Residual root dentin thickness for three different rotary systems: A comparative cone beam computed tomography in vitro study

Matam Glore Suneetha, Ahmed Abdul Moiz¹, Hateem Sharief², Kalyani Yedla³, Mubashir Mirza Baig⁴, Mohammed Ali Salem Abu Al Qomsan⁴

Department of Conservative Dentistry and Endodontics, Government Area Hospital Golconda, ¹Department of Conservative Dentistry and Endodontics, Smile Dental Hospital, ²Department of Conservative Dentistry and Endodontics, Clove Dental Hospital, Hyderabad, Telangana, India, ³Department of Health and Bioinformatics, Grand Valley State University, Allendale Charter Twp, MI, USA, ⁴Department of Conservative Dental Sciences, College of Dentistry, Prince Sattam Bin Abdul Aziz University, Al Khurj, Saudi Arabia

ABSTRACT

Background: Residual root dentin thickness (RDT) in endodontically treated teeth is a major factor that is responsible for longevity of treated tooth. Aims and Objectives: To evaluate and compare the amount of RDT during endodontic treatment using manual K-files and rotary Mtwo, ProTaper Next, and Hero shaper instruments. Settings and Design: An in vitro study was carried out on a sample of 100 freshly extracted human single straight rooted mandibular first premolar teeth. Methodology: The teeth were divided into five groups of twenty each and mounted on wax rims for a preoperative cone beam computed tomography scan to calculate the dentin thickness 3 and 6 mm from the apex. All the teeth were treated according to their groups. Statistical Analysis: The observations were then statistically analyzed using one-way ANOVA to evaluate the difference among four groups followed by post hoc test for pairwise comparison. Results: Maximum preservation of dentin was seen in Group V (cleaning and shaping done with rotary Hero shaper files) at 3 and 6 mm from the apex, whereas minimum preservation of dentin was seen in Group IV at 3 mm (cleaning and shaping done with rotary ProTaper Next files) and Group II at 6 mm (cleaning and shaping done with hand K-stainless steel files) from the apex. Overall there was a statistically significant difference in RDT values between Group V and Groups I, II, III, IV both at 3 and 6 mm from the apex. Conclusion: Cleaning and shaping with rotary Hero shaper files preserved more amount of dentin when compared to hand K-files, rotary Mtwo, ProTaper Next.

KEYWORDS: Hand K-files, Hero shaper files, Mtwo files, ProTaper next files, remaining dentin thickness

Introduction

The success of endodontically treated teeth depends on proper biomechanical preparation, final restoration and also on the amount of remaining dentine tissue. It has been emphasized that most vital factor determining the fracture resistance of endodontically treated teeth

How to cite this article: Suneetha MG, Moiz AA, Sharief H, Yedla K, Baig MM, Al Qomsan MA. Residual root dentin thickness for three different rotary systems: A comparative cone beam computed tomography in vitro study. J Indian Soc Pedod Prev Dent 2020;38:48-55.

Submitted: 13-Jun-2019 Revised: 28-Jun-2019
Accepted: 28-Dec-2019 Published: 12-Mar-2020

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com
is the amount of remaining tooth structure. Hence, conserving the dentinal structure is vital in preventing the fracture of endodontically treated teeth.\(^{[1,2]}\)

The introduction of predefined tapered shaped instruments in endodontic treatment was achieved by the advent of rotary systems. Nickel–Titanium (Ni-Ti) instruments stay better centered in the canal compared to hand instrumentation with stainless steel (SS) files and engine-driven Gates Glidden burs. This alloy is strong and has good flexibility property, thus allowing a tapered and flute design, which was not possible with instruments made of SS. A major advantage with such instruments is that they result in consistent canal shapes. Among the recently introduced rotary files proTaper Next, Mtwo, and Hero shaper are few systems that preserve the root dentin than conventional step back preparation, but no study has been done comparing the three file systems with hand instruments.\(^{[2-5]}\) Cone beam computed tomography (CBCT) can be a powerful tool in endodontic diagnosis, treatment planning and follow-up.\(^{[3-5]}\)

Bhaumik \textit{et al}. found that protaper showed minimum reduction in dentin thickness followed by Mtwo and WaveOne (WO), but the intergroup comparison was insignificant.\(^{[1]}\) Jain \textit{et al}. found that WO single reciprocation file showed better canal-centering ability and preserves more dentine than one shape rotary systems.\(^{[3]}\) Harandi \textit{et al}. found that Gates-Glidden drills with hand files removed significantly more ($P < 0.001$) dentine than the engine-driven systems in all canal walls (buccal, palatal, mesial, and distal).\(^{[4]}\)

The fact that our study compares three file systems, \textit{i.e.}, rotary Mtwo, ProTaper Next, and Hero shaper instruments with manual k files by means of CBCT scan makes it unique study. The purpose of the present \textit{in vitro} CBCT study was to compare the amount of remaining dentin thickness (RDT) in the root canal using manual SS files and three rotary Ni-Ti instruments (ProTaper Next, M2, Hero shaper rotary systems).

