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ORIGINAL ARTICLE

Shaping Ability of the Root Canal System Using Reciproc and Reciproc Blue in Preparation of Artificial Canals

Hawazin Majdi[1], Khalid Merdad[2], Tariq Abuhaimed[3], Lujain Mirdad[4], Omar Alkhattab[2], Abdulaziz Bakhsh[5]

[1]Dental Speciality Centre, King Fahad Hospital, Ministry of Health, Al Madinah Al Monawara, Saudi Arabia.
[2]Endodontic Department, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.
[3]Biomaterials Division, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.
[4]Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.
[5]Department of Restorative Dentistry, Faculty of Dental Medicine, Umm Al-Qura University, Makkah, Saudi Arabia.

Corresponding author: Khalid Merdad **E-mail:** kmerdad@kau.edu.sa

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ABSTRACT
Objective: To evaluate the effect of repeated usage of Reciproc and Reciproc Blue on their shaping ability and to determine the maximum number of artificial canals that they can prepare until fracture. **Material and Methods:** The two file systems, Reciproc and Reciproc Blue, were used to instrument a total of 436 resin blocks. The blocks simulated standardized root canals with a 35° angle of curvature. The rotary systems were divided into two groups (n=21). All canals were prepared to an apical size of 25 according to the manufacturer's instructions. A computer imaging program was then used to analyze canal straightening after pre- and post-instrumentation digital photography was superimposed. **Results:** Both Reciproc and Reciproc Blue instruments respected the original canal curvature. There were no significant differences between the instruments in terms of maintaining canal curvatures. Moreover, there were no significant differences in preparation time and the number of canals prepared before failure between the two instruments. **Conclusion:** Reciproc and Reciproc Blue were safe to use under the conditions of this study. Reciprocal motion files with or without heat treatment had comparable preparation time, shaping abilities, and the ability to maintain root canal curvatures.

Keywords: Endodontics; Root Canal Therapy; Root Canal Preparation.

Introduction

Root canal treatment aims to clean and disinfect the root canal system while maintaining the original canal shape [1]. Endodontic instruments have evolved over the years. Nickel-titanium (NiTi) endodontic rotary instruments are well known for their superior properties when compared to stainless steel files [2]. NiTi instruments have unique characteristics, such as being more flexible and resistant to fracture compared to stiff and less resistant stainless-steel alloys [3]. It has been found that NiTi files have a lower incidence of dentine removal, transportation, and less working time. Moreover, shaping the root canal system using rotary NiTi instruments is faster, centered, and shows fewer errors and internal irregularities inside the root canal [4].

Several techniques have been introduced for the preparation of the root canal. One of these techniques is the reciprocation movement, which uses a clockwise and anticlockwise movement of the file inside the canal [5]. The reciprocation movement has been shown to decrease the failure incidence of a file when compared to continuous rotation and demonstrate a higher instrument resistance to cyclic fatigue [6,7].

In recent years, manufacturers have introduced new alloys using new manufacturing processes in order to improve the fracture resistance of NiTi files [8]. The memory wire (M-Wire) is made using a thermo-mechanical process, allowing for greater flexibility and cyclic fatigue resistance. The M-Wire structure has a mixture of equal amounts of austenite and R-phase structures. However, thermally treated M-Wire instruments have a martensitic structure at body temperature. Martensitic phases have unique characteristics such as remarkable fatigue resistance, a twinned-phase structure with unique properties, and a phase transformation with excellent energy absorption, making the endodontic instrument more durable [9].

