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Research Article

CONE BEAM COMPUTED TOMOGRAPHY FOR CENTERING ABILITY, DENTIN THICKNESS AT CRITICAL CANAL FURCATION, CANAL TRANSPORTATION AND DENTIN VOLUME ANALYSIS USING RECIPROCATING K-FILE AND HYBRID TECHNIQUE RECIPROCATING-ROTARY PROTAPER ENDO SYSTEM-AN IN-VITRO STUDY

Abdulaziz A Al Eid*

College of Dentistry, Qassim University, Buraidah, Kingdom of Saudi Arabia

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A B S T R A C T

Aim: The aim of the present study was to compare and evaluate the root canal shaping ability of Hybrid combination of Nickel-Titanium reciprocating-rotary Protaper files and hand NiTi files in Endo-Express hand-pieces with "concept of Pre-prepared canal for Rotary".

Methodology: Forty canals straight and curved(20^0-30^0) of maxillary first premolars with two roots Buccal and Palatal were selected and randomly assigned to four experimental groups. Gr.1 (RPRT)s:Buccal straight roots (n=10) shaping was done with hybrid combination of alternate hand NiTi in endo-Express Reciprocating-rotary Protaper. Gr.2 (RP)s: Palatal straight roots (n=10) shaping was done with Hand NiTi K-files in Endo-Express hand-pieces in reciprocating motion. Gr.3 (RPRT)c: Buccal curved roots (n=10) shaping was done with hybrid combination of alternate hand NiTi in endo-Express Reciprocating-rotary Protaper. Gr.4 (RP)c:shaping was done with Hand NiTi K-files in Endo-Express hand-pieces in reciprocating motion. Cone Beam Computed Tomography used to assess Centring ability, canal transportation, Total dentin Volume loss and dentin thickness at furcation, Before and after canal preparation. Statastic Descriptive analysis with ANOVA and Tukey's post Hoc test was applied.

Results: There was no statistical significant difference at any level 1-,3-,5-,7-,and 9mm in centring ability and canal transportation of canal in all four groups (P>0.05). Total dentin volume loss for group (1 &2) was 6.64% and for group (3&4) was 7.86%. Dentin thickness at furcation Bs-1.52±0.02, Ps-2.07±0.28, Bc-1.45±0.15 and Pc-1.5±0.33 after canal preparation.

Conclusion: Hybrid combination technique of RPRT with the concept of pre-prepared canal is safest to use for Protaper Rotay without the fear of fracture of instrument. Excellent centring ability without any canal deviation can be achieved. The disadvantage is more armamentarium is required for good root canal preparation.

INTRODUCTION

The success of root canal treatment depends on many interrelated procedures. Access opening debridement of root canal removal of pulp tissue remnants, microorganism and microbial toxcins and root canal irrigation.(Basmadjian *et al*,2002).

The endodontic devices and the techniques for root canal preparation can be manual or machine assisted. The machine assisted endodontic files, allow faster and ease of instrumentation (Schäfer *et al*, 2004).

Corresponding author:* **Abdulaziz A Al Eid
College of Dentistry, Qassim University, Buraidah, Kingdom of Saudi Arabia

The machine assisted techniques consist of sonic and ultra sonic preparation, automated root canal preparation, Lasersystems and non-instrumental technique (Hülsmann *et al*, 2005). [3] With the introduction of rotary Nickel-Titanium (NiTi –files) instruments into endodontic practice, has improved the efficacy of endodontic practice of instrumentation technique, procedural time, centering accuracy and risk reduction as compared to previously used manual stiff stainless steel files.(Parashos *et al*, 2006; Taschieri *et al*, 2005; Schweiz 2005; Kobayashi *et al*, 1997).

Rotary NiTi instruments are widely accepted and studies demonstrated that NiTi files possess substantial improvement over the manual stainless steel files in resisting fracture caused due to bending and torsion (Walia *et al*, 1988). Protaper rotary files are designed, to provide, shaping and finishing canals, that are safe and efficient in preparing fully tapered shape

canals. A unique feature of the protaper is varying percentage of taper over the length of cutting blades the geometry of instrument can effectively cut dentin and also reduce torsional load, however aggressive cutting could produce increased canal transportation (Ruddle 2001).

