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Research Article

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Comparison of the shaping ability of novel thermally treated reciprocating instruments

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No potential conflict of interest relevant to this article was reported.

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ABSTRACT

Objectives: The present study aimed to evaluate the shaping ability of 2 thermally treated nickel-titanium reciprocating systems in simulated curved canals.
Materials and Methods: Forty simulated canals were prepared to apical size 25 using Reciproc Blue R25 (VDW) and WaveOne Gold Primary (Dentsply Sirona) instruments. Standard pre- and post-preparation images were taken and superimposed. The removal of resin material was measured at 5 standard points: the canal orifice, halfway between the canal orifice and the beginning of the curve, the beginning of the curve, the apex of the curve, and the end-point of the simulated canal. The data were analysed using the independent sample *t*-test with a 5% significance threshold.
Results: The canals in which Reciproc Blue R25 was used showed a significantly greater widening than those in which WaveOne Gold was used at 4 of the 5 measurement points ($p < 0.05$). The Reciproc Blue R25 instrument removed significantly more resin from the inner aspect of the curve at 2 of the 5 points and similar amounts at the remaining 3 points. At the 2 apical points, there was no significant difference between the Reciproc Blue R25 and WaveOne Gold Primary instruments.
Conclusion: Both instruments respected the original canal anatomy; however, WaveOne Gold resulted in a more conservative shape with less transportation.

Keywords: Reciproc Blue; WaveOne Gold; Nickel-titanium instruments; Simulated root canals

INTRODUCTION

Root canal preparation is one of the most important steps of root canal treatment [1]. An optimal root canal preparation aims to create a tapered funnel-shaped form flaring from the apical constriction to the canal orifice [1]. However, the anatomical complexity of the root canal system presents challenges for root canal preparation [2]. Complications such as canal transportation and the creation of ledges, elbows, or zips can occur during the preparation of a curved thin root canal. Nickel-titanium (NiTi) alloys have been introduced to eliminate these complications and to achieve optimum shaping and cleaning [3]. NiTi instruments have been reported to make root canal preparation easier, safer, and more efficient than when stainless steel instruments are used, due to their superelasticity and shape memory properties [4]. However, NiTi instrument separation without a clinical warning has been an

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ongoing problem that has led manufacturers to develop new alloys, instrument designs, and kinematics [3,5].

Reciprocating movement regained popularity in 2008, when Yared [6] proposed a novel approach that led to a new perspective on NiTi instrument kinematics. The ProTaper F2 instrument was used with reciprocating movement, with clockwise and counter-clockwise rotations set at four-tenths and two-tenths of a circle, respectively. Reciprocating movement prevented the instrument from screwing into the root canal and allowed the root canal preparation to be completed with a single instrument [6]. Studies reported that, compared to continuous rotation, reciprocating motion increased the fatigue resistance of instruments by decreasing the stress values [6,7].

WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) is a novel reciprocating instrument system, which upgraded and replaced WaveOne. WaveOne Gold combines the metallurgical improvements of gold wire and thermal treatment to increase the elasticity and reciprocating motion. The instrument also has a new parallelogram cross-sectional design with 2 cutting edges [8]. Reciproc R25 (VDW, Munich, Germany) is another single-file reciprocating instrument, which was recently upgraded to Reciproc Blue through the application of an innovative heat treatment that transforms the molecular structure of the alloy and gives the instrument a blue colour [9]. This heat treatment has been reported to increase flexibility and cyclic fatigue resistance and to cause the instrument to demonstrate smaller surface microhardness values than its predecessor [10]. To the authors' knowledge, to date, the shaping abilities of Reciproc Blue and WaveOne Gold have not been compared. Therefore, the present study aimed to compare the shaping ability of the Reciproc Blue R25 with that of the WaveOne Gold Primary instrument. The shaping ability was evaluated by quantitative measurements of the removed resin material, canal transportation, and the incidence of errors such as perforations, elbows, ledges, and zips.

