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ORIGINAL ARTICLE

Comparison of the Cyclic Fatigue Resistance of Reciproc and Reciproc Blue Nickel-Titanium Instruments in Artificial Canals with Single and Double (S-shaped) Curvatures

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ABSTRACT

Objective: The aim of this study was to compare the cyclic fatigue resistance of Reciproc (VDW, Munich, Germany) and Reciproc Blue (VDW) in artificial canals with both single and double (s-shaped) curvatures.

Methods: In total, 80 instruments were tested in this study. Reciproc R40 and Reciproc Blue R40 instruments were selected for the cyclic fatigue resistance test (n=20 in each test). Each instrument was rotated in canals with a single curvature (60° curvature, 5-mm radius) and a double curvature (first coronal curve: 60° curvature and 5-mm radius; second apical curve: 70° and 2-mm radius) until fracture. The time to fracture was calculated, and the length of each fractured fragment was recorded. A one-way analysis of variance (ANOVA) and Tukey's post hoc tests were used to analyse the time to failure.

Results: All the instruments had significantly higher fatigue resistance in the single simulated curvature canal than in the double curvature canal ($P<0.05$). In both curvature groups, the time to fracture of the Reciproc Blue was longer than that of the Reciproc instruments ($P<0.05$). In the double curvature canal, the instruments tended to fracture more often in the apical curvature than in the coronal curvature. There was no significant difference in the length of the broken fragments between the two groups in either the single or double canal curvatures ($P>0.05$).

Conclusion: The Reciproc Blue instruments showed higher cyclic fatigue resistance than the Reciproc instruments in both single and double canal curvatures.

Keywords: Cyclic fatigue resistance, endodontics, reciproc, reciproc blue

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HIGHLIGHTS

- Cyclic fatigue resistance of Reciproc R40 and Reciproc Blue R40 instruments were evaluated in both single and double (S-shaped) artificial curvatures.
- In both curvature groups, the time to fracture of Reciproc Blue was longer than Reciproc instruments. In the double curvature, the instruments tend to fracture in the apical curvature then in the coronal curve.
- The Reciproc Blue instruments showed higher cyclic fatigue resistance than Reciproc instruments in both single and double canal curvatures ($P<0.05$).

INTRODUCTION

The use of nickel-titanium (Ni-Ti) in endodontic instruments has opened a new era in endodontics. Stainless steel instruments result in more zip, perforations and ledge formation in curved canals than in straight canals. Ni-Ti instruments have enhanced mechanical properties, such as flexibility, conformation to the curvature of the canal and higher resistance to fracture, compared to stainless steel instruments (1, 2). Despite the increased strength and flexibility of Ni-Ti-based instruments, there is still a risk that rotary instruments may fracture during preparation of the canal. Fracturing may occur as a result of cyclic fatigue or torsional fracture (3). Torsional fatigue takes place when the tip of the instrument becomes stuck in the root canal during rotation of the instrument. Cyclic fatigue occurs when tension-compression stress exceeds the maximum flexure capacity when preparing curved canals, eventually leading to fracture (4). The main reasons for such fractures are the angle and degree of the curvature of the root canal (5). Secondary reasons include factors related to the file, such as its size, taper, alloy composition, manufacturing method, cross-sectional geometry, flute design and heat treatment (6). Improvements in manufacturing methods and new designs in Ni-Ti alloys have enhanced the cyclic fatigue resistance of Ni-Ti based instruments.

There has been significant progress in the use of single-file Ni-Ti reciprocating systems in endodontic practice. Since the introduction of Reciproc (VDW, Munich, Germany) files in 2011, single-file systems have gained widespread acceptance. Reciproc instruments are fabricated from heat-treated Ni-Ti M-wires (7). The single-file reciprocating system has many advantages compared to one-file rotary systems. These include time savings, improved safety and enhanced longevity of the files (8, 9). An instrument with reciprocating motion rotates in one direction and then reverses direction before completing a full cycle. During a counter-clockwise motion, the file engages and cuts dentin. During a clockwise motion, it disengages from dentin to avoid taper lock and relieve stress on the file. This type of two-step motion increases resistance to cyclic and torsional fatigue (10).

