Changes in diameter, cross-sectional area, and extent of canal-wall touching on using 3 instrumentation techniques in long-oval canals

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Objective. The objective of this study was to compare the shaping ability of manual H-files, rotary nickel-titanium ProTaper system, and reciprocating SafeSiders in long oval-shaped root canals.

Study design. The roots of 45 human premolars were sectioned at 2 levels in the middle third and reassembled using a 3-piece metal mold. Pre- and postinstrumentation cross-sectional images were superimposed and evaluated in terms of change in buccolingual-to-mesiodistal canal ratio, maximum buccolingual and mesiodistal canal dimensions, and cross-sectional areas. Ratios of touched canal wall and canal outline with more than 200 μm dentin removal to the original canal perimeter were also calculated.

Results. The buccolingual-to-mesiodistal ratio decreased after instrumentation with no difference among techniques (P > .05). The change in the buccolingual dimension was significantly less for SafeSiders compared with H-files and ProTaper (P < .05). The change in mesiodistal dimension was significantly less with SafeSiders compared with H-files only (P < .05). The area in change, in descending order, was as follows: H-files > ProTaper > SafeSiders (P < .05). The ratio of touched canal outline was highest with H-files, compared with ProTaper and SafeSiders (P < .05), and H-files recorded the highest ratio of canal outline with more than 200 μm of dentin thickness removal (P < .05).


Thorough debridement of the root canals by mechanical instrumentation is one of the primary objectives in endodontic therapy. A complete mechanical preparation of the root canal system is, however, rarely achievable because of variation in root canal anatomy. An oval-shaped root canal is a configuration that imposes a challenge to complete cleaning, shaping, and obturation.

Different instrumentation techniques have been used to prepare oval canals, including sonic and ultrasonic, manual, rotary nickel-titanium (NiTi), and reciprocating instrumentation. None, however, was able to completely prepare and maintain oval shape outline. In oval-shaped root canals, most rotary NiTi instrumentation techniques and manual instrumentation used with modified reaming actions, e.g., balanced force and quarter-turn techniques, lead to deviation from the oval pattern showing key-hole, dumbbell-shaped, and central bulge effects. Files used circumferentially in a reciprocating handpiece are claimed to better prepare the oval coronal-middle part of the canal.

Research, thus, has been directed to design instruments or modify the method of use of existing instrumentation systems so as to clean and shape oval-shaped canals. Recently, a reciprocating instrumentation system, SafeSiders (Essential Dental Systems, South Hackensack, NJ), was introduced for preparing curved canals. The system comprises a series of non-circular instruments that have a patented, noninterrupted, flat-sided architecture. The instruments are used in a 30-degree 4:1 reciprocating handpiece (Endo-Express, Essential Dental Systems). According to the manufacturer, SafeSiders have 16 flutes compared with 24 flutes in files. The design of SafeSiders was initially introduced for hand instrumentation, where faster preparation of simulated canals in comparison with conventional instruments was shown. In a recent study, stainless steel SafeSiders, attached to a reciprocating handpiece, exhibited greater cutting efficiency than similar motion of K-files and K-reamers of the same size and taper. The reciprocating NiTi 30/0.04 SafeSider showed higher resistance to cyclic fatigue than
rotary NiTi instruments (K3, ProFile, GT Series X) of the same size. A recent study, however, showed that it significantly straightened curved canals when used in sizes larger than ISO 20. It was of interest to investigate how this reciprocating system might perform in shaping oval canals. The aim of the present study, thus, was to compare the shaping ability of manual instrumentation (H-files), rotary NiTi instrumentation (ProTaper), and reciprocation instrumentation (SafeSiders) in shaping long, oval-shaped root canals.

MATERIAL AND METHODS

Tooth selection

Human, single-rooted premolars with single canals were collected. Initial identification of the oval canal was radiographically done by comparing the proximal and clinical views for each root. Canals with a buccolingual dimension of the root canal that was more than twice the mesiodistal dimension were selected. Only straight roots or those with canal curvature less than 10° were included. Teeth were disinfected in 5% NaOCl for 10 minutes. Soft and hard deposits were removed using hand scalers. The teeth were stored in phosphate-buffered saline until use.