MATERIALS AND METHODS

Forty simulated J-shaped clear resin canal blocks (Endo Training blocks, Dentsply Sirona) were used. The curvature angle was 40° and the total length of the simulated canals was 19 mm, with a 13 mm straight coronal section and a 6-mm curved apical section. The canals were injected with black ink (Pelikan, Istanbul, Turkey) and the numbered blocks were photographed in a standard setup prior to preparation. The blocks were randomly divided into 2 groups, the Reciproc Blue and WaveOne Gold preparation groups (n = 20), depending on which instruments were to be used.

The WaveOne Gold instruments were operated at 350 rpm with the “WaveOne ALL” program using the VDW Silver endomotor (VDW). The instrument was introduced into the canal with a light and slow in-and-out pecking motion, the amplitude of which was 3 mm. Following 3 pecking motions, the instrument was pulled out and the flutes were cleaned with soaked gauze. The instrumentation was carried out until the 19-mm working length was reached.

The Reciproc Blue instruments were operated at 300 rpm with the “Reciproc ALL” program using the VDW Silver endomotor (VDW) with gentle pecking movements with an amplitude of 3 mm. After the completion of 3 pecking motions, the instrument was pulled out from the canal and cleaned. The instrumentation was carried out until the 19-mm working length was reached.

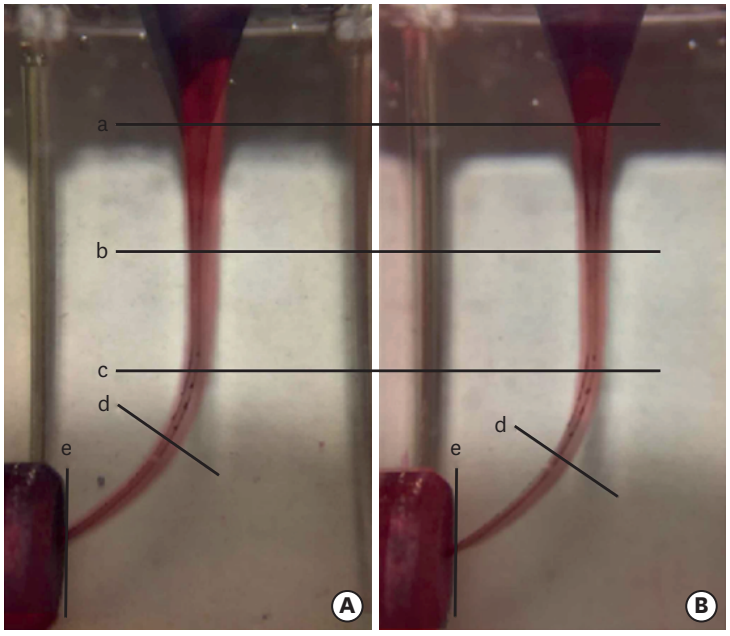

Figure 1. Superimposition of pre- and post-operative images and measurement points. (A) Reciproc Blue R25; (B) WaveOne Gold Primary. The 5 measurement points are as follows: (a) the canal orifice; (b) halfway between the canal orifice and the beginning of the curve; (c) the beginning of the curve; (d) the apex of the curve; (e) the end-point of the simulated canal.

A total of 10 mL of distilled water was used for irrigation in all specimens. All preparation procedures were performed by the same operator, who is an experienced endodontist. The resin blocks were covered with rubber sheets during preparation. Both the Reciproc Blue and WaveOne Gold instruments were used for a single block and then discarded.

Following preparation, the blocks were photographed, and pre- and post-preparation images were superimposed using AutoCAD software (Autodesk, San Rafael, CA, USA) (**Figure 1**). The amount of resin removed from the following 5 points was analysed: the canal orifice, halfway between the canal orifice and the beginning of the curve, the beginning of the curve, the apex of the curve, and the end-point of the simulated canal. Canal transportation values were calculated by subtracting the amount of removed resin from the inner aspect from the amount removed from the outer aspect [11]. Canal aberrations such as zips, elbows, ledges, and perforations were assessed on the superimposed images.

The normality of the data was tested using the Shapiro-Wilk test, which confirmed a normal distribution. Therefore, the data were analysed with the independent sample *t*-test using SPSS software (version 16.0, IBM SPSS Inc., Chicago, IL, USA) with a level of significance of 5%.

