Effect of Endodontic Instrumentation Technique on Root Canal Geometry

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Abstract
Root canal morphology can be changed after root canal preparation depending on the technique used. Therefore, the object of this study was to use micro-CT to investigate the shaping ability of the ProTaper rotary system and stainless steel manual files in permanent premolars.

Material and methods
Sixty extracted upper premolars were used for this study. They were divided into 2 groups of 30 teeth each. Before preparation, all samples were scanned by micro-computed tomography. Thirty teeth were prepared with the ProTaper system and the other 30 with stainless steel files. The root canal models before and after preparation were reconstructed and superimposed, and the volume, surface area and diameter changes were quantitatively measured in 3D analysis with SkyScan according to preparation techniques.

F test and t test showed a statistically significant difference in the root canal diameter increase between the ProTaper group and the manual instrumentation group (P < 0.000001).

The ProTaper system produced a greater volume change than the manual instrumentation technique (P < 0.001).
The ProTaper system produced a greater change in surface area than the manual instrumentation technique (P < 0.00001).

ProTaper system produced significantly increased root canal diameter, volume and surface area when compared with the manual instrumentation technique.

Keywords: Root canal geometry, ProTaper, stainless steel, micro CT.
Received date: 30 August 2017 Accept date: 04 October 2017

Introduction
Mechanical instrumentation of the root canal system is a key factor in endodontic therapy. The anatomy of the root canal system is the main variable that should be considered as a factor for achieving successful root canal therapy. The desirable shape is achieved by gradually decreasing the cross-sectional diameter of the root canal towards the apex of the root.

Root canal instrumentation involves mechanical debridement, creating space for medicaments, and optimizing the root canal geometry for quality obturation. Many rotary instruments have been developed for use in endodontics. Root canal preparation is influenced by the complex anatomy of root canals, which may be oval, flat, or curved.

A variety of methodologies have been used to determine the shaping ability of endodontic instruments, including decalcification techniques, sectioning techniques, and radiographic examination. The limitations of these methodologies have influenced researchers to look for new methods that can realize better results. Micro-computed tomography (micro-CT) techniques are now widely used in many fields of research. Micro-CT imaging was initially used for evaluating tooth morphology, surface area and volume changes, but more recently it has been used.
to study canal curvature,\textsuperscript{12} the percentage of instrumented canal wall,\textsuperscript{6,13,14} and volume changes within the tooth.\textsuperscript{15} Although micro-CT is not available for clinical dental use, it is an important technique in 3D dental research.\textsuperscript{16} From 3D color coded images, researchers can determine morphological changes in the root canal system after instrumentation.\textsuperscript{17} Therefore, the object of this study was to use micro-CT to investigate the shaping ability of the ProTaper rotary system and stainless steel manual files in permanent premolars.

**Materials and methods**

This study used 60 upper premolars which had been extracted for periodontal and orthodontic reasons. Tissue fragments and calcified debris were removed by scaling, and the teeth were stored in 10% formalin. At the time of the study, the teeth were washed with distilled water to remove residual formalin. All teeth were placed in a sample holder before micro-CT scanning to allow reproducible orientation in the pre- and post-preparation scans.

All teeth were scanned using the SkyScan 1173 micro-CT system (Bruker-microCT, Kontich, Belgium) with an isotropic voxel size of 22.86 µm at 70 kV/114 microA using a 1-mm aluminum filter, and the SkyScan 1174 micro-CT system (Bruker-microCT) with an isotropic voxel size of 24 µm at 50 kV/800 microA. Two-dimensional lateral projections of the samples were created over 360°, with a rotation step of 0.4°. An algorithm allowed co-registration, visualization and quantification of the analyzed variables. Root canals were three-dimensionally reconstructed using SkyScan NRecon with graphics processing unit recon server version 1.6.8.0 (SkyScan, Kontich, Belgium) and evaluated root canal diameter, surface area and volume before and after shaping (figure 1, 2 and 3). The root canal models before and after preparation were reconstructed and superimposed, and instrumentation techniques were quantitatively measured in 3D analysis in SkyScan CTAn software version 1.12.10.3 (SkyScan, Kontich, Belgium).

