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ORIGINAL ARTICLE

Comparison of Surface Defects in Different Rotary Files: An *in-Vitro* Study

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ABSTRACT

Objective: To evaluate the surface defects in Wave One Gold and Jizai rotary files after 1 and 3 uses. **Material and Methods:** Ninety-six resin blocks with stimulated canals and 12 files per system were used. The files were pre-examined under scanning electron microscopy (SEM) to exclude files with pre-existing cracks and craters. Instrumentation and SEM evaluation of the files were performed after 1 and 3 uses, respectively. Two independent operators analyzed the images, and scoring was carried out for each file's coronal, middle, and apical thirds. The surface defects at different thirds of the file systems were analyzed using the Chi-Square test and Kendel Tau's test. **Results:** After one use, both the file systems did not produce any significant surface defects in the coronal, middle, and apical thirds. However, after three uses, there was minor plastic deformation in the coronal and middle thirds of the Wave One Gold file system. Jizai file system did not produce any surface defects in the coronal, middle, and apical thirds. **Conclusion:** After one use, no surface defects were created in Wave One gold and Jizai rotary files. Wave One Gold exhibited more significant surface defects after three uses in the coronal and middle thirds.

Keywords: Elasticity; Endodontics; Microscopy; Alloys; Root Canal Preparation.

Introduction

Root canal instruments are essential for canal preparation during endodontic treatment [1]. In recent years, several advances have taken place pertaining to its armamentarium, such as the introduction of NiTi rotary instruments. Initially, instruments based on stainless steel were widely used. However, the high rigidity of stainless-steel instruments has impeded efficient root canal cleaning, especially in curved canals. Nickel-titanium (NiTi) alloy-based instruments exhibit super elasticity and shape memory. The super elasticity of NiTi permits their use in curved root canals with minimum canal transportation [2-5]. These instruments save the operator's time and combat iatrogenic errors owing to their flexibility and efficiency. It is also known that the use of these files is associated with an increased incidence of progressive surface changes post-instrumentation, which may hamper the efficiency of the files and may lead to subsequent fracture [6,7]. Cyclic fatigue is the most common cause of fracture incidence, which can be visualized as structural changes on the surface of these instruments after use [8,9]. The formation of craters/microcracks hampers the cutting efficiency of the files and decreases their resistance to fracture [4], leading to inadequate preparation and debridement of the canals. Hence, studies evaluating the changes in the surface topography of the files are essential in understanding and making an informed decision regarding their use.

Since their introduction in the 1980s, NiTi rotary files have undergone several advances in metallurgical properties, cross-sectional geometry, and kinematics (continuous, reciprocation, and adaptive motion). These changes were made to prevent canal transportation during instrumentation and reduce the changes in the surface topography of the files [10]. One of the most widely used file systems is the WaveOne (WO) (Dentsply Sirona, Ballaigues, Switzerland). It was introduced in 2011 and was then modified to WaveOne Gold (WOG) (Dentsply Sirona, Ballaigues, Switzerland) in 2016, where the kinematic remained unchanged. The modification involved a change in the metallurgy from M-Wire to Gold wire and a heat-treated NiTi alloy that gives the file high flexibility, resistance to cyclic fatigue, and excellent cutting efficiency. The gold heating process results in an increased amount of martensite in the crystalline structure of the Gold-Wire compared to the M-Wire alloy, reducing its surface microhardness and structural changes [6-8]. However, these structural changes cannot be assessed clinically and can be seen using advanced imaging techniques like a stereomicroscope or scanning electron microscope [9].

Previous studies have shown that intact and used WOG instruments have rougher surfaces than new and used WO and M-Wire instruments. Convex triangular cross-section was also changed to a parallelogram with two cutting edges and an off-center design [10]. There are four types of WOG files available in various lengths: Small (yellow 20/07), Primary (red 25/07), Medium (green 35/06), and Large (black 45/05). Each file has a fixed taper from D1-D3 and a progressively decreasing percentage tapered design from D4-D16. For example, the Primary file has diameters of 0.85 mm and 1.0 mm at D9 and D12, respectively, or the length of this file typically extends below the orifice during canal preparation. It has been stated that the Primary 25/07 file is generally the only file required to shape virtually any given canal [11] fully.

