Flat-Oval Root Canal Preparation with Self-Adjusting File Instrument: A Micro–Computed Tomography Study

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Abstract

Introduction: The aim of this study was to evaluate the root canal preparation in flat-oval canals treated with either rotary or self-adjusting file (SAF) by using microtomography analysis. Methods: Forty mandibular incisors were scanned before and after root canal instrumentation with rotary instruments (n = 20) or SAF (n = 20). Changes in canal volume, surface area, and cross-sectional geometry were compared with preoperative values. Data were compared by independent sample t test and χ² test between groups and paired sample t test within the group (α = 0.05). Results: Overall, area, perimeter, roundness, and major and minor diameters revealed no statistical difference between groups (P > .05). In the coronal third, percentage of prepared root canal walls and mean increases of volume and area were significantly higher with SAF (92.0%, 1.44 ± 0.49 mm³, 0.40 ± 0.14 mm², respectively) than rotary instrumentation (62.0%, 0.81 ± 0.45 mm³, 0.23 ± 0.15 mm², respectively) (P < .05). SAF removed dentin layer from all around the canal, whereas rotary instrumentation showed substantial untouched areas. Conclusions: In the coronal third, mean increases of area and volume of the canal as well as the percentage of prepared walls were significantly higher with SAF than with rotary instrumentation. By using SAF instruments, flat-oval canals were homogeneously and circumferentially prepared. The size of the SAF preparation in the apical third of the canal was equivalent to those prepared with #40 rotary file with a 0.02 taper. (J Endod 2011;37:1002–1007)

Key Words

Micro-computed tomography, nickel-titanium instruments, root canal preparation, self-adjusting file

Selected Japanese Studies

Selection of Teeth

The ultimate goal of chemomechanical preparation is to remove the inner layer of the dentin, while allowing the irrigant to reach the entire length of the root canal, eradicating bacterial populations or at least reducing them to levels that are compatible with periradicular tissue healing (1, 2). Although many technical advances have been made in endodontics, canal preparation is still adversely influenced by the highly variable anatomy (1, 3, 4), especially in oval, flat, or curved root canals (5–9). In flat-oval canals, rotary files have failed to perform adequate cleaning and shaping, leaving untouched fins or recesses on the buccal and/or lingual aspects of the central canal area prepared by the instrument (5, 6, 9, 10).

The self-adjusting file (SAF) (ReDent-Nova, Ra’anana, Israel) has been devised with the purpose of sidestepping some of the limitations of nickel-titanium (NiTi) rotary instruments (11, 11–14). During its operation, the file is designed to adapt itself three-dimensionally to the shape of the root canal. Rather than machining a central portion of the root canal into a round cross section, the SAF is claimed to maintain a flat canal as a flat canal with slightly larger dimensions (12, 13). Hence, SAF system has the potential to be particularly advantageous in promoting cleaning and shaping of flat-oval–shaped canals (1, 11, 12).

The development of x-ray micro–computed tomography (μCT) has gained increasing significance in the study of hard tissues (4). μCT offers a noninvasive reproducible technique for three-dimensional assessment of the root canal system and can be applied quantitatively as well as qualitatively (3, 4, 13, 15). Recent ex vitro μCT studies showed that the percentage of root canal area affected by the SAF method is larger than that affected by popular rotary instrumentation systems in different teeth (10, 13, 16).

To date, root canal preparation with SAF has been quantitatively and qualitatively described in different teeth, but not in mandibular incisors. Thus, the purpose of this study was to evaluate the root canal preparation in flat-oval root canals of mandibular incisors treated with either rotary or SAF by using three-dimensional μCT analysis.

Materials and Methods

Selection of Teeth

After ethics committee approval, 40 single-rooted freshly extracted human mandibular incisor teeth with fully formed apices were selected and stored in 9°C aqueous 0.1% thymol solution until further use. Each root was radiographed in buccolingual and mesiodistal projections to categorize them and to detect any possible obstruction. When the buccolingual diameter was 4 or more times larger than that of the mesiodistal diameter, the canals were classified as flat-oval. All teeth presenting isthmus, lateral, accessory, apical curvature, or 2 canals were excluded from the study.

