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COMPARATIVE STUDY OF CANAL TRANSPORTATION, CENTERING ABILITY AND VOLUMETRIC CHANGES OF DIFFERENT NICKEL-TITANIUM ROTARY SYSTEM USING CONE BEAM COMPUTED TOMOGRAPHY-AN IN VITRO STUDY

Endodontic

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ABSTRACT

AIM: To evaluateand compare the effect of different Nickel-Titanium system-Twisted File Adaptive (TFA), WaveOne and ProTaper Next (PTN) on canal transportation, centering ability and volumetric changes of mesiobuccalroot canal of mandibular molars via cone beam computed tomography (CBCT) imaging.

METHOD: Mesiobuccal root canals of 30 mandibular molars with angle of curvature ranging from 10-20˚ were divided randomly into three groups of 10 each. Canals were prepared to a tip size 25 using TFA, WaveOne and PTN. Pre and post instrumentation scans were performed to compare canal transportation and centering ability at level of2mm, 5mm and 8mm from CEJusing 3D CBCT images. Volumetric changes were estimated by comparing the difference in volume of root canals recorded before and after instrumentation of canal. One way ANOVA was used to compare canal transportation, centering ratio and volumetric changes between groups. All statistical procedures were performed with significance level set at 5%.

RESULTS: The result demonstrated that Gp I (TFA) and Gp II (WO) showed statistically significant difference in canal transportation at all three levels. Gp I and Gp II showed significant difference at coronal level only. All file systems based on different kinematics remained well centered in canal at all levels. There was no significant difference in volumetric changes among three Ni-Ti file systems.

CONCLUSION:PTN and TFN had similar results regarding canal transportation. WaveOne caused more canal transportation. All file system remain well centered. No significant difference in volumetric changes in root canals instrumented using three different Ni-Ti file systems.

KEYWORDS

Canal Transportation, Centering Ability, Cone Beam Computed Tomography, Protaper Next, Twisted File Adaptive, Waveone.

INTRODUCTION

The two primary goals of root canal instrumentation are: to provide a biological environment that is conducive to healing and conformable to sealing.[1]Objective of root canal preparation is to develop a shape that tapers from apical to coronal while maintaining the original canal shape.[2] Successful endodontic therapy depends on effective cleaning and shaping of root canal system while retaining the original root canal anatomy and thus minimizing unnecessary weakening of tooth structure. It is very difficult to maintain original root canal anatomy due to canal curvature, variation in cross sectional shape, presence of anatomical irregularities and there is always tendency of preparation techniques to divert the prepared canal away from original root canal axis.[3]

According to the Glossary of Endodontic Terms of the American Association of Endodontists, Canal transportation is defined as " Removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation; may lead to ledge formation and possible perforation." [4]Risk factors associated with canal transportation are degree and radius of canal curvature, cross section of file, design features, different alloys for manufacturing files, operator skills etc. Centering ability of file is the ability of file to remain centered in the root canal. It is influenced by the design of instrument(taper, flexibility, type of alloy) and root canal anatomy.

Over the last two decades progress has been made in manufacturing as well as alloy processing. Ni-Ti have undergone revolution regarding different designs to produce an instrument that can cut effectively while exhibiting resistance to fracture even in most challenging anatomical confines. All file systems have benefits and weakness. Instrument properties are derived from type of alloy, degree of taper, cross sectional design.