Recently, Reciproc Blue (VDW, Münich, Germany) systems have been introduced that use the same reciprocating motion and kinematics as Reciproc. According to the manufacturer, the geometry, size and design of Reciproc Blue files are the same as those of the Reciproc files. Furthermore, neither the Reciproc nor Reciproc Blue instruments depend on the creation of a glide path in patients with severe canal curvatures (11). The Reciproc Blue instrument has been produced using an innovative type of thermal treatment that modifies its molecular structure (12). Thus, the new system is much more flexible and resistant to cyclic fatigue-related fractures compared to its predecessor. An additional improvement of Reciproc Blue is the ability to pre-bend the instrument. The manufacturer claims that the new technology and design improve the flexibility of the file.

The goal of the present study was to compare the cyclic fatigue resistance of the Reciproc and Reciproc Blue files in single curvature and double curvature (s-shaped) fabricated root canals. The null hypothesis was that there would be no difference in the cyclic fatigue resistance of the two groups.

METHODS

In total, 80 instruments were tested in this study. The Reciproc and Reciproc Blue files were evaluated in canals with single and double (s-shaped) simulated curvatures. The Reciproc R40 and Reciproc Blue R40 instrument systems were selected for the cyclic fatigue resistance test (n=20 in each test). Before the experiment, the instruments were inspected under a dental operating microscope to detect defects or deformities.

Both instrument systems were exposed to fatigue tests inside artificial canals with a single curvature (60° curvature, 5-mm radius) and a double curvature (first coronal curve: 60° curvature and 5-mm radius; second apical curve: 70° curvature and 2-mm radius). The artificial canal with a single curvature was prepared in a stainless steel block, as described previously by Larsen et al. (2). The artificial s-shaped canal was fabricated from a stainless steel block containing a double curvature (diameter of 1.4 mm and length of 18 mm), which was specifically developed for this study and which has been used in previous studies by Al-Sudani and Topçuoğlu (13, 14).

For the single curvature, the working lengths of both systems were adjusted to 19 mm. Synthetic oil (WD-40 Company, Milton Keynes, U.K.) was used for lubrication. The stainless steel block was covered with a glass plate to prevent the instruments from sliding out and to observe the files during the experimental procedure. The instruments were allowed to rotate according to the manufacturers' instructions. The instruments were used with a torque-controlled motor (Silver; VDW, Munich, Germany) in the 'Reciproc ALL' mode. For all instruments, the time until fracture was recorded in seconds. The lengths of the fractured tips of the instruments were also measured by a digital caliper, with accuracy to 0.01 mm (Digimatic, Mitutoyo Co., Kawasaki, Japan).

For the double curvature, the Reciproc R40 and Reciproc Blue R40 instruments were operated using the same device and mode. The same lubricant was used to reduce friction while working inside the artificial canal. The time to failure for each instrument was calculated (in seconds). Furthermore, in the double-curved artificial canals, if the fracture occurred first in the apical curve, the time to fracture was also recorded for the coronal fragment. The length of each fractured tip was measured using the same digital caliper.

The mean values and standard deviations of the time to failure were calculated for each group. The data were analysed by a one-way analysis of variance. Tukey's honest significant difference test was used to detect any statistical differences among the groups. Statistical significance was defined at the 95% confidence level. The Student's t-test was performed to compare the means between the fragment lengths in the two groups in the same root canals.

RESULTS

The results for the time to failure and length of the fractured parts in each group are displayed in Table 1. All the instruments had significantly higher fatigue resistance in the single simulated curvature than in the double (coronal and apical) curvature canals ($P<0.05$). In both curvature groups, the time to fracture of the Reciproc Blue was longer than that of the Reciproc instruments ($P<0.05$). In the double curvature canal, the instruments tended to fracture in the apical curvature more often than in the coronal curvature. However, there was no significant difference in the length of the broken fragments in either group in both the single and double curvatures ($P>0.05$).

