

TYPES OF SURFACE DEFECTS AFTER ROOT CANAL PREPARATION OF DIFFERENT PEDIATRIC SINGLE FILE SYSTEMS WITH VARYING MOTION: A SCANNING ELECTRON MICROSCOPY ANALYSIS

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ABSTRACT

Background: Effective cleaning and shaping are essential for successful endodontic treatment. Nickel–titanium instruments have improved root canal preparation by making it faster and more efficient while maintaining the natural shape of the canal. However, these instruments can still break during use, so evaluating surface changes is important because they often indicate a risk of failure. **Aims:** To assess types of surface defects on Kedo S Plus rotary files and WaveOne Gold reciprocating files after root canal preparation of molar teeth using SEM. **Design:** A total of 20 files were used: Group I (10 Kedo S Plus files) and Group II (10 WaveOne Gold files). **Method:** After pre-operative records, access cavities are prepared, and the working length (WL) will be determined. In group I, biomechanical preparation will be done by Kedo S Plus files and in group II by WaveOne Gold files according to the manufacturer's instructions. The samples will be sent for evaluating surface defects after preparing the root canals of the molar teeth. **Results:** Kedo S Plus appears more resistant to microstructural damage. In contrast, WaveOne Gold demonstrates superior cutting efficiency but a higher tendency for fatigue-related surface defects. **Conclusions:** Neither file system can be considered unequivocally superior, as each exhibits a distinct wear profile. Kedo S Plus tends to lose cutting ability earlier; still, it appears structurally safer. In contrast, WaveOne Gold maintains cutting ability for longer but exhibits more fatigue-related defects.

KEYWORDS: Kedo S Plus, WaveOne Gold, Single-file system, Surface defects, Scanning Electron Microscopy.

INTRODUCTION

Preserving primary teeth is crucial, and endodontic treatment is often required to prevent premature loss when chronic inflammation or periradicular pathology persists.^[1]

New-generation of Nickel–titanium (Ni–Ti) instruments offer superior flexibility, superelasticity, shape memory^[2], reduced chair-side time and improved canal

shaping^[3] during endodontic treatment. However, these files can still undergo deformation or fracture due to torsional stress, rotational speed, and canal curvature.^[4]

Therefore, regular replacement of rotary files is recommended to minimise instrument failure.

This study aims to identify, categorise, and compare surface defects of Kedo-S Plus rotary files and WaveOne

Gold reciprocating files under Scanning Electron Microscopy (SEM) and evaluate their clinical relevance.

MATERIALS AND METHOD

This in vivo research study was given ethical approval by the institutional review board (IEC/2025/700/06).

In this study, two different endodontic instruments, including KedoSPlus P1 (25/0.04-0.08) and WaveOne Gold Primary (25/0.07), were assessed (n = 10/group).



Fig. 1(a).



Fig.1(b).

Fig. 1: (a) Kedo S Plus rotary file and (b) WaveOne Gold Reciprocating file.

The samples were examined for any existing defects under a scanning electron microscope after removal from the packages for the pre-operative records. In both groups, samples were again further divided into three subgroups based on the number of uses for instrumentation:

(i) files used in only one molar tooth, (ii) files used in two molar teeth, and (iii) files used in three molar teeth.

Samples showing any surface or structural deformation were excluded. Patients presenting open apices, internal or external resorption, severe dilaceration, canal calcification, or requiring re-pulpectomy were also excluded. To ensure standardisation across file systems, only teeth with root curvature $\leq 45^\circ$ and with three roots and three canals were selected.

After preparation of the access cavities, the working length was determined radiographically. The patency of the canal was established with a #10 K-file, followed by glide path preparation using #15 and #20 K-files.

In Group I, biomechanical preparation was done using Kedo-S Plus files, and in Group II, using WaveOne Gold files, according to the manufacturers' instructions. During preparation, an in-and-out brushing motion was used until resistance was felt in the canal. After each withdrawal, the files were cleaned and visually inspected before reuse. This process was carried out repeatedly until the working length (WL) was attained. The instrument was removed after three pecking motions, debris was cleared, and 3mL of 2.5% sodium hypochlorite was used to irrigate the root canals. All root canal preparations were completed by one trained operator.

The samples were cleaned using an endodontic brush and a disinfectant after every usage. Following drying, the files were placed in sterilisation pouches categorised by subgroups and autoclaved for 20 minutes at 134 °C under 30 psi.

After preparing one molar tooth, two molar teeth and three molar teeth, respectively, the samples were sent for

microscopic analysis of surface defects at 1 mm, 3 mm, and 5 mm from the apical section.

These samples were examined under Scanning Electron Microscope (TESCAN MAGNA) at 400x magnification to evaluate surface changes and defects.



Fig. 2(a)



Fig. 2(b)



Fig. 2(c)

Fig. 2: (a) Sample Holder, (b) Sputter Coater and (c) TESCAN Magna Scanning Electron Microscope.

