CBCT evaluation of canal centering ratio, apical transportation and dentin thickness of root canals after using reciprocating and rotary instrument systems: -an in-vitro study.

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Abstract

Aim: This study was done to evaluate the efficacy of rotary and reciprocating endodontic instruments in maintaining the root canal anatomy during instrumentation procedure. **Methodology:** Forty human single-rooted mandibular premolars extracted for orthodontic reasons were used. Teeth were decoronated, access cavities were made, working length was determined and samples were subjected to Pre-instrumentation Cone Beam Computed Tomography (CBCT) scanning. The samples were randomly divided into two groups (n=20): Group 1: Wave-One (WO) reciprocating system and Group 2: ProTaperNext (PTN). The samples were prepared with these two systems and post instrumentation scans were performed.Pre and post instrumentation scans were compared to determine the canal-centering ratio at 0mm, 3mm and 5mm from canal orifice, apical transportation, and remaining dentin thickness (RDT) at 3,5 and 7mm from the root apex using Planmeca Romexis software.For statistical analysis, Shapiro Wilk test, paired t test, one way ANOVA and post hoc Tukey's test were used. **Results: -**Results showed that group 1 (WO) had better centering ability at all three levels (at orifice 0.75; at 3mm 0.62; at 5mm 0.65) than group 2 (PTN) (at orifice 0.65; at 3mm 0.54; at 5mm 0.47). apical transportation was minimum with WO (0.056) than PTN (0.113). It was also observed that WO preserved dentin better than (RDT at 3mm .062; at 5mm .104; at 7mm .107) than PTN (at 3mm .062; at 5mm .104; at 7mm .107). **Conclusion:** WO showed better canal-centering ability with lesser canal transportation and more dentin remaining peripherally thanPTN.

Keywords: Canal-centering ratio; Apical-transportation; Remaining Dentin Thickness (RDT); Cone Beam Computed Tomography; Wave-one; ProTaper Next

DOI: 10.48047/ecb/2023.12.si4.976

Introduction

Success of the root-canal therapy depends on effective cleaning and shaping of root canals. While shaping the root canal system it is important to maintain the original canal anatomy without any deviation in original shape and form of the canal. A well-prepared root canal should be uniformly flared from apical to coronal regions, maintain the apical foramen and the original canal curvature.The original form and shape of the canal will be maintained only if the instruments remain centered in the canal. The canal-centering ability of the instruments depends on its design features including cross section, taper, tip size, and flexibility.[1]

In curved canals, one of the common iatrogenic errors occurring duringinstrumentation is apical transportation which may result in excessive removal of dentin removal in one direction awayfrom the main canal axis and undesirable deviation of canal from the original path.[1]Apical transportation results in incomplete removal of debris and micro-organisms as instruments do not touch theroot canal space completely. It affects the seal of the obturating material leading to the failure of the treatment.[2]It also weakens the root due to over reduction of the sound dentin. The apical transportation is commonly associated with improper access cavity preparation, use of less flexible instruments, instrumentation technique, tip design, canal curvatures not seen on radiographs and operator's skill.[1]

The remaining dentin thickness after instrumentation procedures affects the fracture resistance of the root.[2] An ideal technique of instrumentation should uniformly prepare the canal space to preserve the sound peripheral dentin.[3] Excessive coronal flare should be avoided as it reduces the peri-cervical residual dentin and increases susceptibility to vertical root fractures.[4]Apical-third preparation can weaken apical root structure due to removal of sound dentin.[5,6] It has been proved that the strength of a tooth after endodontic treatment is directly related to the amount of RDT.[7-10] Instrumentation can significantly weaken the roots.[11]

Endodontic instruments are continuously evolving with important modifications in their design and manufacturing process. With the introduction of the super-elastic nickel–titanium alloy, Endodontics has witnessed tremendous strides in manufacture of instruments. Ni-Ti instruments exert fewer forces on the root canal walls and are far more flexible than stainless-steel instruments.[12-14]Ni-Tirotary instruments are supposed to be more reliable for theirperformance and safety. Ni-Ti rotary ProTaper Next (PTN, Dentsply, Maillefer, Switzerland) instruments are manufactured with modified cross-section allowing for elective dentin cutting thus reducing torsional loads. But they cut aggressively which could lead to canal transportation. In 2008, Wave One (Dentsply, Sirona, USA)Ni-Ti instrument system wasintroduced.It's a single file technique based on asymmetric reciprocation thatimproved its effectiveness and safety during the shaping procedure. Wave One files are manufactured from a thermal treatment process, M-wire technology. M-wire alloy exhibit increased flexibility and can resist the cyclic fatigue. The instrument is to be used with a reciprocating motion whichreduces the screwing effect and file breakage.[15]