The current literature is controversial regarding surface changes in the file after their use. Alternatively, a new file system known as Jizai (Mani Inc., Tochigi, Japan) was launched in individual ISO-sized packs of 3 files or as part of a standard kit which includes a sequence of 25.04, 25.06, and 35.04 files. The manufacturer has stated that the off-center file axis promotes the formation of a pocket, leading to less debris accumulation and smooth instrumentation. It has also been stated that the file has good strength and flexibility, which minimizes canal transportation. It is designed to instrument straight and slightly curved canals and has to be used at a speed of 300-500 rpm and torque of 1Ncm-3Ncm. It has been stated that canal preparation will be terminated, preferably

at 25.06 or 35.04. Although the manufacturer recommends the WOG file system to be a single-use file system, it does not specify its use per the number of canals. It can vary from one use in the case of anterior teeth to three or more use in the case of posteriors.

Hitherto, no studies have compared the surface topography of the Jizai files before and after use. Hence, the aim of the present study was to evaluate the surface defects of WOG and Jizai rotary file systems after one and three uses in curved root canals. The null hypothesis tested was that WOG and Jizai rotary file systems would produce similar surface defects after one or three uses.

Material and Methods

Sample Size Estimation

G*Power software (Heinrich Heine University, Dusseldorf, Germany) was used to estimate the sample size. With a 95% confidence level and 90% power based on previously published literature [12], a standard deviation of 1.1, and a mean difference of 1.3, a minimal sample size of 12 per group was required.

Ethical Clearance and Sample Preparation

Ethical clearance was obtained from the institutional review board (25/2023). The study was conducted on 96 resin blocks (Vasa Denticity Pvt Ltd, New Delhi, India) with stimulated canals at a curvature of 30°. This would allow for its standardization and 12 files per rotary system. Only new and unused WOG (Dentsply Sirona, Ballaigues, Switzerland) and Jizai (Mani) files were used. Prior to instrumentation, the files were subjected to scanning electron microscopy (SEM) examination to rule out those with pre-existing cracks, craters, or fractures. The working length of the resin blocks was determined with a #10 K file (Dentsply Sirona, Ballaigues, Switzerland), which was inserted into the canal until the tip was visible from the apical end, and 1 mm was subtracted from this measurement. The apical enlargement was done until a #20 K file (Dentsply Sirona, Ballaigues, Switzerland), after which the instrumentation was carried out using the aforementioned rotary files per the manufacturer's instructions. Irrigation was performed using 5 ml of 2.5% sodium hypochlorite (Vista Dental Products, Racine, WI, USA) for 1 min using a 27-gauge side vented needle (Vista Dental Products, Racine, WI, USA) which was placed 1mm short of the working length.

Primary WOG rotary file was used at 150-degree counter-clockwise rotation and 30 degrees clockwise rotation in a Tri Auto mini Endomotor handpiece (J Morita Tokyo MFG Corp, Saitama, Japan) using reciprocating motion according to the manufacturer's recommendation. The WOG primary file was used first to enlarge the coronal third of the canal using pecking motion, after which the file was withdrawn, and the canal was recapitulated with a #10 K file (Dentsply Sirona, Ballaigues, Switzerland). Irrigation was performed using 5 ml of 2.5% sodium hypochlorite (Vista Dental Products, Racine, WI, USA) for 1 min using a 27-gauge side vented needle (Vista Dental Products, Racine, WI, USA) placed 1mm short of the working length. Subsequently, enlargement of the middle and apical thirds of the canal was performed similarly. Irrigation was performed after the enlargement of the middle and apical thirds of the root canal in a manner similar to the one mentioned above. The Jizai file system (25.06) was used at 300 rpm and 1.5 Ncm torque in the Tri Auto mini Endomotor handpiece (J Morita Tokyo MFG Corp, Saitama, Japan). The file was used in a similar way to WOG. First, a coronal third of the root canal was enlarged using brushing motion, followed by the middle and apical thirds. The previously described irrigation regimen was carried out after the enlargement of each canal third. A single experienced operator performed the instrumentation in both groups. After the first use of both file systems, files were cleaned in an ultrasonic bath. Each file was stored in 5 ml of distilled water in an Eppendorf tube (Eppendorf SE,

Hamburg, Germany) until the post-instrumentation scanning electron microscopic (SEM) analysis. The instrumentation technique described above was then repeated three times using the same files, followed by SEM analysis.

