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In Vitro Comparison of Volumetric Analysis of Root Canal Obturation After Instrumentation with Three Rotary File Systems: Cone Beam Computed Tomography Evaluation

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Abstract

Aim: To comparatively evaluate the volumetric analysis of root canal obturation after instrumentation with three rotary file systems namely, Pro Taper Gold, Pro Taper Next, Reciproc Blue using CBCT analysis.

Objectives: To compare the rotary file system that enables complete obturation of the root canal space with more volume of the root canal filling material using CBCT.

Materials and methods: Thirty freshly extracted mandibular premolars with single canal and fully formed apices that had been extracted for orthodontic reasons were used in this study. The teeth were decoronated and randomly divided into 3 groups of ten teeth each. Pre-obturation CBCT images were obtained. Biomechanical

preparation was performed up to working length with three rotary files, namely Pro Taper Gold, Pro Taper Next, Reciproc Blue. Obturation of the canals were done using Master cone #25/6% and completed using lateral compaction technique with 2% gutta percha coated with AH plus sealer. Post-obturation CBCT images were obtained. Statistical analysis was performed via one-way ANOVA (Post hoc) followed by Scheffes test.

Results: Root canals prepared with Protaper Gold rotary file system shows greater volume in root canal obturation followed by Protaper Next and the least by Reciproc Blue. Data analysis revealed significant differences between the groups in the apical and middle thirds ($P<0.05$).

Conclusion: Within the limitations of this *in vitro* study it can be concluded that Protaper Gold rotary file system showed greater increase in root canal obturation volume followed by Protaper Next while Reciproc Blue rotary file system did not signifcantly increase root canal obturation volume during preparation.

Keywords: Cone beam computed tomography, Protaper Gold, Protaper Next, Reciproc Blue, Volumetric analysis before obturation, Volumetric analysis after obturation.

Introduction

The ideal goal of endodontic treatment is to maintain the natural root canal morphology while preserving dimensions of apical foramen.[1] The canal volume may change as a result of operational procedure faults like over or under-instrumentation which can cause changes in the canal volume.[2- 4] However it is critical to avoid too much dentin removal as this could jeopardize the treatment's efficacy. The final root canal preparation should maintain the shape and direction that mirrors the initial canal anatomy. This is necessary for carrying out a proper irrigation and eliminating all the debris, bacteria. The basic anatomy of the canal must be preserved through biomechanical preparation in both shape and orientation.[5-7]

Biomechanical preparation of the root canal is an essential first step in endodontic treatment .After biomechanical preparation the root canal system should be completely sterile and hermetically sealed to stop reinfection. The physical removal of contaminated dentin and the facilitation of the delivery of irrigants that disinfect the canal's apical regions are two important functions of biomechanical instrumentation. [8]

Pro Taper Gold rotary files was introduced as a multiple file sequence that is manufactured with advanced metallurgical process and convex triangular cross section that enhances cutting action while decreasing rotational friction between the file blade and dentin. Pro Taper Gold exhibits high austenite finish temperatures and two-stage specific transformation behavior. Protaper Gold rotary file system have three shaping (Sx, S1, and S2) and five finishing (F1, F2, F3, F4, and F5) files.[9,10] Protaper Gold rotary files(Sx, S1, S2, F1, F2) was used to prepare the canals till working length in this study.

Pro Taper Next files is a M-Wire NiTi alloy with variable taper design and off-centered axis with a rectangular cross-section. It exhibits increased cyclic fatigue resistance compared to those constructed of traditional super elastic NiTi alloys.[11,12] Every file presents a single file concept with an increasing and decreasing percentage tapered design. Pro Taper Next X1 and X2 were used to prepare the canals up to working length in this study

Reciproc Blue is a single file system with reciprocating motion and High efficiency cutting performance are provided by the unique s-shaped cross section, the variable taper, the cutting angles, and the thermally

enhanced raw material. Additionally, the Reciproc Blue file can be pre-bent to access curved canals, thanks to a unique temperature protocol of the file system and titanium oxide layer.[13] Reciproc blue rotary file R25 was used to prepare the canals till working length in this study.

The use of radiographic evaluation is crucial for diagnosis and treatment planning in the field of endodontics. Three-dimensional objects are represented in two dimensions by conventional radiographic technology whereas cone-beam computed tomography is one of the modern digital imaging modalities that was introduced in dentistry to address the limitations of conventional radiographs.[14,15]

The purpose of this study was to determine the rotary file system that enables complete preparation of the root canal space with more volume of the root canal filling material using CBCT. The null hypothesis was that the use of all the three different rotary file systems would result in the same amount of root canal obturation volume.

