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ORIGINAL ARTICLE

# Residual dentin thickness at the apical third of mandibular first molar mesial root instrumented by nickel-titanium rotary and manual files with different tapers: an *ex vivo* study


## ABSTRACT

***Aim:*** *The residual root dentin thickness (RDT) in endodontically treated teeth is a major factor affecting their longevity. This study aimed to assess and compare the RDT in teeth instrumented with hand files and also with Dia-PT, Edge Taper Platinum (ETP), and Mani-Silk rotary instruments with different tapers.*

***Materials and Methods:*** *Sixty-eight extracted human mandibular first molars with separate mesial and distal roots were evaluated. The teeth were mounted in Speedex putty and underwent cone-beam computed tomography (CBCT). The primary thickness of the mesial and distal root canal walls was measured at 1, 2, and 3 mm from the apex. The teeth were divided into four groups (n=17) for instrumentation of the mesiobuccal canal with Dia-PT with 0.09 taper, ETP with 0.08 taper, Mani-Silk with 0.04 taper, and stainless steel K files with 0.02 taper. They were then placed back in the putty in their previous position and underwent CBCT again. The RDT was measured at 1, 2, and 3 mm from the apex in the mesial and distal surfaces, and compared with the baseline values. Data were analyzed by the Kruskal-Wallis and Mann-Whitney tests using SPSS version 20 at P<0.05 level of significance.*

***Results:*** *In the mesial surface, hand files yielded the maximum RDT. Mani-Silk and Dia-PT showed comparable RDT at all levels from the apex lower than the values yielded by hand files, except at 3 mm from the apex, where Mani-Silk yielded RDT comparable to hand files. In the distal surface, hand files and Mani-Silk yielded maximum RDT at all levels from the apex, except at 1 mm, where Mani-Silk showed significantly lower RDT. RDT in ETP and Dia-PT groups was almost similar, and significantly lower than other groups at all levels, except at 1 mm where RDT in ETP group was similar to that in Mani-Silk and hand file groups.*

***Conclusions:*** *Use of hand files resulted in maximum RDT at all three levels from the apex. Files with greater taper removed greater amount of dentin from the distal surface.*



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## Introduction

Mechanical preparation of the root canal system is an important step in endodontic treatment. According to the qualitative guidelines of the European Endodontics Society, elimination of the residual pulpal tissue and debris, and preservation of the original shape of the canal curvature during the cleaning and shaping process are the main goals of root canal instrumentation (1). The amount of dentin removed in the process of instrumentation is an important parameter in prevention of procedural errors such as strip perforation (1). The residual root dentin thickness (RDT) after instrumentation should not be lower than 0.3 mm in order to be able to resist condensing forces during obturation (2).

Morfis et al. (3) found a direct association between the amount of lost tooth structure and risk of crown or root fracture. Cheung et al. (4) evaluated the mesial root of mandibular first molars and demonstrated that nickel-titanium (NiTi) files left a thicker layer of RDT than stainless steel files after use. In another study, Portenier et al. (5) showed that the RDT was higher after using the Light Speed system (Lightspeed Technology Inc., San Antonio, TX, USA) compared with manual filing by the step-back technique.

Dia-PT rotary file (Dia-Dent, Cheongwon, Korea) is a commercial subtype of the ProTaper rotary system, and is similar to the ProTaper system in terms of shape and transverse cross-section. It has a triangular convex cross-section and properties similar to those of ProTaper in root canal preparation (6).

Edge Taper Platinum (ETP) rotary system (EdgeEndo, Albuquerqu, NM, USA) was recently introduced on the market and has the properties of heated NiTi files. Its characteristics are similar to those of ProTaper Gold files (PTG; Dentsply Maillefer, Ballaigues, Switzerland). Its manufacturer claims that ETP files have a fatigue resistance twice that of ProTaper Gold and 6 times that of ProTaper Universal files (PTU, Dentsply Maillefer) under optimal speed and torque conditions (7).

The Mani-Silk (Mani, Japan) file has a tear-shaped cross-section, which results in unique cutting of dentin, and confers fracture resistance to the file. It eliminates the screwing effect and decreases the amount of debris, and the stress applied to the file as such. On the other hand, decreasing the number of instruments in this system decreases the instrumentation time and allows more efficient treatment by the clinician (8).