WaveOne (DentsplyMalliefer) was introduced as reciprocating system based on M-wire technology in 2011. It is singlefile system with modified convex triangle at tip and convex triangle at coronal end. It has variable pitch flutes along length of instrument considerably improving safety.[5]

ProTaperNext (asymmetric rotary motion) also based on innovative M-wire technology. It has variable tapered design and unique offset mass of rotation with swaggering movement.[6]

The TF™Adaptive technique has been proposed in order to maximize the advantages of reciprocation, while minimizing its disadvantages. The movement of the file depends on the stress rate in the canal that the file faces. When there is no stress on the file, the file rotates 600° clockwise and stops and then restarts again in the clockwise direction. In cases in which the stress rate on the file increases, the movement changes to reciprocation.TF™ instruments are created by taking a raw Ni-Ti wire in the austenite crystalline structure phase and transforming it into a different phase of crystalline structure (R-phase) by a process of heating and cooling.[7]

CBCT allows assessment of exact location and anatomy of root canals with less radiation exposure to patient and 3D representation of structures.[8,9]

Various studies have been done comparing canal transportation and centering ability using different file systems. Present in vitro study compares volumetric changes, canal transportation and centering ability using twisted file adaptive, WaveOne and ProtaperNext which are based on different kinematics.

MATERIALS AND METHODS

The research protocol was revised and approved by the Institutional Ethics Committee(IEC) Ref No.CODS/IEC/ 1837;2016-2017.

Thirty permanent mandibular molars, with completely separated roots and extracted for reasons not related to this study were selected and stored in saline at room temperature. Only teeth with moderate curvature (10-20)(Schneider's Technique) of mesial root were included. After access, canals not patent to its length with a size 10K file (Dentsply Maillefer) were discarded.Subsequently, each sample was randomly assigned into one of the 3 experimental groups (n=10) according to the system used for canal instrumentation: TFA,WaveOne and PTN.

ROOT CANAL PREPARATION

Samples were accessed with a diamond bur, and working length of canal was determined by introducing 10-K file into canal until it exited from the apex and apical patency was confirmed. Working length was set 1mm short of this length. Glide path was established with a size 15-K file(Dentsply Mallifer) up to working length for all three groups. Thereafter samples were subjected to preinstrumentationCBCT.

The samples in first group TFA group were prepared with single controlled motion (TFA program) of Elements Adaptive Motar, SM1(size 20, .04 taper) and SM2(size25, .06 taper) files according to manufacturer instructions.

In PTN group, X1(size17,.04 taper) and X2(size 25,.06 taper) instruments and WaveOne primary(size25,.08) using X-smart Plus endodontic motar on ProTaper mode at 300 rpm and 2N cm and WaveOne mode respectively using 6:1 reduction ratio handpiece as per manufacturer instructions.

Between instruments, canals were irrigated by applying 2ml of 5.25% sodium hypochlorite and saline. All instruments were cleaned after each use, each sequence were used four timesbefore beingdiscarded. Apical preparation was completed with size 25 instrument by using instrument order specified by manufacturer. Afterinstrumentation, specimen were scanned and post operative images were captured under same condition as initial scans and were analyzed before and after instrumentation for transportation and centering ability at cross sectional level of 2mm, 5mm and 8mm from CEJ using CBCT (Planemecapromax CBCT machine, 90 kV, 10mA for 13-15 sec)**(Fig 1,2**).Volumetric changes were analysed by comparing changes in canal volume in mm3 **.**

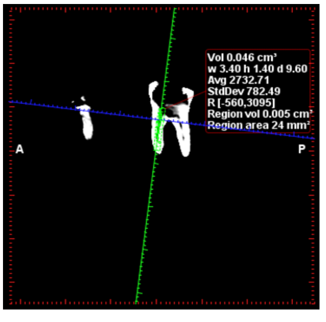

Fig 1

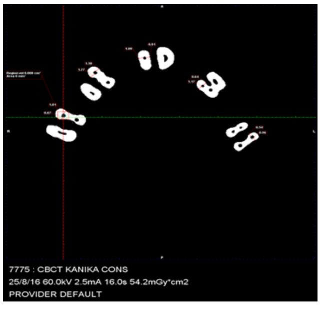

Fig 2

CANAL TRANSPORTATION AND CENTERING RATIO

Pre and post instrumentation measurements of mesiobuccal canal were performedusing the Romexis 6.1.2 Image Analysis software. Canal transportation and centering ratio were calculated at 3 cross section levels that correspond to 2mm, 5mm and 8mm distance from CEJ of root using following equations.[10]

Degree of canal transportation
(m1-m2)-(d1-d2)
Canalcentering ratio (m1-m2)/(d1-d2).

