Micro–computed Tomography Evaluation of the Preparation of Long Oval Root Canals in Mandibular Molars with the Self-adjusting File

Frank Paqué, Dr Med Dent,* and Ove A. Peters, MS, DMD, PhD†

Abstract
Introduction: The aim of this study was to assess the shaping potential of a novel nickel-titanium instrument, the self-adjusting file (SAF), in long oval root canals in distal roots in mandibular molars. Methods: Twenty mandibular molars with long oval distal root canals were selected and scanned preoperatively and postoperatively by using micro–computed tomography at an original resolution of 20 μm. Canals were shaped with the SAF, three-dimensionally reconstructed, and evaluated for volume, surface area, canal transportation, and prepared surface. Data were statistically contrasted by using paired t tests and regression analysis. Results: Preoperatively, canal volume was 7.73 ± 2.13 mm³, and canal area was 42.83 ± 8.14 mm². Volumes and surface areas increased significantly (P < .001) by 4.84 ± 1.73 mm³ and 3.34 ± 1.73 mm², respectively, and no gross preparation errors were detected. Unprepared canal surface varied between individual canals, and mean unprepared surface was 23.5% ± 8.9%. Prepared areas were significantly larger compared with rotary canal preparation done in a previous study. Canal transportation scores were higher in the coronal root canal third (106 ± 50 μm) compared with the apical third (81 ± 49 μm). Conclusions: In vitro, preparation of long oval-shaped root canals in mandibular molars with the SAF was effective and safe. Moreover, shapes generated with the SAF were more complete compared with rotary canal preparation. (J Endod 2011;37:517–521)

Key Words
Long oval root canals, micro-computed tomography, nickel-titanium instruments, root canal preparation, self-adjusting file

One of the major procedural steps in root canal therapy is to thoroughly remove debris, pulp tissue, and microorganisms from the root canal system, which can be accomplished by chemomechanical preparation (1). To this end, it has been suggested to prepare canals to a homogenous tapered shape with the prepared canal including the preoperative outline (1, 2). However, the root canal system is anatomically complex, and mechanical instrumentation might result in preparation errors. Moreover, the use of both conventional hand files and current nickel-titanium (NiTi) rotary instruments does not result in a fully prepared root canal surface (3).

A funnel-shaped canal with a circular base is not the common configuration in root canal anatomy (2). Recently, cross-sectional root canal configurations have been classified as round, oval, long oval, flattened, or irregular (4). Metrically, Jou et al (4) defined oval as having a maximum diameter of up to 2 times greater than the minimum diameter and long oval as having a maximum diameter of 2–4 times greater than the minimum diameter.

A high prevalence of oval and long oval root canals even in the apical root canal portion has been reported (5–7). According to Wu et al (5), the prevalence of long oval root canals in the apical third of human teeth is generally about 25%; in some groups of teeth such as mandibular incisors and maxillary second premolars the prevalence is greater than 50%, and in distal roots of mandibular molars the prevalence is 25%–50%. This complex anatomy might be regarded as one of the major challenges in infection control through root canal preparation.

One aim in the preparation of infected root canals is to remove the inner layer of dentin (8, 9). This is particularly hard to achieve when preparing long oval root canals. Furthermore, after preparation, uninstrumented recesses might be left in many oval canals, irrespective of the instrumentation technique, thus leaving debris and unprepared root canal surfaces behind (8, 10–14).

All the mentioned studies were done in vitro by using extracted teeth that had been sectioned before root canal preparation. Then, root cross sections were assessed before and after preparation, thus representing two-dimensional analyses. In contrast, the technique of micro–computed tomography (MCT) allows a complete description of three-dimensional effects that root canal preparation exerts on root canal anatomy without altering the root during the experiments (3). This research tool allows calculation of the root canal area that is not mechanically prepared and remains as a so-called untreated surface (15).

Recently, a new instrument type, the self-adjusting file (SAF) (ReDent Nova, Ra’anana, Israel), was introduced (16); because of its construction out of a NiTi meshwork, this instrument is believed to expand into long oval root canals and therefore promote a canal preparation that circumferentially removes a layer of dentin in oval as well as round canals (17).

