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Canal Centering, Transportation and Curature Using 5th Generation NiTi Rotary Systems

Dr. Sudha B. Mattigatti1 Professor & HOD Conservative Dentistry ,
Dr. Neelam Manohar Patil2 P.G. Student
Dr. Saleem Makandar3 Reader
Dept. of Conservative Dentistry and Endodontics
Krishna Institute Of Medical Sciences, "Deemed To Be University", Karad (Dist. Satara), Maharashtra, India-415110

Abstract

Cleaning and shaping of the root canal space is the primary objective of endodontic therapy. Its purpose is to prepare the canal space in order to improve disinfection with the use of irrigants as part of chemo mechanical preparation. Infiltration and subsequent infection of the root canal system by microorganisms and their byproducts is the primary etiology of endodontic pathosis. Chemo-mechanical preparation aims to remove microorganisms, remaining pulp tissue and dentin debris from the root canal system.

The main objective of shaping is to maintain or develop a continuously tapering funnel from the canal orifice to the apex; however the complex canal anatomy causes instrumentation challenges, which may prevent adequate disinfection of the root canal system, or cause procedural errors such as instrument separation, transportation, ledges or perforations. The present study was set out to determine canal centering ability, transportation and curvature using 5th generation NiTi rotary systems as mentioned above.

Key Words: root canal space, Infiltration, infection, microorganisms, Chemo-mechanical, canal anatomy

Introduction

Nickel-Titanium alloy (NiTi) was introduced to endodontics by Walia et al in 1988. In 1993 when Serene et al. extensively tested and marketed the first Ni-Ti rotary files, some of the more than 30 current Ni-Ti instruments systems in the market are classified according to their design, shaping characteristics, breakage potential, and clinical performance. Out of which shaping or centering ability, which is the ability of an instrument to remain centered in the root canal system is the most important characteristic to be studied. A number of studies on both extracted teeth and simulated canals have shown that rotary NiTi instruments allow more rapid, more centered canal preparations than stainless steel instruments. The centering ability of different rotary NiTi instruments was also compared according to their design features such as taper, tip and cross-sectional design.

The new and more flexible instruments work more efficiently and safely thus preventing unwanted changes when shaping curved canals. With advent of instruments manufactured from nickel titanium alloys (NiTi), there is significant improvement of quality of root canal shaping, with predictable results and less iatrogenic damage, even in severely curved canals.

Recently a new concept for NiTi files has recently been introduced with asymmetric cross sections that finish root canal shaping. The 5th generation single file system, One Shape file (OS, Micro Mega, Besancon, France) is one of the few single file instruments used in continuous clockwise rotational motion for quick and safe root canal preparation. The OS file has an asymmetric cross-sectional geometry that generates traveling waves of motion along the active part of the file.

The ProTaper Next (PTN, Dentsply Maillefer, Ballaigues, Switzerland) is another NiTi file system which has three significant design features including progressive percentage tapers on a single file; M-wire technology and off set design which in turn decreases the dangerous taper lock and screw effect by minimizing the contact between a file and dentin.

Revo S (RS) is a sequence of 3 NiTi files with an asymmetric cross section which facilitates penetration by a snake like movement and offers root canal shaping which is adapted to biological and ergonomic imperatives. Sequence of Revo S facilitates upward removal of generated dentin debris.

Aim and Objectives

The Aim is to evaluate and compare the shaping ability of three different 5^{th} generation nickel titanium rotary systems in curved root canals using CBCT. The objectives are threefold:

(i) To evaluate centring ability using three different rotary systems: One Shape (Micro Mega, Besancon, France), Pro Taper Next PN (Dentsply Tulsa Dental Specialities, Maillefer), Revo S (Micro Mega, France).

(ii) To evaluate canal transportation using three different rotary systems: One Shape (Micro Mega, Besancon, France), Pro Taper Next PN (Dentsply Tulsa Dental Specialities, Maillefer), Revo S (Micro Mega, France).

(iii) To evaluate canal cuvature after using three different rotary systems: One Shape (Micro Mega, Besancon, France), Pro Taper Next PN (Dentsply Tulsa Dental Specialities, Maillefer), Revo S (Micro Mega, France).

Review of Literature

S. Kakehashi, H.R. Stanley, R.J. Fitzgerald in 1965 studied the effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats with a normally complex microflora. The pulp tissues of these rats were exposed by drilling through the occlusal surface of the maxillary right first molar with a carbide round bur mounted in a jeweler's spindle-topped hand mandrel. After varying postoperative time intervals (1 to 42 days), the animals were killed and the appropriate tissues were serially sectioned. By the eighth day, vital pulp tissue remained only in the apical half of the roots in the conventional animals. Complete pulpal necrosis with granulomas and abscess formation occurred in all older specimens. Evidence of repair was uniformly lacking.

H. Schilder in 1974 conducted a review on cleaning and shaping of the root canal. In order to achieve a predictable outcome, the “root canal system must be cleaned and shaped; cleaned of their organic remnants and shaped to receive a three-dimensional hermetic filling of the entire root canal space. Cleaning and shaping mechanics (design objectives for gutta percha cases, tapering funnel preparation, cross-sectional diameter, canal preparation and original canal, position of the foramen, small apical opening), design objectives for silver cone cases, biologic objectives of cleaning and shaping (confine instrumentation to the root canals, beware of forcing necrotic material beyond the foramen during canal preparation, remove all tissue debris from the root canal system, try to complete the cleaning and shaping of single canaled teeth in one visit and, whenever possible, prepare multi-canaled teeth one at a time, create sufficient space during canal enlargement to receive intracanal medicaments and to accommodate small amounts of periapical exudate), instruments for cleaning and shaping (barbed broaches, reamers and files, engine driven instruments, instrument stops), radiographic control, clinical preparation of root canals (serial reaming and filing and recapitulation), clinical preparation to receive gutta percha and silver cones.

Walia HM, Brantley WA, Gerstein H in 1988 investigated the bending and torsional properties of Nitinol root canal files. Fluted cross sectional shaped was machined on Nitinol wire blanks, .020 inch in diameter. This is different than the conventional manufacturing of twisting the blank. They were made with a triangular cross section and to a size 15, for comparison with a stainless steel file of the same size and same manufacturing process. The files were tested in three mechanical modes for cantilever bending, clockwise torsion, and counter clockwise torsion. There were five replicas of each group to compare the properties in a chart in regards to relative flexibility and resistance to fracture in torsion. The files were also examined under an SEM after manufacturing and after failure. The Nitinol files had considerably greater elastic flexibility in all three testing modes, with it being near 2 to 3 times greater. Permanent deformation was present with SS at 30 degrees; however elastic deformation was seen with Nitinol at 90 degrees. The Nitinol files also exhibited greater resistance to fracture in torsion than the SS files.

Glossen CR, Hiller RH, Dove B, del Rio CE in 1995 compared of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. This study used a modified Bramante technique and new digital subtraction software to compare root canals prepared by nickel-titanium (Ni-Ti) hand, NiTi engine-driven, and stainless steel hand endodontic instruments. Sixty mesial canals of extracted human mandibular molars were randomly divided into five groups. The roots were embedded in clear resin and cross-sectioned in the apical and mid-root areas.

