



Research Article

COMPARATIVE EVALUATION OF EFFECT OF ROTARY PROTAPER UNIVERSAL HAND FILES, PROTAPER GOLD, RECIPROCATING WAVEONE GOLD ON PERI CERVICAL DENTIN AND CANAL TRANSPORTATION USING CONE BEAM COMPUTED TOMOGRAPHY: AN IN VITRO STUDY

Krishna Prasada L and Hithysh T Vidhyadhara*

Dept of Conservative Dentistry and Endodontics, K.V. G Dental College & Hospital, Sullia. D.K. Karnataka

ARTICLE INFO

Article History:

Received 6th January, 2021

Received in revised form 15th

February, 2021

Accepted 12th March, 2021

Published online 28th April, 2021

Key words:

Peri Cervical Dentin, Canal transportation, Nickel Titanium, WaveOne Gold, ProTaper Gold, ProTaper Universal, CBCT, Gold heat treatment, Reciprocating Files.

ABSTRACT

Aim: This study aimed to compare and evaluate the effect of ProTaper Universal hand files, rotary ProTaper Gold and reciprocating WaveOne Gold on Peri Cervical Dentin (PCD) and canal transportation using Cone Beam Computer Tomography (CBCT).

Materials and Methods: A total of sixty bifurcated maxillary first premolars with Schneider's root angle curvature between 10°–40° (moderate to severe root curvature according to Schneider's technique) were collected and divided into three groups, Group 1 – ProTaper Universal hand files, Group 2 – Rotary ProTaper Gold and Group 3 – Reciprocating WaveOne Gold. Preoperative scans of each were taken followed by conventional access cavity preparation and working length determination with 10-k file. Instrumentation of the canal was done according to the respective file system, and post instrumentation CBCT scans of teeth were obtained. Ninety µm thick slices were obtained 4 mm apical and coronal to the cemento-enamel junction. The PCD thickness was calculated as the shortest distance from the canal outline to the closest adjacent root surface, which was measured in four surfaces, i.e., facial, lingual, mesial, and distal for all the groups in the two obtained scans. To compare and evaluate canal transportation, canals were scanned before and after instrumentation at 3, 6, and 9 mm from the apex. The data obtained were entered in an excel spread sheet and analyzed using SPSS (Statistical Package for Social Sciences) V.20 software. The significant value (P value) was set for 0.05 and any value equal to or less than was considered to be significant. Peri Cervical Dentin was analyzed using One Way Anova followed by Tukeys Post Hoc Test and canal transportation was analyzed using Kruskal Wallis Test followed by Tukeys Post Hoc test. Pairwise comparison between files was done using Anova for both Peri Cervical Dentin thickness and canal transportation.

Results: There was significant difference between all the tested groups and reciprocating WaveOne Gold and rotary ProTaper Gold was found to be significantly better when compared to ProTaper Universal hand files in Peri Cervical dentin removal and causing canal transportation. When comparing was done between reciprocating WaveOne Gold and rotary ProTaper Gold, WaveOne Gold was also found to be significantly better.

Conclusion: Gold heat treated reciprocating WaveOne Gold removes the least Peri Cervical Dentin and causes least canal transportation when compared to other two groups and conventional NiTi ProTaper Universal hand files causes the most.

Copyright©2021 Krishna Prasada L and Hithysh T Vidhyadhara. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Any successful endodontic therapy depends upon many factors among which efficacious cleaning and shaping of the root canal by sticking to the original anatomy being very important. It is expected from all the instruments used during root canal treatment, especially in the curved root canal system, to not to alter the original shape of the root canal system by sticking to original axis and still effectively clean to get the desired results without unnecessary weakening the tooth structure during biomechanical preparation of various techniques.¹

Clark and Khademi in 2008 defined Peri Cervical Dentin (PCD) as an area roughly 4 mm coronal and 4 mm apical to crestal bone. It effectively transfers all the masticatory forces to the root and the bone by acting as the neck of the tooth. It provides resistance to fracture and contributes to ferrule in a restored tooth and it is believed that strong and unchanged pericervical dentin during root canal therapy is one of the most important factor in the long-term success of the treatment.²

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

*Corresponding author: Hithysh T Vidhyadhara

Dept of Conservative Dentistry and Endodontics, K.V. G Dental College & Hospital, Sullia. D.K. Karnataka

original linear shape during canal preparation.³ During the instrumentation of curved root canals, one of the most common endodontic mishap frequently expected is canal transportation. Harboring of debris and residual microorganisms due to improper cleaning and shaping of the root canal system will happen because of canal transportation. It will also lead unnecessary weakening of root structure and loss of integrity especially in the apical third of the root.¹

Nickel- titanium (NiTi) alloys used in endodontics has various modified design concepts and geometric properties depending upon their respective metallurgy and manufacturer. NiTi files offer significant advantages over the stainless steel files such as greater flexibility, cutting efficiency, resistance to cyclic fatigue and canal centered preparations and prevents the creation of ledging, dentin wall perforations, instrument fracture among others.⁴

In the last few years, manufacturers have come up with various NiTi alloys with proprietary post-machining or post-twisting heat treatments which offer better cutting efficiency, fracture resistance, strength and flexibility.⁴ The gold process is a post-manufacturing heat treatment procedure in which the ground NiTi files undergoes special thermomechanical treatment which gives its distinct gold color. It also considerably improves its strength and flexibility far in the excess of its predecessor conventional NiTi files without any post-manufacturing heat treatments.⁵

ProTaper Gold rotary file (PTG; Dentsply Tulsa Dental Specialties, Tulsa, OK) is one of the instruments manufactured with proprietary advanced metallurgy with post manufacturing heat treatments. Its design features exact geometries as ProTaper Universal (PTU, Dentsply Tulsa Dental Specialties) although several advantages have been reported when compared with ProTaper Universal.⁶