RESULTS

No instrument was separated during the preparation procedures, and no preparation aberrations such as zips, elbows, ledges, or perforations occurred during the experiments. The total width of the canals at 5 different measurement points after preparation with Reciproc Blue and WaveOne Gold are presented in **Table 1**. The Reciproc Blue group showed

Table 1. Total width (mm) of the canal at 5 different measurement points after canal preparation with 2 reciprocating instruments

Measurement point	Reciproc Blue R25	WaveOne Gold Primary	*p* value
Canal orifice	1.246 ± 0.18	1.043 ± 0.16	0.001
Halfway between the orifice and the beginning of the curve	0.969 ± 0.02	0.800 ± 0.02	0.000
Beginning of the curve	0.800 ± 0.06	0.722 ± 0.02	0.000
Apex of the curve	0.553 ± 0.03	0.442 ± 0.04	0.000
End-point of the canal	0.256 ± 0.02	0.298 ± 0.02	0.000

The values are presented as means ± standard deviations.

Table 2. Measurements of the inner and outer width (mm) of the canals at 5 different measurement points after canal preparation with 2 reciprocating instruments

Instrument	Canal orifice		Halfway between the orifice and the beginning of the curve		Beginning of the curve		Apex of the curve		End-point of the canal	
	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Reciproc Blue	0.302 ± 0.03[a]	0.296 ± 0.03[a]	0.150 ± 0.03[a]	0.278 ± 0.04[a]	0.339 ± 0.03[a]	0.232 ± 0.01[a]	0.018 ± 0.00[a]	0.125 ± 0.03[a]	0.035 ± 0.00[a]	0.013 ± 0.00[a]
WaveOne Gold	0.249 ± 0.02[b]	0.177 ± 0.01[b]	0.150 ± 0.01[a]	0.221 ± 0.03[b]	0.231 ± 0.01[b]	0.116 ± 0.02[b]	0.016 ± 0.00[a]	0.114 ± 0.02[a]	0.032 ± 0.00[a]	0.017 ± 0.00[a]

The values are presented as means ± standard deviations. Different superscript letters indicate a statistically significant difference between groups ($p < 0.05$).

a significantly greater widening than the WaveOne Gold group at the canal orifice, the beginning of the curve, halfway between the orifice and the beginning of the curve, and the apex of the curve ($p < 0.05$). However, at the end-point of the canals, the WaveOne Gold group showed significantly greater widening than the Reciproc Blue group ($p < 0.05$).

Table 2 presents the mean amount of resin removed at the 5 measurement points by the Reciproc Blue R25 and WaveOne Gold Primary instruments. Significantly more resin was removed from the inner aspect of the curve by the Reciproc Blue R25 instruments at the canal orifice and at the beginning of the curve ($p < 0.05$). There was no significant difference between Reciproc Blue R25 and WaveOne Gold Primary at the halfway point between the orifice and the beginning of the curve, at the apex of the curve, or at the end-points of the canals.

The amount of resin removed from the outer aspect of the curve by the Reciproc Blue R25 was significantly greater than the amount removed by the WaveOne Gold Primary instrument at the canal orifice, halfway between the orifice and the beginning of the curve, and at the beginning of the curve ($p < 0.05$). At the apex of the curve and the end-point of the canal, there was no significant difference between the Reciproc Blue R25 and the WaveOne Gold Primary instruments.

Table 3 presents the mean values of transportation irrespective of the direction of the 5 measurement points. At the canal orifice and beginning of the curve, there were no significant differences between Reciproc Blue and WaveOne Gold. At the halfway point between the orifice and the beginning of the curve, the apex of the curve, and the ending of the canal, Reciproc Blue R25 led to more significant transportation than WaveOne Gold did.

