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Effects of preparation techniques on root canal shaping assessed by micro-computed tomography

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Background: Root canal shaping without any procedural error is of the utmost preference. Therefore, the purpose of this study was to use micro-computed tomography to evaluate and compare the root canal shaping efficacy of ProTaper rotary files and standard stainless steel K-files.

Material/Methods: Sixty extracted upper second premolars were selected and were divided into 2 groups of 30. Before preparation, all samples were scanned by micro-CT. Then, 30 teeth were prepared with stainless steel files and the remaining 30 with ProTaper rotary files. Canal transportation and centering ability before and after root canal shaping were assessed using micro-CT. The amount and direction of canal transportation and the centering ratio of each instrument were determined in the coronal, middle, and apical parts of the canal. The 2 groups were statistically compared using one-way ANOVA.

Results: ProTaper rotary files gave less transportation ($p<0.001$) and better centering ability ($p<0.00001$) compared with stainless steel files.

Conclusions: The manual technique for preparation of root canals with stainless steel files produces more canal transportation, whereas rotary files remain more centered in the canal.

Key words: stainless steel • ProTaper • micro CT • centering ability • canal transportation

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Background

Mechanical preparation of the root canal system is recognized as being one of the most important stages in root canal therapy [1,2]. This process serves to optimize the shape of the canal for disinfection and obturation, giving it a uniformly tapered funnel shape, with a diameter that increases smoothly from the apex toward the coronal orifice [3]. However, endodontic preparation with different techniques and instruments becomes more challenging when the root canal has pronounced curvature, and in such cases there is a tendency for deviation of the prepared canal away from its natural axis [4]. The ability of an instrument or technique to stay centered within the natural canal path during preparation is seen as a highly positive property [5]. Iatrogenic preparation errors such as canal transportation are clearly undesirable, and can be broadly defined as any deviation from the natural canal path [6]. Thus, techniques and endodontic instruments should be employed that cause fewer errors, give greater precision, and decrease working time [7]. Recently, the development of nickel-titanium (Ni-Ti) instruments has significantly improved the quality of root canal shaping, resulting in less iatrogenic damage [6]. Their design allows Ni-Ti instruments to stay more centered in the canal, producing rounder preparations and reducing procedural errors [8]. These advantages have been reported to result in better clinical outcomes [9].

Various methods have been used to investigate the efficacy of different endodontic instruments with regard to their centering ability and tendency to produce root canal transportation. Classical *in vitro* methods of studying the morphologic characteristics of root canal systems produce irreversible changes in the samples and can yield only a 2-dimensional image [10,11]. More accurate information can be achieved with micro-computed tomography (micro-CT), which provides quantitative and qualitative evaluation of the root canal in 3 dimensions [12,13]. Micro-CT is a non-invasive experimental method that allows the comparison of pre- and post-preparation images of root canals. The aim of this study was to use micro-CT to evaluate root canal transportation and centering ability of ProTaper rotary files (Dentsply, Maillefer, Ballaigues, Switzerland) and standard stainless steel K-files (Diadent, France).

Material and Methods

A total of 60 maxillary second intact premolars with fully formed apices were selected from a pool of extracted teeth that were removed for periodontal and orthodontic reasons. Teeth were stored in 10% formalin until use. Prior to the study, the teeth were washed with distilled water to remove residual formalin.

Before the initial micro-CT scan, each tooth was mounted in a sample holder to allow reproducible orientation in the pre- and post-preparation scans. Prior to preparation, all teeth were scanned using a SkyScan 1173 micro-CT system (Bruker microCT, Kontich, Belgium) with an isotropic resolution of 22.86 µm at 70 kV/114 microA using a 1-mm aluminum filter, or a SkyScan 1174 system (Bruker microCT, Kontich, Belgium) with an isotropic voxel size of 24 µm at 50 kV/800 microA. Two machines were used to allow scanning in the shortest period of time.

Initially, 2-dimensional lateral projections of the samples were created over 360°, with a rotation step of 0.4°. Subsequently, the projection images were reconstructed using a modified Feldkamp algorithm (NRecon with a GPU recon server version 1.6.8.0, SkyScan, Kontich, Belgium) and 2-D cross-sectional images were acquired. Distance calculations were made using SkyScan Dataviewer software (Version 1.4.4; SkyScan, Kontich, Belgium).