SEM Analysis

Both systems' used files were mounted on metal stubs and examined with SEM JSM 6010 (JEOL Ltd., Tokyo, Japan). Images of both the file systems were captured at 60 X magnification and 10 kV at a working distance of 11.0 mm at room temperature (37°C), and 200µm of the file area was captured along the coronal-third, middle-third, and apical-third of each specimen. These images were evaluated by two independent evaluators who were blinded to the group designations. The images were scored according to previously-reported criteria [12]: 1= No defect (No plastic deformation or bending or other deformation of the cutting edge is visible); 2= Minor plastic deformation (The cutting edge or flute of the instrument is curved or deformed with the disruption of cutting edge); 3= Blunting of cutting edges/Microcracks (The flute or cutting edges of the instrument is blunt with or without microcracks; 4= Craters (Some part of the flute or cutting edge of the instrument is missing as indicated by a crater on the surface); and 5= Fracture.

Statistical Analysis

Data was analyzed using a statistical package (SPSS 22.0, IBM Corp., Chicago, IL, USA). The surface defects at different thirds of the file systems were analyzed using the Chi-Square test and Kendel Tau's test. The level of significance was set at $p<0.05$.

Results

After one use, both WOG and Jizai files did not produce any significant surface defects in the coronal middle and apical thirds ($p>0.05$) (Figure 1). After three uses, the WOG file exhibited minor plastic deformation in the coronal ($p=0.046$) and middle third ($p=0.041$) when compared to the Jizai file, which was statistically significant. However, in the apical third, no significant changes were observed between the WOG ($p=0.672$) and the Jizai file ($p=0.710$) (Figure 2). Figure 3 represents the SEM images of the instrument surface of WOG and Jizai files after one and three uses.

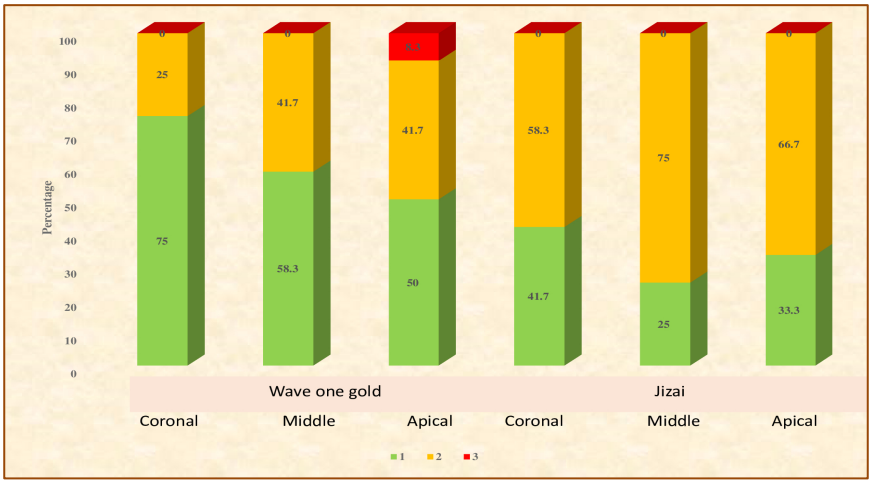

Figure 1. Percentage of surface topographic changes observed in WOG and Jizai rotary files in the coronal, middle, and apical thirds after one use. The defects are categorized as (1) No defect; (2) Minor plastic deformation; and (3) Blunting of cutting edges/microcracks.