Recently, Wave One Gold (WOG, Dentsply Maillefer) reciprocal file has been introduced, that only has the name in common with its predecessor Wave One instruments. The metallurgy, design, cross-section, size and geometry have been completely changed, although the movement is identical to WaveOne.⁵

The NiTi ProTaper Universal hand file system has identical design to the rotary ProTaper Universal file system. It comprises of instruments with multiple taper design as shaping files and finishing files. They are supposed to be used in reaming or “modified balanced forces” motion. The mechanical stresses acting on a hand-operated instrument might differ during root canal preparation from those on engine-driven instruments in terms of torsional stresses, torque and shear failure among others.⁷

Various methods like radiographic method, serial sectioning technique, photographic assessment, scanning electron microscope, and computer manipulation technique were used for assessment of canal transportation, remaining dentin thickness, and centering ability. The main drawbacks of these methods were that it was invasive in nature and precise repositioning of pre and post-instrumented specimens was strenuous, whereas radiographic method gives 2D representation of 3D objects. The introduction of Cone beam computed tomography (CBCT), which is a non-destructive technology, has been used evaluations of canal before and after

instrumentation. The major advantages of CBCT is that it can give 3D images, which are highly accurate, has high resolution which are fully quantifiable results which are repeatable.¹

Considering the above-mentioned factors, this study was conducted to compare and evaluate the effect of ProTaper Universal hand files, rotary ProTaper Gold, reciprocating WaveOne Gold on Peri Cervical Dentin and canal transportation using cone beam computed tomography.

MATERIALS AND METHODOLOGY

Sixty maxillary first premolar teeth was selected after checking for angle of curvature. It was assessed using criteria described by Schneider and teeth with canals with curvature between 10°–40° (moderate to severe root curvature according to Schneider’s technique) was included in this study.

Conventional access cavity preparation was done and working length of the canals was determined by inserting a size 10 K file into the root canal terminus and subtracting 1 mm from this measurement. A manual glide path was till 15K file. The specimens was mounted in rubber base impression material and then was scanned by CBCT before instrumentation. The images was stored and the teeth was randomly divided into three groups of twenty each.

Group 1 - Protaper Universal Hand Files

Twenty teeth was prepared with Pro Taper Universal hand file system using crown down technique according to the manufacturer’s instructions. Files was used in reaming and “modified balanced forces” motion.

Group 2- Protaper Gold

Twenty teeth was prepared with ProTaper Gold file system using crown down technique according to the manufacturer’s instructions. ProGlider was used for glide path. The shaping files were used with a brushing action, and the finishing files were used with as low in-and-out pecking motion until the working length was reached. Files were used at 300 rpm and torque of 1 to 2 N/cm as recommended by the manufacture

Group 3- Waveone Gold

Twenty teeth was prepared with WaveOne Gold file system according to the manufacturer’s instructions WaveOne Gold Glider was used for glide path. The primary file was used in reciprocating, slow in-and-out pecking motion according to the manufacturer’s instructions until the working length was achieved. It engages and cut dentine in a 150-degree counter-clockwise (CCW) direction and then, before the instrument has a chance to taper lock, disengages 30 degrees in a clockwise (CW) direction.

Then the samples was again subjected to the CBCT imaging, and post instrumentation images was taken in the same manner and superimposed with the older images. As the Peri Cervical Dentin extends 4 mm above and 4 mm below the cementoenamel junction, ninety µm thick slices were obtained 4 mm apical and coronal to the cementoenamel junction. The PCD thickness was calculated as the shortest distance from the canal outline to the closest adjacent root surface, which was measured in four surfaces, i.e., facial, lingual, mesial, and distal for all the groups in the two obtained scans.

To compare and evaluate canal transportation, canals were scanned before and after instrumentation at 3, 6, and 9 mm from the apex. For measurement of canal transportation, the pre and post instrumentation scans was superimposed and the shortest distance from the edge of the uninstrumented canal to the edge of the tooth in both mesial (X1) and distal (Y1) directions was measured and then compared with values measured from prepared canals (X2 and Y2). The following formula was used for the calculation of transportation: (X1-X2) - (Y1-Y2). The data obtained were entered in an excel spread sheet.

RESULTS

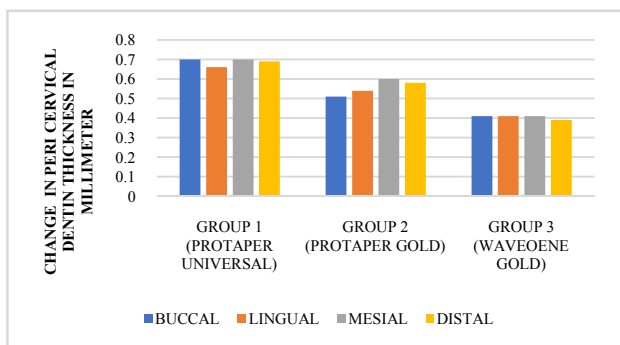
The data was analyzed using SPSS (Statistical Package for Social Sciences) V.20 software. The significant value (P value) was set for 0.05 and any value equal to or less than was considered to be significant. Peri Cervical Dentin was analyzed using One Way Anova followed by Tukeys Post Hoc test. Canal transportation was analyzed using Kruskal Walis test followed by Tukeys Post Hoc test. Pairwise comparison between files was done using Anova for both Peri Cervical Dentin thickness and canal transportation.

Table 1 and Graph 1 shows changes in Peri Cervical Dentin thickness reading in millimeter seen in buccal root of all the three groups which was found to be significant. Table 2 and Graph 2 shows changes in Peri Cervical Dentin thickness reading in millimeter seen in palatal root of all the three groups which was again found to be significant.