Materials and methods

Procedure

This study was done after receiving ethical clearance from the Institutional Ethical committee .Thirty freshly extracted mandibular premolars with single canal and fully formed apices that had been extracted for orthodontic reasons were used in this study. The teeth were stored in saline at 4°C until use. All teeth were scanned by cone-beam computed tomography machine (Planmeca Promax 3D Max, Helsinki, Finland) to determine the root canal morphology.

The teeth was decoronated with diamond disc(SS white, New Jersey, USA) to obtain a standardised root length of 16mm and then the roots were embedded in putty index which was simulated in mandibular arch form. The teeth were randomly divided into three groups of ten teeth each according to the rotary file system used. The teeth were scanned using cone-beam computed tomography and pre obturation volume of the apical, middle and coronal third of the root was evaluated. Biomechanical preparation were completed and root canal irrigation was done with 3ml of 5.25% sodium hypochlorite solution (NaOCl)(Septodont, Lancaster, England) followed by normal saline . An ISO10 K-file, 25mm length (Dentsply Maillefer, Ballaigues, Switzerland) was placed into the canal until visible at the apical foramen and the working length was established 1 mm short of this length.

Group I (n = 10) - Canals instrumented with Protaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) according to manufacturer's recommendations.

Group II (n = 10) - Canals instrumented with Protaper Next (Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturers' recommendations

Group III (n = 10) - Canals instrumented with Reciproc Blue (VDW GmbH, Munich, Germany) according to the manufacturers' recommendations.

All canals were instrumented using endomotor X Smart plus (Dentsply Sinora, Ballaigues, Switzerland) upto the desired working length. Each canal was irrigated with 3 ml of 5.25% sodium hypochlorite solution in all the groups. Glyde (Dentsply Maillefer, Ballaigues, Switzerland) was used as a lubricant during instrumentation. After root canal instrumentation was completed, 1 ml of 17% ethylene diamine tetra-acetic acid (Coltene, Langenau, Germany) was used in the canal for 1 min followed by a final flush with NaOCl. Following this the canals were dried with absorbent paper points (Dentsply, DeTrey, Konstanz, Germany).

Master cone was placed corresponding to the file system used which was coated with AH-Plus sealer

(Dentsply, De Trey, Konstanz, Germany) and the obturation was completed using additional 2% gutta-percha (Dentsply, DeTrey, Konstanz, Germany) using lateral condensation technique.

The excess gutta-percha in the coronal portion was removed with a heated plugger, and the root canal openings of all specimens were sealed with temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). Radiographs were taken from the buccolingual and mesiodistal directions to asses the quality of the obturation.

The samples were stored at 37°C and 100% relative humidity for the complete setting of the sealer.

Cone-beam computed tomography procedures and evaluation

The pre obturation and post obturation CBCT images were taken and volume of the apical, middle and coronal third of the root was evaluated using Planmeca promax 3D software (90KHZ, 8mA, 0.04sec) in axial, coronal, and sagittal planes. CBCT cross-sections were 90 μm thick, and interslice distance was 1 mm for axial and coronal planes and 90 μm for sagittal plane. In this way, the entire root was viewed in the apical one-third, middle one-third and coronal one third.

The percentage of obturated volume was calculated using the formula:

Post obturation volume(Y)/Pre obturation volume(X) × 100

Statistical analysis

Data was entered in Microsoft Excel 2010. The data was expressed with Mean and Standard Deviation. The values obtained were statistically analyzed using computer software statistical package for social sciences (SPSS) version 20.0 (SPSS Inc., Chicago, USA). One-way ANOVA (Post hoc) followed by Scheffes test was applied to find the statistical significance between the groups. P value less than 0.05 ($P<0.05$) was considered to be statistically significant at 95% confidence interval.

Results

The root canals prepared with Protaper Gold showed greater root canal obturation volume in coronal third, middle third, apical third than Protaper Next and Reciproc Blue rotary files. Protaper Next showed greater root canal obturation volume in coronal third and middle third of root canal when compared to Recoproc Blue rotary files. Recioproc Blue showed greater root canal obturation volume in apical third of root canal when compared to Protaper Next rotary file systems (Table 1).

Discussion

According to this study it was found that canal instrumented with Protaper Gold resulted in greater percentage of obturation volume in coronal, middle, apical third of root canal region followed by Protaper Next and Reciproc Blue rotary file systems. Protaper Next resulted in greater percentage of obturation volume in middle third of root canal region compared to Reciproc Blue rotary file system. Reciproc Blue resulted in greater percentage of obturation volume in apical third of root canal region compared to Protaper Next rotary file system. Thus the null hypothesis that the use of all the three different rotary file systems would result in the same amount of root canal obturation volume was rejected.