Where m1 is the shortest distance from mesial margin of root to mesial margin of uninstrumented canal, m2 is shortest distance from mesial margin of root to mesial margin of instrumented canal, d1 is the shortest distance from distal margin of uninstrumentedcanal and d2 is distance from distal margin of root to distal margin of instrumented canal.

Canal transportation equal to 0 means that no transportation occur, a negative value means that transportation occur in distal direction and positive value indicates transportation occur in mesial direction. In centering ratio, value equal to 1 indicated perfected centering ability of the instrument, while closer to 0 indicated a reduced ability of instrument to maintain in the central axis of root canal.

STATISTICALANALYSIS

ANOVA (one way analysis of variance) and Tukey's honest significance difference post hoc tests were run on data to determine significant difference between the groups. All statistical procedures were performed with cut off for significance at 5%.

RESULTS

Root canals instrumented with either PTN or TFA systems had similar canal transportation. WaveOne system had not well respected canal anatomy and caused more dentin removal and thus more canal transportation(Table1). No significant difference in centering ratio among groups(Table2).

Table1: Comparison of three groups (I,II and III) with respect to transportation scores at 2mm,5mm and 8(from CEJ)GpI TFA, GpII WaveOne,GpIII PTN

Groups	2mm		5mm		8mm	
	Mean	SD	Mean	SD	Mean	SD
Gp I	-0.37	0.44	-0.15	0.453	0.19	0.43
GpII	0.14	0.46	0.177	0.293	0.69	0.49
GpIII	0.28	0.52	-0.12	0.177	0.22	0.65

Table2:Comparison of three groups(I,II and III) with respect to centering ratio at 2mm, 5mm and 8mm

Groups	2mm		5mm		8mm	
	Mean	SD	Mean	SD	Mean	SD
Gp I	-0.21	2.33	1.16	1.02	0.99	1.42
GpII	2.39	3.23	-0.34	11.0	-3.17	8.05
GpIII	1.93	3.26	1.63	0.86	2.71	4.48

Table3:Intergroup comparison of canal transportation at three different levels i.e sub GpA(2mm from CEJ), Sub Gp B (5mm from CEJ) and Sub Gp C(8mm from CEJ) for three different file systems.

Group	P value Sub Gp A vs B	P value Sub Gp A vs C	P value Sub Gp B vs C
Group I	0.27	0.01	0.10
Group II	0.869	0.008	0.012
Group III	0.11	0.83	0.22

Table4:Intergroup comparison of canal transportation between three different groups at three different levels of root canals.

Sub group	P value Gp I vs II	P value Gp I vs III	P value Gp II vs III
Sub Gp A	0.023	0.007	0.537
Sub Gp B	0.038	0.871	0.081
Sub Gp C	0.043	0.901	0.108

Table 5: Comparative evaluation of volumetric changes between three different Ni-Ti systems

Volumetric changes	Mean±SD	p- value	F value
Group I	0.03±0.02	0.05	3.399
Group II	0.017±0.014		
Group III	0.014±0.013		

DISCUSSION

Root canal shaping is considered an essential step in endodontic treatment.[11] According to Schilder,[2] the preferred shape of the canal after mechanical shaping is a tapering funnel following the original shape and curvature of the canal, while keeping the original position of the foramen, and and size as small as practically possible.

Biomechanical preparation has been traditionally accomplished by hand files but most neglected phase of endodontic treatment during that time was inability to maintain the original root canal shape and apical curvatures. Weine[12] stated that files tended to straighten the root canals irrespective of instrument selection or techniques.

