-shape design, ProTaper instruments demonstrate a new convex, triangular cross-section (Fig. 6). This design results in a reduced contact area between dentin and the cutting blade of the instrument, achieving

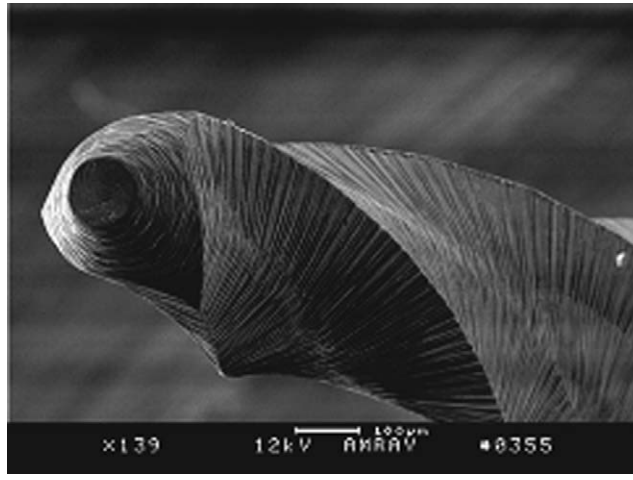

Fig. 4. Scanning electron microscope (SEM) picture demonstrating the modified guiding tip of a ProTaper file. (*From* Baumann MA. ProTaper—a new generation of NiTi-files in endodontics. Endodontie 2001;10:353; with permission.)

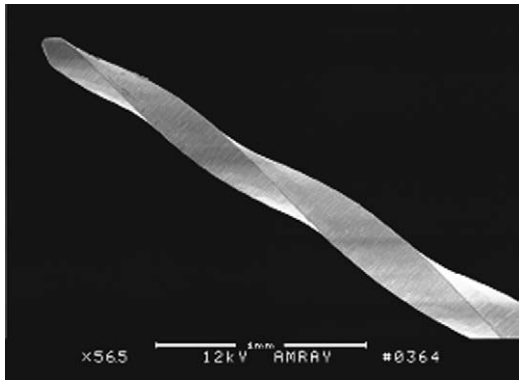

Fig. 5. SEM picture demonstrating the cutting blades of a ProTaper file. (*From* Baumann MA. ProTaper—a new generation of NiTi-files in endodontics. Endodontie 2001;10:353; with permission.)

cutting efficiency that was not possible previously. In the same process, it is possible to reduce the torsional strain and ease the pressure to achieve widening of the root canal. In comparison with other file geometries with radial lands that produce a passive cutting and scraping action, the ProTaper system works with an active cutting motion, which substantially increases the effectiveness of the system and reduces torsional strain [4]. Regarding instrument geometries, only F3 has a reduced cross-section with a U-shape to facilitate a higher degree of flexibility (Figs. 7 and 8).

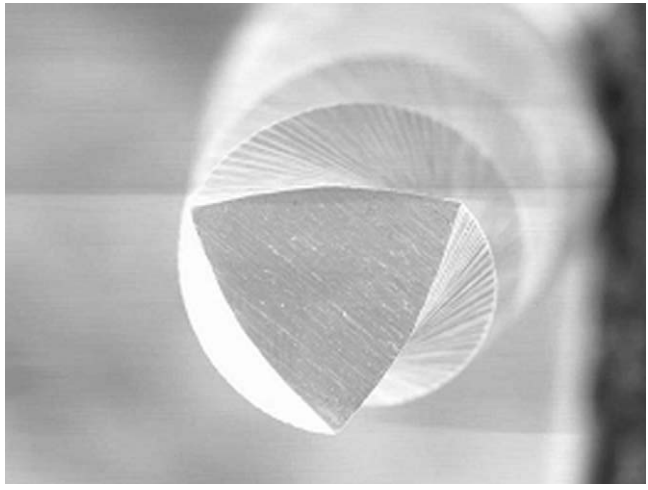

Fig. 6. SEM picture demonstrating the convex, triangular cross-section of the ProTaper files. (*From* Baumann MA. ProTaper—a new generation of NiTi-files in endodontics. Endodontie 2001;10:353; with permission.)

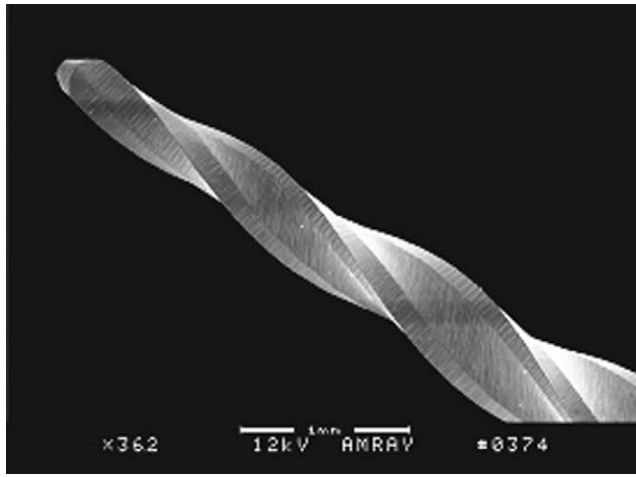

Fig. 7. SEM picture demonstrating the cutting blades of F3 with a reduced core. (*From* Baumann MA. ProTaper—a new generation of NiTi-files in endodontics. Endodontie 2001;10:353; with permission.)

