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In Vitro Evaluation of Surface Topography and Shaping Ability of Reciprocating Vs Rotary System in Primary Teeth using Scanning Electron Microscopy and Cone Beam Computed Tomography

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ABSTRACT

Introduction:

"Dental caries affecting the pulp of primary teeth may require extraction if left untreated for a period of time. The most common type of treatment used to save such teeth is Polypectomy. The biomechanical preparation is a crucial aspect of Pulpectomy success. The use of rotary tools in primary tooth endodontics has optimised treatment outcomes because they are flexible and shape the canals evenly.

Methods:

Two groups of 52 main mandibular second molar teeth were selected. Distal canals were chosen for standardisation. Pre-instrumentation CBCT and radiovisiography (RVG) determined the working length. Pre-instrumentation file system SEM images were captured. Group 1 utilized WaveOne Gold reciprocating files, whereas Group 2 employed Kedo S

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(Kids Endodontic Shaper) - E1 files. Post-op CBCT and SEM images were compared to pre-instrumentation images to assess tooth shaping ability and surface topography alterations, respectively.

Results:

"Two parameters determined the shape. 1. "Centering ability" was calculated as (a1-a2)/(b1-b2) or (b1-b2)/(a1-a2) 2. Dentin thickness was measured by comparing pre-instrumentation and post-instrumentation dentin. The experimental groups' mean values were compared using the "independent sample t-test" (P 0.05). Wave one had improved centering ability at the cervical, intermediate, and apical levels. Kedo S outperformed WaveOne Gold in dentin thickness and surface topography.

Conclusion:

In primary teeth, file system exclusively manufactured for primary root canals i.e., Kedo S is regarded as more appropriate for endodontic canal preparation than the single file reciprocating system WaveOne Gold.

Keywords: Rotary endodontics, primary teeth, Kedo files, WaveOne files, Pulpectomy.

Introduction:

If dental caries affecting the primary teeth are left untreated for an extended period of time, they become severely deteriorated and must be extracted. The arch integrity is highly affected by the premature loss of primary teeth with caries associated pulpal pathology [1]. This has been a major concern for pedodontists over years, when extraction was the only options preferred then but now the main goal is to preserve the tooth till its natural exfoliation by performing a Pulpectomy[2,3].

In pulpectomy procedure, biomechanical preparation is a determinant of success because it cleans, debrides, and shapes the canals so that irritants are eliminated and obturating material may be received properly[4]. For a successful biomechanical preparation, the efficiency of the instruments used for shaping of the canal is vital."

In 1988, Walia manufactured the first endodontic device with NiTi orthodontic wire, a hand file [5]. After hand-held NiTi instruments gained popularity, engine-driven NiTi rotary files became indispensable.

In 2000, Barr and his team were the first to propose using rotary files on primary teeth. According to him, The titanium rotary files have the flexibility and instrument design that allows them to adhere to the original root canal channel. This is made possible by the material composition of the files. This results in a smooth funnel-shaped preparation that readily accepts pulpectomy paste[6].

However, due to the morphological complexities of primary root canals, rotary instrument designs have had to be modified and improved to avoid complications such as undesirable canal transportations, ledges, perforations, and instrument breakage [7].

In 2008, a group of six international clinicians began work on designing a new WaveOne Gold reciprocating single file system by M-Wire NiTi technology for canal shaping in collaboration with Dentsply. Since then, In order to better prepare root canals with reciprocating tools, which have a higher cycle fatigue resistance than rotatory NiTi instruments, new and improved reciprocating instruments have been designed and enhanced [8]. It shapes the canal by moving back and forth in both clockwise and anticlockwise directions [9]. One example of such a file is the WaveOne Gold single file reciprocating system.

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Four WaveOne Gold files of differing lengths are offered to more effectively address a broader range of endodontic anatomy. Yellow represents the Small (20/07) size, red represents the Primary (25/07) level, green represents the Medium (35/06) level, and white represents the Large (45/05) level. Fortunately, In most cases, the Primary 25/07 file is the only one that is required to finish shaping practically any canal, and the cross-section of this file bears the shape of an alternating offset parallelogram [10]. This design lessens the likelihood of taper lock and the screw effect by decreasing the amount of interaction that occurs between the file and the dentin at any given cross-section to one or two points of contact [11].

"The introduction of an exclusive paediatric rotary system—the Kedo-S file system (Reeganz Dental Care Pvt. Ltd. India)—is an advancement in the field of endodontics in paediatric dentistry [12]. It is a straightforward NiTi single file system comprised of D1, E1, and U1 files. The total length of these files is 16 mm, and the working area (cutting flutes) is 12 mm, with a triangular cross section and uniform three-point contact. These files are distinguished by their variable taper (4-8%) and varying tip diameters D1-0.25, E1-0.30, and U1-0.40, which correspond to their use in primary teeth. The D1 file is designed to prepare the primary teeth's narrower canals, namely the mesiobuccal and mesiolingual canals, whereas the E1 file is designed to prepare the primary teeth's wider canals."

"The ability of these file systems to be shaped and their surface topography have not been compared in the research that has been done so far. Consequently, the goals of this research are to analyse the similarities and differences between the changes in surface topography and shaping ability of WaveOne Gold (group 1) and Kedo S (group 2) rotary files that are utilised in the process of removing the pulp from teeth that come in first.