The reciprocating endodontic instruments are developed with the aim of reducing incidence of cyclic fatigue or instrument breakage in the canal. The reciprocating motion can be described as clockwise and counter clockwise movement. The instrument rotates in one direction and reverses direction and travels a shorter angular distance than a rotary instrument, thus the reciprocating instrument is subjected to lower and lesser stress values caused by tension and compression. Consequently reciprocating files will have extended fatigue life as opposed to rotary file motion (Jeffery Wan *et al*, 2011). Reciprocal motion requires special automated devices like Endo-express handpiece. In general, the reciprocating canal shaping is an evolution of the balanced force technique that allows shaping of even severely curved canals with hand instruments to the larger diameters (Roane *et al*, 1985).

Cleaning and shaping of canal is a great challenge during root canal treatment. Preserving and maintaining canal anatomy and avoiding endodontic procedural errors are important for success. Centering ability of instrument in the canal is influenced by the design of the file-taper, flexibility, the type of alloy and the root canal anatomy (Moghadam *et al*, 2014).

The combination of instruments and file movements are developed with the aim of simplifying canal preparation technique, to improve the centralization, decrease canal transportation and reduce the risk of canal deformation during preparation (Berutti *et al*, 2012).

It has been observed that nickel-titanium files are safer with reciprocating movement than when used in continuous rotary motion.

The Maxillary first premolars have two roots, with wide range of anatomical variations. The roots are flattened in the mesiodistal direction. The furcation widely varies in Premolars and is located at the base of the pulp chamber apical to cementoenamal junction. The issue of remaining dentin thickness and dentin volume loss after root canal preparation needs to be evaluated. The internal anatomy of roots is ovoid with the bucco-lingual walls thicker and thin mesio-distal walls allowing files to remove more dentin in the mesio-distal direction (Pilo *et al* 2008).

Currently there are no studies available on combination of reciprocating –rotary (Hand NiTi files and Protaper) hybrid canal shaping technique with the concept of "pre-prepared canal for Rotary" and Hand Niti file in Endo-express handpiece used with reciprocating motion. And to compare centering ability, canal transportation, dentin thickness at furcation and total dentin volume loss, before and after root canal instrumentation, using cone beam computed tomography.

MATERIALS & METHODS

After ethical clearance and approval from the research ethical committee, College of Dentistry, Qassim University, twenty extracted mature intact maxillary first premolars with similar dimensions and shape, and with buccal and palatal roots were selected, so as to have total forty (n=40)samples. All selected teeth were examined under Endo operating microscope (Carl Zeiss Meditec AG, Jena, Germany) for normal Anatomy. Teeth were randomly divided into four groups. Group1 (RPRT)S : (n=10) straight buccal roots. Group2 (RP)S: (n=10) straight palatal roots. Group3 (RPRT)C: (n=10) 20-30 degree curvature buccal roots and Group4 (RP)C: (n=10) 20-30 degree curvature palatal roots. The ten teeth with straight roots were embedded 2mm from cemento-enamel junction(CEJ) in the elastomeric impressiom material (aquasil putty , Australia) upper rubber base mould , similarly ten teeth with curved roots were mounting identically. Teeth were placed in the maxillary arch form in bucco-palatal and vertical orientation aligned with the long axis of the root, perpendicular to the cone beam. Galileos (Dentsply Sirona, Germany) 3D x-ray unit for cone beam computed tomography (CBCT). 3D image acquisition was performed using the CBCT unit (98kV, 6mA, voxel size0.25mm, field of view 15cm, scan time 14sec, The sidexis 4 proprietary software open source software was used. All CBCT measurements were performed by a single experienced investigatorScan and perfect repositioning of tooth before and after root canal instrumentation. . After the scan the crowns were separated at CEJ with thin Diamond disc so as to avoid any hindrance during root canal instrumentation. All the parameters were evaluated at five levels at 1mm, 3mm, 5mm, 7mm, 9mm from apex towards orifice.

