MEDICAL SCIENCE MONITOR BASIC RESEARCH

BIOTECHNOLOGY

eISSN 2325-4416
© Med Sci Monit Basic Res, 2015; 21: 123-130
DOI: 10.12659/MSMBR.893950

Received: 2015.02.25
Accepted: 2015.05.24
Published: 2015.06.20

Evaluation of Root Canal Preparation Using Rotary System and Hand Instruments Assessed by Micro-Computed Tomography

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Source of support: Departmental sources

Background: Complete mechanical preparation of the root canal system is rarely achieved. Therefore, the purpose of this study was to evaluate and compare the root canal shaping efficacy of ProTaper rotary files and standard stainless steel K-files using micro-computed tomography.

Material/Methods: Sixty extracted upper second premolars were selected and 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. After preparation, the untouched surface and root canal straightening were evaluated with micro-computed tomography. The percentage of untouched root canal surface was calculated in the coronal, middle, and apical parts of the canal. We also calculated straightening of the canal after root canal preparation. Results from the 2 groups were statistically compared using the Minitab statistical package.

Results: ProTaper rotary files left less untouched root canal surface compared with manual preparation in coronal, middle, and apical sector ($p<0.001$). Similarly, there was a statistically significant difference in root canal straightening after preparation between the techniques ($p<0.001$).

Conclusions: Neither manual nor rotary techniques completely prepared the root canal, and both techniques caused slight straightening of the root canal.

MeSH Keywords: **Root Canal Preparation • Stainless Steel • X-Ray Microtomography**

Full-text PDF: http://www.basic.medscimonit.com/abstract/index/idArt/893950

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Indexed in: [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS] [Index Copernicus]

Background

Preparation of the root canal system includes both enlargement and shaping of the complex endodontic space, together with its disinfection. However, complete mechanical preparation of the root canal system is rarely achieved because of its variety and complexity [1,2]. Additionally, geometrical dissymmetry between the root canal and the preparation instrument may prevent the preparation instrument from acting efficiently on all canal walls. In simple, narrow, straight root canals with round cross-sections, most currently used rotary instruments will adequately clean and shape the canal, with favorable results. However, in oval, flat, or curved root canals, rotary files often fail to adequately clean and shape the canal, leaving fins that may not have been touched [3,4].

Several types of endodontic instruments have been recommended as being capable of achieving the primary objectives of root canal preparation [5,6]. The shaping of curved canals presents a problem for operators when stainless steel instruments are used, and all preparation techniques have a tendency to move the prepared canal from its original axis. Parameters affected by preparation, such as the angle of curvature determined by a line from the apical termination to the point of departure from a straight line drawn through the middle of the coronal part of the canal, can have a significant effect on endodontic treatment success. The use of rotary Ni-Ti files for root canal preparation has significantly reduced the time required to prepare the root canal, with minimal deviations from the original canal path compared with manual instrumentation [5,7].

A variety of methodologies have been used to evaluate the shaping ability of endodontic instruments, including simulated root canal models, decalcification techniques, sectioning techniques, and radiographic comparison, but the limitations of these techniques have led researchers to look for new methods that can produce more accurate results. Micro-computed tomography (micro CT) systems are now widely used in many academic fields. In recent years, micro CT has proved to be an efficient tool for evaluating the morphologic changes in the root canal shape before and after preparation [8]. Based on the fact that adequately cleaning and shaping of the root canal can optimize its disinfection and filling, the purpose of this study was to use micro CT to determine the percentage of untouched surface and the change in the angle of curvature after root canal preparation with stainless steel files and the ProTaper system in second upper premolars.

Material and Method

We used 60 intact maxillary second premolars that had been extracted for periodontal and orthodontic reasons. Prior to extraction, patients were informed about and agreed to the scientific work to be performed. All teeth had fully developed roots and were stored in 10% formalin until use. Prior to the study, the teeth were washed with distilled water to remove residual formalin.