Furthermore, new design features are the variable helical angel and balanced pitches in the instrument, which improve cutting action, allow for better removal of debris out of the root canal, and prevent the instrument from screwing into the canal. The length of the file handle of the instruments was reduced from 15 mm to 12.54 mm to allow for better access in difficult

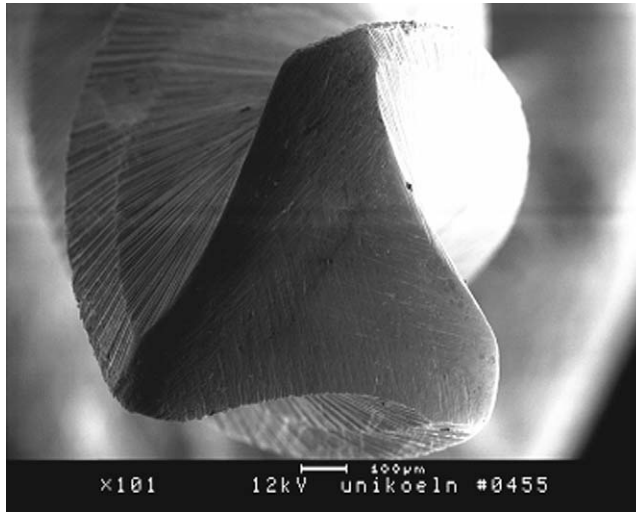

Fig. 8. SEM picture demonstrating the cross-section of F3 with a reduced core. (*From* Baumann MA. ProTaper—a new generation of NiTi-files in endodontics. Endodontie 2001;10:353; with permission.)

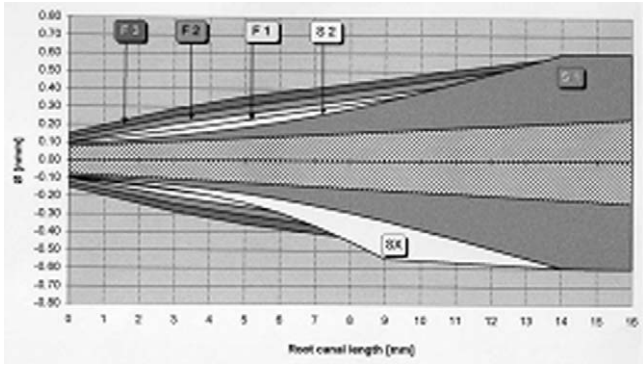

Fig. 9. This graphic model, overlapping the taper of ProTaper instruments, shows the complex design of the instruments.

posterior areas, which could compromise the treatment result. The files are available in 21- and 25-mm lengths.

Instrument design

Shaping files

The ProTaper system features six NiTi files, the first of which is the auxiliary shaping file, called Shaper X or SX. SX is recognized by its lack of an identification ring on its handle and its extraordinary shape, reminding Prof. Pierre Machtou—one of the three specialists involved in the development of

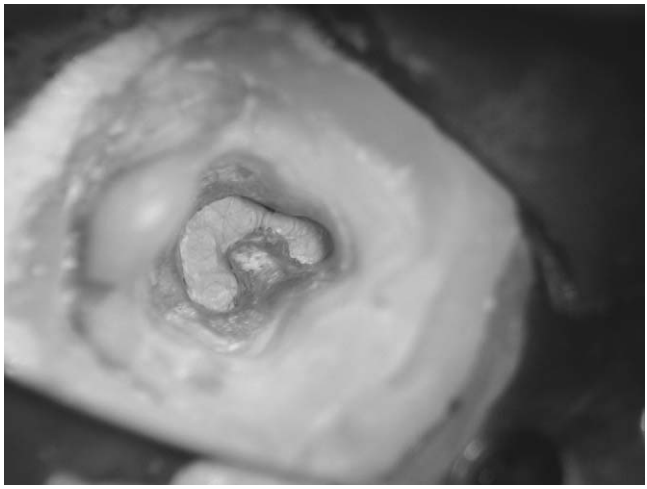

Fig. 10. Straight-line access is of major importance, especially in complex canal systems such as the obturated c-shaped lower molar. (Courtesy of Thomas Clauder, DDS.)