OBSERVATIONS

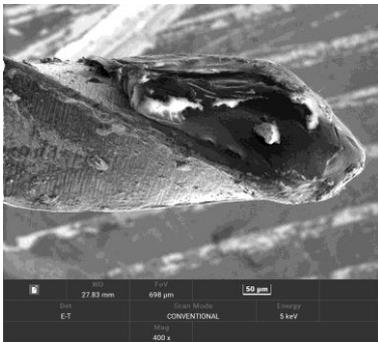


Fig. 3(a)

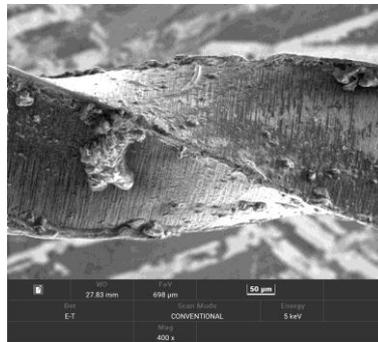


Fig. 3(b)

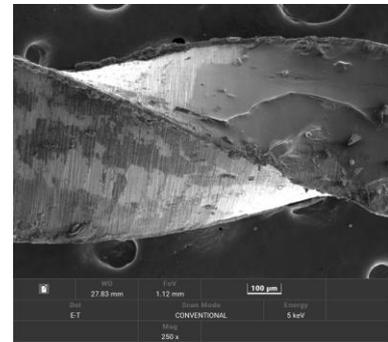


Fig. 3(c)

Fig. 3: Pre-operative SEM images of Kedo S Plus rotary file (a) at tip (b) at 3mm (c) at 5 mm.

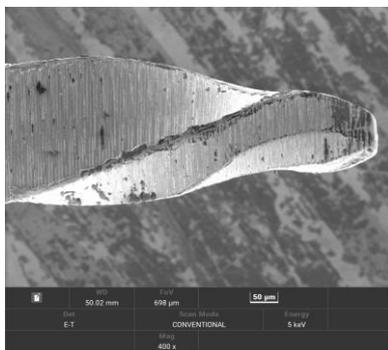


Fig. 4(a)

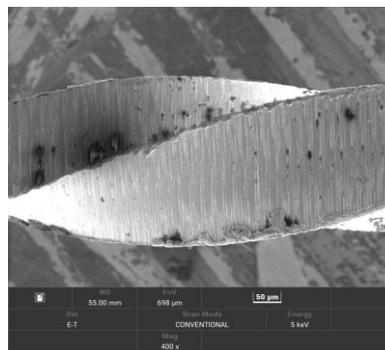


Fig. 4(b)

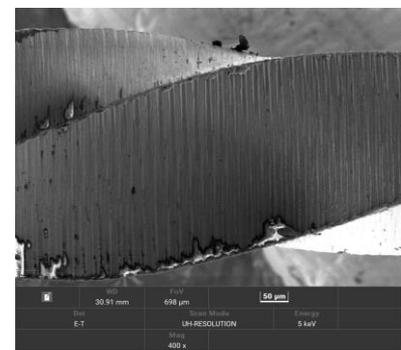


Fig. 4(c)

Fig. 4: Pre-operative SEM images WaveOne Gold reciprocating file (a) at tip (b) at 3mm (c) at 5 mm.

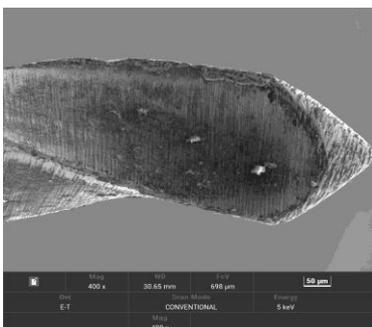


Fig. 5(a)

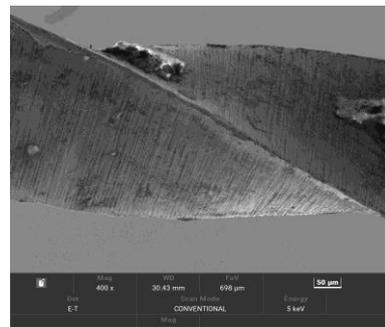


Fig. 5(b)



Fig. 5(c)

Fig. 5: After using in a single molar tooth, SEM images of Kedo S Plus rotary file (a) at tip (b) at 3mm (c) at 5 mm.