After initial scanning, the access cavities were prepared and root canals localized and explored with a size 15 K-file (Diadent, France) until they were visible to the apical foramen. The working length was determined by subtracting 1 mm from the length to the apical foramen. At this point, the total sample was divided into 2 groups of 30 teeth each.

The root canals of teeth in the first group were instrumented with stainless steel K-files (Diadent, France) using a step-back technique. Apical enlargement was made with instrument size up to no. 30. The root canals of teeth in the second group were prepared with the ProTaper rotary system (Dentsply, Maillefer, Ballaigues, Switzerland) using a crown-down approach. In this technique, the Sx instrument was used to relocate the canal orifice and shape the coronal part of the canal. Instrumentation of the middle and apical sectors of the canal up to working length was achieved using S1 and S2 shaping files and F1, F2, and F3 finishing files. Each instrument was passively introduced into the canal at a rotation rate of 250 rpm. During instrumentation, root canals of both groups were irrigated with 2 ml of 3% sodium hypochlorite (Ultradent products, Inc. South Jordan, USA) after each file. After preparation was completed by an experienced operator, each sample was inserted into the micro-CT scanner in the same sagittal position and re-scanned using the same parameters as in the initial scan, for comparison against 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 degree of canal transportation was calculated by measuring the shortest distance from the edge of a non-instrumented canal to the periphery of the root (mesial and distal) and then comparing this with the same measurements made in images

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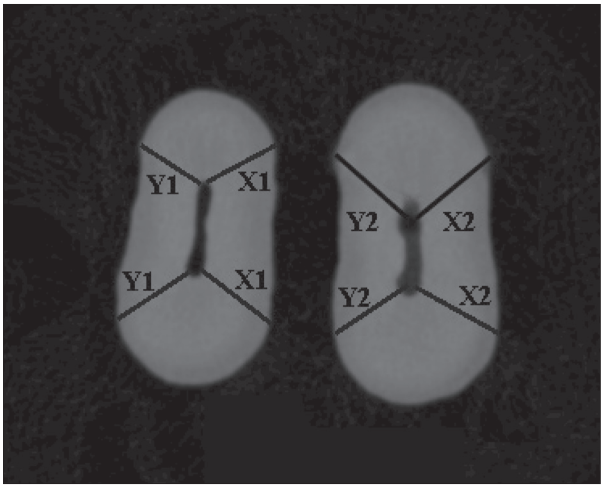

Figure 1. Schematic view of pre- and post-operative cross-section describing the parameters used in the Gambilli method.

of instrumented canals. According to Gambilli et al. (1996), the formula for canal transportation (in mm) is:

[(X1-X2)-(Y1-Y2)]

where X1 and X2 are the shortest distances between the mesial root periphery and the canal in non-instrumented and instrumented canals, respectively, and Y1 and Y2 represent the shortest distance between the distal root periphery and the canal in non-instrumented and instrumented canals, respectively [14] (Figure 1).

Pre- and post-operative calculations were compared to determine the existence of canal transportation in the coronal, middle, and apical sectors (Figure 2).

According to this formula, a '0' value indicates no canal transportation. Any result other than '0' shows that transportation of the root canal has occurred. A negative value represents transportation occurring in the direction facing the furcation, whereas positive values represent transportation lateral to the curvature.

The mean centering ratio is a measure of the ability of an instrument to stay centered within the canal [14] and can be calculated using the formulae:

[(X1-X2)/(Y1-Y2)] or [(Y1-Y2)/(X1-X2)]

where X1, X2, Y1, and Y2 are the same parameters as listed in the formula for canal transportation above. According to this formula, a centering value of '1' means perfect centering, 0.60–0.99 indicates good centering ability, 0.40–0.59 shows moderate centering ability, 0.01–0.39 shows poor centering ability, and a value of 0 indicates no centering.

The transportation and centering ratio results were analyzed statistically using SPSS for Windows (SPSS® Statistics 15.0).