Group 1(RPRT)S: (Hybrid Technique Reciprocating-Rotary combination(RPRT), Straight roots (S):

A size #10 K file was used as a patency file, and #15 K file was used for canal glide path. Working length for each root canal was established at the 0.5mm short of apex. Irrigation of the root canal was done with 3% sodium hypochlorite in 2 ml syringe 27 gauge curved needle and Ethylene diaminetetraacetic acid (EDTA) MD-chelcream (MetaBiomed, Korea) was used as lubricant during preparation of the root canals. Instrumentation for straight premolar buccal root canal (n=10) was done with the modified Hybrid technique using reciprocating –rotary combination. The reciprocating (RP) Endo- Express EX series (NSK EX1 reduction ER16, Japan) 16: 1 reduction contra-angle, 60 degree reciprocating , 1200 RPM connected to E-type motor was used for hand K-files # 15 to #35 (Mani NiTi, Japan)an ISO 0.20 taper and the ProTaper universal rotary endodontic file system (RT) from S1 to F2 (Dentsply Maillefer, Ballaigues, Switzerland) operated with the X Smart Endodomotor (Dentsply Maillefer, Japan) speed 300 RPM, torque 2.5 Ncm was used for continuous rotary endodontic technique. Files Sequence for canal preparation was as follows: (RP) #15-#20,(RT)S1, (RP) #25, (RT)S2, (RP) #30-#35, (RT) F1-F2. Files were used in sequential order till the working length in each canal. Same files were used for all ten buccal root canals preparation. The hybrid technique of reciprocating-rotary combination was used to reduce stress on rotary file as well as root dentin and for better centering and avoid fracture of rotary endodontic instruments, and for proper cleaning and shaping of root canals.

Group 2 (RP)S: (Reciprocating instrumentation technique) (RP) Straight roots (S):

The working length, root canal irrigation and lubrication was with same protocol as group 1. Instrumentation of straight

palatal root canal (n=10) of premolars was done with Reciprocating Endo-Express hand –piece, the Endo Hand files will fit in the push button chuck head of the Endo-express hand piece, the sequence was as follows: RP #15-#20-#25-#30-#35. The root canals were prepared till working length with the same files for all ten palatal root canals.

Group3 (RPRT)C: (Hybrid Technique Reciprocating-Rotary combination(RPRT),Curved roots (C):

Cleaning and shaping was done for curved Buccal root canal (n=10) of premolars following the same technique as for Group 1.

Group4 (RP)C: (Reciprocating instrumentation technique) (RP), Curved roots:

The root canal instrumentation was done for (20-30 degree) curved Palatal root canal (n=10) of premolars with the same technique as for the Group2.

Evaluation of dentin thickness at root canal furcation

Root dentin thickness at the furcation was evaluated for all experimental groups 1 to 4, shortest distance from the canal outline to the closest adjacent furcation root surface was measured.

Evaluation of Centring ability of Endo file in the root canals

To evaluate and compare the instruments to remain centred in the root canal, the technique developed in 1996 by James Gambill. To determine the canal centring ratio, from the CT scan images the measurement of shortest distance from the inner edge of un-instrumented canal to outer periphery of the root in mesial (X_1) and distal (Y_1) direction, then comparing similar measurements obtained from the instrumented canal in mesial (X_2) and distal (Y_2). $[(X_1-X_2)/ (Y_1-Y_2)$ or $(Y_1-Y_2)/X_1-X_2)=1$ indicates result 1 as perfect centering of instrument in the canal. The results closer to 1, better the centring ability of the instrument in the canal. The mean centering ratio will indicate the ability of root canal instrument to stay centred. If these numbers were not equal than lower figures was considered as the numerator of the ratio. However, if result is closer to zero, the bad the ability is of the instrument to remain centred in canal.

Canal transportation evaluation

Canal transportation is an undesirable deviation taken by the endodontic instrument from the natural canal path. A technique to compare the degree of canal transportation was determined by measuring the shortest length from the inner edge of the un-instrumented canal to the outer periphery of the root in the mesial (X_1) and distal (Y_1) direction. And then comparing similar measurements obtained from the instrumented canals in mesial (X_2) and distal (Y_2) direction. The formula for calculation of root canal transportation used was $[(X1-X2) - (Y_1-Y_2)]$. According to the Gambill- formula, the result 0 will indicate no canal transportation and results other than 0 will indicate that the canal transportation has occurred. A positive result will indicate transportation towards mesial aspect; a negative result will indicate transportation towards the distal aspect of the canal.