**Materials and Methods**

This present \textit{in vitro} study included 100 human single rooted mandibular first premolar teeth, extracted for orthodontic reasons from patients aged between 20 and 25 years. The sample was calculated with G*Power software (Institute for Experimental Psychology in Dusseldorf, Germany).

**Inclusion criteria**

Teeth with a single root, single straight canal, with one apical foramen and mature apex.

**Exclusion criteria**

Teeth with caries, cracks, fractures or craze lines, calcifications, resorptions, and open apices.

**Grouping of the sample**

All the teeth were randomly divided into five groups of twenty each as follows,

1. Group I: ($n = 20$)-Control group – No cleaning and shaping done
2. Group II: ($n = 20$)-Cleaning and shaping was done with Hand SS K-files
3. Group III: ($n = 20$)-Cleaning and shaping was done with rotary Mtwo file system
4. Group IV: ($n = 20$)-Cleaning and shaping was done with ProTaper Next rotary file system
5. Group V: ($n = 20$)-Cleaning and shaping was done with rotary Hero shaper rotary file system.

**Preparation of samples**

The study was carried out after obtaining Institutional Ethical Committee clearance (ECR/12. CDEN/2014). The teeth were stored following Occupational Safety and Health Administration and Centers for Disease Control and Prevention guidelines, and washed under running tap water to remove blood clots and were cleaned of debris and soft-tissue remnants with the help of a sharp sickle scaler. Later, the teeth were stored in germicidal solution containing 3% sodium hypochlorite and water (1:10) solution in a humidor at room temperature for a period of 2 weeks.

**Access cavity preparation**

After determining the shape and size of the pulp chamber mesially, distally, coronally in the diagnostic radiograph, access cavities were prepared with an endoaccess bur in a high-speed aerotor hand-piece with water coolant. The enamel was penetrated at the upper third of lingual incline of the facial cusp centered mesiodistally and directed along the long-axis of the root. The ovoid preparation was extended buccally and lingually enough to allow the complete removal of the roof of pulp chamber. The Buccal cusp edge of each tooth was flattened with a tapered fissure bur to serve as a reference point. Pulp tissue remnants were removed using fine barbed broach taking care not to engage the canal walls.

**Working length determination**

Apical patency was determined with a 10 size K-file. The working length was established 1.5 mm shorter than the length at which a 10 size K-file was visualized at the apical foramen. 0.5 mm was calculated as safety factor.

**Cleaning and shaping**

Root canal preparation was initially done at the coronal portion by flaring with sizes 1–3 Gates-Glidden drills in a sweeping upward motion. Canals were then checked for apical patency with #10 K-file at the working length.
Experimental design
All the teeth were randomly divided into five groups of twenty each. Group I (n = 20) included controls in which cleaning and shaping was not done. Groups II to V included twenty samples each in which cleaning and shaping was done with Hand SS K-files, rotary Mtwo file system, ProTaper Next rotary file system, and rotary Hero shaper rotary file system. Twelve wax blocks (three for each group) with dimensions (4 cm × 3 cm) were made, such that each wax block can accommodate a maximum of eight samples. All the teeth were inserted into the wax blocks till the level of cemento-enamel junction and subjected for a preoperative CBCT scan at 3 and 6 mm from the apex in axial view, at 60 KV voltage potential, 8 mA of current and time of 38.2 s with 4 × 6 and 6 × 12 display field of view, and beam incidence at the central portion of the device used to fix the specimens [Figures 1-4]. CS three-dimensional (3D) Imaging software (Carestream Dental LLC 3625, Cumberland Blvd. Ste. 700, Atlanta) was used to calculate the Dentin Thickness preoperatively (D1).