Considering the significance of adequate RDT, this study aimed to compare the RDT following instrumentation of root canals with Dia-PT, ETP, and Mani-Silk NiTi rotary instruments with different tapers in comparison with hand files using cone-beam computed tomography (CBCT).

## Materials and Methods

Sixty-eight human mandibular first molars of patients between 20-30 years that had been extracted due to periodontal reasons were collected. The study was approved by the ethics committee of Zahedan University of Medical Sciences (IR.ZAUMS.REC.1397.358). The teeth were first immersed in 2.5% sodium hypochlorite (Cerkamed, Stalowa Wola, Poland) for 3 h, and calculus and debris were removed by an ultrasonic scaler.

The inclusion criteria were teeth with separate mesial and distal roots, Vertucci's type II (9) mesial canals such that the canals merged at over 3 mm from the apex, 20-22 mm root length, 20-35° canal curvature, and closed apices.

The exclusion criteria were teeth with cracks, fracture, caries, calcifications, internal and/or external root resorption, and open apex (Figure 1).

Standard access cavity was prepared by a diamond fissure bur (Diatech, Coltene Whaledent, Altstetten, Switzerland) under air and water coolant. A #10 K-file was introduced into the canal to ensure canal patency. The apical diameter of the canal was evaluated by introducing a #15 K-file into the canal (Mani, Tochigi, Japan) not passing through the apex. A #15 K-file was