Each tooth was mounted in a sample holder before the micro CT scanning to allow reproducible orientation in the pre- and post-preparation scans. All teeth were scanned using either a 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 aluminium filter or a SkyScan 1174 system (Bruker-microCT, Kontich, Belgium) with an isotropic voxel size of 24 μm at 50 kV/800 microA. To allow scanning within the shortest possible period of time, we used 2 micro CT machines. Two-dimensional lateral projections of the samples were created over 360°, with a rotation step of 0.4°. A modified Feldkamp algorithm (NRecon with a GPU recon server version 1.6.8.0, SkyScan, Kontich, Belgium) was used for reconstruction of projection images, and 2-dimensional cross-sectional images were created. SkyScan Dataviewer software (Version 1.4.4, SkyScan, Kontich, Belgium) was used for distance calculations.

The access cavities of all samples were prepared, and the root canals were localized and explored with size 15 K-files (Diadent, France) until their tips were visible to the apical foramen. Working length was set at 1 mm from the apical foramen. All samples were divided into 2 groups of 30 teeth each.

The root canals of the teeth in the first group were prepared with the ProTaper rotary system (Dentsply, Maillefer, Ballaigues, Switzerland) using a crown-down technique. In this technique, instrumentation was performed by using a Sx, S1, S2, F1, F2, and F3 sequence. Sx instrument was used to shape the coronal part of the canal, to continue with preparation of the middle and apical sectors of the canal up to the working length with S1, S2 shaping files and F1, F2, and F3 finishing files. The X-Smart endodontic motor (Dentsply, Maillefer) was used at a rotation 250 rpm, introducing the instruments passively into the root canal. The root canals of teeth in the second group were prepared with stainless steel K-files (Diadent, France) using a step-back technique. Apical enlargement was performed with an instrument size of up to No. 30 for both techniques. 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 teeth were re-scanned (using the same parameters used for the initial scan) for comparison with the pre-preparation images. All scans were recorded on a computer in bitmap image format.

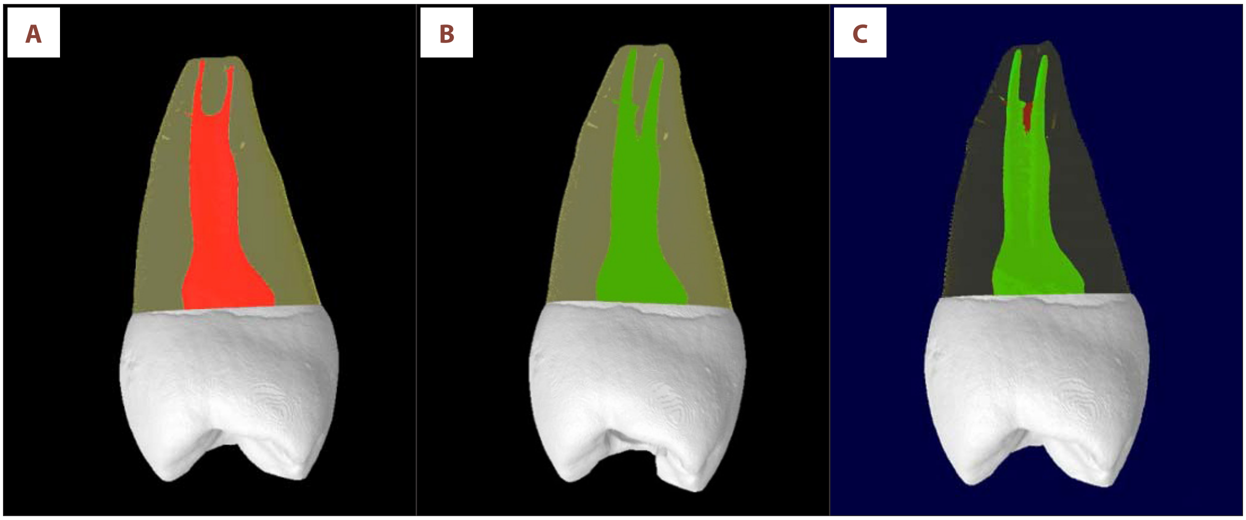

Figure 1. Three dimensional image of tooth with surface rendering (**A**) Before preparation; (**B**) After preparation; (**C**) Superimposition.

