ORIGINAL ARTICLE

Turk Endod J 2019;4(1):1–5
doi: 10.14744/TEJ.2019.79553

Bending cyclic fatigue failure test, comparison of two motions: Continuous rotation versus reciprocating motion

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Objective: In endodontic therapy, reciprocating motion is presented as being able to limit instrument fatigue. The aim of this work was to compare endodontic files used in continuous rotation during two types of motion: continuous rotation and reciprocating.

Methods: Seventy two instruments from six systems [MTwo (VDW), ProTaper (Dentsply-Maillefer), RaCe (FKG), HERO 642, HeroShaper, and RevoS (Micro-Mega)] were tested. All these instruments had a 6% taper, a size 25 tip, and a length of 25 mm, except the ProTaper, which was an F2. Each file was mounted on an i-ENDO Dual motor (ACTEON), then subjected to bending fatigue on a fatigue test bench composed of a hollow steel tube with a 60° bend, in which the instrument was set in either continuous rotation or reciprocating motion at the same speed. The time to fracture was recorded in seconds using a chronometer. Analysis of variance and a Wilcoxon non-parametric test with an alpha risk fixed at 5% were done.

Results: Reciprocating motion preserved the instruments better than continuous rotation did with significant differences ($p<0.001$).

Conclusion: Ni-Ti files break less fast in reciprocating motion than in continuous rotation.

Keywords: Continuous rotation, cyclic fatigue, failure, Ni-Ti, reciprocating, root canal shaping.

The use of Nickel-Titanium (Ni-Ti) files in endodontic treatment has brought about a real revolution as they have made this type of work considerably simpler. Their super-elasticity[1] allows curved canals to be shaped in continuous rotation. They save time for the practitioner and patient while enabling therapeutic difficulties in connection with the root canal anatomy to be handled more easily.[2] However, their regular use has brought some weaknesses to light. Although it occurs only rarely, separation of an instrument in a root canal – be it due to misuse or to instrument fatigue[3–5] – compromises the prognosis for the tooth under treatment. Fracture by cyclic fatigue is the result of the repeated tension-compression that the instruments undergo in curved canals.[6] In the aim of limiting this risk, in addition to a learning period before the dentist uses the files, some processes have been proposed to change their surface finish.[7,8] For several years now, reciprocating motion has been presented as a new dynamic that can limit instrument fatigue.[9–15] This motion seems to reduce the cyclic fatigue of instruments habitually used

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Submitted: January 29, 2019 Accepted: March 10, 2019

in continuous rotation[9–11] and Franco et al.[16] have also described an improvement of instrument centering. In addition, since the presence in the pulp of pathogens presenting a serious threat to systemic health was revealed, research has been oriented toward employing only one single-use device.[17] There are now numerous systems on the market that use this concept. Some also exploit the improvement that can be obtained in the mechanical properties of Ni-Ti by thermal treatment (M-wire, T-wire, C-wire, etc.). In spite of their many advantages, the high cost of these systems seems to limit their accessibility in some low-income countries, where, in addition, the principles of endodontics are not always fully respected.[18] The adaptation of multiple use devices to the new, lower risk concept of reciprocating motion motivated the present work. The objective was to compare six different Ni-Ti files habitually used in continuous rotation, in two types of motion: continuous rotation and reciprocating motion.

Materials and methods

Seventy-two instruments taken from six systems were tested: 12 MTwo® (VDW, Munich, Germany); 12 ProTaper® (Dentsply-Maillefer, Balaigues, Switzerland); 12 RaCe® (FKG, La Chaud de Fond, Switzerland); 12 HERO 642®, 12 HeroShaper®, 12 RevoS® (Micro-Mega, Besançon, France). All instruments had a 6% taper, a 25/100 diameter tip, and a length of 25 mm, except the ProTaper, which was an F2. Each file was mounted on a fatigue test bench (16 mm hollow steel tube with a 60° bend and a radius of curvature r=10 mm) and driven by an electric motor (i-ENDO-Dual, Acteon, Mérignac, France) and a contra angle handpiece (WD-75M, 16: 1, W&H, Strasbourg, France) (Fig. 1) able to produce continuous rotation or reciprocating motion (the angles chosen for this study were 60° clockwise and 300° anticlockwise). The handpiece was locked into a reproducible position by a clamping device (Fig. 1). The instrument, fixed on to the handpiece, was inserted into the cylinder, reaching 4 mm beyond it at the apex. Half of each group of instruments was subjected to a continuous rotation at 300 rpm and the other half to a reciprocating motion at 300 rpm. The time to fracture was measured with a chronometer. The analysis of variance and the Wilcoxon non parametric test were then applied with an α risk of 5%.