After being washed in running water for 24 hours, each tooth was dried, mounted on a custom attachment, and scanned in a desktop x-ray microfocus CT scanner (SkyScan 1174v2; SkyScan N.V., Kontich, Belgium) at an isotropic resolution of 19.7 μm. The system consisted of a sealed air-cooled x-ray tube, 20–50 kV/40W/800 μA, with a precision object manipulator with 2 translations and 1 rotation direction. The system also included a 14-bit charge-coupled device (CCD) camera based on a 1.3 meg-pxel (1304 × 1024 pixels) CCD sensor.

Teeth were accessed by using high-speed diamond burs, and patency of the coronal canal was confirmed. Coronal flaring was accomplished with #2 and #3 Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland), in a low-speed contra-angle handpiece, placed to 2–4 mm below the cementoenamel junction. Flaring was followed...
by irrigation with 5 mL of 2.5% NaOCl delivered in a syringe with a 27-gauge needle (Endo Eze; Ultradent Products Inc, South Jordan, UT). Subsequently, apical patency was determined by inserting a size 10 K-file into the root canal until its tip was visible at the apical foramen; working length (WL) was set 0.5 mm shorter of this measurement. A glide path was confirmed at least to a size #20 K-file. Specimens were then randomly assigned to 2 experimental groups (n = 20) according to the instrumentation technique: SAF (group A) and rotary (group B). Canals in group A were shaped by a general practitioner who had been specifically trained with the SAF instrument and in group B by a specialist (M.A.V.) with 12 years of clinical experience with rotary instruments.

**Root Canal Preparation with SAF**

A 1.5-mm diameter SAF (ReDent-Nova) was operated for 4 minutes by using a trans-line (in-and-out) vibrating handpiece (Gentle-Power Lux 20LP; KaVo, Biberach, Germany) adapted with a RDT3 head (ReDent-Nova) at a frequency of 83.3 Hz (5000 rpm) and amplitude of 0.4 mm. The instrument was used with a manual in-and-out motion to the WL. Continuous irrigation with 2.5% NaOCl was applied throughout the procedure at 5 mL/min by using a special irrigation apparatus (VATEA; ReDent-Nova) (2).

**Root Canal Preparation with Rotary Instruments**

The coronal and middle thirds were serially enlarged with NiTi rotary instruments sizes #25, 0.12 taper, #25, 0.10 taper, and #25, 0.08 taper (K3; SybronEndo, West Collins, CA) in a crown-down manner by using gentle in-and-out motion toward the apex. Then, instruments of sizes #25, 0.02 taper, #25, 0.04 taper, #30, 0.02 taper, #30, 0.04 taper, #35, 0.02 taper, #35, 0.04 taper, and #40, 0.02 taper were used to the WL. To avoid fracture, 5 canals were instrumented with 1 set of instruments at the WL, which were driven by a torque-controlled motor (X-Smart; Dentsply Maillefer) set to 300 rpm. The instruments were withdrawn when resistance was felt and changed for the next instrument. Passive ultrasonic irrigation was performed between each instrument by using a size #20 K-file mounted on a piezoelectric handpiece (JetSonic Four; Gnatus, Ribeirão Preto, SP, Brazil) at a power setting of 3, which was activated for 10 seconds at the WL. Each canal was irrigated with a total of 20 mL of 2.5% NaOCl.

In all groups after root canal preparation, a final rinse with 5 mL of normal saline solution was performed, the root canals were dried with paper points, and teeth were resubmitted to a postoperative μCT scan by applying the initial parameter settings.