Fig. 11. The file in the unshaped canal gives information about the angulation of the coronal part of the canal. (Courtesy of Clifford J. Ruddle, DDS.)

the system—of the Eiffel Tower in Paris (see Fig. 3). SX is available with cutting blades of 14 mm and a tip diameter of 0.19 mm. All of the ProTaper shaping files have a progressively increasing taper; SX has the highest increase. At D6, D7, D8, and D9, the cross-sectional diameter increases from 0.50 mm, 0.70 mm, 0.90 mm, and 1.10 mm, according to a taper of 11%, 14.5%, 17%, and 19%, respectively. The total increase of taper in SX from D0 to D9 is defined with nine different tapers from 3.5% to 19%.

Fig. 12. With brushing motions, the canal orifice has to be relocated to achieve straight-line access to the apical region of the canal. (Courtesy of Clifford J. Ruddle, DDS.)

Fig. 13. Shaping with SX leads to removal of the overlapping dentin walls and allows for straight-line access. (Courtesy of Clifford J. Ruddle, DDS.)

The complex file design allows for ideal and efficient shaping of the coronal aspects of the root canal and the relocation of canal orifices, resulting in a straight-line access. The relocation of the canal orifices should be in the direction of overhanging dentin areas and away from ''danger zones'' in furcation areas and thinner dentin walls, where strip perforations can compromise treatment objectives. The instrument is used in a brushing motion and is designed to replace Gates-Glidden drills (Dentsply Maillefer,

Fig. 14. Precise determination of working length and establishing patency with hand files are key factors for further cleaning and shaping procedures. (Courtesy of Clifford J. Ruddle, DDS.)

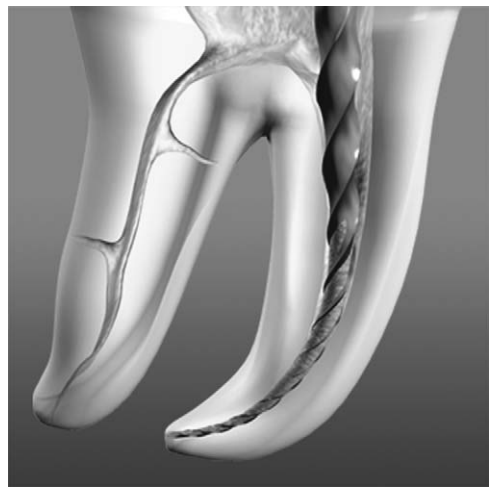

Fig. 15. S1 and S2 are carried to working length, shaping primarily the coronal two thirds of the canal, but also pre-enlarging the apical area. (Courtesy of Clifford J. Ruddle, DDS.)

Ballaigues, Switzerland). The diameter at D10 is 1.11 mm, which corresponds to a Gates-Glidden drill size of four.

Shaping file 1 (S1) has a purple identification ring and shaping file 2 (S2) has a white identification ring on their handles (see Fig. 3). The diameter at the tip of S1 is 0.19 mm and of S2 is 0.20 mm. Both instruments have an increasing taper over the whole working range, although the increase is not as aggressive as that of SX. S1 has an increasing taper from 2% on D1 to

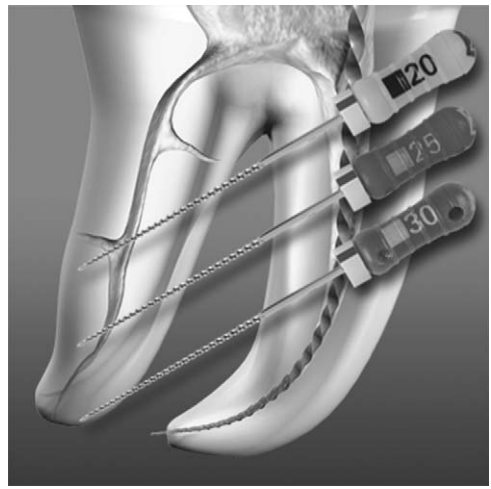

Fig. 16. Gauging the apical canal diameter provides further information that influences the finishing criteria. (Courtesy of Clifford J. Ruddle, DDS.)

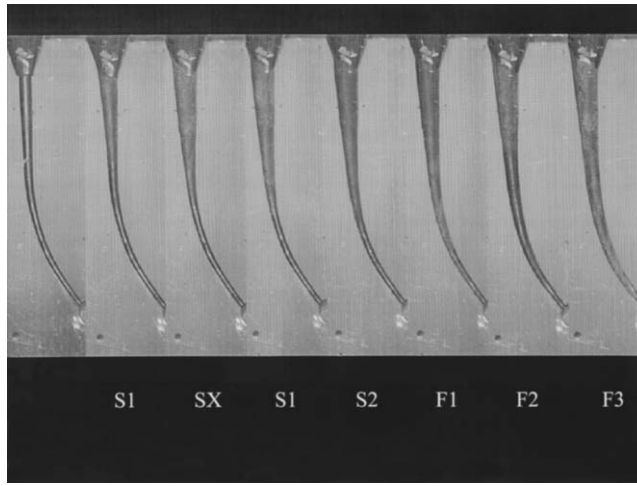

Fig. 17. ProTaper files, used in the described sequence, engage special sections of the root canal shown in the graphic.

