ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at: www.ijdsir.com
Volume – 5, Issue – 5, October - 2022, Page No. : 63 - 73

Assessment of Remaining Root Dentin and Fracture Resistance of Root Dentin after using Four File Systems

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Citation of this Article: Jyotirmayee Rath, Prof. Dr. Shashirekha Govind, Prof. Dr. Debkant Jena, Prof. Dr. Amit Jena, "Assessment of Remaining Root Dentin and Fracture Resistance of Root Dentin after using Four File Systems", IJDSIR- October - 2022, Vol. – 5, Issue - 5, P. No. 63 – 73.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Aim: Endodontic files evolve periodically; investigation is essential to analyse root canal instrumentation and deleterious effects on dentin. Thus, the study compare the fracture resistance of obturated mandibular premolars instrumented with Protaper Gold, Wave One Gold, 2Shape, and Endo Eze Genius files.

Material & Methods: Sixty - five non-carious mandibular premolars with a single straight root and canal were decoronated at the cement-enamel junction. Except for the control (n=5), the samples were divided into five groups (n=15 each). Control (Group A); Protaper Gold (Group B); Wave One Gold (Group C); 2Shape (Group D); Endo Eze Genius (Group E). All four groups except the control group were instrumented and obturated with gutta-percha and an AH Plus sealer using a cold lateral compaction technique. The samples were temporarily restored, and mounted with acrylic resin. Pre and postoperative CBCT determined the Bucco-lingual and mesio-distal widths. After 7 days of obturation, samples were subjected to fracture on a Universal Testing Machine. Kruskal Wallis ANOVA and post-hoc Mann-Whitney statistical analysis were applied (P 0.05).

Result: Group E had the highest fracture resistance, followed by D and C, and B had the lowest. There were no statistically significant differences between Group B and C, but there were between Group B and D and E.

Conclusion: Endo Eze Genius file (reciprocating) system outperformed (rotary) Protaper Gold, 2Shape, and (single reciprocating) Wave One Gold file systems in terms of fracture resistance.

Keywords: Fracture resistance, Root canal treatment, Rotary filesystem, Reciprocating filesystem.

Introduction

Root canal treatment has changed considerably since the hollow tube theory was first postulated in 1930. Research continues into the intricate anatomy of the root canal system and also into the microbials of endodontically related diseases. Since bacteria causes pulp and periapical diseases, the goal of root canal treatments is to eliminate bacteria from the root canal system.[1]

Maintaining the root canal anatomy and preparing the canal uniformly is the most important part of the shaping process. This is done to prevent errors such as zipping, ledging, perforation, and apical transportation, which are all associated with a loss of working length. These complications are encountered during root canal preparations which have been reported to be associated with increased incidence of vertical root fractures.[2]

Vertical root fractures (VRF's) is a sequel of gradual propagation of microcracks in tooth structure. Primarily VRF is associated due to instrument design, kinematics, and mechanical behaviour.[3] Various factors contributing towards increased susceptibility to fractures are: dehydration, increased dentin loss, caries removal, access cavity preparation, canal shaping techniques, effects of irrigating solution, prolonged placement of calcium hydroxide, pressure during obturation, post placement, tooth preparation, and retreatment procedures.[4] VRF They are serious clinical situations that will lead to the extraction of teeth. According to studies by Wilcox et al, preservation of dentin is an important factor for preventing VRF's.[5]

Nickel-Titanium (NiTi) endodontic instruments revolutionised the fundamental instruments of biomechanical preparation of the root canal system. In 1988, Walin et al. introduced NiTi alloy to endodontics. NiTi is considered to be an unique alloy because of its superior mechanical properties, i.e. shape memory effect and super elasticity.[6] A non-diffusive transformation of the lattice structure into a martensitic phase under stress is a characteristic property of these alloys. Stress induced martensitic is reversible even from highest strain without breaking. This property of greater flexibility, combined with high cutting efficiency, enhances the safety and effectiveness of instrumentation of curved canals without any deviation (stay-cantered) in final preparation.[2] In curved canals, NiTi files are 2-3 folds more elastic and flexible to bending, torsion and exhibits higher resistance to torsional fracture than stainless steel files.[3]