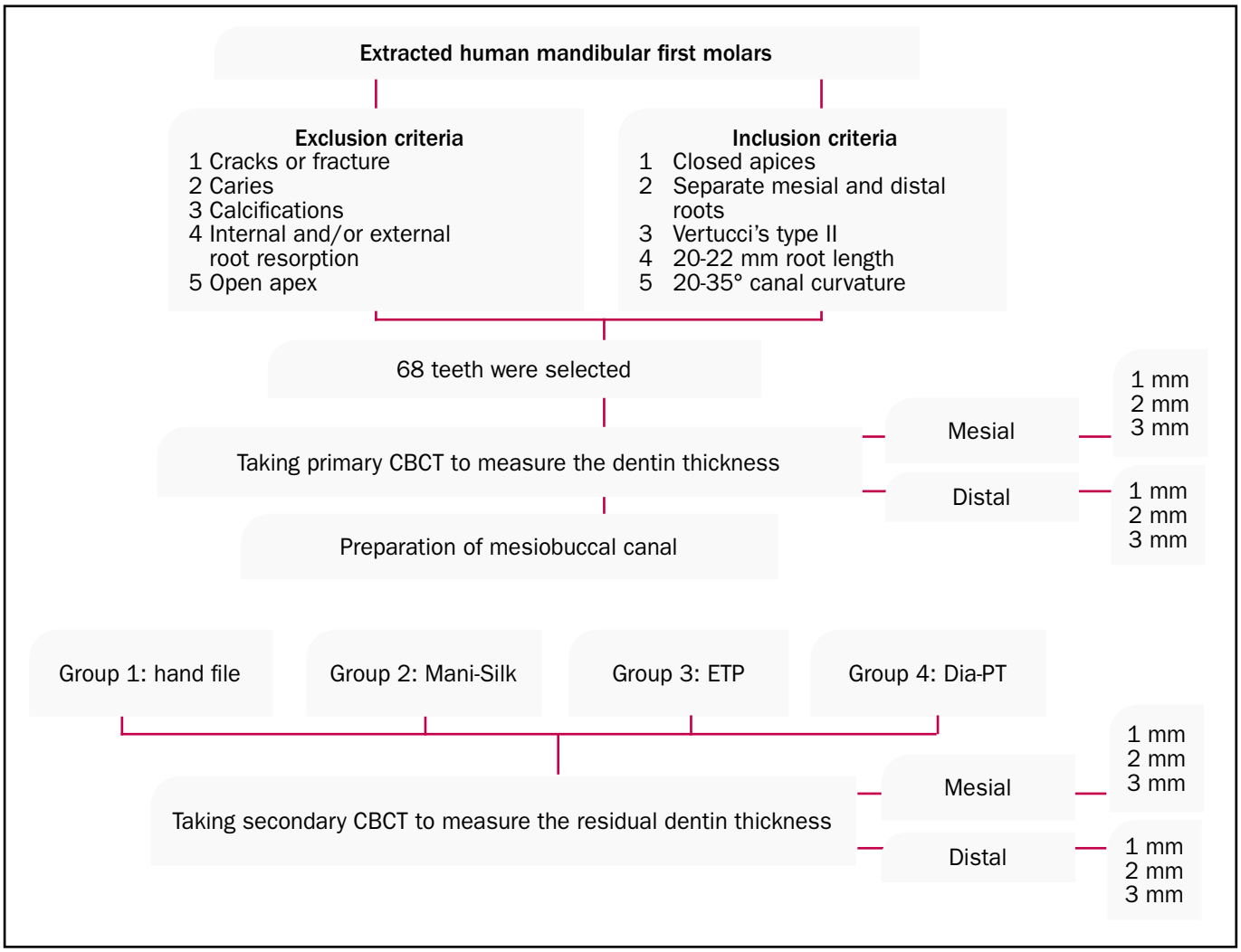



**Figure 1**
Flowchart of the study.

then introduced into the mesiobuccal canal and a digital radiograph (EZ Sensor; Vatech, Hwaseong, Republic of Korea) was obtained by the parallel technique from different directions. The degree of curvature of the mesiobuccal canal was then determined according to the Schneider's method (10). Teeth with 20-35° curvature were included in this study. The teeth were stored in saline until the experiment. They were then coded and mounted in Speedex putty blocks measuring 15x15 mm. Next, they underwent CBCT (NewTom Giano; QR, Verona, Italy) with the exposure settings of 8x5 field of view, 9 s exposure time, 90 kV voltage, and 59-30 mA amperage. Images of different sections with 0.16 mm slice thickness were reconstructed. After determining the center of the mesiobuccal canal, the primary thickness of the mesial and distal root canal surfaces was measured by drawing lines perpendicular to the center of the canal. For each surface, the distance between the inner and outer walls of the root canal was considered as the thickness of the respective surface. The primary thickness of mesial and distal surfaces at 1, 2 and 3 mm from the apex of the mesiobuccal canal was measured independently by an endodontist and an oral and maxillofacial radiologist. The measurements were repeated in cases where different values were reported by the endodontist and oral and maxillofacial radiologis. The measurement accuracy of the device software was 0.01 mm. The teeth were then randomly divided into four groups (n=17). A

**Table 1**
**Residual dentin thickness of the mesial wall before and after instrumentation (mm)**

| P value | After Mean (SD) | Before Mean (SD) | Distance from apex | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dia-PT | ETP | Mani silk | Hand file | Dia-PT | ETP | Mani silk | Hand file | |
| 0.005 | 0.67±0.13[b] | 0.80±0.14[a] | 0.64±0.20[b] | 0.79±0.17[a] | 0.87±0.15 | 1.05±0.25 | 0.86±0.21 | 1.16±0.23 | 1 mm |
| 0.000 | 0.85±0.15[b] | 0.65±0.24[c] | 0.94±0.16[b] | 1.24±0.23[a] | 0.91±0.26 | 0.85±0.21 | 1.32±0.18 | 1.38±0.20 | 2 mm |
| 0.000 | 0.89±0.12[b] | 0.78±0.20[b] | 1.25±0.22[a] | 1.38±0.25[a] | 1.06±0.15 | 1.01±0.16 | 1.75±0.21 | 1.61±0.24 | 3 mm |

*SD: Standard deviation.*

*Different superscripted letters indicate a significant difference between groups (P<0.05).*

**Table 2**
**Residual dentin thickness of the distal wall before and after instrumentation (mm)**

| P value | After Mean (SD) | Before Mean (SD) | Distance from apex | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dia-PT | ETP | Mani silk | Hand file | Dia-PT | ETP | Mani silk | Hand file | |
| 0.008 | 0.67±0.14[b] | 0.86±0.17[a] | 0.70±0.18[b] | 0.75±0.18[a] | 0.90±0.20 | 1.16±0.29 | 0.89±0.19 | 1.10±0.27 | 1 mm |
| 0.000 | 0.88±0.19[b] | 0.70±0.17[b] | 1.11±0.23[a] | 1.18±0.23[a] | 0.99±0.21 | 0.92±0.21 | 1.34±0.21 | 1.33±0.23 | 2 mm |
| 0.000 | 0.92±0.19[b] | 0.81±0.19[b] | 1.45±0.43[a] | 1.38±0.28[a] | 1.01±0.28 | 1.10±0.17 | 1.76±0.27 | 1.59±0.24 | 3 mm |

*SD: Standard deviation.*

*Different superscripted letters indicate a significant difference between groups (P<0.05).*

#10 K-file was inserted into the mesiobuccal canal until its tip was visible at the apex; 1 mm was subtracted from this length to determine the working length.