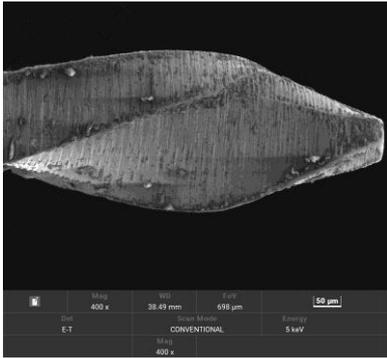


Fig. 6(a)

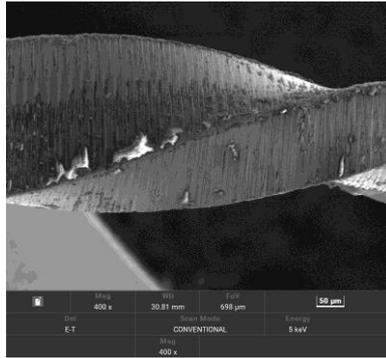


Fig. 6(b)

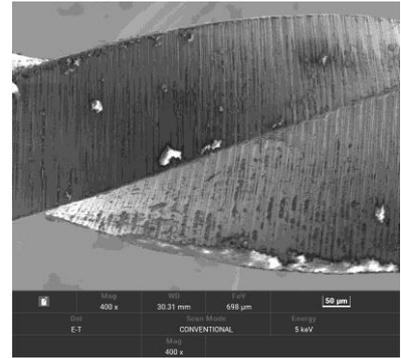


Fig. 6(c)

Fig. 6: After using in a single molar tooth, SEM images of WaveOne Gold reciprocating file (a) at tip (b) at 3mm (c) at 5 mm.

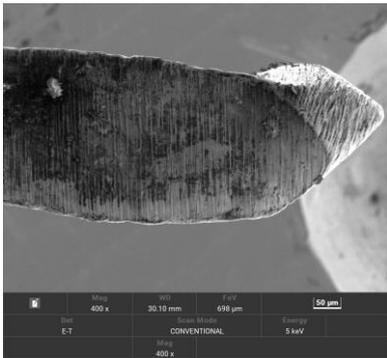


Fig. 7(a)

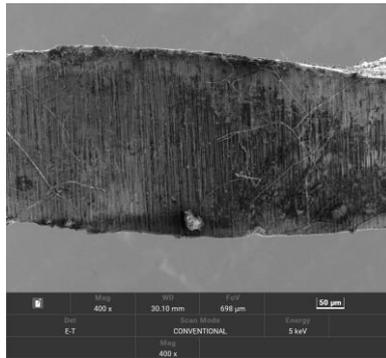


Fig. 7(b)

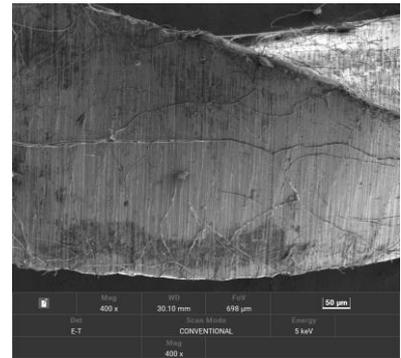


Fig. 7(c)

Fig. 7: After using in two molar teeth, SEM images of Kedo S Plus rotary file (a) at tip (b) at 3mm (c) at 5 mm.

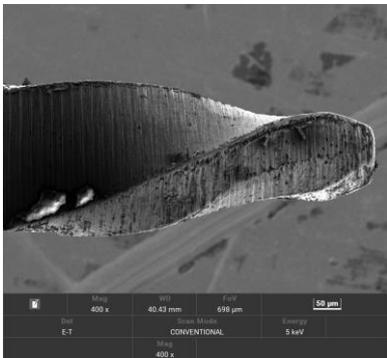


Fig. 8(a)

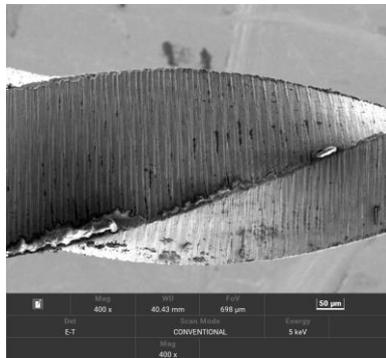


Fig. 8(b)

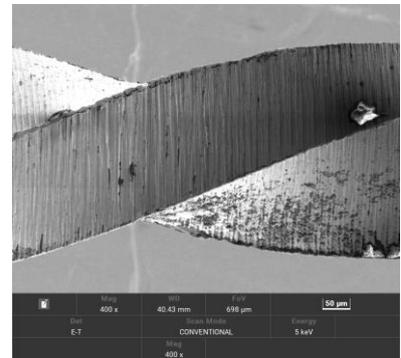


Fig. 8(c)

Fig. 8: After using in two molar tooth, SEM images of WaveOne Gold reciprocating file (a) at tip (b) at 3mm (c) at 5 mm.

