Reciprocating instruments in Endodontics: a review of the literature

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INTRODUCTION

When conventional nickel titanium (Ni-Ti) instruments are rotated in root canals, they are subjected to structural fatigue that, if continued, will eventually lead to fracture.[1,2] Torsion and fatigue through flexure are the two main reasons for this failure.[3] Torsional fracture occurs when the tip or any other part of the rotating instrument binds to the root canal walls, while the rest of the file keeps turning. Fracture due to flexural fatigue (bending stress) occurs when an instrument that has already been weakened by metal fatigue is placed under further stress. The instrument does not bind to the root canal walls but rotates freely until fracture of the instrument occurs at the point of maximum flexure.[4,5] The amount of bending stress imposed on an instrument depends on the anatomy of the root canal and is obviously greater in curved root canals.[6]

The first study experimenting with an alternating movement was that of Yared in 2008, which used the ProTaper F2 instrument (Dentsply/Maillefer) in a reciprocating movement.[7] The alternating changes in direction of rotation would, in theory, reduce the number of cycles of the instrument and, therefore, reduce the cyclic fatigue on the instrument compared with that imposed when instruments are used in a consistent rotating motion.[8,9] The study showed great promise for the reduction in the number of instruments required in the cleaning and shaping sequence; in minimising possible contamination; and alleviating operator anxiety of the possibility of instrument failure.[7] Apart from these benefits, preparation time was shown to be faster than when using the same instrument in full rotation.[8] These findings were confirmed by Burklein and Schäfer in 2012 when they compared Reciproc (VDW) and WaveOne (Dentsply/Maillefer) functioning in reciprocating motion to Mtwo (VDW) and ProTaper "Universal (Dentsply/Maillefer)" in conventional use.[10]

Alternating (reciprocation) of Ni-Ti instruments have the following advantages over continuous rotation:

- Binding of the instruments into the root canal dentine walls is less frequent, reducing torsional stress.[11]
- The reduction of the number of cycles within the root canal during preparation results in less flexural stress on the instrument.[5]
- There is decreased risk of instrument fracture.[7,11]

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ACRONYMS

CW:	clockwise
CCW:	counter clockwise
SAF:	Self-Adjusting File

The WaveOne NiTi File System (Dentsply/Maillefer) was introduced to the dental market in 2010. It is a pre-packaged, pre-sterilised, single-use system that is designed to shape root canal systems to a continuously tapering morphology.[12,13]

In the majority of cases a single file can be used to complete root canal preparation in single- or multiple root canal systems. Instead of a rotary motion, the files work in a reverse "balanced force" cutting motion[1] and are driven by a pre-programmed motor (X-Smart Plus motor fitted with 6:1 reducing hand piece)(Dentsply/Maillefer) that is capable of turning the files in a back and forth "reciprocating" motion. The counter clockwise (CCW) movement of 150 degrees is capable of advancing the instrument apically as the dentine on the root canal wall is engaged and cut. This movement is followed by a 30 degrees clockwise (CW) movement, which ensures that the instrument disengages before excessive torsional stress is transferred onto the metal alloy and before the instrument can bind (taper lock) into the root canal. Three sequential reciprocating cycles will complete one complete reverse (CCW) rotation and the repeated cutting and release process allows the instrument to advance apically into the root canal.[12]

The WaveOne single-file reciprocating system (Dentsply/Maillefer) (Figure 1) is available in three different file sizes in lengths of 21mm, 25mm, and 31mm:

Figure 1: WaveOne instruments: Small 21/06 (yellow ring); Primary 25/08 (red ring); Large 40/08 (black ring).

1. WaveOne Small File – Tip of the file is size ISO 21 and the shaft has a continuous taper of 6%.
2. WaveOne Primary File – Tip of the file is size ISO 25 and the shaft has a continuously decreasing taper of 8% from its tip to its shaft (0.8, 0.65, 0.6, 0.55).
3. WaveOne Large File – Tip of the file is ISO 40 and the shaft has a continuously decreasing taper of 8% from its tip to its shaft (0.8, 0.65, 0.6, 0.55).