Tooth preparation

Following conventional access preparations, patency of the root canal was established with a #15 K-file. The working length was determined by observing the tip of the file protruding through the apical foramen and subtracting 1 mm from the recorded length. The apices of teeth were closed with sticky wax, followed by embedding the teeth up to the cervical line in an epoxy resin using a 3-piece constructed mold. The long axis of the tooth was secured parallel to the long axis of the mold bucconlingually and mesiodistally. The root was sectioned at 2 levels in the middle third, as previously described, using a water-cooled precision saw. The coronal level was just apical to the junction between the coronal and middle thirds, whereas the apical level was just coronal to the junction between the middle and apical thirds. Pre- and postinstrumentation images of the coronal and apical surfaces of the cut middle section were taken under standardized conditions using a stereomicroscope (SZ-PT, Olympus, Tokyo, Japan). Images were superimposed and analyzed using the PC software AutoCAD 2010 (Autodesk, San Rafael, CA).

After tracing the preinstrumentation canal contour image using the AutoCAD software, the maximum buccolingual (BL) and mesiodistal (MD) canal dimensions were measured (in mm). Teeth with a definite BL-to-MD ratio of 2 to 4 were included. Thus, 45 teeth were selected of 70 initially selected teeth. Teeth were randomly assigned to 3 equal groups (n = 15) according to the instrumentation technique: group 1, manual instrumentation using stainless steel H-files (Dentsply Maillefer, Ballaigues, Switzerland); group 2, rotary NiTi instrumentation using ProTaper instruments (ProTaper Universal, Dentsply Maillefer); and group 3, reciprocation instrumentation using SafeSiders.

Sections of each root were then, reassembled for instrumentation. Manual instrumentation was done using H-files in a circumferential filing motion. Coronal prefllaring was initially done using sizes 3 and 2 Gates Glidden burs (Dentsply Maillefer). H-files from #15 to #40 were taken to the working length in sequence ending with #40 as the master apical file. Each file was moved around the oval canal at least 3 times, by pressing against the root canal sides, until it was loose and the canal wall felt smooth.

In the rotary NiTi instrumentation group, ProTaper instruments (Sx, S1, S2) were used in a crown-down manner, then S1, S2, F1, F2, and F3 up to the finishing file F4 reached the full working length. Each ProTaper instrument was worked along the oval root canal at least 3 times in a circumferential motion similar to H-files. An attempt was made to reach all the BL recesses of the canal by circumferential motion as described in a previous study. The ProTaper instruments were used in a torque- and speed-controlled endodontic motor (Endo-Mate DT, NSK Nakanishi, Inc., Tochigi, Japan) at a speed of 300 rpm.

SafeSiders were used in a reciprocating handpiece (Endo-Express) at 2000 rpm. The sequence of the preparation was done following the manufacturer’s instructions. After coronal flaring, stainless steel (SS) Yellow #20 SafeSider was used to the full working length. This was followed by Red SS #25, Blue SS #30, orange NiTi #30/4% taper, Green SS #35, Black SS #40 SafeSider, and pink NiTi #25/6% taper to the working length. The instruments were used along the oval canal in a circumferential manner.

For all the canals, irrigation was performed with 2.5% NaOCl using 30-G irrigation probe (Canal Clean, Biodent, Co, Ltd, Paju City, Korea) so that 2 mL of irrigant was used between every 2 successive instruments in each group. The final rinse was performed using 2.5% NaOCl followed by 17% EDTA, then distilled water. The canals within each group were prepared by the same operator who was experienced with the technique.

Evaluation of root canal shaping

After root canal preparation, the root sections were disassembled and postinstrumentation images were taken for the coronal and apical surfaces of the middle third section at the same preinstrumentation conditions. Pre- and postinstrumentation canal contours were
traced in different colors (blue and red, respectively) (Fig. 1, A and B). Superimposition of pre- and postinstrumentation canal contours, guided by the outer contour of the root section, revealed regions that were not prepared (yellow contour) and allowed evaluation of cross-sectional shape (Fig. 1B).