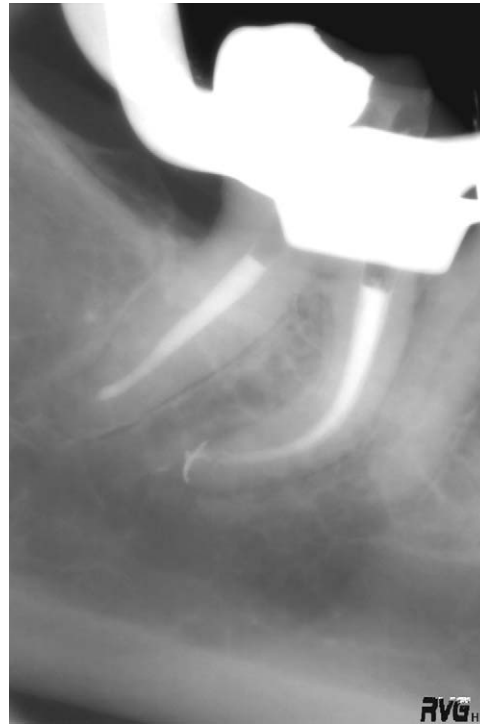

Fig. 18. Radiograph showing a curved lower molar instrumented with ProTaper rotary files. (Courtesy of Thomas Clauder, DDS.)

11% on D14. S2 has an increasing taper from 4% on D1 to 11.5% on D14. S1 is designed to shape mainly in the coronal section of the root canal; in comparison, S2 is designed to shape the middle section of the root canal system. Because these instruments are already at working length after initial preflaring, they shape the apical region increasingly (doubling of the taper at the instrument tip).

Finishing files

The finishing files F1, F2, and F3 are marked with a yellow, red, and blue identification ring, respectively (see Fig. 3). Their diameters at the tip (D0) are 0.20 mm, 0.25 mm, and 0.30 mm, respectively. All three instruments have a fixed taper in the first 3 mm from D0 to D3. F1 has a taper of 7%, F2 has a taper of 8%, and F3 has a taper of 9% in this region. Over the remaining length of the cutting blade, a reverse taper can be found. The decreasing taper ensures a continuing flexibility within the file and avoids too large a diameter at the shaft area of the instrument. The instruments have been developed for superior apical preparation, in addition to shaping the middle section preferably. This complex and demanding instrument design can be appreciated best when comparing the cross-sections in an overlapping model highlighting the tapers graphically (Fig. 9) [5].

Instrumentation with ProTaper files

The ProTaper system is a preparation system that can be used for complex and standard cases, allowing for a clean, efficient, and predictable preparation of the root canal. The successful application of the system demands certain preconditions.

Torque-controlled endodontic motors

Ruddle [6] has shown that with the use of rotating NiTi instruments, the risk of instrument separation increases. These fractures often occur in the apical portion of the root canal system, impeding adequate cleaning, shaping, and obturation. Although the manufacturers of NiTi systems recommend checking the files frequently to prevent possible fracture, instruments may break without warning or any indication of a previous, permanent, visible deformation or defect. To minimize this risk of separation, it is recommended that inexperienced users take advantage of torque-controlled endodontic motors [7]. Although experience and routine is of great importance to the successful usage of the system [8], even experienced operators can reduce the risk of separation by working with the recommended range of torque. The use of new instruments also reduces the risk of instrument fracture significantly [9]. Force should never be applied to

Fig. 19. ProTaper files were used for hand instrumentation to instrument the extreme curvature of the lower molar. (Courtesy of Thomas Clauder, DDS.)

a file; only a light brushing motion should be used to achieve the desired results.

Straight-line access

An ideal access cavity preparation is very important to successful treatment, independent from the file system and the technique used (Fig. 10). To avoid staining the files unnecessarily and instrumenting unnecessary curvatures, it is necessary to achieve a straight-line access and to reduce all overlapping dentin areas. The ProTaper SX file may be used to remove the triangle of dentin rapidly, effectively, and safely [1,10]. Furthermore, it has to be ensured that all orifices can be viewed on the mirror without any movement of it. In addition, access cavities should be reshaped so that a straight-line access to apical regions can be achieved. The angle of the inserted instrument is a good indicator: if straight-line access has been achieved, the instrument should stand upright (Fig. 11) [1]. The angulations after the initial crown down should be parallel to the axis of the tooth to ensure the most effective cutting efficiency in the regions of application. A recent study showed that the ProTaper System—like most other rotational

Fig. 20. Previous endodontic treatment resulted in persisting apical periodontitis and is a source of acute symptoms. (Courtesy of Thomas Clauder, DDS.)

systems—tends to result in slight transportation, which increases when the root canal systems show an increased initial angulation [11]. A well-prepared coronal shaping minimizes this problem and therefore is of utmost importance to a successful result [11].