*Root canal cleaning and shaping*
The process of cleaning and shaping of the canals was performed by an experienced operator. Apical preparation size was #25 in all canals, and all preparations were performed by a rotary motor (VDW Silver; VDW, Munich, Germany). During instrumentation, each root canal was rinsed with 5 mL of double-distilled water using a syringe with a side-vented needle (0.3x25 mm; Endo-Top; Cerkamed, Stalowa, Wola, Poland). Next, 2 mL of 17% ethylenediaminetetraacetic acid (Meta BioMed, Korea) was used for smear layer removal followed by 2 mL of 5% sodium hypochlorite (Cerkamed, Stalowa Wola, Poland), and a final rinse with 2 mL of saline. The canals were then dried and divided into 4 groups (group 1: hand files, group 2: Mani-Silk, group 3: ETP and group 4: Dia-PT).

*Root canal Instrumentation*
In group 1, which was prepared manually, #2 and #3 Gates-Glidden drills were used in the crown-down technique for coronal flaring. The apical area was prepared up to file #25. The rest of the canal was prepared by the step-back technique up to file #40 by subtracting 1 mm from the file length.
In group 2, Mani-Silk (Mani, Japan) pack was used at a speed of 500 rpm and 3 N/cm torque according to the manufacturer's

**Figure 2**
Residual dentin thickness of the mesial wall before and after instrumentation (mm).

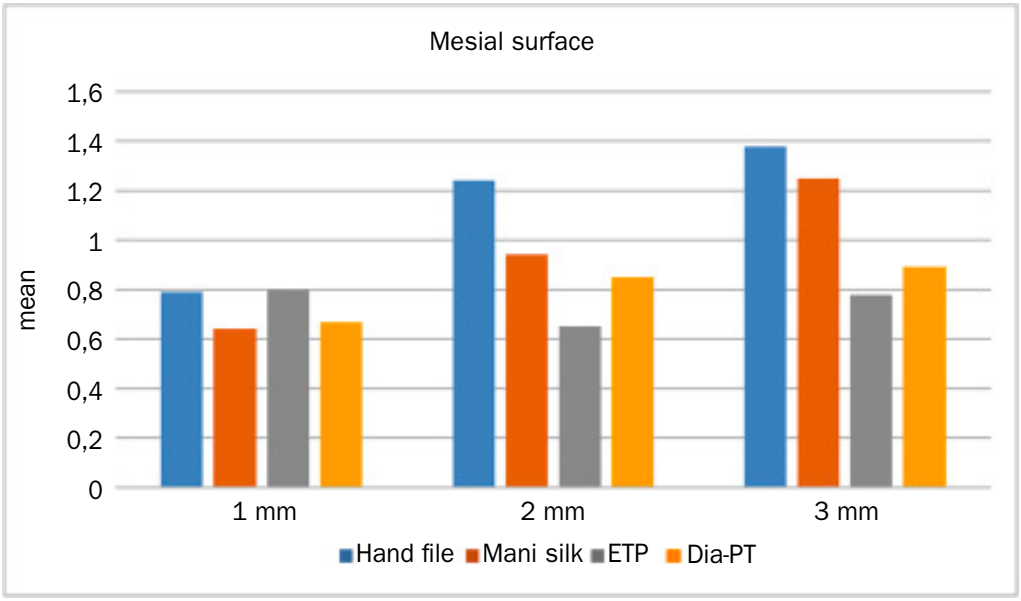
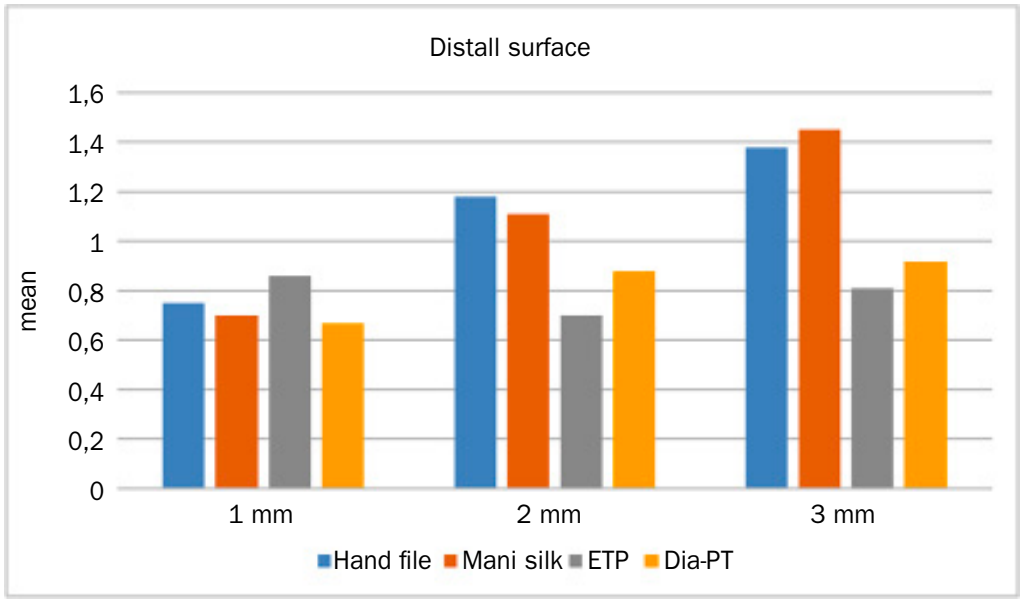