Volume and Percentage of total dentin removal measured before and after instrumentation using ITK-SNAP version 3.6.0 software (Paul *et al*, 2006).

Statistics

One-way analysis of variance (ANOVA) followed by post hoc Tukey significant difference test were conducted to evaluated the significant difference in mean degree of canal transportation and centring ratio between the two canal shaping procedures. The level of significance was set at 0.05

RESULTS

Comparisions in both, straight root Buccal group 1 and Palatal group 2, and curved roots Buccal group 3 and Palatal group 4 showed no difference for centering ability in the 1 mm, 3 mm, 5mm, 7 mm and 9 mm cervical, middle and apical third ($p>0.05$) between the hybrid combination of Reciprocating-Rotary Protaper and the Reciprocating K –NiTi file hand file in Endo- Express handpiece (Table 1).

Regarding canal transportation recorded at different levels between four groups there were no significant statistical differences among all the experimental groups ($p>0.05$).

CT Comparison of dentin thickness recorded at premolar root furcation, group 2and group 4 Palatal roots have more remaining dentin thickness than group1 and group 3- Buccal roots.

Total Volume of dentin, before and after, instrumentation with Hybrid RPRT-combination and RP Hand NiTi in Endo-Express:

The total dentin volume before and after instrumentation for group1&2 was 262 mm^3 and 244.42 mm^3 and for group3 & 4 was 299.99 mm^3 and 276.42 mm^3 respectively. The percentage of total dentin volume loss for group 1& 2 was 6.64 % and for group 3 & 4 was 7.86 %.

DISCUSSION

Endodontic instruments used in cleaning and shaping of the root canal should not deviate from the canal pathways and should maintain the canal Anatomy. Instrumentation can cause trajectory deviation in canal with endodontic mishaps leading to failure or unsuccessful endodontic treatment (Ounsi *et al*, 2011).

Compared to the stainless steel files, the super-elastic flexible NiTi files are superior in canal centering ability (Lee *et al*, 2011). From review of literature on rotary Endo system it was very obvious that the main drawback with NiTI file was unpredictable fracture due to torsional or cyclic fatigue. Reciprocating files are more resistance to these fractures Perez-Higueras *et al*, 2013). The reciprocating motion is an oscillating motion where the instrument rotates in clockwise direction and reverses in counter clockwise direction travelling shorter angular distance than an Endo rotary which subjects the reciprocating file to low stress (Jeffrey *et al*, 2011). In our present study we describe a new hybrid method for canal preparation, evaluated the root canal preparation using a combination of hybrid reciprocating-rotary technique and NiTI hand files in reciprocating Endo-express hand-piece. Using CBCT scanned images before and after canal preparation, the following parameters were assessed: Dentin thickness at furcation in premolar, canal transportation, centering ratio, and total dentine volume loss.

To evaluate the of canal centering ability various method like radiographic imaging (Sydney *et al*, 1991)

Kuttler's endodontic cube (Kuttler *et al*, 2001), cross-sectioning, optic microscopic investigation (Simon *et al*,2008), Bramante Method (Bramante *et al*, 1987), Longitudinal sectioning, photographic assessment and computer manipulation (Barthel *et al*, 1999) are used for analysis and assessment of root canal instrumentation. These methods are invasive, laborious, not accurate in repositioning of specimen before and after canal preparation and loss of specimens (Gambill *et al*, 1996). CBCT with innovative techniques non,-destructive and non-invasive, precise and accurate are used for the assessment of shaping ability of Endo files.

CBCT method produces 3D axial, sagital and coronal section scan images that are highly accurate and quantifiable (Gluskin *et al*, 2001). In our study CBCT scanned images, before and after canal instrumentation, were used to measure canal transportation and canal centering at 1mm, 3mm, 5mm, 7mm and 9mm apex to orifice. (Table 1)

Dentin thickness at furcation

Table 1 Dentin thickness at furcation before and after canal instrumentation.