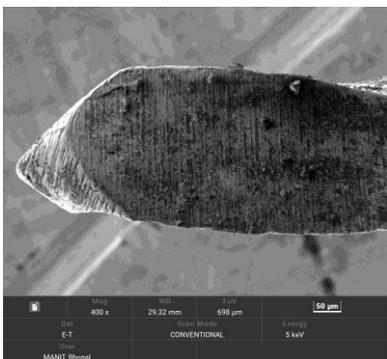


Fig. 9(a)

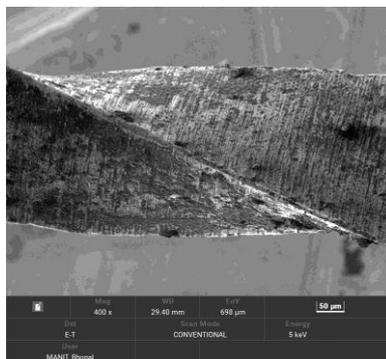


Fig. 9(b)



Fig. 9(c)

Fig. 9: After using in three molar teeth, SEM images of Kedo S Plus rotary file (a) at tip (b) at 3mm (c) at 5 mm.

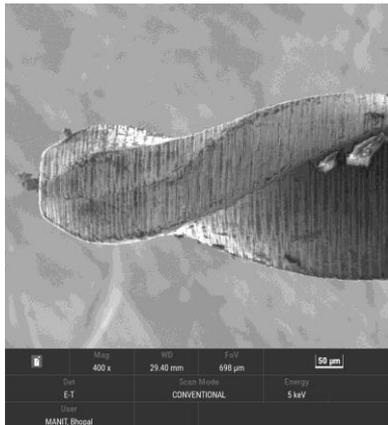


Fig. 10(a)

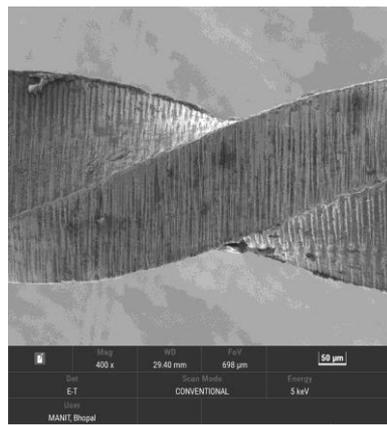


Fig. 10(b)

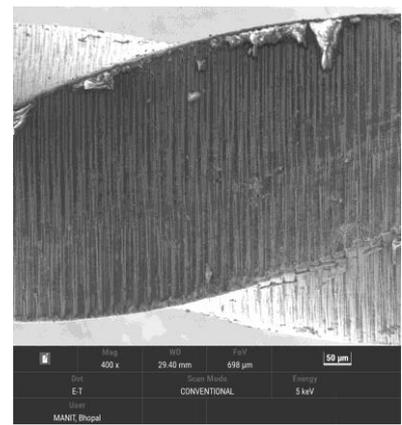


Fig. 10(c)

Fig. 10: After using in three molar teeth, SEM images of WaveOne Gold reciprocating file (a) at tip (b) at 3mm (c) at 5 mm.

RESULTS

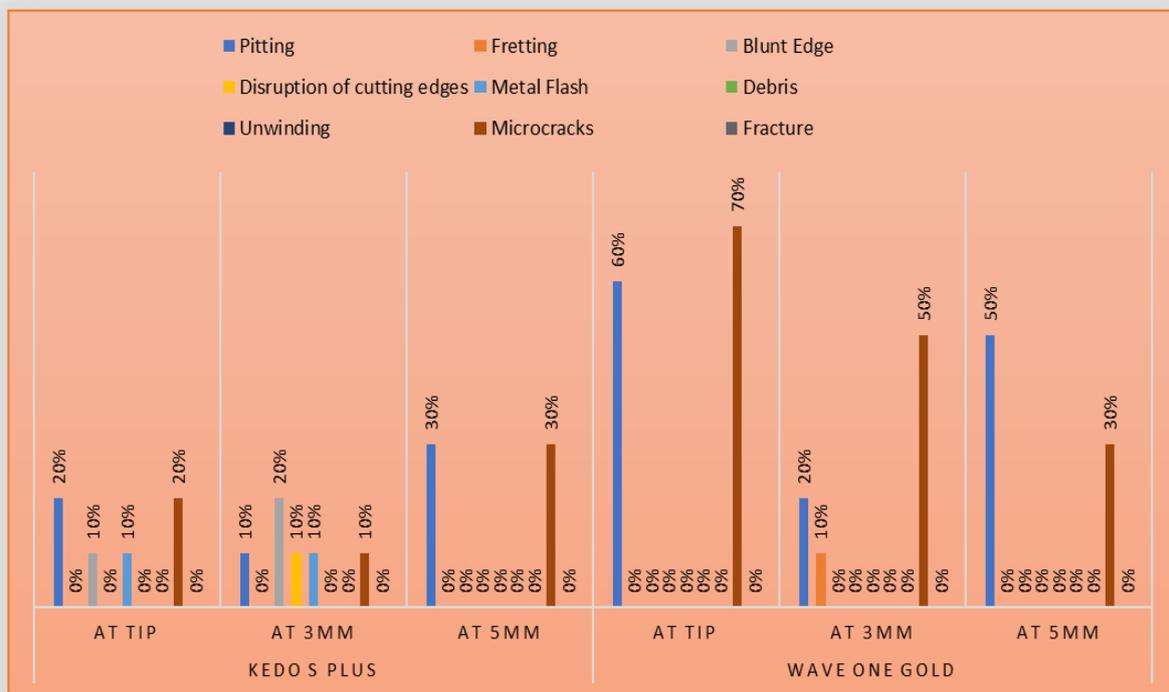


Fig. 11: Pre-operative SEM Defect Analysis between Kedo S Plus and WaveOne Gold Reciprocating Files (Level-wise).

