The Saudi Dental Journal 36 (2024) 650–655

Contents lists available at ScienceDirect

The Saudi Dental Journal

journal homepage: www.ksu.edu.sa
www.sciencedirect.com

Original Article

Comparative evaluation of remaining dentin thickness, canal centering ability and apical deformity between ProFit S3 and Protaper gold – A nano CT study

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ARTICLE INFO

Keywords:
Nano-CT
Rotary file
Remaining dentin thickness
ProFit S3
Canal centering

ABSTRACT

Purpose: For the root canal treatment to be successful, the root canal system must be cleaned and shaped, and must be gradually widened from the apical to the coronal region in order to preserve dentin thickness. ProFit S3 (Profit Dental, India) patented rotary file with variable taper design preserves dentin. The study employs ultra-high-resolution nano-computed tomography to assess the volumetric changes of two new rotary files in permanent mandibular premolars.

Materials and methods: Based on inclusion and exclusion criteria, this in-vitro investigation used extracted premolars. Before the pre-operative scan, samples were made and the working length was determined using a high-precision nano-CT (SkyScan 2214, Bruker, Kontich, Belgium). A single skilled pediatric dentist used ProFit S3 (Profit Dental, India) and Protaper Gold (PTG; Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) to prepare the canals. Post-op scans were similar to pre-ops. For 3D root canal visualization and analysis, NRecon software was used to rebuild images.

Results: Profit S3 has a mean value of 0.65500 and Protaper gold 1.38800, indicating a significant range. Protaper gold followed Profit S3 in canal volume differential. The two rotating file systems differed significantly (p 0.05). ProFit S3 maintained mesiodistal and buccolingual dentin thickness at 4 mm, 8 mm, and 12 mm, followed by Protaper Gold.

Conclusions: ProFit S3 exhibited the lowest mean canal volume difference compared to Protaper gold. Unlike Protaper Gold, ProFit S3 offers a variable taper design that preserves root canal anatomy, peri cervical dentin, and dentin thickness.

1. Introduction

Cleaning and eradicating bacteria from the root canal system is crucial to the effectiveness of endodontic therapy (Pinto et al., 2019). A sufficient irrigation system and canal obturation are made possible by chemo-mechanical preparation that preserves the natural canal anatomy without iatrogenic occurrences (Radwański et al., 2021). As much as feasible, the root canal's original shape must be preserved while it is progressively increased in size from the coronal to the apical region (Faisal et al., 2021). A significant problem for dentists is the root canal system's anatomical complexity and variances, which increase the risk of complications such ledges, zips, perforations, and canal transportation during the canal-shaping process (Xu et al., 2021).

In an effort to make the process of preparing canals simpler and reduce the likelihood of operational errors, manufacturers are continually developing new instruments or making modifications to existing ones. In actuality, the alloy has experienced constant alteration, as have the cutting blade designs, tapers, helix angles, number of flutes, cross-sectional designs, and tip patterns (Shen et al., 2013). Variations in these factors affect the instruments' mechanical characteristics, cutting

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https://doi.org/10.1016/j.sdentj.2024.01.002
Received 15 September 2023; Received in revised form 27 December 2023; Accepted 1 January 2024
Available online 2 January 2024

effectiveness, and shaping capacity (Drukteinis et al., 2019). NiTi files reduce the frequency of procedural errors and enable faster instrumentation of the root canals while maintaining a greater degree of safety (Shojaeian et al., 2021). To keep the original canal form centered, a variety of root canal shaping approaches have been proposed using various NiTi systems (as M-wire, R-phase, traditional NiTi) and varied dynamics (continuous rotation, reciprocating motion, and adaptive motion) (Pedullà et al., 2016). Investigations have revealed that although NiTi instruments are flexible, torsionally strong, and have elastic memory, they nonetheless leave a sizable portion of the canal surface undisturbed (Sousa-Neto et al., 2018).