Radiographic analysis, serial sectioning, diafonization, stereomicroscopic evaluation, Scanning Electronic Microscopy are some of the methods to evaluate canal transportation, remaining dentin thickness (RDT), and canal-centering ability of endodontic instruments. However, these methods are invasive, repositioning of specimens accurately before and after instrumentation is difficult and loss of specimen is common occurrence. Radiographs are not very effective as they can't providea three-dimensional image of an object.[16]Cone-beam computed tomography (CBCT) is non-invasive and is effective in evaluatingcanal space, canal transportation, centering ratio, and the amount of dentin removed during instrumentation.[17]

This in-vitro study evaluated the canal-centering ability, canal transportation, and remaining dentin thickness after using Rotary and Reciprocating endodontic instruments by CBCT.

Methodology

Fortysingle-rooted single-canaled humanmandibular premolars extracted for orthodontic reasons were used in this study. Teeth were cleaned and stored in 10% formalin solution. Angle of curvature was assessed by Schneider's method[18]and teeth having canal curvature within10° and 24° were included. The teeth were decoronated with a diamond disk (NSK, Inc. Japan) to obtain 9-mm length of each root. Access cavities were prepared, and #10 K-file (Dentsply, Switzerland)was used for working length. File was inserted till seen at apical foramen and 0.5 mm was subtracted to obtain final working length.

For pre-instrumentation CBCT scanning of the samples, roots were embedded in a silicone template till the cervical region so as to maintain the constant position of samples. The template assembly was fitted horizontally to the chin support of CBCT machine and the occlusal plane was kept parallel to the plate. For CBCT scanning the exposure time was 3.0 s, operating at 75 kV and 2.0 mA. The scanned images were stored electronically for further comparison with post-instrumentation scanned images.The samples were randomly divided into two groups (n=20)

Group 1: Wave-One (WO)

Group 2: ProTaper Next (PTN)

Root canal instrumentation

Manufacturer's instructions were followed for instrumentation of samples in both the groups. During instrumentation irrigation was done with 5% sodium hypochlorite (Hyposept, Sterilla). After every single use, the instrument flutes were cleaned with gauze dampened with sodium hypochlorite. A # 25 file was used for the final apical preparation of all the samples.

For Group 1, canals were prepared using a primary Wave One file #25 with 8% taper in a reciprocating, slow in-and-out pecking motion in an electric endomotor (Eighteeth, China) at 350rpm and 1.5 Torque.

In Group 2, PTN rotary files were used sequentially and for all canals apical preparation was done till X2.

After instrumentation, post -instrumentation scanning was done in a similar way as for pre-instrumentation scanning. The Pre- and post-instrumentation images of all the samples were then compared for centering ability, apical transportation and remaining dentin thickness using Planmeca Romexis software.

The values of each parameter to be tested were obtained using formulae introduced by Gambill *et al.*[19]:

Canal-centering ratio : $(a_1 - a_2)/(b_1 - b_2)$ **or** $(b_1 - b_2)/(a_1 - a_2)$

a_1= distance from outer surface of mesial portion of the root to the mesial wall of unprepared canal.

a_2= distance from inner root surface of the mesial portion of the root to the wall of canal after preparation.

b_1= distance from outer surface of distal portion of the root to the distal wall of unprepared canal,

b_2= distance from the outer surface of the distal portion of the root to distal surface of canal after preparation.

The higher value was considered as denominator. A ratio equal to 'one' indicated an ideal centering ratio and a value closer to zero indicated poor centering ability. The canal centering ratio was obtained at three levels for each sample in both the groups: at orifice level, at 3mm from orifice and at 5mm from the orifice.

Apical transportation: ($[a_1 - a_2] - [b_1 - b_2]$)

a_1 is the shortest distance from the mesial edge of the root to the mesial edge of the canalbefore instrumentationand a_2 corresponds to same distance but after instrumentation. b_1 is the shortest distance from the distal edge of the root to the distal edge of the canal before instrumentation and b_2 corresponds to same distance but after instrumentation. The canal transportation is considered minimum when the value obtained is closer to ‘zero’.

