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Canal Shaping with WaveOne Primary Reciprocating Files and ProTaper System: A Comparative Study

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Abstract

Introduction: This study compared the canal curvature and axis modification after instrumentation with WaveOne Primary reciprocating files (Dentsply Maillefer, Ballaigues, Switzerland) and nickel-titanium (NiTi) rotary ProTaper (Dentsply Maillefer). **Methods:** Thirty ISO 15, 0.02 taper, Endo Training Blocks (Dentsply Maillefer) were used. In all specimens, the glide path was achieved with PathFile 1, 2, and 3 (Dentsply Maillefer) at the working length (WL). Specimens were then assigned to 1 of 2 groups for shaping: specimens in group 1 were shaped with ProTaper S1-S2-F1-F2 at the WL and specimens in group 2 were shaped with WaveOne Primary reciprocating files at the WL. Pre- and postinstrumentation digital images were superimposed and processed with Matlab r2010b (The MathWorks Inc, Natick, MA) software to analyze the curvature-radius ratio (CRr) and the relative axis error (rAe), representing canal curvature modification. Data were analyzed with one-way balanced analyses of variance at 2 levels ($P < .05$). **Results:** The instrument factor was extremely significant for both the CRr parameter ($F_1 = 9.59$, $P = .004$) and the rAe parameter ($F_1 = 13.55$, $P = .001$). **Conclusions:** Canal modifications are reduced when the new WaveOne NiTi single-file system is used. *(J Endod 2012;38:505–509)*

Key Words

Canal shaping, nickel-titanium, ProTaper, reciprocating motion, WaveOne

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Root canal shaping is one of the most important steps in canal treatment (1). It is essential in determining the efficacy of all subsequent procedures, including chemical disinfection and root canal obturation (2). However, even if this stage is adversely influenced by the highly variable root canal anatomy (3), it aims to achieve complete removal of the vital or necrotic tissue to create sufficient space for irrigation (2, 4). Furthermore, shaping tends to preserve the integrity and location of the canal and apical anatomy in preparation for an adequate filling (2, 5, 6). The avoidance of both iatrogenic damage to the root canal structure and further irritation of the periradicular tissue is demanding for all the newest instrumentation techniques (2, 7). Maintaining the original canal shape using a less invasive approach is associated with better endodontic outcomes (1). Previous studies have shown that canal transportation leads to inappropriate dentine removal, with a high risk of straightening the original canal curvature and forming ledges in the dentine wall (8, 9). Nickel titanium (NiTi) rotary instruments have shown efficiency in achieving optimal root canal shaping (1, 10), with less straightening and better centered preparations of curved root canals (2). The superelasticity of NiTi rotary files may allow less lateral forces to be exerted against the canal walls, especially in severely curved canals, reducing the risk of canal aberrations and better maintaining the original canal shape (1, 11). However, in clinical practice, these instruments may be subjected to fracture, mainly because of flexural (fatigue fracture) and torsional (shear failure) stresses (12–14). Torsional stresses may be increased with a wide area of contact between the canal walls and the cutting edge of the instrument (3, 15). To reduce such stresses, the ProTaper rotary design combines multiple progressive tapers, adequately maintaining the original canal curvature (1, 16, 17). Canal curvature is suspected to be the predominant risk factor for instrument failure because of flexural stresses and cyclic fatigue (1–3). The clinician can do very little to prevent or reduce such stresses. The reciprocating motion of the NiTi rotary instrument has been shown to decrease the impact of cyclic fatigue compared with rotational motion (18–20). Therefore, it has been recently proposed that the single-file shaping technique may simplify instrumentation protocols and avoid the risk of cross-contamination. Moreover, the use of only one NiTi instrument is more cost-effective, and the learning curve is considerably reduced (20).

The new WaveOne NiTi single-file system has been recently introduced by Dentsply Maillefer (Ballaigues, Switzerland) (21). The system is designed to be used with a dedicated reciprocating motion motor. It consists of 3 single-use files: small (ISO 21 tip and 6% taper) for fine canals, primary (ISO 25 tip and 8% taper) for the majority of canals, and large (ISO 40 and 8% taper) for large canals. The files are manufactured with M-Wire (Dentsply Tulsa Dental Specialties, Tulsa, OK) NiTi alloy (22). The WaveOne Primary file has the same tip size and taper features as the ProTaper F2 but a variable section and reverse cutting blades. The purpose of this study was to compare the ability of the WaveOne Primary file with the ProTaper system up to F2 rotary file in preserving canal anatomy.