To date, the number of times a NiTi rotary instrument can be used is unknown [10,11]. However, there are concerns regarding the reuse of nickel-titanium instruments. These concerns are mainly centered on their liability to undergo cyclic and torsional fatigue and separate without any visible defects or plastic deformation [12]. Multiple studies have proven that cyclic fatigue resistance of NiTi was significantly reduced after repeated clinical use [13-17]. Furthermore, repeated clinical use of nickel-titanium instruments is associated with the possibility of prion transmission, which was found to be resistant to standard sterilization methods [18]. Even with the potential risks, some clinicians still choose to reuse NiTi rotary instruments due to financial reasons. Therefore, the aim of this study was to compare and evaluate the effect of multiple uses of Reciproc and Reciproc Blue (VDW, Munich, Germany) files on their ability to shape simulated resin canals and to determine the number of artificial canals that can be prepared until the file fractures.

Material and Methods

Specimens

A total of 436 resin blocks (VDW GmbH, Munich, Germany) with 18mm length and standardized taper 0.02 root canals were used in this study. The blocks had a 35° apical curvature. Forty-two rotary instruments equally divided between Reciproc and Reciproc Blue were used to prepare the resin blocks. All preparations and evaluations were done by one calibrated operator.

Block Preparation

All simulated canals were filled with blue ink (Indústria de Tintas Corfix Ltda, Porto Alegre, RS, Brazil) using a 30-gauge needle (Ultradent Products Inc., South Jordan, UT, USA). A customized mold was prepared for the resin blocks and positioned on a tripod to maintain a fixed distance of 90 degrees angle to a digital camera (EOS Rebel T3; Canon, Taichung, Taiwan). Each block was photographed pre-operatively (Figure 1A), followed by irrigation of the blue ink using distilled water.

Block Instrumentation and Preparation

Resin blocks were fixed in a metal vice to maintain a standardized and fixed position during instrumentation. Two orientation holes were made into the acrylic block for each canal inside the block, using a high-speed handpiece 330 carbide bur (Komet Dental, Lemgo, Germany). All canals were instrumented using the same sequence and according to manufacturers' instructions.

Reciproc or Reciproc Blue R25 file was introduced in the resin canal with light apical pressure in an in-out pecking motion with three strokes. Then, the instrument was brought out from the canal to remove debris using copious irrigation. Finally, apical patency was confirmed using an ISO size 10 K-file. These steps were repeated until each resin canal was completely prepared or until the instrument fractured.

Postoperative photographs were taken for each canal when the instrumentation was completed using the same position and magnification used before starting instrumentation (Figure 1B). Furthermore, after each file fracture, the number of prepared canals and the preparation time for one canal were calculated. A scanning electron microscope (JSM 5800; JEOL Ltd., Tokyo, Japan) was used to evaluate the topographic features of the fracture surfaces of all instruments at 550x magnification.

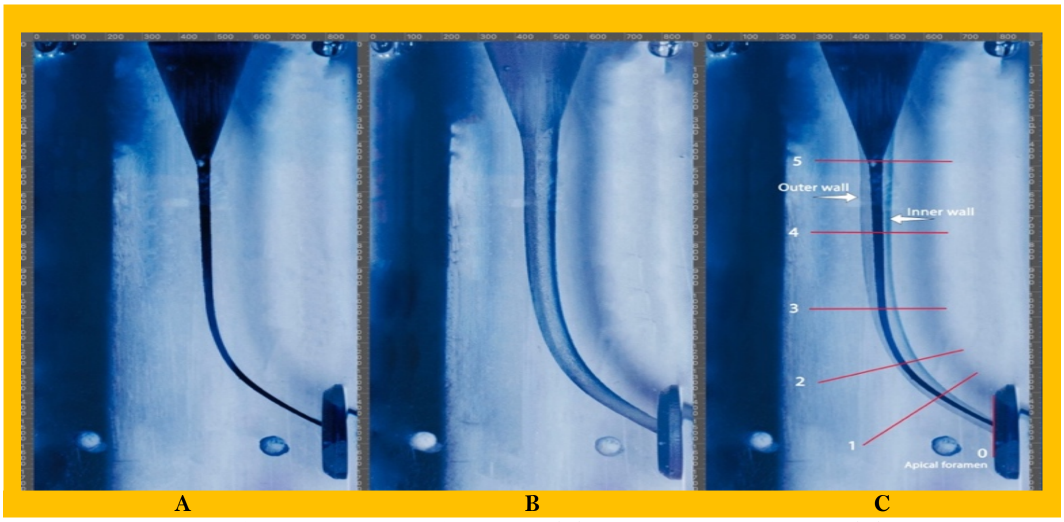

Figure 1. (A) Pre-operative resin block filled with blue ink; (B) Prepared resin block; (C) Superimposed image of the pre-operative and post-operative block including the six points of analysis.