The three WaveOne instruments are also characterised by different cross-sectional designs over the entire length of the working part of the instruments. In the tip region the cross-section presents radial lands while in the middle part and near the shaft the cross-sectional diameter changes from a modified triangular/convex cross-section with radial lands to a neutral rake angle with a triangular/convex cross-section (Figure 2).[14]

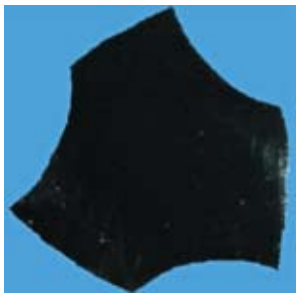

Figure 2: WaveOne triangular/convex cross-section

Figure 3: Reciproc instruments: R25 (red ring); R40 (black ring); R50 (yellow ring).

The Reciproc system also includes three instruments (R25, R40 and R50) (Figure 3) and is driven by the VDW Silver Reciproc Motor (VDW) or the X-Smart Plus motor (Dentsply/Maillefer). The instruments have an S-shaped cross section and demonstrate a progressive taper (Figure 4).[15] The Reciproc R25 instrument has a diameter of 0.25mm at the tip and an 8% taper over the first 3mm from the tip. The diameter at 16mm from the tip (D16) is 1.05mm. The Reciproc R40 has a diameter of 0.40mm at the tip, 6% taper over the first 3mm from the tip and at D16 a diameter of 1.10mm. The third instrument, R50, has a diameter of 0.50mm at the tip, a 5% taper over the first 3mm from the tip and at D16 a diameter of 1.17mm.[15] The motors are programmed with specific angles for CW and CCW rotations for Reciproc. When the instrument rotates in the cutting direction it will advance in the canal and engage dentine to cut it before the instrument will rotate in the opposite direction to ensure disengagement.

As mentioned, the reciprocating instruments are single use. This provides the clinician with the following advantages:

- A general decrease in instrument fracture associated with the reduction of instrument fatigue.[7]
- Elimination of possible cross contamination that is associated with the inability to adequately clean and sterilise previously used instruments;[7,12]

Figure 4: Reciproc S-shaped cross-section

- No need to disinfect, clean, sterilise and organise because the instruments are disposed of after each use.

Both systems, WaveOne and Reciproc, are manufactured from M-Wire technology to improve the fracture resistance of the instruments. M-Wire is a new Ni-Ti alloy that is prepared by a special thermal process, claimed to increase flexibility and resistance to cyclic fatigue.[16,17] It is reported that instruments made from M-Wire with a ProFile (Dentsply/Maillefer) design exhibit nearly 400% more resistance to cyclic fatigue than do super-elastic wire instruments of the same size.[18]

LITERATURE REVIEW ON RECIPROCATING INSTRUMENTS

a. Cyclic fatigue

De Deus *et al*. (2010) evaluated the cyclic fatigue resistance of ProTaper F2 instruments in reciprocating motion compared with continuous rotation.[19] The results demonstrated that the reciprocating movement induced less cyclic fatigue and promoted an extended life of the ProTaper F2 instruments in comparison with conventional rotation.

The influence of different angles of reciprocation on the cyclic fatigue of different Ni-Ti instruments was investigated by Gambharini *et al*. in 2012.[20] These authors evaluated the cyclic fatigue resistance of K3XF size 40 files (SybronEndo) in relation to different angles of reciprocation to determine the extent to which changes in the angles of rotation could affect the life span of the instruments. The results indicated that movement kinematics (reciprocation at various angles) had a significant influence on the cyclic fatigue life of the instruments. All the test groups in which the turning motion was reciprocal showed a significant increase in time to failure when compared with failures in the control group where continuous rotation was performed.

Gavini *et al*. (2012) evaluated the resistance to flexural fatigue of the Reciproc R25 files under either continuous rotation or reciprocation, using simulated root canals of tempered steel.[21] The results showed that the reciprocation motion improves the flexural fatigue resistance of the Reciproc R25 when compared with continuous rotation.