Kum KY, Spängberg L, Cha BY, Il-Young J, Msd, Seung-Jong L, et al. in 2000 compared shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. Prevalence of canal aberrations, change in working length, and preparation time were measured.

Thompson SA in 2000 conducted a review on nickel-titanium alloys used in dentistry. The super-elastic behaviour of Nitinol wires means that on unloading they return to their original shape following deformation. These properties are of interest in endodontology as they allow construction of root canal instruments that utilize these favourable characteristics to provide an advantage when preparing curved canals.

Schäfer E, Dzepina A, Danesh G in 2003 compared the bending properties of different rotary nickel-titanium instruments and investigated the correlation between their bending moments and their cross-sectional surface areas. Resistance to bending was determined. The sample size was ten files for each type, taper, and size. The cross-sectional surface area of all instruments was determined by using scanning electron microscope photographs of the cross section.

Peters OA in 2004 discussed the current challenges and concepts in the preparation of root canal systems: a review. Nickel-titanium rotary instruments are important adjuncts in endodontic therapy. Despite the existence of one ever-present risk factor, dental anatomy, shaping outcomes with nickel-titanium rotary instruments are mostly predictable. Current evidence indicates that wider apical preparations are feasible. Nickel-titanium rotary instruments require a preclinical training period to minimize separation risks and should be used to case-related working lengths and apical widths. However, and despite superior in vitro results, randomized, clinical trials are required to evaluate outcomes when using nickel-titanium instruments.

Young GR, Parashos P, Messer HH in 2007 discussed the principles of techniques for cleaning root canals. Chemomechanical preparation of the root canal includes both mechanical instrumentation and antibacterial irrigation, and is principally directed toward the elimination of micro-organisms from the root canal system. A variety of instruments and techniques have been developed and described for this critical stage of root canal treatment. Since their introduction in 1988, nickel-titanium (NiTi) rotary instruments have become a mainstay in clinical endodontics because of their exceptional ability to shape root canals with potentially fewer procedural complications.

Mallet JP in 2009 conducted a review on, an instrument innovation for primary endodontic treatment: The Revo-S sequence. A new NiTi file sequence has been developed by Micro-Mega®. Its purpose is to simplify the initial endodontic treatment and to optimise the cleaning. The asymmetrical cutting profile of the Revo-S® facilitates penetration by a snake-like movement, and offers, a root canal shaping which is adapted to the biological and ergonomic imperatives.

Bernardes RA et al in 2010 compared the increase of the root canal area after instrumentation with EndoSequence or ProTaper rotary systems. Twenty-two mesial root canals from mandibular molars were instrumented. Teeth were mounted on a base, numbered, and divided into 2 groups; teeth from 1–11 (PT group) were instrumented by using the Pro- Taper system, and teeth from 12–22 (ES group) were instrumented by using the EndoSequence system. Cone beam computed tomography was performed on all teeth before and after instrumentation.

Pak JG, White SN in 2011 determined the influence of root canal treatment on pain prevalence and severity and estimates the prevalence and severity of pretreatment, treatment, and posttreatment pain in patients receiving root canal treatment. L’Abbe plots were used to evaluate the influence of root canal treatment on pain prevalence and severity. Pretreatment, treatment, and postreatment pain prevalence and severity data were analyzed. L’Abbe plots revealed that pain prevalence and severity decreased substantially after treatment.

Gergi R et al in 2012 compared the taper variation in root canal preparations among Twisted Files and PathFiles-ProTaper .08 tapered rotary files to current standards. Sixty root canals with severe angle of curvature (between 25º and 35º) and short radius (r < 10mm) were selected. The canals were divided randomly into two groups of 30 each. After preparation with Twisted Files and PathFiles- ProTaper to size 25 taper .08, the diameter was measured using computed tomography (CT) at 1, 3, and 16 mm. Canal taper preparation was calculated at the apical third and at the middle-cervical third. Of the 2 file systems, both fell within the ±.05 taper variability.

Pereira ES et al in 2013 compared physical and mechanical properties of one conventional and a new NiTi wire, which had received an additional thermomechanical treatment. Specimens of both conventional (NiTi) and the new type of wire, called M-Wire (MW), were subjected to tensile and three-point bending tests, Vickers microhardness measurements, and to rotating-bending fatigue tests at a strain-controlled level of 6%. Fractured surfaces were observed by scanning electron microscopy and the non-deformed micro-structures by transmission electron microscopy.

Ismail Davut Capar in 2014 compared different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals. Mesiobuccal root canals of one-twenty mandibular first molars with an angle of curvature ranging from 20º-40° were divided into 6 groups of 20 canals. Based on CBCT images taken before instrumentation, the groups were balanced with respect to the angle and radius of canal curvature. Root canals were shaped with the following systems with an apical size of 25: One Shape (OS) (MicroMega, Besancon, France), Pro Taper Universal (PU) F2 (Dentsply Maillefer, Ballaigues, Switzerland), Pro Taper Next X2 (Dentsply Maillefer), Reciproc (R) R25 (VDW, Munich, Germany), Twisted File Adaptive (TFA) SM2 (SybronEndo, Orange, CA), and Wave One primary (Dentsply Tulsa Dental Specialties, Tulsa, OK). After root canal preparation, changes were assessed with CBCT imaging.

Jason Gagliardi et al in 2015 evaluated the shaping characteristics of ProTaper Gold, ProTaper NEXT, and ProTaper Universal in curved canals using micro–computed tomographic imaging. Twenty-four mandibular first molars with 2 separate mesial canals were matched anatomically using micro–computed tomographic scanning with a voxel size of 19.6 mm. Canals were prepared with PTG, PTU, or PTN rotary systems to F2 or X2 instruments, respectively, and scanned again. Co-registered images were evaluated for 2- and 3-dimensional morphometric measurements of canal transportation, centering ability, untouched canal walls, and remaining dentin thickness.

Filipa Neto, António Ginjeira in 2016 did a comparative analysis of simulated root canals shaping, using ProTaper Universal, Next and Gold. Evaluation of the changes to the initial simulated root canal anatomy when comparing the preparation made by three different rotary systems: ProTaper Universal, ProTaper Next and ProTaper Gold. Methods: The quantitative analysis was made by measuring the canal width of 36 S-shaped canals, distributed by three groups of twelve samples each (Group A – ProTaper Universal, Group B – ProTaper Next, Group C – ProTaper Gold). To measure canal width, pre and post instrumentation images were superimposed and studied using Rhinoceros Software.

Giuseppe Troiano in 2016 assessed the influence of operator experience on: shaping and centering ability, mean preparation time and presence of canal aberrations of Pro Taper

Universal and Wave One systems on simulated root canals. Sixty S-shaped canals in resin blocks were assigned to four groups (n=15 for each group). Group1 (Experienced operator, Pro Taper), Group2 (Experienced operator, Wave One), Group3 (Inexperienced operator, Pro Taper), Group4 (Inexperienced operator, Wave One). Photographic method was used to record pre- and post-instrumentations images. After superimposition, it has been evaluated presence of canal aberrations and differences in shaping and centering ability between groups.

Martial and Methods

The present study was conducted in the Department of Conservative Dentistry and Endodontics, School of Dental Sciences Karad. The Cone Beam Computed Tomographic imaging was done in i-CAT, Insight CBCT Centre, Mumbai.