Pre-operative SEM evaluation revealed the presence of manufacturing-related surface defects in both file systems, even before clinical use. Pitting and microcracks were the most observed defects across all levels. Although WaveOne Gold files consistently showed a higher frequency of pitting and microcracks compared to Kedo S Plus files at the tip, 3-mm, and 5-mm levels, none of these differences reached statistical

significance ($p > 0.05$). Other defects such as fretting, blunt edges, disruption of cutting edges, metal flash, debris, unwinding, and fracture were either absent or infrequent in both groups. These findings suggest that both file systems possess inherent surface irregularities attributable to manufacturing processes, with a tendency toward greater defect prevalence in WaveOne Gold files.

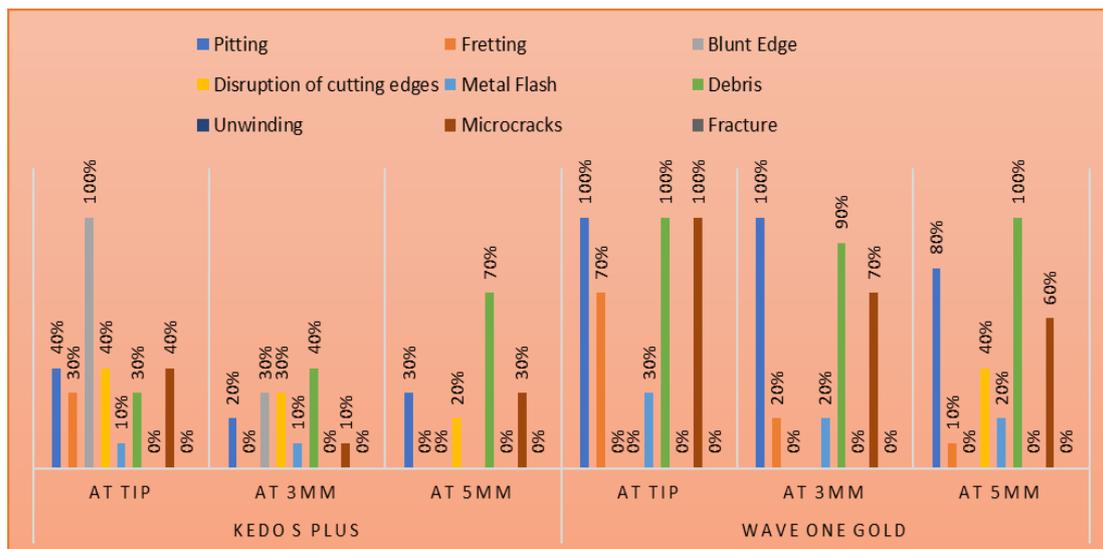


Fig. 12: SEM Defect Analysis after Single Use (One Molar) – Level-wise Comparison.

Following single clinical use, a marked increase in surface defects was observed in both file systems, particularly at the tip and 3-mm levels, which are subjected to maximum torsional and flexural stresses during instrumentation. WaveOne Gold files demonstrated significantly higher frequencies of pitting, debris accumulation, and microcrack formation, especially at the tip and 3-mm levels ($p < 0.05$). In contrast, Kedo S Plus files showed a significantly higher incidence of blunt edge formation at the tip, indicating

early loss of cutting efficiency. Although fretting and disruption of cutting edges were more frequently observed in WaveOne Gold files, these differences were not statistically significant. No unwinding or fracture was noted after single use in either group. These results indicate that initial clinical use produces rapid surface deterioration, with WaveOne Gold files showing greater structural surface damage, while Kedo S Plus files exhibit earlier edge blunting.