Methodology:

Study design:

This is an experiment carried out in vitro approved by university ethical board with IEC number. **2315/IEC/2020.**

Sample collection and storage:

Fifty-two extracted primary mandibular second molars, obtained after arriving at the appropriate sample size with the use of the G power programme, are stored in 1 % chloramine T solution. The selection of teeth is done based on the inclusion criteria.

Inclusion criteria:

- ✓ Extracted mandibular primary second molar teeth.
- ✓ Teeth extracted for carious defects.
- ✓ Teeth with at least 7mm root length.

The selected teeth are then stored in distilled water till the experiment is carried out [9].

Sample preparation:

The teeth are decoronated up to the cemento-enamel junction (CEJ) with diamond disc. For improved instrumentation repeatability and accuracy of the cone beam computed tomography (CBCT) images that were taken of the teeth. mounted on a preformed wax occlusal rim with the distal root facing distally from midline. Because of its rounded shape, shorter length, and more apical taper, the roots of the primary mandibular second molar that are further out from the tooth were chosen for this procedure. The working length of the roots were kept 1mm shorter of the apex, as confirmed by placing a 10 k file and measuring with radiovisiography (RVG). [13]

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Instrumentation:

Teeth are then separated into 2 groups. Group 1 has 26 teeth that will be instrumented with WaveOne Gold reciprocating file. Group 2 has 26 teeth that will be instrumented using a Kedo S rotary file.

Group 1: WAVE ONE:

Twenty-six canals were instrumented with the crown-down technique using Densply Maillefer's WaveOne Gold (primary), made in Switzerland by Densply Maillefer, comes with a a reciprocating action with a variable taper (30 clockwise and 150 anticlockwise). The Coltene Canal pro CL2i endodontic motor was used to power the instruments. Following instrumentation, each canal was irrigated with 1ml of normal saline. After instrumentation, the file flutes were cleaned with 96% ethyl alcohol on dental gauze. After 8 canals, each file was deleted and a fresh one was saved in its place [13].

Group 2: KEDO S:

E1 Kedo-S files of varying taper 26 canals were instrumented with a Swiss-made Dentsply Maillefer X Smart Endodontic Motor, which can reach speeds of 300 RPM and generate a torque of 2.2 N cm. Following instrumentation, each canal was irrigated with 1ml of normal saline. After instrumentation, the file flutes were cleaned with 96% ethyl alcohol on dental gauze. After 8 canals, each file was replaced with a new one.[14].

Determining centering ability:

Pre and post instrumentation with parameters of 60 kvp, 4 mA, 20 sec of exposure time, and a 50 mm field of view at cervical, coronal and apical levels. Capturing of all the images were done voxel by voxel. The formula in **Figure 1** was used to conduct an analysis of centering ability.

Interpretation:

A score of 1.0 implies that there is no degree of decentralisation. When it approaches zero, it signifies that the files' capacity to keep themselves in the canal's middle line has diminished to a significant degree [9,13].

Determining dentin thickness:

On axial view from the tooth's outer surface to the perimeter of the pulp region, dentin thickness was assessed at three levels (cervical, middle, and apical). Pre and post instrumentation values were statistically analysed.[13]

Determining surface topography:

Prior to SEM examination at 150X and 500X magnification, the files were taped to the shank of the SEM holder. Following the pictures of the active section of the cutting blade were processed in order to facilitate the viewing of each individual file, as were active part micrographs of the instrument., At a magnification of 500x, the whole cutting edge, as well as the areas 2 and 4 millimetres short of the tip, were scrutinised. The pre and post instrumentation images were examined by all three authors.[15].

Statistical analysis:

It was the version 20.0 of IBM SPSS Statistics for Windows that was used to present and analyse all data. For each group, the mean and standard deviation were computed. To compare mean values between experimental groups, the independent sample t-test was used, and the paired t-test was used to compare two time points. Alpha was set to 5%. (two-tailed). The significance level was set at $P \leq 0.05$.

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RESULTS

Surface topography:

The pre- and post-instrumentation SEM images of the Wave one group of files and the Kedo S group of files revealed that the Wave one rotary experienced visible topographic changes after eight canals of use, such as loss of manufacturer grooves on flute surfaces, blunting of tips, and denting of flute edges and surface **(Figure 2)**. Kedo S exhibited few topographic changes, minor scrapes at the tip and minimum denting at flute edges were appreciated **(Figure 3).**

Centering ability: (Figure 4 & 6)

The measurement for centering ability yields a result of 1.0, indicating complete centralization. When it approaches zero, it is assumed that the file system has a reduced ability to maintain itself in the middle of the canal's main line. The centering ability of Wave one was 1 at the cervical and middle levels and 0.86±1.31 at apical level, which is almost nearer to 1. At all three levels of Kedo S, values were nearer to zero. In contrast to Kedo S, wave one exhibited more centralization at the cervical, middle, and apical levels, which is statistically significant (p value 0.05). is statistically significant (p value < 0.05) **Table: 1**

The graphical representation of the centering ability of WaveOne Gold files in all the samples is close to 1, which indicates a tendency towards centralization. Only 26% of samples are off-center at the cervical level, as shown in **Figure 8**. Similarly, at the middle and apical, around 30% and 34% of the samples were away from the centre. Whereas in the Kedo S group at cervical, middle and apical levels (**Figure 9**), 46%, 53% and 46% of the samples were away from centre. Thus in wave one, group centralization was low at the apical level, but since the majority of samples were centred, we conclude that WaveOne Gold performed well in terms of centring ability.