Table 3, 4 and 5 and Graph 3, 4, and 5 shows canal transportation reading at 3mm, 6mm and 9mm pre- and post-instrumentation in buccal canal of all the three groups in millimeter. Table 6, 7 and 8 and Graph 6, 7, and 8 shows canal transportation reading at 3mm, 6mm and 9mm pre- and post-instrumentation in palatal canal of all the three groups in millimeter. The results were found to be significant for both buccal and palatal canal in all the three groups.

Table 1 Change in Peri Cervical Dentin Thickness In Millimeter Seen In Buccal Root

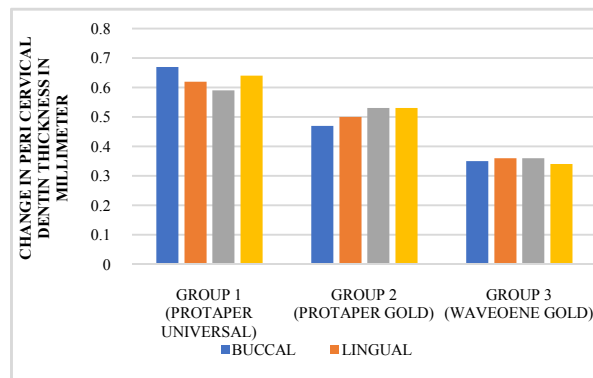
Files	Buccal		Lingual		Mesial		Distal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group 1 (Protaper Universal)	0.70	0.11	0.66	0.13	0.7	0.11	0.69	0.11
Group 2 (Protaper Gold)	0.51	0.09	0.54	0.08	0.6	0.08	0.58	0.10
GROUP 3 (Waveoene Gold)	0.41	0.07	0.41	0.07	0.41	0.07	0.39	0.07
P Value	<0.01		<0.01		<0.01		<0.01	



Graph 1 Change in Peri Cervical Dentin Thickness In Millimeter Seen In Buccal Root

Table 2 Change in Peri Cervical Dentin Thickness In Millimeter Seen In Palatal Root

FILES	Buccal		Lingual		Mesial		Distal	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Group 1 (Protaper Universal)	0.67	0.11	0.62	0.10	0.59	0.09	0.64	0.08
Group 2 (Protaper Gold)	0.47	0.07	0.50	0.09	0.53	0.09	0.53	0.09
Group 3 (Waveoene Gold)	0.35	0.06	0.36	0.04	0.36	0.07	0.34	0.06
P Value	<0.01		<0.01		<0.01		<0.01	



Graph 2 Change In Peri Cervical Dentin Thickness In Millimeter Seen In Palatal Root

Table 3 Canal Transportation in Millimeter Seen At 3 mm of Buccal Root

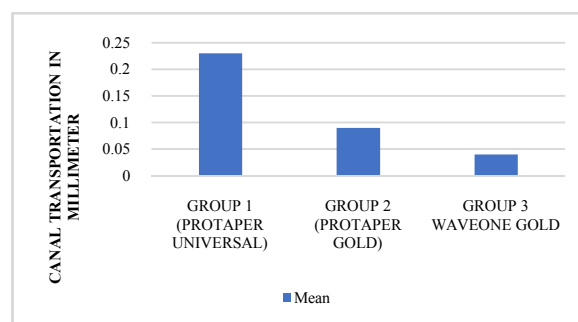
Group	Mean	SD	P value
Group 1 (Protaper Universal)	0.23	0.1	
Group 2 (Protaper Gold)	0.09	0.09	<0.01
Group 3 (Waveoene Gold)	0.04	0.02	

Table 4 Canal Transportation in Millimeter Seen At 6 mm of Buccal Root

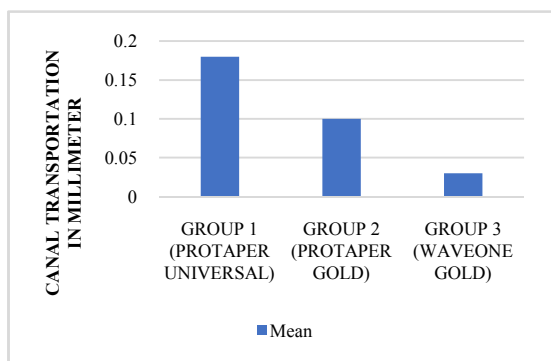
Group	mean	SD	P Value
Group 1 (protaper universal)	0.18	0.16	
Group 2 (protaper gold)	0.10	0.09	<0.05
Group 3 (waveoene gold)	0.03	0.08	

Table 5 Canal Transportation In Millimeter Seen At 9 mm of Buccal Root

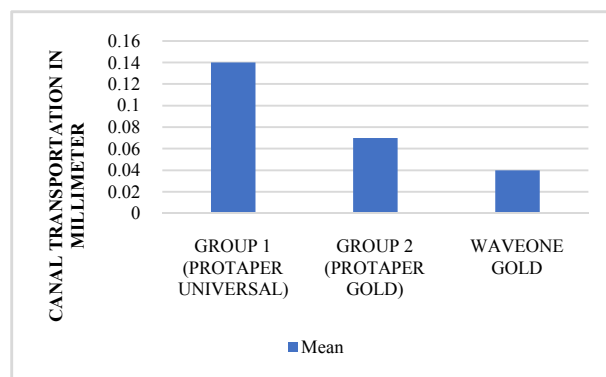
Group	Mean	SD	P Value
Group 1 (Protaper Universal)	0.22	0.15	<0.01
Group 2 (Protaper Gold)	0.10	0.09	
Group 3 (Waveoene Gold)	0.02	0.06	