Plotino *et al*. (2012) evaluated the cyclic fatigue resistance of Reciproc and WaveOne in simulated root canals.[22] The results showed that the Reciproc instruments were associated with a significantly higher cyclic fatigue resistance than the WaveOne instruments. The authors speculated that this could be attributed to the possible difference in the reciprocating movements and to the variations in the cross-sectional designs, of the two instruments. The WaveOne instruments have a modified convex triangular cross section at the tip, the middle and coronal parts of the instrument, with three cutting blades. Reciproc instruments have an S-shaped cross section with only two cutting blades. However, there is no agreement in the literature regarding the influence of instrument design on the behaviour of instruments under cyclic fatigue.[23,24,25,26] Kim *et al*. (2012) evaluated the cyclic fatigue and torsional resistance of Reciproc, WaveOne and ProTaper. These authors concluded that the WaveOne system had a higher torsional resistance whilst Reciproc showed a higher number of cycles before fracture, compared with the other instruments. Both reciprocating instruments demonstrated significantly higher cyclic fatigue resistance and torsional resistance than did ProTaper.[27] Similar observations were noted in a study by Pedullà *et al*. (2013).[28]

In a study conducted by Castelló-Escrivá *et al*. (2012) the researchers compared the cyclic fatigue resistances of ProTaper Universal (F2, 25/08), WaveOne (Primary, 25/08) and Twisted Files (25/08)(Sybron Endo).[29] The results showed that WaveOne in the reciprocating mode was more resistant to fatigue-related failure compared with the ProTaper and Twisted files in full rotation. Twisted files showed a higher number of cycles to failure than ProTaper Universal.

b. Debris removal

A study by Bürklein *et al*. (2012) compared the efficacy of instruments functioning in a conventional rotating action with instruments functioning in reciprocating motion.[30] The WaveOne 25/08 Primary file and Reciproc R25 file were compared with ProTaper Universal and Mtwo instruments. The results demonstrated that, in general, the use of Mtwo, Reciproc and WaveOne instruments resulted in less residual debris compared with canal shaping performed with ProTaper instruments. The paper also showed that Reciproc and Mtwo left the least amount of debris in the apical region compared with WaveOne and ProTaper Universal when curved root canals were prepared on extracted human teeth.

A further study by Dietrich, Kirkpatrick and Yaccino (2012) compared the canal and isthmus debris removal of the Self-Adjusting File (SAF) (Reodent, Nova), K3 (Sybron Endo) and WaveOne files in the mesial roots of human mandibular molars.[31] The results indicated that there were no differences in the canal cleanliness achieved by the three file systems. However, the SAF and K3 files performed significantly better than the WaveOne with respect to isthmus cleanliness. The authors of this study explained that the minimal time of instrumentation with the primary WaveOne instrument (86 sec/tooth) may not have permitted enough contact time for the sodium hypochlorite to aid in debriding canal irregularities untouched by the file.

Factors that could also have influenced the data in this study could include the fact that no glide paths were prepared before canal preparation and also the manner in which the instruments were used. The authors state that prior to instrumentation the curved canals had a diameter that was compatible with an ISO size 15. The manufacturers of ProTaper Universal and WaveOne instruments recommend using PathFiles (Dentsply/Maillefer) before canal preparation. The PathFile system enlarges the glide path to an ISO size 19, which will possibly result in less stress on the instrument and less debris compaction. Secondly, the WaveOne instrument was used with in-and-out pecking motions instead of brushing motions as recommended by several authors.[12,13] A pecking motion could lead to debris compaction while a brushing motion leads to debris removal.