Materials:

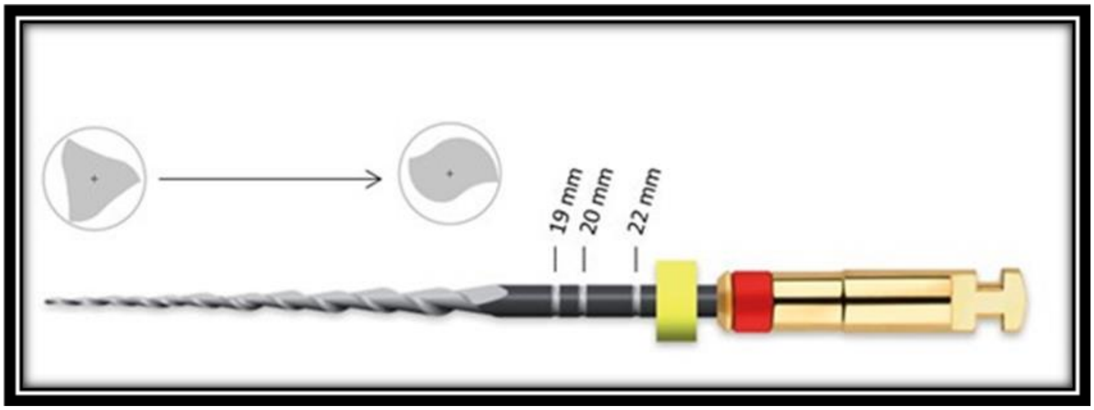
1. Old generation One Shape NiTi files (OS; Micromega, Besancon, France)
2. Pro Taper Next (PTN) (Dentsply Maillefer)
3. Revo S (RS) (Micromega, Besancon, France)
4. K files no. #10 and #15 (Mani, Japan)
5. Storage media - 0.9% saline solution.
6. Acrylic resin
7. Sodium hypochlorite (3%)
8. Ethylene diamine tetra acetic acid 17% (EDTA)

Armamentarium: (Fig 1)

1. Airotor hand-piece (NSK, Japan)
2. Ultrasonic scaling unit (EMS, Mini piezon)
3. Round diamond point (Mani BR-45)
4. Cylindrical diamond point (Mani SF-12)
5. Endo Z bur (Dentsply, Maillefer)
6. Tweezer (GDC)
7. Gloves
8. Mouth mask

Equipments used:

1. Cone Beam Computed Tomography (i-CAT, Insight CBCT Centre, Mumbai). (Fig 16)
2. Apex Locator (Root ZX mini, J Morita, USA) (Fig 1)
3. X Smart Endo Motor with 16:1 reduction gear hand piece. (Dentsply, Maillefer) (Fig 1)



METHOD OF SAMPLE COLLECTION:

Sixty sound human mandibular permanent molars, (Fig 2) extracted due to periodontal reasons or caries were collected from the Department of Oral and Maxillofacial Surgery. Samples were made free of debris and calculus. The teeth were cleaned with slurry of pumice. Samples were stored in 0.9% saline solution at room temperature till use. The study was performed on mesiobuccal root canals of extracted molars.

SELECTION OF SPECIMENS:

Radiographs of each tooth in both the buccolingual and mesiodistal directions were taken for selecting the right samples. Teeth with two separate mesial canals and no significant calcifications were included. Mesiobuccal root canals with curvatures ranging from 20° to 40° were selected. Radiographic images were digitized and with the aid of the AutoCAD 2012 software measurements were taken of the angle of curvature (in degrees) of the mesial root of each tooth. In order to measure the angle of curvature of the root, the Schneider method was followed, by tracing a line (w) parallel to the long axis of the root as from the canal opening orifices, and another (x) that began in the apical foramen and ended at the intersection with the first line, at the point where the curvature of the root began. The acute angle (α) formed by these two lines determined its degree of curvature. If the angle is less than 5°- the canal is straight; if the angle is 5-20°- the canal is moderately curved and if the angle is greater than 20°- the canal is classified as a severely curved canal. 60 teeth with 20 to 40^0 canal curvature were selected and divided into three groups. (*n* = 20)

GROUP A: ONE SHAPE

Old generation One Shape (OS) file having a taper of 0.06 and a tip size of 25 was used at a rotational speed of 400 rpm along with torque values of 4 Ncm. One Shape instrument was first taken down to two thirds of working length of each tooth using in and out movement (picking motion) without any pressure while performing an upward circumferential filling movement in order to pre enlarge the canal. File was withdrawn and cleaned. Irrigation with sodium hypochlorite (3%) was done and canal patency was checked.

One Shape instrument was again placed under rotation in the canal by taking 3mm from working length using previously described in and out movement without any pressure. The instrument was withdrawn and cleaned from debris and canal was irrigated and patency was checked.

One Shape instrument was placed under rotation into canal and was taken to working length, performing the picking motion without any pressure.

GROUP B: PRO TAPER NEXT

Pro Taper Next (PTN) files were used with the sequence Pro Taper Universal (PU) SX, PTN X1, and X2.

The original Pro Taper system offers the auxiliary shaping file, termed SX. Initially PU SX was used for radicular access at speed of 300 rpm and torque values of 4 Ncm. The SX file was used in a brushing manner on the outstroke, to pre-flare the orifice, which helps to eliminate triangles of dentin, relocate the coronal most aspect of a canal.

The PTN files were used at rotational speed of 300 rpm and a torque of 4 Ncm using outward brushing motion when progressively shaping canals.

In the presence of NaOCl, outward brushing motion was used and the glide path was followed, with the PTN X1 (17/04) file, in one or more passes until the working length was reached. After every few millimeters of file progression, file was removed to inspect and clean its flutes. Before reinserting the X1 file, irrigation was done to flush out gross debris, recapitulation was done with a #10 K file to break up residual debris and move it into solution and then again irrigation was done. In one or more passes, we continued with the X1 file until the full working length is reached.

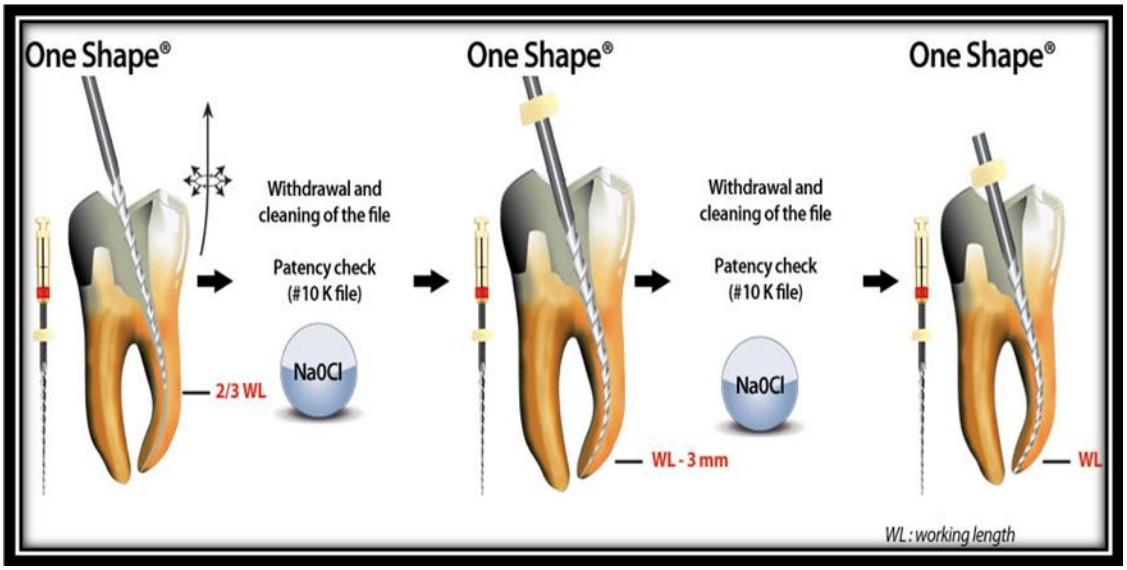
PTN X2 (25/06) was used to run inward. Lateral brushing motion was used against the dentinal walls, which, in turn enables the X2 file to passively and progressively advance inward. Then X2 file was used until the working length is passively reached.

