Cyclic fatigue resistance of different continuous rotation and reciprocating endodontic systems

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ABSTRACT

Objective: The objective of this study is to compare the cyclic fatigue resistance of nine types of endodontic instruments of nickel–titanium.

Materials and Methods: Five files of 25 mm of length of each group: Reciproc (RC) R25; WaveOne (WO) Primary; Unicone (UC) L25 25/0.06; K3XF 25/0.06; ProTaper Universal F2 (PTF2); ProTaper Next X2 (PTX2); Mtwo 25/0.06; BioRaCe 25/0.06; One Shape L25 25/0.06 were subjected to a cyclic fatigue resistance test on a mechanical apparatus. The mean fracture time was analyzed statistically by one-way analysis of variance and Tukey’s honest significant difference post hoc test, with significance set at \( P < 0.05 \).

Conclusion: It was observed that the groups PTX2, RC, R25, UC L25 25/0.06, and WO Primary presented greater cyclic fracture resistance than the other groups \( P < 0.001 \).

Key words: Cyclic fatigue resistance, endodontic, instrumentation, Reciproc, reciprocating motion

The nickel–titanium (NiTi) rotary instruments are known for their root canal cleaning and shaping effectiveness, for its high cutting efficiency and fastness. Despite these advantages, a major concern among professionals is the fracture of these instruments, which may occur during clinical practice.[1–3]

The files fracture mechanisms are classified into two types in literature, fracture caused by cyclic fatigue (flexural) fracture or by torsion.[3,4] The cyclic fatigue fracture occurs when the instrument is subjected to repetitions of cyclical tension and compression, causing microcracks to form in its structure and finally resulting in file separation. These repeated cycles of tension and compression caused by the rotation of curved instruments increase cyclic fatigue failure over time, and may be an important factor for fracture.[5] Fracture caused by torsion occurs when a part of the metal is fixed in position, whereas the rest of the instrument continues to rotate around its longitudinal axis.[6,7]

The cyclic fracture is a major cause of fractures and currently one of the most studied topics with respect to NiTi rotary instruments.[8]

There are on the market a variety of these instruments-driven motor with different kinematics, compositions, and shapes, which are gaining increasing acceptance and popularity among specialists.

Considering these information and the importance to know more about the existing endodontic files on the market, the purpose of the present study was to evaluate the cyclic fatigue resistance of different endodontic instruments of reciprocating movement and continuous rotary motion.

MATERIALS AND METHODS

To conduct this experiment, a total of 45 NiTi rotary files, ISO tip size of 25 were used, taper 0.06% or 0.08% and
length of 25 mm. These were divided into nine experimental groups (n = 5 each) of different types of endodontic files. Each endodontic file of a specific group is named according to the type of file and used a number from 1 to 5, where Group 1 was ProTaper Next X2 (PTX2) (Dentsply Maillefer, Ballaigues, Switzerland), Group 2 Reciproc (RC) R25 (VDW, Munich, Germany), Group 3 WaveOne (WO) Primary (Dentsply Maillefer, Ballaigues, Switzerland), Group 4 Unicone (UC) L25 25/0.06 (MEDIN SA, Nové Město na Moravě, Czech Republic), Group 5 One Shape (OS) L25 25/0.06 (Micro-Mega SA, Besançon, France), Group 6 K3XF 25/0.06 (Sybron Dental Specialties, Orange, CA, USA), Group 7 Mtwo 25/0.06 (VDW, Munich, Germany), Group 8 ProTaper Universal F2 (PTF2) (Dentsply Maillefer, Ballaigues, Switzerland), and Group 9 BioRaCe (BR3) (FKG Dentaire SA, La Chaux de Fonds, Switzerland). The groups were provided in Table 1.

All experimental groups were subjected to cyclic fatigue resistance test. They were activated by a contra-angle of 6:1 (Sirona Dental Systems GmbH, Bensheim, Germany) coupled to an electric motor handpiece (VDW Silver, VDW Dentsply International Inc., GmbH, Munich, Germany) and adjusted to the torque and speed recommended by the file manufacturer. The instrument rotated freely in a stainless steel metal in angled manner, under constant pressure, with no sliding when activated on the metal. The bumps on the metal were used to mark their position and reduce vibration [Figures 1 and 2].