Dentin thickness: (Figure 5 & 7)

When the pre-instrumentation dentin thicknesses of both groups were compared to the post-instrumentation dentin thicknesses, the wave one group demonstrated a substantial decrease in the quantity of remaining dentin thickness post instrumentation at all cervical, middle, and apical levels. Considering the fact that p values were ≥ 0.05 at all three levels, Kedo S did not show any significant removal of dentin post instrumentation, depicting Kedo S showed better results in terms of remaining dentin thickness. **(Table: 2)**

DISCUSSION

The goal of this research was to compare and evaluate the changes in surface topography and shaping ability of the WaveOne Gold and KEDO S rotary files. Primary teeth being more susceptible to caries, there is a disparity in the occurrence of caries between the maxillary and mandibular arches [16]. The mandibular arch is more susceptible to caries especially the mandibular second molars[17]. Due to the presence of deep pits and fissures in occlusal anatomy, occlusal caries are more common in primary mandibular second molars [18]. Hence these tooth are most commonly subjected to caries with pulpal pathology, which in turn requires to be treated by pulpectomy procedure[9]. Hence primary mandibular second molar has been selected as the tooth of interest in this study. According to Mahesh et al's study the primary mandibular second molar has most commonly three canal morphology with distal canal being more conical, tapered and easy to instrument; hence distal canal is selected for standardization [19].

After Barr et al. introduced rotary files for shaping canals during primary tooth pulpectomy in 2000 [6], file systems have been modified to address treatment challenges.

The progressive widening of canals by increasing file taper may finish permanent teeth well, while primary teeth may not. The thin dentinal wall near the bifurcation of the primary mandibular second molar's root might perforate or cause root fracture. Thus, pediatric endodontists prefer single-file systems. WaveOne Gold used a single-file system design with reciprocation to prevent cyclic fatigue and torsional failure[10].

Ganesh Jeevanandham created a main tooth preparation NiTi rotary file technique in 2016. These files were non-cutting and tapered to match canal morphology. His investigation demonstrated good obturation outcomes [20]

In this study, the single file reciprocating WaveOne Gold and the file exclusive for primary teeth Kedo S were used in primary teeth pulpectomy to assess their efficiency in terms of centering ability, remaining dentin thickness, and surface topography.

As per the manufacturer's instructions Kedo S was meant to have a maximum of 10 canals. In this study, 8 canals have been maintained as standard for both the groups 1 and 2.

Previous studies have used factors such as analysing the amount of dentin that an instrument cuts and the ability of a file to maintain a centered position inside the canal to avoid anticurvature filing (which is controlled and directed filing away from the thinner portion of dentin in the root canal) to determine the reliability of a filing instrument [21]. A better way of visualizing the instruments ability is by CBCT (cone beam computed tomography) as it reduces the loss of tooth structure by other techniques like destructive sectioning [22]. Hence, in this study analysis, centering ability and remaining dentin thickness were used as determining factors for shaping ability of instruments. The visualization and measurement of these two parameters were done using CBCT.

The amount of stress an instrument is undergoing also influences its performance efficiency. Understanding the surface changes of the instruments used will help the operator to judge whether the instrument serves the purpose intended. For determining this factor, the 'scanning electron microscopy surface topography analysis' has been proven to be an effective method[15,23]. Hence, in our study, SEM is used for assessing surface topographical changes occurring post instrumentation in WaveOne Gold and Kedo S groups.

Shaimaa et al. (2018) an investigation into the capabilities of a variety of file systems was the subject of a study to shape permanent teeth as well as the surface topography of those systems[24]. Comparable to a few other experiments, their findings demonstrated that WaveOne Gold had extremely low edge and tip blunting, as well as efficient shaping ability [23,25]. In contrast, permanent teeth in the study by Shalini Singh et al (2019) did not exhibit WaveOne Gold's efficacy when compared to other files used in their study [26]. In our study, WaveOne revealed the majority of topographic changes. This could be due to the complexity root canals of primary teeth as a result of an increased degree of curvature at the bifurcation region. It turns, this increases the contact surfaces when the file is inserted into the canal.

Bahar et al found WaveOne Gold improved centering and dentin thickness [13]. In our investigation, centering ability was substantial at all three cervical, intermediate, and apical levels. The canal-placed file (7–12 mm) had a lesser taper due to the file's taper. Selvakumar et al. found that Kedo S had good centering[14]. Reciprocating WaveOne Gold files avoid file deflection. The WaveOne Gold file is 25 mm long with a 16mm cutting edge that is only 7–12 mm (maximum operating length determined in our testing is 12 mm) inside the canal,

therefore significant deflection cannot be expected since the file outside the canals provides balancing force. Kedo S's 12 mm cutting edges rotate one-sidedly inside the canal without counterforces to centralise.

The WaveOne Gold files are produced using M wire technology and continuous heat treatment, which improves flexibility, reduces cyclic fatigue, and allows the files to adapt to the shape of canals [10]. Whereas, Kedo S files are plain NiTi files that are incapable of contouring itself to the altering shapes of canals [20]. These properties of the file system might have also influenced the study results of centering ability.

Dual side rotation of wave one causes dentin thickness loss. Using one or two points of contact, wave the active 85-degree cutting edge at any cross section may have sliced more dentin than Kedo S's single side rotation. The WaveOne Gold group has higher dentin reduction because to its 1mm tip diameter compared to Kedo S' 0.30mm.