The ProTaper Gold (PTG) system, according to the manufacturer, combines a continuously tapered form with a for a more effective, adaptable, and secure cutting action, use a convex triangular cross-section, changeable progressive taper, and rotational motion (Yılmaz Çırakoglu and Özbay, 2021). Profit S3 (PS3), titanium oxide-coated heated rotary system based on Blue Technology, was presented in 2019. It has a rectangular cross-section with a variable taper design. With two points of contact, its cross-section lessens debris ejection. One orifice opener and three finishing files make up the PS3. The finishing files P0 orifice opener, PF1 (yellow), PF2 (red), and PF3 (blue). The PS3 has exceptional flexibility, fracture resistance, and form memory. The taper can be ranging between 4 % and 8 % (Antony et al., 2020).

Micro-computed tomographic (micro-CT) imaging for root canal studies enables a thorough and non-destructive 2- and 3-dimensional root canal morphology analysis. Accurate measurement equipment makes it possible to compare multivariate data from samples prior and post GPP and shaping (van der Vyver et al., 2019). The industry standard for examining the shaping capabilities of NiTi systems is high-resolution X-ray micro-CT, despite the fact that several other methods have been developed. Since it makes it possible to analyze several sample variables in three dimensions, quantitatively, and without causing damage (Velozo et al., 2020). In the medical field, bone cells, cartilage, and vascular networks can now be seen using nano-CT systems that have extremely high spatial resolution and a nano-focal point source of less than 400 nm (Ahmed, 2016).

Therefore, the objective is to assess the volumetric changes of two recently introduced rotary files in permanent mandibular premolar using ultra-high-resolution nano-computed tomography.

2. Materials and methods

2.1. Study design and ethical clearance

G power algorithm was used to calculate the sample size. This was performed from the data obtained from the results of the previously published research conducted with a similar methodology at 95 % power with a significance level of 0.05 (Loch et al., 2013). The calculated sample consisted of 20 permanent mandibular single canal premolars between two groups (ten teeth per group). Ethical clearance for the current study was granted from the institutional human ethical committee for dental research with the approval number SRB/SDC/ENDO-2106/23/116.

2.2. Study samples – inclusion and exclusion criteria

The samples used in the study are mandibular lower premolar. The patients refused root canal therapy for their symptomatic deteriorated teeth; therefore the teeth were extracted due to trauma, orthodontic treatment, or symptomatic decay. A consent document was signed for extraction after the patients were informed that the extracted teeth may be used for research. In the event of any internal or external resorption, as determined by radiographic and visual examination, the teeth were excluded. The teeth with abnormal root morphology were excluded.

2.3. Teeth sample preparation

Tap water was used to rinse the extracted teeth. Using ultrasonic scaler tips, the debris from the soft and hard tissues was eliminated. The samples are moved to specimen containers filled with distilled water, later all the samples were disinfected using 10 % formalin solution for one minute (Sandhu et al., 2012). Two groups were prepared by a single operator, which also removes any potential bias resulting from inter-operator variability. Using a high-speed air-rotor and a no. 6 round bur from Mani Corp., Japan, caries excavation was carried out after the canal preparation. The access cavity was cleaned up until it was possible to see every canal clearly. A side vented needle was used to irrigate with normal saline solution in order to clean and flush any debris from the pulp chambers (30G and 21 mm).

2.4. Preoperative scan

After the initial preparation of the samples, they were subjected to initial scanning using a maximum-resolution nano-CT (SkyScan 2214, Bruker, Kontich, Belgium). The samples were rotated by 0.3 degrees in specific increments to scan 360 degrees across the vertical axis. The voltage for the x-ray source is set at 80kv and current of 110 μA with voxel size of 1.58 μm. During the imaging process, each degree of rotation was maintained for 1200 ms, using a detector consisting of 1280 × 1280 pixels. To guarantee the best level of image accuracy, this detector was chosen. Adherence to the manufacturer's recommendations for beam hardening correction and the establishment of ideal contrast limits was observed to verify the precision of the imaging findings. On the basis of preliminary scanning and reconstruction testing, several alterations were performed. After the initial scan the samples are randomly allocated to two groups (i.e. 10 premolars in each of the groups) using the block randomization method.