Design features like taper, core diameter, rake angle sectional shape and flute depth were proposed so that a predefined canal shape can be maintained with the application of less instrumentation and procedural steps. Several automated instrumentation systems based on rotary modified NiTi have been developed. Recently, newer generation NiTi instruments have been designed, namely the Protaper Gold system, Wave One Gold system, 2Shape file system, and Endo Eze Genius system. These file systems exhibit superior functional properties over one another because of their varying designs and features. Thus, the aim of this in-vitro study is to evaluate the fracture resistance of mandibular

premolars obturated after instrumentation with Protaper Gold, Wave One Gold, 2Shape, and Endo Eze Genius files.

Methodology

A total of 96, non-carious, human mandibular premolars (extracted for orthodontic treatment) were collected from Department of Oral and Maxillofacial Surgery, Institute of Dental Sciences, Bhubaneswar. Ethical clearance was obtained for the study - Ref No./DMR/IMS-SH/SOA/170057. The teeth were cleaned and stored in a solution containing thymol until use.

Inclusion criteria: single rooted mandibular premolars (both first and second) with single root canal; teeth with completely formed, intact apex. Exclusion Criteria: teeth with cracks; teeth with resorption of root; teeth with dilacerations; teeth with caries below CEJ; teeth with restorations; teeth with calcified root; teeth with aberrant root anatomy. Sixty-five teeth were selected at random from the 96 samples collected. The samples were then weighed using a digital weighing machine (Eurotech India, Pvt. Ltd., Delhi, India), and those weighing between 0.6 g and 1.1 g were considered and stored in saliva substitute (ICPA Health Product Ltd., Mumbai, India) at 37^0 C till usage.

The samples were decoronated at 15 mm in length from the CEJ using a diamond coated disc (927F, SS White) under water coolant. A stereomicroscope with 30x magnification (Motic GM-168, Motic Asia, Hong Kong) was used to examine samples for craze lines or cracks. Preoperatively, Cone beam computed tomography [(CBCT) (G1ano, New Tom, Imola, Italy)] was used to scan samples, and root length, mesiodistal and buccolingual root diameters were measured using the digital software of NNT, 7.2 VERSION (New Tom, Imola, Italy) (Figure 1). The samples were then weighed using digital weighing machine (Eurotech India, Pvt. Ltd., Delhi, India) and those having similar weight ranging from 0.6g-1.1g were taken into consideration and stored in saliva substitute (ICPA Health Product Ltd., Mumbai, India) at 37˚C till their use. Then samples were randomly divided into 5 groups: Group A: Control, Group B: Protaper Gold File System (PGT), Group C: Wave One Gold File System (WOG), Group D: 2Shape File System, and Group E: Endo Eze Genius File System. Total of 5 teeth (control group) were left uninstrumented. For 60 teeth, apical patency with #10 K-file and working length (WL) was determined using #15 K-files (Dentsply Maillefer, North America). To clean the pulp chamber, canals were irrigated with 2.5% NaOCl (Safe Plus, Neelkanth, Health Care (P) Ltd. Jodhpur, Rajasthan, India) and initial apical preparation with #15 K-file till the working length was done. EDTA gel (Dental Avenue, Thane, India) was applied along with instruments, which serves as a lubricant. After every instrumentation, canal irrigation was performed using 1mL of 2.5% NaOCl in a 5 mL syringe with a side vent needle. Furthermore, file systems were used for respective groups.

Group B: Protaper Gold File System

After initial apical preparation (#15 K-file) coronal flaring with SX Protaper Gold. (Dentsply, Tulsa Dental Specialities, Tulsa, OK, USA) at 300 rpm speed and 5.10 Ncm torque with a brushing motion was used. The canals were flushed with 1 mL of 2.5% NaOCl for 1 min to remove debris and give space for irrigants up to the apical third. In the presence of NaOCl, S1 is passively placed into the canal to follow the glide path with the same speed and torque as SX. The file was then laterally brushed to cut dentin and produce a straight-line access till the WL.