Mahesh et al. [19] and Wang et al [18] found that the distal canal of primary mandibular second molars is ribbon-shaped cervically and ovoid at the apex. WaveOne Gold has an alternating contact point parallelogram cross section. [10,27]. Kedo S is triangular with uniform 3-point contact. [28]. WaveOne Gold's alternating one- or two-point contact per half rotation may have caused more dentin wall loss than Kedo S.

Surface topographical changes were more evident in Wave one group, which was also in accordance with other studies [23,24]. In our investigation, we also observed denting of flute edges, fading of manufacturer's grooves on flute surface and blunting of tips. This is the first study done to evaluate the surface topographical changes between WaveOne Gold and Kedo S files. After instrumentation of eight canals, Kedo S demonstrated promising outcomes, with little surface morphological changes, according to the findings of this study. Due to the absence of a manufacturer's groove in Kedo S, Kedo S exhibited fewer obvious changes than WaveOne Gold, which could be a factor in this study.

Our investigation is limited by the selection of big distal canals with a more uniformly tapering diameter. If the more difficult mesial canals are instrumented, an even clearer picture of the efficacy of each file can be observed. In our study, surface alterations were also analysed based on morphological assessment, although chemical examination could provide definitive results regarding changes in the fundamental characteristics of files.

CONCLUSION

Kedo S demonstrated much less morphological alterations than WaveOne Gold in surface topography, according to study data. Kedo S retained more dentin after instrumentation than WaveOne Gold, but WaveOne Gold has superior centering. Thus, Kedo S is better than WaveOne Gold for shaping main teeth. Effective instrument selection is crucial for efficient treatment outcomes as rotational development may extend beyond the horizon.

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FIGURES

$$\text{Centering ability} = \frac{a1-a2}{b1-b2} \quad \text{or} \quad \frac{b1-b2}{a1-a2}$$

a1: The shortest distance starting in the mesial edge of the canal to the mesial edge root in un-instrumented canal.
b1: The shortest distance starting in distal edge of the canal to the distal edge of the root in un-instrumented canal.
a2: The shortest distance starting in the mesial edge of the canal to the mesial edge of the root in instrumented canal.
b2: The shortest distance starting distal edge of the canal to the distal edge of the root in the instrumented canal.

Figure:1 - Formula to determine centering ability

Figure: 2 – WaveOne Gold pre instrumentation SEM images at **A.**working tip 150X, **B**. flutes at 500 X and **C**.tip at 500 X post instrumentation SEM images at **a.**working tip 150X, **b.**flutes at 500 X showing loss of manufacturer's grooves and **c.**tip at 500 X showing blunting of tip and denting of flute edges.

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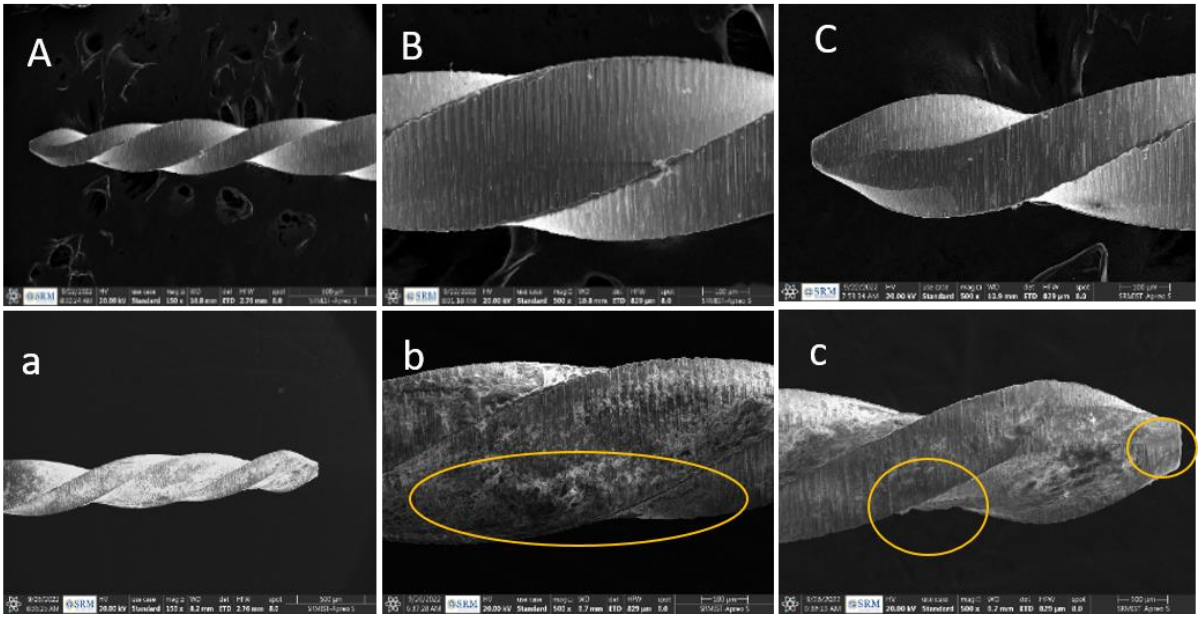


Figure: 3 – Kedo S pre instrumentation SEM images at **A.**working tip 150X, **B**.flutes at 500 X and **C.**tip at 500 X post instrumentation SEM images at **a.**working tip 150X, **b**.flutes at 500 X showing denting of flute edges and **c**.tip at 500 X blunting of tip and scratches in the tip surface.

