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Edited by Hiroj Bagde
E-mail: hirojbagde8@gmail.com
Phone: +91 9766105900
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Pericervical dentin preservation and fracture resistance across three instrumentation systems: A CBCT study

Sarang B. Satheesh*, Rekha P. Thankachan, Anoop Samuel, K. Ranjith, H. Azeem & P.V Bhagyalakshmi

Department of Conservative Dentistry and Endodontics, MES Dental College, Perinthalmanna, Kerala, India; *Corresponding author

Affiliation URL:
https://mesdc.edu.in/

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Author contact:
Sarang B. Satheesh - E-mail: sarangbsatheesh116@gmail.com
Rekha P. Thankachan - E-mail: rekhasamuel7@gmail.com
Anoop Samuel - E-mail: anoopzsam@gmail.com
K. Ranjith - E-mail: ranjukarat86@gmail.com
H. Azeem - E-mail: drazeemhassan@gmail.com
P.V. Bhagyalakshmi - E-mail: bhagyalakshmi.pvs@gmail.com

Abstract:
Excessive pericervical dentin removal during root canal instrumentation may weaken endodontically treated teeth and reduce fracture resistance. Therefore, it is of interest to compare the Hand K-Files, ProTaper Gold, WaveOne Gold and One Curve in 40 mandibular premolars. CBCT quantified pre- and post-instrumentation canal wall thickness and a universal testing machine measured fracture resistance. Overall wall-thickness reduction was 16.40%, 18.32%, 18.90% and 18.04%, respectively; Hand Files had the highest fracture resistance, while One Curve ranked highest among rotary systems. Thus, One Curve showed the most favorable balance of dentin preservation and fracture resistance among the rotary systems.

Keywords: Pericervical dentin (PCD), fracture resistance, nickel–titanium rotary instruments, cone beam computed tomography (CBCT), root canal preparation

Background:
The amount of tooth structure preserved, irrigation, disinfection, post endodontic restorations and minimally invasive preparation are all factors that affect how well endodontic therapy works **[1].** Endodontically treated teeth are more prone to fracture owing to the loss of tooth structure and the compromise of the internal dentinal architecture resulting from access cavity preparation and root canal instrumentation. The widening of the canal taper, insufficient preservation of the pericervical dentin (PCD), the impact of ongoing occlusal pressures, the dehydration of dentinal tubules and the reduced mechanical properties of the tooth are further factors that contribute to decreased fracture resistance in endodontically treated teeth (ETT) **[2, 3].** Quantifying this residual dentin thickness and its impact on fracture resistance has been the subject of recent research. To support a ferrule and increase the tooth's overall fracture resistance; the pericervical dentin must be preserved. According to earlier research, teeth with root canal therapy show little resistance to fracture when the level of preparation is high. Smaller-tapered nickel titanium (NiTi) files are more resistant to fracture than larger-tapered files. To increase the shaping process' efficiency, a number of rotating NiTi endodontic file systems was introduced in the last ten years. In order to increase shaping effectiveness with minimum dentin loss, single rotary file systems use a continuous 360-degree rotation with files made up of flexible, heat-treated NiTi alloys. These files frequently have variable tapers (progressive, regressive, or fixed). Single reciprocating file systems, on the other hand, rotate in alternate directions, which lessen file fatigue and stress. Compared to continuous rotary devices, reciprocation allows for safer and more cautious canal negotiation, reducing the danger of excessive dentin removal and canal transit. Although successful, typical sequential instrumentation frequently removes more dentin overall, especially when utilizing bigger tapers (*e.g.,* ProTaper Gold with up to 7% taper). Sequential file systems use a series of files with progressively increasing taper for gradual canal widening. PCD thickness can be accurately measured for endodontic diagnosis, treatment planning and evaluation thanks to CBCT, one of the available methods that offer a more accurate three-dimensional representation of maxillofacial osseous structures at a comparatively low radiation dose **[4].** Therefore, it is of interest to compare the preservation of pericervical dentin and fracture resistance of root canal-treated teeth prepared with a single rotary file system, a single reciprocating file system and a sequential file system, using CBCT as an evaluation tool in this *in vitro* study.