**Evaluation of the Root Canal Preparation**

Images were reconstructed from the apex to the level of the cementoenamel junction (NRecon v1.6.1.5; SkyScan), providing axial cross sections of the inner structure of the samples. For each tooth, evaluation was done for the full canal length in approximately 400 slices per specimen. GTan v1.10.1.0 software (Skyscan) was used for two- and three-dimensional volumetric analysis and measurements of area, perimeter, roundness, major diameter, minor diameter, volume, and surface area. The cross-sectional appearance, round or more ribbon-shaped, was expressed as roundness. This index varies from 0 (parallel plates) to 1 (perfect ball). Mean increase (Δ) of each analyzed parameter was calculated by subtracting the scores for the treated canals from those recorded for the untreated counterparts. The percentage of increase of each parameter (%Δ) was calculated by using the scores measured before (B) and after (A) root canal preparation, according to the formula:

$$\%\Delta = \frac{A - B}{B} \times 100$$

**Table 1: Morphometric Two-dimensional Data (mean ± standard deviation) and Their Changes for Root Canal in Lower Incisors before and after Preparation with SAF or Rotary Systems**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>All thirds</th>
<th>Apical third</th>
<th>Middle third</th>
<th>Coronal third</th>
<th>SAF</th>
<th>Rotary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (mm²)</td>
<td>0.22 ± 0.07</td>
<td>0.21 ± 0.07</td>
<td>0.22 ± 0.08</td>
<td>0.22 ± 0.08</td>
<td>0.22 ± 0.07</td>
<td>0.22 ± 0.07</td>
</tr>
<tr>
<td>Perimeter (mm)</td>
<td>4.31 ± 0.26</td>
<td>4.31 ± 0.26</td>
<td>4.31 ± 0.26</td>
<td>4.31 ± 0.26</td>
<td>4.31 ± 0.26</td>
<td>4.31 ± 0.26</td>
</tr>
<tr>
<td>Roundness</td>
<td>0.31 ± 0.18</td>
<td>0.31 ± 0.18</td>
<td>0.31 ± 0.18</td>
<td>0.31 ± 0.18</td>
<td>0.31 ± 0.18</td>
<td>0.31 ± 0.18</td>
</tr>
<tr>
<td>Minor diameter (mm)</td>
<td>0.07 ± 0.04</td>
<td>0.07 ± 0.04</td>
<td>0.07 ± 0.04</td>
<td>0.07 ± 0.04</td>
<td>0.07 ± 0.04</td>
<td>0.07 ± 0.04</td>
</tr>
<tr>
<td>Major diameter (mm)</td>
<td>0.12 ± 0.01</td>
<td>0.12 ± 0.01</td>
<td>0.12 ± 0.01</td>
<td>0.12 ± 0.01</td>
<td>0.12 ± 0.01</td>
<td>0.12 ± 0.01</td>
</tr>
<tr>
<td>%Δ Perimeter</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
</tr>
<tr>
<td>Δ Mean Increase (%)</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
<td>0.7 ± 0.9</td>
</tr>
</tbody>
</table>

For each parameter, evaluation was done for full canal length in approximately 400 slices. Statistically significant differences between groups were marked with * in the same row (independent sample t-test, P < .05). Within group, there was significant statistical difference between preoperative and postoperative results (paired sample t-test, P < .05).
CTVol software (Skyscan) was used for three-dimensional visualization and qualitative evaluation of the preinstrumented and postinstrumented canals. Color-coded root canal models (green indicates preoperative, red postoperative canal surfaces) enabled qualitative comparison of the matched root canals before and after shaping.

OnDemand 3D software (Cybermed Inc, Irvine, CA) was used for the analysis of the 15 superimposed cross-sectional images of each specimen (n = 300 per group) regarding the percentage of instrumented and noninstrumented walls. The root canal preparation was classified into 2 categories: (1) cross section in which the whole perimeter or almost all the perimeter was treated (80% or more of the perimeter treated) and (2) cross section in which most of the perimeter was untreated (20% or less of the perimeter treated).