Preparation Assessment

Using the pre and post instrumentation images of each canal, a composite image was constructed using the two holes in the resin blocks. Adobe Photoshop (CS6, version 13.0; Adobe Systems, San Jose, CA, USA) was used to make the measurements on the superimposed digital images with an accuracy level of 0.001mm.

Preparation Analysis

Preparation was analyzed using six points at different levels of the resin block (Table 1 and Figure 1C).

Table 1. Six points analyzed at each block.

Position Number	Location
Position 5	Canal Orifice (O)
Position 4	Mid Canal (MC)
Position 3	Beginning of the Curvature (BC)
Position 2	Mid Curvature (MOC)
Position 1	End of Curvature (EOC)
Position 0	Apex of the curve of the original canal and End Point of the Preparation (EP)

Evaluation of Centring Ability

After transferring the images to the computer, the shortest distance between the root canal and the mesial and distal walls was measured and recorded using Adobe Photoshop software (CS6, version 13.0; Adobe Systems, San Jose, CA, USA). Measurements were taken post-instrumentation at the same levels as those taken pre-instrumentation. The formula of Gambill et al. [19] was used to determine the canal's transportation and centering capability [$(X_1-X_2)/(Y_1-Y_2)$ or $(Y_1-Y_2)/(X_1-X_2)$]. A value other than "0" indicates that some transportation took place.

The transportation results indicate the amount of material removed in comparison to the ideal preparation (which involves no transportation). The centering ratio was calculated at each measuring point using the following formula (amount of resin removed from the outer side) - (amount of resin removed from the inner side)/ post instrumentation canal diameter. Positive and negative values, respectively, indicate transportation to the outer and inner sides, while a value of 0 indicates perfect centering. Furthermore, the canal straightening was determined by comparing the curvatures of the canals before and after shaping (Figure 2).