In fact, a recent MCT-based study indicated a superior potential to prepare long oval mesiobuccal canals in maxillary molars with the SAF compared with rotary instrumentation techniques (18), as measured by lesser amounts of untreated canal surface. This measure might be conceived as a three-dimensional indicator for the completeness of a root canal shape, depending on instrument and canal type (19). Preparations of mandibular molar canals with the SAF have not been assessed; therefore, the aim of the current study was to evaluate the prepared surface areas of long oval–shaped root canals in mandibular molars with this instrument.
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Materials and Methods

Selection of Teeth

From teeth that had been extracted for reasons unrelated to the current study, 20 human mandibular molars were collected and stored in 0.1% thymol solution at 4°C until further use. Teeth were initially scanned at an isotropic resolution of 80 μm in a desktop MCT unit (μCT 40; Scanco Medical, Britttisellen, Switzerland) by using previously established methods (15, 19). All slices were checked carefully, with the distal root tip serving as reference point to count back the slices until the exact slice 6 mm coronal to the apex was found. The minimum diameter of the root canal was measured mesiodistally, and the maximum diameter was measured buccolingually. Only teeth with a ratio of the maximum to the minimum diameter of more than 2 were selected for further investigation. The mean diameter ratio (maximum divided by minimum cross-sectional distance) in the selected sample was 3.8. Subsequently, teeth were mounted on scanning electron microscopy stubs, accessed by using high-speed diamond burs (Dentsply Maillefer, Ballaigues, Switzerland). Subsequently, canal lengths and apical patency were determined with Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland). Enlargement restricted to the coronal canal third was accomplished with continuous irrigation (16); preparations were done by a general practitioner who had been specifically trained with the SAF instrument.

Root Canal Instrumentation with the SAF

The SAF was operated by using a trans-line (in-and-out) vibrating handpiece (GENTLEpower; KaVo, Bieberach a. d. Rhô, Germany) combined with a RD73 head (ReDent-Nova) (16) at a frequency of 83.3 Hz and amplitude of 0.4 mm. This movement combined with intimate contact along the entire circumference and length of the canal and the slightly rough surface of the file removes a layer of dentin with a filing motion. The hollow design allows for continuous irrigation throughout the procedure. A special irrigation device (VATEA; ReDent-Nova) was connected to the irrigation hub on the file and was delicately advanced apically with an intermittent in-and-out hand movement of about 5-mm amplitude until it reached the predetermined working length. Each SAF was operated for 4 minutes per canal with continuous irrigation (16); preparations were done by a general practitioner who had been specifically trained with the SAF instrument. The clinician had also prepared canals with the SAF in maxillary incisors and molars in earlier studies (20).

The clinician was not allowed to see the virtual models of reconstructed teeth before preparing the root canals and during the course of the treatment. This was done to avoid bias by an attempt to manually direct the preparation instrument into any potentially uninstrumented areas.

Evaluation

Virtual root canal models were reconstructed on the basis of MCT scans and superimposed with a precision of better than 1 voxel. Precise repositioning of pre-preparation and various post-preparation images was ensured by a combination of a custom-made mounting device and a software-controlled iterative superimposition algorithm (19, 21, 22); the resulting color-coded root canal models (green indicates preoperative, red indicates postoperative canal surfaces) enabled quantitative comparison of the matched root canals before and after shaping. From individual canal models, canal volumes up to the level of the cementoenamel junction (CEJ) as well as in the apical 4 mm were determined by using custom-made software (IPL, Scanco Medical) as described previously (19).

Increases in volume and surface area were calculated by subtracting the scores for the treated canals from those recorded for the untreated counterparts. Matched images of the surface areas of the canals before and after preparation were examined to evaluate the amount of uninstrumented area. This parameter was expressed as a percentage of the number of static voxel surface to the total number of surface voxels. The cross-sectional appearance, round or more ribbon-shaped, was expressed as the structure model index (SMI). This stereological index varies from 1 (parallel plates) to 4 (perfect ball) and was described earlier in more detail (21). Canal transportation was assessed from centers of gravity that were calculated for each slice and connected along the z-axis with a fitted line. Mean transportation scores were then calculated by comparing the centers of gravity before and after treatment for the apical, middle, and coronal thirds of the canals.

Comparison Data and Statistical Analysis

A data set from a previously published study (23) done with the same experimental design was selected to compare the present results. Specifically, the data used refer to group PT/2, in which shaping with ProTaper (Dentsply Tulsa Dental, Tulsa, OK) was done, considering buccal and oral aspects each as 2 individual canals. Normality assumptions in both data sets were verified, and therefore data were reported as means ± standard deviation (SD). Original voxel volume in this data set was 8 × 10⁻⁶ mm³; volume data were rounded to the nearest 1/100 mm³, and area data were reported to the nearest 1/100 mm².

Data for prepared canal surface area were presented as percentages relative to preoperative canal surface areas, and canal transportation was rounded to the nearest 1/100 mm distance. For comparison, untreated canal surface scores in the present study were recalculated for 34-μm resolution, because this resolution had been used in a previous study (23).

Regression analysis was used to correlate canal dimension with the amount of untreated surface and preoperative SMI, respectively. Because normality assumptions were verified, means were compared by using one-way as well as repeated-measures analyses of variance (ANOVs), followed by Bonferroni/Dunn tests for post hoc comparisons or paired t tests; the level of statistical significance was set at α = 0.05.