Remaining dentin thickness (RDT): The values for RDT were obtained at three different levels (3, 5, and 7 mm from the apical end), by measuring the shortest distance from the outer wall to the inside canal wall of the canal, before and after instrumentation and by subtracting the pre-instrumentation values from post-instrumentation values.

Statistical analysis

The statistical analysis was performed using SPSS version 21**.** The distribution of the data set was assessed with normality test (Shapiro Wilk test). Mean and standard deviation (SD) were calculated along with chi-square test of homogeneity. paired sample ‘t’ test was used for theintra group comparison whereas inter group comparison was done using one way analysis of variance (one way ANOVA) along with post hoc Tukey’s test. The observations were then assessed and interpreted based on the t/F values and p value. The mean difference was analysed. The p values of <0.05 was statistically significant at 95% confidence interval.

Results

Table 1 shows results of centering ratio and apical transportation. For group 1 (WO) the mean centering ratio was .753 at 0mm; .621 at 3mm and .92 at 5mm.For group 2 (PTN) the mean centering ratio was .655 at 0mm; .542 at 3mm and .475 at 5mm.Though statistically significant difference was not seen at 0mm($P<0.120$) and 3mm($P<0.274$), at 5mm the difference was significant ($P<0.003$). WO showed lesser apical transportation than PTN. Mean Apical transportation for Wave Onewas 0.056 and for PTN was 0.113 with no significant difference($P<0.304$). (Graph 1)

Table 2 shows Pre- and Post-instrumentation Remaining Dentin Thickness (RDT)at 3mm, 5mm and 7mm. In both the groups, RDT was reduced after instrumentation. Group 1 (WO) showed minimum reduction in dentin at all three levels [at 3mm .062; at 5mm .104 and at 7mm .107] when compared to Group 2 (PTN) [at 3mm .223; at 5mm .180 and at 7mm .249]. The post instrumentation difference in RDT between WO and PTN was not statistically significant at 5mm ($P<0.221$) and 7mm($P<0.716$) however at 3mm significant difference was observed ($P<0.020$). Wave One preserved dentin better than PTN at all three levels. (Graph 2)

Discussion

In this study we evaluated the centering ability, apical transportation and RDT of Wave One and PTN. Evaluation of these influential parameters helps in assessing the efficacy of the instruments in maintaining the original canal anatomy. These parameters affect the quality of root canal preparation. CBCT is a valuable non-invasive method to evaluate changes in canal geometry after instrumentation. In this study, we used CBCT effectively to calculate centering ratios, canal transportation and RDT after using WO and PTN instrument systems.

The ability of an instrument to remain centered in the canal is decided by its centering ratio[19]. The deviation of original path of the canal during instrumentation results in canal transportation and it is a measurement of the extent and direction of deviation. Excessive removal of dentin weakens the root and affects the fracture resistance of the tooth.[20]

In this study, centering ratio was taken at three cross-sectional levels: 0, 3, and 5 mm to represent at orifice, middle, and apical thirds of root canals respectively. Similarly, for RDT three cross-sectional levels were chosen: 3 mm5 mm and 7mm to represent at apical, middle, and coronal thirds of root canals respectively. WO files performed better than PTN for all tested parameters i.e. centering ability, apical transportation and RDT.

Wave One showed better centering ability presumably due to improved core alloy of the file and variable pitch design.The cross-sectional designs of Wave One are different over the entire length of the working part. The cross section in the tip region is modified triangular convex and has radial lands whereas in the middle part and near shaft it is triangular convex with neutral rake angle.[21]

The centering ratio of PTN(0.55) was less than WO(0.67). This may be due to the pecking motions required during PTN instrumentation to attain the full working length leading to misdirected instrumentation. The canal-centering ability of One Shape and Wave One systems was evaluated using CBCT by Jain A *et al* and they observed that Wave One showed better canal-centering ability.[22] Elnaghy AM and Elsaka SE evaluated centering ability of PTN. They observed that PTN remains less centered in the canal; however, PTN demonstrated better centering ability when used after a previous glide path.[23]

In our study the results for apical transportation showed that both the groups exhibited apical transportation with no significant difference. However, theminimum apical transportation was with WO (.056) as compared to PTN (0.113). WO caused minimum apical transportation mainly due to its canal-centering ability. Other contributing factors are M-wire technology used in manufacturing, non-cutting tip design and the radial lands in tip regionthus avoiding excessive cutting on external curvature of the canal. PTN showed more apical transportation, may be due to its aggressive cutting action and inability to remain centered in the canal, more so in the apical-third.