Irrigation regimen
Irrigation was done with 2 ml of 3% sodium hypochlorite for 1 min and recapitulation was done after every

![Figure 1: Cone beam computed tomography scan images of samples at 3 mm (K-Files)](image1)

![Figure 2: Cone beam computed tomography scan images of samples at 6 mm (Mtwo files)](image2)
instrument. When instrumentation of the root canal was completed, 2 ml of 17% ethylenediaminetetraacetic acid (EDTA) solution was applied for 1 min to remove the smear layer, and the canal was flushed again with 2 ml of 3% NaOCl and 2 ml saline solution for 1 min each to remove remnants of EDTA.

In Group II subjects after preparation of access cavities apical patency was determined with a 10 size K-file. All the teeth were cleaned and shaped till international organization for standardization (ISO) size 25 file as master apical file and step back was done with three subsequent files. In Group III subjects the working length with a 10 size K-file. Canals were instrumented #15 K-file till the working length and later with Mtwo rotary files and Endomate Endomotor at 16:1 gear reduction in a simultaneous preparation technique at 280 rpm, using a gentle in-and-out and lateral motion. Very light pressure was applied during instrumentation. In case the rotary file would not go deeper, #15-K file was used to establish a glide path before the rotary instrument was reintroduced. File sequences were used as follows: 15 size K file was used to create a glide path. Mtwo File size 10 (0.04 taper) followed by sizes 15 (0.05 taper), sizes 20,25 (0.06 taper) were used for entire working length. Recapitulation was
done after every instrument with 15 K-file, followed by irrigation.

In Group IV individuals, teeth were instrumented with 15 K-file till the working length to create a glide-path and later instrumented with ProTaper Next rotary file system and Endomate Endomotor at 16:1 gear reduction, in a crown down preparation technique at 300 rpm using a gentle in-and-out motion applying very light pressure. File sequences were used as follows: Size 15 K file is used to create a glide path till the working length then ProTaper Next File X1 of size 17 (0.04 taper) was used at the working length, later file X2 of size 25 (0.06 taper) was used till the working length. Recapitulation was done after every instrument with 15 K-file and irrigation was done. In Group V subjects, teeth were instrumented with 15 K-file till the working length to create a gliderpath and later instrumented with Hero shaper rotary file system and endomate endomotor at 16:1 gear reduction in a crown down preparation technique, at 350 rpm using a gentle in-and-out motion applying very light pressure. File sequences were used as follows: Size 15 K file used to create a glide path till the working length then Hero shaper File size 20 (0.06 taper) was used at the working length later file size 25 (0.06 taper) was used till the working length. Recapitulation was done after every instrument with 15 K-file and irrigation was done. Each root canal was prepared by the same operator to reduce interoperator variability.

Evaluation
On completion of cleaning and shaping in all the samples, teeth were remounted back on their respective positions using previously given sample notations on the wax blocks till the level of cementoenamel junction and CBCT imaging was done to measure the RDT (D2) at 3 and 6 mm from the root apex in axial view, at 60 KV potential, 8 mA of current and time of 38.2 s. CS 3D Imaging software was used to calculate the difference in preoperative and postoperative dentin thickness for each tooth.

The RDT was calculated by the formula RDT = D1-D2. The results were tabulated and subjected to statistical analysis.

Results
The observations were statistically analyzed using analysis of variance (one-way ANOVA) to evaluate the difference among five groups followed by post hoc test for pair-wise comparison by means of SPSS version 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: USA, IBM Corp.). “P” <0.05 was considered for statistically significant. The mean values of RDT and standard deviations revealed a statistically significant difference (P < 0.001) among the groups at 3 mm [Tables 1 and 2] and 6 mm [Tables 3 and 4]. Overall it was found that cleaning

Table 1: Mean and standard deviation of remaining dentin thickness among four groups at 3 mm

| Groups   | RDT=(D1-D2) Mean | SD  | F    | P      |
|----------|------------------|-----|------|--------|
| Group I  | 0                | 0   | 289.89 | <0.001** |
| Group II | 1.18             | 0   |       |        |
| Group III| 0.67             | 0.07|       |        |
| Group IV | 0.77             | 0.11|       |        |
| Group V  | 0.50             | 0.02|       |        |

One-way ANOVA showing *P<0.001, **Highly significant, †RDT, ‡A large F value and small P value indicates statistically significant results.[17]

RDT=Residual root dentin thickness; SD=Standard deviation

Table 2: Mean and standard deviation of remaining dentin thickness among four groups at 6 mm

| Groups   | RDT=(D1-D2) Mean | SD  | F    | P      |
|----------|------------------|-----|------|--------|
| Group I  | 0                | 0   | 225.83 | <0.001** |
| Group II | 1.30             | 0   |       |        |
| Group III| 0.88             | 0.04|       |        |
| Group IV | 1.06             | 0.09|       |        |
| Group V  | 0.79             | 0.09|       |        |