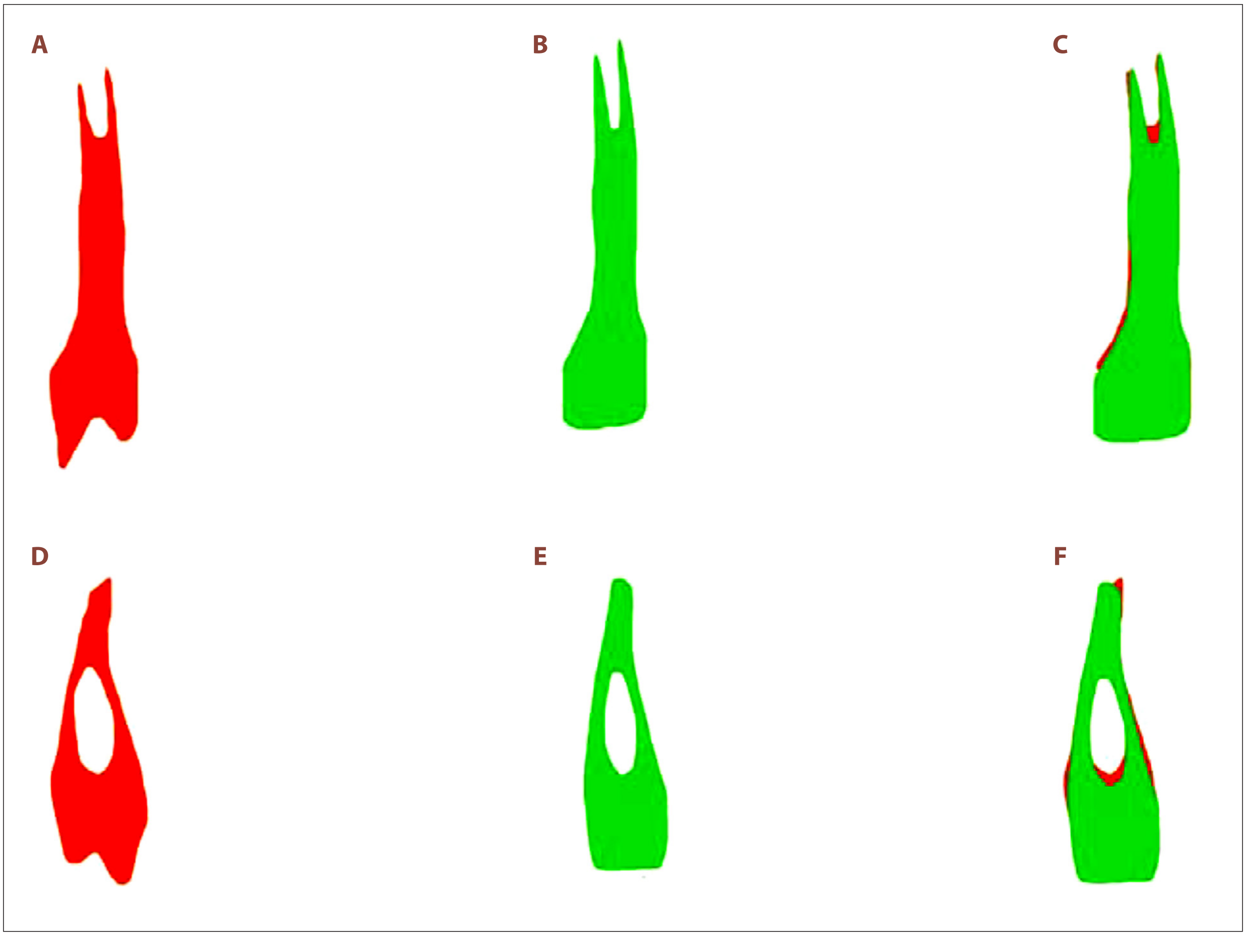

Figure 2. Before and after instrumentation scans according to preparation techniques: (**A–C**) (preoperative, postoperative, superimposition of pre and postoperative surfaces-Protaper); (**D–F**) (preoperative, postoperative, superimposition of pre and postoperative surfaces-stainless steel).

