Micro-computed tomography evaluation of root canal preparation using rotary system and hand instrument in young permanent molars

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ABSTRACT

The aim of this study was to evaluate the shaping potentials of the ProTaper system and nickel-titanium (Ni-Ti) hand-files using micro-computed tomography (μCT) in young permanent teeth. Thirty-second permanent molar teeth extracted from patients 15 to 18 years of age were divided into two groups with 15 samples of each. Group I: were instrumented using the traditional "step-back" technique by Ni-Ti K-files. Group II were instrumented using the "crown-down" technique by ProTaper rotary instruments. Before and after root canal preparation, the μCT data were analyzed for the canal volume changes, the percentage differences between these volumes and unprepared surface area ratio of the total surfaces. At all root canals in both groups, the difference between the percentage of the root canal volume before-after preparation was significant ($P < 0.05$). There was no significant difference between the groups in terms of root canal volume changes and unprepared surface area ratios ($P > 0.05$). There was no difference between the systems in terms of shaping ability. Considering the shortening session time of the child patient ProTaper system appeared to be beneficial.

Key words: Micro Computed Tomography, ProTaper, Root Canal, Shaping Ability, Young Permanent Teeth

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INTRODUCTION

The primary objective of the root canal therapies is to fill the root canals in three-dimension (3D), through the apex of the root by mechanically extending and eliminating the microorganism from the canals following the removal of the crown and pulp. The cleaning and shaping of the root canals is a mechanical and biological process, which is the most important phase of the endodontic therapy. For this purpose, the root canal should be cleared of all disinfected residues, and the canal should be conic-shaped in order to hermetically and three-dimensionally fill the canal by Gutta-percha and cement.[1,2]

In this context, several endodontic tools and preparation systems have been developed in the last 2 decades. Nickel-titanium (Ni-Ti), due to its highly small elasticity module and ability to be easily shaped, is a superior alloy with fracture resistance.[3] The development of Ni-Ti preparation systems, which is currently driven by low-speed micro engine-like devices with high torque or by electrical engines with same properties, have positively affected the success of endodontic therapy.[4]

Extended canals in young permanent teeth with a newly closed root apex lead to insufficient lifting of the affected canal walls. In such canals, it is highly important to provide sufficient canal extension using files of a large size. In addition, these types of patients have also problems, such as adaptation and insufficient mouth opening.[5] At the present time, it is possible to find many studies investigating the canal-shaping properties of rotary Ni-Ti root canal preparation systems.[6-10] However, there are no studies identified that investigate the efficacy of these systems on young permanent teeth.

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The studies that evaluate the root canal preparation have used different experimental methods in order to assess various factors before and after the shaping procedure.[6-10] Micro computed tomography (μCT) is one of these methods and provides significant superiority compared to other traditional methods by the capacity of sectioning without any structural changes to the teeth and allowing 3D analysis.[11-13] There have been no studies identified that investigate the efficacy of rotary Ni-Ti systems and use μCT method allowing 3D analysis in young permanent teeth.

The present study aimed to evaluate the ProTaper rotary Ni-Ti file system (Dentsply Maillefer, Ballaiques, Switzerland) with different design characteristics and root canal shaping properties provided by the Ni-Ti hand-file using μCT for canal space volume and surface area in young permanent teeth.

MATERIALS AND METHODS

This study used 30 extracted second molar teeth from individuals, 15-18 years of age, which had an extraction indication for orthodontic reasons, closed apex and no root anomalies and resorption. The cleaned teeth were kept in normal saline at +4°C until the laboratory procedures were completed. The teeth were placed at the exact center of the prepared cylindrical standard casts, of 2 cm and transparent acrylic resin (Orthoplast, Vertex, Zeist, The Netherlands) was poured into the casts to prepare the specimens. Using a round diamond bur under cooling, the endodontic access cavities of the teeth were opened, and pulps were removed with "trinerf." Prior to the procedures, the files were examine to determine if they achieved the working length from the digital radiographic images mesiodistally and buccolingually by placing ISO size 10 K-type file (Henry Schein Dental, ABD) into the canals of all teeth. The teeth with compression felt by ISO size 15 K-type file at the working length were considered to be apex-closed. In order to determine the references for working length, the teeth crowns were removed from 2 mm coronal to the enamel-dentin joint via a separator.

The acrylic resin-embedded teeth were screened with a μCT device (SkyScan 1174 compact μCT, Kontich, Belgium) and recorded before the shaping.

The specimens were randomly divided into two trial groups (n = 15) with 15 teeth in each group.

Group 1

The root canals were shaped using the traditional "step-back" technique via size 15-60 K-type Ni-Ti hand-files (Nitiflex®, Maillefer, Dentsply, Ballaigues, Switzerland). During the preparation, root canal irrigation was performed using 2 ml of 2.25% NaOCl solution between each file change.

