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## Single file reciprocation: A literature review



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Root canal preparation with only one nickel-titanium instrument used in reciprocation has been recently introduced. New endodontic systems using this concept, such as Reciproc and WaveOne, have also been developed. The purpose of this review was to identify publications regarding the evaluation, to present comprehensive and critical summaries of current knowledge, and to provide an update of the single file reciprocating concept.

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### ■ Introduction

Different techniques of root canal preparation have been described in the related literature. Stainless steel instruments have been traditionally used for the canal preparation. Presently, the use of nickel-titanium instruments engine-driven in continuous rotation is widely accepted. Endodontic instruments have also been used in rotational or axial reciprocation or a combination of both movements<sup>1</sup>. Interestingly, the combination of axial and rotational reciprocation was firstly introduced in 1928 (Cursor Filing Contra-Angle; W & H, Bürmoos, Austria) followed by axial reciprocation in 1958 (Racer; W & H) and rotational reciprocation (Giomatic; Micro Méga, Besançon, France) in 1964<sup>1</sup>. Since then, several handpieces were developed to drive the endodontic instruments in a reciprocal movement<sup>1</sup>. However, concerns were raised about the shaping ability of endodontic files used in reciprocation with these engine-driven devices in many studies<sup>1</sup>.

In 1985, Roane et al introduced the balanced force technique using instruments in rotational recip-

rocation for the preparation of curved root canals<sup>2</sup>. They were the first to report the use of hand files with unequal clockwise and counter-clockwise movements in reciprocation. The efficacy and the safety of this technique were questioned considering the relatively high incidence of procedural complications, such as instrument fracture and root perforations<sup>3-6</sup>. However, numerous reports indicated good results were obtained with this technique for the preparation of curved canals without or with only minimal straightening, rekindling the interest in rotational reciprocation for canal preparation<sup>7-19</sup>. Consequently, handpieces using 'rotational reciprocation' (referred to as Reciprocation/Reciprocal in the text) systems were introduced such as the M4 (SybronEndo, Orange, CA, USA)<sup>20</sup>, the Endo-Eze AET (Ultradent Products, South Jordan, UT, USA) and the Endo-Express (Essential Dental Systems, South Hackensack, NJ, USA)<sup>21</sup>. The results on the shaping ability of curved canals with these reciprocating systems were not encouraging<sup>20,22,23</sup>.

In 2008, Yared introduced engine-driven single file reciprocation for the preparation of curved



canals. He reported good clinical results<sup>24</sup>. He used an F2 ProTaper instrument (Dentsply Maillefer, Ballaigues, Switzerland) in reciprocation with unequal clockwise (CW) and counter-clockwise (CCW) movements. The F2 ProTaper instrument was driven by an ATR motor (ATR, Pistoia, Italy). Studies conducted on the single file reciprocation technique with the F2 ProTaper instrument showed promising results with this technique. The interest in reciprocation was renewed, however, the ATR motor was discontinued. In 2010, Dentsply introduced two single file (rotational) reciprocation systems, Reciproc<sup>25</sup> (VDW, Munich, Germany) and WaveOne<sup>26</sup> (Dentsply Maillefer) based on the concept developed by Yared<sup>24</sup>. Many articles were published on single file reciprocation since the introduction of these two systems to the market.

The instruments, their design, the technique of canal preparation and the rationale of using a single engine-driven file in reciprocation were described in detail for Reciproc<sup>25</sup> and WaveOne<sup>26</sup>. The instruments in both systems are driven with a reciprocating motor. The angles of rotation are unequal and lower than the angle at which the elastic limit of the metal composing the instrument develops. Consequently, torsional stress would be reduced and safety would be enhanced. The benefits of single file reciprocation are: shorter working time; shorter learning curve; reduction of number of instruments required to obtain a desired shape; simplicity (reduction of the number of steps for the canal preparation); and safety with regards to instrument fracture and procedural errors. An additional advantage specific to the Reciproc system is its efficiency in the removal of obturating materials, including plastic-carrier based obturations similar to Thermafil<sup>25</sup> (Tulsa Dental Specialties, Tulsa, OK, USA). Also, Yared claimed that the creation of a glide path is not required in the majority of the canals prior to using a Reciproc instrument in reciprocation<sup>25</sup>; therefore, it was expected that the incidence of procedural errors resulting from the use of small hand files in narrow canals will be reduced.