Materials and Methods

Thirty ISO 15, 0.02 taper, Endo Training Blocks (Dentsply Maillefer) were used. Each simulated canal was colored with ink injected with a syringe. In each block, landmarks were placed 3 mm from the 4 corners of the side of interest. Each specimen was mounted on a stable support consisting of a rectangular slot the size of the specimen (30 × 10 mm) and a support for a digital camera (Nikon D70; Nikon, Tokyo, Japan) positioned centrally and at 90° to the specimen. Digital images of all specimens before instrumentation were obtained and saved as JPEG files. Specimens were then randomly assigned to 2 different groups (n = 15 each).

In group 1, the glide path was created with PathFile 1, 2, and 3 (Dentsply Maillefer) at the full working length (WL) using Glyde (Dentsply Maillefer) as the lubricating agent. Each canal was shaped using ProTaper S1-S2, and then the WL was checked and shaping was accomplished with F1-F2 at the WL with the X-Smart motor (Dentsply Maillefer) set to 300 rpm and a 5-Ncm torque with a 16:1 contra-angle. Canal patency was checked with a #10 K-file (Dentsply Maillefer) before the glide path, after the glide path, before using ProTaper S1, and after ProTaper S2 but before using the F1-F2 finishing files.

In group 2, the glide path was created with PathFile 1, 2, and 3 at the full WL by using Glyde as the lubricating agent. Canals were shaped with WaveOne Primary reciprocating files using a pecking motion. The WL was checked when the instrument had reached the limit between the middle and apical third, and then shaping was accomplished at that the definitive WL. The dedicated reciprocating motor (Dentsply Maillefer) of the WaveOne file was used with the manufacturer configuration setup. Canal patency was checked with a #10 K-file (Dentsply Maillefer) before the glide path, after the glide path, and before using WaveOne Primary, and when WaveOne Primary had reached the limit between the middle and the apical third before completing shaping at the full WL.

All specimens were prepared by the same expert operator who is competent in both instrumentation techniques. New instruments were used in each specimen. After use, each instrument was observed under a magnification of 3.5× loupes by a different expert operator and compared with a new instrument in order to detect any macroscopic deformation. After instrumentation, all specimens in each group were repositioned in the slot and photographed as described previously. By using digital imaging software (Adobe Photoshop CS4; Adobe Systems Inc, San Jose, CA), the preinstrumentation digital images were superimposed on the postinstrumentation images, taking the landmarks as reference points (Fig. 1, Stage 1). Images were magnified and cropped to focus on the canal geometry. The edges of each preinstrumented (initial) and postinstrumented (final) canal were automatically detected by means of Adobe Photoshop automatic tools, and the edges of each initial canal were processed separately from the edges of the corresponding final canal. The area within edges was colored in white, whereas the area outside the edges was colored in black. Images were finally saved in a black and white .tiff format (Fig. 1, Stage 2).

Black and white images were then imported in Matlab r2010b software (The MathWorks Inc, Natick, MA) for mathematic processing. A software program was written in Matlab code in order to automatically (1) identify the mean axis of each canal (Fig. 1, Stage 3) and (2) determine the osculating circle that best fits the mean axis of each canal (Fig. 1, Stage 4).

In particular, an arc corresponding to 45° was considered for the optimal fit algorithm, and the correlation coefficients were larger than 99.99%. By considering the fitted osculating circles, both the curvature radius of each initial canal (CRi) and the curvature radius of the corresponding final canal (CRf) were obtained, and the geometric parameter called the curvature-radius ratio (CRr) was computed for each canal as CRr = 100 · CRf/CRi. The closer the CRr parameter is to the value 100, the smaller the canal shape modifications caused by the instrumentation.

As shown in Figure 2, another geometric parameter identified as the relative axis error (rAe) was computed in order to better investigate canal modifications induced by instrumentation. In particular, to obtain the value of rAe for each canal, the following actions were performed: (1) superimposition of the initial and the final osculating arcs; (2) determination of $\Delta\theta$ (ie, the angle with vertex in the center of the initial osculating circle for which both the initial and the final osculating arcs coexist; (3) numeric computation of the axis error (Ae) (ie, the area enclosed by the initial and the final osculating arcs [Fig. 2, magnification]); and (4) computation of rAe as rAe = 100 · Ae/CSi, where CSi denotes the circular sector corresponding to $\Delta\theta$ (ie, CSi = $CRi^2 \cdot \Delta\theta/2$). Therefore, the smaller the rAe, the less the canal shape had been modified by instrumentation.