For standardization cleaning and shaping with PTN was performed till PTN X2.

GROUP C: REVO S

Revo S (RS)[16] was used at rotational speed 400 rpm and torque values of 4 Ncm. SC1 (25/06) was used with slow and unique downward movement in a free progression and without pressure followed by SC2 (25/04) with a progressive 3 wave movement (up and down movement). Finally SU (25/06) was used with a slow and unique downward movement in a free progression and without pressure. Apical patency was then checked and an upward circumferential filing movement was done.

The canal was thoroughly irrigated using sodium hypochlorite (3%) between the uses of each instrument. The use of a chelating agent was done for instrument lubrication and dentine debris removal.



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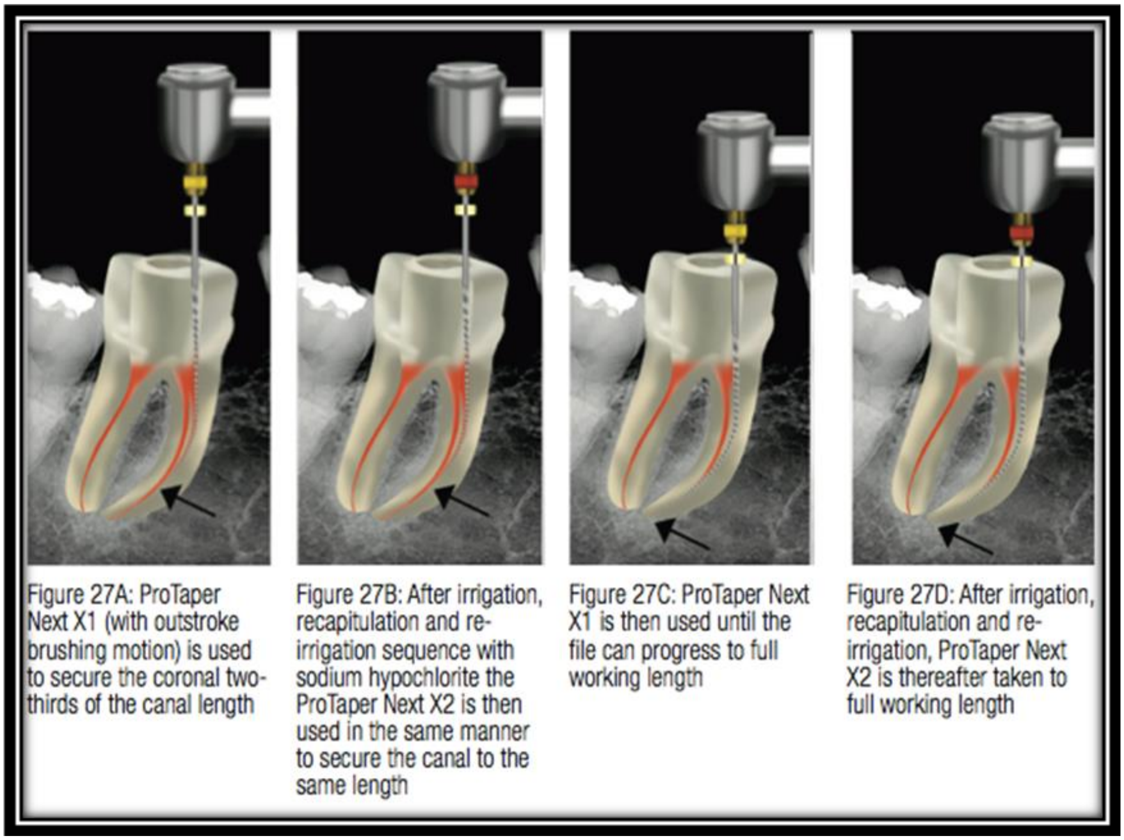

Figure 27A: ProTaper Next X1 (with outstroke brushing motion) is used to secure the coronal two-thirds of the canal length

Figure 27B: After irrigation, recapitulation and re-irrigation sequence with sodium hypochlorite the ProTaper Next X2 is then used in the same manner to secure the canal to the same length

Figure 27C: ProTaper Next X1 is then used until the file can progress to full working length

Figure 27D: After irrigation, recapitulation and re-irrigation, ProTaper Next X2 is thereafter taken to full working length