Group 2

The root canals were shaped using the "crown-down" technique by irrigating with Glyde lubricating gel (Dentsply International Inc., York, PA, USA) and 2 ml of 2.25% NaOCl solution in accordance with the recommendation of the manufacturer via a ProTaper rotary file system (Maillefer, Dentsply, Ballaigues, Switzerland). Using an auxiliary SX file, the coronal 2/3 of the canal was extended. ProTaper S1 and S2 files were used at the working length. Following the check for the canal opening in the apical zone, the root canal was extended to at least the length of the size 15 K-type file. A ProTaper F1 file was used a few times so that it would reach the canal working length and the apex foramen diameter was checked by placing a size 20 K-type file into the canal. The files F2, F3, F4, and F5 were used, respectively, by checking the apical foramen diameter.

The specimens were placed in the μCT device, and an 850-900 section was obtained at a size of 21 μ from each one via a 1.3 megapixel camera.

To create 3D models from the images, pre- and post-model reconstruction, conducting necessary measurements as a result of reconstruction, a computer equipped with Intel Pentium® D CPU 3.00 GHz processor, 250 GB hard disk, 3.00 GB RAM and with an operating system of Windows XP Professional Version 2002 Service Pack, and a 3D modeling software of Rhinoceros 4.0 (3670 Woodland Park Ave N, Seattle, WA 98103, USA) were used. The obtained sections were converted into 3D models via 3D - Doctor software and pre- and post-preparation images were superimposed [Figure 1a-c].

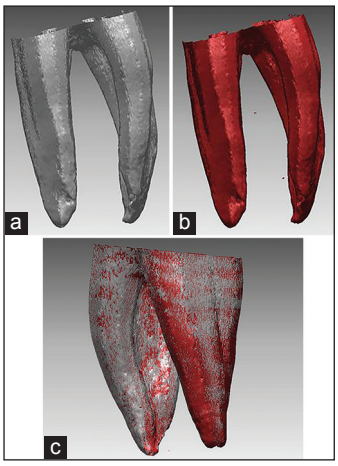

Figure 1: (a) Preoperative surfaces, (b) Postoperative surfaces, (c) Superimposed pre- and-postpreparation root canal models

Using the superimposed pre- and post-preparation root canal models, the free canal models within the tooth model were dissociated from the outer surface of the tooth, and the percent changes between the volumes of the canal models [Figure 2] and the ratio of the unprepared surfaces to the total surface were calculated [Figure 3].

The data were analyzed using SPSS for Windows v.11.5 software package (SPSS Inc., Chicago, USA). The importance of the difference among the groups was analyzed using the Student's *t*-test in terms of mean values and using the Mann–Whitney U-test in terms of median values. The importance of the difference within the groups was assessed using the dependent *t*-test in terms of mean values and using the Wilcoxon signed-rank test in terms of median values. The results were considered statistically significant for $P < 0.05$.

RESULTS

The root canal volumetric changes

At the end of the study, the pre- and post-preparation canal volume difference and the volumetric increase rates were statistically significant in all canals in both groups [Table 1] ($P < 0.001$). The postpreparation volumetric changes to the root canal were analyzed in terms of amount and percentage [Table 2].

When an evaluation was made between the Ni-Ti hand-file group (Group 1) and the ProTaper rotary Ni-Ti file system (Group 2) group and within the groups (narrow and wide canals), no statistically significant difference was found in the canal volume difference and the volumetric increase rates ($P > 0.05$). Although it was not statistically significant, the highest increase was observed in the wide canals of the Ni-Ti hand-file group, and the lowest increase rate was observed in the wide canals of the ProTaper group.

Amount of unprepared surface area in the root canal

The evaluations between the Ni-Ti hand-file group (Group 1) and ProTaper rotary Ni-Ti file system (Group 2) group and within the groups (narrow and wide canals) revealed no statistically significant difference in unprepared surface area ($P > 0.05$) [Table 3]. Although it was not statistically significant, it was found that the

Table 1: Pre- and post-operative volume changes according to the groups and root canal types

Groups	Preoperative (mm^3)	Postoperative (mm^3)	P^a
ProTaper group			
Wide canal	13.0±5.47	18.9±4.83	<0.001
Narrow canal	13.2±6.82	19.4±6.03	<0.001
Whole tooth	13.1±5.51	19.2±4.85	<0.001
Ni-Ti hand-file group			
Wide canal	10.4±2.87	17.4±4.29	<0.001
Narrow canal	11.3±6.02	17.4±5.27	<0.001
Whole tooth	10.8±4.00	17.4±3.31	<0.001

[a]Dependent *t*-tes, Ni-Ti: Nickel titanium

Table 2: Changes in root canal volume according to the groups and root canal types