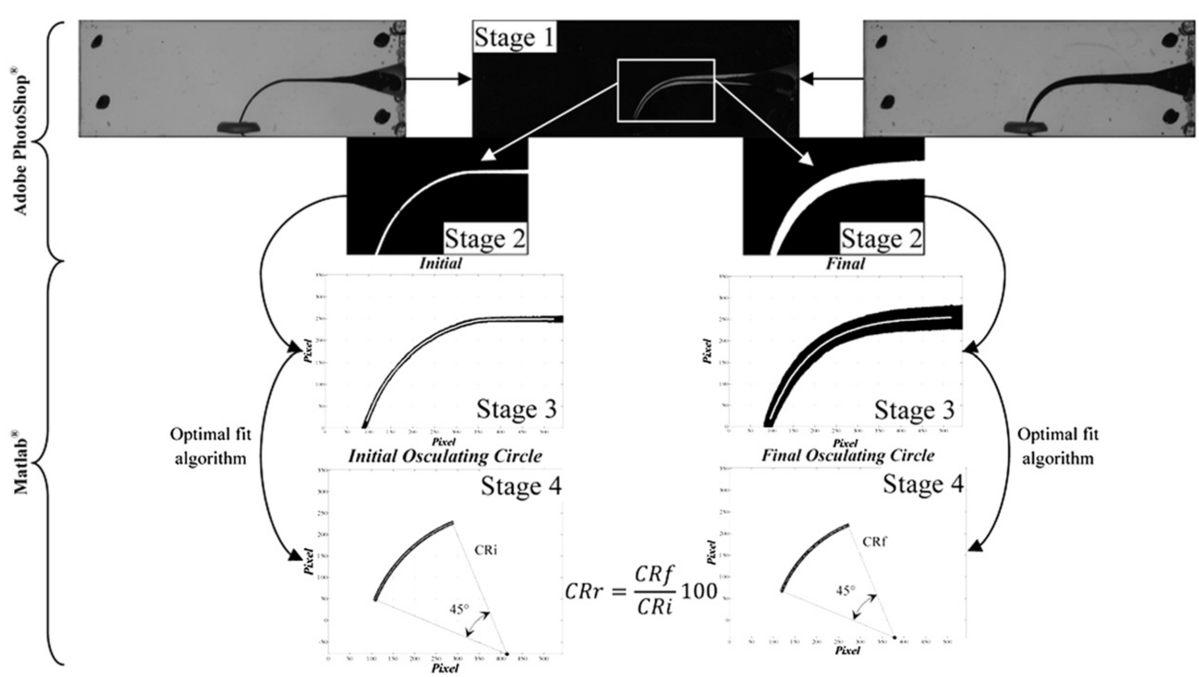

Figure 1. A schema to determine the CRr parameter.