Further, the shaping was done with S2, which followed the same glide path as S1. The canals were irrigated and

recapitulated with #15 K-file to working length until they exhibited free in the canal. The first finishing file F1, which performed in a non-brushing action till WL. S2 and F1 were used at a speed of 300 rpm and a torque of 1.50 Ncm. Similarly, all canals were prepared till F3 at 300 rpm and 3.10 Ncm. Following final preparation, the final irrigation regimen consisted of irrigation with 5 mL of 2.5 percent NaOCl for 1 minute, followed by 5 mL of 17 % EDTA for 1 minute, and finally rise with 5 mL of normal saline.

Group C: Wave One Gold File System

The preliminary procedure enumerated in group B was followed. Prior to instrumenting the canals with shaping files, the canals' glide path is confirmed. The Wave One Gold Primary file (25/.07) (Dentsply, Maillefer, Ballaigues, Switzerland) was inserted into the canal in the presence of NaOCl using a gentle inward pecking motion with short amplitude strokes in a reciprocating mode at 350 rpm.

The primary file passively advances up to the working length along a smooth, reproducible glide path in one or two passes. The canals were irrigated with 1ml of 2.5% NaOCl and recapitulated with #15K file. The Small (20/.07) file was used in cases where the primary file doesn't progress till the WL and after the primary file was loose at length, the next shaping file, i.e., medium (35/.06) (last file) file was used. The final irrigation protocol was followed.

Group D: 2Shape File System

Randomly samples were instrumented using 2Shape files (Micro Mega, Besancon Cedex, France). The TS1 (20/.04) is the first file in the sequence coated with EDTA gel, placed inside the canal using continuous rotational mode at 250 rpm. The file was progressively advanced till an obstruction was felt. The files were removed, flutes were cleaned, reinserted, and circumferential brushing movement was performed to eliminate the constraints. One ml 2.5 % NaOCl was used to flush debris from canals. TS1 is continued downward for 2-3 cycles to reach WL. Canals were recapitulated with #15K file as to prevent the canals from blocking. Next is TS2 (25/.06) used similarly to TS1. The final irrigation protocol was followed.

Group E: Endo Eze Genius File System

Samples were instrumented with Endo Eze Genius group (Ultra dent Products, Inc, South Jordan, Utah, USA) and the canals were copiously filled with 2.5% NaOCl. Using reciprocation mode with settings of 350 rpm-Fwd.˚ 90; Rev˚ 30, the orifice shaper (30/.08) was used to open up the orifice and allow entry of irrigants into the canal. The Genius 25/.04 file was inserted into the canal using a gentle pecking motion until initial resistance was encountered. It was continued in the same way for 3 - 4 strokes in order to eliminate all constraints and reach WL. At WL, the canal opening was enlarged by brushing the file away from the external root concavities. Then irrigation was done using 2.5% NaOCl and canals were recapitulated with a hand file #15K file. The canals were instrumented similarly with Genius 30/.04 and Genius 35/.04. The final irrigation protocol was performed at the end of the instrumentation procedure.

For all groups, CBCT scanning was done before obturation to evaluate the remaining dentin thickness (Figure 1). The canals were dried using paper points of size 35/.06 and 30/.04 (Diadent Dental Products, Chungcheong Buk-do, Korea). The master apical cone was taken to be 35/.06 (Diadent Dental Products, Chungcheong Buk-do, Korea) for Groups B, C, and D and 35/.04 for Group E. Obturation was done using AH plus sealer (Dentsply India Pvt. Ltd., Indiranagar, Noida,

India) followed by a cold lateral compaction technique using 20/.02 and 25/.02 gutta percha points.

Access cavities of all samples were temporarily restored with Tempfil-G (Shivam Industries, Jammu, India). Cylindrical acrylic resin blocks were prepared with plastic moulds (Long last Pipes Pvt. Ltd., Kolkata, India) using self-cure acrylic resin. (DPI-RR, Dental Products of India, Mumbai, India). The apical root ends of the samples were vertically inserted in a 4 mm acrylic block, exposing 11 mm of the coronal region of each root prior to curing the acrylic.