A very recent study reported that the reciprocating root canal technique induces greater debris accumulation than continuous rotary techniques when assessed by three-Dimensional Micro-computed Tomography.[32] The performance of the primary WaveOne instrument on mesial roots of extracted mandibular molars was compared with that of ProTaper instruments. The conclusion of this paper was that in root canals with a prevalence of isthmuses and protrusions, it is preferable to use multi-file rotary systems over single reciprocating instruments because they yield cleaner canals with less debris accumulation. However, the methodology may be questioned. The authors state that two thirds of the canal length was prepared with the WaveOne instrument, followed by preparation of the final third, without mentioning whether this was done with a brushing or a pecking motion. According to our personal clinical experience, it takes at least three or more cutting cycles to prepare a mesial root canal on a mandibular molar with WaveOne instruments. Another factor that could have led to more debris accumulation is the fact that the canals were irrigated with 2ml of sodium hypochlorite after each usage of the primary WaveOne file between the two cutting cycles. According to our clinical experience it is essential to perform a recapitulation step with a hand instrument after irrigation and then to re-irrigate in order to remove cutting debris from the root canal before the next cutting cycle. The fact that only two cutting cycles were done (and no mention is made of recapitulation being done between cutting cycles) could have led to more debris accumulation in the root canals, as indeed was found in the study under review.

c. Debris extrusion

The extrusion of dentinal chips, micro-organisms, pulp tissue and other materials can cause post-operative complications such as flare-ups.[33] A study conducted by De-Deus *et al*. (2010) found that when the ProTaper Universal file F2 was used in a reciprocating motion, no significant difference was found between the full sequence of ProTaper Universal and the single ProTaper file F2,[34] both causing similar amounts of apical extrusion of debris. The authors also stressed that their study was unable to confirm the influence of the type of instrument movement on the amount of debris extruded apically.

Bürklein *et al*. (2012) compared the debris extrusion associated with the larger reciprocating files of WaveOne (40/08) and Reciproc (40/06 black) to that recorded in the full sequences of ProTaper Universal and Mtwo.[10] The results demonstrated that there was no statistically significant difference between the two rotary systems. The full sequence rotary instrumentation systems were associated with less debris extrusion compared with the reciprocating single-file systems, one of which, Reciproc, produced significantly more debris compared with all the other systems. The authors also advise caution when the results of their *in vitro* study are applied to a clinical situation. Similar observations were made by Xavier *et al*. (2014) when they conducted a study using mandibular premolars in comparing the apical extrusion of debris associated with the action of Reciproc (40/06) and of WaveOne (40/08) instruments. Their findings also concluded that filing with Reciproc showed more apical debris extrusion compared with that seen with WaveOne.[35] The absence of physiological back pressure provided by periapical tissues may influence debris extrusion in experimental studies as discussed by Myers and Montgomery in 1991.[36]

Again, it should be noted that the reciprocating instruments (WaveOne and Reciproc) were used in a pecking motion instead of a brushing motion as suggested previously, and that no mention is made of any recapitulation after each cutting cycle to loosen up debris in the root canal. Another factor that might have influenced the results of this study is the use of water for irrigation instead of sodium hypochlorite.

d. Bacterial reduction

According to Kakehashi *et al*. (1965) the presence of bacteria is the main cause of the development of periodontal infection and apical periodontitis.[37] The aim of chemo-mechanical root canal preparation is to eradicate residual vital and non-vital pulp tissue and reduce the number of pathogenic organisms.[38] Mechanical instrumentation can disrupt the bacterial biofilm and has the potential to reduce the presence of bacteria in the main root canal.[39] The rotary

systems, ProTaper Universal and Mtwo have been shown to provide adequate geometry[40] and substantial bacterial reduction in the root canal.[41]

A recent study compared the influence of the reciprocating single-file technique with conventional rotary instrumentation on the bacterial reduction in infected root canals.[42] The systems for instrumentation included WaveOne, Reciproc, ProTaper Universal, Mtwo and manual instrumentation. The results demonstrated that the bacterial count was significantly reduced after instrumentation in all groups. However, there were no significant differences in the bacterial count reductions effected by the reciprocating, rotary and manual techniques. Hence, the conclusion of the study was that reciprocating systems resulted in similar bacterial reductions to those obtained with rotary systems or with the manual instrumentation technique. Similar observations were made by Nabeshima *et al*. in 2014.[43]

e. Maintenance of root canal antomy

Originally, the use of a reciprocating motion with hand instruments was proposed to increase canal centring ability, minimise torsional and flexural stresses, reduce the taper lock within the number of instrument cycles within the root canal, and to reduce the risk of producing root canal deformity.[44,45,46] Berutti *et al*. (2012) compared canal shaping efficacy between WaveOne primary reciprocating files and the ProTaper Universal system.[47] The study concluded that canal modifications were reduced when the WaveOne single-file system was used compared with ProTaper instruments.