**Figure 3**
Residual dentin thickness of the distal wall before and after instrumentation (mm).




instructions as follows: First #25/0.08 file was used for coronal preparation and then files #20/0.04 and #25/0.04 were used to the working length.
In group 3, Edge Taper Platinum (ETP) rotary system (EdgeEndo, Albuquerqu, NM, USA) was used at 300 rpm speed and 3 N/cm torque according to the manufacturer's instructions: SX file was first used for coronal preparation followed by S2, F1, and F2 (#25/0.08) to the working length.
In group 4, Dia-PT (Dia-Dent, Cheongwon, Korea) was used at 300 rpm speed and 2 N/cm torque according to the manufacturer's instructions: DX file was first used for coronal flaring followed by D1 to half the working length, D2 to two-thirds of the working length, and D3 and D4 (#25/0.09) to the working length.
After cleaning and shaping, the teeth were placed back in the putty in their previous position and underwent CBCT with the same parameters. The preoperative and postoperative CBCT scans of each tooth

were compared, and the RDT was measured at 1, 2 and 3 mm from the apex in the mesial and distal surfaces, and compared with the primary thickness.

*Statistical analysis*
Data were analyzed by the Kruskal-Wallis and Mann-Whitney tests using SPSS version 20 (SPSS Inc., IL, USA) at $P<0.05$ level of significance.

## Results

Tables 1 and 2 and Figures 2 and 3 present the RDT of the mesial and distal walls before and after instrumentation with hand files with 0.02 taper, Mani-Silk files with 0.04 taper, ETP files with 0.08 taper, and Dia-PT files with 0.09 taper at 1, 2 and 3 mm from the apex.
In both the mesial and distal walls, the RDT was maximum at 3 mm and minimum at 1 mm from the apex ($P=0.000$).
In the mesial surface, hand files yielded the maximum RDT. Mani-Silk and Dia-PT showed comparable RDT at all levels from the apex lower than the values yielded by hand files, except at 3 mm from the apex, where Mani-Silk yielded RDT comparable to hand files. In the distal surface, hand files and Mani-Silk yielded maximum RDT at all levels from the apex, except at 1 mm, where Mani-Silk showed significantly lower RDT. RDT in ETP and Dia-PT groups was almost similar, and significantly lower than other groups at all levels, except at 1 mm where RDT in ETP group was similar to that in Mani-Silk and hand file groups.