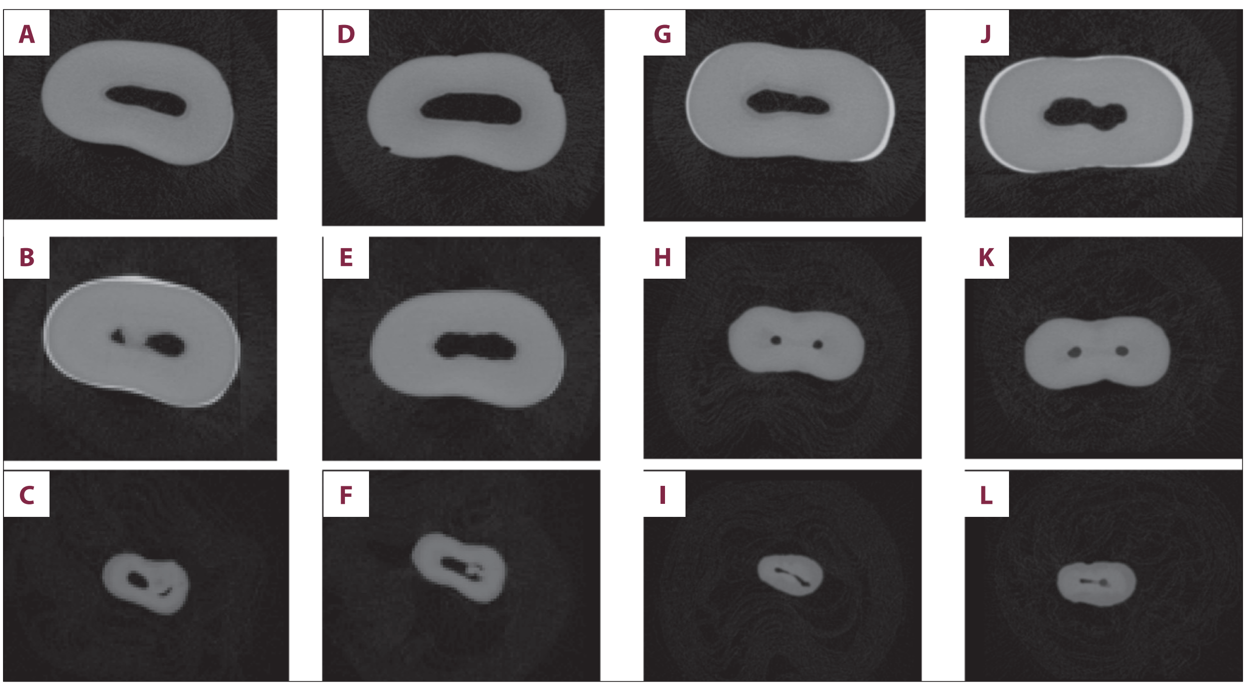

Figure 2. Representative cross-section of micro-CT data. (**A–C**) Images of teeth before preparation with hand files in three dimensions. (**D–F**) Images showing teeth after canal preparation with hand files. (**G–I**) Teeth before canal preparation with the ProTaper system. (**J–L**) After preparation with ProTaper.

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Table 1. Frequency and direction of root canal transportation in each sector of the root canal associated with preparation using stainless steel and rotary instruments.

	Stainless steel files			Protaper system		
	Inside	Outside	None	Inside	Outside	None
Coronal	27 (90.0%)	0	3 (10.0%)	25 (83.3%)	0	5 (16.7%)
Middle	24 (80.0%)	2 (6.7%)	4 (13.3%)	22 (73.3%)	3 (10.0%)	5 (16.7%)
Apical	4 (13.3%)	21 (70.0%)	5 (16.7%)	2 (6.7%)	19 (63.3%)	9 (30.0%)

Data are the number of teeth displaying each characteristic, with the percentage of the total sample that this number represents shown in parentheses.

Table 2. Canal transportation (mm) for each preparation technique at each sector of the canal.

Instruments	Coronal	Middle	Apical
Stainless steel files	−0.20±0.07	−0.10±0.08	0.05±0.06
ProTaper system	−0.13±0.06	−0.05±0.05	0.02±0.02
One-way ANOVA	P<0.001	P<0.01	P<0.05

Data are mean ± standard deviation. Statistical analysis was by one-way ANOVA.

Table 3. Centering ratios by preparation techniques in different canal sectors.

Instruments	Coronal	Middle	Apical
Stainless steel files	0.44±0.04	0.49±0.03	0.56±0.04
ProTaper system	0.53±0.05	0.61±0.05	0.67±0.05
One-way ANOVA	P<0.0001	P<0.00001	P<0.00001

Data are mean ± standard deviation. Statistical analysis was by one-way ANOVA.

Parametric statistical test (one-way ANOVA) was used to determine any statistically significant differences amongst the groups. A 0.05 level of confidence was used for all analyses.