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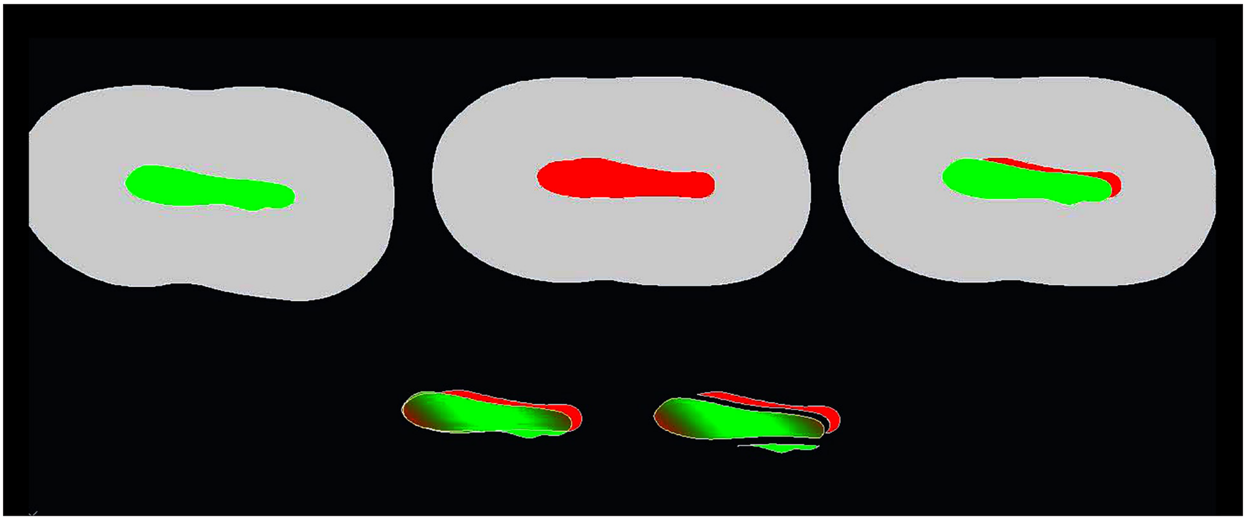

Figure 3. Untouched surface after preparation- root canal cross sectional images.