With the advent of endodontic files manufactured with Ni-Ti, which has low modulus of elasticity, three to four times more flexible than stainless steel files and higher resistance to torsional stresses. The increased flexibility of file has overcome all problems faced during instrumentation of canal with stainless steel files.After the advent of NiTi instruments, various improvements have been done in instrum entation techniques and instrument design. Very recently, focus has been shifted towards kinematics of instrument.

In the current study specimen instrumented with twisted file adaptive showed lesser canal transportation compared to wave one (reciprocating) (Table 4). The result of present invitro study is in agreement to study conducted by **Gergi et al** which stated that **adaptive motion** and flexibility of file due to **R- phase technology** can be the reason for less canal transportation at apical level compared to wave One (reciprocating).[13]

According to **Capar et al,** shaping ability of Ni-Ti instruments is multifactorial phenomenon related to kinematics, taper, cross section, design and metallurgy of file.[14]

WaveOne single reciprocating file with sharp cutting edges which lead to more cutting in canal wall and increased canal transportation as compared multiple file system.[22] Reciprocation does not affect internal rigidity of file and when the single, rigid file of greater taper of (25,8%) is slightly forced into canal, it will create **more canal transportation** than a more flexible one, due to inherent tendency to straighten.[5]

In the current study specimen instrument with Twisted file adaptive and ProTaperNext equally respected root canal anatomy at apical level (table 4) and this result is in accordance to study conducted by **Silva et al,**[15] they concluded that PTN and TFA had equally transported canal during instrumentation. In adaptive motion technology, there is change in motion from rotary to reciprocating depending upon intracanal stresses, providing increased file flexibility, resistance to fatigue and maintenance of cutting efficiency throughout.

PTN is manufactured with M-wire, a Ni-Ti alloy manufactured with thermal treatment process that reportedly increases flexibility and resistance to flexural fatigue while retaining cutting efficiency. Its asymmetric rotary motion due to offset design improves its shaping effectiveness.[16,17]

OTHER PROBABLE REASON COULD BE:

- Non- cutting modified safety tip of both file system
- Standardization of apical diameter size (25,6%)
- Small apical dimension of file at apical region, so little increase in flexibility

In this current in vitro study Wave One (Reciprocating) and Protaper Next (Rotary) showed no statistically significant difference in canal transportation. But, WO had caused more canal transportation apically which can be appreciated in Table 1 because increase in taper decrease file flexibility. This is in accordance to **Alrahabi et al** [14] they conducted a study comparing apical canal transportation between TF, OneShape, PTN and WO. They concluded that TF and OneShape caused less canal transportation than WaveOne and PTN, which could be due to similar design of these file system.[18] The PTN has progressive taper and WO has taper of 8% which may have affected apical transportation.

The result is also in accordance with study done by **Karatas et al,**[19] they concluded that when specimen were instrumented using twisted file using rotary and reciprocating motion, there was no significant difference in canal transportation and centering ability.

The result is not in accordance with study conducted by **Wu et al** [20]**and Toirano G etal**[21] which may be due to difference in methodology.

In this vitro study, there was significant difference in canal transportation at coronal level and middle level between twisted file adaptive and WO. This result is similar to study conducted by Kishore A et al,[22] where they compared canal transportation between WO, HyflexCM, TF,PTN at three different levels and concluded that WO lead greatest canal transportation at all three levels. This may be due to inherent rigidity of WO file as it is single, rigid file reaching till working length compared to twisted file which is manufactured in R-phase and by twisting rather than grinding.

In this vitro study, there was significant difference in canal transportation at **coronal level** between twisted file adaptive and Pro Taper Next (Table3). The bigger size of coronal and middle part of file due to taper affects file flexibility which is overcome by heat treatment of file (R-Phase technology) and manufactured by twisting of file. PTN file has progressive taper and offset rectangular cross sectional design.[23]

In this in vitro study there is no significant difference of canal transportation at middle level of root canal (Table 2b) as there was no significant contributory factor like apical canal curvature or variation in dimension of files, so both files system had equally transported canal at middle level. Both files proved to be equally efficient because of increased flexibility of TFA due to R phase and adaptive motion technology. PTN has increased flexibility due to M-wire technology and asymmetric rotation of motion.