2.5. Root canal preparation

The initial preparation of all samples involved the use of a size 15 K-file (Mani. Inc., Tochigi, Japan) according to the manufacturer's recommendation, before introducing rotary files into the canal. Throughout the preparation process, a 15 % EDTA (RC Help, Prime Dental Products Pvt Ltd, Thane, India) and 5.25 % of sodium hypochlorite irrigant was used in all sample groups. The samples were assigned into 2 groups. Group 1 was cleaned and shaped with ProFit S3 files (n = 10) according to manufacturer's recommendations till PF2. Group 2 were cleaned and shaped with Protaper Gold rotary files (n = 10) according to manufacturer's recommendations till F2.

2.6. Post operative scan

After the completion of the root canal preparation, the samples were subjected to scanning. following a similar protocol as the pre-operative scan analysis described earlier. During the scanning process, starting with the canal orifice and extending 1 mm short of the apical foramen, the volume of each canal in all of the samples was calculated. This volumetric analysis allowed for a quantitative assessment of the variation in canal volume resulting from the root canal preparation procedure. The remaining dentin thickness and apical deformity were also assessed.

2.7. Imaging reconstruction and processing

The software NRecon (ver. 2.1.0.2, SkyScan, Kontich, Belgium) was used for image reconstruction. This software produced two-dimensional, axial images with a resolution of 1000 1000 pixels using a specialized method. To ensure that the original image data was little modified during the reconstruction process, the values for ring rectification and reduction of artifacts were kept at 0. The resultant images gave an

excellent three-dimensional representation of the root canal architecture.

After image reconstruction, CTAn Application was employed to accomplish the root canals and 3D volumetric imaging was explored (ver. 1.21.2.0, Skyscan, Aartselaar, Belgium). A thorough investigation of the changes in canal morphology brought on by the root canal preparation methods was made possible thanks to the software's facilitation of the examination and measuring of the canal volumes. The root canal architecture may be precisely and thoroughly visualized and analyzed in three dimensions thanks to the software combination of NRecon and CTAn.

2.8. Data collection and statistical analysis

The collected data were analyzed and presented as mean values along with standard deviations. One-way ANOVA (analysis of variance) and post-hoc tests were employed to assess the statistical significance when comparing within-groups and between-groups differences using SPSS software (version 17, SPSS Inc., Chicago, IL, USA) ($p < 0.05$).

Superimposing pre-op and post-op nano CT images was done, with red areas representing pre-op and green areas representing post-op (touched areas) of the canal volume. It was discovered that the majority of the areas in the canal were green, indicating that it had maintained the total canal volume.

3. Results

Upon comparing the pre-volumetric and post-volumetric changes in all the samples across the different groups, it was observed that the protaper gold group exhibited the highest difference in canal volume, followed by the Profit S3. This difference was found to be statistically significant ($p = 0.045$). These findings are summarized in Table 1, providing a clear overview of the variations in canal volume changes among the study's various file systems.

The intergroup comparison between the two file systems revealed that the mean difference in canal volume was statistically significant ($p = 0.045$) among the groups. This indicates that there were significant differences in canal preparation among the two file systems. Table 2 provides a detailed summary on the amount of residual dentin thickness at 4 mm, 8 mm and 12 mm both mesiodistally (MD) and buccolingually (BL). Fig. 1 displays the mean value of canal volume after shaping and cleaning using the different file systems. Fig. 2 demonstrates the middle and apical thirds of the canal space had untouched regions, while the coronal third showed complete preparation of the canal. Fig. 2 Processed 3D image (A-C) of nano-CT scan of a sample root canal model used in the study which was prepared using ProFitS3 (Group1) and ProTaper gold rotary files (Group 2) respectively. Fig. 3 represents the processed 2D image Pre op (A); Post op (B); Superimposition (C, D) of pre op and post op of nano-CT scan of a sample root canal model used in the study which was prepared using ProFit S3(Group1) and ProTaper gold rotary files (Group 2) respectively.

A result of one indicates perfect canal centering ability; the closer the result is to zero, the worse the ability is of the instrument to remain centered in the canal. ProFit S3 had a better centering ratio at 1mm, 3mm,5mm and 7mm ($p < 0.05$). Transportation inferred ProFit S3 is significant at 1mm,3mm, and 5mm respectively ($p < 0.05$) (Table 3).

Table 1
Comparison of pre- and post-volumetric changes within groups.