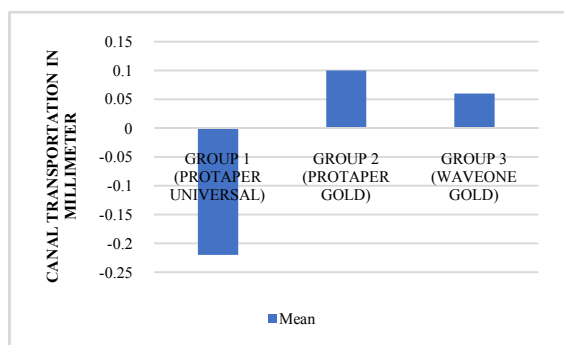
Graph 3 Canal Transportation in Millimeter Seen At 3 Mm of Buccal Root



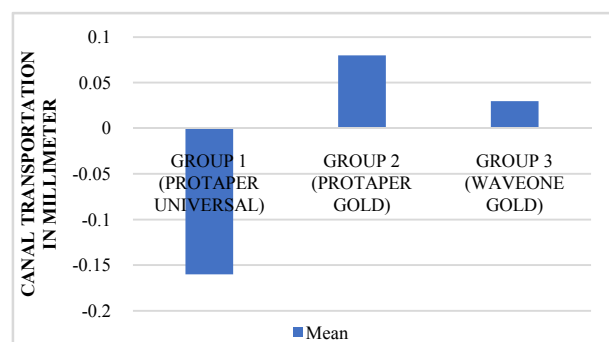
Graph 4 Canal Transportation in Millimeter Seen At 6 Mm of Buccal Root



Graph 7 Canal Transportation In Millimeter Seen At 6 Mm of Palatal Root



Graph 5 Canal Transportation in Millimeter Seen At 9 mm of Buccal Root



Graph 8 Canal Transportation in Millimeter Seen At 9 mm of Palatal Root

Table 6 Canal Transportation in Millimeter Seen At 3 mm of Palatal Root

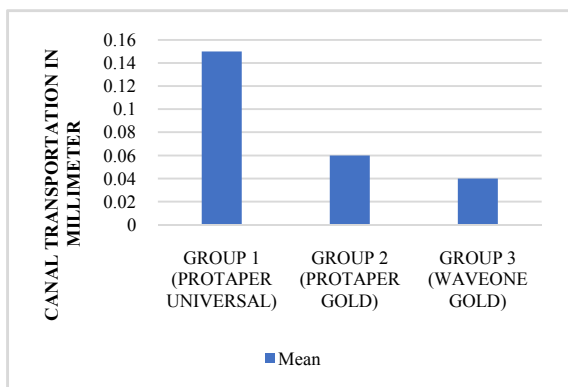
Group	Mean	SD	P Value
Group 1 (Protaper Universal)	0.14	0.13	
Group 2 (Protaper Gold)	0.07	0.07	<0.05
Group 3 (Waveone Gold)	0.04	0.06	

Table 7 Canal Transportation in Millimeter Seen At 6 Mm of Palatal Root

Group	Mean	SD	P value
Group 1 (Protaper Universal)	0.15	0.10	
Group 2 (Protaper Gold)	0.06	0.07	<0.05
Group 3 (Waveone Gold)	0.04	0.05	

Table 8 Canal Transportation in Millimeter Seen At 9 Mm of Palatal Root

Group	Mean	SD	P Value
Group 1 (Protaper Universal)	-0.16	0.12	
Group 2 (Protaper Gold)	0.08	0.07	<0.01
Group 3 (Waveone Gold)	0.03	0.04	



Graph 6 Canal Transportation In Millimeter Seen At 3 mm of Palatal Root

Table 10 and 11 shows pairwise comparison done for change in Peri Cervical Dentin thickness in buccal root and palatal root.

Table 10 Pairwise Comparison for Change in Pericervical Dentin Thickness Seen In Buccal Root

	Protaper Universal	Protaper Gold	Waveone Gold
Group 1 (Protaper Universal)	<0.01	-	-
Group 2 (Protaper Gold)	<0.01	<0.01	-
Group 3 (Waveone Gold)	<0.01	<0.01	<0.01

Table 11 Pairwise Comparison for Change in Pericervical Dentin Thickness Seen In Palatal Root

	Protaper Universal	Protaper Gold	Waveone Gold
Group 1 (Protaper Universal)	<0.01	-	-
Group 2 (Protaper Gold)	<0.01	<0.01	-
Group 3 (Waveone Gold)	<0.01	<0.01	<0.01

Table 12 Pairwise Comparison for Canal Transportation Seen In Buccal Root

	Protaper Universal	Protaper Gold	Waveone Gold
Group 1 (Protaper Universal)	<0.01	-	-
Group 2 (Protaper Gold)	<0.01	<0.01	-
Group 3 (Waveone Gold)	<0.01	<0.01	<0.01

Table 13 Pairwise Comparison for Canal Transportation Seen In Palatal Root

	Protaper Universal	Protaper Gold	Waveone Gold
Group 1 (Protaper Universal)	<0.01	-	-
Group 2 (Protaper Gold)	<0.01	<0.01	-
Group 3 (Waveone Gold)	<0.01	<0.01	<0.01

Reciprocating WaveOne Gold was found to be significantly better to both rotary ProTaper Gold and ProTaper Universal hand files and rotary ProTaper Gold was found to be significantly better than ProTaper Universal hand files.

Table 12 and 13 shows pairwise comparison done for canal transportation in buccal root and palatal root. Reciprocating WaveOne Gold was found to be significantly better to both rotary ProTaper Gold and ProTaper Universal hand files and rotary ProTaper Gold was found to be significantly better than ProTaper Universal hand files.