Root canal preparation was assessed by calculating:

- The resultant changes in the root canal BL-to-MD ratio ($\Delta$ BL: MD), which was calculated as follows: $\Delta$ BL: MD = Pre BL: MD – Post BL: MD. The ratios of the maximum BL to maximum MD were measured before (Pre BL: MD) and after (Post BL: MD) instrumentation.
- The resultant changes in maximum buccolingual dimension ($\Delta$BL) and mesiodistal dimension ($\Delta$MD) in mm, where $\Delta$BL = Post BL – Pre BL and $\Delta$MD = Post MD – Pre MD. The BL and MD dimensions were measured before (Pre BL and Pre MD, respectively) and after (Post BL and Post MD, respectively) instrumentation.
- The resultant changes in the cross-sectional canal area in mm$^2$ ($\Delta$A) by subtracting the preinstrumentation cross-sectional area from the postinstrumentation cross-sectional area.
- The ratio of the length of the touched canal-wall outline to the original canal perimeter ($L_{touched}/L_{orig}$) for each level, where a value of 0 indicates that the root canal outline was completely untouched by the instruments, and a value of 1 indicates that the entire original canal outline was touched (Fig. 1, B).
- The ratio of the length of the canal outline with more than 200 $\mu$m (0.2 mm) dentin thickness removal to the original perimeter ($L_{200}/L_{orig}$) as previously described.$^{1,4}$

**Statistical analysis**

After calculations, data obtained from the 2 sectioning levels were pooled together. The 1-way analysis of variance (ANOVA) test was used to compare means among groups followed by Tukey’s post-hoc test for multiple comparisons in case of statistically significant difference. Means of 2 groups were compared using Student t test. The significance level was set at $P$ less than .05. Statistical analysis was carried out.
Table I. Mean and standard deviation values of the ratio of the buccolingual-to-mesiodistal dimension before (Pre BL: MD) and after instrumentation (Post BL: MD) and resultant change in ratio ($\Delta$BL: MD) of the 3 instrumentation techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Pre BL: MD Mean (±SD)</th>
<th>Post BL: MD Mean (±SD)</th>
<th>$\Delta$BL: MD Mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-files</td>
<td>3.30* (±0.98)</td>
<td>2.51* (±0.60)</td>
<td>0.85 (±0.61)</td>
</tr>
<tr>
<td>ProTaper</td>
<td>3.01* (±1.02)</td>
<td>2.1* (±0.60)</td>
<td>0.70 (±1.06)</td>
</tr>
<tr>
<td>SafeSiders</td>
<td>3.14* (±1.14)</td>
<td>2.28* (±0.76)</td>
<td>0.75 (±0.63)</td>
</tr>
</tbody>
</table>

*Indicates significant difference between Pre BL: MD and Post BL: MD within the same group ($P < .05$).

RESULTS

The mean and standard deviation values of Pre BL: MD, Post BL: MD and their resultant difference ($\Delta$BL: MD) are listed in Table I. Among the 3 instrumentation techniques, Pre BL: MD ranged from 3.01 to 3.30, whereas Post BL: MD decreased to within the range between 2.10 and 2.51. There was no significant difference in Pre BL: MD ($P = .28$), Post BL: MD ($P = .08$), or $\Delta$ BL: MD ($P = .88$) among groups. Within each group, paired t test showed that the decrease in Post BL: MD was statistically significant compared with the Pre BL: MD (H-files, $P = .012$; ProTaper, $P = .015$; SafeSiders, $P = .002$).