Effective endodontic treatment can only be accomplished with a well-executed biomechanical preparation and complete canal space disinfection are favourable conditions for periradicular healing which are the main objectives that an endodontist must accomplish with root canal therapy.[16]The field of endodontics has significantly changed in recent decades including advancements in instrument design, materials,

equipment, and obturation techniques. However, endodontic therapy's primary goal has remained unchanged. The main strategy for eliminating the debris and microbes causing endodontic pathosis is to clean and shape the root canal system to eradicate infection in canal preparation. Thus it is important to preserve the original root canal anatomy from coronal to apical by maintaining adequate dentin thickness. [17,18]

The preparation of the apical root canal is essential for infection control.[19] Despite their great flexibility, nickel-titanium instruments leave a portion of untouched space .[20]Therefore, following preparation, bacteria and necrotic tissue might still be present in these areas. [21] More infected dentin is removed by apical enlargement, which also encourages a lower proportion of uninstrumented surfaces in the root canal. Increased apical enlargement during preparation enhances the benefits of irrigation and cleaning of the apical root canal. [20]

In the present study the crown down instrumentation sequence was followed. This instrumentation technique minimizes the risk of instrument separation and reduce intracanal friction. [22] One of the variables in this study that was most difficult to control was the degree of anatomical variances that are frequently present in human teeth and influenced by variations in the root canal morphology. In an attempt to minimize these factors mandibular premolar teeth with straight single canals were selected. The teeth were decoronated to obtain a standardised root length of 16mm.[23]Gutta-percha is the most commonly used and accepted obturation material because of its biocompatibility, inertness, dimensional stability, compactability, plasticity when heated, and ease of removal. 25/6% gutta-percha is used as master cone and cold lateral compaction method using 2% gutta-percha coated with AH Plus sealer was used to obturate the canal.[24] The epoxy-based endodontic sealer AH-Plus has superior flow values. More flow enhances the capacity to enter irregularities and accessory canals. [25]

A root canal filling material's ability to seal is crucial for avoiding microbial leakage and reinfection of the root canal system. This has demonstrated the significance of removing the smear layer in order to increase the filled canals' resistance to bacterial leakage from either the coronal or in apical direction. When instrumenting root canals, a useful technique for eliminating the smear layer from the canal walls and dentinal tubules is to combine 5.25% NaOCl and EDTA .[26,27]

The Pro Taper Gold has a convex triangular cross-section and a progressive taper. It also has a non-cutting tip design, allowing the instrument to follow the original shape of the root canal.[28]In this study the canals were prepared in the sequence from Sx 19/04, S1 18/02, S2 20/04, F1 20/07, F2 25/08 up to working length according to the manufacturer's instructions. In this study the use of Protaper Gold resulted in more amount of obturation volume. This may be because of the excessive amount of dentin removal by the aggressive cutting and variable tip diameters. [28,29] According to a study by Khdairah HR et al. it was found that Protaper Gold files work on the coronal and middle thirds of the canal, increasing the canal taper in these areas to allow the force to be more evenly distributed in the apical third of the canal. This gradually produces a funnel-shaped canal related to file tapers which leads to increase in root canal volume as compared with Protaper Next. [30] This was in accordance with this study. In a study by Singh et al. it was found that Protaper gold produced significantly more dentin

removal and greater root canal volume than Wave one Gold in mandibular molars with root curvatures.[31]

The Pro Taper Next file system is based on innovative metallurgy in which manufacturers introduce M-Wire alloy to improve the fatigue life and flexibility of the files.[32]In this study the canals were prepared in the sequence from X1 17/04, X2 25/06 with torque ranging from 2 to 5.2 N-cm up to working length according to the manufacturer's instructions. In this study Protaper Next showed greater root canal obturation volume in coronal third, middle third, when compared to Reciproc Blue rotary files. According to a study by Shivashankar MB et al. it was stated that Protaper Gold and Protaper Next removed a greater volume of dentin than Mtwo because of Variable taper and glide path created .[33] In a study by Celik G et al., when it comes to preserving the original canal shape , volume, minimizing ledges, and superior fracture resitance the Protaper Next may be better in in severely curved root canals when compared to Protaper universal due to its M-Wire alloy, include variable tapers and rectangular cross- sections with a remote center.[34] In a study done by van der Vyver PJ et al. Protaper Next shows increased canal volume when compared with Wave one Gold and One Shape due to its multiple sequence and its off-centered rectangular cross section.[35]