Glide path

Establishing a smooth glide path is a top priority for all endodontic manipulations, and also is necessary for the safe use of the ProTaper System. The ProTaper system is designed so that the files—after initial preflaring with S1 and SX—can be carried easily to working length. A carefully prepared glide path allows for the safe use of the instrument. The following instruments engage different parts of the canal system as far as their instrument geometry allows, and also widen the apical portion of the canal [7].

Irrigation and chelators

The pulp chamber has to be filled with irrigating solution (NaOCl or ethylenediaminetetraacetic acid [EDTA] solution) during the whole shaping

Fig. 21. The ProTaper files also can be used for retreatment cases. This postoperative radiograph shows the tooth after instrumentation and obturation of all four canals. (Courtesy of Thomas Clauder, DDS.)

procedure. In addition, a viscous chelator should be used to minimize force on the instrument. After the use of each instrument, irrigation confirming patency and reirrigation is of main importance. One of the first steps after carefully preparing an ideal access cavity to working length is the initial negotiation of the canals with a #10 or #15 K-file up to about two thirds of the estimated working length. This is a decisive step in the use of any rotary system, and important information can be deduced from the angle of the canal and the confirmation of straight-line access (see Fig. 11). Additional knowledge also can be gathered on the anatomy of the canal and potential anatomic problems that could influence the treatment plan, such as confluent or dividing canals, severe curvatures, or s bends [12]. A further aspect is the canal diameter—the procedure is influenced substantially when open, constricted, or complete calcified canals are present.

After a glide path has been established with K-files, S1 is the first instrument used. During insertion, a brushing motion against the canal wall in the direction of repositioning the canal orifice is used. This motion is repeated a few times before removing the file from the canal. Coronal

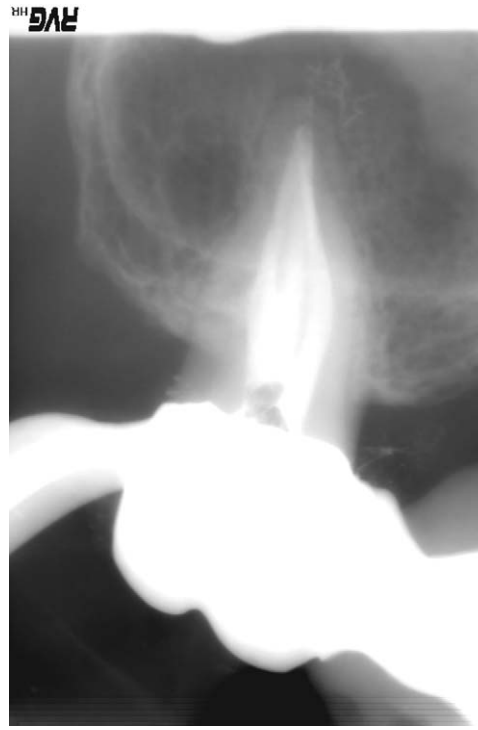

Fig. 22. This interesting canal anatomy was cleaned and shaped with ProTaper files. (Courtesy of Thomas Clauder, DDS.)

shaping with SX then can be started. SX is inserted while rotating into the root canal. If a light resistance is felt on the instrument, the file is withdrawn and worked in a brushing motion against the dentin wall of choice (Fig. 12) [1,6]. Repeating this procedure allows for deeper insertion of the instrument, enabling the removal of all overlapping dentinal walls and a perfect coronal shape of the root canal. It is important to inspect the instrument after each use to prevent fractures of the instrument. Deformed instruments must be discarded immediately. Shaping with SX should result in generous dentin removal; inadequate widening of the coronal aspects of the root canal can complicate and slow down further instrumentation, because following instruments can get stuck in thin coronal parts of the canal. After the initial crown down is finished, the files inserted into the root canal should be parallel to the axis of the root (Fig. 13).

After the initial crown down, the working length is confirmed and patency is established (Fig. 14). A #10 K-file is inserted passively into the canal. Working length should be checked with an electronic apex locator and confirmed with a well-angulated radiograph. Patency is of great importance and must be maintained during the complete shaping procedure