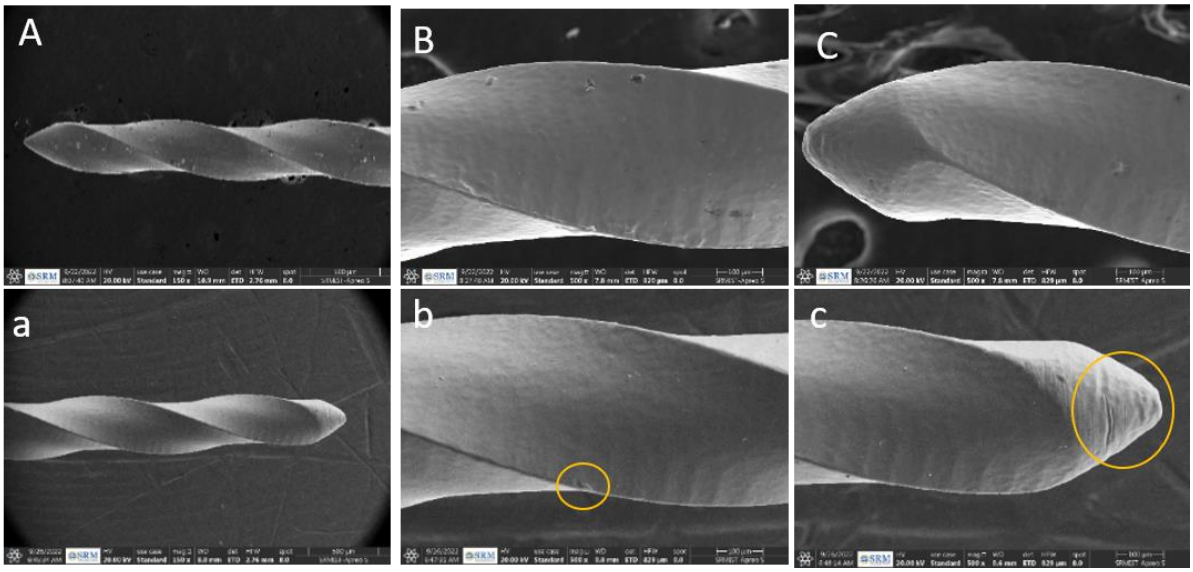


Figure: 4 – WaveOne Gold pre instrumentation CBCT images for centering ability at **A.**cervical level, **B**.middle level and **C.**apical level;

post instrumentation CBCT images for centering ability at **a**.cervical level, **b.**middle level and **c**.apical level

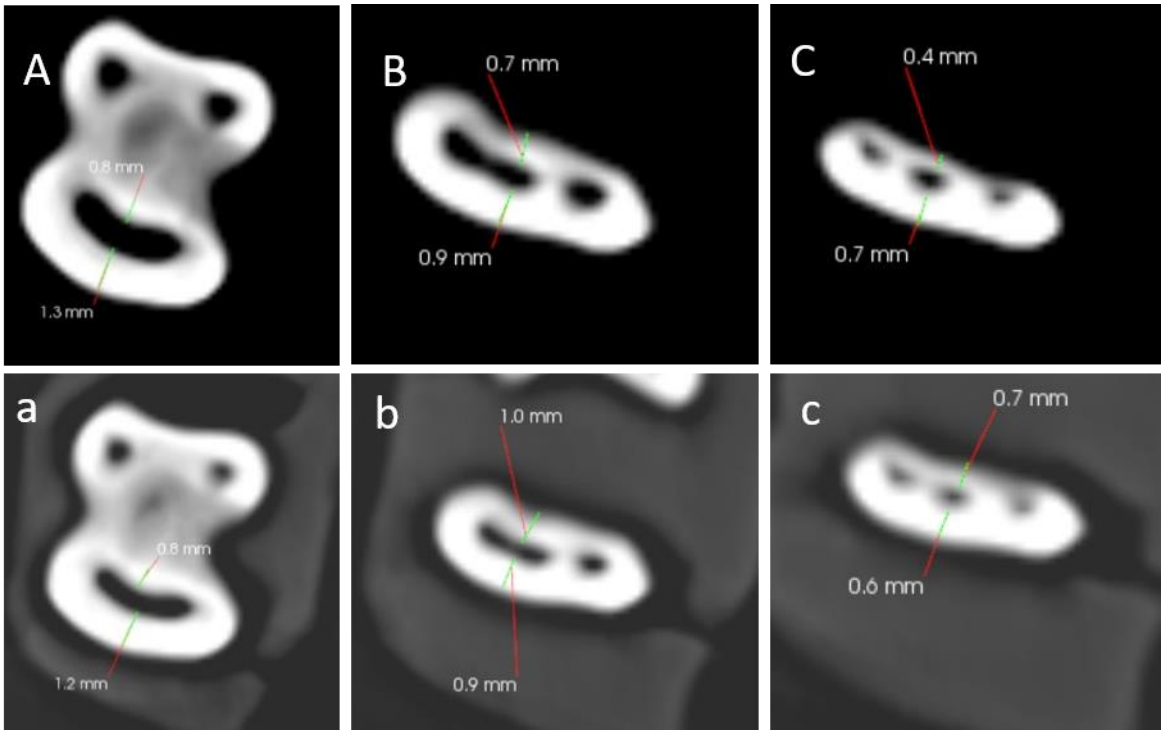


Figure: 5 – WaveOne Gold pre instrumentation CBCT images for dentin thickness at **A.**cervical level, **B**.middle level and **C**.apical level;

post instrumentation CBCT images for dentin thickness at **a**.cervical level, **b.**middle level and **c.**apical level