In this invitro study, there was not much statistically significant difference in canal transportation at middle and coronal level of root canal compared to PTN (Table 3). The cross section and the surface treatment of the Wave One system increase their mechanical efficiency and contribute to a balanced action in CMP. However, the time required for instrumentation seems to influence directly the appropriate modeling of the root canal system. This may have been the reason why Wave One did not produce significant results in this study, corroborating with the results of Kim et al.[24] This indicates that the WaveOne single file system does not create excessive transportation compared with PTN, allowing inferring that the reciprocating systems are an effective alternative and tend to be routinely used in endodontic treatment, being a safe technique.

PTN has offset and progressive taper design, asymmetrical rotary motion which lead to greater envelope of motion,[14] which can be reason of comparable results between WO and PTN.

In this in vitro study TFA had produced no significant difference in canal transportation at all three levels which can be attributed to adaptive motion technology or may be due to its manufacture in R-Phase and by twisting process (table 1).

In this in vitro study WO had produced significant difference in canal transportation at apical level of root canal compared to middle and apical level (Schafer et al)[25] maintained that the size of a taper is one of the main factors involved in apical root transportation because an increase in the taper reduces instrument flexibility; therefore, recommended that Ni-Ti files with tapers greater than 4% should not be used to shape the apical area of curved canals.

In this invitro study PTN had equally transportedcanal at all three levels with no significant difference. It may be due to offset, progressive taper design with swaggering motion.[6] According to Mc Spadden,[26] less canal transportation occurs when the file has greater flexibility, an asymmetrical cross-section design and a radial land.

In this in vitro study all Ni-Ti file systems remain well centered in canal at all levels which might be due to

- R Phase manufacturing technology, twisting of file, adaptive motion which reduces intracanal stresses and all these lead to increased flexibility.
- Reciprocation motion which lead to reduced intracanal stresses and M-wire technology.
- Offset asymmetrical design with swaggering rotational motion and M-wire technology.

This in accordance with study conducted by **Capar ID,** [14] **Silva et al,** [15] they concluded that twisted adaptive and PTN and WaveOne had same centering ability.

The result is not in accordance to study conducted **Toirano G et al** [20]which concluded that PTN remained more centered in canal compared to WO, this might be due to difference in methodology because this study used photographic method and J-shaped resin block as specimen.

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In the current in vitro study there was not much significant difference in **volumetric changes** between three different groups because it is tendency of Ni-Ti files to remain centered, thus producing not much statistically significant difference in 3-D parameter like volumetric changes of canal. But WO had produced more volumetric changes compared with Twisted file adaptive and PTN. This result is in accordance to study conducted by **Gergi et al**, [27]they concluded that adaptive motion and flexibility of file might lead to lower volumetric changes as compared to Wave One (reciprocating).

Wave One Ni-Ti file system has taper of 25, 8% and it is single rigid file reaching till working length, which could be probable reason of increased volumetric changes of root canal.

This result is not in accordance with study conducted by **Alves et al,** [28]Twisted File Adaptive and Wave One had no significant difference in volumetric changes and might be explained as the consequence of the similarity regarding the dimensions of the final instrument used in each group (size 25, .08 taper) and the sample distribution based on 3D morphological parameters of the root canal.

WO and PTN had produced similar volumetric changes in root canal, the result is similar to the study conducted by Jain A et al. [3]

CONCLUSION

PTN and TFA had produced similar canal transportation in comparison to wave one.TwistedFile system result in exceptionaldebris removal and less chance of file pull in and debris extrusion as it is able to adjust to intracanaltorsional forces depending on amountof pressure placed on the file. File is twisted to shape for improved file durability, features R phase to improve file flexibility. Twisted file adaptive and adaptive motion, give best of both worlds.[29] So, cross sectional design and movement kinematics have great impact on effective biomechanical preparation.

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