Through the AutoCAD (Autodesk Inc., San Rafael, CA, USA) software and using the method to determine the curvature of the root canal described by Pruett et al.,[3] it was set an angle of approximately 30° and 23 mm radius of curvature. Using the calculation to determine the curvature described by Schneider in 1971,[9] we obtained a curvature angle of approximately 18° [Figure 3].

Similar to other studies, a synthetic oil (White Lub Multiuso, Orbi Química Ltda., São Paulo, Brazil) was used to reduce friction of the endodontic instrument to the metal after each use.[10,11] All files were driven until fracture. The timing of fracture of each instrument was recorded by a stopwatch (HS-80TW, Casio Computer Co., Inc., Tokyo, Japan) to the thousandth of a second and tabulated. Data were evaluated by analysis of variance (ANOVA) with one factor and

### Table 1: Experimental groups

| Group | Kinematics | Length/ISO | n  |
|-------|------------|------------|----|
| PTX2  | Continuous rotation at 300 rpm | 25 mm/25/0.06 | 5  |
| RC    | Reciprocation at RC ALL mode (variable taper) | 25 mm/25/0.08 | 5  |
| WO    | Reciprocation at WO ALL mode (variable taper) | 25 mm/25/0.08 | 5  |
| UC    | Reciprocation at RC ALL mode (variable taper) | 25 mm/25/0.06 | 5  |
| OS    | Continuous rotation at 350 rpm (variable taper) | 25 mm/25/0.06 | 5  |
| K3XF  | Continuous rotation at 350 rpm (variable taper) | 25 mm/25/0.06 | 5  |
| Mtwo  | Continuous rotation at 280 rpm (variable taper) | 25 mm/25/0.06 | 5  |
| PTF2  | Continuous rotation at 300 rpm (variable taper) | 25 mm/25/0.08 | 5  |
| BR3   | Continuous rotation at 600 rpm (variable taper) | 25 mm/25/0.06 | 5  |

PTX2=ProTaper Next X2, RC=Reciproc, WO=WaveOne, UC=Unicone, OS=One Shape, PTF2=ProTaper Universal F2, BR3=BioRaCe

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followed by Tukey’s honest significant difference (HSD) post hoc test in software (SPSS 20.0 for Windows, SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P < 0.05$.

**RESULTS**

Descriptive statistics for the experimental groups are listed in Table 2.

PTX2 had the longest cyclic fatigue resistance mean time, followed by the files RC, WO, UC, OS, K3XF, Mtwo, PTF2, and BR3.

Using ANOVA, the results showed that the groups PTX2, RC, WO, and UC were significantly more resistant to cyclic fatigue than the other experimental groups ($P < 0.001$) but with a mean difference of no significant time with each other. The groups OS and K3XF showed no statistical difference between them ($P > 0.05$) but were shorter cyclic fatigue resistance mean time than the groups PTX2, RC, WO, and UC, however, higher than the groups BR3, PTF2, and Mtwo ($P < 0.01$). The average time of fracture of the Groups 1–3 had no statistically significant difference between them although they were significantly less resistant to cyclic fatigue than the other groups ($P < 0.01$) [Table 3].

**DISCUSSION**

The purpose of this study was to compare the cyclic fatigue resistance among nine NiTi files, under continuous rotation and reciprocating motion, in each group using the manufacturer’s recommendations. These instruments are commonly used in endodontic practice today because they offer many advantages over conventional stainless steel files; they are more flexible and have increased cutting efficiency.\[12\]

However, despite these advantages, NiTi instruments appear to have a high risk of separation during use,\[13\] which can be by cyclic or torsional fatigue.\[3,4\] Considering the cyclic fatigue fracture, the resistance of these instruments is smaller when their diameter is larger;\[2\] so the diameter of the instruments was standardized in this study.

The influence of cross-section, alloy type, and type of driving motion on the cyclic fatigue strength of NiTi instruments has been the object of several recent studies.\[14,15\] Nevertheless, how and why the design of the instrument might influence its behavior under cyclic fatigue stress remains unclear. Cheung and Darvell\[16\] showed, in various instruments, that fatigue strength does not appear to be affected by instrument design, suggesting that neither the cross-sectional area nor the shape of an instrument is the primary determinant of its fatigue life.