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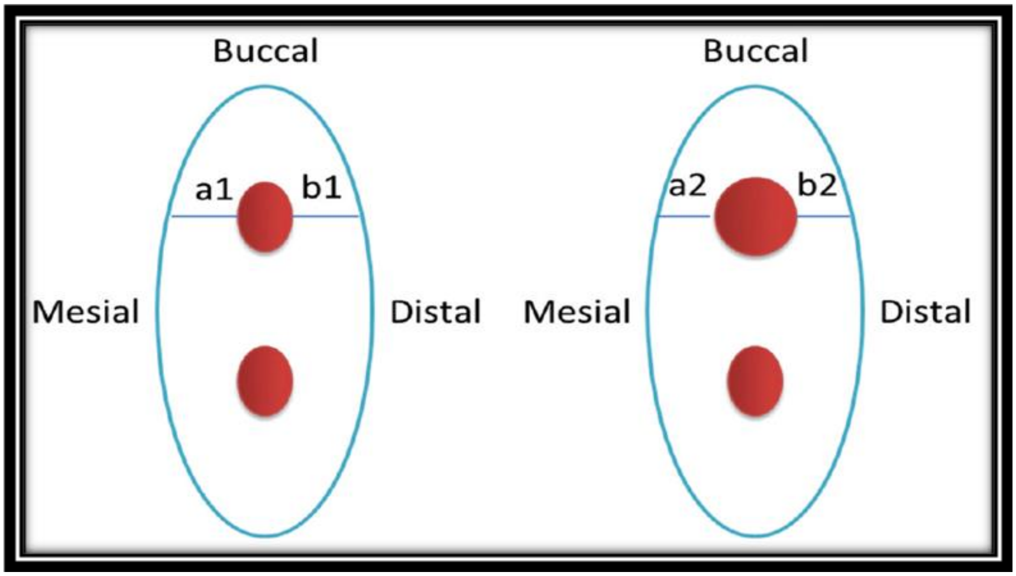
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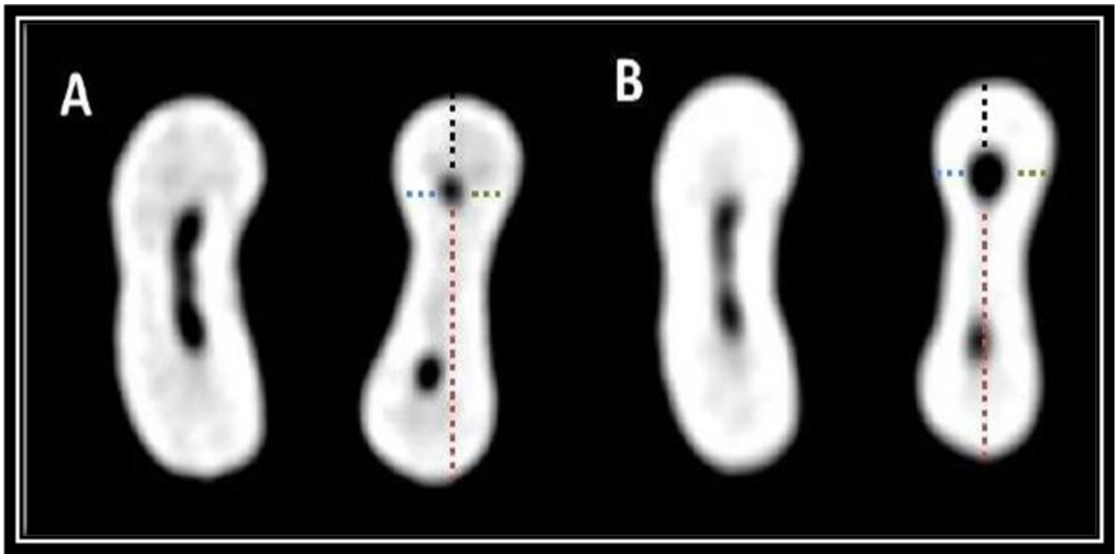
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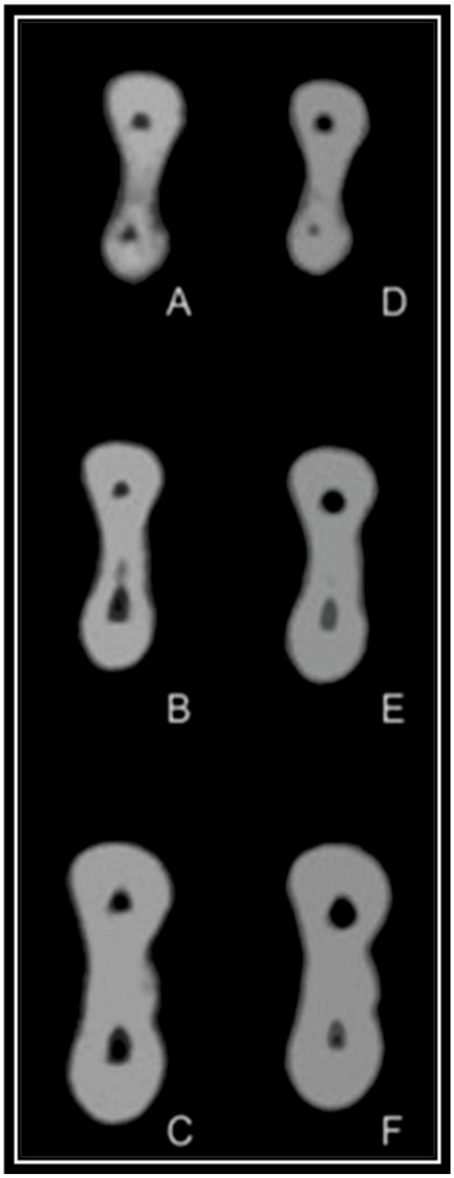
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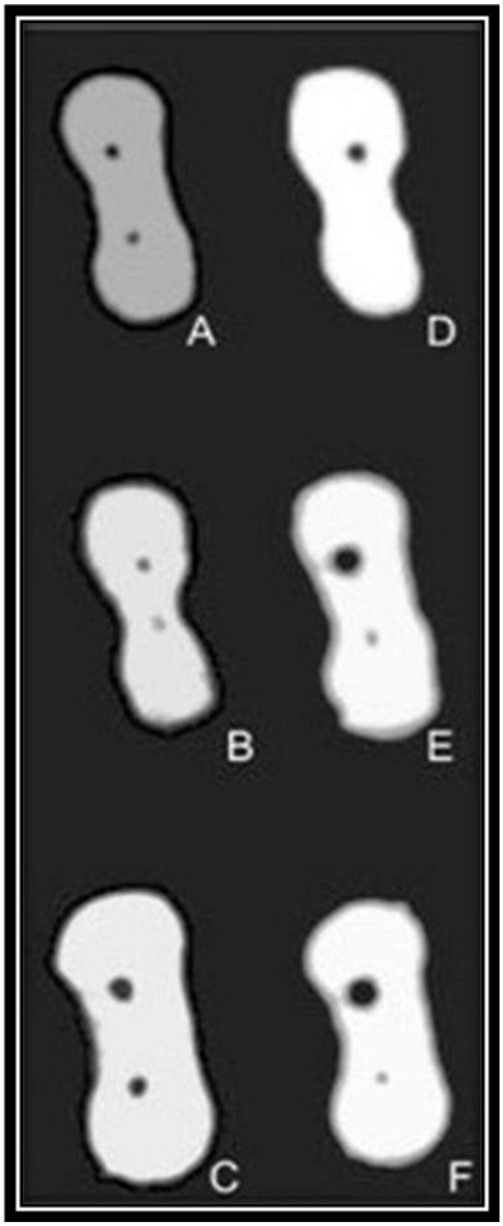
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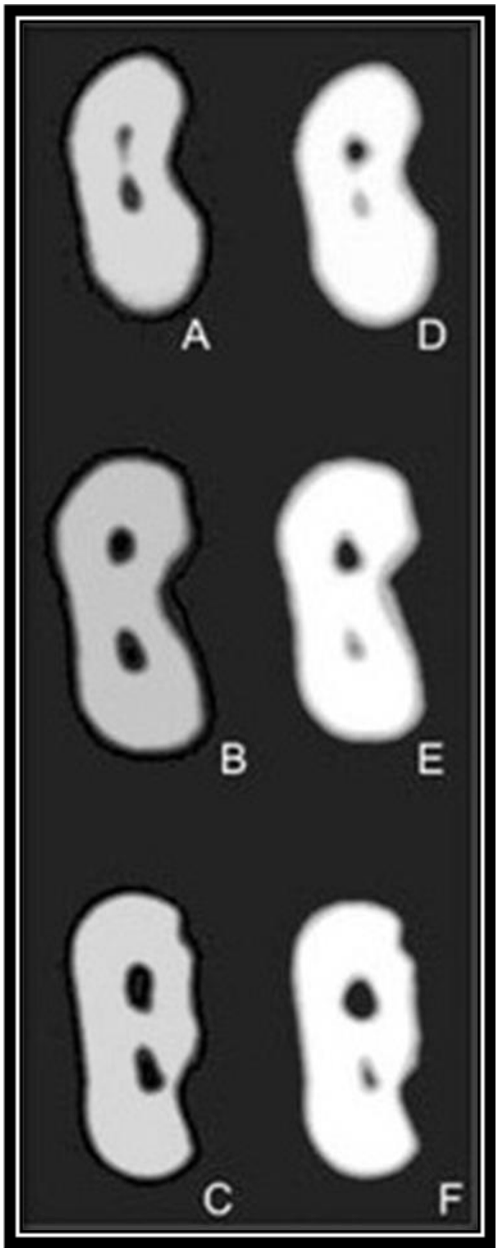

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RESULTS

The present in vitro study was conducted to evaluate canal transportation, centering ability and canal curvature with nickel titanium rotary instruments of 5th generation by using Cone Beam Computerized Tomography.