The mean and standard deviation values of the resultant changes in maximum buccolingual dimension ($\Delta$BL) and mesiodistal dimension ($\Delta$MD) are listed in Table II. For $\Delta$BL, the highest change was for H-files (0.3 ± 0.21 mm), followed by ProTaper (0.25 ± 0.24 mm), and the least was for SafeSiders (0.11 ± 0.11 mm). One-way ANOVA showed a significant difference among the groups ($P = .004$). Pairwise comparisons revealed that H-files and ProTaper were not significantly different ($P = .65$); however, both had more significant change compared with SafeSider ($P = .01$ and $P = .02$, respectively). For $\Delta$MD, the highest change was for H files (0.31 ± 0.11 mm), followed by ProTaper (0.27 ± 0.16 mm) and the least for SafeSider (0.21 ± 0.08 mm). One-way ANOVA showed a significant difference among the groups ($P = .03$). H-files showed significantly more change than SafeSiders ($P = .045$), whereas there was no significant difference between H-files and ProTaper ($P = .62$) or between ProTaper and SafeSiders ($P = .15$). Within each group, Student t test showed that, for SafeSiders, the $\Delta$MD was significantly higher than $\Delta$BL ($P < .001$). There was no significant difference, however, between $\Delta$MD and $\Delta$BL for either of the H-files ($P = .98$) or ProTaper ($P = .72$).

One-way ANOVA showed a significant difference among the groups regarding the change in cross-sectional area ($\Delta$A) ($P = .001$). Results revealed the change in cross-sectional area for H-files (0.70 ± 0.23 mm$^2$) was significantly higher than both ProTaper (0.42 ± 0.19 mm$^2$) and SafeSiders (0.3 ± 0.12 mm$^2$) ($P < .001$); ProTaper, also, showed significantly more $\Delta$A than SafeSiders ($P = .02$).

The mean and standard deviation values of $L_{touched}/L_{orig}$ are presented in Table II. There was a statistically significant difference among groups ($P = .029$). H-files showed a significantly higher ratio than ProTaper ($P = .036$) and SafeSiders ($P = .037$); however, there was no significant difference between ProTaper and SafeSiders ($P = 1.00$). Interestingly, the percentage of section levels revealing touching of the entire canal wall (i.e., $L_{touched}/L_{orig} = 1$) was 66%, 23%, and 14% for H-files, ProTaper, and SafeSiders, respectively.

The mean and standard deviation values of $L_{2nd}/L_{orig}$ are presented in Table II. Results revealed a statistically significant difference among groups ($P = .002$). H-files showed a significantly higher ratio than ProTaper ($P = .06$) and SafeSiders ($P = .00$). There was no significant difference, however, between ProTaper and SafeSiders ($P = .4$).

Photomicrographs of representative sections of the experimental groups are shown in Fig. 2. Postinstrumentation canal shape tended to deviate from the original canal shape by all of the instrumentation techniques. Manual instrumentation using H-files circumferentially, however, showed the least deviation where it tended to touch most of the original canal perimeter in canals with larger MD dimension (wide) or smaller MD dimension (narrow) (Fig. 2, A and B, respectively); 66% of the sections showed touching of the entire canal outline. Rotary instrumentation using ProTaper in circumferential brushing tended to reach the buccal and lingual recesses of the oval canal in wide canals (Fig. 2, C), whereas in narrow canals, a circular-shaped preparation occurred either in the center or toward 1 pole of the canal (Fig. 2, D). Reciprocating instrumentation using SafeSiders tended to produce a preparation shifted toward the mesial or distal side of the canal in wide canals (Fig. 2, E) or with minimal, irregular, somewhat circumferential touching in narrow canals (Fig. 2, F).