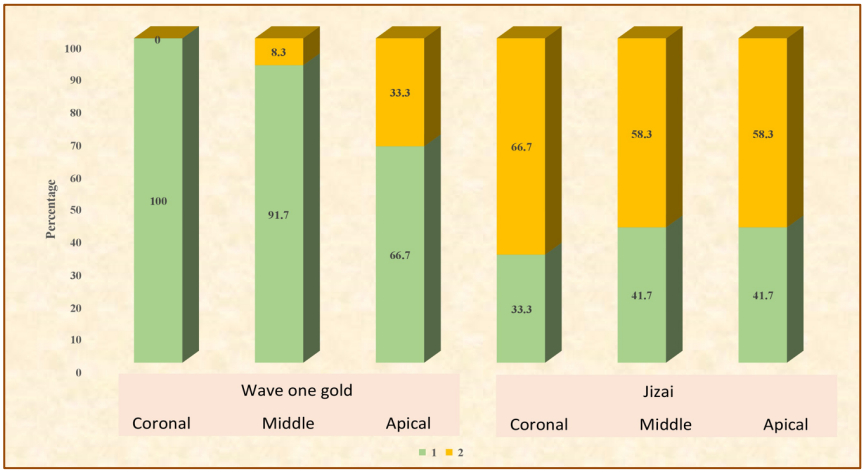

Figure 2. Percentage of surface topographic changes observed in WOG and Jizai rotary files in the coronal, middle, and apical third after three uses. The defects are categorized as (1) No defect and (2) Minor plastic deformation.

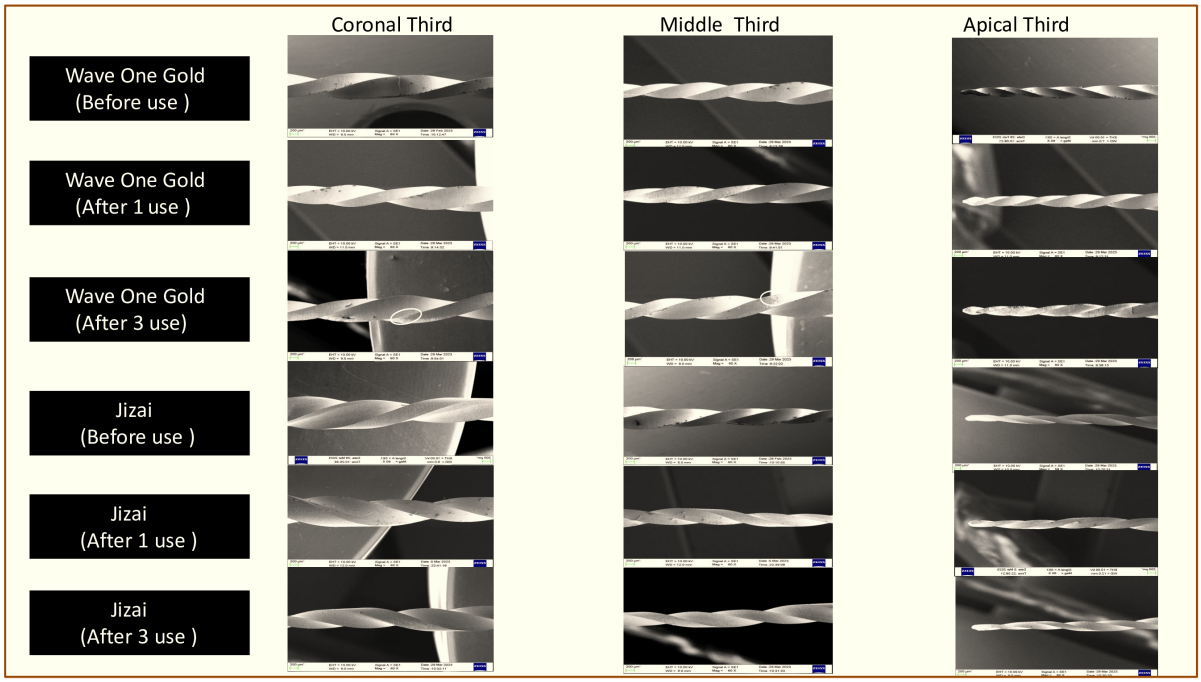

Figure 3. Representative SEM micrographs of WOG and Jizai rotary files before, after one, and three uses. The encircled area represents the plastic deformation seen in the coronal and middle thirds of the WOG files after three uses.

Discussion

The current study evaluated the surface defects produced by WOG and Jizai files when used in a simulated root canal model. The results demonstrated that after one use, there were no defects to the file systems; however, after three uses, WOG exhibited plastic deformation in the coronal and middle thirds. Hence, the null hypothesis was partially rejected.