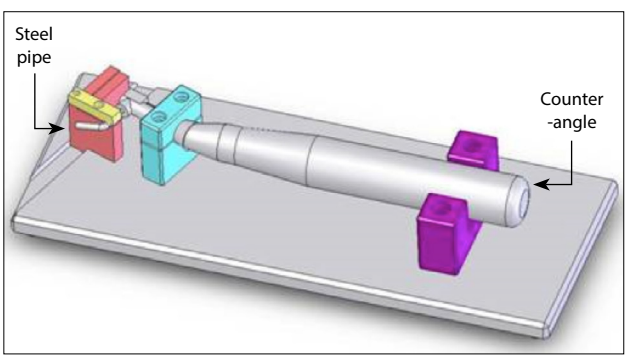

Fig. 1. Fatigue bench diagram.

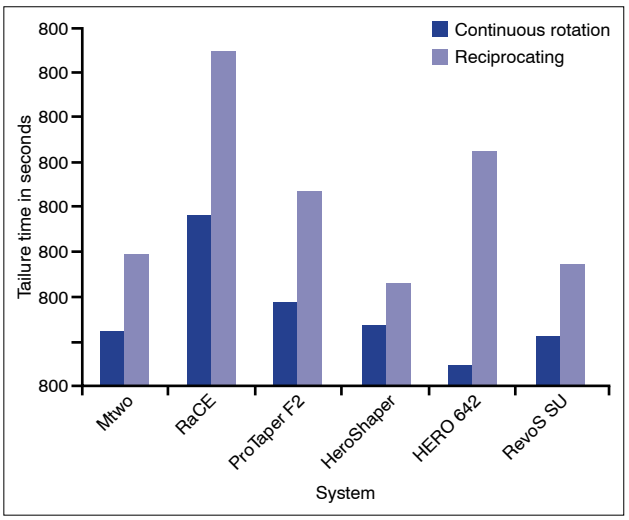

Fig. 2. Failure time depending on the system.

Results

The times recorded varied greatly (Table 1 and Fig. 2), both in continuous rotation and reciprocating motion. The mean times to fracture were longer in reciprocating motion than in continuous rotation (1.7 to 10.8 times longer). The differences were more marked with the HERO 642® (continuous rotation = 48 s, reciprocating motion = 525 s) and the RaCes® (continuous rotation = 380 s, reciprocating motion = 748 s). All the differences observed were statistically significant ($p<0.001$).

Discussion

Protocol

Reciprocating motion is a relatively recent discovery, a new root canal preparation technique using Ni-Ti instruments that is reminiscent of the alternating motion of the Giromatic®, except that, here, the clockwise angle of attack is different from the anticlockwise angle, while, in the Giromatic®, both these angles are identical (90°). For the present study, we chose a clockwise angle of 60° and an anticlockwise angle of 300°, which, in absolute value, gives an angle of 360°. Thus, the two motions (continuous rotation and reciprocating motion) are comparable and, in addition, the speed of rotation is identical for both and fixed at 300 rpm, which enables us to compare only the effect of the motion on the fracture resistance of the instrument. Nonetheless, other angles of reciprocity could

Table 1. Mean times to fracture of instruments in seconds according to type of motion

Motions	Continuous rotation		Reciprocating	
Instrument	Time to fracture (s)	Standard deviation	Time to fracture (s)	Standard deviation
HERO 642	48.63	6.86	525.51	46.64
HeroShaper (HS)	137.25	67.53	232.23	31.78
RevoS SU	113.74	27.84	275.88	258.17
RaCe	380.51	63.87	747.86	136.17
Mtwo	125.42	18.15	296.19	51.46
ProTaper F2	188.99	49.49	433.79	63.85