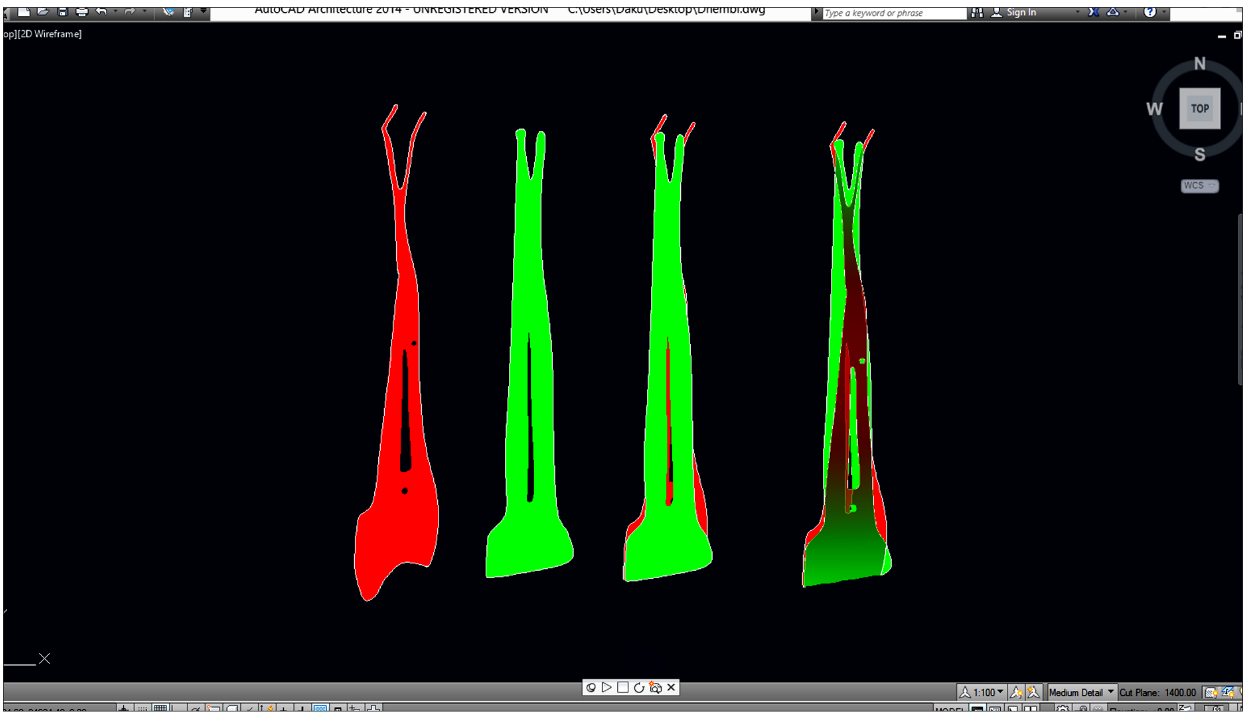

Figure 4. Before and after preparation scans – Auto Cad program evaluation of untouched surface.

CTVox software (version 2.4.0, Bruker-microCT, Kontich, Belgium) and CTVol software (version 2.2.3.0, Bruker-microCT, Kontich, Belgium) were used for 3-dimensional visualization and qualitative evaluation, respectively, of the pre- and post-instrumented canals (Figure 1A–1C). The color red was used to indicate the preoperative canal surface and the color green to indicate the postoperative canal surface (Figure 2A–2F).

Post-preparation changes in all canal parameters were calculated by subtracting the scores for the treated canals from those recorded for the untreated canals. The AutoCAD 2012-CDW program was used to analyze the 15 superimposed cross-sectional images for each sample (5 for each sector of the tooth: coronal, middle, and apical) and to evaluate the percentage of uninstrumented walls (Figures 3 and 4).

The percentage of uninstrumented walls was calculated by determining how much of the root canal perimeter was treated in cross-section. The same program was used to calculate differences in straightening of the canal between the 2 root canal preparation techniques (Figure 5). The angle of curvature was considered to be the angle formed by a line joining the apical

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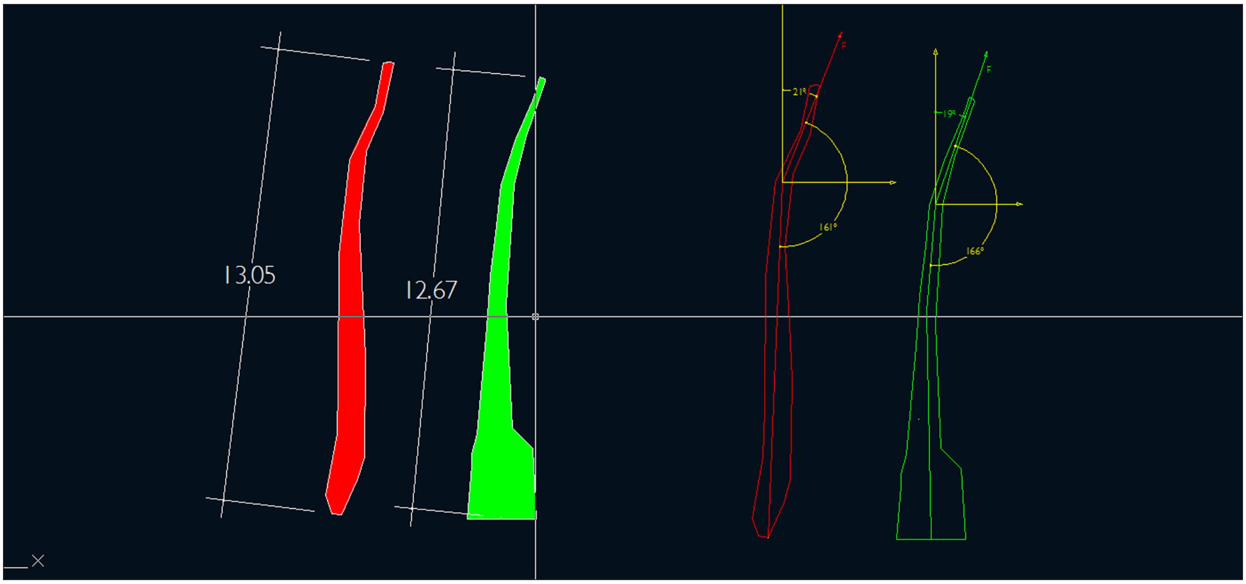