TABLE 1. Mean values (± standard deviation) for the time to failure (TtF) and fragment length (FL)

	Double Curvature					
	Apical curve		Coronal Curve		Single Curvature	
Groups	TtF (sec)	FL (mm)	TtF (sec)	FL (mm)	TtF (sec)	FL (mm)
Reciproc	166.1±24.38*	2.20±0.22	191.4±35.95*	6.15±0.63	356.5±52.29*	6.31±0.45
Reciproc Blue	298.1±18.02*	2.26±0.24	328.5±34.59*	6.21±0.47	556.4±64.11*	6.18±0.53

*displays significant difference between groups.

DISCUSSION

The present study compared the cyclic fatigue resistance of Reciproc and Reciproc Blue instruments. The results revealed that the cyclic fatigue resistance of Reciproc Blue files in both single and double canal curvatures was superior to that of the corresponding Reciproc files. Thus, the null hypothesis that there would be no difference in the cyclic fatigue resistance of the tested systems was rejected.

Many studies have compared the cyclic fatigue resistance of Reciproc systems and other systems. In a number of studies, Reciproc instruments showed significantly higher cyclic fatigue resistance than WaveOne reciprocating instruments and continuous rotation instruments (14-16). To our knowledge, no studies have evaluated the cyclic fatigue performance of both file systems in double curved canals. This is the first study to test Reciproc Blue instruments in a double curvature canal. As there are no reported studies in the literature on the cyclic fatigue resistance of the Reciproc Blue file system in double curvature canals, a direct comparison with the findings of previous studies is not possible. Recently, De-Deus et al. (12) revealed that Reciproc Blue R25 files exhibited greater cyclic fatigue resistance than Reciproc R25 files in single curvature canals. The findings of their study are in accordance with the results of the present study. Torsional fracture was observed more often in lower numbered instruments, whereas cycling fatigue was recorded frequently in higher numbered instruments (17). Thus, Reciproc R40 and Reciproc Blue R40 instruments were preferred in this study.

According to the manufacturer, the characteristics of the Reciproc Blue file system differ from those of the Reciproc system. However, many features of the Reciproc Blue system are the same as those used in the Reciproc file system. The only difference between the Reciproc and Reciproc Blue systems was the superior flexibility of the latter, which may be attributed to the innovative thermal treatment used to produce Reciproc Blue instruments. Heat treatment or thermo-mechanical treatment is the main reason for the transformational behaviour of Ni-Ti alloys (7, 12). By modifying the molecular structure of Reciproc Blue files, the heat treatment has a positive effect on the properties of the files. The new heating process turns the colour of the file to blue. The manufacturer claims that this new procedure gives the Reciproc Blue files more strength and flexibility than Reciproc file systems. The innovative thermal treatment procedure of the Reciproc Blue instruments may have influenced the results of the present study.

In the present study, as the complexity of the curvature increased, the fracture resistance of the instruments decreased. In the less complex curvature model, the instruments lasted longer. The results of previous studies by Pruett et al. (18) and Plotino et al. (19) support the findings of the present study.

The anatomy of a double curvature canal is much more challenging than that of a single curvature canal (13). No data are available on the mechanical performance of Reciproc Blue instruments in double curvature canals. In the present study, there was a significant decrease in cyclic fatigue resistance when the instruments were tested in the double curvature versus single curvature canals. The difference was extremely high, especially in the apical curvature, where the reduction in resistance was obvious. In addition, the reduction in resistance was lower in the coronal curvature. This can be seen in all instruments, irrespective of their design or alloy composition, showing that anatomical complexities are the main reason for intracanal fracture of files.

In this study, the mean lengths of the whole fractured parts were the same in both the single and double (apical or coronal) curved canals. The fractured length of the instrument was at the centre of the curvature or just below the centre, which endorses the positioning of the instruments in a certain orbit.

CONCLUSION

Within the limitations of this study, the cyclic fatigue resistance of the Reciproc Blue instruments was higher than that of the Reciproc instruments in both single and double canal curvatures.

Ethics Committee Approval: The authors declare that this article does not contain any studies with human participants and does not require ethics committee approval.

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