Results

Regarding the direction of root canal transportation, both preparation techniques caused transportation toward both the inside and outside of the curvature. There was more frequent transportation toward the inside of the curve in the coronal and middle sectors after preparation with both stainless steel files and the ProTaper rotary system. The apical third showed more canal transportation toward the outside of the curve in both experimental groups (Table 1).

In the analysis of the same 5 cross-sectional images (before and after preparation) in each of the 3 root canal sectors (coronal, middle, and apical), one-way ANOVA showed a significantly lower frequency of transportation in root canals prepared with the ProTaper rotary system compared with those prepared using stainless steel files (Table 2).

The data describing the centering ability of each system in each of the 3 root canal sectors are shown in Table 3.

The ProTaper system demonstrated significantly superior centering ability in each of the 3 root canal sectors compared with stainless steel files ($p<0.00001$). However, neither technique showed perfect centering ability. In the apical third, 93.3% of ProTaper instruments showed good centering ability, compared with only 16.7% of hand files. In the middle sector, the rotary Ni-Ti instruments showed good centering ability in 50% of samples, whereas hand files exhibited poor centering. Both techniques showed poor centering in the coronal sector.

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Discussion

Recently, new methods for evaluating procedural errors after root canal preparation have improved our understanding of which preparation techniques are most efficient. The present research used a model that allows quantitative and qualitative evaluations of root canals, revealing their anatomical properties and variations in 3 dimensions, increasing the success rate of endodontic treatment and the progress of research [15].

The first parameter evaluated was canal transportation. The crown-down technique using ProTaper rotary files gave less canal transportation compared with manual preparation with stainless steel files. This may be attributed to instrumentation technique, and/or to the type and design of the instruments. The crown-down technique improves access for subsequent files, but is somewhat dependent on the higher flexibility of Ni-Ti alloys compared with stainless files [16]. This superior flexibility reduces the risk of canal transportation during enlargement of curved canals [17]. Indeed, it has been shown that ProTaper instruments (in the absence of major procedural errors) may even be more effective in shaping narrow canals than wide ones [18].

Evaluation of root canal preparation by different techniques demonstrated that rotary Ni-Ti instruments produced less canal transportation than stainless steel or Ni-Ti hand files [19], but similar research in a different laboratory reported contrary results, finding that canal transportation was less frequent with Ni-Ti hand files than with rotary techniques [20]. These divergent results may be explained by methodological differences.

Our present study shows that the direction of transportation in the apical area is toward the outside curvature, a finding that corroborates previous studies reporting that the superelasticity of the instruments allows them to follow the canal curvature [21–23]. Canal transportation of up to 0.15 mm is considered acceptable [6], but anything higher than 0.30 mm has a negative impact on the resultant apical seal [24]. In the present study, we demonstrated canal transportation of less than 0.30 mm with both techniques.

The second parameter evaluated was centering ability, which gives an indication of whether the dentine removal over the prepared area is spread evenly by the instrument. Good centering ability reduces the risk of transportation, zips, elbows, and other errors. A number of studies have shown that the centering ratio of rotary Ni-Ti instruments was better than stainless steel files [25,26]. A safe, non-cutting tip allows the instrument to move properly in the canal and, importantly, to remain centered within it [5]. Centering ability is, at least in part, determined by the flexibility of Ni-Ti instruments. We found that ProTaper rotary files had superior centering compared with stainless steel hand files, especially in apical and middle thirds of the canal. However, neither of the systems used in the study had perfect centering, with both showing a mixture of good and poor centering ability.

In the present study, micro-CT provides images at a resolution of 22.86 μm, making it an excellent method for the evaluation of procedural errors after root canal preparation. However, more studies are required to further develop the evaluation of root canal preparation by different techniques, which should drive improvements in success rates of endodontic therapy.

Conclusions

According to the methodology used, and on the basis of the results of this study, we conclude that 1) manual preparation with stainless steel files produces more canal transportation than the ProTaper rotary system, and 2) the ProTaper rotary system has better centering ability than stainless steel files.