Materials and Methods:
The study was conducted Department of Conservative Dentistry and Endodontics at MES Dental College in Perinthalmanna. The ethical clearance was obtained from the institutional ethical committee. Mandibular premolars extracted for orthodontic purpose were collected and carefully screened followed by disinfection and standardized storage.

Pre-operative scans:
Preoperative CBCT scans (New Tom) with 11 × 8 FOV were performed to measure the thickness of the pericervical dentin. At the cementoenamel junction (CEJ), CBCT imaging was performed at 90 kVp, 10 mA, for 40 s and 150 µm thick slices were acquired. The pericervical dentin thickness is computed as the shortest distance between the facial lingual, mesial and distal surfaces of all the groups in the scans and the closest adjacent root surface **[5]**. NNT software was used to take the measurements.

Instrumentation:
The access cavity was prepared to provide straight-line access using an endodontic access bur. Canal patency was determined by passing 10K file passively and working length was established until the file is seen at the apex. 17% EDTA (PREVEST Denpro Ltd.) normal saline, 5.25%sodium hypochlorite (Septodent) were used to irrigate canal while instrumentation the sample by no 15K file up to working length

to produce a reproducible glide path. The samples were then instrumented with corresponding rotatory file system according to the manufactures instructions. Depending on the type of rotary files used for cleaning and shaping, samples were divided into four groups.

[1] Group A: (control group): Hand files (fixed taper) Samples were prepared with hand file (Mani Inc., Japan) of 2% taper sequentially used up to size 30.

[2] Group B: ProTaper Gold (PTG) (progressive taper, Dentsply Millefleur) Samples were prepared with ProTaper Gold files in the sequence of SX, S1, S2 and F1and F2 at 300 RPM, torque 4.0 - 5.2 Ncm using gentle in-and-out brushing motion.

[3] Group C: Wave-One Gold (single file reciprocating system) The WO (primary; 25, 0.06% taper; Dentsply Millefleur) reciprocating single file system was used to instrument the samples in this group at 350 RPM and 2.0 Ncm to 5.2 Ncm. Following flaring, the WO files were used in pecking motion with Xsmart Plus (Dentsply Maillefer).

[4] Group D: The One Curve ((OC): Micro -Mega, Besancon, France) Samples were prepared using OC (25/0.06) at 300 rpm to 450 rpm and 2.5Ncm.

Post-operative analysis:

Post-instrumentation CBCT scans were obtained after repositioning each specimen in the customized template at the same angulation as the preoperative scan and PCD thickness was recorded using the same landmarks. After the final irrigation protocol, canals were dried with sterile paper points and master gutta-percha cone fit was confirmed radiographically. All four groups were obturated: Groups B, C and D were filled using a single-cone technique with gutta-percha corresponding to the final instrument, whereas Group A was filled by lateral condensation with a master cone and accessory cones using a #25 stainless-steel finger spreader. The dentinal walls were coated with AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) before placement of the gutta-percha. Excess gutta-percha was removed with a heated hand plugger, access cavities were restored with composite resin and specimens were stored for 7 days at 37°C and 100% humidity to allow sealer setting. The specimens were then subjected to fracture-resistance testing.

Fracture resistance analysis:

After post CBCT analysis samples were mounted in an acrylic block 2mm apical to CEJ. Wax was removed and replaced by silicon impression material to simulate the periodontal ligament. Fracture resistance was checked by applying force of 1mm/ min using universal testing machine along the long axis of the tooth until fracture and calculated in Newtons (N).

Statistical analysis:

Data were analyzed using SPSS version 26.0 (SPSS Inc., Chicago, IL), with statistical significance set at $p < 0.05$. Continuous variables were summarized as mean ± standard deviation and normality was assessed using the Shapiro-Wilk test. Within each instrumentation group, pre- and post-instrumentation canal wall thickness at each segment was compared using a paired t-test when normally distributed; the Wilcoxon signed-rank test was used when normality was not met. Between-group comparisons for each canal wall segment and for fracture resistance were performed using one-way ANOVA with post-hoc pairwise testing when parametric assumptions were satisfied; otherwise, the Kruskal-Wallis test with Bonferroni-adjusted pairwise comparisons was used. Overall percentage reduction in canal wall thickness was calculated as [(preoperative thickness − postoperative thickness) / preoperative thickness] × 100 and 95% confidence intervals were reported where applicable.