The statistical analysis was performed using Analysis of Variance (ANOVA) whenever a statistical significant difference was recorded, Pairwise comparisons between tested adhesives was performed using Tukey's HSD pairwise comparison test, at 95% level of confidence using SPSS version 20.0 software.

Table 1: GROUP A: ONE SHAPE (Canal Curvature)

No	Pre instrumentation (º)	Post Instrumentation (º)	Straightening (º)
1	28.3	25.2	3.1
2	29.2	25.2	4.0
3	30.3	27.2	3.1
4	28.4	24.3	4.1
5	29.6	25.1	4.4
6	29.5	25.1	4.4
7	28.4	25.3	3.1
8	29.8	25.4	4.4
9	27.4	24.1	3.3
10	29.6	26.2	3.4
11	28.4	24.1	4.3
12	30.2	26.1	4.1
13	27.4	23.2	4.2
14	28.8	24.4	4.4
15	27.2	24.4	2.8
16	28.2	24.1	4.1
17	29.8	25.3	4.5
18	29.4	26.2	3.2
19	30.8	26.6	4.2
20	28.4	25.2	3.2

Table 2: GROUP B: Pro Taper Next (Canal Curvature)

No	Pre instrumentation (º)	Post Instrumentation (º)	Straightening (º)
1	28.3	25.2	3.1
2	29.4	27.5	1.9

3	28.4	26.2	2.2
4	28.6	25.7	2.9
5	29.8	26.4	3.4
6	28.4	26.6	1.8
7	29.8	26.5	3.3
8	30.6	27.8	2.8
9	28.4	25.3	3.1
10	30.6	28.8	1.8
11	28.6	25.2	3.4
12	27.7	25.1	2.6
13	29.8	26	3.8
14	28.6	25.8	2.8
15	27.7	24.6	3.1
16	28.6	25.7	2.9
17	29.2	26.9	2.3
18	29.6	27.4	2.2
19	30.6	28.0	2.6
20	28.2	25.1	3.1

Table 3: GROUP C: Revo S (Canal Curvature)

No	Pre instrumentation (º)	Post Instrumentation (º)	Straightening (º)
1	28.6	26.3	2.3
2	29.8	27.6	2.2
3	30.6	27.9	2.7
4	28.4	26.5	3.9
5	29.6	26.9	2.7
6	30.4	28.6	1.8
7	30	26.4	3.6
8	28.6	26	2.6
9	29.2	27	2.2
10	30.6	28	2.6
11	28.4	26	2.4
12	29.5	26.1	3.3
13	28.6	26.2	2.4
14	30	27.6	2.4
15	28.2	25.2	3
16	29	26.9	2.1
17	28.6	24.9	3.7
18	29.6	27.2	2.4

19	30.4	27.6	2.8
20	30	27	3

Table 5: GROUP A: ONE SHAPE (Centering Ratio and Transportation)

Sr. No.	Group A SAMPLES	2mm	5mm	8mm	Sr. No.	Group A SAMPLES	2mm	5mm	8mm
1	Transportation	0.1	0.3	0.2	11	Transportation	0.1	0.1	0.2
	Centering ratio	0.5	0.25	0.2		Centering ratio	0.66	0.66	0.5
2	Transportation	0.2	0.3	0.4	12	Transportation	0.2	0.2	0.3
	Centering ratio	0.33	0.25	0.5		Centering ratio	0.5	0.5	0.25
3	Transportation	0.3	0.4	0.2	13	Transportation	0.2	0.3	0.3
	Centering ratio	0.25	0.2	0.33		Centering ratio	0.5	0.25	0.25
4	Transportation	0.2	0.2	0.3	14	Transportation	0.2	0.1	0.2
	Centering ratio	0.33	0.33	0.25		Centering ratio	0.33	0.5	0.5
5	Transportation	0.2	0.1	1.3	15	Transportation	0.1	0.3	0.2
	Centering ratio	0.33	0.66	0.25		Centering ratio	0.5	0.33	0.5
6	Transportation	0.3	0.2	0.3	16	Transportation	0.1	0.3	0.2
	Centering ratio	0.25	0.33	0.25		Centering ratio	0.5	0.25	0.33
7	Transportation	0.1	0.2	0.2	17	Transportation	0.2	0.3	0.3
	Centering ratio	0.66	0.6	0.5		Centering ratio	0.33	0.25	0.25
8	Transportation	0.2	0.2	0.3	18	Transportation	0.3	0.2	0.3
	Centering ratio	0.33	0.33	0.25		Centering ratio	0.25	0.33	0.25
9	Transportation	0.2	0.2	0.3	19	Transportation	0.2	0.3	0.2
	Centering ratio	0.5	0.33	0.25		Centering ratio	0.33	0.25	0.5
10	Transportation	0.3	0.1	0.2	20	Transportation	0.2	0.1	0.1
	Centering ratio	0.33	0.75	0.5		Centering ratio	0.33	0.66	0.5

Table 5: GROUP B: PROTAPER NEXT (Centering Ratio and Transportation)

Sr. No.	Group B SAMPLES	2mm	5mm	8mm	Sr. No.	Group B SAMPLES	2mm	5mm	8mm
1	Transportation	0.2	0.1	0.1	11	Transportation	0.1	0.1	0.2
	Centering ratio	0.33	0.5	0.5		Centering ratio	0.5	0.5	0.33
2	Transportation	0.1	0.1	0.2	12	Transportation	0.1	0.2	0.2
	Centering ratio	0.5	0.5	0.33		Centering ratio	0.25	0.33	0.33
3	Transportation	0.1	0.2	0.2	13	Transportation	0.1	0.1	0.2
	Centering ratio	0.5	0.5	0.5		Centering ratio	0.25	0.25	0.33
4	Transportation	0.1	0.2	0.1	14	Transportation	0.1	0.1	0.3
	Centering ratio	0.5	0.33	0.66		Centering ratio	0.5	0.5	0.25
5	Transportation	0.1	0.2	0.3	15	Transportation	0.1	0.2	0.1
	Centering ratio	0.5	0.33	0.25		Centering ratio	0.5	0.33	0.66
6	Transportation	0.1	0.1	0.2	16	Transportation	0.1	0.1	0.1
	Centering ratio	0.5	0.5	0.33		Centering ratio	0.5	0.5	0.66
7	Transportation	0.1	0.1	0.2	17	Transportation	0.1	0.2	0.2
	Centering ratio	0.5	0.5	0.33		Centering ratio	0.66	0.33	0.5
8	Transportation	0.1	0.1	0.1	18	Transportation	0.1	0.1	0.1
	Centering ratio	0.66	0.5	0.5		Centering ratio	0.66	0.66	0.75
9	Transportation	0.1	0.1	0.2	19	Transportation	0.1	0.1	0.1
	Centering ratio	0.5	0.5	0.5		Centering ratio	0.5	0.5	0.75
10	Transportation	0.1	0.2	0.3	20	Transportation	0.1	0.1	0.1
	Centering ratio	0.5	0.33	0.25		Centering ratio	0.66	0.66	0.75