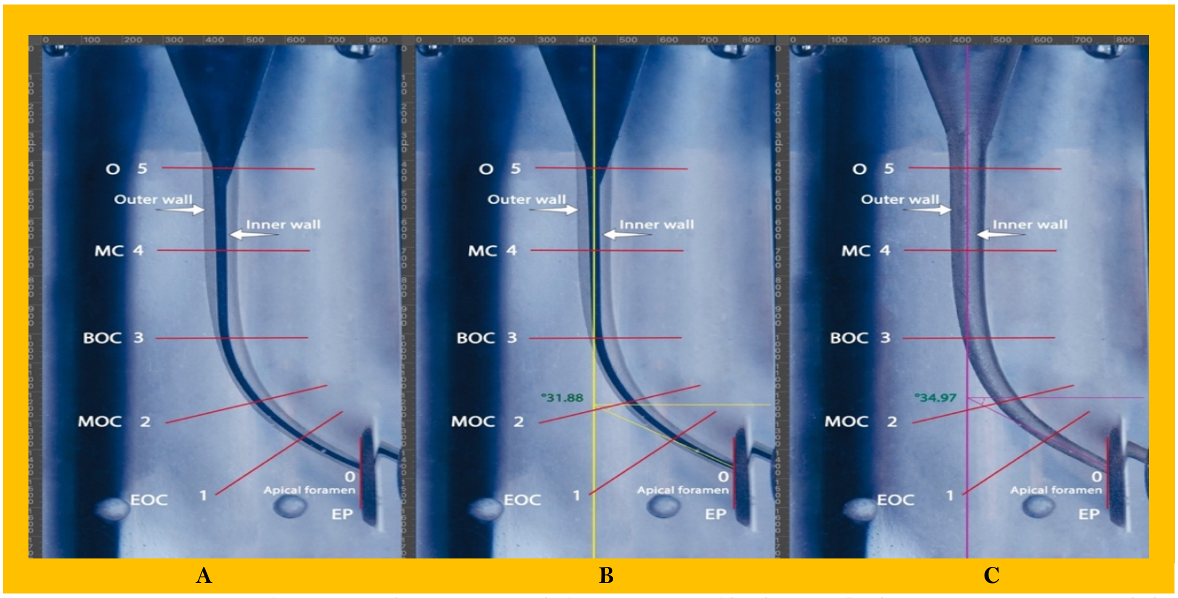

Figure 2. Measuring the angle of curvature of the resin canal before and after instrumentation. (A) superimposed image; (B) Angle of curvature before preparation; (C) Angle of curvature after preparation

Statistical Analysis

Analysis was done using IBM Statistical Package for Social Science for Windows, version 23 (IBM SPSS Corp. Armonk, NY, USA). The Mann-Whitney U-test was used to compare the outcome variables between the test groups. At the same time, the Kruskal-Wallis test was used to compare the changes in canal angle and diameter, as well as the centering ability of the tested groups.

Results

The mean number of canals prepared before failure for Reciproc and Reciproc Blue were (11±2) and (10±2), respectively. While the mean time to failure for Reciproc and Reciproc Blue were (201.1±36.7s) and (192.9±44.8s), there was no statistical difference between Reciproc and Reciproc Blue files in terms of the number of prepared canals and the time to failure (Table 2).

Table 2. Comparison of the time to failure, canal preparation time, and number of simulated canals prepared before failure between the test groups.

Variables	Reciproc		Reciproc Blue		p-value*
	Mean ± SD	Median (Min.-Max.)	Mean ± SD	Median (Min.-Max.)	
Time to failure (seconds)	201.09 ± 36.72	192.57 (150.43–274.8)	192.98 ± 44.8	188.76 (131.31–269.09)	0.45
Time/canal	18.77 ± 0.76	18.94 (17.01–19.89)	18.88 ± 0.9	19.05 (16.41–20.02)	0.50
No of canals	11 ± 2	10 (8–14)	10 ± 2	10 (7–14)	0.38

Min.: Minimum; Max.: Maximum; * Mann-Whitney U test.

Reciproc files showed a statistically higher change in canal angle (2.6±0.5°) when compared to Reciproc Blue (1.9±0.3°) ($p<0.001$).

Comparison of Centric Ratio (CR) in the Reciproc group was found to be at the inner wall of the block when tested at the canal orifice (O) point and mid-canal point (MC) with no significant difference between the tested blocks. However, the CR was in the outer wall of the tested block at both the beginning of the curve (BC) and at the end of the curve (EOC), with no statistically significant difference (Table 3).

Table 3. Comparison of the changes in the canal angle and diameter at different points along the canal between the test groups.

Variables	Reciproc		Reciproc Blue		p-value*
	Mean ± SD	Median (Min.-Max.)	Mean ± SD	Median (Min.-Max.)	
Angle change	2.62 ± 0.47	2.70 (1.69–3.59)	1.87 ± 0.29	1.93 (1.39–2.76)	<0.001
Diameter change (O)	0.42 ± 0.01	0.42 (0.39–0.44)	0.42 ± 0.01	0.42 (0.40–0.44)	0.52
Diameter change (MC)	0.45 ± 0.01	0.45 (0.43–0.47)	0.45 ± 0.02	0.45 (0.40–0.47)	0.97
Diameter change (BOC)	0.39 ± 0.02	0.39 (0.34–0.44)	0.38 ± 0.03	0.39 (0.30–0.42)	0.35
Diameter change (MOC)	0.34 ± 0.02	0.34 (0.27–0.39)	0.33 ± 0.02	0.33 (0.30–0.37)	0.38
Diameter change (EOC)	0.26 ± 0.02	0.26 (0.21–0.32)	0.25 ± 0.03	0.26 (0.22–0.32)	0.09
Diameter change (EP)	0.21 ± 0.03	0.21 (0.17–0.31)	0.18 ± 0.03	0.19 (0.11–0.23)	0.001