Figure 5. Auto Cad program evaluation of straightening the root canal after preparation.

Table 1. The mean percentage of untouched surface according to root canal sectors and preparation technique-coronal sector.

Group	Mean %	SD	SE
Protaper	26	2.11	0.39
Stainless steel	29	1.97	0.36
P-value 0.000			

termination and the point of departure from a straight line drawn through the middle of the coronal part of the canal [9]. Based on the canal curvatures assessed before and after instrumentation, canal straightening was determined as the difference between canal curvature prior to and after instrumentation.

All analyses were carried out using the Minitab Statistical Package at a significance level of 5%.

Results

A 2-way analysis of variance (ANOVA) test was performed to test for significance of the average proportions of each third not being prepared by instruments, aggregated across both groups. Results suggest that there was a significant difference between average proportions not being prepared by instruments in each third (coronal third average=27%, middle third=38%, and apical third=23%) (p-value=0.000); therefore, at least 1 of the averages differs significantly from the other 2. Similarly, there was a significant difference between each average proportion not being prepared by instruments when compared with the means of 2 groups (average of group 1=27% and average of group 2=32%) (p-value=0.000). Finally, the p-value (0.001) for the interaction effect shows that there is at least 1 combination of group and thirds that is significantly different from the rest, indicating that there is an interaction effect.

F-tests for equality of variances were carried out for all 3 thirds (coronal, middle, and apical), and results indicate that for both groups across all thirds there are no significant differences between variances (respective p-values were 0.713, 0.059, and 0.257). Therefore,

t-tests assuming equal variances were used in the 3 thirds to determine if there were significant differences between group averages. Results are summarized below:

Coronal third:
A p-value of 0.000 (Table 1) shows that there was a significant difference between the averages of the 2 group, with the average of group 1=26% and the average of group 2=29%.

Middle third:
A p-value of 0.000 (Table 2) shows that there was a significant difference between the averages of the 2 group, with average of group 1=35% and the average of group 2=41%.

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Table 2. The mean percentage of untouched surface according to root canal sectors and preparation technique-middle sector.

Group	Mean %	SD	SE
Protaper	35	2.22	0.41
Stainless steel	41	1.55	0.28
P-value 0.000			

Table 3. The mean percentage of untouched surface according to root canal sectors and preparation technique-apical sector.

Group	Mean %	SD	SE
Protaper	20	1.49	0.27
Stainless steel	25	1.84	0.34
P-value 0.000			

Table 4. The straightening of the canal after root canal preparation.

Group	Mean (°)	Standard deviation (SD)	Standard error (SE)
Protaper	5.00	1.34	0.24
Stainless steel	11.00	1.23	0.22
P-value 0.000			

Apical third:
A p-value of 0.000 (Table 3) shows that there was a significant difference between the averages of the 2 groups, with average of group 1=20% and the average of group 2=25%.

This part of the analysis involves performing a 1-way ANOVA for equality of means (averages) between each third for individual groups. In the group in which the ProTaper system was used, the p-value of 0.000 shows that there was a significant difference between the averages of the 3 thirds, with coronal third=26%, middle third average=35%, and apical third average=20%.

In the group in which stainless steel files were used, the p-value of 0.000 shows that there was a significant difference between the thirds averages, with coronal third average 29%, middle third average 41%, and apical third average 25%.