One-way ANOVA *P<0.001, **Highly significant, †RDT, ‡A large F value (value on the F distribution) and small P value indicates statistically significant results.[17] RDT=Residual root dentin thickness; SD=Standard deviation

Table 3: Pairwise comparison of mean and standard deviation among four groups (at 3 mm)

| Code (I) | Code (J) | Mean difference (I-J) | P       |
|----------|----------|-----------------------|---------|
| Group I  | Group II | −0.43                 | 0.000 (S) |
| Group I  | Group III| −0.33                 | 0.000 (S) |
| Group I  | Group IV | −0.41                 | 0.000 (S) |
| Group I  | Group V  | −0.60                 | 0.000 (S) |
| Group II | Group III| −0.12                 | 0.191 (NS) |
| Group II | Group IV | 0.04                  | 0.130 (NS) |
| Group II | Group V  | 0.605                 | 0.000 (S) |
| Group III| Group IV | 0.125                 | 0.05 (S)  |
| Group III| Group V  | 0.095                 | 0.001    |
| Group IV | Group V  | −0.27                 | 0.000 (S) |

*Statistical analysis: Post hoc test was done to compare the means between groups.[5] The results were considered statistically significant if P<0.05.
S=Significant; NS=Not significant

Table 4: Pairwise comparison of mean and standard deviation among four groups (at 6 mm)

| Code (I) | Code (J) | Mean difference (I-J) | P       |
|----------|----------|-----------------------|---------|
| Group I  | Group II | −0.24                 | 0.000 (S) |
| Group I  | Group III| −0.42                 | 0.000 (S) |
| Group I  | Group IV | −0.33                 | 0.000 (S) |
| Group I  | Group V  | −0.51                 | 0.000 (S) |
| Group II | Group III| 0.06                  | 0.210 (NS) |
| Group II | Group IV | 0.11                  | 0.320 (NS) |
| Group II | Group V  | 0.51                  | 0.000 (S) |
| Group III| Group IV | 0.125                 | 0.905 (NS) |
| Group III| Group V  | 0.095                 | 0.001 (S) |
| Group IV | Group V  | 0.185                 | 0.000 (S) |

Statistical analysis: Post hoc test was done to compare the means between groups.[5] The results were considered statistically significant if P<0.05.
S=Significant; NS=Not significant
and shaping reduces the dentin thickness of root canal wall. The results of the study show that maximum preservation of dentin among the experimental groups was seen in Group V (cleaning and shaping done with rotary Hero shaper files) at 3 and 6 mm from the apex. Minimum preservation of dentin was seen in Group IV at 3 mm (cleaning and shaping done with rotary ProTaper Next files) and Group II at 6 mm (cleaning and shaping done with hand K-SS files) from the apex. At 3 and 6 mm from apex cleaning and shaping with rotary Hero shaper files preserved statistically more dentin when compared to rotary Mtwo files, Pro Taper next and hand K-files ($P = 0.000$). At 3 mm, the three groups (Groups II, III, IV) removed more dentin than Group V during the process of cleaning and shaping but the difference was not statistically significant ($P = 0.191$). At 6 mm from the apex, Group II (Hand K-files) removed more amount of dentin followed by Group III (Mtwo rotary files) and Group IV (ProTaper Next), but the difference was not statistically significant ($P = 0.210$).

**Discussion**

Substantial amount of tooth structure is lost because of root canal treatment procedures. Hence, such teeth are vulnerable for mechanical failure than intact vital teeth. Many studies have been carried out to evaluate the RDT using various instrumentation techniques for chemo-mechanical preparation of endodontically treated tooth comparing conventional SS hand instrumentation and more novel approach of Ni-Ti instruments.[6-9]

Shahriari et al. compared the amount of RDT after canal preparation with SS hand instruments and rotary ProFile instruments. They found that more dentin was removed mesially in all sections in hand instrumentation group, the difference being statistically significant.[10]

Rao et al. in their study on comparison of various hand versus rotary instruments and found that Mtwo preserved more remaining dentin than other techniques.[11] Whereas Weller et al. showed that K3 rotary files preserved more dentin than hand instrumentation.[12]