Groups	Mean dentin thickness. Buccal and palatal (furcation to canal) in mm	
	Before instrumentation	After instrumentation
1 (RPRT)s	1.699	1.519
2 (RT)s	2.41	1.631
3 (RPRT)c	1.77	1.45
4 (RP)C	1.65	1.51

Various studies investigated rotary NiTi instruments for cleaning and shaping of root canal in extremely curved canals have shown that NiTi files maintained the original canal shape (Glosson *et al*,1995; Park, 2001; Jardine and Gulabivala, 2000).

For evaluation of possible errors and deviations occurring during canal shaping, centralization of endo files in the root canal is an important factor in canal preparation (Aguiar *et al*, 2013)

The kinematics movements and the file sequence will influence the centring ability. In the present study the centring ability of RP-RT and RP in coronal, middle and apical third of root canal good, without and deviation in the canals. In the group 1 &2 with straight canals there was perfect centring during shaping, however in the group 3 & 4 with cured roots there was statistically no significant difference, but the canal preparation was more on the distal side of the canals as shown through the results.

Mean dentin thickness at furcation was evaluated and the results are as shown below in the (Table 2) for remain dentin before and after canal instrumentation. The remaining dentin thickness at the furcation, may indicate the safety of Endo files system in shaping the root canal. An ideal Endo file removes equal dentin from canal walls, simultaneous debride the canal without cutting excess root dentin. The evaluation of dentin thickness at furcation was to confirm the hybrid combination canal shaping technique will not cause excessive dentin removal or thin dentin at critical area. (Table 2)

In a study on apical canal transportation it was stated that if deviation is >0.3mm the canal obturation and treatment outcome will decrease significantly (Moghadam *et al*, 2014).

Instruments Centering ability

Table 2 Centring ability for reciprocating-rotary (RPRT) and rotary (RP) at five levels from apex to coronal third. Mean±SD

Group	Level	Mean±SD	p-value
1 (RPRT)S		1.39±.26	
2 (RP)s	1 mm	1.01±.18	0.226
3 (RPRT)c		0.96±.83	
4 (RP)c		0.93±.21	
1 (RPRT)s	3 mm	1.3±.78	0.805
2 (RP)s		1.2±.39	
3 (RPRT)c		1.1±1.0	
4 (RP)c		1.0±.20	
1 (RPRT)s	5 mm	.62±.31	0.436
2 (RP)s		1.1±.21	
3 (RPRT)c		.85±.21	
4 (RP)c		1.03±.51	
1 (RPRT)s	7 mm	1.27±.81	0.359
2 (RP)s		.96±.18	
3 (RPRT)c		.92±.29	
4 (RP)c		1.03±.31	
1 (RPRT)s	9 mm	.94±.14	0.289
2 (RP)s		1.1±.15	
3 (RPRT)c		1.02±.15	
4 (rp)c		1.05±.20	

In our study the mean apical canal deviation were 0.07mm, -0.01mm, 0.08mm, and -0.02 for group1-4 respectively, the values for apical third canal transportation were close to zero for all 1-4 groups, with no significant canal transportation in any study group (Table 3).

Canal transportation

Table 3 Mean ±SD for canal transportation in four groups at designated root levels.

Groups	Level	Mean±SD	p-value
1 (RPRT)S	1 mm	0.05±0.22	0.223
2 (RP)s		0.07±0.13	
3 (RPRT)c		0.08±0.04	
4 (RP)c		0.02±0.05	
1 (RPRT)s	3 mm	0.3±0.17	0.844
2 (RP)s		0.02±0.5	
3 (RPRT)c		0±0.01	
4 (RP)c		0±0.05	
1 (RPRT)s	5 mm	0.08±0.35	0.814
2 (RP)s		0.08±0.04	
3 (RPRT)c		0.04±0.06	
4 (RP)c		0.07±0.08	
1 (RPRT)s	7 mm	0.04±0.18	0.403
2 (RP)s		0.01±0.05	
3 (RPRT)c		0.01±0.48	
4 (RP)c		0.01±0.06	
1 (RPRT)s	9 mm	0.02±0.06	0.198
2 (RP)s		0.02±0.04	
3 (RPRT)c		0.01±0.02	
4 (RP)c		0.01±0.03	