Prior to strength testing, the roots were kept moist using a wet cloth. After seven days of obturation, the temporary restoration was removed and the fracture resistance of the groups was evaluated using the Universal Testing Machine (Model No.8801, Instron, Massachusetts, United States). To retain acrylic blocks during testing, a steel jig with a 30° angle between the long axis of the root and the steel rod (tip diameter = 0.2 mm) was fabricated. The resistance test was conducted using a Universal Testing Machine (UTM) with a crosshead speed of 1 mm/min. The load required to fracture the samples was recorded in Newton (N). The values obtained were statistically analysed.

Results

Mean Fracture resistance (± standard deviation) were calculated for each group, the groups were compared using Kruskal Wallis ANOVA and a multiple comparison test was performed using Post hoc Mann Whitney Comparison Test (SPSS software version 20, SPSS).

CBCT postoperative remaining dentin thickness shown in the table 1 is evident that reciprocating group E file system has removed less dentin from coronal, middle and apical root dentin. (Figure 1)

The mean fracture load required for Group A (Control) 485.42 ± 7.02N, Group B (Protaper Gold) 242.57 ± 13.41 N, Group C (Wave One Gold) 271.82 ± 12.06 N and Group D (2Shape) 292.45 ± 8.72 N, and Group E (Endo Eze Genius) 398.75 ± 9.94 N. (Table 2)

The fracture resistance exhibited significant differences between the groups ($p < 0.05$). Post hoc Mann Whitney comparisons showed that Group A (control) significant differences from all other groups. Group B (Protaper Gold) did not differ from Group C (Wave One Gold) ($P>0.05$), but did differ from D (2Shape) and E (Endo Eze Genius) ($P<0.05$). Group C (Wave One Gold) exhibited insignificant difference compared to Group D (2Shape) ($P>0.05$), but significant difference with Group E ($P<0.05$). Group D (2Shape) was statistically significant with respect to Group E (Endo Eze Genius) ($P<0.05$). To summarize, Group E (Endo-Eze Genius) exhibited the maximum fracture resistance among groups and Group B (Protaper Gold) exhibited the least. (Table 2)

Discussion

Endodontic and restorative procedures have been reported to affect the microhardness, elasticity, and fracture resistance of dentin.[7] Several predisposing factors, such as excessive loss of tooth structure due to caries or trauma, dehydration of dentin, access cavity preparation and instrumentation with rotary files, undesirable effects of irrigating solution, excessive pressure during filling procedure, and preparation of intra-radicular post space, affect the strength of endodontically treated teeth.[8,9]

Human mandibular premolars are used in this study because of their similarity in shape and their availability after orthodontic extraction. In the present study to eliminate the differences statistically similar samples having straight root with single straight canal and with

similar weights were taken into account. A thorough radiographic assessment assists the operator in determining the location and angulation of the root canal system. Historically, this was accomplished with periapical and bitewing radiographs in two dimensions. Today, CBCT is an additional and quite effective imaging method.[7]

In collaboration, the American association of Endodontics (AAE) and the American academy of Oral and Maxillofacial Radiology (AAOMR) established the application of cone beam computed tomography (CBCT) in endodontics.[10] CBCT technology can guide CEA (Conservative Endodontic Access) preparation by providing valuable information for pre-access analysis. Complex anatomy (isthmus, buccolingual canals, developmental defects, etc.) can be considered.[7] In this study, CBCT measured pre- and post-biomechanical preparation dentin levels in all groups. CBCT results showed less tooth structure loss in reciprocating system than rotary system, suggesting dentin loss in rotary groups is due to continuous clockwise rotation, Where in the reciprocating system, clockwise and anticlockwise motion lead to less cutting of dentin, preserving the remaining tooth structure.

Chadha et al. evaluate the effect of various obturating materials on the fracture resistance of root canal treated teeth and concluded that teeth obturated with AH Plus + GP are more resistance to fracture than those obturated with Resilon-Epiphany, ZOE and unobturated group.[11] In the present study, the teeth were kept at 37˚ C for 7 days prior to the strength test to allow complete setting of sealer.