DISCUSSION

Grossman and Schilder described mechanical instrumentation as the most important part of root canal therapy and considered as the foundation for successful outcome of endodontic treatment.^{8, 9} A successful treatment can be achieved by preparing a smooth and progressively tapered preparation without diverting from the original anatomy with the canal becoming narrower as it goes from coronal to apical end of the preparation without getting over enlarged. This will facilitate chemical debridement and subsequent filling to prevent re infection.¹⁰

According to the Glossary of Endodontic Terms of the American Association of Endodontists (AAE), 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.¹⁰ Insufficient access cavity, use of endodontic instruments which are inflexible along with its tip design and their instrumentation technique, improper irrigation and irrigation needles used during biomechanical preparation are some of the important aetiology factors of canal transportation. The other associated factors includes degree and radius of a canal curvature, skill of the dentist and unseen canal curvatures in most commonly used two-dimensional (2D) radiograph, will also lead to increased risk of canal transportation.¹ Therefore canal transportation is serious threat during instrumentation and every precautionary measure should be taken to avoid canal transportation during root canal treatment.

Clark and Khademi in 2008 defined Pericervical Dentin (PCD) as an area roughly 4 mm coronal and 4 mm apical to crestal bone. It effectively transfers all the masticatory forces to the root and the bone by acting as the neck of the tooth. It provides resistance to fracture and contributes to ferrule in a restored tooth and it is believed that strong and unchanged pericervical dentin during root canal therapy is one of the most important factor in the long-term success of the treatment.²

Root canal treatment leads to weakened tooth structure as a result of change in tooth internal structure, loss and dehydration of PCD along with changes in its physical and mechanical properties and strains due to excessive pressure during obturation. Over the last few years, there is numerous advancements in rotary root canal instruments which have led to greater root canal enlargements and increased taper during root canal preparations. This leads to significant weakening of teeth due to excessive loss of PCD with variable taper instruments as reported in the literature especially in the cervical region of the tooth which is more prone to fracture. The orifice openers and gates-glidden drills are the main

instruments responsible for the loss of PCD. To further add on this effect is the use of greater taper files which also induces dentinal cracks during preparation which can change the structure and stress bearing capacity of PCD. These micro cracks can lead to weakened PCD with reduced resistance to fracture.^{2, 11, 12}

Historically, root canal instrumentation has involved the use of stainless steel hand files. Numerous investigations have shown that procedural errors like elbows, zips, and danger zones and canal transportation (Cheung & Liu 2009) occurred with stainless steel instruments during preparation of curved root canals.¹³

To overcome this drawback, Nickel-titanium (NiTi) alloy was proposed to be used in endodontics (Civjan, 1975).¹⁴ Walia *et al* (1988) suggested a greater modification in endodontic instruments replacing stainless steel with a NiTi alloy. Instrumentation of curved canals is made easier with introduction of NiTi instruments. These instruments are super elastic and more flexible than stainless steel instruments before exceeding their elastic limits and hence does not require the pre-curving compared to stainless steel instruments to negotiate the curved canal.¹⁵

However, the major shortcoming of NiTi endodontic rotary files were and are the undesirable and unexpected separation of files during root canal instrumentation. This file separation which is caused by cyclic fatigue and/or torsional overload still remains a serious concern and drawback in clinical use.¹⁶ Additionally, in parallel with these developments, endodontic motors have undergone enhancement regarding torque control and kinematics that are adjustable in several directions to increase Cyclic and / or Torsional resistance especially in curved canal.¹⁷ Yared *et al* (2008) introduced engine driven single file reciprocation for the preparation of curved canals. They used F2 ProTaper instrument in reciprocation with unequal clockwise and anticlockwise movements which showed promising clinical results. This led to the introduction of reciprocation technology. This concept of reciprocation is evolved from balanced force technique which was given by Roane *et al.* in the year 1985.¹⁸

Further there was advancement in technology by the introduction of single file system. Benefits of single file system are shorter working time, reduction in number of instruments required to obtain desired shape, reduces cross contamination and instrument fatigue, unlike the commonly used full sequence rotary system. Reciproc (VDW, Munich, Germany) WaveOne and WaveOne Gold (Dentsply, Maillefer, Switzerland) are example to reciprocating single file system in the market. It is reported that these file system prepare and clean root canals with only one instrument.¹⁹

In addition, constant hunt to improve the properties of the instrument has led to the introduction of newer innovative technologies like Gold treatment and Electric discharge machining (EDM) in endodontic files. In the last few years, manufacturers have come up with various NiTi alloys with proprietary post-machining or post-twisting heat treatments which offer better cutting efficiency, fracture resistance, strength and flexibility.⁴ The purpose of this study was to evaluate and compare the PCD and canal transportation of ProTaper Universal hand NiTi files which is made up of conventional NiTi alloy (PTU, Dentsply Maillefer, Ballaigues, Switzerland) without any proprietary post-machining or post-

twisting heat treatments and is recommended to be used in reaming or “modified balanced forces” motion, rotary gold heat treated ProTaper Gold files (PTG; Dentsply Tulsa Dental Specialties, Tulsa) which consists of multiple files having progressively tapered design and gold heat treated reciprocating single file WaveOne Gold (WOG, Dentsply, Maillefer, Switzerland) using CBCT on fully formed bifurcated maxillary first pre molars. In this study apical preparation was standardized to size 25. According to Buchanan, the amount of canal transportation increases with apical preparation greater than size 25. Hence, the apical preparation was limited to size 25 in the present study.