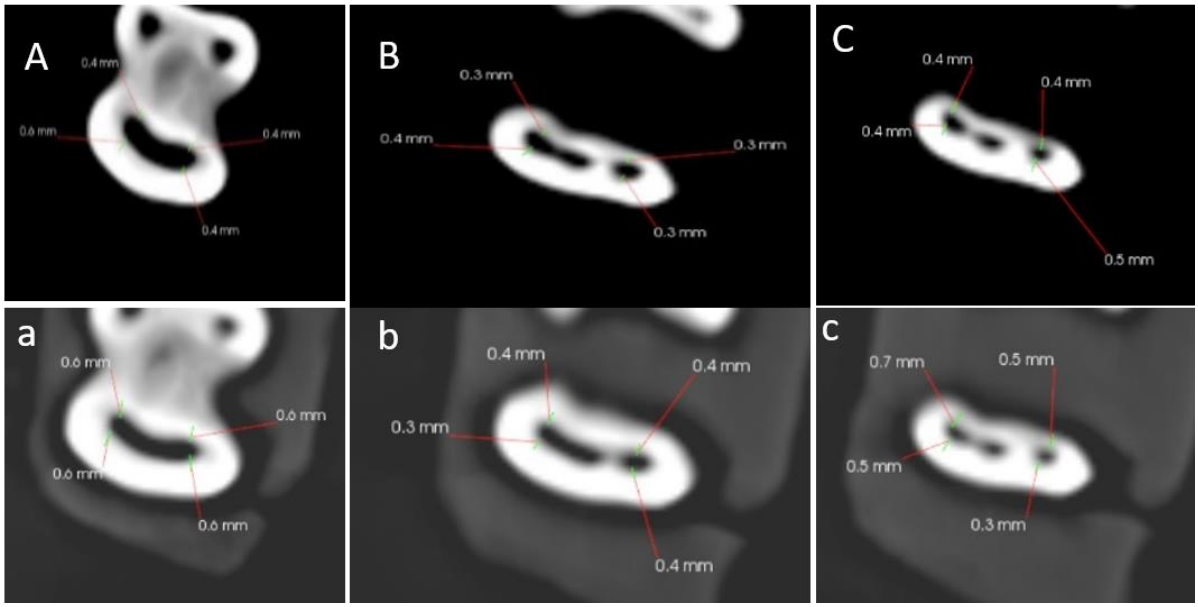


Figure: 6 – Kedo S pre instrumentation CBCT images for centering ability at **A.**cervical level, **B**.middle level and **C.**apical level;

post instrumentation CBCT images for centering ability at **a.**cervical level, **b.**middle level and **c**.apical level

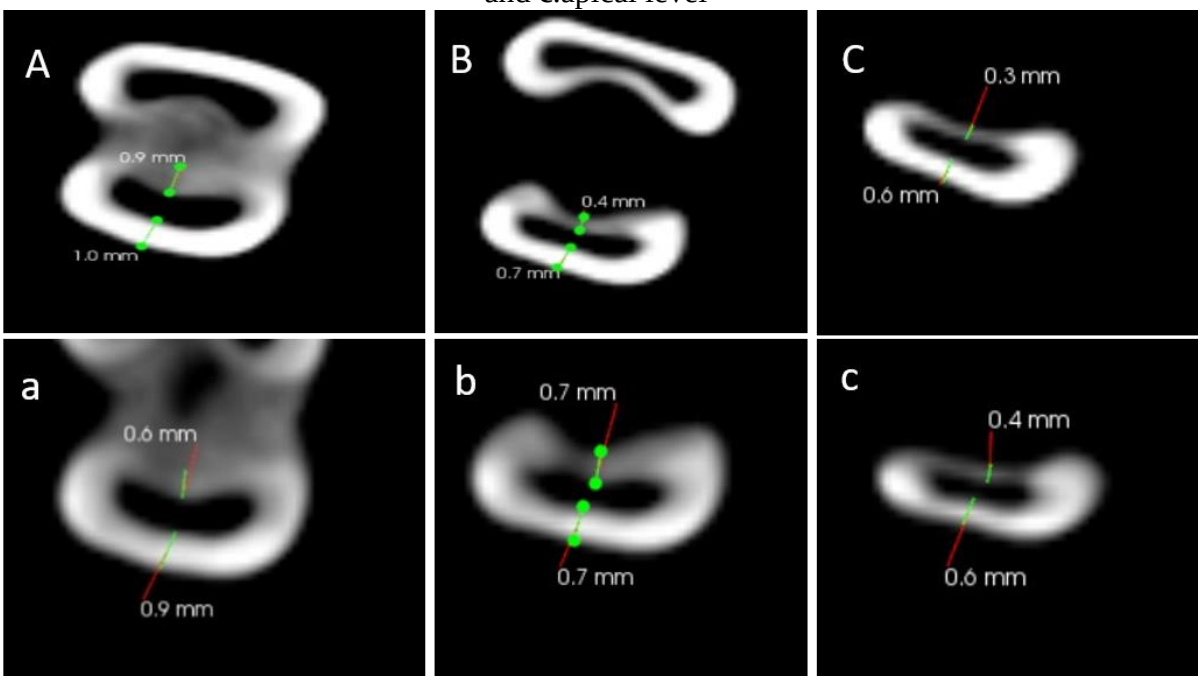


Figure: 7 – Kedo S pre instrumentation CBCT images for dentin thickness at **A.**cervical level, **B**.middle level and **C**.apical level;

post instrumentation CBCT images for dentin thickness at **a.**cervical level, **b.**middle level and **c.**apical level