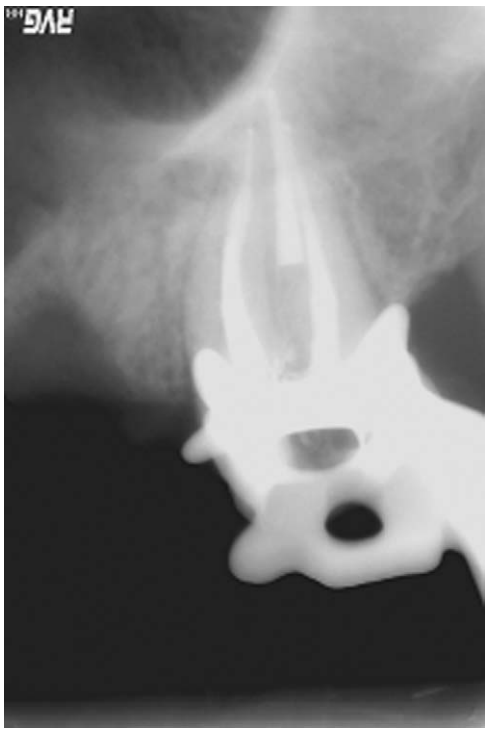

Fig. 23. "Straight forward cases" can be shaped without procedural errors. (Courtesy of Thomas Clauder, DDS.)

[10]. In most cases, an initial apical instrumentation with hand instruments to a size of #15 K-files is necessary and very important. Widening the apical portion seems to reduce the risk of fracture in constricted, narrow canals [10,13]. In special cases with complex anatomic structures, in which it is likely that the use of rotary instrumentation will result in failure, continuing the shaping procedure by hand instrumentation is the method of choice. In all other situations, the shaping procedure with ProTaper instruments is continued. S1 is moved carefully to working length in a brushing technique. If this goal cannot be achieved or can be achieved only by forcing the instrument, there are several possibilities that can prevent the file from moving to apical areas:

1. The flutes are covered with debris and dentin chips. The ProTaper system usually works very efficiently and reliably. Efficiency decreases rapidly when the flutes of the instrument are blocked with debris. Cleaning the instrument thoroughly, irrigating the canal, confirming patency, and repeating the last step usually solves these problems.
2. The coronal aspect of the root canal has not been widened enough, which occurs most often in long canals. In this case, SX should be used

Fig. 24. The lower molar was shaped for three-dimensional obturation of the root canals. (Courtesy of Thomas Clauder, DDS.)

in a more effective way or, as an alternative in very long canals, Gates Glidden drills can help to widen the coronal and middle portion of the canal to prevent following files from blocking in these areas.

3. The canal is obstructed in apical areas. Blockage of a rotating instrument in the apical tight canal leads to extreme torsional loads on the instrument and high risk of separation. The fact that a canal is very tight or calcified can be detected by scouting the apical portion of the canal and establishing working length. The canal should be instrumented by hand to an appropriate size to reduce the torsional load on the instrument.
4. The canal is blocked by dentin chips or pulp tissue in the apical portion. A viscous chelator (EDTA solution) should be irrigated into the canal, patency should be established with an adequate K-file, and the instrumentation should be repeated with smaller files.

After successful insertion of S1, S2 is used in one or two strokes to working length in the same manner as described previously (Fig. 15). The coronal two thirds of the root canal now should be shaped ideally. Apical

Fig. 25. Anatomic variations, like this premolar with three roots, can be introduced with the system. (Courtesy of Thomas Clauder, DDS.)

preparation is done with the finishing files. For apical gauging and shaping the technique preferred by Dr. Clifford Ruddle is as follows [12].

The last instrument reaching working length is S2, which has a diameter of 0.20 mm at the instrument tip and a taper of 4%. F1, which has the same diameter at the instrument tip, can be worked to working length. Due to the design of the file, a uniform taper of 7% is produced in the apical portion of the root canal. The apical diameter of the root canal is gauged with a #20 K-file. The instrument is inserted passively into the canal to working length, tapping on the head of the instrument to prevent cutting action. If the file binds in the apical region, the preparation is finished. If the file is loose in the canal, F2 is inserted to working length. Apical gauging should be repeated now with a #25 K-file. During this procedure, attention is given to maintain working length. Does the #25 K-file bind at working length preparation of the root canal is finished, if the file is loose in the canal, F3 should be used to working length. Apical gauging should be repeated now with a #30 K-file (Fig. 16). Does the #30 K-file bind at working length preparation of the root canal is finished, if the file is loose in the canal a different technique should be chosen to finish apical preparation. With the second use of S1, all