O: Orifice; MC: Mid Canal; BOC: Beginning of Curve; MOC: Mid of Curve; EOC: End of Curve; EP: End Point of Preparation; *Mann-Whitney U-test.

When testing the CR in the Reciproc Blue group, it was found that at the orifice level, the CR was in the inner and outer wall of the block without any statistically significant difference. At the MC, BC, and MOC the CR was found to be in the inner wall. However, the outer wall was affected by CR at the EOC point. There was no statistically significant difference between all the points (Table 4).

Table 4. Comparison of the centering ability at different points along the canal between the test groups.

Variables	Reciproc		Reciproc Blue		p-value*
	Mean ± SD	Median (Min.-Max.)	Mean ± SD	Median (Min.-Max.)	
Diameter change (O)	-0.22 ± 0.16	-0.24 (-0.51 – 0.24)	-0.02 ± 0.06	-0.04 (-0.12 – 0.15)	<0.001
Diameter change (MC)	-0.22 ± 0.4	-0.27 (-0.80 – 1.81)	0.11 ± 0.1	0.12 (-0.09 – 0.54)	<0.001
Diameter change (BOC)	-0.06 ± 0.21	-0.04 (-0.57 – 0.55)	-0.11 ± 0.1	-0.11 (-0.55 – 0.09)	<0.001
Diameter change (MOC)	0.41 ± 0.9	0.21 (-0.62 – 5.34)	-0.12 ± 0.29	-0.18 (-0.54 – 0.98)	<0.001
Diameter change (EOC)	0.10 ± 0.13	0.07 (-0.04 – 0.69)	0.09 ± 0.44	0.00 (-0.20 – 2.57)	<0.001
Diameter change (EP)	-1.87 ± 4.54	-1.23 (-20.46 – 11.24)	0.04 ± 0.17	0.03 (-0.30 – 0.49)	<0.001

O: Orifice; MC: Mid Canal; BOC: Beginning of Curve; MOC: Mid of Curve; EOC: End of Curve; EP: End Point of Preparation; *Mann-Whitney U-test.

The cross-sectional analysis of the fractured surfaces of the Reciproc and Reciproc Blue instruments revealed typical features of torsional fractures, with concentric abrasion marks and fibrous dimples from the torsional center (dotted circle) (Figure 3).