ProTaper universal files were chosen for comparison as they are amongst the most commonly used conventional Ni-Ti instruments globally (Dentsply Maillefer, Ballaigues, Switzerland). The ProTaper Universal instruments were designed by Dr. Cliff Ruddle, Dr. John West and Dr. Pierre Machtou and comprised of six instruments: three shaping files and three finishing files.²⁰

ProTaper universal files set is now available with two larger finishing files. It has a convex, triangular cross section and no radial lands; this creates a stable core and sufficient flexibility for the smaller files. The increased flexibility of PTU finishing files is due to slightly relieved cross section of the files. The varying tapers along the instruments long axes makes the unique design element of PTU files. The three shaping files have tapers that increase coronally, and the reverse pattern is seen in the five finishing files.²⁰

The partially active tip of shaping files S1 and S2 have tip diameters of 0.185 mm and 0.2 mm respectively with 14 mm long cutting blades. The diameter of these files at D14 are 1.2 mm and 1.1 mm, respectively. The finishing files, F1-F5 have tip diameters of 0.2 mm, 0.25 mm, 0.3 mm, 0.4 mm and 0.5mm, respectively, between D0 and D3, and the apical tapers are 0.07, 0.08, 0.09, 0.06, and 0.05, respectively. The finishing files have rounded noncutting tips and are used in crown down manner.¹⁶

The ProTaper Universal hand file system (Group 1) used in this study has identical design to the rotary ProTaper Universal file system. It comprises of 5 instruments with multiple taper design as shaping files and finishing files. They are supposed to be used in reaming or “modified balanced forces” motion. The mechanical stresses acting on a hand-operated instrument might differ during root canal preparation from those on engine-driven instruments in terms of torsional stresses, torque and shear failure among others.⁷

ProTaper Gold rotary file (Group 2) is one of the instruments manufactured with proprietary advanced metallurgy with post manufacturing heat treatments. Its design features exact geometries as ProTaper Universal, although several advantages like greater flexibility, strength and better canal centering ability have been reported when compared with ProTaper Universal. These files are available in eight sizes with three shaping files and 5 finishing files having exact geometries as ProTaper Universal.⁶

WaveOne Gold (Group three) single-file reciprocating system available in four tip sizes: small (tip size 20 with taper of 0.07), primary (tip size 25 with taper of 0.07), medium (tip size 35 with taper of 0.06), and large (tip size 45 with taper of

0.05) and are available in 21 mm, 25 mm and 31 mm lengths. WaveOne Gold has active cutting lengths of 16 mm, shortened 11 mm handles for improved posterior access. The cross-section of WaveOne Gold is a parallelogram with two 85-degree cutting edges in contact with the canal wall. It also features the off-centre design, where only one cutting edge is in contact with the canal wall. Decreasing the contact area between the file and the canal wall reduces binding and ensures little or no screwing effect.²¹

The tip of WOG is roundly tapered and semi-active, modified to reduce the mass of the center of the tip and improve its penetration into any secured canal with a confirmed, smooth and reproducible glide path. They engage and cut dentine in a 150 degree counter clockwise (CCW) direction and then, before the instrument has a chance to taper lock, disengage 30 degrees in a clockwise (CW) direction. The cyclic fatigue resistance of WOG Primary is 50% greater than that of its predecessor WaveOne Primary (which itself was twice as great as most standard rotary file systems), and the flexibility of WaveOne Gold Primary is 80% greater than that of WaveOne Primary.²¹

The glide path files used in this study were ProGlider (PG) (Dentsply Sirona, Ballaigues, Switzerland) and WaveOne Gold Glider (WOGG) (Dentsply Sirona, Ballaigues, Switzerland). The ProGlider which is used in a continuous rotary motion is manufactured using M-Wire NiTi alloy, has a quadrangular cross section with an initial diameter of 0.16 mm, and a progressive taper ranging from 2 to 8%.⁵² M-wire consists of 55.8% nickel and 44.2% titanium and of approximately equal proportions of R-phase and austenite at 37 °C. Numerous studies have consistently shown that M-wire has increased flexibility and a significantly increased cyclic bending fatigue resistance compared to conventional NiTi alloys.⁵

The WaveOne Gold Glider (WOGG) is used in a reciprocating motion is manufactured using NiTi Gold alloy, has a parallelogram cross-section, along with a semi-active guiding tip 0.15 mm in diameter, and variable conicity ranging from 2 to 6%. The progressive tapered design of these file systems provides a glide path and preliminary enlargement of the root canal in the middle and coronal regions. This feature has been reported to reduce stress to the subsequent shaping NiTi instruments.²²

Sodium hypochlorite of 2.5 % was used for irrigation in the present study because higher concentrations of sodium hypochlorite (NaOCl) can significantly decrease the elastic modulus, and flexural strength of dentine when used as an endodontic irrigant. Sim *et al.* (2001) reported decreased microhardness of radicular dentine after exposure to NaOCl in concentrations 5.25%, but not when NaOCl was used in lower concentrations.²³ EDTA of 17% was used in this study, in gel form, to facilitate instrumentation of the root canal and make the negotiation of canals easier as they help of the file within the root.⁸ It was used in the early stages of canal negotiation and shaping and in adjunct with the Nickel Titanium file systems. Sterile saline was used to neutralize the various chemical of the irrigants by its flushing action. After instrumentation, Groups were subjected for post-operative CBCT scanning. Reading were taken at axial sections.