Amount of change in volume (mm^3)	ProTaper group	Ni-Ti hand-file group	P^a
Wide canal	5.8±2.77	7.0±3.30	0.290
Narrow canal	6.2±4.42	6.1±2.59	0.977
P^b	0.648	0.323	–
Whole tooth	6.0±3.42	6.6±2.43	0.595
Percentage change in volume (%)			
Wide canal	56.2±34.41	72.8±39.24	0.229
Narrow canal	71.9±69.43	78.2±60.97	0.794
P^b	0.232	0.706	–
Whole tooth	33.1±17.85	39.0±14.37	0.326

[a]Student's *t*-test, [b]Dependent *t*-test, Ni-Ti: Nickel titanium

Figure 2: The image of the canals separated from the outer surface of the tooth

Figure 3: Uninstrumented areas

Table 3: Unprepared surface area ratios according to the groups and canal types

Canal type	ProTaper group	Ni-Ti hand-file group	*P*[a]
Wide canal	54.3 (15.4-77.8)	40.7 (18.9-76.2)	0.233
Narrow canal	51.6 (9.7-78.5)	56.3 (21.0-74.0)	0.653
P[b]	0.609	0.041	–
Whole tooth	50.2 (12.7-73.0)	47.0 (27.6-71.1)	0.935

[a]Mann-Whitney U-test, [b]Wilcoxon signed-rank test, Ni-Ti: Nickel-titanium

amount of unprepared surface area in the wide canals of Ni-Ti hand-file group was considerably lower ($P > 0.05$).

DISCUSSION

Since it is known that live microorganisms may penetrate into the dentin canals and survive during the endodontic therapy, the clinical importance of the shaped surface concept gains a different meaning for endodontic therapy. The guideline published by the European Society of Endodontics states that the preparation should cover the entire wall of the canal for a canal to be considered as completely cleaned and shaped.[14] Many researchers have demonstrated that the dentin at the root canal wall might be infected with microorganisms and their endotoxins, extending to a depth of 1-2 mm.[2,14,15] Dentin is thinner in young permanent teeth, and the dentin tubules are wider. A wide dentin tubule is an important factor increasing the bacterial penetration of the dentin. The wide canals in the young permanent teeth with newly-closed root apices may lead to insufficient levels of lifting of the affected canal walls.[5] There are many studies evaluating endodontic therapy in mature permanent teeth in the dentistry literature;[6-15] however, there are no studies investigating endodontic therapy in young permanent teeth with completed apical development. The development of the second molar teeth emerges at the age of 11.7-12.7 years and is generally completed around the age of 15-16.5.[16] This study used young second molar teeth from individuals aged 15-18 years, with completed apical development.

Modern root canal tools are made from stainless steel and Ni-Ti. Ni-Ti files manufactured for manual root canal preparation have similar characteristics to the stainless steel files, and also have been demonstrated to exhibit a less persistent deformation and better metal memory due to the elasticity of the Ni-Ti alloy.[3] The present study preferred the use of Ni-Ti hand-files with the traditional "step-back" technique in the study group, where the root canal was shaped by traditional hand filing in young permanent teeth.

In recent years, several tools, devices, and preparation techniques have been developed for making the root canal preparation easier and shorter-timed. In particular, the use of the Ni-Ti alloy in the rotary tools is recognized as an important revolution in endodontic therapy because of the decreased time required for the completion of the preparation, minimizing the tiredness of the physician, and reducing the functional errors.[17,18] Today, many Ni-Ti rotary systems with different characteristics from various manufacturers are available in the market. These systems mainly differ in the design of the cutting surfaces and the conicity of files.[18] ProTaper rotary Ni-Ti-based tools, which are one of the third-generation rotary Ni-Ti systems differing in design, have been reported to be effective in shaping the root canals by many investigators.[7,17,19] The most distinctive characteristic of the ProTaper system from the other systems in the market is that the file has an angulation varying from 3.5% to 19% rather than standard angulations. It is stated that the amount of the canal surface achieved during the shaping is increased due to this distinction.[20]

Ozgur Uyanık *et al*.[21] compared the canal extension efficacies of Hero Shaper, RaCe, and ProTaper with CT and reported that the ProTaper system lifted more dentin. Another study comparing the ProFile and ProTaper files reported that more unprepared area remained in the roots extended by ProFile compared to the roots extended by ProTaper.[22] The study by Guelzow *et al*.[23] compared six different rotary Ni-Ti systems and hand-files for root canal shaping and reported that the ProTaper system provided shaping that was more regular and in line with the canal diameters. The study by Moore *et al*.[24] compared three different preparation techniques using μCT and reported that the stainless steel files created more transportation in the apical zone, and ProTaper and FlexMaster systems might lead to less iatrogenic errors. Foschi *et al*.[6] and Paqué *et al*.[17] reported that the ProTaper system provided safe preparation, however, it was insufficient in removing the smear layer and debris. The study of Williamson *et al*.[7] compared three different Ni-Ti systems (ProTaper, ProFile GT, and EndoSequence) with scanning electron microscopic and reported that the three systems showed similar effects in removing the debris in the root canal.