have been added to this study to assess the influence of the proportion of clockwise rotation over anticlockwise rotation. Apart from RaCe®, for which the recommended rotation speed is between 500 and 600 rpm, all the other systems include our chosen speed (300 rpm) in their intervals of rotation speed. Also, in a recent publication, Higuera et al.[19] did not find a correlation between the fatigue resistance and the rotational speed advised by the manufacturers for instruments used in reciprocating motion. All the instruments of the study had the same taper (6%) and the same apical diameter (25/100), with the exception of the Protaper® F2, which had a variable taper. In the Protaper® system, the F2 is the only instrument that is close to those used in this study and, indeed, it was the first instrument employed in reciprocating motion studies.[17] De-Deus et al.[9] also used it in their test comparing continuous rotation and reciprocating motion in cyclic fatigue. Kim et al.[20] compared this instrument with WaveOne® and Reciproc®, the first Ni-Ti files to be used alone, in a single sequence and in reciprocating motion. With respect to the type of fatigue, fracture in bending fatigue or cyclic fatigue seems to be clinically more frequent in curved root canals[21] whereas rupture in torsion occurs even in straight canals. Kim et al.[4] have shown that cyclic fatigue reduces the resistance to torsion fracture. For Lee et al.,[5] the more curved the canal is, the sooner the instruments break. The protocol used here has already been published in a study of the effect of electropolishing on the mechanical resistance and the surface quality of instruments made of Ni-Ti.[7]

Results

Whatever the system, the files broke sooner in continuous rotation than in reciprocating motion. These results are in agreement with the literature.[9,11–15,20] Several authors have pointed out the interest of reciprocating motion, which offers greater safety of use for mechanized instruments and, compared to continuous rotation, reduces the risk of fracture occurring in blocks of resin[14] by reducing cyclic fatigue.[9,11] In a dynamic trial, Gavini et al.[12] also confirmed the improved resistance of Ni-Ti files to bending fatigue (Reciproc R25) in reciprocating motion compared with continuous rotation. A study by Kim et al.[22] showed that files designed for the former dynamic are safe if their principle of use is respected. However, according to findings by You et al. in 2011,[13] reciprocating motion does not seem to differ from continuous rotation as far as the principles of root canal shaping are concerned. Also, in an assessment of the cutting capacity of Ni-Ti instruments used in reciprocating motion, Franco et al.[16] Pointed out that, although the instruments remained better centered with this approach, the working time was longer than with continuous rotation. These authors used standard sequences. From his work in 2007, Yared[17] concluded that this type of movement would be suited to the use of a single instrument. At present, some innovative motors offer the possibility of using continuous rotation or reciprocating motion associated with specific movements or series of movements when a predefined torque is reached. Others, such as the Tri Auto ZX® (Morita, Kyoto, Japan), offer two variants of reciprocating motion, called "Optimum Torque Reverse" and "Optimum Glide Path", where the angles, determined by the operator, also have an influence, according to a very recent study by Gambarini et al.[23] concerning the resistance of instruments to fracture. In the present study, instruments designed for continuous rotation were used in reciprocating motion or continuous rotation. The results indicate that the files seemed to resist cyclic fracture better in reciprocating motion than in continuous rotation. Moreover, certain instruments, such as the HERO 642 and the RaCe, even seemed better suited to reciprocating motion than to continuous rotation (Table 1, Fig. 2). These results could be explained by the alternation of rotations (clockwise and anticlockwise) in the reciprocating motion. A release of stress probably takes place, reducing the fatigue of the instrument. This would be even more obvious when the instrument is cutting dentin because, during the anticlockwise movement, it disengages from the dentin. In fact, the principal criticism voiced against HERO 642s is that they become a thread in due to their relatively short pitch.[24] This screwing into the root

canals is often a cause of file separation. The reciprocating movement would avoid the screwing in problem of these files and, from the dynamics point of view, seems to suit them better. The contribution of the instrument design to its fracture resistance can vary greatly, but this resistance also depends on the type of motion. There are currently a number of single-use instruments on the market, which simplify endodontic treatment, while giving satisfactory results.[22,25,26] The advantages of a single use instrument are numerous: reduction of investment costs, except for those that require a specific motor, elimination of the problem of instrument sterilization, prevention of transmissible diseases,[17] reduction of the risk of fracture[27] and also a reduction in working time.[16] However, a risk that does occur is that of not respecting the principles of root canal preparation, notably a risk of insufficient irrigation. Dynamic ultrasonic irrigation should be associated when single use instruments are employed.

Conclusion

In conclusion, it can be stated that, in the conditions of this study, Ni-Ti instruments for root canal shaping seem to show a higher resistance to fracture in cyclic fatigue when used in reciprocating motion than in continuous rotation. Certain instruments designed for use in continuous rotation can thus be suitable for reciprocating motion in single-use conditions.

Funding

No funding was received for this work.

Conflict of interest: None declared.

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