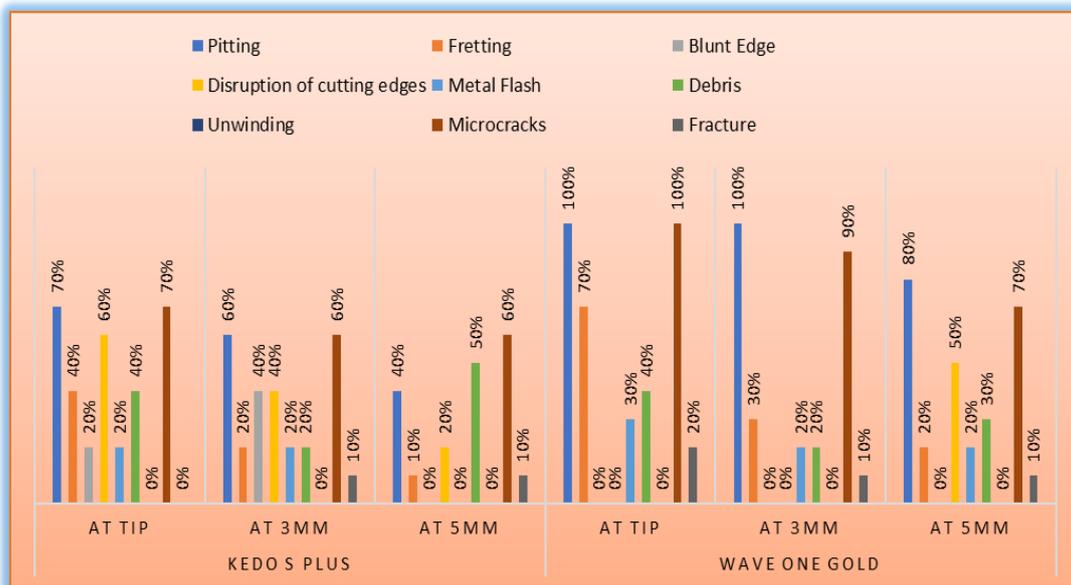


Fig. 13: SEM Defect Analysis after Use Twice (Two Molars) – Level-wise Comparison.

After instrumentation of two molars, progressive worsening of surface defects was evident in both systems. At the tip level, a significantly higher disruption of cutting edges was observed in Kedo S Plus files compared to WaveOne Gold files ($p < 0.05$). At the 3-mm level, both blunt edge formation and disruption of cutting edges were significantly more frequent in Kedo S

Plus files ($p < 0.05$). Pitting and microcracks continued to increase in both groups, with WaveOne Gold files showing higher absolute frequencies; however, these differences were largely not statistically significant. The appearance of fracture defects in both systems, though minimal and statistically non-significant, suggests the onset of structural fatigue after repeated use. These

findings imply that repeated clinical use leads to cumulative mechanical damage, with Kedo S Plus files showing greater functional deterioration of cutting edges,

while WaveOne Gold files continue to demonstrate higher microstructural defects.

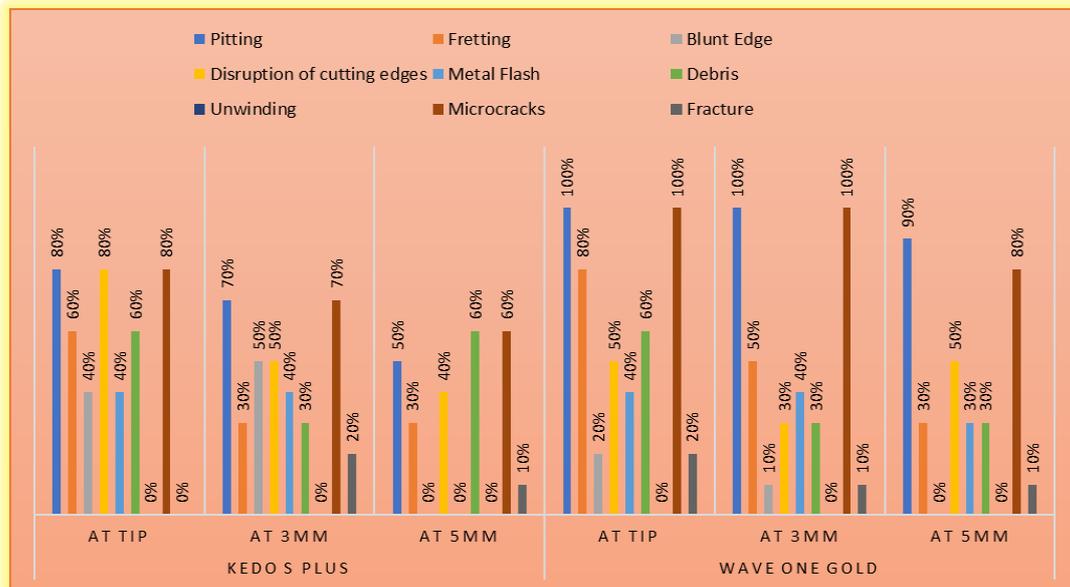


Fig. 14: SEM Defect Analysis after Use Thrice (Three Molars) – Level-wise Comparison.

After three uses, extensive surface degradation was evident in both file systems across all evaluated levels. Pitting, fretting, microcracks, and debris were highly prevalent, particularly at the tip and 3-mm levels. A significant increase in blunt edge formation at the 3-mm level was observed in Kedo S Plus files ($p < 0.05$), indicating substantial loss of cutting efficiency with repeated use. Additionally, pitting at the 5-mm level was significantly higher in WaveOne Gold files ($p < 0.05$), reflecting progressive surface fatigue even in the coronal portion of the instrument. Although microcracks were more frequent in WaveOne Gold files across all levels, the differences were not statistically significant. Occasional fractures were observed in both groups, confirming that cyclic fatigue and cumulative microdamage increase substantially after three uses.