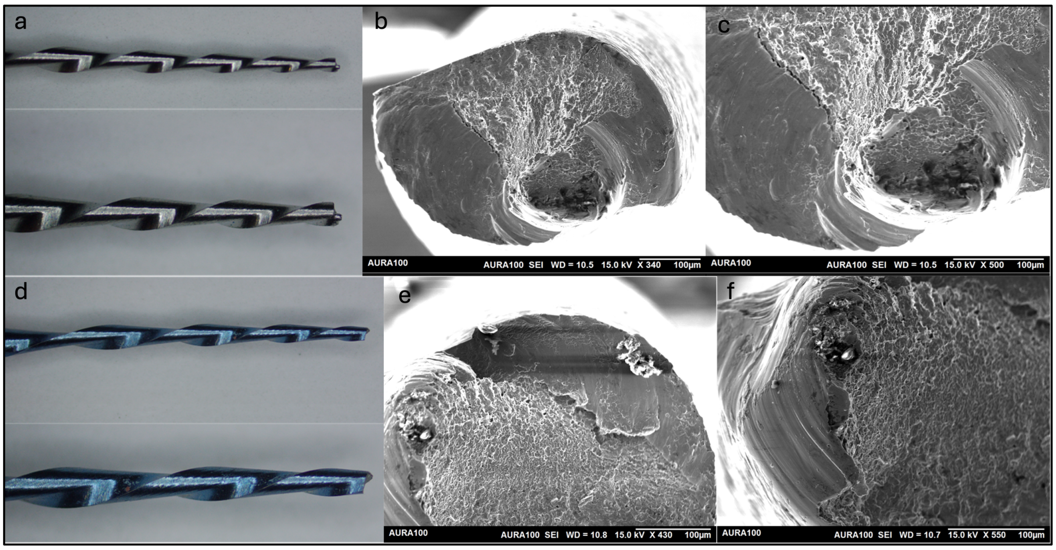

Figure 3. An image of fractured Reciproc and Reciproc Blue files. (a) Fractured Reciproc file; (b) Scanning electron microscope (SEM) image of fractured Reciproc file at 430x; (c) SEM image of fractured Reciproc file at 500x; (d) Fractured Reciproc Blue file; (e) SEM image of fractured Reciproc Blue file at 430x; (f) SEM image of fractured Reciproc Blue file at 550x.

Discussion

This study compared Reciproc and Reciproc Blue's ability to shape resin block canals after repeated use and quantified the number of uses until fracture. The results of this experiment can help clinicians to consider the number of canals that could be prepared for each patient and predict the final shape of the prepared canal when single use of the file is not feasible. Reciprocation in a clockwise and counterclockwise direction was proven to alleviate stress on the file and increase torsional fatigue resistance [20]. Additionally, it was more successful than the rotary motion in preserving the canal's original curvature [21]. The M-wire technology in Reciproc was developed through a thermal process that provides the instrument with the flexibility and cyclic fatigue resistance critical when preparing curved root canals [1,22,23]. Lately, an innovative heat treatment technology has been developed to enhance further flexibility and fatigue resistance, which resulted in the development of Reciproc Blue [24]. Both studied files have the same design, cross-section, taper, instrument sequence, and operational speed. As a result, any advantage one file has over the other could be primarily due to the different wire processing technologies. In this study, we adopted a crown-down approach, using a single file system to shape the canals. The single file system offers many benefits, such as shorter working time, a more rapid learning curve, and fewer required instruments to obtain the desired shape [25].

Evaluation of shaping ability is often done using either double image overlapping, micro-CT, or cone beam computed tomography [26]. Micro-CT, CBCT and the digital overlapping method offer unique advantages in the evaluation of the shaping ability in endodontics. Micro-CT is considered the most accurate technique for in vitro analysis as it provides high-resolution three-dimensional images that enable assessment of the canal morphology and preparation to a high level of detail; however, it is limited to laboratory setting and is associated with high costs and long processing time [27]. CBCT, on the other hand, offers a three-dimensional representation with moderate resolution; it is widely used in the clinical practice for diagnostic and treatment planning, which makes it a valuable tool in the field of dentistry; however, it has a lower resolution than Micro-CT and is incapable of identifying fine details [28].

In our study, the shaping ability was evaluated using high-resolution digital photography and a digital overlapping method. The image overlapping technique is simple to perform and the operator can control the contrast and brightness of the image [29]. One of the challenges of using image analysis software is improving the superimposition accuracy of the pre-and post-preparation images. Although there were four reference points on each block, minor discrepancies still occurred. To overcome this issue, whenever an inaccuracy was suspected, the superimposition was then repeated, and new measurements were taken. The two sets of measurements were then compared, and an average was taken. To further enhance the accuracy of superimposition, another reference point was drilled into the resin blocks.