Hülsmann<sup>27</sup> stated: "A review can be an important source of knowledge if written with a critical perspective. However, it does not make sense to collect and condense invalid and useless data. Moreover, it would be of utmost value and would suggest important avenues for further research if reviews in

future focused on the most critical and pertinent gaps in knowledge. Reviews evaluating the benefits and shortcomings of current research methods and technology would also be of importance".

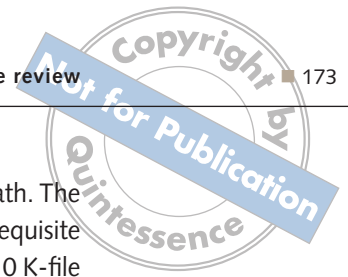
The present article presents a comprehensive, critical summary of current knowledge and literature concerning Reciproc and WaveOne single file (rotational) reciprocation.

## ■ Single file reciprocation and cyclic fatigue

When used in curved canals, an instrument is subjected to cycles of compressive and tensile stresses caused by the repeated bending of the instrument in the canal curvature. In addition, the instrument is subjected to torsional fatigue resulting from the repeated stresses in torsion during the frequent engagement of the root canal walls and continuous dentine cutting. With extended use, the stresses accumulate, leading to torsional and flexural fatigue and weakening of the instrument, and ultimately fracture.

Several studies<sup>28-41</sup>, except for one<sup>42</sup>, have shown that reciprocation extends the flexural cyclic fatigue life of the tested instruments in comparison with continuous rotation. However, these results are not clinically relevant with regards to single file reciprocation for at least two reasons. First, in continuous rotation, multiple instruments are used to prepare a canal. The use of these instruments in a sequential manner would reduce the stresses to which these instruments are subjected. In single file reciprocation, only one instrument is used; stresses on the instrument would be expected to be higher than the stresses on each of the instruments used in continuous rotation. It is noteworthy that the WaveOne and Reciproc single file reciprocating instruments are intended for single use. Second, these studies did not include an evaluation of torsional fatigue. Flexural and torsional fatigue might be inter-dependent. For example, the changes in the physical properties of an instrument subjected to flexural fatigue might also affect the torsional fatigue resistance of the instrument.

Future research should evaluate the influence of canal preparation (using standardised teeth models)



with single file reciprocation and continuous rotation on different parameters, such as the number of cycles to fracture, the torque at fracture, and the angle at fracture.

Interestingly, all four studies<sup>34,36,39,41</sup> comparing the flexural fatigue resistance of WaveOne and Reciproc instruments found that the latter performed better. The difference between both instruments was attributed to the cross section, and the reciprocating movement (angles and speed of reciprocation). Studies done on different engine-driven instruments showed that the parameters of the reciprocating movement affected flexural fatigue<sup>28-30,37</sup>.

### ■ Single file reciprocation, without or with a minimal glide path, and shaping ability

A glide path is a minimal canal enlargement required before the use of rotary instruments in continuous rotation to minimise the incidence of binding and torsional fracture. For example, a glide path with a size 20 file is required for the safe usage of ProTaper instruments<sup>43</sup>.

The WaveOne instrument was claimed to be able to safely and completely prepare a canal with only one instrument following the creation of a small path with a size 10 file<sup>26</sup>. One of the claims of the Reciproc single file reciprocation system is that the creation of a glide path is not required to reach the working length in the majority of the canals, regardless of the severity of the curvature<sup>25</sup>. This would help to reduce canal aberrations and procedural errors usually encountered with the use of hand files to create a glide path<sup>44</sup>.