**Statistical Analysis**

The results were statistically analyzed with independent sample t test and \( \chi^2 \) test (with Yates correction) between groups and paired sample t test within the group, with the null hypothesis set as 5%, by using SPSS v17.0 for Windows (SPSS Inc, Chicago, IL).

**Results**

**Quantitative Evaluation**

**Two-Dimensional Analysis.** The results of two-dimensional analysis are detailed in Table 1. Overall, area, perimeter, roundness, and major and minor diameters revealed no statistically significant difference between SAF and rotary preparation (\( P > .05 \)). However, percentage mean increase of the root canal area in the coronal third was significantly higher with SAF (65.07% \( \pm \) 18.4%) than with rotary instrumentation (38.02% \( \pm \) 29.3%) (\( P = .03 \)). Despite differences between groups in the postoperative results in relation to roundness (\( P = .02 \)) and minor diameter (\( P = .01 \)), no difference was observed in the preoperative and postoperative increase of these parameters (\( P > .05 \)). No statistical difference was observed regarding the analyzed parameters in the middle and apical thirds (\( P > .05 \)). Within group, there was a significant statistical difference between preoperative and postoperative results (\( P < .05 \)).

**Three-Dimensional Analysis.** The results of three-dimensional analysis are detailed in Table 2. No statistical difference in volume or surface area was observed in the middle or apical thirds between the groups (\( P > .05 \)). Despite that the mean increase of the canal volume in the coronal third was significantly higher with SAF (1.44 \( \pm \) 0.49 mm\(^3\)) than with rotary instrumentation (0.81 \( \pm \) 0.45 mm\(^3\)) (\( P = .01 \)), the same was not observed with the surface area (\( P > .05 \)). Within group, volume and surface area showed a significant statistical difference between preoperative and postoperative results (\( P < .05 \)).

**Qualitative Evaluation**

Preoperatively, root canal cross sections presented significantly flatter in the mesiodistal view than in the buccolingual aspect. Its geometry was changed after root canal preparation with both instruments. Superimposed \( \mu \)CT reconstructions in all thirds demonstrated that the use of SAF resulted in a more uniform dentin removal along the perimeter of the canals than with rotary instrumentation. The latter showed substantial untouched areas mainly on the lingual side of the canal. The number of samples in which all or most of the root canal perimeter was untreated, considering the coronal, middle, and apical thirds, was 58 (19.3%) for SAF group and 119 (39.7%) for rotary group. There was a statistically significant difference between the

\[
\% \Delta = (A \times 100/B) - 100.
\]
instrumented and the noninstrumented walls between groups at coronal and middle thirds (Table 3). Cross sections and tridimensional analysis showed that the use of SAF resulted in a more homogenous preparation of the root canal walls compared with rotary instruments (Figs. 1 and 2).

**Discussion**

Variations in canal geometry before shaping and cleaning procedures seem to have more influence on the changes that occurred during preparation than the instrumentation techniques themselves (3). Therefore, in the present study care was taken to ensure that the sample was balanced in terms of preoperative morphologic parameters between groups. The root canals in both groups were preflared and a #20 K-file was used for apical sizing because this procedure reflects clinical conditions under which root canal treatment is performed, as recommended by SAF's manufacturer (1, 11, 12). Because the operator tactile skills have been considered more important than the technique in the thoroughness of canal debridement (4, 17), root canal preparations were carried out by dentists with expertise in each of the tested techniques. Nonetheless, as previously pointed out (10), a potential limitation of this study could also be a result from the relatively small sample size of 20 teeth per group; however, it is similar to recent μCT studies (3, 4, 10, 16).

