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INFLUENCE OF HEAT-TREATED SINGLE FILE ROTARY SYSTEMS ON REMAINING DENTIN THICKNESS IN THE DANGER ZONE OF THE MANDIBULAR FIRST MOLAR. AN IN-VITRO CBCT STUDY

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ABSTRACT

Purpose: This in-vitro study was to investigate the influence of heat-treated single file rotary systems (TruNatomy, Reciproc blue, and Hyflex EDM) on remaining dentin thickness in the danger zone of mandibular first molars utilizing cone beam computed tomography (CBCT).

Materials and methods: Thirty human mandibular first molars were chosen. After determining the working length and preparing the access cavity, pre-instrumentation CBCT scans were taken and recorded 4mm apical to the furcation area in the distal aspect of the mesiobuccal root canal. Instrumentation was done according to the recommended instructions of the used file. Teeth were randomly divided into three groups (n=10) based on the respective single file system, group 1: TruNatomy, group 2: Reciproc blue, and group 3: Hyflex EDM. Post-instrumentation CBCT scans were captured and recorded under the same protocol as the pre-instrumentation scans. Finally, comparisons were performed between the post and pre-instrumentation CBCT scans to calculate the remaining dentin thickness.

Data of residual dentin thickness were statistically analyzed using one-way ANOVA, followed by Tukey post hoc test at a significance level of $P \leq 0.05$.

Results: TruNatomy removed the minimum amount of dentin in the danger zone of mandibular first molar while Reciproc blue removed the maximum amount, while no significant difference was recorded among groups ($P > 0.05$).

Conclusions: The tested heat-treated single file system had no noticeable effect on residual dentin thickness at the danger zone of the mandibular first molar.

KEYWORDS: Cone beam computed tomography, danger zone, Hyflex EDM, Reciproc blue, TruNatomy.

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INTRODUCTION

Root canal chemomechanical preparation is crucial for the success of endodontic treatment. Maintaining the original canal anatomy and dentine thickness enhances treatment outcomes [1].

Significant distal concavity and thin dentine characterize the mesial root of mandibular first molars[2]. The "danger zone" is always found between 4 and 6 mm under the canal orifice [3]. Over-preparation of the internal thin dentin wall in this area can lead to mechanical strip perforations, making it important to take care when preparing this region.

The thickness of the remaining dentin (RDT) plays a crucial role in preventing tooth fractures. Having enough RDT not only strengthens the tooth structure but also helps to maintain the restoration. Therefore, it is important to study the impact of dentin removal during mechanical instrumentation.

The single file shaping technique simplifies root canal preparation procedure and reduces the risk of cross contamination by using only one instrument instead of multiple instruments in a sequence [4]. This method requires minimal or no glide path and can be used for complete root canal instrumentation. It is recommended for single use, which reduces instrument fatigue and working time [5]. Furthermore, the use of thermomechanically treated nickel-titanium (Ni-Ti) alloys has improved this technique's clinical performance.

TruNatomy (TN) is a single rotary file system made from specially treated metallurgical process, which makes it superelastic and has less memory. The 0.8mm Ni-Ti wire used to make TN has a narrow profile, regressive tapers, and an off-center parallelogram square cross-sectional design in minimally invasive instrumentation. TN shaping instruments come in three sizes: small (20/.04), prime (26/.04), and medium (36/.03) [6, 7].

Reciproc Blue is an enhanced version of the original Reciproc file. The innovative thermal treatment procedure it undergoes gives it a blue color, this makes it more adaptable and resistant to fatigue from repeated use and minimizes surface microhardness compared to conventional M-wire. This file operates with a reciprocating motion, alternating between 150° counterclockwise and 30° clockwise movements. The files come in different sizes: R25 (25, 8%), R40 (40, 6%), and R50 (50, 5%). They regressively taper from around 3 mm from the tip with a cross-section of S-shaped.