Endodontic access was obtained in all the samples, and the root canals were localized and explored with size 15 K-files (Diadent, France) until their tips were visible at the apical foramen. Working length was set at 1 mm from the apical foramen. The samples were divided into two groups of 30 teeth each. The root canals of the first group were prepared with the ProTaper rotary system (Dentsply, Maillefeur, Ballaigues, Switzerland) using a crown-down technique. An X Smart Plus motor (Dentsply) was used in
accordance with the manufacturer’s instructions and the canals were instrumented with an in-and-out motion in an apical direction. An SX instrument was used to shape the coronal part of the canal. S1 and S2 files were then used to prepare the middle and apical sectors of the canal up to the working length, followed by F1, F2, and F3 files for finishing of the canal.

Each instrument was passively introduced into the canal at a rotation rate of 250 rpm. The root canals of the second group were prepared with stainless steel K-files (Diadent, France) using a step-back technique. The root canals of both groups were irrigated with 2 ml of 3% sodium hypochlorite (Ultradent Products Inc., South Jordan, USA) after each file use. When the preparation was completed, each sample was inserted into the micro-CT scanner and the teeth were re-scanned (using the same parameters as for the initial scan) for comparison with the pre-preparation images. Typically, 500–750 slices were scanned per tooth. All CT scans were recorded on a computer in bitmap image format.

The volume, surface area and diameter changes were analyzed statistically using SPSS for Windows (SPSS® Statistics 15.0). The differences between samples to determine any statistically significant differences between the groups have been tested with (ANOVA) test. A 0.05 level of confidence was used for all analyses.

Results

The root canal diameter of all tested teeth was determined before and after preparation. In all teeth, the root canal diameter increased substantially after root canal preparation.

Table 1 shows the means and standard deviations of the root canal diameters of the three sections of the teeth (coronal, middle and apical) before and after preparation. Statistically significant differences in the diameter of the root canals were observed after root canal preparation in both techniques (P < 0.00001).

There was a statistically significant difference in the root canal diameter increase between the ProTaper group and the manual instrumentation group (P < 0.00001).

Table 2 shows the root canal volume change before and after instrumentation in both groups.

The ProTaper system produced a greater volume change than the manual instrumentation technique. The F test value of the ProTaper group was 12.2 (P < 0.001), while the F test value of the manual instrumentation group was 19.56 (P < 0.00001).

There was a statistically significant difference in the t test values between the ProTaper group and the manual instrumentation group (t = -16.3, P < 0.00001).

Differences in the surface area (ΔA in mm²) and volume (ΔV in mm³) of each canal before and after preparation were calculated using custom-made software. The mean ΔV for the ProTaper group was 2.4 mm³, but only 1.1 mm³ for the manual instrumentation group.

Table 2. Root canal volume change before and after instrumentation.

Table 3 shows the change in root canal surface area before and after instrumentation in the two groups. The ProTaper system produced a greater change in surface area than the manual instrumentation technique. The F test values
were 21.5 (P < 0.00001) for the ProTaper group and 15.59 (P < 0.00001) for the manual instrumentation group.

There was a statistically significant difference in the t test between the ProTaper group and the manual instrumentation group (t = -13.6, P < 0.00001).

The mean ΔA was 3.4 mm² for the ProTaper group and 1.2 mm² for the manual instrumentation group.

Discussion

This study investigated how root canal morphology can be changed after root canal preparation depending on the technique used. We also determined quantitative changes in the volume, surface area and diameter after root canal preparation with two different techniques.