The Reciproc blue rotary files have an S-shaped cross-section that employs an identical reciprocating motion and kinematics. The instrument produces aggressive cutting due to its more positive cutting angle and blue sharp cutting edges. Because of this it removes a significant amount of dentin in a comparatively short amount of time. However, because it is used as a solitary instrument, debris and smear layer evacuation is minimal.[36] When compared to Protaper Next, Reciproc blue consists of a newly developed alloy that is obtained through a proprietary-specific oxide surface layer.[36,37]

In this study Reciproc blue showed lesser root canal obturation volume in coronal and middle third of the root canal when compared with Protaper Gold and Protaper Next but greater apical third root canal obturation volume when compared to Protaper Next. This may due to the S shaped cross-section of Reciproc blue which provides an effective cutting ability to the instrument blades and tip diameter.[37] In a study by Sroa DR et al. it was found that the Reciproc blue system performs marginally better than Pro Taper Gold root canal volume in the apical third of the canal due to its tip diameter and cross-section.[38] This was in accordance with this study. According to a study by Peters OA et al., Reciproc blue demonstrated average increase in root canal volume than Wave one Gold and XP endo shaper. This may be explained by the material's good cutting ability, its "S" cross-section, an 8% taper at the apical third, and the reciprocating movement that produces an effective dentine cutting surface.[39] In a study by Gundogar M et al. Reciproc blue single file system outperformed Wave One Gold and One Shape instruments in terms of cyclic fatigue resistance and root canal volume preparation.[40] According to a study by Liu Y et al., in the apical thirds, Reciproc blue and XP-endo Shaper were linked to a lower smear layer and root canal volume than Wave One Gold.[41]

In endodontics, radiographic examination is crucial for both diagnosis and treatment planning. Three-dimensional objects can be represented in two dimensions using conventional radiography technologies. Cone-beam computed tomography is one of the advanced digital imaging modalities that was

introduced into dentistry to address the drawbacks of traditional radiographs. [14,42]

In the present study, CBCT was used which provide practical and non-destructive technique for assessment of canal volume of obturation before and after shaping .It is possible to examine the root canal in three dimensions, both before and after obturation. Cone beam computed tomography scanning is a simple, efficient, and sensitive method for analyzing root canal obturation volume. It offers a three-dimensional assessment of the root canal system. Patients are exposed to significantly less radiation with CBCT than with traditional computed tomography. It is a non-invasive method that doesn't require the tooth samples to be destroyed. CBCT is less radiation-intensive than medical computed tomography.[15,43]

A limitation of this study is that parameters were limited to the mandibular first premolar with straight roots and a single oval canal. The impact of the curvature of the root canal which also affects volume of root canal and dentin thickness is not examined in this study. Moreover the rotary files tend to give round shape to oval canal and hence some parts of canal may remain untouched. The objective of this study was to assess the preparation of root canal with more obturation volume with the use of three different rotary file systems and more studies are recommended using multiple rotary file systems. Another drawback of this study was the use of Cone-beam computed tomography system evaluation. Micro-computed tomography would be a more precise and accurate method for a thorough analysis of the root canal system. Moreover an in vitro study does not precisely replicate in vivo settings.

Conclusion

Within the limitations of this in vitro study, it may be stated that:

1. Use of Protaper Gold rotary files showed greater root canal obturation volume in coronal third, middle third, apical third when compared to Protaper Next and Reciproc Blue rotary files
2. Use of Protaper Next showed greater root canal obturation volume in coronal third, middle third, when compared to Reciproc Blue rotary files.
3. Use of Reciproc Blue rotary files showed greater root canal obturation volume in, apical third when compared to Protaper Next.
4. Use of Protaper Gold resulted in more root canal obturation volume followed by Protaper Next and Reciproc blue rotary files.

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Legend Tables

Table 1: Multiple comparison of mean coronal third, middle third, apical third volume of obturation values between the groups

Observation	Group-I (MEAN±SD)	Group-II (MEAN±SD)	Group-III (MEAN±SD)
Volume of coronal third before obturation	0.0052±0.0007	0.0049±0.0001	0.0046±0.0004
Volume of coronal third after obturation	0.0049±0.0001	0.0046±0.0005	0.0043±0.0004
Volume of middle third before obturation	0.0043±0.007	0.0040±0.0002	0.0038±0.0004
Volume of middle third after obturation	0.0040±0.0001	0.0038±0.0006	0.0036±0.0007
Volume of apical third before obturation	0.0015±0.0006	0.0012±0.0001	0.0014±0.0005
Volume of apical third after obturation	0.0013±0.0007	0.0010±0.0004	0.0012±0.0007

(P<0.05 significant compared group-I with other groups)
(P<0.05 significant compared group-II with other groups)