Table 3. Distance of canal transportation (mm) at 5 different measurement points after canal preparation with 2 reciprocating instruments

Measurement point	Reciproc Blue R25	WaveOne Gold Primary	*p* value
Canal orifice	0.053 ± 0.04	0.024 ± 0.06	0.069
Halfway between the orifice and the beginning of the curve	0.191 ± 0.04	0.128 ± 0.01	0.000
Beginning of the curve	0.107 ± 0.05	0.115 ± 0.08	0.482
Apex of the curve	0.022 ± 0.04	0.011 ± 0.01	0.000
End-point of the canal	0.021 ± 0.00	0.004 ± 0.01	0.000

The values are presented as means ± standard deviations.

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DISCUSSION

The present study evaluated the shaping abilities of novel reciprocating instruments using simulated curved canals of resin blocks. Natural teeth present high variability in the dimensions, size, and shape of the root canal system. The use of resin blocks enables standardization of the dimensions of a simulated canal, including factors such as length, diameter, curvature angle, and the radius of curvature. However, the inability to mimic human teeth due to a much inferior surface hardness compared to dentin and the possibility of resin softening due to the friction during preparation are drawbacks of this technique. It has been suggested that softened resin might attach to the blades of the instrument and cause the instrument to deform or separate [12]. In the present study, no separation or visible instrument deformation occurred. Nevertheless, the performance of instruments has been associated with their ability to respect the original canal anatomy [13]. Therefore, the resin blocks were preferred in the present study.

According to the authors' literature review, the shaping ability of the novel reciprocating instrument Reciproc Blue has not yet been compared with that of the WaveOne Gold instrument. Reciprocating movement was developed mainly to reduce torsional stress around an instrument, thereby decreasing the rate of torsional failure [6]. In addition, reciprocating movement has been associated with higher efficacy in maintaining the original curvature than can be achieved through rotating movement [14]. Another factor that influences the shaping ability of NiTi instruments is the alloy of the instrument [15]. WaveOne Gold is manufactured from gold wire, using advanced metallurgy and heat treatment to increase the flexibility of the instrument [8]. The effects of thermomechanical treatments applied to gold wire have been evaluated using differential scanning calorimetry, and higher cyclic fatigue resistance values have been associated with 2-stage specific transformation behaviour and high austenite finish temperature [16]. A previous study compared the shaping ability of gold wire, m-wire, and conventional NiTi alloy and reported that the gold wire and m-wire alloys exhibited significantly less canal transportation, which was attributed to the increased flexibility of the alloys [15]. The Reciproc Blue alloy receives an innovative heat treatment that transforms the molecular structure of the alloy and gives the instrument a blue colour [9]. Both instruments have been reported to display better cyclic fatigue resistance than m-wire or conventional NiTi instruments and are preferable for the preparation of curved root canals [10,17].

An ideal root canal preparation technique should respect the original anatomy of the root canal, meaning the removal of the same proportion of material from the inner and outer aspects of root canals, and minimize apical foramen displacement. This principle is vital during preparation in order to prevent iatrogenic complications such as stripping and canal aberrations. The mean total width of the simulated canals was significantly greater in the Reciproc Blue group than in the WaveOne Gold group at all 4 coronal measurement points, from the orifice level to the apex curve. This difference could be attributed to the smaller core diameter and taper design of the WaveOne Gold Primary (size 25/0.07) compared to the Reciproc Blue (size 25/0.08). In their review of instrument kinematics, Çapar and Arslan [18] reported that instruments with an offset cross-section design exhibited a larger envelope motion than instruments with a similar size but a symmetrical mass and rotation axis. At the end-point of the canal, where the sizes of the 2 instruments were equal, the mean width was significantly greater in the canals in which the WaveOne Gold instrument was used than in those in which Reciproc Blue was used, which could be attributed to the cross-sectional shape of the WaveOne Gold instrument.

In the present study, the canal transportation values of WaveOne Gold were significantly lower than those of Reciproc Blue at the halfway point between the orifice and the beginning of the curve, the apex of the curve, and the ending of the canal. However, there was no significant difference between the instruments at the canal orifice or the beginning of the curve.

CONCLUSIONS

Within the parameters of this study, both instruments preserved the original canal anatomy and were safe to use in curved canals. However, the WaveOne Gold Primary produced more conservative enlargement with less apical transportation.

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