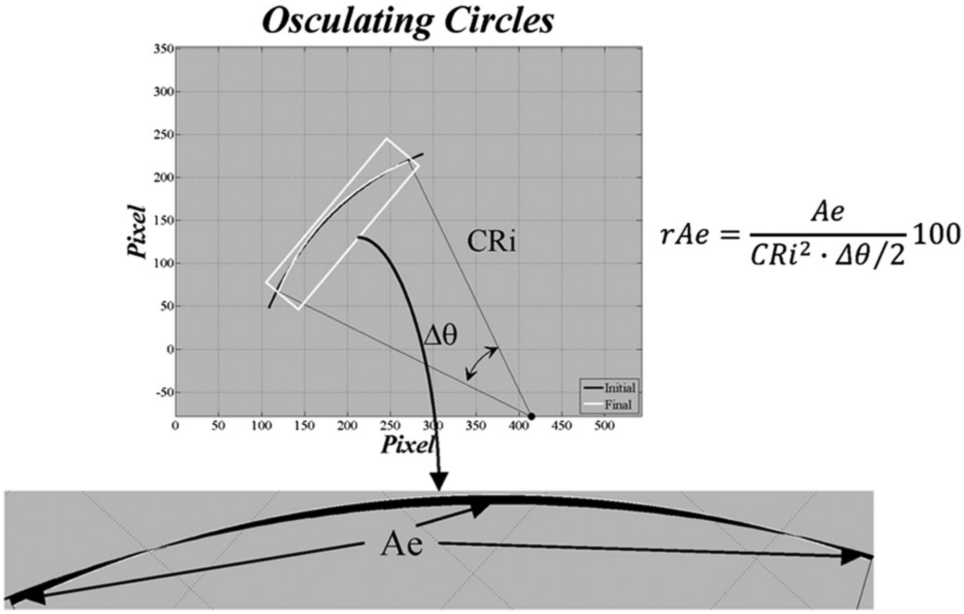

Figure 2. A schema to determine the rAe parameter.

Two, 1-way balanced analyses of variance were performed to investigate canal modifications induced by instrumentation and evaluate the significance of the instrument factor at 2 levels (PT and W1) both on CRr and on rAe. The significance level was set to 5% ($P < .05$). All statistical analyses were performed by using the Minitab 15 software package (Minitab Inc, State College, PA).

Results

The instrument factor was extremely significant for both the CRr parameter (F_1 = 11.16, P = .002) and the rAe parameter (F_1 = 12.18, P = .002). The interval plots for the CRr parameter (Fig. 3*A*) and the rAe parameter (Fig. 3*B*) graphically confirmed statistical significance of the instrument factor. Moreover, if the instrument factor is at level WaveOne (W1), then the CRr parameter is closer to the value 100 and the rAe parameter to the value 0 (ie, if WaveOne is used, the canal modifications seem to be significantly reduced). No macroscopic deformations or fractures of any instrument, mechanical or manual, occurred during the experiment.

Discussion

The purpose of this study was to compare the ability of 2 NiTi instruments, the WaveOne Primary and the ProTaper system used up to F2 rotary file, in preserving original canal anatomy. The WaveOne Primary and the ProTaper F2 have different sections but an identical taper and tip diameter. The WaveOne Primary has a reverse cutting blades design (21). They were used with the following motions: reciprocating motion for the WaveOne Primary and rotary motion for the Protaper system. In this study, geometric variations of canal curvature in the middle plane of standardized resin blocks were analyzed through a 2-dimensional (2D) photographic method. Simulated root canals have been widely used to allow a direct analysis of post-instrumentation changes in canal curvature and thus to evaluate the tendency of these techniques to maintain the original canal anatomy under standardized conditions (23). It has recently been suggested that micro–computed tomographic 3-dimensional (3D) analysis is more discriminative of changes in the canal spaces associated with repeated instrument use than photographic measurements; however, volumetric changes only were assessed, and possible geometric

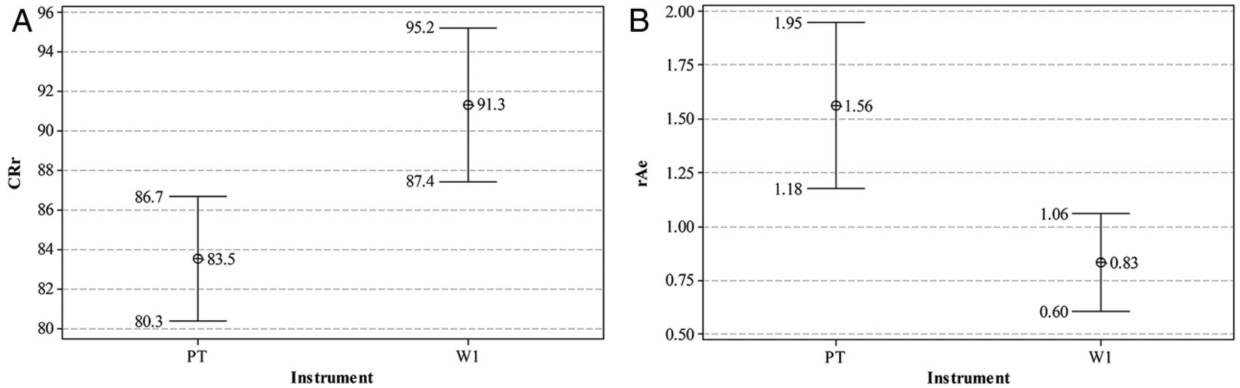

Figure 3. (*A*) The interval plot for the CRr parameter; 95% confidence intervals for the mean. (*B*) The interval plot for the rAe parameter; 95% confidence intervals for the mean.

changes were not analyzed (24). 3D analysis is determinant in the study of the variability of human teeth root canal anatomy with 3D development of the canal path (1).