The second evaluated parameter, the straightening of the canal after root canal preparation, is presented in Table 4.

An F-test for equality of variances with a p-value of 0.656 indicates that these 2 samples had equal variances, thus a t-test assuming equal variances was performed. A p-value of 0.000 shows that there was a significant difference between the 2 group averages of angle of curving after the treatment, with the average of the 1st group=5° and the average of the 2nd group=11°.

Discussion

The simultaneous needs to enlarge the root canal and preserve its anatomy are a challenge for the practitioner. In this study, we analyzed the effect of canal instrumentation using the variables of untouched surface and the straightening of the curvature after root canal preparation. The method used in the current study – 3-dimensionally reconstructed images of the canal system – allowed us to evaluate morphological changes after root canal preparation.

The percentage of untouched canal surface is very important to characterize the completeness of root canal preparation; it should be as low as possible to enable good endodontic treatment. Superimposed micro CT reconstructions in 3 sectors of the root canal showed that the use of the ProTaper system resulted in less untouched surface than did the use of hand files. However, oval and long oval canals are common in most roots that contain 2 canals in the same root and represent a challenge in endodontics.

Numerous studies using extracted human teeth have discovered uninstrumented areas with remaining debris in all areas of the canals, irrespective of the preparation technique. Cleanliness was found to decrease from the coronal to the apical part of the root canal [10,11]. Peters et al. [12] found that, after preparation of the root canals of maxillary first molars with K-type hand files and 3 rotary Ni Ti files, 35% or more of the canals' dentine surface was left untouched, with very little difference between all experimental groups. Paque et al. [13] reported that a variable portion of the surface area of oval-shaped root canals in mandibular molars was left unprepared regardless of the instrumentation technique used; they found less unprepared canal perimeter in oval canal shapes created with rotary instruments, ranging from 25% to 35%. Weiger et al. [14] showed that 44–68% of the canal surface was unprepared in long oval canals. Rotary instruments with a greater than 4% taper have been shown to be more efficient than hand files in preparing root canals. However, even the Ni Ti instruments that were used in this study did not completely prepare oval root canal walls [15]. Tan and Messer [16] found that instrumentation with larger file sizes using rotary Ni Ti instruments resulted in significantly cleaner canals in the apical 3 mm than did hand instrumentation. Divergent results were obtained by Yin et al. [17], who reported that hand files removed more dentin, resulting in less unprepared surface compared with the ProTaper system, which produced 50.6% untouched surface. These contradictory results may be explained by differences in methodology, preparation technique, and tooth selection.

The other parameter that was examined in this study was canal straightening, which can be classified as a procedural error. The present data suggest that the manual instrumentation technique resulted in more root canal straightening compared with the ProTaper system. The preoperative canal curvature affects the type and frequency of instrumentation errors [18,19]. Several studies have revealed that Ni Ti instruments maintain the original canal curvature better than stainless steel files, especially in the apical region of the root canal. Ni-Ti instruments produce significantly less straightening and better-centered preparations, reducing the potential for iatrogenic errors [10,20,21]. Although Rahman et al. [22] and Capar et al. [23] concluded that instrumentation systems used in their studies tended to induce various degrees of dentinal damage during root canal preparation, Pagliosa et al. [24] reported that the ProTaper system can safely be used in instrumentation of curved canals at full working length with satisfactory preservation of the original canal shape. This may be due to their flexibility and mechanical memory.

Micro CT provides images at a resolution of up to 22.86 µm, making it an excellent method for the evaluation of morphological root canal changes after canal preparation. In our study, evaluation with this technique suggests that both manual and rotary endodontic instruments have limited ability to prepare and clean root canals, emphasizing the importance of antibacterial agent use for enhanced disinfection of the root canal system.

Conclusions

On the basis of the results of this micro CT study it may be concluded that: (1) both manual preparation with stainless steel files and motorized preparation with ProTaper left unprepared root canal surface, and (2) both techniques caused slight straightening of the root canal after preparation.

Acknowledgements

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.

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