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Conflict of interest

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

References:

1. Schilder H: Cleaning and shaping the root canal. Dent Clin North Am, 1974: 18: 269–96
2. Ruddle C: Cleaning and shaping the root canal system. In: Cohen S, Burns R, eds. Pathways of the Pulp, 8th dn. St Louis, MO: Mosby, 2002; 231–92
3. Musikant BL, Cohen BL, Deutsh AS: Simplified obturation of tapered canal preparations. Compend Contin Educ Dent, 1998; 19: 1152–55
4. Abou-Rass M, Frank Al, Glick DH: The anticurvature filling method to prepare the curved root canal. J Am Dent Assoc, 1980; 101: 792–94
5. Kandaswamy D, Venkateshbabu N, Porkodi I, Pradeep G: Canal-centering ability: An endodontic challenge. J Conserv Dent, 2009; 12: 3–9
6. Peters OA: Current challenges and concepts in the preparation of root canal systems: a review. J Endod, 2004; 30: 559–67
7. Iqbal MK, Maggiore F, Suh B et al: Comparison of apical transportation in four Ni-Ti rotary instrumentation technique. J Endod, 2003; 29: 587–91
8. Glosson CR, Haller RH, Dove SB, del Rio CE: A comparison of root canal preparations using NiTi hand, NiTi engine-driven, and K-Flex endodontic instruments. J Endod, 1995; 21: 146–51

9. Pettiette MT, Delano EO, Trope M: Evaluation of success rate of endodontic treatment performed by students with stainless-steel K-files and nickel-titanium hand files. J Endod, 2001; 27: 124–27
10. Gonzales-Rodriguez MP, Ferrer-Luque CM: A comparison of Profile, Hero 642 and K3 instrumentation systems in teeth using digital imaging analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2004; 97: 112–15
11. Microgeorgis G, Molyvdas I, Lyroudia K et al: A new methodology for the comparative study of the root canal instrumentation techniques based on digital radiographic image processing and analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2006; 101: 125–31
12. Peters OA, Schonenberg K, Laib A: Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro CT. Int Endod J, 2001; 34: 221–30
13. Paque F, Barbakow F, Peters OA: Root canal preparation with Endo-Eze AET: changes in root canal shape assessed by micro CT. Int Endod J, 2005; 38: 456–64
14. Gambill JM, Alder M, del Rio CE: Comparison of nickel-titanium and stainless steel hand-file instrumentation using computed tomography. J Endod, 1996; 22: 369–75
15. Kim J, Paik KS, Lee SP: Quantitative evaluation of the accuracy of micro-computed tomography in tooth measurement. Clin Anat, 2007; 20: 27–34
16. Ehsani M, Zahedpasha S, Moghadamnia AA, Mirjani J: An *ex vivo* study on the shaping parameters of two Ni-Ti rotary systems compared with hand instruments. Iran Endod J, 2001; 6: 74–79
17. Schäfer E, Schlingemann R: Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J, 2003; 36: 208–17
18. Peters OA, Peters CI, Schonenberger K, Barbakow F: ProTaper rotary root canal anatomy on final shape analysed by micro CT. Int Endod J, 2003; 36: 86–92
19. Gergi R, Rjeily JA, Sader J, Naaman A: Comparison of canal transportation and centering ability of twisted files, pathfile-ProTaper system and stainless steel hand K-files by using computer tomography. J Endod, 2010; 36: 904–7
20. Kosa DA, Marshall G, Baumgartner JC: An analysis of canal centering using mechanical instrumentation techniques. J Endod, 1999; 25: 441–45
21. Taşdemir T, Aydemir H, Inan U, Unal O: Canal preparation with Hero 642 rotary NiTi instruments compared with stainless steel hand K-file assessed using computed tomography. Int Endod J, 2005; 38: 402–8
22. Merrett SJ, Bryant ST, Dummer PM: Comparison of the shaping ability of RaCe and FlexMaster rotary nickel-titanium systems in simulated canals. J Endod, 2006; 32: 960–62
23. Pasternak-Junior B, Sousa-Neto MD, Silva RG: Canal transportation and centring ability of RaCe rotary instruments. Int Endod J, 2009; 42: 499–506
24. Wu MK, Fan B, Wesselink PR: Leakage along apical root fillings in curved root canals. Part I: effects of apical transportation on seal of root. J Endod, 2000; 26: 210–16
25. Short JA, Morgan LA, Baumgartner JC: A comparison of canal centering ability of four instrumentation techniques. J Endod, 1997; 23: 503–7
26. Schäfer E, Florek H: Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 1. Shaping ability in simulated curved canals. Int Endod J, 2003; 36: 199–207

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