Also, some authors<sup>45,46</sup> consider that single file reciprocation is a modification of the balanced force technique<sup>7</sup>, which allows the preparation of severely curved canals with large and rigid stainless steel hand instruments. Yet, concerns were raised regarding the shaping ability of Reciproc and WaveOne instruments, considering that these instruments are relatively large and are used in curved and narrow canals without any prior instrumentation or following a minimal canal preparation with a size 10 hand file.

De-Deus et al<sup>47</sup> showed that 80% of canals with a moderate to a severe curvature could be prepared

with a Reciproc instrument without a glide path. The Reciproc instrument was able to reach the requisite length in 67% of the canals, in which a size 10 K-file had been previously unable to penetrate. In a similar situation, an attempt to create a glide path with hand files will likely lead to procedural errors, especially with inexperienced operators<sup>44</sup>. They attributed the efficacy of the no glide path concept to the angles used in reciprocation, and the flexibility and the cutting ability of the Reciproc instruments.

Several studies<sup>45,46,48-53</sup> have evaluated the degree of canal transportation, preparation time, the occurrence of canal aberrations and the incidence of instrument fracture associated with the Reciproc and WaveOne systems. Different methodologies were used to compare the single file reciprocating systems to instruments used in continuous rotation. The results showed that single file systems, Reciproc and WaveOne, performed at least equally to the rotary multiple file systems. However, the manufacturers' recommendations with regards to the use of Reciproc and WaveOne instruments were not followed; all the studies were done on canals after the creation of a glide path with a size 15 file, or on canals in extracted teeth or resin blocks that had a diameter compatible with ISO size.

Interestingly, only one study compared experienced and inexperienced operators<sup>49</sup>. They showed that the canal preparation by inexperienced operators with Reciproc required less time compared to experienced operators using multiple Twisted File instruments (SybronEndo, Orange, CA, USA).

Future studies should evaluate the shaping ability and the efficacy (ability to reach the working length) of single reciprocation without or with a minimal glide path in accordance with the manufacturers' instructions. Sufficient data should be included in the published articles to allow the reproduction of studies and comparisons between studies. Studies should not be carried on resin blocks<sup>27</sup> because the behaviour of instruments in resin blocks might differ to dentine<sup>54</sup>. The concept of single file reciprocation without or with a minimal glide path could be interesting from a teaching perspective because it could reduce the learning curve by simplifying the canal preparation procedure<sup>30</sup>. Therefore, it is also important to compare the learning curve and the incidence of procedural errors between single file



reciprocation, and single and multiple file continuous rotation during canal preparation<sup>52</sup> performed by inexperienced operators and students.

The canal preparation of the MB2 canal in a maxillary molar is challenging<sup>55</sup> considering the complexity of the canal anatomy<sup>56</sup> and the presence of calcifications<sup>57</sup> mainly in the coronal third of the canal. Yared<sup>25</sup> suggested the use of the R25 Reciproc instrument without a glide path for the preparation of MB2 canals in maxillary molars. He discussed the benefits of this approach compared to traditional techniques for the management of the MB2 canal. The efficiency of the Reciproc instrument in the management of MB2 canals should also be investigated considering the possible advantages this approach would offer as discussed by Yared<sup>25</sup>.

#### ■ **Single file reciprocation and dentinal defects**

The current standards require the use of instruments in a sequential manner to shape the canal. The use of a single file without or with a minimal glide path to completely prepare a canal to a desired shape raised concerns about the stresses generated and the possible formation of dentinal defects during the preparation procedure.

Only two studies<sup>58,59</sup> have compared the presence of dentinal defects and microcracks following canal preparation with single file reciprocation (Reciproc and WaveOne), and single and multiple file continuous rotation.