The recurrent use of endodontic rotary files may lead to dullness and blunting, which rapidly causes irregularities on the surface [13,14]. The production of these surface defects can cause microporosities and initiate crack propagation, which could lead to subsequent fractures [15]. The manufacturer of WOG recommends the files be of single-use. Single-use of the file does not mean that the file would only be used in a

single canal; a single-use file can be used in teeth having multiple canals. For this reason, each of the files was tested for up to 4 canals (3 uses). After the first use, no significant difference in the surface defects was found at the WOG's coronal, middle, and apical thirds compared to the Jizai files. This may be attributed to the metallurgical properties of the WOG files, which employ the gold wire technology that improves the files' strength and flexibility and increases the cyclic fatigue resistance. After three uses, plastic deformation was seen on the coronal and middle thirds of WOG files. Pirani et al. [16] have stated that the use of a single file in reciprocating motion could lead to a concentration of flexural and cyclic wear on the surface of the file, which could lead to greater production of surface defects. The more significant contact of the coronal and the middle third of the files against the resin block may have led to the concentration of these stresses on the coronal and middle third surface of the files after three uses [16].

In the apical third, WOG files had no surface defects after three uses. This may be attributed to the reciprocating motion of WOG files, which causes less torsional stress at the interface between the resin block and the file in the apical third, which leads to less crack initiation and fewer surface defects [15]. Turker et al. have reported a correlation between the production of surface defects and the cross-section design of the rotary file. WOG primary file has a parallelogram cross-section design, which leads to lesser contact of the apical portion against the resin block [17]. This may be why no surface defects were observed in the apical third file after three uses. The result of the present study is in accordance with a previous study, which demonstrated significant surface defects in WOG files at coronal and middle thirds but not in the apical [16]. In contrast, Gawdat et al. observed that WOG files upon instrumentation only produced mild blunting of the tip at the apical third with no surface defects in the coronal and middle third [18].

In the present study, Jizai files had no surface defects after one and three uses in coronal, middle, and apical thirds. This may be attributed to these files' rhomboidal cross-section and heat treatment, which resist surface changes upon instrumentation. Using SEM images to evaluate topographic changes on the surface of endodontic files is a well-documented method to measure morphological features accurately [13-18]. Hence, in the current study, SEM was used to evaluate the surface defects of the two file systems. In previous studies, both artificial root canals made up of acrylic teeth and root canals of permanent teeth have been used to evaluate the surface defects of files after use [19,20]. Artificial canals might be preferred to minimize variation caused by natural teeth and to ensure root canal diameter, length, and curvature standardization in terms of angle and radius [21]. Hence, the current study used acrylic resin blocks with stimulated canals, allowing for more canal curvature standardization. The results of the present study have a few limitations and may not necessarily be extrapolated to the clinical scenario. First, SEM was used to analyze the surface defects of the rotary files. SEM provides only a two-dimensional image of the object.

Further similar studies need to be performed using atomic force microscopy (AFM), which provides the operator with a three-dimensional image that could better evaluate the surface defects of the rotary files [19]. Second, the mono-method approach employed in this study is compared to the clinically relevant multimethod approach. It has been demonstrated that the performance of NiTi instruments is affected by several factors, and hence, it is crucial to adopt the multimethod approach. This approach incorporates the study of mechanical properties, metallurgical characterization, shaping ability, and irrigation efficiency [22]. This approach reduces the risk of inaccurate findings and comprehensively evaluates the phenomena being studied. However, since the present study was a preliminary study on Jizai files, which were recently marketed, only the surface defects were assessed after its use in curved canals. Future studies have to be performed to evaluate its various other mechanical properties in a clinically simulating model.

Conclusion

Wave One Gold and Jizai rotary files had no surface defects after one use. After three uses, plastic deformation was observed in Wave One Gold files in the coronal and middle thirds.

Authors' Contributions

KC	https://orcid.org/0009-0009-0929-1450	Methodology, Formal Analysis, Investigation, Data Curation and Writing - Original Draft.
NVB	https://orcid.org/0000-0002-2208-9443	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Review and Editing, Supervision and Project Administration.

All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published.

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None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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