However, there are no studies identifying the efficacy of these systems on young permanent teeth. The present study evaluated the efficacy of the ProTaper system, one of the third-generation rotary Ni-Ti systems, for root canal shaping in young permanent teeth. Depending on the stress limits and enhanced conicity structure in the Ni-Ti hand-files, the main principle of all rotary Ni-Ti file systems is the "crown-down" preparation.[18] In the present study, the root canals of the teeth from the ProTaper rotary file system (Group 2) were shaped using the "crown-down" technique.

In recent years, CT and μCT have begun to stand out in the evaluation of the efficacy and characteristics of the preparation techniques. With the CT technique, cross section images from various levels can be analyzed before performing the cutting procedure. However, in the root section studies, the sharp edges of the canals may become even on CT images; the contrast difference between the root canal space and root canal walls may be insufficient, and this interferes with the detailed measurements. However, μCT is considered as the most successful method used to evaluate the root canal preparation, due to its high resolution. Another advantage of using the μCT device is the ability to collect volumetric data from the teeth.[12,13,25] There have been no studies identified that investigate the efficacy of rotary Ni-Ti systems and use the μCT method allowing 3D analysis in young permanent teeth. The study conducted in this context evaluated the root canal shaping properties using μCT.

Peters *et al*.[26] used μCT in their studies and evaluated the volume change and unprepared surface area in an upper molar tooth undergoing root canal shaping with the ProTaper system. They reported that there was a statistically significant difference in volume and surface area for all roots, and the increased volume was found to be lower in the wide root canals in a manner that was statistically significant. Although the present *in vitro* study achieved similar results, the increased volume was found to be lower with the ProTaper system for the preparation of wide root canals, in a manner that could not be statistically significant. This result is believed to be due to the different manipulation characteristics of the systems that were used in the study. No statistically significant difference was found between the narrow and wide canals in the ProTaper system for surface area.

Paqué *et al*.[27] compared the preparations made with FlexMaster, GT, Lightspeed, ProFile, ProTaper, and Ni-Ti K-type hand-files using μCT in their study, and reported that the highest volumetric increase in the root canal was observed in the groups where the preparations were made with ProTaper and Ni-Ti K-type hand-files. The highest increased volume was found to be in the palatal canal in the ProTaper group. Similarly, the present study found no statistically significant difference in volumetric increase after the preparation made with ProTaper and Ni-Ti K-type hand-files. Different from the results of the study conducted by Paqué *et al*.,[17] an increased volume was observed in the wide canals in the Ni-Ti hand-file group compared to the ProTaper group, but this difference was not statistically significant. The cause of this difference is believed to be associated with the fact that the study was conducted in young permanent teeth with wider canals.

The *in vitro* study by Paqué *et al*.[11] evaluated the preparation efficacy of the ProTaper system versus stainless steel hand-files in the oval distal canals of the lower molar teeth, using the μCT technique. They reported that the unprepared areas varying from 59.6% to 79.9% in the study occurred regardless of the file and technique used, and created no statistically significant difference between the groups. The increased volume observed in the root canal was also reported to be found similar in all groups ($P < 0.001$). Parallel to the study by Paqué *et al*.,[11] the present study found no statistically significant difference between the groups for volume and surface area ($P > 0.05$). However, in this study, the rates of unprepared canal surface areas varied from 40.6% to 46.2%. This difference in the surface areas is thought to be explained by the fact that the last file used was size 40 in the hand-file group and F4 in the ProTaper group in the study by Paqué *et al*.,[11] whereas the file was size 60 and F5, respectively, in the present study.

Yin *et al*.[28] conducted a study on 24 lower molar teeth with C-shaped canals and evaluated the preparation efficacy of the ProTaper system and stainless steel hand-files using the μCT technique. They reported that more dentin was removed, and less unprepared surface area was formed in the preparations made with hand-files; the preparation was completed in a shorter time, and less apical transportation and perforation were observed with the ProTaper system. Similarly, the present study found that more dentin was removed in wide canals, and less unprepared surface area was formed in the preparations made by hand-files. However, the evaluations made between the hand-files and ProTaper and also between the narrow and wide canals revealed no statistically significant difference in volume and surface area.

CONCLUSION

The volumetric changes to the root canal and the amount of unprepared surface area were evaluated in young permanent teeth, and the conclusions achieved were parallel for all parameters between two systems. Given the superiority of rotary Ni-Ti systems over the hand tools in terms of working time, the ProTaper system is believed to provide an important advantage in pediatric groups.

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