Another recent study by Berutti *et al*. (2012) assessed how effective the primary WaveOne reciprocating instrument was in preserving root canal anatomy in acrylic simulators, with or without a glide path preparation with PathFiles. The authors concluded that canal modifications seem to be significantly reduced when a previous glide path is performed prior to canal preparation with the primary WaveOne instrument.[48]

Two reciprocating systems (WaveOne, Primary R25/08 and Reciproc, Primary 25) were compared by Yoo and Cho (2012) with ProTaper Universal and Profile instruments operating in full rotation.[49] The reciprocating systems were used in a lateral brushing motion. Reciproc and WaveOne instruments were found to maintain the original canal contour in curved canals better than did instrumentation with either ProTaper Universal or ProFile, which tend to transport (erode) the outer canal wall of the curve in the apical part of the canal. Yoo and Cho recommended that both reciprocating systems showed good ability and should be suitable for shaping curved canals with only one instrument.

Lim and co-workers evaluated the shaping ability of WaveOne and Reciproc instruments in terms of maintaining the original canal configurations and curvatures, with and without a glide path.[50] The results indicated that without a glide path preparation the WaveOne instruments demonstrated a reduced centring ability in the last 2mm of simulated canals in resin. The authors recommended that WaveOne instruments should only be used following the establishment of a glide path larger than size 15 (ISO).

A recent study evaluated and compared several parameters of root canal preparation, namely: changes in canal curvature, transportation, and volume of removed dentine produced by two different Ni-Ti systems (Twisted Files, a continuous rotation full sequence system, and WaveOne, a reciprocating single file system). Extracted human teeth were used and the root canals were examined by cone-beam computed tomography (CBCT).[32] The study concluded that both Twisted files and WaveOne can be safely used to the full working length, resulting in satisfactory preservation of the original canal shape. However, the results also indicated that the use of the reciprocating motion with WaveOne resulted in increased transportation when compared with the continuous rotation instruments (Twisted Files). In a very recent study similar observations were also made by Giuliani *et al*. (2014) where the effect of the reciprocating cutting action of the WaveOne system was compared with that of the ProTaper Universal system used in full rotation.[51] These findings are in direct contrast to earlier results by authors Yoo and Cho,[49] but it must be noted that the WaveOne instruments were again used in a pecking motion instead of a brushing motion.[41]

f. Dentinal defects/cracks

In the modern era, various Ni-Ti instruments have been introduced with different designs but, unfortunately, most systems cause dentinal defects and even vertical root fractures.[52,53,54,55] A recent study compared the incidence of dentinal defects after root canal preparation with reciprocating (WaveOne 40/08 and Reciproc R40) and with rotary instrumentation (Mtwo and ProTaper Universal) on extracted human central lower incisors.[56] The study concluded that all four systems caused dentinal defects, but both reciprocating systems caused significantly more incomplete cracks in the apical (3mm) portion of the root canals. Reciproc was associated with more complete cracks compared with the full sequence rotary systems.

These observations are in agreement with those from an earlier study by Adorno *et al*. (2011) which demonstrated that instrumentation with larger files could potentially cause more cracks.[57] The tips of the reciprocating instruments used in the study were size 40 with an 8% taper (WaveOne) and size 40 with a 6% taper (Reciproc). It must again be emphasised that a pecking motion was used for the reciprocating instruments and not a brushing motion. In the materials and methods the authors also state that the canal before preparation with the reciprocating instruments was a size 20. Taking this into account and the fact that the study was carried out on mandibular central incisors, it may have been advisable to have rather selected the primary 25/08 WaveOne or Reciproc R25 instruments instead of the large 40/08 WaveOne or Reciproc R40 instruments. The incorrect selection of the preparation instrument for these small root canals could easily have contributed to the findings in their study. This statement is confirmed by a study conducted by Abou El Nasr *et al*. (2014) in which single canal mandibular premolars were used. The authors used the primary WaveOne instruments (25/08) as part of the experiment and found these to produce fewer dentinal cracks compared with the incidence when ProTaper F2 files were used in either full rotary or reciprocating motion.[58]

g. Effect of preparation with reciprocating instruments on canal length

Studies demonstrate a minimal decrease in working distance in canals that are prepared with rotary Ni-Ti instruments.[59,60] In the study by Yoo and Cho (2012), where the shaping abilities of reciprocating instruments in simulated curved canals were compared, the authors were unable to notice a statistically significant loss in working length.[49]