The Hyflex EDM is electric discharge machining (EDM) in a single-file format to produce a file with extreme flexibility and increased fracture resistance. It is made from a controlled memory alloy and undergoes a special heat treatment process that enhances its mechanical properties [9]. The Hyflex EDM file has a kinematic movement based on a full rotation concept, with an alternating taper and a diameter of 0.25 mm at its tip. The file has three different cross-sectional designs: a square cross-section near the tip, which means there's more core material overall and the files are less likely to break apart; a flexible triangular segment near the handle and a more rigid trapezoidal piece in the middle of the file [10, 11].

CBCT is an effective nondestructive diagnostic aid due to its three-dimensional (3D) view, accuracy, and reliability. In terms of thickness measurement of dentin in root canal walls, it is essential for evaluating RDT, especially in teeth with complex root canal architecture [12, 13].

The heat treatment on Ni-Ti alloys can enhance their effectiveness when preparing a root canal with rotary endodontic instruments. However, there is limited information on the impact of heat-treated single files on RDT in endodontic literature. To address that, the purpose of this research was to analyze the amount of residual dentin thickness in the danger zone of the mesial root of the mandibular first molar after instrumentation with heat-treated single files utilizing CBCT.

MATERIALS AND METHODS:

Freshly extracted permanent human mandibular first molars were collected. The study protocol included selection of thirty teeth that met these specific criteria: separate mesiobuccal and mesiolingual canals (no confluent canals), no prior root canal treatment and mature teeth with closed apex. Additionally, the mesial canals should accommodate an initial file #15 with 20-35° curvature based on Schneider's method [14].

The selected teeth were cleaned of soft tissues and calculus, then immersed in normal saline solution at 4°C until use.

The purpose of the study was explained to the patients and informed consents were obtained to use their extracted teeth in the research according to the guidelines adopted by the Research Ethics Committee at Faculty of Dentistry, Tanta University.

First, a traditional straight-line access cavity was created using a round bur size #3 (Dentsply Maillefer) then an Endo-Z bur (Dentsply Maillefer). The distal root of each tooth was cut at the furcation level using water-cooled diamond disc (Komet, Brasseler, Lemgo, Germany). Next, the mesiobuccal root canals were scouted and visually confirmed to have apical patency using a #10 K-file (Dentsply Sirona, Ballaigues, Switzerland). The working length (WL) was detected by reinserting this file until it was evident at the anatomical tip, then WL was 1 mm less than that measured length.

The specimens were then numbered and coded then mounted in a customized Speedex silicone putty (Coltene-Whaledent, Altstätten, Switzerland) blocks to ensure a constant position before and after instrumentation CBCT scanning.

Pre-instrumentation CBCT scans were taken to establish a baseline measurement against which the remaining dentin thickness could be calculated after instrumentation by various single file systems. Pre-instrumentation axial views of CBCT images were captured for all the samples using KaVo OP 3D Vision device (KaVo Dental, Biberach, Germany) operating at 120 kV, 5 mA and 0.5 voxel size, with the same exposure circumstances prior to and after instrumentation.

Teeth were randomly divided into three equal groups of 10 each based on the used file system.

Group 1: Root canals were prepared using TruNatomy (Dentsply Sirona, Ballaigues, Switzerland) TN Prime (#26/04) operated in continuous rotation at 500 rpm and 1.5 Ncm.

Group 2: Root canals were prepared using Reciproc Blue (VDW GmbH, Munich, Germany) R25 (25, 0.08) operated in the "RECIPROC" mode of the endodontic motor.

Group 3: Root canal preparation was performed using Hyflex EDM (Coltene-Whaledent, Altstätten, Switzerland) (#25/~) in continuous rotation at speed of 400 rpm and 2.5 Ncm torque.

An X-Smart Plus endodontic motor (Dentsply, Maillefer) was used in accordance with the protocol and preset mode specified by the manufacturer for each file system.

Before and after each instrument, irrigation was done using 5 mL of 5.25% NaOCl solution with 27-gauge side-vented NaviTip (Ultradent Inc., South Jordan, Utah, USA) fitted in a plastic disposable syringe. After preparing the canals, 3mL of 17% ethylenediamine tetracetic acid (EDTA) was used for 1 minute before being followed by 3mL of normal saline solution.