Results:

For segment-wise comparison within each group (buccal versus lingual versus mesial versus distal), one-way analysis of variance (ANOVA) was used. The F-value and corresponding p-value were calculated to determine whether significant differences existed among the canal wall segments. To compare canal wall thickness among the four instrumentation groups, another one-way ANOVA was performed separately for each canal wall segment during both pre-operative and post-operative intervals. When statistically significant differences were observed, Tukey's post-hoc test was applied to identify the specific groups responsible for the differences. 95% confidence intervals (CI) were also calculated for the mean differences. Fracture resistance values were analysed using one-way ANOVA to compare the mean fracture resistance among the four instrumentation groups. When significant differences were identified, Tukey's post-hoc test was performed to determine pairwise group differences. The within-group changes in canal wall thickness are summarized in **Table 1**, while the between-group comparisons at the pre-operative and post-operative intervals are presented in **Table 2 (Figure 1, 2).**

Table 1: Within-group comparison of canal wall thickness

Group	Segment	Pre-operative Mean ± SD	Post-operative Mean ± SD	Mean Difference	t value	p value
Group A – Hand Files	Buccal	2.32 ± 0.28	1.86 ± 0.40	0.46	4.59	0.001*
	Lingual	2.27 ± 0.32	2.08 ± 0.27	0.19	3.48	0.007*
	Mesial	1.56 ± 0.48	1.23 ± 0.30	0.33	3.46	0.007*
	Distal	1.41 ± 0.38	1.16 ± 0.33	0.25	2.47	0.036*
Group B – ProTaper Gold	Buccal	2.28 ± 0.34	1.87 ± 0.48	0.41	2.7	0.024*
	Lingual	2.29 ± 0.34	1.87 ± 0.26	0.42	3.33	0.009*
	Mesial	1.42 ± 0.19	1.14 ± 0.24	0.28	3.56	0.006*
	Distal	1.65 ± 0.31	1.35 ± 0.28	0.3	3.74	0.005*
Group C – WaveOne Gold	Buccal	1.87 ± 0.32	1.56 ± 0.25	0.31	3.54	0.006*
	Lingual	2.00 ± 0.41	1.53 ± 0.29	0.47	4.75	0.001*

Group D – One Curve	Mesial	1.25 ± 0.33	1.02 ± 0.25	0.23	4.44	0.002*
	Distal	1.44 ± 0.35	1.19 ± 0.26	0.25	4.61	0.001*
	Buccal	1.89 ± 0.36	1.61 ± 0.30	0.28	5.06	0.001*
	Lingual	2.26 ± 0.45	1.98 ± 0.40	0.28	5.47	0.0004*
	Mesial	1.57 ± 0.40	1.30 ± 0.41	0.27	5.22	0.0006*
	Distal	2.05 ± 0.39	1.45 ± 0.39	0.6	4.02	0.003*

*Paired t test, *P<0.05 is statistically significant*

Table 2: Between-group comparison of canal wall thickness at different segments

Segment	Interval	Group A (Mean ± SD)	Group B (Mean ± SD)	Group C (Mean ± SD)	Group D (Mean ± SD)	F value	p value
Buccal	Pre	2.32 ± 0.28	2.28 ± 0.34	1.87 ± 0.32	1.89 ± 0.36	5.84	0.002*
	Post	1.86 ± 0.40	1.87 ± 0.48	1.56 ± 0.25	1.61 ± 0.30	2.46	0.078
Lingual	Pre	2.27 ± 0.32	2.29 ± 0.34	2.00 ± 0.41	2.26 ± 0.45	1.34	0.276
	Post	2.08 ± 0.27	1.87 ± 0.26	1.53 ± 0.29	1.98 ± 0.40	5.72	0.003*
Mesial	Pre	1.56 ± 0.48	1.42 ± 0.19	1.25 ± 0.33	1.57 ± 0.40	1.64	0.198
	Post	1.23 ± 0.30	1.14 ± 0.24	1.02 ± 0.25	1.30 ± 0.41	1.93	0.141
Distal	Pre	1.41 ± 0.38	1.65 ± 0.31	1.44 ± 0.35	2.05 ± 0.39	8.64	<0.001*
	Post	1.16 ± 0.33	1.35 ± 0.28	1.19 ± 0.26	1.45 ± 0.39	1.56	0.213