Results

SAF Preparation

Distal canals included in the present study had long oval cross sections, as indicated by an SMI, a three-dimensional measure for cross-sectional “flatness,” ranging from 1.3–2.6. Volumes and areas ranged from 5–13.5 mm³ and from 33.5–60.3 mm², respectively (Table 1). Canal preparation with the SAF led to enlarged canal shapes with no evidence of preparation errors (Fig. 1). No SAF instrument fractured during the course of this study; on the basis of red-green color.
coded superimposed images, shapes were judged satisfactory, with evidence of circular dentin removal in most cross sections (Fig. 1).

Shaping with an SAF for 4 minutes resulted in significantly increased volumes and surface areas ($P < .001$); dentin removal in individual canals varied between 2.7 and 9.6 mm$^3$, with a mean of 4.84 ± 1.73 mm$^3$ (Table 2). Canal surface areas increased by 3.34 ± 1.73 mm$^2$.

The SMI showed a small but significant increase to 2.71 ± 0.30 ($P < .05$). There was no significant correlation between SMI scores and amounts of untreated canal surface ($r^2 = 0.001$).

Mechanically untreated canal areas overall ranged from 6.7%–44%. Mean untreated canal surface was 23.4% ± 8.9% for the whole canal length for the apical; correspondingly in the apical 4 mm, 40.1% ± 13.4% canal surface was counted as untreated.

Mean canal transportations in coronal, middle, and apical canal thirds were 106 ± 50, 64 ± 36, and 81 ± 49 μm, respectively. Canal transportation of 150 μm or more was noted in 8 of 60 root sections assessed, the majority of which was found in the coronal root canal third. Furthermore, mean canal transportation was larger in the coronal third compared with the middle third ($P < .01$).

Comparison to NiTi Rotary Preparation

To facilitate direct comparisons, all data were recalculated with 34-μm resolution. This resulted in slight changes in canal volume, area, and SMI (~0.5%–2%) but in larger amounts of untreated surface when 34-μm resolution was chosen (Table 2). Mean scores describing preoperative canal morphology for specimens included in the present experiment were statistically similar to those in an earlier study (23) on rotary preparation of long oval root canals in mandibular molars (Table 1).

Comparing the 2 shaping techniques, canal enlargement was significantly more pronounced with the SAF ($P < .002$), and changes in SMI were similar ($P = .176$). However, SAF preparation resulted in significantly less untreated surface for both the full canal length ($P < .001$) as well as the apical 4 mm ($P < .05$) (Table 2).

Discussion

The main aim of this third study in a series was to assess, by using the novel SAF, the preparation of root canals with long oval cross section, on the basis of MCT reconstructions. Distal root canals in

Figure 1. Representative example of MCT data of distal canals in mandibular molars, initially (left column) and prepared with the SAF (2 middle columns). Preparation time was 4 minutes; length bars 1 mm. (A) Three-dimensional views from the buccal, distal, and mesial in the top, middle, and bottom rows, respectively. Green area is unprepared; red area is prepared. (B) Cross sections at the levels indicated in (A). Note that unprepared canal is completely enclosed by prepared shape, and that Gates Glidden use led to a rounded shape in the coronal section.
mandibular molars represented an adequate model for this experiment, and the presented data suggest that preparation of non-round canals with the SAF can be done safely and effectively.

This study can be directly compared with earlier material that used the same experimental setup and rotary NiTi instruments. The MCT methodology has been used earlier in studies detailing preparation outcomes with various rotary instruments in maxillary molars. In that tooth group, shaping outcomes appeared to be correlated with preoperative anatomy determined by canal volume (15, 19). However, long oval cross sections constitute a different challenge in mandibular molars.

The number of canals included in the present study (n = 20) is higher than in the earlier material (n = 10 and 12 per group, respectively) (15, 23), and very stringent inclusion criteria were applied in the earlier material (n = 10 and 12 per group, respectively) (15, 23), and very stringent inclusion criteria were applied in the present study, and there were few changes to the overall canal shape, which was suggested by comparatively small increases of the respective SMI. Taken together with the lack of correlation between treated surface and canal shape, indicators suggest that the SAF respects the initial canal anatomy and creates adequate preparations largely independent of preoperative canal anatomy.

Future studies should address clinical outcomes of cases after SAF preparation. Such clinical studies will require postoperative observation times of 1 year and longer, but it is anticipated that long oval root canals in particular will be advantageously prepared with the SAF. Another important clinical question is how best to obturate canals prepared with the SAF; initial data (35) suggest that lateral compaction resulted in a better obturation quality after SAF preparation compared with rotary instrumentation.

In conclusion, preparation of long oval–shaped root canals in mandibular molars in vitro with the SAF was effective and safe. Moreover, shapes generated with the SAF were more complete compared with rotary canal preparation.

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References