In the present study, ProTaper Universal hand files system (Group 1) has shown more canal transportation and Peri

Cervical Dentin removal at all the levels 3mm, 6mm and 9mm. At 3mm and 6mm, ProTaper Universal hand file system showed positive transportation i.e. transportation away from the furcation. At 9mm it showed negative transportation i.e. transportation towards the furcation. The positive transportation and Peri Cervical Dentin removal of ProTaper Universal may be attributed to the greater taper (8%) and less flexibility of the instruments as explained by Schafer *et al* and that the percentage of taper is one of the main factors involved in canal transportation and removal of dentin.²⁴

Guelzow *et al* found ProTaper Universal files to show the highest degree of straightening and dentin removal. At the middle (6mm) and coronal third (9mm), transportation was seen which can be mainly due to progressive taper along the cutting surface in combination with the sharp cutting edges which is in accordance with our study. The partially active cutting tip with ProTaper Universal hand files may be reason for increased canal transportation at apical third (3mm).¹⁰ The results obtained were in conformity to Jain *et al*, Bonaccorso *et al*, Maitin *et al* and Javaheri *et al*, who found ProTaper Universal files to produce more apical transportation.^{1, 25, 26, 27}

Wu *et al* has stated that the critical canal transportation value is 0.3mm, as it was found that leakage occurs more frequently when apical transportation index is $> 0.3\text{mm}$.²⁸ In a similar study Peters *et al* reported that apical transportation $\leq 0.1\text{mm}$ is clinically acceptable.²⁹

There was statistical significant difference between ProTaper Universal hand files (Group 1) and WaveOne Gold (Group 3). WaveOne Gold showed significantly less transportation and Peri Cervical Dentin removal at all three levels when compared to ProTaper Universal hand files and rotary ProTaper Gold.

This performance of WaveOne gold in context to pericervical dentin thickness and canal transportation may be due to:

1. Reciprocation motion.^{30, 31}
2. It is manufactured using advanced proprietary thermal process called gold process yielding super-elastic NiTi file.
3. The cross-section of WaveOne Gold is a parallelogram with two 85-degree cutting edges with off-centre design where only one cutting edge is in contact with the canal wall during instrumentation which is DENTSPLY patented.
4. Taper of 25 tip size file is less (7%) when compared to both ProTaper Universal hand files and ProTaper Gold 25 tip size files (8%).^{5, 6, 21, 24,}

It is known that transformation behavior of NiTi alloys is due to thermomechanical process. This transformation occurs as one stage A-to-M transformation in nickel-rich NiTi alloys and two stage A-R-M transformation after additional heat treatment, which creates finely dispersed Ti_3Ni_4 precipitates in the austenitic matrix. This Ti_3Ni_4 particles favors the formation of R-phase, but the alloy requires further cooling for martensite transformation to occur. Therefore, martensitic transformation occurs in 2 steps: A-R-M. Superelasticity or pseudoelasticity is associated with the occurrence of phase transformation of the NiTi alloy upon application of stress above a critical level, which takes place when the ambient temperature is above the so-called Austenite finish temperature of the material. The gold heat treatment process modifies the

transformation temperatures (austenitic start and austenitic finish), and this may have a positive effect of instrument properties on shaping curved root canals.³² In a study, Hieawy *et al* compared ProTaper Gold (Dentsply Maillefer) and ProTaper Universal files and reported that ProTaper Gold had a high austenite finish temperature value and that it exhibited 2-stage transformation behavior and found ProTaper Gold heat treated files to be more flexible than conventional NiTi used in ProTaper Universal files.²¹

Gagliardi *et al* compared the ProTaper Universal (PTU, Dentsply Maillefer), PTN, and ProTaper Gold (PTG, Dentsply Maillefer) NiTi files shaping ability and reported that PTG files performed less canal transportation and argued that this was because of the gold heat treated flexible alloy of PTG files which was far superior than conventional NiTi alloy used in ProTaper Universal.¹⁹

In the present study, the Gold heat treated files showed good shaping ability with least canal transportation and Peri Cervical Dentin removal which might be due to Gold treated file's high Austenite finish temperature value and 2-stage transformation behavior. Therefore, this Gold heat treatment process may be the reason for WaveOne Gold and ProTaper Gold effective performance in curved canal.

CONCLUSION

Within the parameters of the present study, no files system is completely free from causing canal transportation and will remove Peri Cervical Dentin during cleaning and shaping of the curved root canals. The following conclusions can be drawn from this study:

1. The present study showed that there was significant difference in Peri Cervical Dentin thickness removal and canal transportation between ProTaper Universal hand files, rotary ProTaper Gold and reciprocating WaveOne Gold groups.
2. On comparing different groups, reciprocating WaveOne Gold and rotary ProTaper Gold was found to be significantly better when compared to ProTaper Universal hand files in Peri Cervical Dentin removal and causing canal transportation owing to Gold heat treatment of WaveOne Gold and ProTaper Gold files which makes these files more flexible and improves its strength when compared to conventional NiTi used in ProTaper Universal hand files.
3. Reciprocating WaveOne Gold was also found to be significantly better when compared to rotary ProTaper Gold file system in the Peri Cervical Dentin removal and causing canal transportation due to the WaveOne Gold's 25 tip size files having 7% taper compared to that of 8% taper seen in rotary ProTaper Gold's 25 tip size file.
4. Gold heat treated NiTi files with lesser taper should be suggested in cleaning and shaping of root canals as they cause least Peri Cervical Dentin removal and canal transportation, especially in curved canals, leading to success and good prognosis of the root canal treatment.

References

1. Jain A, Asrani H, Singhal AC, Bhatia TK, Sharma V, Jaiswal P. Comparative evaluation of canal transportation, centering ability, and remaining dentin thickness between WaveOne and ProTaper rotary by