Bürklein et al<sup>58</sup> found that Reciproc and WaveOne instruments resulted in significantly more microcracks in the apical level than multiple file rotary systems. However, flaws in the methodology could have affected the results. It was not clear whether the preparation technique recommended by the manufacturer of Reciproc was followed<sup>60</sup>: "A slow in-and-out pecking motion. The amplitude of the in-and-out movements should not exceed 3 mm. Only very light pressure should be applied". In the study of Bürklein et al<sup>58</sup>, the Reciproc was used with a slow in and out pecking motion; they did not make any reference to the amount of pressure applied or to the amplitude of the pecking motion. For example, a greater pecking amplitude in the inward direction might increase instrument binding

in the canal, which would result in the generation of an excessive stress. Also, the authors did not follow the recommendations of the manufacturer regarding the use of the Reciproc instrument<sup>61</sup>: prior to using the R40 Reciproc instrument, a hand file size 20 should go passively and directly to the working length with a gentle watch winding movement but without a filing action. The protocol used by the authors could have resulted in the inclusion of canals not large enough for the safe usage of the R40 instrument. Similarly, it did not appear that a size 20 hand file could reach the working length passively prior to using the WaveOne size 40 according to the manufacturer's instructions<sup>62</sup>. Also, in their study, the largest rotary instruments used at working length had a smaller taper compared to Reciproc and WaveOne.

Liu et al<sup>59</sup> showed that Reciproc and the Self Adjusting File (ReDent Nova, Ra'anana, Israel) caused less dentinal defects compared to single and multiple file rotary instruments. They attributed these results to the reciprocating movement considering that more dentinal defects occurred after a rotary instrument with a smaller taper was used to the working length. However, the Reciproc technique was not applied according to the manufacturer's instructions: the coronal third of the canals was enlarged with a Gates Glidden drill and a glide path with a size 15 file was created prior to using the Reciproc instrument.

Future studies should evaluate the formation of microcracks following the use of the Reciproc and WaveOne instruments according to the instructions recommended by the manufacturers, and without or with a minimal glide path. The larger instruments (for example, the Large WaveOne and the R50 Reciproc) should be included in these investigations. Also, the use of finite element analysis models allowing the inclusion and the control of different variables should be used to evaluate the stresses generated with single file reciprocation under different conditions.

#### ■ **Single file reciprocation and apical extrusion of debris**

Bürklein and Schäfer<sup>63</sup> demonstrated, *in vitro*, that multiple file rotary systems were associated with



less apical extrusion of debris compared to single file reciprocating systems. The authors mentioned that the initial size of the canals was equal to size 20. The determination of the canal size was not clearly described. The manufacturers of Reciproc and WaveOne recommended that a size 20 file goes passively to the working length, without any hand filing (for Reciproc), prior to using the size 40 reciprocating instruments.

In another study<sup>64</sup>, apically extruded debris and irrigant was produced equally with the R40 Reciproc instrument (size 40 and 0.06 mm/mm taper over 3 mm from the tip) and the Mtwo full-sequence retreatment rotary instruments provided an adequate test apparatus was used. However, they only used the R40 against the recommendations of the manufacturer which require using the smaller R25 Reciproc instrument (size 20 and 0.06 mm/mm taper over 3 mm from the tip) to the full working length followed by the R40<sup>65</sup> and which could result in less debris extruded beyond the apex.

Moreover, the validity and clinical significance of similar studies<sup>63,64</sup> have been recently questioned considering the shortcomings of the methodology<sup>66</sup>.

Neuropeptides, inflammatory process mediators, can be released from C-type nerve fibres present in the periapical tissues when stimulated by extruded debris and irrigants<sup>67</sup>. A recent *in vivo* study has shown that the neuropeptide levels following canal preparation with Reciproc were similar to the levels observed in a negative control group (no canal preparation) and lower than the levels expressed following the use of WaveOne<sup>68</sup>. The authors attributed the differences between Reciproc and WaveOne to the instrument design. The instrument kinematics did not appear to influence the amount of debris extruded apically<sup>69,70</sup>.