DISCUSSION

In an attempt to investigate whether new instruments or instrumentation techniques would optimally shape oval canals, manual instrumentation using H-files, rotary NiTi instrumentation using ProTaper, both used in
Table II. Changes in the maximum buccolingual (ΔBL) and mesiodistal (ΔMD) dimensions (in mm), and the ratio of the touched canal outline (Ltouched/Lorig) and ratio of the canal outline with 200 μm or more dentin thickness removal (L200/Lorig)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Mean (±SD)</th>
<th>Mean (±SD)</th>
<th>Ltouched/Lorig Mean (±SD)</th>
<th>L200/Lorig Mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-files</td>
<td>0.30a</td>
<td>0.31a</td>
<td>0.89a 0.15</td>
<td>0.34a 0.23</td>
</tr>
<tr>
<td>ProTaper</td>
<td>0.25a</td>
<td>0.27</td>
<td>0.74 b 0.23</td>
<td>0.18 b 0.17</td>
</tr>
<tr>
<td>SafeSiders</td>
<td>0.11*b</td>
<td>0.21*b</td>
<td>0.75 b 0.23</td>
<td>0.12 b 0.15</td>
</tr>
</tbody>
</table>

Different letters indicate significant difference between every 2 groups (P < .05).
*Indicates significant difference within same group between ΔBL and ΔMD (P < .05).

The amount of dentin removal in buccolingual and mesiodistal directions was judged through obtaining the change in buccolingual (ΔBL) and mesiodistal (ΔMD) dimensions. Results revealed that SafeSiders removed the least dentin thickness buccolingually compared with H-files and ProTaper instrumentation, whereas, mesiodistally, it removed dentin similar to ProTaper but still less than H-files. This is in disagreement with Grande et al., where AET removed less dentin mesiodistally in the middle section of the canal than ProTaper. In that same study, ProTaper did not seem to touch the canal wall buccolingually (0.01 ± 0.01 mm), whereas in the present study, it removed dentin (0.25 ± 0.24 mm) as much as manual H-files (0.30 ± 0.21 mm) (Table II); this could be attributed to both the circumferential motion used with ProTaper in a trial to access the BL recesses and the larger final ProTaper size being F4 in the present study. Interestingly, the mean values of ΔBL were closer to ΔMD for manual and rotary instrumentation, whereas SafeSiders tended to remove dentin mesiodistally nearly twice as buccolingually (Table II); this might suggest even more dentin removal circumferentially with manual instrumentation followed by rotary ProTaper instrumentation. A recent study, however, showed that SafeSiders removed a similar amount of dentin structure as ProFile Vortex rotary NiTi system in curved canals.

Differences in the results of studies evaluating reciprocating instrumentation in oval-shaped canals could be attributed to the different systems used. One reciprocating system, the AET, has stainless steel shaping files that are square in cross section, and are claimed to better prepare the oval coronal-middle part of the canal, with hand NiTi files for apical preparation. This reciprocating system showed better cleanliness compared with rotary NiTi ProFile and manual instrumentation. SafeSiders, on the other hand, have a flat-sided architecture and the system is mainly composed of stainless steel instruments with few NiTi instruments. The cross-sectional design of SafeSiders, especially when used in reciprocation, may have restricted the circumferential uniform dentin removal. The increased rigidity of the larger-sized stainless steel instruments of SafeSiders, however, straightened curved canals compared with the ProFile Vortex NiTi rotary system.

The manner with which the instrument is used could affect the shaping ability in oval canals. Paqué et al. showed that ProTaper left significantly less untreated root canal area in shaping oval-shaped canals when used in a manner such that the canal was considered as 2 individual canals rather than 1 canal; using ProTaper circumferentially also showed fewer mean untreated areas than when considering the canal as 1, yet, without significant difference. In another earlier study, using hand files in a balanced force motion removed less of the inner layer of dentin in oval canals than circumfer-
ential filing. Taken together, this could justify the tendency of manual and rotary instrumentation as circumferentially used in the present study to access more of the canal perimeter in oval canals.

The variation among studies in the preinstrumentation buccolingual-to-mesiodistal ratio (Pre BL: MD) could explain different results. Narrow canals, with small mesiodistal dimension, were observed to be inadequately prepared, most probably because of limited accessibility of instruments to the whole canal outline.\(^4\) In the study by Grande et al.,\(^14\) the mean Pre BL: MD in the middle section was less for the stainless steel AET group (2.18 ± 1.38) than for the NiTi ProTaper group (2.56 ± 2.32). A relatively higher Pre BL: MD in the present study, 3.14 ± 0.14 in the SafeSiders group and 3.01 ± 1.02 in the ProTaper group, might have restricted even circumferential dentin removal especially with reciprocating instrumentation.