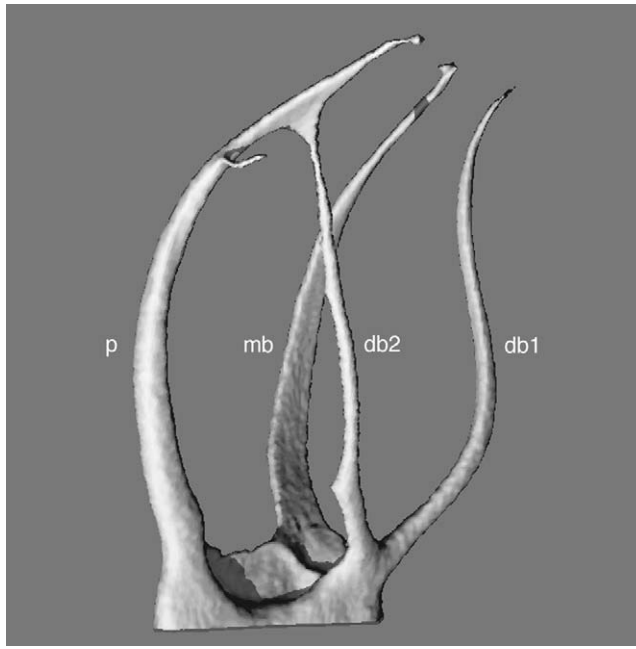

Fig. 26. The micro-CT evaluation demonstrates the canal anatomy of an upper molar before instrumentation. (*From* Peters OA, Peters CI, Schöneberger K, Barbakov F. ProTaper rotary root canal preparation: effects of canal anatomy on final shape analyzed by microCT. Int Endod J 2003;36:87; with permission.)

instruments are inserted to working length. ProTaper instruments provide a continuous tapered preparation of the root canal, without significant transportation of the original position. The ProTaper files engage specific sections of the root canal system, as the instrument geometry and design allows. This can be demonstrated very easily, inspecting the instruments for debris remnants immediately after use. The order of instrumentation and the varying areas of use for each ProTaper file are shown in Fig. 17. During the complete shaping procedure, focus also should be given to maintaining an accurate, precise, and effective antibacterial protocol. After each instrument irrigation, establishing patency and reirrigation is of extreme importance to achieve perfect cleaning and shaping objectives.

In cases of severe curvatures, rotational speed of the instruments could be reduced to a minimum of 150 rotations per minute [14,15] (Fig. 18). In addition, the lifespan of an instrument is directly proportional to a specific number of rotary cycles [16]. In cases of pronounced and acute curvatures [17] with a small radius (Fig. 19), the use of ProTaper files in a hand file manner is helpful, especially because there are new useful handles available (Dentsply/Maillefer). The files can be used safely in a watch-winding motion. Cutting efficiency can be improved in a turning motion. ProTaper

Fig. 27. The micro-CT evaluation demonstrates the canal anatomy of an upper molar after cleaning and shaping procedures with ProTaper files. (*From* Peters OA, Peters CI, Schöneberger K, Barbakov F. ProTaper rotary root canal preparation: effects of canal anatomy on final shape analyzed by microCT. Int Endod J 2003;36:87; with permission.)

instruments can be helpful in retreatment cases; the finishing files are especially useful in the careful removal of gutta percha. For reshaping the canal anatomy after establishing patency, the instruments can be used in the previous described sequence, if pretreatment did not result in far greater apical diameters (Figs. 20 and 21).

Summary

Root canal instrumentation should provide a tapered, adequate canal shape to allow for effective irrigation and obturation [18]. This can be accomplished thoroughly with the ProTaper NiTi system (Figs. 22 and 23). The well-planned file design allows for an ideally prepared root canal of easy or difficult shape (Figs. 24 and 25). The finish of the root canal instrumentation allows for a predictable obturation of the root canal system, independent of technique chosen. ProTaper instruments adequately open canals 5 mm from their apices, with sizes varying from 0.65 mm to 0.79 mm. Spreaders and pluggers with 0.50-mm tips can be used readily during obturation of root canals with such apical preparations [11]. They also can be used for antibacterial therapy, allowing for a thorough irrigation technique.

Fig. 28. Superimposing pre- and postoperative data demonstrates the shape created with ProTaper files following canal anatomy. (*From* Peters OA, Peters CI, Schöneberger K, Barbakov F. ProTaper rotary root canal preparation: effects of canal anatomy on final shape analyzed by microCT. Int Endod J 2003;36:89; with permission.)

After the ProTaper system was introduced, the possibility of more or less severe canal transportation produced by active cutting action was discussed. The latest evidence shows that "canals can be prepared with the ProTaper system without major procedural errors" (Figs. 26–28) [11,19]. Micro-CT evaluation of shaped canal studies showed that the ProTaper System tends to transport canals slightly larger than do file systems with a passive cutting action [11]. Therefore, it is important to immediately remove the instrument out of the root canal once working length is achieved. A prolonged rotation of the instrument with an active cutting blade can lead to unnecessary misshapes in canal anatomy. This tendency can be minimized by achieving proper coronal shaping and straight-line access (Fig. 29). Straight-line access helps to minimize transportation during the shaping procedure [11]. Another study [19] has shown no transportation in the middle section of the tooth and in apical areas, and little transportation in coronal areas toward furcation areas. A center displacement toward the furcation area also has been demonstrated with several NiTi systems on the market [19], but obviously is not as severe as with a standardized instrumentation technique using stainless steal instruments [3].