As far as remaining dentin thickness is concerned, reduction in remaining dentin at three levels in the canals, (3mm, 5mm, 7mm) was observed in both the groups. However, WO showed minimum reduction in dentin at all three levels when compared to PTN. The highest change in RDT values was observed at 7mm in PTN group. The minimum change in RDT with WO instruments may be attributed to its tip design which is non-cutting and the reciprocating motion. The torsional and flexural stresses are reduced in reciprocating motion. Reciprocation motion also increases the canal-centering ability and reduces the taper-lock during reciprocation cycles in the root canals[21]. PTN instruments removed considerable dentin at 3mm and at 7 mm. This may be due to variable taper and convex cross section that may have led to aggressive cutting and excessive dentin removal, especially at coronal level (at 7mm). PTN X2 is associated with the highest torque and may show greater contact with the canal walls hence PTN X2 should be used carefully.[22] Our results are in agreement with study done by Jain A et al.[22]

Though PTN showed increased apical transportation and more amount of dentin removal, the values obtained are within the safety limit oftheir usage. Apical transportation up to 0.15 mm is acceptable and should not be greater than 0.30 mm as it negatively affects apical sealing.[24] Lim and stock[25] suggested minimum 0.3 mm of peripheral dentin should remain after instrumentation. This offers adequate resistance against compaction forces while obturating the canals and occlusal forces.

Conclusion

Canal-centering ability, apical transportation and RDT are inter-related factors that influence the outcome of the endodontic treatment. Any instrument system with better centering ability will show minimum apical transportation and minimum dentin removal. In spite of recent advances in metallurgical science, none of the NiTi instrument systems are capable of producing ideal shape and form of the root-canal. In this study, both the instrument systems were unable to show ideal centering ratio as ONE and canal transportation as ZERO. However, WO respected original canal shape and anatomy by virtue of its ability to remain centered in the canal. It showed minimum canal transportation and minimum dentin removal than PTN. These results cannot be extrapolated in clinical scenario, and we recommend more investigations to be done with larger sample size.

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Table 1: Means and Standard Deviation of Canal Centering Ratio and Apical Transportation of Group 1 and Group

Table 2: Means and Standard deviation of Remaining Dentin Thickness values of Group 1 and

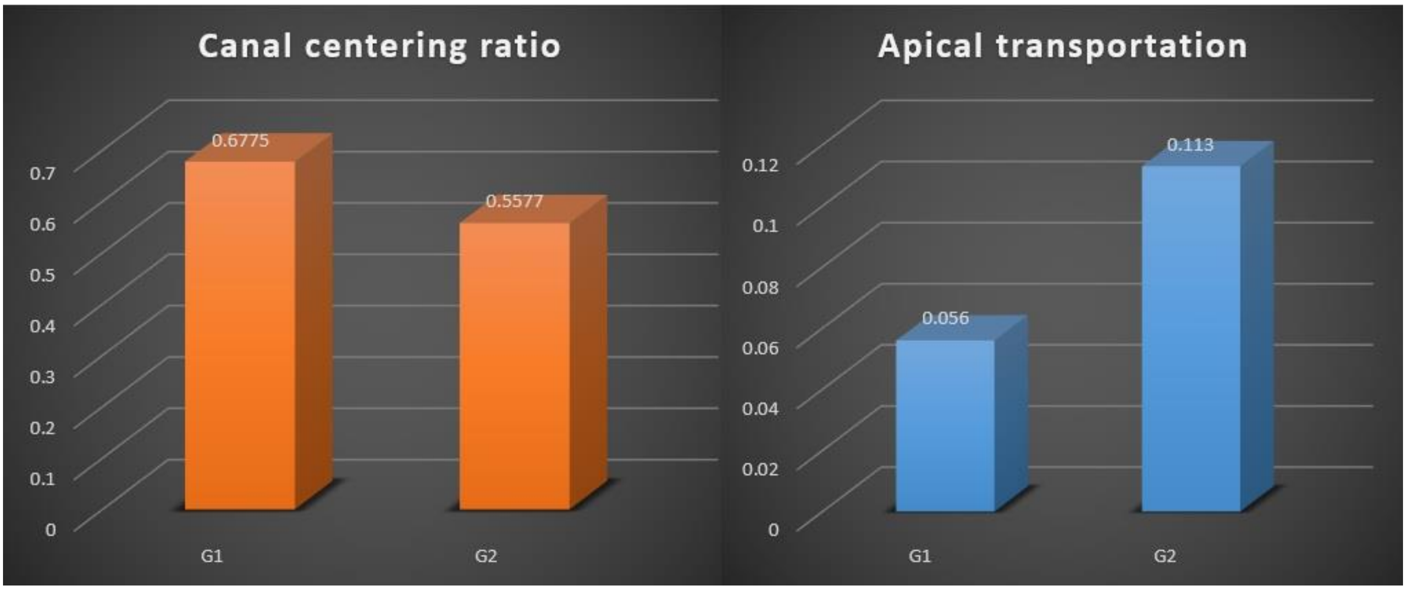
	Canal Centering Ratio								
	0mm			3mm			5mm		
	Mean	Std. Deviation	P value	Mean	Std. Deviation	P value	Mean	Std. Deviation	P value
Group 1 (WO)	.7530	.15553	.120	.6210	.24225	.274	.92	.6585	.003*
Group 2 (PTN)	.6555	.22577		.5425	.20352		.4750	.17443	