The level-wise trend analysis revealed a clear gradient in surface defect distribution along the length of the instruments. The tip region consistently exhibited the highest frequency and earliest appearance of surface defects across all stages of use, highlighting its greater susceptibility to cyclic fatigue and torsional stresses encountered during canal instrumentation. The 3-mm level demonstrated progressive functional deterioration with repeated use, characterised predominantly by blunt edge formation and disruption of cutting edges, changes that were more pronounced in Kedo S Plus files, indicating an earlier loss of cutting efficiency at this level. In contrast, the 5-mm level, which was initially the least affected region, showed a gradual increase in surface damage with repeated use, and after multiple uses, significant pitting and microcrack formation became evident, particularly in WaveOne Gold files,

reflecting cumulative surface fatigue even in the coronal portion of the instruments.

STATISTICAL ANALYSIS

All data were compiled and analysed using IBM SPSS Statistics for Windows, Version 30.0 (IBM Corp., Armonk, NY, USA). The frequency and percentage distribution of surface defects, including pitting, fretting, blunt edge, disruption of cutting edges, metal flash, debris, unwinding, microcracks, and fracture, were calculated for both Kedo S Plus and WaveOne Gold file systems. SEM observations were recorded at three levels (tip, 3 mm, and 5 mm from the tip) and at four stages of use: pre-operative, after single use, after use in two molars, and after use in three molars.

As the outcome variables were categorical, assessment of normality was not applicable, and therefore, non-parametric statistical tests were employed. The association between file type and the presence of individual surface defects at each level and stage of use was analysed using the Chi-square (χ^2) test. Statistical comparisons were performed separately for each defect and level to identify stage-wise and location-specific differences between the two file systems. A p -value < 0.05 was considered statistically significant.

DISCUSSION

Dental caries is highly prevalent worldwide. It is a major cause of dental pain and tooth loss. Without timely intervention, the disease can advance into the pulp. This leads to severe pain, infection, and premature loss of primary teeth.^[5] When chronic inflammation or periradicular pathology persists because of caries or

trauma, endodontic treatment becomes necessary to prevent early tooth loss.^[1] In paediatric endodontics, pulpectomy is commonly performed. This procedure restores the form and function of primary teeth and prevents these complications.^[5]

The American Academy of Pediatric Dentistry (AAPD)^[6] recommends pulpectomy for primary teeth with irreversibly infected or necrotic pulp resulting from caries or trauma. The procedure preserves arch length, maintains occlusal function, and supports the physiologic eruption of the permanent successor.^[7] Clinicians achieve infection control and promote periapical healing by combining biomechanical instrumentation with chemical irrigation; they need to perform meticulous cleaning and shaping to remove pulp remnants, disrupt microbial biofilms, and reduce toxins within the root canal system.^[8]

Endodontic treatment in primary teeth remains significantly challenging owing to physiological root resorption, complex canal morphology, thin radicular dentin, and limited patient cooperation.^[8]

According to Kuo et al.^[9] (2006), an ideal pulpectomy technique for primary teeth should

1. Achieve efficiency: require minimal treatment time and appointments;
2. Provide effective canal debridement without compromising tooth structure or harming the developing permanent tooth;
3. Minimise procedural complications; and
4. Preserve the primary tooth's function until its natural exfoliation.

The success of root canal treatments depends heavily on the type of alloys used to make endodontic instruments. The instruments made from carbon steel remain vulnerable to corrosion. Stainless-steel alloy instruments exhibit a high modulus of elasticity, which makes them less flexible^[10] and causes procedural errors in curved canals.^[11] Nickel–titanium (Ni–Ti) instruments overcome these limitations and are widely used in today's treatments.

The efficiency of endodontic treatments is significantly influenced by the instrument types. The most widely used types of instruments are hand or rotary. Hand instrumentation is time-consuming and associated with

iatrogenic problems. With evolving clinical trends, emphasis has shifted toward improving the efficiency and reducing the duration of pulpectomy procedures. Rotary instrumentation offers a significant advancement in making endodontic treatment efficient and is increasingly used in paediatric dental practice.^[12]

Though efficient, the rotary instrumentation needs to use an appropriate file system to minimise procedural complications. The NiTi rotary file system first introduced by Barr et al. in primary molars, applies the same biomechanical preparation principles established for permanent teeth.^[13] These files incorporate variations in motion and design—such as core diameter, cross-section, rake angle, and flute depth^[14]—which influence cutting efficiency, surface integrity (Tripi TR et al., 2001)^[15], and the risk of dentinal cracks or apical debris extrusion.^[16] However, these files require frequent monitoring as they face deformation if not appropriately used and can lead to procedural errors.