Canal Volume (mm^3)	Groups	Mean	Std. Deviation	p-value
	ProFit S-3	0.65500	0.041635	0.045*
	Protaper Gold	1.38800	0.113470	

A result of p value < 0.05 indicates there were significant differences in canal preparation among the two file systems. ProFit S3 had lesser variations in canal volume.

Table 2
Amount of remaining dentin thickness at 4 mm. 8 mm and 12 mm both mesiodistally (MD) and buccolingually (BL).

		Groups		
		PROTAPER GOLD	PROFIT S3	P value
MD at 4 mm	Mean	0.8300	0.3500	0.043*
	Std. Deviation	0.17029	0.19003	
MD at 8 mm	Mean	0.7030	0.2400	0.03*
	Std. Deviation	0.11176	0.11738	
MD at 12 mm	Mean	0.5910	0.0670	0.00*
	Std. Deviation	0.11949	0.08499	
BL at 4 mm	Mean	0.9420	0.3900	0.039*
	Std. Deviation	0.20943	0.23781	
BL at 8 mm	Mean	0.8560	0.2560	0.028*
	Std. Deviation	0.09559	0.15027	
BL at 12 mm	Mean	0.7200	0.1876	0.012*
	Std. Deviation	0.15492	0.07437	

A result of p value < 0.05 indicates there were significant differences in remaining dentin thickness among the two file systems. ProFit S3 had maintained remaining dentin thickness in both mesiodistal and buccolingual directions.

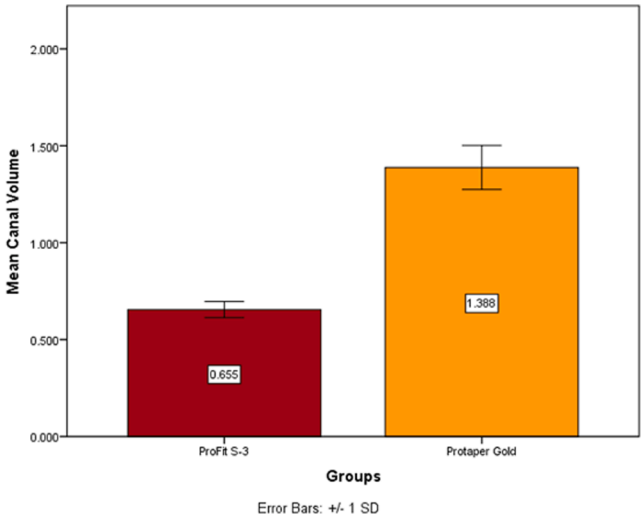

Fig. 1. Represents the mean value of canal volume after shaping and cleaning using the different file systems. X-axis represents the two different rotary systems while Y-axis represents mean value of canal volume. Intergroup comparison revealed there was a statistically significant difference of p value < 0.05.

4. Discussion

To address the anatomic problems of the root canal system, mechanical instrumentation devices have continuously been improved (Xu et al., 2021). The thickness of the dentin should be assessed since too much dentin removal could cause teeth to fracture at the root (Kishen, 2006). The "softer" martensitic alloy was the most effective tool for lateral action, according to current data on the cutting effectiveness of conventional and martensitic NiTi instruments (Morgental et al., 2013).

The ProFit S3 has maintained the canal volume, apical deformity, and remaining dentin thickness as compared to PTG because of its rectangular cross section and variably variable taper design, which stays centered in the canal compared to PTG rotary files. The present study compared ProFit S3 and PTG rotary files on canal centering ability,