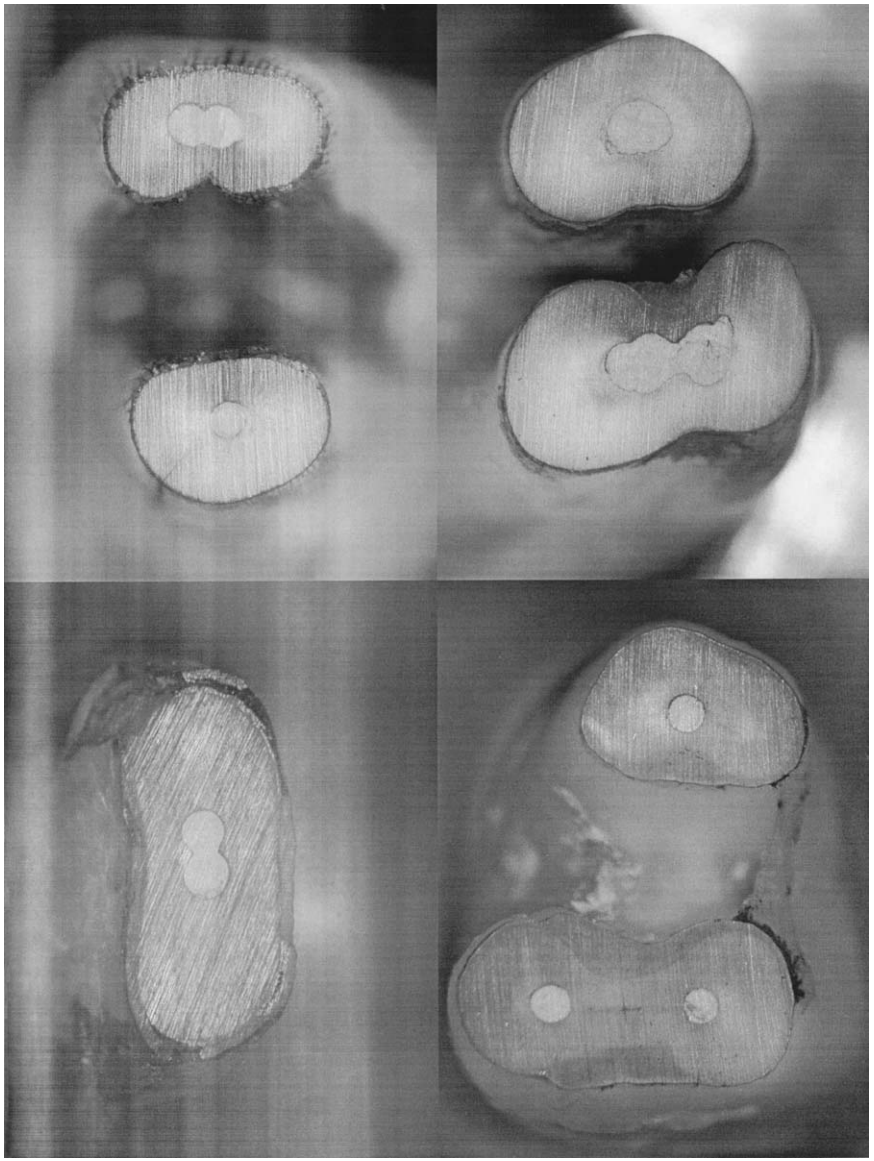

Fig. 29. Sections of treated extracted teeth with ProTaper instruments show a centered preparation allowing for complete obturation.

The ProTaper files generate lower torque scores than do rotary instruments with a U-file design (radial land). Furthermore, high forces that are generated in some cases of constricted canals were insufficient to fracture ProTaper instruments [13]. Constricted canals are a major problem because of the correlation with high torque values. Using a ProTaper file

seems to minimize fracture risk of the instrument [13]. Apical instrumentation with K-files is extremely important in these cases. In addition, discarding instruments—after or during use—that have been used in calcified canals helps to minimize the fracture risk of the instrument. Mathematic models have confirmed that in case of similar apical loads, ProTaper instruments work longer in a super elastic phase than do instruments with a U-file design, allowing for high performance and less risk [20]. The system enables a safe of time compared with hand instrumentation techniques, especially in simple and predictable cases. In more difficult cases, the advantage lies in the perfect preparation of the root canal.

The operator should decide on the size of the apical instrumentation according to the preferred treatment concept, the scientific background, and the special case selected. If the apical regions are to be enlarged wider than ISO 30 in large canals, it might be best to use a different technique to achieve the treatment goal rather than using the ProTaper system. Recent studies have shown that the ProTaper system perfectly shapes curved and constricted canals [11,13,15]. Wide canals were less efficiently instrumented, which is apparent as the design features and sizes available suite less [11]. Combining ProTaper system with other NiTi systems emphasize the advantages of the ProTaper system can provide larger apical sizes. This is discussed in the article on hybridization of file systems elsewhere in this issue.

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