The main reason for this is because combination sequence of reciprocating hand NiTi file 0.02% taper in Endo-express hand piece and followed by rotary ProTaper allowed the pre-prepared-canal for ProTaper an ease canal shaping, with minimal stress on rotary instrument. Thus the instrumentation technique, file and tip design will attribute to follow canal antomy without deviation. Though instrumentation is moving towards single file, the Hybrid combination will be extremely useful in narrow calcified and thin canals, and also it will prevent torsional and cyclic fatigue of instrument thus enhance the quality of root canal treatment. The results of present study are aligned with previous studies (Stern *et al*, 2012; Shruthi and Sreenivasa, 2010). Peters (2003) concluded that Protaper is more useful in flat canals than wide and immature canals.

In our study the hybrid combination RPRT and RP showed excellent centring ability. Centring ability, at five levels, for all four groups were very close to ratio1 with no significant difference in straight and cured canals. The possible reasons are, first, the reciprocating file motion creates balanced force during shaping that keeps the instrument centered in the canal, second the concept of pre-prepared canal for Protaper. Third, the non-cutting tip guides the instrument penetration with minimal pressure (Hashem *et al*, 2012).

In curved or straight canals, if the file fails to remain centered it could result in ledge, elbow, zipping or transportation. To avoid mishaps hybrid combination technique is advocated.

In this study total dentin volume, before and after instrumentation, was obtained. The mean volume of teeth, before and after instrumentation, for group 1 &2 was 262 mm^3 and 244.42 mm^3, for group 3 & 4 was 299.99 mm^3 and 276.42mm^3. The percentage of the preoperative hard tissue tooth dentin volume lost was as low as 6 to 8 % for root canal preparation.

The average percentage of dentin volume loss was 6.64% for straight root group 1 & 2 and 7.86% for curved root group 3 & 4. it is an acceptable, conservative and the combination RPRT technique is comparable to standard Endo canal shaping technique. There is significant statistical difference in loss of total dentin volume before and after instrumentation as shown in table 4, however, there is no statistical difference in total denti volume loss with straight roots (Gr.1&Gr.2) and curved root (Gr.3 &Gr.4) (Table 4)

Total dentin volume, Mean and Standard deviation

Table 4 Dentin loss, before(bp) and after(ap) instrumentation.

Root groups	TDV(bp) Mean ±SD in mm^3	TDV(ap) Mean ±SD in mm^3	TDV percentage loss Mean ±SD in mm^3
Straight (G.1&G.2)	262 ± 44.55	244.43 ± 45	6.63 ± 4.86
Curved (G.1 &G.2)	299.99 ± 43.87	276.51± 42.08	7.86 ± 1.81

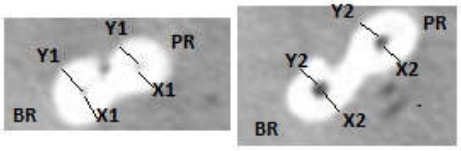

Fig 1 Mesial and distal dentin thickness, before and after root canal instrumentation, for (BR-buccal root and PR- palatal root of premolar)

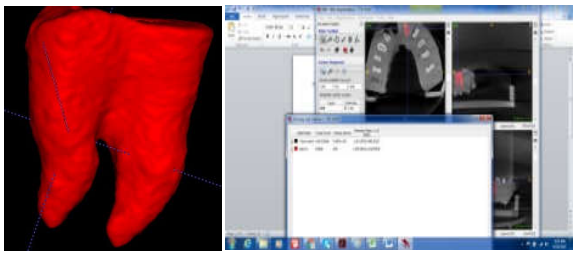

Fig 2 Volumetric hard tissue analysis before and after root canal instrumentation.

CONCLUSION

Hybrid combination technique of hand NiTi in Endo-Express handpiece reciprocating-Protaper Rotary with the concept of pre-prepared canal is safest to use for Protaper Rotary without the fear of fracture of instrument. Excellent centering ability without any canal deviation can be achieved. The disadvantage is more armamentarium is required for good root canal preparation.

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