Each specimen was rescanned with the same scanning parameters as the pre-instrumented CBCT, but this time with the root canals instrumented.

By deducting the dentin thickness of the uninstrumented canal from that of the instrumented canal, the residual dentin thickness was calculated. Axial measurements were recorded at 4 mm apical to the furcation area along the distal aspect of the

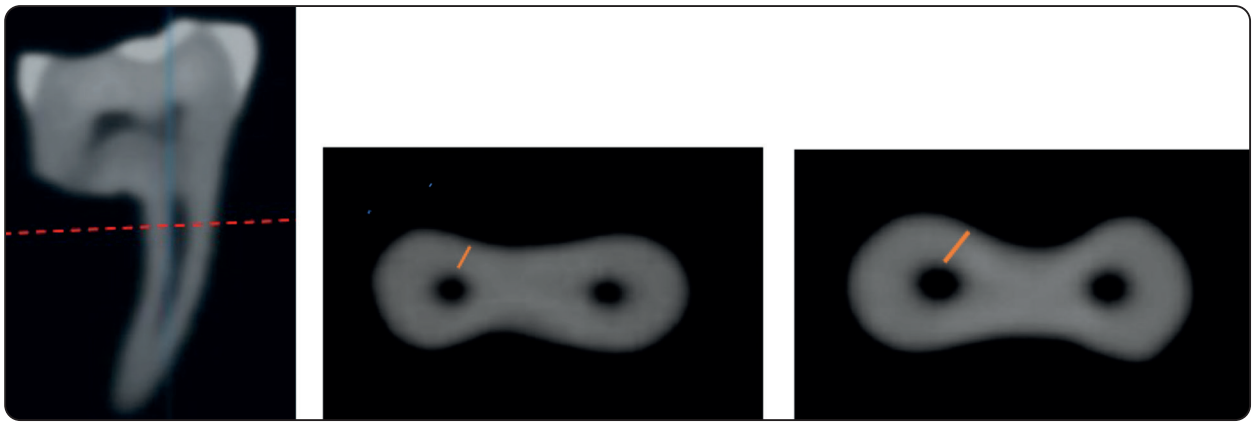

Fig. (1), A: Danger zone is 4 mm apical to the furcation area along the distal aspect of the mesial root, B: Pre-instrumentation dentin thickness (D1), C: Post-instrumentation dentin thickness (D2).

mesiobuccal canals on all scans, calculating the area of thinnest remaining dentin on the distal wall (Fig.1) according to the following formula:[15, 16]

RDT = D1–D2, where D1 is the pre-instrumentation dentin thickness and D2 is the post-instrumentation dentin thickness

D1 is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented MB canal.

D2 is the shortest distance from the distal edge of the root to the distal edge of the instrumented MB canal.

Statistical Analysis:

The remaining dentin thickness data were described as mean and standard deviation (SD). One-way analysis of variance (ANOVA) was done in SPSS version 20 (SPSS inc., Chicago, USA) at a significance level of $P \leq 0.05$, and Tukey's post hoc test was used for multiple pairwise comparisons.

RESULTS

Summary of the mean and standard deviation of the pre-instrumentation, post-instrumentation dentin thickness and amount of removed dentin (mm) at the danger zone of mesiobuccal canals for each group was presented in Table 1.

The results revealed that the three tested rotary file systems removed dentin to varying extent from the danger zone with no detected stripping perforations in all groups.

When comparing post-instrumentation dentin thickness, the maximum thickness of remaining dentin was recorded for TruNatomy (0.801 ± 0.015) while Hyflex EDM recorded the minimum thickness (0.726 ± 0.107) and the statistical analysis did not show any significant difference (*P*=0.2687).