The results of our experiment revealed no differences between the two file systems in the number of canals prepared before file fracture, time until fracture, and preparation time per canal. These findings are consistent with those of Cetinkaya and Başer-Kolcu [30], where authors compared Reciproc and Reciproc Blue instruments in simulated resin-curved root canals. They found that both files had similar preparation time and shaping ability. In contrast, Al-Obaida et al. [31] compared the cyclic fatigue resistance of five heat-treated nickel-titanium reciprocating files with similar tip sizes but different cross-sections in an S-shaped artificial canal. They concluded that Reciproc Blue files were more flexible and resisted cyclic fatigue than Reciproc and other reciprocating files. The contrast in results could be attributed to the different methodology, experiment model, and environment.

In 2017, cyclic fatigue resistance was investigated in stainless steel artificial canals, and the authors found that Reciproc Blue had significantly greater cyclic fatigue resistance than Wave One Gold and Reciproc [32]. The superiority of Reciproc Blue over Reciproc has been demonstrated in the literature, with Reciproc Blue being more resistant to cyclic fatigue and more flexible [32]. However, in the present experiment, there were no statistical differences between the two files. This could be because the files were subjected to both cyclic and torsional components simultaneously and due to differences in simulated canal specifications and raw materials. Although most studies measure cyclic fatigue and torsional failure separately, it is important to emphasize that the type of instrument fracture is not only cyclic or torsional but a combination of both. However, the debate regarding this issue is ongoing [33].

It is critical to maintain the canal's original shape during root canal shaping procedures by removing dentin in equal amounts from the inner and outer sides of the root canals [1]. The files' shaping abilities were determined by their ability to center themselves and maintain the canal's curvature [34-36]. Using a single canal, we demonstrated no difference between Reciproc and Reciproc Blue in shaping simulated resin canals. The canal angle and diameter changes at different points along the canal were compared between the two reciprocating files and we found that the change in the canal angle was significantly higher for Reciproc than Reciproc Blue. The results for the angle of curvature showed that Reciproc straightened the canal 37% more than Reciproc Blue. These results are close to Sebastian et al., where Reciproc straightened the canals approximately 28% more than Reciproc Blue [37]. Another study utilizing micro-CT to examine instrumented extracted teeth showed that Reciproc significantly increased the canal angle twice as much as Reciproc Blue. The superiority of Reciproc Blue over Reciproc could be due to the heat treatment technology, as it is claimed to respect root canal anatomy and provide superior flexibility and less procedural errors [38].

Regarding the change in canal diameter, the results showed no difference between the two files at the coronal and middle third regions but showed a statistical difference at the apical level, as Reciproc files changed canal diameter at that apical level by 17% more than Reciproc Blue. These results are consistent with Pacheco-Yanes et al. [39], who showed no differences at all levels, but at the apical level, Reciproc prepared 25% or 1.25 times more than Reciproc Blue, demonstrating that Reciproc file was more aggressive than the heat treated Reciproc Blue.

The limitation of the study includes using resin blocks rather than natural teeth, which might cause heat generation during preparation, leading to the binding of cutting blades and the deformation or fracture of the file used. However, this study showed that both Reciproc and Reciproc Blue can last for multiple canal preparations, which may reduce the cost for the same patient who has multiple teeth to be treated. It also shows that both files respect the root canal anatomy by maintaining the canal shape.

Conclusion

Both Reciproc and Reciproc Blue files have similar root canal shaping properties and can shape multiple canals before fracture. The fracture of these files is shown to be a mixture of cyclic and torsional fatigue.

Authors' Contributions

HM	https://orcid.org/0009-0002-2134-7516	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
KM	https://orcid.org/0000-0002-1832-0606	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
TA	https://orcid.org/0000-0002-5069-7294	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
LM	https://orcid.org/0009-0000-2879-8665	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
OA	https://orcid.org/0000-0003-4179-0726	Formal Analysis and Writing - Review and Editing.
AB	https://orcid.org/0000-0003-3228-2025	Formal Analysis and Writing - Review and Editing.

All authors declare that they contributed to 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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