The geometrical root canal shape produced by the correct mechanical action of endodontic instruments against the canal walls allows the tapered master cone of gutta-percha to be fitted. By adapting the shaping of the root canal to its anatomy, procedural errors can be overcome to achieve correct mechanical cleaning and disinfection. The clinical importance of a correctly-shaped root canal is well described in the guideline published by the European Society of Endodontics, which states that instrumentation should extend to the entire wall of the canal, so that it is completely cleaned and shaped.

Investigators have demonstrated that the dentin in the root canal wall is infected with microorganisms and their endotoxins, extending to a depth of 1–2 mm. The results of the current study showed significant differences in the diameter, surface area and volume after root canal preparation with the ProTaper technique. Similar results were reported by Al Jabbari et al., who observed significant differences in the geometrical characteristics between endodontic files with different ISO sizes.

A gradual increase in the diameter along the length of the canal was noted by Li et al., who showed that canal volume and surface area of all teeth increased by 5–146% after instrumentation, depending on the root canal type.

The instrumentation of root canals to retain their anatomy and ensure the least amount of dentin removal is a challenge, depending on the system used.

As reported by Yang et al., root canal instrumentation with ProTaper universal and Mtwo, both Ni-Ti instrument systems, resulted in significantly increased root canal volume and surfaces area. Uýanik et al. reported that the ProTaper system removed more dentin than the Hero Shaper and RaCe systems.

The effect of root canal instrumentation is also related to the preoperative canal geometry. In the study of Peters et al., after manual instrumentation, the mean increase in canal volume was 1.28 ± 0.57 and the mean increase in surface area was 2.58 ± 1.83.

In contrast, Moura-Netto et al. reported a significantly greater increase in surface area after instrumentation with the EndoEZE/AET system when compared with the ProTaper system. The increase in volume was found to be lower with the ProTaper system in wide root canals. This can be explained by the different manipulation characteristics of the system that was used. Although the ProTaper system shaped simulated canals without any significant error, the Reciproc system produced increased apical volume changes compared with the ProTaper system.

The variable taper of the files allows optimal root canal shapes to be achieved quickly and safely. It has been reported that instruments with a progressive taper can shape canals more quickly than those with a constant taper. In the progressive ProTaper system, the taper of the shaping files increases from the tip to the coronal area, whereas the finishing files have a decreasing taper.

Rotary instruments with a taper greater than 4% have been shown to be more efficient than hand files in preparing root canals.

Gomes et al. concluded that the mechanical action of instruments eliminated more than 47% of oral bacterial endotoxins against the dentin wall.

However, the manual techniques have less cleaning effect than sonic irrigation technique. But, with a greater volumetric change, the irrigating needle can be placed into deeper apical areas, producing a better irrigating effect, also confirmed by Margono et al. who reported that EDTA 17 % has the most excellent cleaning ability in cases when irrigation needle diameter was adjusted to the size of the apex preparation. Additionally, the final preparation with the F3 instrument increases the root canal
volume and reduces the un-instrumented area.\textsuperscript{42}

The results of the present study reveal that the use of the ProTaper system resulted in significantly greater changes in the root canal diameter, volume and surface area than instrumentation with hand files. The superior performance of the ProTaper system may have resulted from continuing the apical preparation up until the use of the F3 file, which may be associated with better root canal cleaning.

In the present study, the use of micro-CT images at a resolution of 22.86 μm provided an excellent method for evaluating the shaping properties of Ni-Ti rotary instruments and manual files. However, further studies are required to improve the evaluation of root canal preparation to achieve better outcomes for endodontic therapy.

Conclusions

The findings of this study suggest that root canal preparation with the ProTaper system and manual files significantly increased the root canal diameter, volume and surface area. The ProTaper system produced significantly increased root canal diameter, volume and surface area when compared with the manual instrumentation technique.

Acknowledgments

This research was completed in Hacettepe University, Faculty of Dentistry, Department of Endodontics and Hacettepe University, Faculty of Medicine, Department of Anatomy, Ankara, Turkey.

The authors thank the Bruker microCT company for helping in data reconstruction. We thank Helen Jeays, BDSc AE, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Declaration of Interest

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

References