Table 7: GROUP C: REVO S (Centering Ratio and Transportation)

Sr. No.	Group C SAMPLES	2mm	5mm	8mm	Sr. No.	Group C SAMPLES	2mm	5mm	8mm
1	Transportation	0.1	0.1	0.1	11	Transportation	0.1	0.1	0.1
	Centering ratio	0.66	0.5	0.66		Centering ratio	0.5	0.5	0.66

2	Transportation	0.1	0.1	0.2	12	Transportation	0.2	0.1	0.1
	Centering ratio	0.66	0.5	0.52		Centering ratio	0.5	0.66	0.5
3	Transportation	0.1	0.1	0.2	13	Transportation	0.1	0.1	0.2
	Centering ratio	0.5	0.66	0.33		Centering ratio	0.66	0.66	0.33
4	Transportation	0.1	0.1	0.1	14	Transportation	0.2	0.2	0.1
	Centering ratio	0.66	0.33	0.66		Centering ratio	0.33	0.33	0.5
5	Transportation	0.1	0.1	0.2	15	Transportation	0.1	0.2	0.2
	Centering ratio	0.5	0.5	0.33		Centering ratio	0.5	0.33	0.66
6	Transportation	0.1	0.1	0.2	16	Transportation	0.1	0.2	0.2
	Centering ratio	0.5	0.5	0.33		Centering ratio	0.66	0.33	0.33
7	Transportation	0.1	0.2	0.1	17	Transportation	0.1	0.1	0.1
	Centering ratio	0.66	0.33	0.66		Centering ratio	0.5	0.66	0.75
8	Transportation	0.2	0.1	0.2	18	Transportation	0.2	0.1	0.2
	Centering ratio	0.33	0.66	0.33		Centering ratio	0.33	0.5	0.33
9	Transportation	0.1	0.1	0.1	19	Transportation	0.1	0.2	0.2
	Centering ratio	0.5	0.66	0.75		Centering ratio	0.5	0.5	0.5
10	Transportation	0.1	0.1	0.2	20	Transportation	0.2	0.2	0.1
	Centering ratio	0.5	0.66	0.5		Centering ratio	0.66	0.5	0.8

F test revealed no statistical significance difference among the curvature of three instruments (p = 0.27).

Table 8: Statistical analysis for Pre Instrumentation Curvature and Straightening Characteristics of the Curved Canals. (º)

Instrument	**Curvature**		**Straightening**	
	Mean ± SD	**Min - Max**		**Mean ± SD**
One Shape	28.96 ± 1.02	27.2 - 30.8	One Shape	28.96 ± 1.02

Pro Taper Next	29.05 ± 0.93	27.7 - 30.6	Pro Taper Next	29.05 ± 0.93
Revo S	29.41 ± 0.81	28.2 - 30.6	Revo S	29.41 ± 0.81
p value	0.27		<0.0001	

F test revealed a statistical significance difference among the straightening of three instruments, (p value <0.0001). Thus Tukey's HSD pair wise comparison test was performed and recorded statistical significant differences among One Shape and Pro Taper Next (P < 0.001) and also in One Shape and Revo S (P < 0.001)
It was observed that the mean straightening value of One Shape (3.82) was significantly higher than Pro Taper Next (2.76) followed by Revo S (2.71).

Table 9: Statistical Analysis of Mean Transportation (mm) and the Centering Ratio Values for Tested Groups Instrument

Instrument		**Apical**		**Middle**		**Coronal**	
		Mean ± SD	**Min-Max**	**Mean ± SD**	**Min-Max**	**Mean ± SD**	**Min-Max**
One Shape	Transportation	0.19± 0.06	0.1-0.3	0.22± 0.09	0.1-0.4	0.3± 0.24	0.1-1.3
	Centering Ratio	0.40± 0.13	0.25-0.66	0.40± 0.18	0.2-0.75	0.36± 0.12	0.2± 0.5
Pro Taper Next	Transportation	0.11± 0.02	0.1-0.2	0.13± 0.05	0.1-0.2	0.18± 0.07	0.1-0.3
	Centering Ratio	0.49± 0.12	0.25-0.66	0.45± 0.11	0.25-0.66	0.47± 0.18	0.25-0.75
Revo S	Transportation	0.13± 0.04	0.1-0.2	0.13± 0.05	0.1-0.2	0.16± 0.05	0.1-0.2
	Centering Ratio	0.53± 0.11	0.33-0.66	0.51± 0.13	0.33-0.66	0.52± 0.17	0.33-0.8
p value	Transportation	< 0.001*		<0.0001*		0.0067*	
	Centering Ratio	< 0.003*		0.04*		0.005*	

- In all groups at 2, 5, and 8 mm, maximum root canal transportation (0.3, 0.4, and 1.3 mm respectively).
- There was significant difference among the 3 groups in transportation and centering ratio at 2, 5, and 8 mm (P <0 .05, Table 2).
- F test revealed a statistical significance difference among the centering ratio and transportation of three instruments, (p value <0.01) at 2 mm. Thus Tukey's HSD

pair wise comparison test was performed and recorded statistical significant differences among One Shape and Pro Taper Next ($P < 0.05$) and also in One Shape and Revo S ($P < 0.01$)

  - It was observed that the mean canal transportation of One Shape (0.19) was significantly higher than Revo S (0.13) and Pro Taper Next (0.11) at 2 mm. (i.e. RS>PTN>OS)
  - It was observed that the mean canal centering ratio of Revo S (0.53) was significantly higher than Pro Taper Next (0.49) and by One Shape (0.40) at 2 mm. (i.e. OS>PTN>OS)

- F test revealed a statistical significance difference among the transportation and Centering ratio of three instruments, (p value <0.05) at 5 mm. Thus Tukey's HSD pair wise comparison test was performed and recorded statistical significant differences among One Shape and Pro Taper Next ($P < 0.05$) and also in One Shape and Revo S ($P < 0.05$) for transportation and in One Shape and Revo S ($P < 0.05$) for centering ratio.
  - It was observed that the mean canal transportation of One shape (0.22) was significantly higher than Revo S and Pro Taper Next (0.13) at 5 mm. (i.e. PTN=RS>OS)
  - It was observed that the mean canal centering ratio of Revo S (0.51) was significantly higher than Pro Taper Next (0.45) followed by One shape (0.40) at 5 mm. (i.e. OS>PTN>OS)
- F test revealed a statistical significance difference among the transportation and Centering ratio of three instruments, (p value <0.01) at 8 mm. Thus Tukey's HSD pair wise comparison test was performed and recorded statistical significant differences among One Shape and Pro Taper Next ($P < 0.05$) in transportation and One Shape and in Revo S ($P < 0.01$) for Centering ratio.
  - It was observed that the mean Transportation of One shape (0.3) was significantly higher than Pro Taper Next (0.18) followed by Revo S (0.16) at 8 mm. (i.e. RS>PTN>OS)
  - It was observed that the mean Centering ratio of Revo S (0.52) was significantly higher than Pro Taper Next (0.47) followed by One shape (0.36) at 8 mm. (i.e. OS>PTN>OS)

DISCUSSION

CBCT imaging modalities is an effective technique to evaluate and measure dentin thickness, canal curvature, apical transportation and canal centering, as it provides images in orthogonal planes as well as in oblique planes. If we consider the low radiation dose, fast scan, sub-millimetric resolution and interactive software that allow re-orientation of the scan according to the inclination of each tooth, it will be an incredible tool in endodontic evaluation in the future.[22] In the present study, CBCT images permitted observations of the root canal in 3D planes (sagittal, coronal and axial section). The axial slice from CBCT images constituted an important tool to identify centering ratio and canal transportation.