Future studies should evaluate the release of neuropeptides and other inflammatory mediators, the incidence of flare-ups, and the incidence and the quality of postoperative pain associated with the use of single file reciprocation strictly as recommended by the manufacturers for initial treatments and retreatments.

### ■ Single file reciprocation and cleaning ability

The results obtained from different studies were controversial. One study showed that a full-sequence rotary system resulted in cleaner canals than with WaveOne<sup>71</sup>. However, the methodology was questionable because the irrigation parameters such as volume and time of irrigation were not controlled<sup>72</sup>. The other studies showed that the main canal cleanliness was comparable for both systems<sup>45,73,74</sup>. Dietrich et al<sup>73</sup> demonstrated that the SAF and K3 (SybronEndo, Orange, CA, USA) files performed significantly better than the WaveOne with respect to isthmus cleanliness. However, this difference might be related to variations in isthmus width and length, among the teeth included in the experimental groups, which cannot be standardised.

Future studies should be conducted with an irrigation protocol standardised among the experimental groups. Irrigation techniques such as passive ultrasonic irrigation, which is more efficient than conventional needle irrigation, should be used for the comparison of canal cleanliness between single file reciprocation and rotary instrumentation.

Single file reciprocation significantly reduces the working time compared to multiple-file rotary systems<sup>45,50,64</sup>. A longer final irrigation/exposure to the irrigant would be possible with single file reciprocation compared to a full-sequence rotary instrumentation for a similar appointment duration and would warrant investigating its influence on canal cleanliness.

### ■ Single file reciprocation and bacterial elimination

The simplification of the canal preparation process and the shorter working time associated with single file reciprocation have raised concerns about its ability to disinfect the root canal space.

The antibacterial activity of the single file reciprocation technique was comparable with the conventional rotary techniques and the Self Adjusting File in regular and oval shaped canals<sup>72,75-77</sup>. However, those studies were performed *in vitro*. Considering the complexity and the nature of the endodontic flora, the bacterial elimination ability



of single file reciprocation should be evaluated in clinical studies.

### ■ Single file reciprocation and root canal retreatment

The manufacturer claimed that Reciproc instruments could be used efficiently for root canal retreatment procedures<sup>65</sup>.

It was also stated that a solvent might not be required during the retreatment procedures with Reciproc<sup>25</sup>. The use of a solvent led to more gutta-percha and sealer remnants on root canal walls and inside dentinal tubules<sup>78-80</sup> making the removal of the obturating material more difficult and time-consuming.

Zuolo et al<sup>81</sup> found that the Reciproc was more effective in removing obturation material than the Mtwo (VDW, Munich, Germany) retreatment rotary instruments. A solvent was used with both systems. Reciproc was also faster than the Mtwo retreatment instruments<sup>64,81</sup> despite the non-use of a solvent in the study by Lu et al. The longer working time with the rotary retreatment system was attributed to the time spent changing instruments<sup>64</sup>.

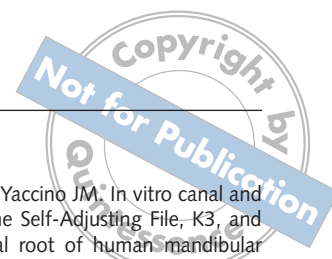
### ■ Conclusions

The present review showed that the concept of root canal preparation with only one file used in reciprocation is promising. However, this review of the current publications demonstrated the need to improve the experimental protocols to allow comparisons between studies<sup>27</sup>. Important aspects of this new concept still have to be evaluated. The technique of canal preparation recommended by the manufacturers should be strictly followed in future studies evaluating single file reciprocation. The assessment of different treatment variables should not be limited to *in vitro* studies. For example, the use of hand files to create a glide path may result in procedural errors that would affect the outcome, whereas canal preparation without a glide path may result in a higher incidence of apically extruded debris that may also impact the outcome. Outcome studies of root canal treatments performed with single file reciprocation are necessary.

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