TABLE (1) Mean and standard deviations of dentin thickness (mm) at D1, D2 and amount of removed dentin

	Groups			
	G1 (TruNatomy)	G2 (Hyflex EDM)	G3 (Reciproc blue)	*P*-value
Pre-instrumentation dentin thickness (D1)	0.958 ± 0.0747	0.887 ± 0.021	0.967 ± 0.072	0.0756
Post- instrumentation dentin thickness (D2)	0.801 ± 0.015	0.726 ± 0.107	0.789 ± 0.095	0.2687
Amount of removed dentin	0.157 ± 0.073	0.161 ± 0.103	0.181 ± 0.099	0.8930

Taking into consideration the amount of removed dentin after instrumentation, Reciproc blue removed the maximum amount (0.181 ± 0.099) while TruNatomy removed the least amount (0.157 ± 0.073) but nonsignificant reduction of the dentin thickness can be recorded among the three groups (P=0.8930).

DISCUSSION

This study analyzed the RDT in the distal aspect of the mesiobuccal canals of mandibular first molars (danger zone) after instrumentation using various single rotary files.

The danger zone is an area of anatomic consideration during instrumentation of mesial root canals of mandibular first molar where thin dentin walls in a curved canal increase the risk of iatrogenic damage such as strip perforation. To avoid this, when instrumenting the mesial canal, it's best to take a cautious mechanical approach. It is crucial that the residual dentin thickness be preserved during instrumentation of endodontically treated teeth to last and be strong. The risk zone lies between 4 and 6 mm beneath the canal orifice [3].

Lim and Stock reported that the minimum residual dentine thickness should be 0.3 mm to endure stresses during canal filling [21].

For this study, mandibular first molars were chosen with 20-35° curvature and two separate mesial canals that fit initial file #15. This was done to maintain consistency in natural tooth selection despite variations in morphology. This study only evaluated the mesiobuccal canals, since there is less dentine near the root's distal surface, these canals are more vulnerable to strip perforation than mesiolingual ones [17].

Furthermore, teeth crowns were preserved to replicate a common clinical scenario where dentin projections cause interference during root canal treatment [18]. The distal roots were removed at the furcation level to simplify repositioning of the samples after instrumentation [19]. All teeth were then placed in a silicon putty mold, which improves X-ray image quality and keeps the teeth at the same angle during pre- and post-instrumentation scans.

The remaining dentin thickness was evaluated using CBCT in this research because this method involves computed tomographs taken in voxels, allowing for 3D analysis without the need for specimen destruction [20].

Heat-treated single file systems tested in this study with their unique design features removed comparable amounts of dentin at the danger zone of mandibular first molar, with no statistically significant difference.

The distinctive design features of TruNatomy instruments includes a regressive taper with a maximum fluted diameter of 0.8 mm on this slim wire [18]. Additionally, the Ni-Ti alloy used in these instruments undergoes heat treatment to prevent unnecessary loss of tooth substance and preserve more dentin in the coronal part [7, 22]. Also, TruNatomy instruments are effective in preserving structural dentin and tooth integrity [23].

When comparing the amount of dentin removed by Hyflex EDM and Reciproc blue, one possible explanation is that the former's variable cross section with an almost triangular cross section facilitates better preparation of curved canal. Since file taper is a crucial factor in canal transportation and dentin removal from the root canal walls, it stands to reason that the alternating taper of Hyflex EDM may explain why less dentin was removed during instrumentation compared to the increased 0.08 taper of Reciproc [24, 25].

These findings were in agreement with Sarjeev Singh Yadav et al. [26], they concluded that Hyflex EDM had the least remaining radicular dentin thickness when compared to other single file rotary systems (One Curve and S-One).

This study findings were supported by Kumar et al [27] who concluded TruNatomy exhibited the maximum remaining dentin thickness in comparison to other rotary systems including Neohybrid and ProTaper Next.

This study's results were in accordance with Sousa et al. [28] Who found that root canals created with files numbered 35 (WaveOne Gold) and 40 (ProTaper Next, BioRace, and Reciproc Blue) left more residual dentin thickness in the distal aspect of the mesial roots of mandibular molars. This indicates that canal preparation in the danger zone can be done safely with these file systems.

CONCLUSIONS

All the tested heat-treated single file systems are safe for mesial canal preparation of mandibular molars with little dentin loss, within the scope of the current investigation.

It is recommended to consider the canal curvature and thickness of dentin when approaching the distal aspect of mesial root canals of mandibular first molars that require a more conservative instrumentation approach to avoid stripping perforation.

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