In this study, we use two single Ni-Ti file systems: Kedo S Plus, which works on rotational motion, and WaveOne Gold, which works on reciprocating motion. Their detailed description is provided below:

Kedo S Plus: a single-file system with an apical cross-section that is triangular and a coronal cross-section that is tear-shaped. It is specifically designed for primary teeth and comprises P1+ for primary molars and A1+ for primary incisors. Its files feature dual metallurgy of gold and blue heat-treated core materials with heat treatment of the coronal half and heat treatment combined with titanium oxide coating in the apical half (Controlled Memory). It uses an electronic endomotor at a speed of 300 rpm and a torque of 2 Ncm (Table 1). It is typically used in crown-down technique with pecking motions to working length, followed by two buccolingual brushing strokes to remove residual debris.

WaveOne Gold: a single-file system with an off-centre parallelogram design with two cutting edges. These files are available in four sizes— Large (45/05, black), Medium (35/06, green), Primary (25/07, red), and Small (20/07, yellow). Each one exhibits a fixed taper from D1–D3, and then gradually decreases from D4–D16. The primary file generally operates in reciprocating motion at 150° counter-clockwise and 30° clockwise using an endomotor (Table 1).

Table 1: Comparison between Kedo S Plus Rotary Files and WaveOne Gold Reciprocating files.

	Kedo S Plus	WaveOne Gold
Length	File length – 16mm	File length – 25 mm
Metallurgy	CM Wire technology Dual Metallurgy	Gold Wire metallurgy
Cross-section	Apical 5mm – triangular Coronal region – teardrop	parallelogram-shaped design with two cutting edges
Taper	VV taper – 4% to 8%	7%
RPM	250 – 300	350
Torque	2.2 - 2.4Ncm	2Ncm

Despite the benefits of a single-file system, these can still undergo topographic and morphological changes and lead to procedural complications and failure of root canal treatment as they get fractured within the root canals. In order to overcome this situation, routine monitoring can be done with Scanning electron microscopy (SEM). It is a well-established method for accurately assessing topographic and morphological changes on endodontic file surfaces. Accordingly, SEM was employed in the present study to evaluate surface defects in the above-mentioned single-file systems.

Çırakoğlu NY et al^[17] in 2022 states that the Reciproc Blue system was the most worn out at apical 1 mm, the WaveOne Gold system at apical 3 mm, and the PTN system exhibits the least wearing at any length. According to a study conducted by Chopra K and Ballal NV^[18] in 2024, Wave One Gold showed more significant surface defects after three uses in the coronal and middle thirds, while the Jizai file system did not produce any defects in the coronal, middle, and apical thirds. A study by Natarajan B et al^[19] in 2025 states that Kedo-Nano Plus demonstrated consistently superior resistance to flute deformation, enhanced dimensional stability, and significantly reduced instrumentation time even with repeated use. In comparison, Kedo-S Plus showed slightly better performance than Kedo-S Square.

In our study, pre-operative SEM analysis reveals manufacturing-related surface defects in both file systems; however, WaveOne Gold files exhibited a higher frequency of pitting and microcracks than Kedo S Plus files at the tip, 3-mm, and 5-mm levels. After a single clinical use, surface defects increased markedly in both systems, predominantly at the tip and 3-mm levels, which are exposed to maximum torsional and flexural stresses. WaveOne Gold files showed significantly greater pitting, debris accumulation, and microcrack formation, whereas Kedo S Plus files demonstrated a higher incidence of blunt edge formation at the tip, indicating early loss of cutting efficiency. With repeated use in two molars, progressive surface deterioration was observed in both systems, and the emergence of minimal, non-significant fracture defects suggested the onset of structural fatigue. After three uses, extensive surface degradation was evident across all levels. The tip region consistently showed the earliest and highest defect frequency, followed by progressive deterioration at the 3-mm level—more pronounced in Kedo S Plus files—while the 5-mm level exhibited cumulative damage, particularly pitting and microcracks in WaveOne Gold files.

CONCLUSION

The present study demonstrates that surface defects in endodontic instruments are not uniformly distributed along their length and increase progressively with repeated clinical use. The tip region was the most vulnerable area, exhibiting the earliest onset and highest frequency of surface defects, reflecting its greater

exposure to cyclic fatigue and torsional stresses during canal instrumentation. The 3-mm level showed progressive functional deterioration with repeated use, particularly in Kedo S Plus files, where pronounced blunt edge formation indicated an earlier loss of cutting efficiency. Although the 5-mm level was initially least affected, cumulative surface damage became evident after multiple uses, with WaveOne Gold files demonstrating a higher incidence of pitting and microcrack formation. These findings underscore the influence of instrument design, metallurgy, and usage frequency on surface integrity and highlight the importance of careful clinical use and timely replacement of rotary and reciprocating files to minimise the risk of instrument failure.

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