For the current study, each tooth was embedded 4 mm vertically in an acrylic resin block, exposing 9 mm of its coronal portion. This is more clinically relevant, as it efficiently simulates the support given to healthy teeth by alveolar bone and results in less catastrophic stress buildup due to unrealistic binding movements.[12]

Using NiTi rotary reciprocating files causes transient strains in dentin due to contact and friction with canal walls. Kim et al. found that rotary files stress outer surface dentin by 311-368 MPa and the tensile strength of radicular dentin is 106 MPa. Excessive taper can cause dentin loss and root thinning, leading to VRF.[13]

Two conventional rotary and two reciprocating systems were used to evaluate fracture resistance in the present study. Group D (2Shape) exhibited higher fracture resistance than Group B (Protaper Gold) among the two rotary file systems. This may be due to the progressive increase in taper of Protaper Gold (9 %) compared to 2Shape (6 %), which leads to an increase in dentin loss and a weakened tooth structure. Endodontic instruments' performance and mechanical properties can be significantly affected by their design, heat treatment, cross-sectional shape, helical angle, and dimensions. According to tests conducted by Hieawy, Protaper Gold possesses a two-stage transformation behaviour (Austenite [A] – R-phase – Martensite [M]), The first stage of transformation (A-M) occurs in nickel-rich NiTi alloys, while the second stage (A-R-M) occurs after additional heat treatment.[14] The heat treatment forms finely dispersed Ti_3Ni_4 precipitate in austenitic matrix. Consequently, R-phase is formed in preference to martensite due to the presence of Ti_3Ni_4 fine particles. However, the alloy needs additional cooling to form martensite, and hence the martensitic transformation occurs in two steps. PTG is manufactured from CM wire, which has a lower percentage (52% by weight) of NiTi than most commonly used wire. Along with CM wire, Protaper Gold is manufactured using complex heat treatment. This gives the characteristic golden colour to them which improves their flexibility to a greater

extent.[15] In present study Protaper Gold showed least fracture resistance. The reason could be its increased progressive taper, i.e. F3 30%/0.09 (9%), which might have resulted in greater amount of dentin loss comparatively. Studies have shown taper to be an important factor in causing root fracture. The greater the amount of taper, increased amount of loss of tooth structure. Though Protaper Gold has improved flexibility and higher cyclic fatigue resistance, according to the study by Elnaghy AM et al., loss of tooth structure was observed in PTG Group B. [16]

Rotary file system 2Shape files is a sequential file with 2 shaping files and 2 apical preparation files. It works in a continuous rotation mode. T-wire technology along with heat treatment which the manufacturer claims to improve cyclic fatigue resistance up to 40% with increased flexibility.[17] The asymmetrical cross-section with triple helix, compromise between cutting efficiency and debris removal.[18] According to the findings of present study, 2Shape performed better than compared to PTG & WOG. This result is attribute to the fact that 6% of 2Shape files (35/.06 used as last apical file) may have resulted in improved resistance than PTG & WOG with taper sizes of 9 % and 7 %, respectively. Not so with Endo Eze Genius (4 %), which has the least taper among the groups. The second reason for improved fracture resistance may be due to the T-wire technology, which may also confer increased resistance to instrument fracture and the enhanced flexibility. In turn, this improves the negotiation of curvature and maintenance of elasticity of NiTi files. [19,20]

Comparing both reciprocating systems, Group E (Endo Eze Genius) demonstrated statistically significant superiority over Group C (Wave One Gold). Possibly due to the taper, as Endo Eze Genius has a 4 percent taper and Wave One Gold has a 7 percent taper, but it could also be due to the increased reciprocating angle of Wave One Gold, where the disengaging and releasing portion of motion occurs less frequently, thereby increasing stress on the tooth structure. The oscillation movement reduces file stress by rotating in the counter clockwise (CCW) direction prior to completing the cycle in the clockwise (CW) direction. According to reports, this benefit increases file fatigue life. Wave One has been modified as Wave One Gold. M wire is a NiTi alloy that has undergone a special thermal treatment and is used to prepare Wave One Gold files. The cross section of the file has been modified to a parallelogram with two cutting edges at an angle of 85 degrees in contact with canal walls, alternating with a patented Dentsply off-centred cross section in which only one cutting edge is in contact with canal walls. To increase its fracture resistance, the file rotates five times faster anticlockwise than clockwise. The CW file movement disengages the instrument from the dentin, relieves stress as it enters the canal, and reduces taper lock.[20] Reducing the file's contact area with the canal wall and maintaining a constant helical angle at 24 degrees reduces binding. Additional space around the instrument helps removal of debris. The Wave One Gold file system has been used sequentially (3 files: small (20/0.07), primary (25/0.07), and medium (35/0.06)) to decrease the cyclic fatigue of file and improve the fracture resistance of teeth.[20]