	Apical Transportation	
	Mean	Std. Deviation
Group 1 (WO)	.0560	.03331
Group 2 (PTN)	.1130	.19298
P value	.304	

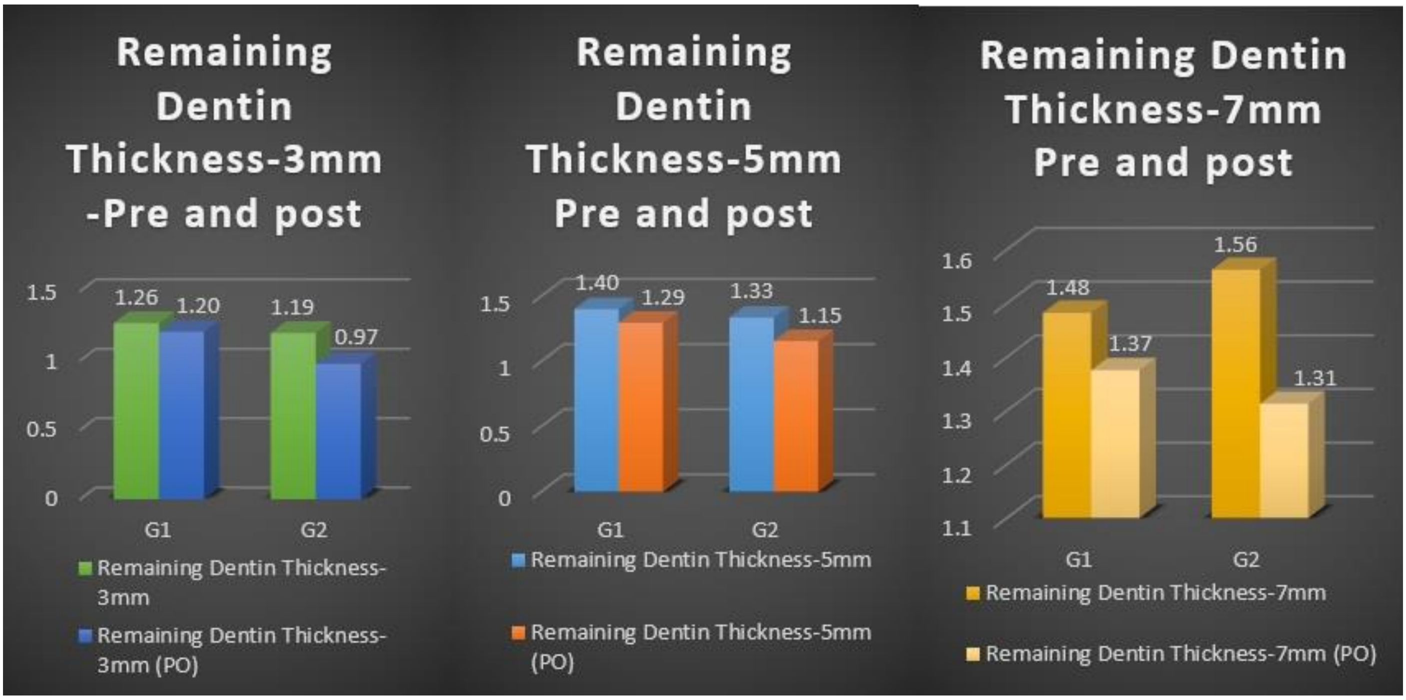
Group 2 (before and after instrumentation)