However, other studies have suggested that difference in cross section appears to be an important determinant of cyclic fatigue strength across different files.\[8,17,18\] In a study conducted by Plotino et al.,\[14\] RC instruments exhibited significantly greater fatigue strength than WO instruments, which suggests that this difference may be related to the differences in cross-sectional area and reciprocating motion between the two systems. Earlier studies also demonstrated the superiority of RC instrumentation over the WO system in fatigue strength testing\[14,19,20\] and have shown that the angles employed in instrument motion have a direct influence on cyclic fatigue.\[21\] Kiefner et al.\[22\] believe another factor that enhances strength in RC and WO instruments is the type of alloy used in their manufacture. The authors showed that a synergistic effect between the M-Wire alloy and reciprocating motion provides a significant increase in cyclic fatigue strength.

Dagna et al.\[23\] compared the cyclic fatigue resistance to RC R25 (VDW), WO Primary (Dentsply), OS (Micro-Mega), and ProTaper F2 (Dentsply), testing 40 instruments of each group. According to the authors, RC R25 (VDW) showed greater resistance to cyclic fatigue, followed by OS (Micro-Mega) and WO (Dentsply) with similar values, and ProTaper F2 (Dentsply), respectively. These results conflict with those of the present study, which did not show significant differences between RC R25 (VDW) and WO Primary (Dentsply), but they performed better than the other two groups, which also obtain no significant difference between them; however, Dagna et al.\[23\] did their experiment simulating different curvatures, and their results

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**Table 2: Descriptive statistics with mean time values in hundredth of a second**

| Group | n  | Mean | SD  | SE  | 95% CI for mean Lower bound | Upper bound | Minimum | Maximum |
|-------|----|------|-----|-----|-----------------------------|-------------|---------|---------|
| PTX2  | 5  | 1254.770 | 313.777 | 140.325 | 865.165 | 1644.376 | 947.646 | 1596.810 |
| RC    | 5  | 1130.601 | 192.760 | 86.205 | 891.258 | 1369.944 | 963.055 | 1453.082 |
| WO    | 5  | 1029.462 | 116.215 | 51.973 | 885.162 | 1173.763 | 917.564 | 1190.563 |
| UC    | 5  | 1003.998 | 264.552 | 118.311 | 675.514 | 1332.482 | 725.682 | 1369.944 |
| OS    | 5  | 468.104  | 29.628  | 13.250  | 431.316 | 504.893  | 426.476 | 504.148  |
| K3XF  | 5  | 414.315  | 206.560 | 92.377  | 157.836 | 670.794  | 234.445 | 650.348  |
| Mtwo  | 5  | 215.198  | 31.557  | 14.113  | 176.014 | 254.381  | 170.625 | 254.009  |
| PTF2  | 5  | 187.935  | 24.460  | 10.939  | 157.564 | 218.306  | 150.063 | 211.285  |
| BR3   | 5  | 159.508  | 20.980  | 9.383   | 133.457 | 186.558  | 139.776 | 186.725  |
| Total | 45 | 651.543  | 453.463 | 67.598  | 515.308 | 787.779  | 139.776 | 1596.810 |

PTX2=ProTaper Next X2, RC=Reciproc, WO=WaveOne, UC=Unicone, OS=One Shape, PTF2=ProTaper Universal F2, BR3=BioRaCe, SD=Standard deviation, SE=Standard error, CI=Confidence interval
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Table 3: Mean times and statistical differences between each group

| Group       | n  | Mean time (thousandth of a second) |
|-------------|----|-----------------------------------|
| PTX2        | 5  | 1254.770                          |
| RC          | 5  | 1130.601                          |
| WO          | 5  | 1029.462                          |
| UC          | 5  | 1003.998                          |
| OS          | 5  | 468.104                           |
| K3XF        | 5  | 414.315                           |
| Mtwo        | 5  | 215.198                           |
| PTF2        | 5  | 187.935                           |
| BR3         | 5  | 159.508                           |

Groups with the same letter do not significantly differ (level of significance=5%).
PTX2=ProTaper Next X2, RC=Reciproc, WO=WaveOne, UC=Unicone, OS=One Shape, PTF2=ProTaper Universal F2, BR3=BioRaCe

CONCLUSION

Following the methodology employed, it can be concluded that the instruments PTX2 (Dentsply), RC R25 (VDW), WO Primary (Dentsply), and UC L25 25/0.06 (Medin) are more resistant to cyclic fatigue than OS L25 25/0.06 (Micro-Mega), K3XF 25/0.06 (Sybro), Mtwo 25/0.06 (VDW), PTF2 (Dentsply), and BR3 (FKG), when using the manufacturers recommendations to speed and torque.

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Conflicts of interest
There are no conflicts of interest.

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