In a study by Berutti *et al*. (2011) the opposite was found with the use of the primary WaveOne reciprocating instrument.[61] These authors evaluated the working length modification after instrumentation with the WaveOne primary reciprocating files and the incidence of over instrumentation in relation to initial working

length. A significant decrease in canal length after instrumentation was detected. The authors suggest re-checking the working length before preparation of the apical third with this single file system to avoid over-instrumentation of the root canal.

h. Clinical efficiency

A recent study by Park *et al.* (2013) compared the efficiency of reciprocating instruments (Reciproc and WaveOne) by measuring the working time required to complete canal shaping.[62] In addition the study also evaluated the reusability of the instruments, assessed by examination under scanning electron microscope. The results showed that the primary WaveOne files were significantly faster (23.9s) for canal preparation compared to the Reciproc R25 files (30.0s). According to the authors with the study the difference can be attributed to the fact that WaveOne instruments have three cutting blades and might have better cutting efficacy than the two-bladed Reciproc instruments. In addition, the existence of a groove between the three cutting flutes of WaveOne instruments might expedite the removal of dentine debris during the preparation phase, enhancing performance. In contrast, Plotino *et al.* (2014) found that the cutting efficiency of Reciproc files was superior to that of the WaveOne system. Once again, both designs were tested on a modified *in vitro* device which is not a true representative of root canal anatomy and the prescribed techniques were not followed during the experiment.[63]

The total canal preparation time also increased for both systems, as the working length and curvature of the canal increased. As the number of files used increased, the efficiency decreased. Only a few or no micro-cracks were detected after reusing files for five canals. The authors concluded that reciprocating files might be able to be re-used up to five times with no critical changes in the metallurgical properties of the instruments.

i. Removal of filling material during retreatment

Endodontic retreatment is indicated when the initial procedure has failed. Ruddle (2004) suggested that retreatment could improve root canal disinfection and debridement before a new homogenous root canal obturation is placed.[64] Techniques advocated to remove gutta-percha and sealer from root canals include hand files, burs and rotary Ni-Ti instruments. A recent study compared the efficacy of reciprocating and rotary techniques for removing filling material during retreatment.[65] Included in the evaluations were Gates-Glidden burs and stainless-steel hand files up to size 50, a rotary technique with Mtwo R files and additional Mtwo files to a size 50, 0.04 taper, and the reciprocating technique with the Reciproc instrument R50, size 50, 0.05 taper. The results of the study demonstrated that: (1) remaining endodontic filling material was observed on the canal walls of all the specimens regardless of the technique used; (2) hand files combined with Gates-Glidden burs and the reciprocating technique removed more filling material from the canal walls than the Mtwo R files; and (3) the reciprocating technique was the most rapid method for removing gutta-percha and sealer. Similar findings were observed by a very recent study reported by Helvacioglu-Yigit *et al* (2014).[66]

CONCLUSIONS

The clinical technique in which reciprocating instruments like WaveOne and Reciproc are used can play a vital role in the successful outcome of the cleaning and preparation phase of endodontic treatment. Most studies agree that the reciprocating movement can reduce torsional (binding to dentine is reduced) and flexural stresses (number of rotation cycles are reduced) on endodontic instruments. These instruments also maintain the original canal anatomy and demonstrate reduced time for canal preparation compared with full rotary systems. However, there are conflicting results in the literature regarding the efficacy of debris removal and bacterial reduction and there remains the possibility of debris extrusion and dentinal crack formation during root canal preparation with reciprocating instruments.

Conflict of interest: none declared

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