	Remaining Dentin Thickness					
	3mm		5mm		7mm	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Group 1 (WO)	1.26± 0.293	1.20±0.318	1.40±0.275	1.29±0.267	1.48±0.270	1.37±0.268
Group 2 (PTN)	1.19±0.305	0.97±0.261	1.33±0.390	1.15±0.265	1.56±0.306	1.31±0.253
P value (intergroup)	.720	.020*	.786	.221	.643	.716

GRAPH 1



GRAPH 2



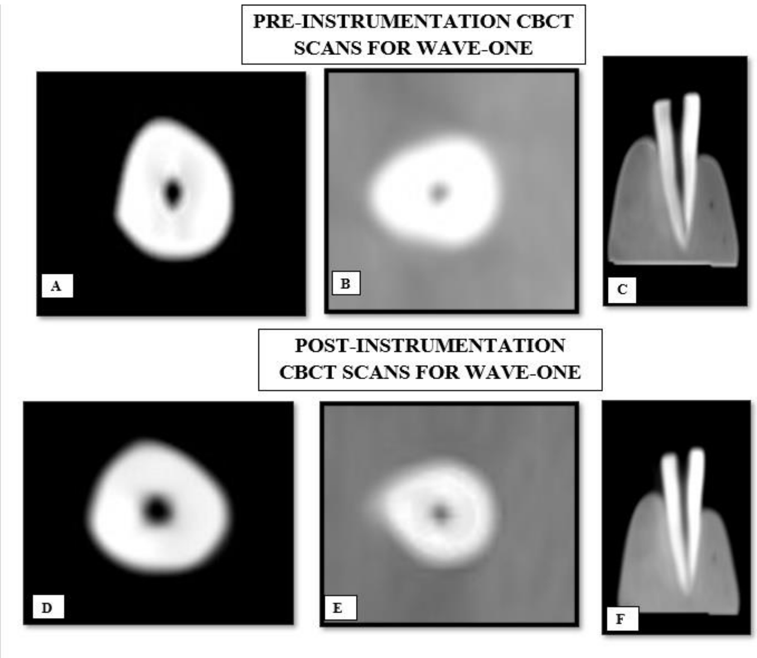


FIG 1: - Representative of CBCT images for Wave-one (WO) group. (A) Pre-instrumentation image for canal centering ratio; (B) Pre-instrumentation image for apical transportation; (C) Pre-instrumentation image for Remaining dentin thickness; (D) Post-instrumentation image for canal centering ratio; (E) Post-instrumentation image for apical transportation; (F) Post-instrumentation image for remaining dentin thickness

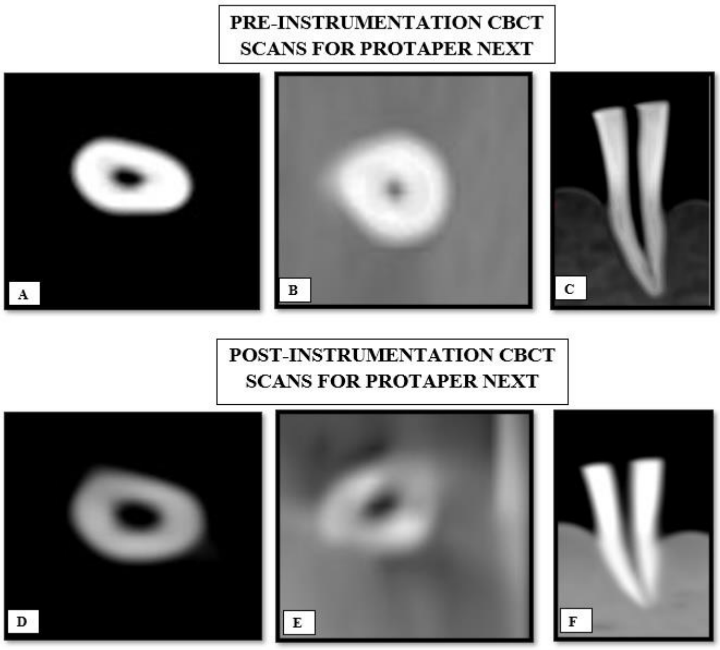


FIG 2: - Representative of CBCT images forProtaper Next (PTN) group. (A) Pre-instrumentation image for canal centering ratio; (B) Pre-instrumentation image for apical transportation; (C) Pre-instrumentation image for Remaining dentin thickness; (D) Post-instrumentation image for canal centering ratio; (E) Post-instrumentation image for apical transportation; (F) Post-instrumentation image for remaining dentin thickness