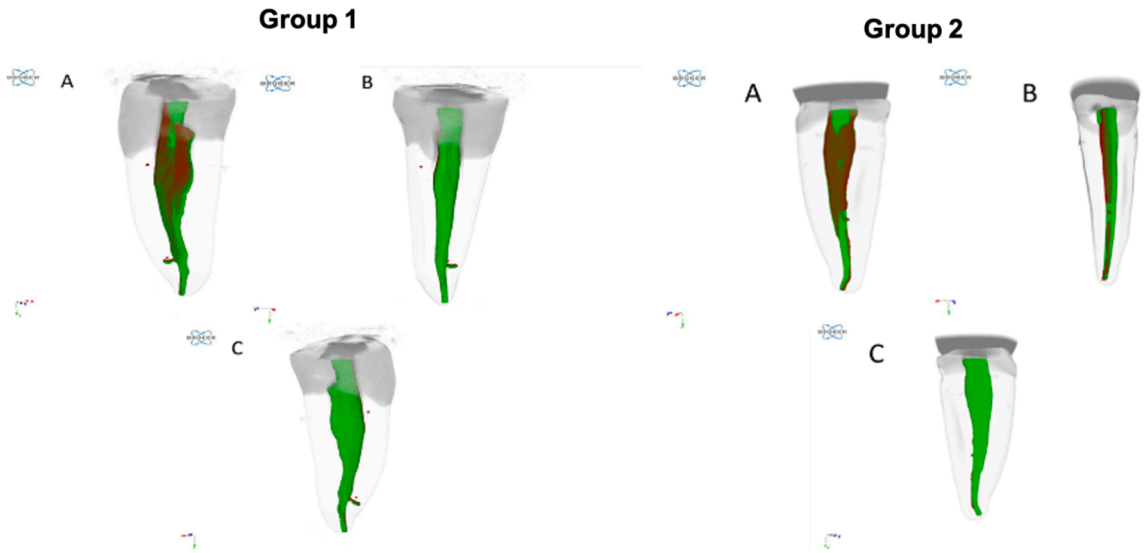

Fig. 2. Processed 3D image (A-C) of nano-CT scan of a sample root canal model used in the study which was prepared using ProFit S3 (Group 1) and ProTaper gold rotary files (Group 2) respectively.

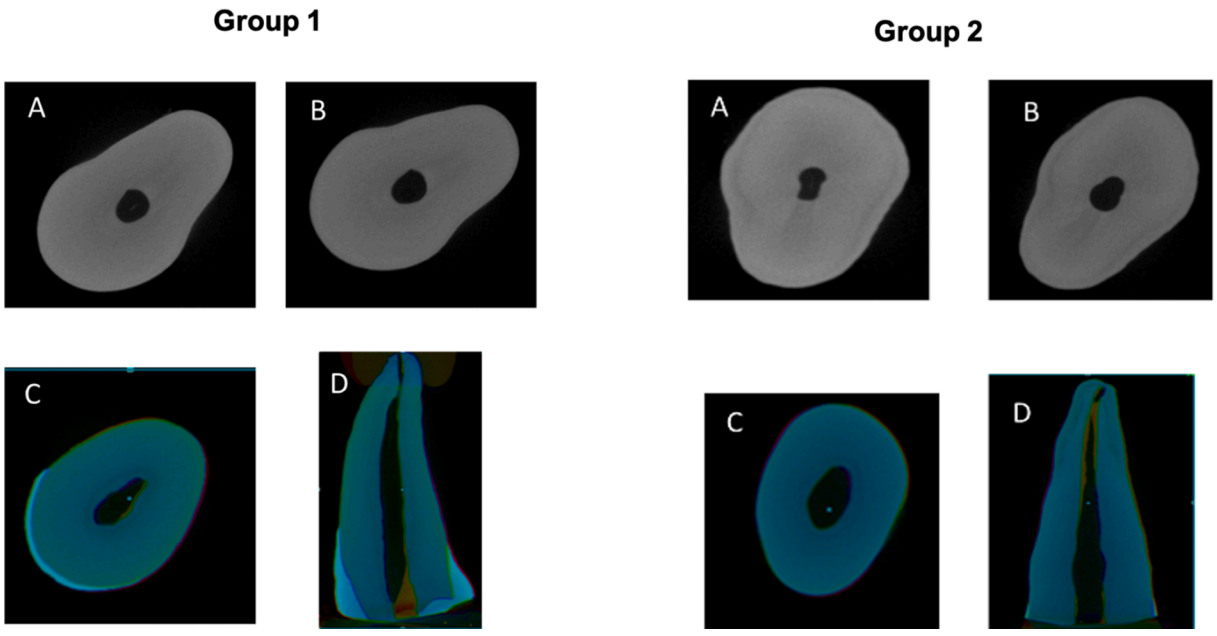

Fig. 3. Processed 2D image Pre op (A); Post op (B); Superimposition (C,D) of pre op and post op of nano-CT scan of a sample root canal model used in the study which was prepared using ProFit S3(Group1) and ProTaper gold rotary files (Group 2) respectively.