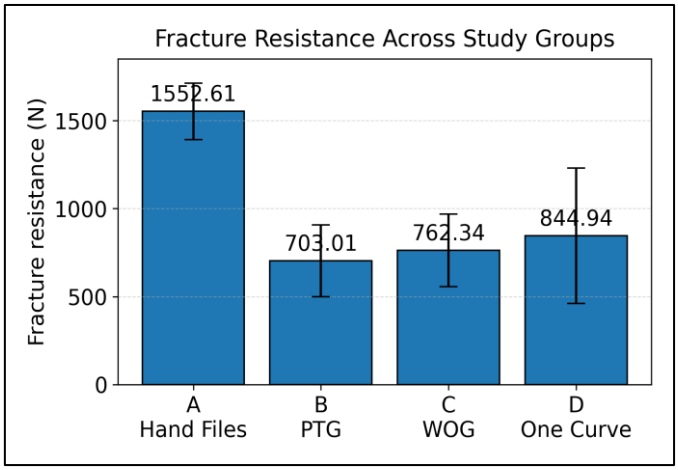

Figure 1: Comparison of fracture resistance of the study groups (A: Hand Files; B: ProTaper Gold (PTG); C: WaveOne Gold (WOG); D: One Curve).

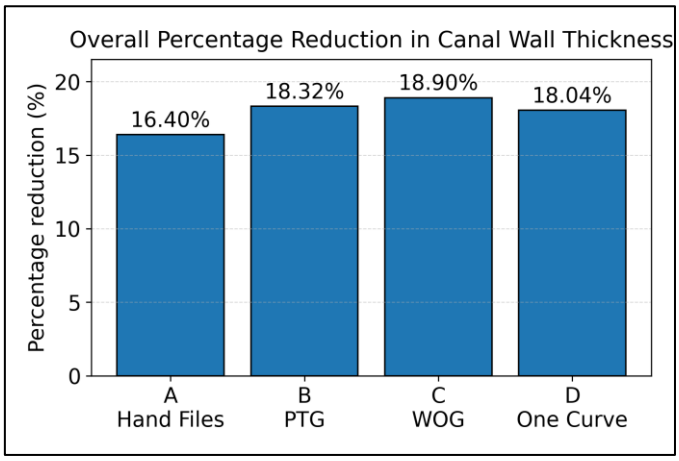

Figure 2: Overall percentage reduction in canal wall thickness (A: Hand Files; B: ProTaper Gold (PTG); C: WaveOne Gold (WOG); D: One Curve).

Discussion:

Preserving the natural tooth structure during endodontic treatment is crucial for predictable clinical outcomes **[6].** Endodontically treated teeth are susceptible to failure due to the cumulative loss of tooth structure resulting from excessive access cavity preparation, root canal instrumentation, instrument taper and canal shaping performed to facilitate obturation. A simple approach that prioritizes dentin preservation is the most recent advancement in endodontics. This bio-minimalism helps to reduce cuspal flexure during mastication and recognizes the vital role of pericervical dentin (PCD) in sustaining the remaining coronal tooth structure under functional loading stress **[7].** The tooth structure is weakened and the root is more likely to fracture if irreplaceable PCD is removed too much from the area surrounding the crestal bone. Larger amounts of this vital cervical dentin are removed by devices with progressive taper, weakening the tooth. Thankfully, developments in instrumentation technology are bringing minimally invasive endodontics closer to reality **[8].** A recent CBCT study by López-Velasco *et al.* **[8]** likewise demonstrated system-dependent pericervical dentin preservation, supporting the present comparison of file design, taper and kinematics. The latest developments in endodontic instruments include flexible martensitic heat-treated NiTi rotary files with different tapers. It is advised that instruments **[8, 18]** should be manufactured of heat treated NiTi material and has a regressive taper for cautious and safe shaping **[9].** Dentin is preserved more when the taper is more regressive. Studies on the fracture resistance of teeth sometimes yield conflicting results due to variations in the quantity of samples, tooth kinds, inclusion criteria and testing circumstances. The amount of remaining dental structure is directly related to a tooth's lifetime and fracture resistance **[10].** The tooth's retention period increases with the amount of remaining dentin **[11].** Furthermore, Zandbiglari *et al.* **[11]** proposed that excessive coronal expansion with more tapered devices weakens the tooth considerably and increases the risk of fracture. Studies by Oliveira *et al.* **[12]** and Assif *et al.* **[13]** showed that endodontically treated teeth are more prone to fractures compared to vital teeth. The present study evaluated the effect of four different instrumentation systems Hand Files

(Group A), ProTaper Gold (Group B), WaveOne Gold (Group C) and One Curve (Group D)-on canal wall thickness and fracture resistance of teeth. Analysis of canal wall thickness showed a reduction in dentin thickness from pre-operative to post-operative measurements in all groups across the buccal, lingual, mesial and distal segments, indicating effective canal preparation. Segment-wise comparison within each group using one-way ANOVA also revealed significant differences among the canal walls, suggesting variation in dentin distribution around the root canal before and after instrumentation. After instrumentation, dentin was significantly reduced in all groups, according to an overall assessment of canal wall thickness. Group C (WaveOne Gold) had the largest percentage drop in canal wall thickness (18.90%), followed by Group B (ProTaper Gold) at 18.32%, Group D (One Curve) at 18.04% and Group A (Hand Files) at 16.40%. This suggests that the One Curve approach has somewhat better dentin preservation. This may be explained by the Wave One Gold system's larger taper (7%), which causes more dentin to be removed, weakening the tooth and making it more prone to fractures **[14].** The WaveOne Gold system's reciprocating action, which consists of a 150° clockwise rotation and a 30° counter clockwise disengagement, produces torsional forces that lead to the production of microcracks and decreased fracture resistance **[15].** Similar results were obtained by Cassimiro *et al.* (2018) **[14]**, who reported that Reciproc, Pro Taper Next and WaveOne Gold produced microcracks in 18.33%, 33.33% and 60% of cases, respectively. The results of this study concluded that Hand K-Files provided the highest fracture resistance among the file systems tested, this could be due to the fact that less taper conserves more root dentin, contributing to improved tooth strength. CBCT has become a potent non-destructive technology that offers images in both oblique and orthogonal planes for improved evaluation **[16].** Therefore, the shaping performance of the evaluated systems and the evaluation of changes in root canal volume before and after instrumentation were assessed in this study using the CBCT technique. PDL may influence fracture patterns and is essential for the dispersion of stress in root canals **[17].** Silicone-based imprint material was employed to replicate the PDL by distributing the force across the root's surface rather than concentrating it in one spot. The study has certain drawbacks **[18-23].** It is still difficult to totally remove the impact of outside influences on the outcomes, even with efforts to reduce differences between experimental and clinical settings. Since this investigation was carried out *in vitro*, it was not possible to recreate some in vivo elements in the lab, such as masticatory forces and the dynamic oral environment. Furthermore, the study's file systems run at particular torque and speed values, which could lead to variances in the amount of stress produced and cutting efficiency.

Conclusion:

One Curve showed higher fracture resistance and somewhat better dentin preservation among the rotational instrumentation methods, making it a preferable choice for preserving tooth strength. On the other hand, ProTaper Gold showed the worst results in terms of fracture resistance, whereas WaveOne Gold was linked to more dentin removal. These results highlight how crucial it is to use instrumentation systems that both effectively prepare canals and preserve dentin in order to improve the long term prognosis of teeth that have had endodontic treatment.

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