As the CBCT scan can provide noninvasive inside view of the root canal system, it is possible to scan the teeth before and after instrumentation and then compare the obtained images. Recently there is a tremendous improvement in imaging technology and softwares, and this has resulted in usage of CBCT in the field of endodontic research.[5,6] This single imaging technique helps us in viewing the images in various planes i.e., coronal, sagittal, or even an oblique or curved image planes, referred to as multiplanar reformation.[5-8]

Raiden et al. found that RDT appeared to be more in radiographic images than what was actually present and suggested that radiographs are not a reliable method for measuring the thickness of the tooth wall.[13]

We performed our study on only single-rooted mandibular first premolars with single straight canal, to avoid any bias and also keeping in mind that they are normally extracted commonly for orthodontic treatment. The results were analyzed both at 3 and 6 mm from the apex in all the groups, to know the effect of shape of the instruments as well as percentage increase in taper of the instrument in cleaning and shaping the root canal along with their mechanical properties. Our findings indicate that the percentage increase in taper of the instrument has its effect on preserving the dentin. Group V preserved more dentin both at 3 and 6 mm from the apex, but Group II (K-files) which preserved more dentin than Group IV (ProTaper Next) at 3 mm, removed more dentin at 6 mm from the apex when compared to Group IV.[11-13]

The results showed that there was no change in the dentin wall thickness in the control group (Group I) where no instrumentation was done pre- and post-operatively. This clearly shows that irrigants could not affect the dentin wall thickness without mechanical instrumentation. Irrigants when used in conjugation with mechanical instruments could affect the dentin thickness postoperatively in other groups.

In Group II, where cleaning and shaping was done with hand SS K-files, the mean change in dentin thickness was 1.18 at 3 mm from apex and 1.30 at 6 mm from the apex. At 3 and 6 mm from the apex the difference in RDT in Group II was statistically significant from Group V. At 6 mm from the apex there was more dentin removal when compared to Groups III, IV, V. This can be attributed to the stiffness of hand K-files which straighten up during root canal instrumentation and its four-point contact to the root canal wall as well as the larger size instruments which were used at 6 mm during step-back preparation. The results are in accordance with study done by Rao et al., who found that instrumentation with K-files removed lesser amount of dentin compared to ProTaper, Light Speed LSX and M2 systems.[11]

In Group III, where cleaning and shaping was done with Mtwo rotary file system, the mean change in dentin thickness was 0.67 at 3 mm from apex and 0.88 at 6 mm from the apex. At 3 mm and 6 mm from the apex the difference in RDT in Group III was statistically significant from Group V. At 3 mm from the apex RDT values with Mtwo rotary files was less than Group V but more than Groups II and IV but the difference was not statistically significant. At 6 mm from the apex, in Group III more dentin as preserved than Groups II and IV but the difference
was not statistically significant. The preservation of dentin in Group III can be attributed to the flexibility of instruments used because of progressive taper and its simultaneous preparation technique where minimal pressure was used to advance the file inside the canal. The results are in accordance with study done by Ramanathan and Solete, who found Mtwo removed less amount dentin when compared to ProTaper Universal and ProTaper Next system at 1 and 3 mm.[14]

In Group IV, where cleaning and shaping was done with ProTaper Next rotary file system, the mean change in dentin thickness was 0.77 at 3 mm from apex and 1.06 at 6 mm from the apex. At 3 and 6 mm from the apex, the difference in RDT in Group IV was statistically significant from Group V. At 3 mm from the apex, RDT values with ProTaper Next rotary file system were less than Group III and V, but more than Group II, the difference being statistically insignificant. At 6 mm from the apex, the RDT values of Group IV were less than Groups III and V, but preserved more dentin than Group II. The preservation of more dentin than hand K-files can be attributed to its improved flexibility due to M-technology and its offset action in instrumentation along with its two-point contact to the canal wall. The results are in accordance with study done by Kuzekanani et al. who noticed that Mtwo system showed less change in canal curvature and better maintained the original shape of the root canal, with less transportation (P < 0.05) than rotary Ni-Ti and ProTaper Next systems.[15]

In Group V, where cleaning and shaping was done with Hero shaper rotary file system, the mean change in dentin thickness was 0.50 at 3 mm from apex and 0.79 at 6 mm from the apex. At 3 and 6 mm from the apex the difference in RDT in Group V was statistically significant from remaining groups. Group V preserved more dentin than Groups II, III, IV both at 3 and 6 mm. This preservation of dentin in Group V when compared to other experimental groups can be attributed to the flexibility and its adapted helical pitch design. The results are in accordance with Reddy et al. who compared RDT at 3 and 7 mm from root apex prior to and after instrumentation with ProTaper, iRace, and Hero shaper rotary files by CBCT. They found that ProTaper causes higher thinning of root dentine at middle third of the root when compared with iRace and Hero shaper rotary files and hence should be used astutely.[16]

Limitation of the study
The limitation of the present study is that the mandibular first premolar straight roots have only been used to assess all the parameters. Curvature of the root canal also influences the RDT, the effect of which is not analyzed in the present study. In vitro studies do not fully reproduce in vivo conditions, and only single-rooted teeth were considered.