Table 3
Transportation and centering ratio between two rotary files at various levels:

File	Parameter	1 mm (mean ± SD)	3 mm (mean ± SD)	5 mm (mean ± SD)	7 mm (mean ± SD)
Profit S3	Transportation	0.002 ± 0.066	0.004 ± 0.047	0.01 ± 0.069	0.017 ± 0.044
	Centering ratio	0.449 ± 0.287	0.493 ± 0.294	0.443 ± 0.212	0.639 ± 0.174
Protaper gold	Transportation	0.010 ± 0.032	0.011 ± 0.06	0.07 ± 0.197	0.020 ± 0.055
	Centering ratio	0.559 ± 0.352	0.614 ± 0.229	0.643 ± 0.305	0.673 ± 0.349

apical deformity, and residual dentin thickness. Since testing file systems in normal dentin is thought to be highly advantageous than utilizing standardized artificial canals due to the dentin's hardness, extracted teeth were employed.

Drukteinis et al. (2019) evaluated mesial root canals of mandibular molars using MCT technology to examine the enhancing abilities of three engine-driven multifile NiTi systems (BR, PTN, and GN). The null hypothesis was supported since there were no significant variations between the groups when it came to alterations in the volume of removed dentin, the area of the canals without instruments, or the movement of the canals after preparation. PTN files were shown to have much less transportation than PTU and WaveOne files in the apical third of both mesial canals, according to a study by Zhao et al. (2014). Regarding apical transportation in distal canals, there was no statistically significant difference between the PTN, PTU, and WaveOne

systems ($p > 0.05$). Comparing the mesial and distal canals, we found that the distal canals had a considerably larger percentage of surfaces that have not been prepared.

On comparing the shaping features of PTN, PTU, and PTG, researchers discovered that PTG and PTN created considerably less canal transportation than PTU devices using micro-computed tomographic (micro-CT) imaging (Gagliardi et al., 2015). According to Pasqualini et al., PTN created a more focused and minimally invasive preparation than the BR technique when they evaluated both PTN and BR in curved canals and produced negligible transportation (Pasqualini et al., 2015).

Using a set of factors, such as canal volume and un-instrumented canal surface area, the impact of canal instrumentation was quantitatively examined. All of these findings are three-dimensional, micro-CT-measured means throughout the whole canal length and over the apical third. The micro-CT system's accuracy and reproducibility have previously been established, and it is recognized as a crucial scientific tool for the investigation of the effects of various shaping processes (Gambarini et al., 2012).

According to the study's findings, both file systems may be used to treat root canals with moderately curved angles and result in the least amount of dentinal wall instrumentation, which is a very desirable outcome in today's endodontics. However, given the constraints of the current investigation, these results must be considered in cases of steeply curved canals where ProFit S3 (Profit Dental, India) could be employed to prevent canal transportation. The main limitation of the study is smaller sample size and additional investigation into multirooted teeth should be taken into consideration. The utilization of hybrid procedures that vary from case to case and the operator experience play a substantial impact in the outcome of root canal therapy, according to literature. No technique is sufficient by itself (Cavenago et al., 2014).

5. Conclusion

The study findings revealed that ProFit S3 (Profit Dental, India) had better canal centering ability, residual dentin thickness, and apical deformity compared to Protaper gold. But considering the fact that Protaper gold is a rotary file system with convex triangular and more taper, while ProFit S3 has a variably variable taper and rectangular cross-section will definitely preserve more dentin and it can be considered more efficient. Further studies will be required in curved canals, multirooted teeth, and different techniques of obturation to substantiate the results obtained.

CRediT authorship contribution statement

S. Swathi: Conceptualization, Methodology. **Delphine Priscilla Antony:** Conceptualization, Methodology. **Pradeep Solete:** Methodology, Formal analysis. **Ganesh Jeevanandan:** Conceptualization, Methodology, Formal analysis. **Satish Vishwanathaiah:** Conceptualization, Methodology, Formal analysis. **Prabhadevi C.Maganur:** Conceptualization, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

Conflict of interest: The authors have declared that no conflict of interest exists.

Funding

Nil.

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