Endo Eze Genius files can be used both in reciprocating and rotary modes. In this study, the Endo Eze Genius files were used in reciprocating mode to compare rotational and reciprocating motions of the file system. Endo Eze showed better resistance to fracture than Wave One Gold because of an increased taper of 7% of WOG compared to Endo Eze Genius. [21,22]

The reciprocating at 90-degree clockwise movement and 30-degree counter clockwise movement of the file relieves stress on the file. The system maintains a 4 % taper. The smaller the reciprocating angle, the more often the releasing and disengaging portion of motion occurs. Group E (Endo Eze Genius) may have shown better tooth fracture resistance due to this feature and the taper (Wave One Gold).

Root canal apical preparation involves larger files to reach the canal's entire perimeter.

This will improve canal irrigation, infection control, and root canal filling quality.[23] Disparity between rotary or reciprocation file apical size and canal apical cross section led to larger file recommendations.[24] Multiple instrument systems for glide path preparation produce less peak torque and force than single instrument systems.[25]

Restoration of endodontically treated teeth with extensive loss of tooth structure remains a formidable clinical challenge. The clinical survival of these teeth is contingent on a number of factors, including dental type, occlusal load, the restorative material used, and the remaining tooth structure. Clinician should always be familiar with various file systems, and root canal anatomy should determine instrumentation.

Conclusion

As to conclude, the Endo Eze Genius file system exhibited the highest fracture resistance compared to the Protaper Gold system, which exhibited the least fracture resistance across the groups. Therefore, the choice of files should be based on the anatomy and configuration of the canal.

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Legend Tables

Table 1: CBCT Pre-postoperative Remaining Dentin Thickness.

	Coronal third		Middle third		Apical third	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Group B (Protaper)	2.3mm, 2.1mm	2.3mm, 2.1mm	1.5mm, 1.7mm	1.5mm, 1.7mm	0.9mm, 1.1mm	0.9mm, 1.1mm
Group C (Wave One Gold)	2.2mm, 2.1mm	2.1mm, 1.7mm	1.8mm, 1.8mm	1.5mm, 1.4mm	1.1mm, 0.9mm	0.8mm, 0.9mm
Group D (2Shape)	1.9mm, 2.3mm	2.0mm, 1.8mm	1.6mm, 1.7mm	1.5mm, 1.4mm	1.1mm, 1.2mm	1.1mm, 0.9mm
Group E (Endo Eze Genius)	2.0mm, 2.0mm	2.0mm, 2.0mm	1.7mm, 1.8mm	1.7mm, 1.6mm	1.1mm, 1.1mm	0.9mm, 1.0mm

Table 2: Comparison of fracture resistance among the groups.

	N	(Fracture force) mean	Standard deviation	Std. Error	Interval for mean		Minimum values	Maximum values
Group A (control)	5	485.42	7.02	3.14	476.70	494.14	473.76	491.63
Group B (Protaper)	15	242.57	13.46	3.46	235.77	249.85	211.23	265.67
Group C (Wave One Gold)	15	271.82	12.06	3.11	265.14	278.50	251.65	291.53
Group D (2Shape)	15	292.45	8.72	2.25	284.97	300.63	253.67	302.45
Group E (Endo Eze Genius)	15	398.75	9.94	2.57	393.24	404.25	377.32	412.67
Total	65	307.29	89.10	11.05	285.21	329.37	169.97	491.63
Kruskal Wallis ANOVA, $p<0.05$.								

Figure 1: Representing the CBCT images: a) pre- and postoperative CBCT Images of group B b) pre- and postoperative CBCT Images of Group E.