## Discussion

This study assessed the RDT in the apical third of the mesiobuccal canal of mandibular first molars following instrumentation with three rotary files in comparison with hand files. During root canal preparation, high amounts of tooth structure are removed, which increases the risk of mechanical fracture of endodontically treated teeth compared with vital teeth (11). Evidence shows that a minimum of 0.3 mm root dentin thickness should remain after root canal instrumentation as the minimum RDT (2). In the present study, over 0.3 mm of RDT remained after using all four types of files; thus, all tested systems left adequate thickness of residual dentin. However, Sathorn et al. (12) discussed that dentin removal does not necessarily increase the risk of tooth fracture and some other factors are also involved in this matter.
At present, CBCT enables precise assessment of the function of rotary files and evaluation of canal transportation. In this study, measurements were made on preoperative and postoperative CBCT scans, and the values were compared to determine the changes. This technique is highly accurate and provides several images without damaging the specimens. Also, evidence shows that CBCT measurements made in the apical third are comparable with the standard references with no significant difference (13).
The present study, similar to some other investigations (14, 15), was conducted on the mesiobuccal canal of the mesial root of mandibular first molars because accessing its canals is difficult and these canals have high frequency of procedural errors due to the presence of concavity at the furcation area and having a curvature. Also, maximum curvature is often at the apical third. Thus, the amount of dentin removed from the mesial and distal walls at 1, 2 and 3 mm from the apex was quantified in this study.
In both the mesial and distal canal walls, the RDT was maximum at 3 mm and minimum at 1 mm from the apex; this difference was statistically significant. In line with the present results, Garala et al. (16) reported that the primary root dentin thickness appears to be the most important factor in determining the RDT after root canal instrumentation.
The RDT in both the mesial and distal walls was significantly higher in the hand file group at 1, 2 and 3 mm from the apex. Shahriari et al. (17) assessed the RDT of the mesiobuccal canals of mandibular molars following instrumentation with Profile and hand files. They concluded that dentin removal by hand files at all sections

was greater than that by rotary files. Difference between their results and ours may be due to the manual preparation technique since they first prepared the apical third and then the coronal third while we first performed coronal flaring by the Gates Glidden drills and then prepared the apical third.

This sequence can significantly affect the involvement of the file with the root canal walls in the apical third and consequently the RDT. The same technique was used by Rama Roa et al (18). They compared the RDT in use of hand files and four rotary file systems. They found that the RDT was greater in use of hand files than rotary files. In the present study, Mani-Silk and Dia-PT showed comparable mesial RDT at all levels from the apex lower than the values yielded by hand files, except at 3 mm from the apex, where Mani-Silk yielded RDT comparable to hand files. This finding is due to a constant increase in taper of Mani-Silk file, which results in an increase in the material volume in the entire body of the file, resulting in greater stiffness and subsequently greater dentin removal (19). On the other hand, although teeth with severe root curvature were excluded from the study, root canal irregularities can increase the risk of procedural errors such as root canal transportation and excessive dentin removal (20).

This may explain comparable dentin removal by Mani-Silk and Dia-PT although Dia-PT has greater taper (0.09.). Also, the operation speed was higher for Mani-Silk than other files, which may also explain greater dentin removal from the apical third. In the distal surface, hand files and Mani-Silk yielded maximum RDT at all levels from the apex, except at 1 mm, where Mani-Silk showed significantly lower RDT. RDT in ETP and Dia-PT groups was almost similar, and significantly lower than other groups at all levels, except at 1 mm where RDT in ETP group was similar to that in Mani-Silk and hand file groups.

It appears that by an increase in file taper, RDT deceases in the distal surface, which may be attributed to the rotational movement of high-taper rotary files, which results in greater dentin removal compared with manual filing. Also, Kunert et al, (21) and Gundappa et al. (22) discussed that file taper is an important factor that plays a pivotal role in canal transportation and dentin removal from the root canal walls. It should be noted that several factors such as the age and dentin properties (23) can affect the results. Although teeth with severe root curvature were excluded from this study, different degrees of curvature significantly affect the treatment results. Thus, use of precise measurement techniques such as micro computed tomography and evaluation of higher number of sections are recommended.

## Conclusions

This *ex vivo* study indicated that all root canal cleaning and shaping techniques decreased the dentin thickness. However, increasing the file taper is not directly correlated with greater removal of dentin or RDT.

## Clinical Relevance

The result of this study showed that increasing the file taper does not necessarily lead to greater dentin removal.

## Conflict of Interest

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

## Acknowledgements

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