In this study, the distribution of the 3 groups with respect to canal curvature was well balanced. The curvatures of all root canals ranged between 20^0 and 40^0. In previous studies, two experimental models were usually preferred: Simulated canals vs. extracted teeth. Using extracted teeth has an advantage over resin blocks because they provide conditions closer to clinical situations.[20] Even the hardness and abrasion behavior of acrylic resin and root dentin are not identical[34] and the heat generated may soften the resin material.[35] Therefore, we used extracted teeth in this study to compare the shaping ability of rotary NiTi instruments which were used to provide clinical conditions. The mesiobuccal mandibular root canals are often narrow and curved, which increases the level of instrumentation difficulty, so were used in this study.[46]

NiTi rotary instruments are important in endodontics because of their ability to shape root canals with minimum complications.[21] As the rotary NiTi instruments maintained the original canal curvature, particularly in the apical region of the root canal better than stainless steel hand instruments, studies compared the shaping ability of different rotary NiTi systems with different designs.

Another important property of NiTi is its superelasticity and is a result of stress induced transformation from the austenite to martensite phase. Deformation of up to 8% strain (vs. 1% in stainless steel) can occur as a result of this phase change without plastic or permanent, deformation.[10,27,55] Where austenite is hard and strong, martensite has the ability to be deformed much easier.[54] The martensitic phase consists of a closely packed hexagonal lattice,[10] which allows for the large recoverable strain without permanent deformation. Application of force results in the twinned martensite formation of the crystal structure to a de-twinned martensite configuration.[10] A certain amount of de-twinning can take place upon the application of force before plastic deformation occurs. If this threshold is not exceeded, the crystal structure will revert back upon the removal of the applied forces. After enough deformation, the alloy will not even revert to the original shape when it is heated above the austenite finish temperature.

The third major phase, R-phase, has a rhombohedral crystal structure. It can form under certain conditions as an intermediate transition between austenite and martensite phases.[54] The R-phase occurs during a very narrow temperature range on the heating or cooling transitions between martensite and austenite.[27] A proprietary method of twisting NiTi wire, which is only possible in R-phase, has been used by one company to manufacture files as an alternative to the traditional grinding process.[56-57]

CANAL CENTERING:

It denotes the ability of instruments to remain centered in the canal.
Centering Ratio: the mean centering ratio is measure of the ability of the instruments to stay centered in the canal. A ratio of 1.0 would indicate perfect centering.[72]

CANAL TRANSPORTATION:

It is 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.[73]

Ultimately these both factors can lead to canal straightening. In our study changes in canal curvature after the use of the different NiTi file systems were statistically significant. It was observed that the mean straightening value of One Shape (3.82) was significantly higher than Pro Taper Next (2.76) followed by Revo S (2.71) which caused the least coronal curvature straightening.

Hui Wu et al[78] also reported that PTN caused less transportation at apical section and better maintained the canal curvature than PTU and WO in severely curved canals.

Dhingra *et al*. and A. Ghobashya et al.[34] that showed that PTN resulted in less canal transportation, this was attributed by the author to the presence of only two points of the rectangular cross section of PTN that touches the wall of the root canal during preparation which causes negligible transportation and more centered preparations.

However, the PTN files having an apical 0.06 taper removed similar amounts of dentin compared with other instruments having a 0.08 apical taper as a result of the asymmetrical design. Therefore centering ratio was less as compared to RS at apical middle and coronal sections.[32]

This is in agreement with Capar et al.[32] who investigated six rotary file systems (ProTaper Next, ProTaper Universal, classical (old) One Shape, Reciproc, Twisted File Adaptive, SM2 and WaveOne).

Each file system has its own advantages and disadvantages. Cross sectional geometry of NiTi files are various such as triangle, rectangle, slender-rectangle, or square. Some studies find that files with square cross section have the highest screw-in force and flexural stiffness followed by the rectangular ones, the triangular ones and the slender rectangle ones.

Revo S has shown overall better shaping ability as compared to both PTN and OS. The reason might be the combination of asymmetrical cross section of SC1 and SU which usually have one point contact i.e. one cutting edge which may act less aggressively as compared to others and the symmetrical cross section of SC2 with 0.04 taper may be a perfect guide for shaping with no zipping. Another reason may be contributed to improved helical angle and adapted pitch.

Our results are in agreement with Hashem et al. who reported that the Revo-S group created significantly less transportation than ProTaper and Mallet *et al*.[16] reported that the Revo-S rotary system enables a fast shaping quality, a real cleaning and maintains the original canal path, which is in accordance with the results of the present research.

This results are in agreement Anil Dingra et al., comparing the canal shaping ability of One shape file with wave one file on endo-training blocks (Densply) the study concluded that wave one file shaped better, the reason attributed by the authors is its improved core alloy of the file and variable pitch design.

Another reason for the difference in shaping ability in the present study may be also the less flexibility gained by the file from the shorter pitch of the old generation one shape file as compared to new generation One Shape. The fundamental difference of the NGOS NiTi files from OGOS is their longer pitch.

Up to now, there have been two sorts of file system composition, that is, single-file system and multi-file system. Single-file system usually associates with reciprocating motions (i.e. WO and Reciproc), as well as continuous motion (OS), while multi-file system with continuous rotation (i.e. RS and PTN). It is demonstrated single-file system cause more transportation as compared to conventional rotary systems. The present study exhibited that OS produced more transportation than RS and PTN in severely curved canals.

CONCLUSION

The mechanical properties of the NiTi alloy can be improved by altering the microstructure via heat treatment. Therefore, new NiTi endodontic files with superior properties can be developed through thermomechanical processing, which is a metallurgical process that integrates hardening and heat treatment into a single process. The newly developed thermomechanical treatment of NiTi files gives them better flexural fatigue esistance than files of similar design and size made from conventional NiTi alloy. Therefore unique material properties make them particularly suited for the endodontic treatment of curved canals.

Each new generation of shaping files has had something to offer, which has been described in different ways and been intended to improve on previous generations. The 5th generation system is designed to bring the most proven performance features from the past together with the most recent technological advancements. These shaping files have been designed such that the center of mass and/or the center of rotation are offset. In rotation, files that have an offset design produce a mechanical wave of motion that travels along the active length of the file. Therefore it simplifies rotary shaping procedures by eliminating the number of files typically used to shape canals and the so called hybrid techniques. Clinically, it fulfills the 3 sacred tenets for shaping canals, which are safety, efficiency, and simplicity. Scientifically, evidence-based further research will be needed to validate the potential benefits of all system.

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