Conclusion
The present in vitro study was conducted to evaluate and compare the amount of RDT during endodontic treatment using manual K-files and three Rotary Ni-Ti instruments (Mtwo, ProTaper Next, and Hero shaper). It was concluded that all cleaning and shaping techniques resulted in decrease in dentin thickness during endodontic treatment. However, the use of engine driven Ni-Ti instrumentation techniques (Hero shaper files) resulted in significantly greater preservation of dentin thickness at 3 and 6 mm from the apex when compared to other groups. RDT was observed in the following order - Hero shaper files > Mtwo files > ProTaper Next files > Manual K-Files.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References
1. Bhaumik T, Roy M, Das UK, Dutta K. Comparison of apical transportation and centering ability of ProTaper next, HyFlex cm and twisted files by using cone beam computed tomography. J Med Dent Sci Res 2017;3:29-34.
2. Chaudhary NR, Singh DJ, Somani R, Jaidka S. Comparative evaluation of efficiency of different file systems in terms of remaining dentin thickness using cone-beam computed tomography: An in vitro study. Contemp Clin Dent 2018;9:367-71.
3. Tomer AK, Miglani A, Chauhan P, Nagarjuna P, Rana S, Kumari A. An in vitro evaluation of remaining dentine thickness through CBCT using different files. IOSR J Dent Med Sci 2017;16:121-4.
4. Harandi A, Mohammadpour Maleki F, Moudi E, Ehsani M, Khafri S. CBCT assessment of root dentine removal by gates-Glidden drills and two engine-driven root preparation systems. Iran Endod J 2017;12:29-33.
5. Jain A, Gupta AS, Agrawal R. Comparative analysis of canal-centering ratio, apical transportation, and remaining dentin thickness between single-file systems, i.e., oneshape and waveone reciprocation: An in vitro study. J Conserv Dent 2018;21:637-41.
6. Shah DY, Wadekar SI, Dadpe AM, Jadhav GR, Choudhary LJ, Kalra DD. Canal transportation and centering ability of protaper and self-adjusting file system in long oval canals: An ex vivo cone-beam computed tomography analysis. J Conserv Dent 2017;20:105-9.
7. Mangal S, Mathew S, Sreenivasa Murthy BV, Nagaraja S, Dinesh K, Ramesh P. Cone-beam computed tomographic evaluation of remaining dentin thickness in bifurcated roots of maxillary first premolars after rotary instrumentation and post space preparation: An in vitro study. J Conserv Dent 2018;21:63-7.
8. Saberi E, Farhad-Mollahashi N, Bijari S, Daryaeian M.
Comparative evaluation of root canal transportation by three NiTi single-file systems in curved canals: A cone beam computed tomography study. Int J Dent 2018;2018:4151692. doi: 10.1155/2018/4151692.

8. Sharma N, Sarfi S, Sharma A, Grewal MS. Evaluation of canal preparation with rotary and hand NiTi files in curved root canals using cone beam computed tomography: An in vitro study. IAIM 2017;4:45-55.

9. Shahriari S, Abedi H, Hashemi M, Jalalzadeh SM. Comparison of removed dentin thickness with hand and rotary instruments. Iran Endod J 2009;4:69-73.

10. Rao MS, Shameem A, Nair R, Ghanta S, Thankachan RP, Issac JK. Comparison of the remaining dentin thickness in the root after hand and four rotary instrumentation techniques: An in vitro study. J Contemp Dent Pract 2013;14:712-7.

11. Weller PJ, Svec TA, Powers JM, Ludington JR Jr., Suchina JA. Remaining dentin thickness in the apical 4 mm following four cleaning and shaping techniques. J Endod 2005;31:464-7.

12. Greenland S, Senn SJ, Rothman KJ, Carlin JB, Poole C, Goodman SN, et al. Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. Eur J Epidemiol 2016;31:337-50.