Previous studies have shown that preserving the original canal shape with a less invasive approach minimizes the risk of canal transportation with a subsequently lower incidence of canal curvature straightening, the formation of ledges, and irregular apical enlargement (8, 9). The prevention of apical transportation and irregular foramen widening may also lead to a well-sealed root filling with less extrusion of debris and reduced postoperative discomfort (1, 7, 25). Preservation of the original canal shape and the lack of canal aberrations are associated with increased antimicrobial and sealing efficiency (5) and reduced weakening of the tooth structure (6). Besides canal anatomy, other factors contribute to optimal mechanical instrumentation outcomes, such as instrument design, instrumentation sequence, rotational speed, operator's experience, and the use of irrigants (1, 26). Several studies showed that the use of NiTi rotary instruments enabled more predictable and efficient canal preparation with less procedural errors, particularly in narrow and severe curved canals, compared with hand instrumentation (10, 27, 28). Recently, a new WaveOne NiTi single-file reciprocating system has been introduced to simplify root canal preparation (20). Only one single shaping file is required to provide the canal with an adequate size and taper. The main characteristics of this system are single use, a reciprocating action, and M-Wire technology alloy manufacturing. The use of a single ProTaper F2 used in a reciprocating motion to reach an adequate root canal shaping has been previously investigated (29). On engagement with the root canal wall, the counter-clockwise rotation disengages the instrument, promoting a safer use of single-file instruments in curved canals (29). An alternating motion was introduced to reduce excessive torsional stresses induced by rotary instrumentation with a single-file technique (19). The reciprocating movement promoted an extended cyclic fatigue life of F2 ProTaper instruments when compared with the conventional rotary motion (20). The single-file F2 ProTaper alternating technique showed similar shaping outcomes compared with the ProTaper full-sequence rotary approach up to F2. However, the single-file technique gave markedly faster results (30). Furthermore, the reciprocating motion has been significantly correlated to a more centered preparation compared with continuous rotating motion as evidenced by an increased enlargement at the external side of the canal, especially in the apical third (31). Moreover, the single-file technique presented similar debridement quality in round canals compared with the complete sequence of ProTaper rotary instruments regardless of the reduced number of files (32).

The advantages of the reciprocating motion are based on the physics law of action and reaction applied to root canal instrumentation, which results in a balanced force, as theorized by Roane et al (33). This concept, despite incomplete elucidation (34), has shown its clinical relevance in severely curved canals (35). The reciprocating movement minimizes torsional and flexural stresses, increases the canal centering ability, and reduces the taper lock within the number of instrument cycles within the root canal (35, 36). Recent studies showed that an alternating rotary movement is a valid option to optimize endodontic instrumentation by reducing the risk of instrument fracture and root canal deformity (19). The use of the reciprocating motion instead of the continuous rotation method could be advantageous in terms of stresses and the time required for the preparation of curved root canals with a single use of an NiTi file (18). In our study, the single-file technique used with the reciprocating motion enhanced the canal centering ability, leading to less invasive root canal preparation. This outcome may be particularly significant where dentine thickness is lower (37). Furthermore, the WaveOne files are manufactured with the M-Wire NiTi alloy (22), a novel variant NiTi alloy, composed of 508 nitinol, under specific tension and heat treatments at various temperatures. This alloy has been associated with an increase in cyclic fatigue of up to 390% compared with the same instrument design produced from stock 508 nitinol and maintained comparable torsional properties (22). The single use of endodontic instruments was recently recommended to decrease instrument fatigue and possible cross-contamination (38), reducing the number of NiTi rotary instruments required for canal preparation. The single-file technique was also suggested as being cost-effective (29).

In conclusion, within the limits of this study, the new WaveOne NiTi Primary reciprocating single-file better maintained the original canal anatomy, with less modification of the canal curvature compared with the ProTaper system up to F2. Further investigations are needed to understand whether the better performance of the instrument may be attributed to the reciprocating motion, the variable section design, the M-Wire alloy or the reverse cutting blades, or a combination of these variables.

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