- using cone beam computed tomography: An in vitro study. *Journal of conservative dentistry*: JCD. 2016 Sep;19(5):440.
2. Arora V, Yadav MP, Singh SP. Peri-Cervical Dentin (PCD): A new paradigm for endodontic success. *Global J Res Anal*. 2015 Jul;4(7):490-3.
 3. Dhingra A, Ruhail N, Miglani A. Evaluation of single file systems Reciproc, Oneshape, and Wave One using cone beam computed tomography—an in vitro study. *Journal of clinical and diagnostic research: JCDR*. 2015 Apr;9(4):ZC30.
 4. Gutmann JL, Gao Y. Alteration in the inherent metallic and surface properties of nickel–titanium root canal instruments to enhance performance, durability and safety: a focused review. *International endodontic journal*. 2012 Feb;45(2):113-28.
 5. Bürklein S, Flüch S, Schäfer E. Shaping ability of reciprocating single-file systems in severely curved canals: WaveOne and Reciproc versus WaveOne Gold and Reciproc blue. *Odontology*. 2019 Jan 25;107(1):96-102.
 6. Elnaghy AM, Elsaka SE. Shaping ability of ProTaper Gold and ProTaper Universal files by using cone-beam computed tomography. *Indian Journal of Dental Research*. 2016 Jan 1;27(1):37.
 7. Pasqualini D, Scotti N, Tamagnone L, Ellena F, Berutti E. Hand-operated and rotary ProTaper instruments: a comparison of working time and number of rotations in simulated root canals. *Journal of endodontics*. 2008 Mar 1;34(3):314-7.
 8. Gutmann JL, Lovdahl PE. Problem Solving in Endodontics-E-Book: Prevention, Identification and Management. Elsevier Health Sciences; 2010 Aug 6.
 9. Schilder H. Cleaning and shaping the root canal. *Dent Clin North Am*. 1974;18: 269-96.
 10. Schäfer E, Dammaschke T. Development and sequelae of canal transportation. *Endodontic Topics*. 2006 Nov; 15(1):75-90.
 11. Rundquist BD, Versluis A. How does canal taper affect root stresses?. *International endodontic journal*. 2006 Mar;39(3):226-37.
 12. Karataş E, Gündüz HA, Kırıcı DÖ, Arslan H, Topçu MÇ, Yeter KY. Dentinal crack formation during root canal preparations by the twisted file adaptive, ProTaper Next, ProTaper Universal, and Wave One instruments. *J Endod*. 2015 Feb;41(2):261-4.
 13. Zhou H, Peng B, Zheng YF. An overview of the mechanical properties of nickel–titanium endodontic instruments. *Endodontic topics*. 2013 Sep;29(1):42-54.
 14. Capar ID, Ertas H, Ok E, Arslan H, Ertas ET. Comparative study of different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals. *Journal of Endodontics*. 2014 Jun 1;40(6):852-6.
 15. Chole D, Burad PA, Kundoor S, Bakle DS, Devagirkar DA, Deshpande DR. Canal transportation-a threat in endodontics: a review. *IOSR-JDMS*. 2016;15:64-72.
 16. Ingle JI, Bakland LK, Baumgartner JC. Ingle's endodontics/John I. Ingle, Leif K. Bakland, J. Craig Baumgartner. Hamilton, Ont.: BC Decker.; 2008.
 17. Çapar ID, Arslan H. A review of instrumentation kinematics of engine-driven nickel–titanium instruments. *International endodontic journal*. 2016 Feb;49(2):119-35.
 18. Yared G, Alasmar Ramli G. Single file reciprocation: A literature review. *Endodontic Practice Today*. 2013 Sep 1;7(3).
 19. Özyürek T, Yılmaz K, Uslu G. Shaping ability of Reciproc, WaveOne GOLD, and HyFlex EDM single-file systems in simulated S-shaped canals. *Journal of Endodontics*. 2017 May 1;43(5):805-9.
 20. Ruddle CJ. The ProTaper endodontic system: geometries, features, and guidelines for use. *Dent today*. 2001;20:60-7.
 21. Webber J. Shaping canals with confidence: WaveOne GOLD single-file reciprocating system. *Roots*. 2015; 1(3):34-40.
 22. Vorster M, van der Vyver PJ, Paleker F. Canal transportation and centering ability of WaveOne Gold in combination with and without different glide path techniques. *Journal of endodontics*. 2018 Sep 1;44(9):1430-5.
 23. Sim TP, Knowles JC, Ng YL, Shelton J, Gulabivala K. Effect of sodium hypochlorite on mechanical properties of dentine and tooth surface strain. *International Endodontic Journal*. 2001 Mar;34(2):120-32.
 24. Schäfer E, Dzepina A, Danesh G. Bending properties of rotary nickel-titanium instruments. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2003 Dec 1;96(6):757-63.
 25. Javaheri HH, Javaheri GH. A comparison of three Ni-Ti rotary instruments in apical transportation. *Journal of endodontics*. 2007 Mar 1;33 (3):284-6.
 26. Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. *International endodontic journal*. 2005 Jan;38(1):8-16.
 27. Khurana P, Nainan MT, Sodhi KK, Padda BK. Change of working length in curved molar root canals after preparation with different rotary nickel-titanium instruments. *Journal of conservative dentistry: JCD*. 2011 Jul;14(3):264.
 28. Wu MK, Fan B, Wesselink PR. Leakage along apical root fillings in curved root canals. Part I: effects of apical transportation on seal of root fillings. *Journal of Endodontics*. 2000 Apr 1;26(4):210-6.
 29. Peters OA, Schönenberger K, Laib A. Effects of four Ni–Ti preparation techniques on root canal geometry assessed by micro computed tomography. *International endodontic journal*. 2001 Apr;34(3):221-30.
 30. You SY, Bae KS, Baek SH, Kum KY, Shon WJ, Lee W. Lifespan of one nickel-titanium rotary file with reciprocating motion in curved root canals. *Journal of Endodontics*. 2010 Dec 1;36(12):1991-4.
 31. Berutti E, Chiandussi G, Paolino DS, Scotti N, Cantatore G, Castellucci A, Pasqualini D. Canal shaping with WaveOne Primary reciprocating files and ProTaper system: a comparative study. *Journal of endodontics*. 2012 Apr 1;38(4):505-9.
 32. Özyürek T. Cyclic fatigue resistance of Reciproc, WaveOne, and WaveOne Gold nickel-titanium instruments. *Journal of endodontics*. 2016 Oct 1;42(10):1536-9.