The quantity of dentin removal was evaluated through determining the change in cross-sectional area (A). Results showed that manual instrumentation removed significantly more dentin area than rotary instrumentation, which removed significantly more dentin than reciprocating instrumentation. These results support those of a recent study, which suggested that reciprocation motion in oval canals may be responsible for suboptimal cleaning in comparison with rotary instrumentation.\(^6\) It can be suggested that reciprocating motion simulated balanced force motion, which may tend to remove less of the inner layer of dentin in oval canals than circumferential filing.\(^10\) The present study results, however, were in contrast to those of previous studies.\(^12,14\) In one study,\(^14\) rotary and reciprocating instrumentation techniques showed similar change in root canal area in the middle third of the canal; the different designs of the reciprocating systems and the difference in the final ProTaper sizes could probably explain the difference. In the other study,\(^12\) the cross-sectional area after instrumentation was not significantly different on comparing hand instrumentation using H-files, rotary instrumentation using ProTaper, and reciprocating AET where only the postinstrumentation area was considered.

The ratios of \(L_{\text{touched}}/L_{\text{orig}}\) and \(L_{200}/L_{\text{orig}}\) revealed the extent to which the instrumentation techniques prepared the root canal outline lengthwise and depthwise, respectively. No instrumentation technique was able to prepare the dentin walls entirely in oval-shaped canals, which is in agreement with previous studies.\(^1,3-5,10,12\) In the present study, manual instrumentation resulted in the highest mean ratio of \(L_{\text{touched}}/L_{\text{orig}}\) (0.89 ± 0.15) compared with rotary (0.74 ± 0.23) and reciprocating (0.75 ± 0.23) instrumentation (Table II). This may be because of the use of stainless steel H-files in a circum-

Fig. 2. Representative sections of the 3 instrumentation techniques. Manual instrumentation with H-files shows circumferential touching of the entire canal outline in (A) wide and (B) narrow canals. Rotary ProTaper instrumentation shows (C) touching of the buccal and lingual canal recesses in wide canals, and (D) circular-shaped preparation toward one pole of the canal in narrow canals. Reciprocating SafeSiders instrumentation shows (E) canal shifting proximally toward one side of the canal in wide canals, and (F) minimal, irregular, somewhat circumferential touching in narrow canals. Images are available in color at www.ooooe.net.
ferential manner, which might have allowed access to the narrow root canal recesses. Consequently, the ratios of untouched canal wall, complementary to the $L_{\text{touched}}/L_{\text{orig}}$ ratio, in present study ranged between 0.11 and 0.26 and were relatively higher than those obtained for the middle third of oval root canals in another study ranging from 0.02 to 0.11. In that study, Taha et al. evaluated the uninstrumented canal wall in relation to the postinstrumentation outline and not to the original canal outline, as in the present study. In the same study, hand instrumentation (H-files) eliminated canal fins significantly better than rotary and reciprocating instrumentation. Hand instrumentation of oval-shaped canals showed better cleaning efficiency than with rotary instrumentation. The touched canal wall ratio for ProTaper instrumentation (0.75) in the present study was similar to that of a previous study using ProTaper and Mtwo. However, it was higher than that in a previous study (from 0.42 to 0.58); the difference in preinstrumentation canal ratio between studies, being between 5.4 and 6.1 in that study, whereas it ranged from 3.01 to 3.30 in the present study, probably imposed higher anatomical difficulty in complete shaping. Removal of 200 μm from dentin has been suggested as sufficient in preparing molars. For $L_{\text{touched}}/L_{\text{orig}}$ manual instrumentation performed significantly better (0.34) than rotary (0.18) and reciprocating (0.12) instrumentation (Table II). Previous studies revealed lower values of the canal outline length with more than 0.2 mm dentin removal on using manual instrumentation ranging between 0.15 and 0.16, which could be attributed to the use of nickel-titanium K-files and/or the higher Pre BL: MD.