When compared with rotary NiTi instrumentation, it has been reported that SAF leaves less unprepared areas (16) and was significantly more effective in disinfecting long oval root canals in vitro (14). In the present study, SAF presented a higher increase of area (two-dimensional analysis) and volume (three-dimensional analysis) than the rotary group only at the coronal third. It might be explained as the relative softness of dentin near the pulp chamber as a result of the higher dentinal diameter and density (18), compared with the other canal regions. Besides, preflaring with Gates Glidden burs facilitated endodontic instrumentation and allowed SAF to act freely at this portion, promoting more dentin removal than with rotary instruments.

At middle third, although no differences have been observed regarding area or volume between groups, SAF system presented significantly higher percentage of prepared root canal walls (65%) than rotary instrumentation (44%). It might be inferred that this result would be due mainly to the anatomic feature of the flat-oval–shaped canal of mandibular incisor (19).

The preparation of the most apical canal section remains a challenge (20). At this region, previous studies on root canal preparation with SAF have left uninstrumented areas ranging from 28.8%–47.4% in maxillary molar root canals (10). Although there is disagreement among endodontic specialists about the maximal enlargement at WL (4, 21), in the present study the final apical preparation with size

### Table 3. Statistical Comparison of Percentage of Root Canal Wall Preparation by Using SAF System or Rotary Instruments at Different Thirds

<table>
<thead>
<tr>
<th>Category</th>
<th>Coronal third</th>
<th>Middle third</th>
<th>Apical third</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rotary SAF</td>
<td>P value</td>
<td>Rotary SAF</td>
</tr>
<tr>
<td>All or most of root canal perimeter is treated</td>
<td>62 92</td>
<td>.0001*</td>
<td>44 65</td>
</tr>
<tr>
<td>(80% or more treated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All or most of root canal perimeter is untreated</td>
<td>38 8</td>
<td></td>
<td>56 35</td>
</tr>
<tr>
<td>(20% or less treated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (%)</td>
<td>100 100</td>
<td>100 100</td>
<td>100 100</td>
</tr>
</tbody>
</table>

Statistically significant difference between groups is marked with * in the same row ($\chi^2$ test with Yates correction, $\alpha = 0.05$).

**Figure 1.** Representative example of μCT data of flat-oval–shaped root canal of mandibular incisor prepared with SAF system at middle level of the root (yellow line, A). Two-dimensional analysis shows the preoperative (B), postoperative (C), and superimposed reconstructions (D) of the root canal (green and red areas are preoperative and postoperative superimposed cross sections, respectively). Note that SAF instrumentation removed a uniform layer of dentin from root canal walls (D). In the qualitative evaluation, three-dimensionally reconstructed μCT images show the root canal before preparation in buccal (E) and distal views (G). The superimposed μCT reconstructions in buccal (F) and distal (H) views demonstrate a uniform preparation of the canal surface with SAF system.
Conclusions

Within the limitations of this ex vivo study, it can be concluded that in the coronal third, mean increases of area and volume of the root canal, as well as the percentage of prepared walls, were significantly higher with SAF than with rotary instrumentation. By using SAF instrument, flat-oval–shaped canals of mandibular incisors were homogeneously and circumferentially prepared. The size of the SAF preparation in the apical third of the canal was equivalent to those prepared with #40 rotary file with 0.02 taper.

Acknowledgments

The authors thank ReDent-Nova for providing the SAF instruments used in this study.

The authors deny any conflicts of interest related to this study.

References


ERRATUM

Due to an oversight, the authors omitted follow-up data from the article titled, “Squamous Odontogenic Tumor-like Proliferations in Radicular Cysts: A Clinicopathologic Study of Forty-two Cases,” by Rinku M. Parmar, Robert B. Brannon, and Craig B. Fowler, which was published in J Endod 2011;37:623–6. In the article, this data should follow the section, “Histopathologic Features.” The missing text appears below.

Data on Cases with Follow-up Information

Follow-up information was available for 11 cases. The range of follow-up was 1 month to 10 years, and the average length of follow-up was 2.5 years. There were no recurrences or unexpected clinical behavior reported among the 11 cases with follow-up.