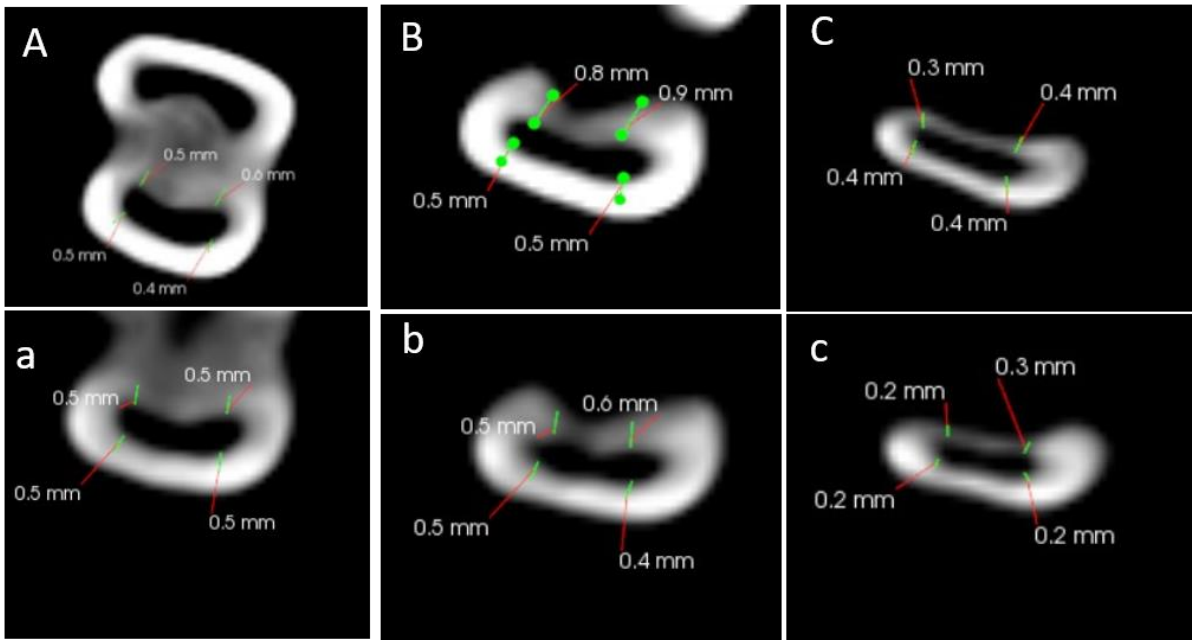


Figure: 8 – Pictoric representation of centering ability of WaveOne Gold group at cervical, middle and apical level