Manual, rotary, and reciprocating instrumentation techniques were evaluated regarding their ability of to clean and shape oval canals. Barbizam et al. compared the cleaning efficiency of ProFile and K-files, used in a crown-down technique, in flattened canals of mandibular incisors. Manual instrumentation showed better cleanliness compared with rotary instrumentation, although neither completely cleaned the canals. Wu et al. evaluated the capability of 2 hand instrumentation techniques, namely balanced force and circumferential filing, to remove the inner layer of dentin in oval canals of mandibular incisors. The balanced force method removed the inner layer of dentin from 38.6% of the circumference of the canal wall, whereas circumferential filing removed 57.7% without statistically significant difference. NiTi hand files, used circumferentially, were less efficient in preparing the oval outline of root canals than rotary instruments with greater taper (ProTaper and Mtwo).

Although rotary NiTi instruments were originally introduced for preparing curved canals, their ability to prepare oval-shaped root canals has been frequently investigated. Taha et al. compared 3 techniques (AET, hand, and rotary) for preparing oval-shaped canals. They showed that rotary NiTi could be considered as a preferred technique in the apical third of oval-shaped canals (less debris and round-oval canal shape that was easier to obturate) and hand instrumentation eliminated fins completely in the coronal third. They concluded that combining H-files with rotary instrumentation could prepare oval canals better than reciprocating instrumentation using AET. In spite of the circumferential motion used with ProTaper in the present study, the canal shape tended to show a circular bulge. According to an earlier study, the design of rotary instruments was not suitable to completely prepare oval canal walls because of the difference between the instrument design and canal geometry. Rodrigo et al. revealed incompletely instrumented buccal and lingual canal extensions on using Lightspeed, Quantec SC, or ProFile. However, circumferential filing of rotary NiTi systems with greater taper (6% Hero instruments) in the middle third of oval root canals showed similar shaping ability to conventional Hedström hand files. Considering oval canals as 2 separate entities during preparation using ProTaper, however, seemed beneficial in increasing overall prepared canal surface.

A system, AET, has been introduced for the preparation of oval-shaped root canals using stainless steel instruments in a reciprocating motion and was evaluated for cleaning and shaping abilities with conflicting results. Zmener et al. demonstrated that AET showed less debris and less smear layer in instrumented areas of canals than ProFile and hand instrumentation. AET removed more tooth structure with much lower variation in the canal BL-to-MD ratio than ProTaper in the coronal and middle thirds of oval canals. On usage in curved canals, however, AET showed gross preparation errors and straightening. Another system using a reciprocating handpiece, SafeSiders, was introduced with design modifications to suit preparing curved canals and was purported to overcome the threat of instrument breakage more than rotary NiTi instruments; however, it was unable to prevent the creation of aberrant canal shapes in curved canals, which was suggested to be consequence of mechanical reciproca-
which is more likely to show an oval cross section of the canal than more apically.\textsuperscript{1,2} The middle third is also, the part of the canal that would be most likely instrumented by the systems to be compared, as the coronal third was prepared using instruments for coronal preflaring instruments. Although not sufficient in the case of infected root canals, the removal of 200 \mu m of the dentin wall as one of the parameters for evaluating dentin thickness removal in previous studies,\textsuperscript{1,4} it was, thus, assessed in the present study for comparison purposes.

In spite of the difficulty of extrapolating results of ex vivo studies onto long-term clinical performance, the use of the SafeSider design did not provide benefit in preparing oval-shaped canals. Within the conditions of this study, it could be concluded that manual and rotary instrumentation may show better shaping of oval-shaped canals than reciprocating instrumentation using SafeSiders. Further studies are needed to evaluate the shaping ability of SafeSiders in curved root canals especially on using noninvasive assessment methods, such as micro-computed tomography, as well as its working efficiency, safety, and potential in cleaning debris.

REFERENCES


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