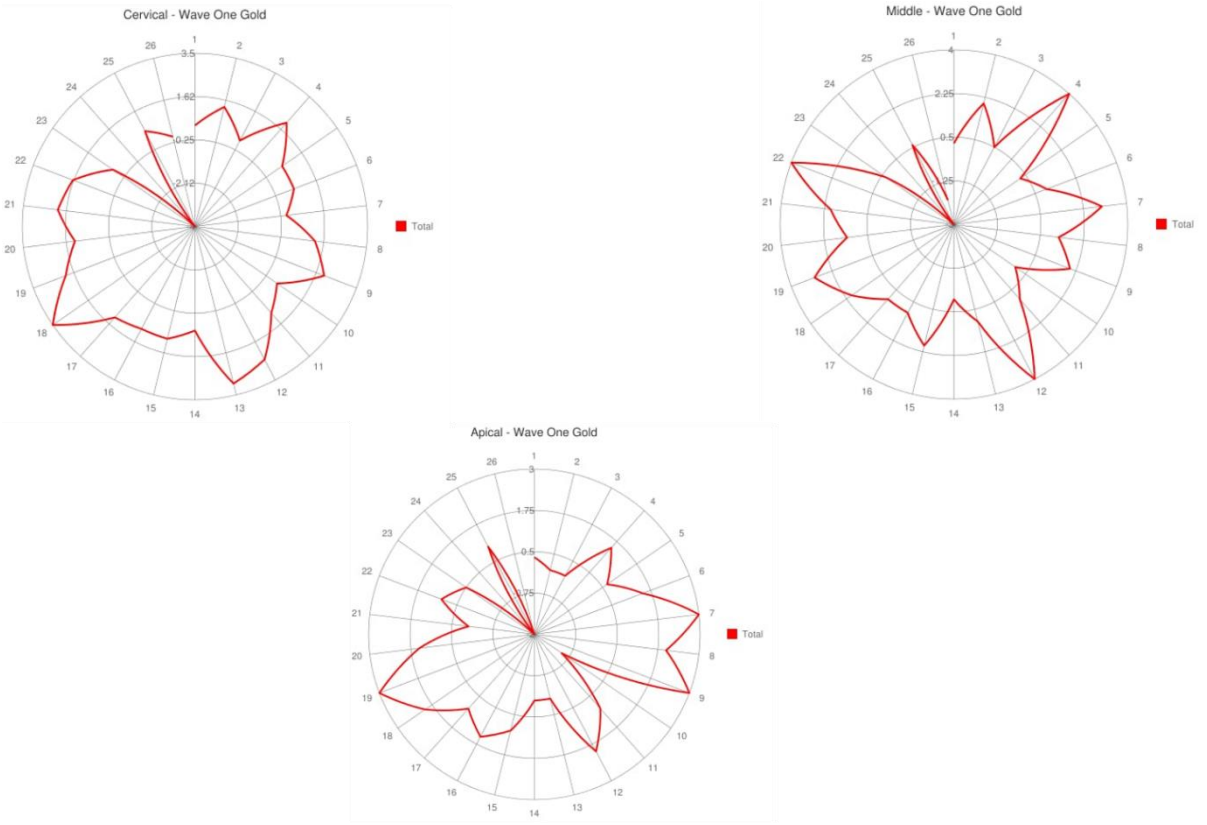
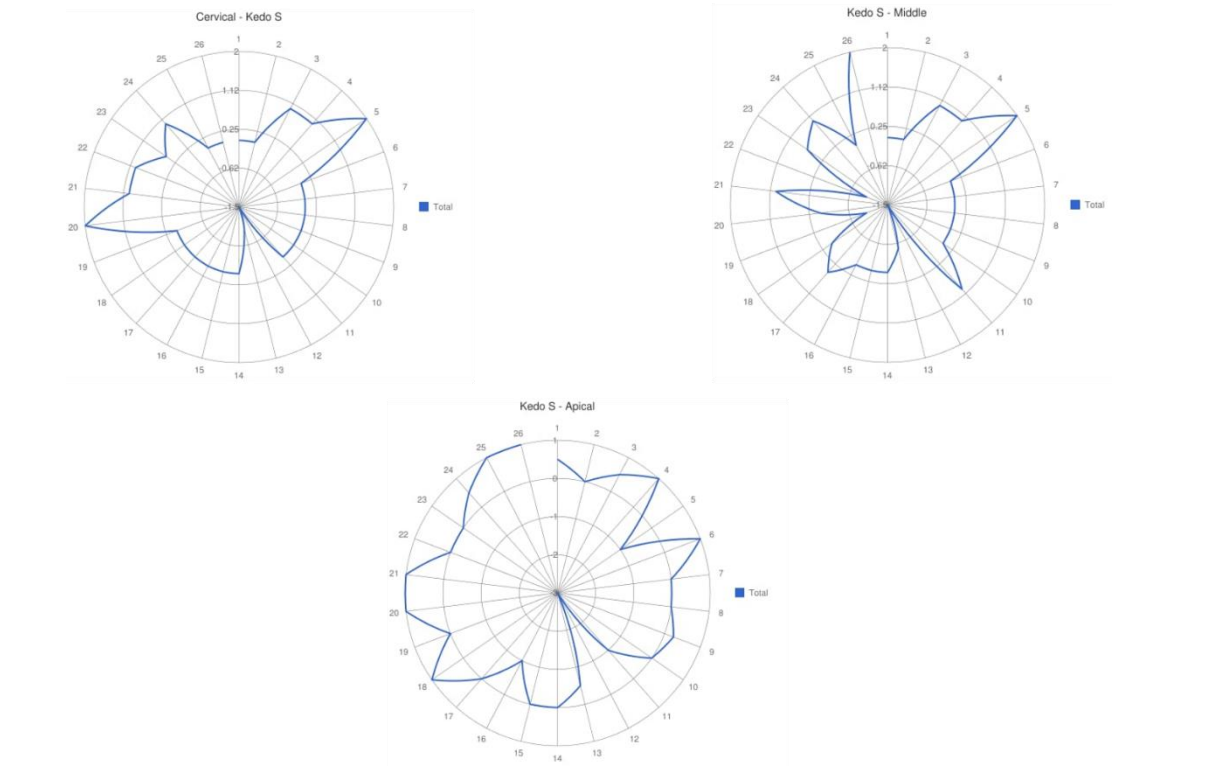


Figure 9 – Pictoric representation of centering ability of Kedo S group at cervical, middle and apical level



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TABLES

Table: 1
Mean and standard deviation of centering ability of the experimental groups at cervical, middle and apical levels.

Groups	Cervical	P value	Middle	P value	Apical	P value
WaveOne Gold	1.01±1.37	*0.019	1.25±1.64	*0.007	0.86±1.31	*0.016
Kedo S	0.26±0.76		0.23±0.82		0.08±0.89	

* p value < 0.05
Mean values are measured in mm

Table 2:
Mean and standard deviation of dentin thickness of the experimental group at cervical, middle and apical levels.

Groups	Cervical		P value	Middle		P value	Apical		P value
	Pre op	Post op		Pre op	Post op		Pre op	Post op	
WaveOne Gold	1.09±0.15	0.90±0.21	*0.001	0.89±0.12	0.76±0.19	*0.001	0.69±0.14	0.62±0.17	*0.022
Kedo S	0.64±0.11	0.60±0.12	0.615	0.46±0.10	0.45±0.10	0.050	0.36±0.08	0.35±0.10	0.209

* p value < 0.05
Mean values are measured in mm