Current Assessment of Reciprocation in Endodontic Preparation: A Comprehensive Review—Part I: Historic Perspectives and Current Applications

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Abstract

Introduction: During the evolution of mechanical instrumentation in endodontics, an important role has been played by reciprocating stainless steel files using horizontal rotational, vertical translational, or combined movements. These kinds of systems are still in use mainly as an accessory to help in the first phases of the treatment. **Methods:** The literature concerning these systems has been analyzed using selected criteria. **Results:** The latest evolution of horizontal rotational reciprocating movement brought to the development of a different kind of movement in which the angles are asymmetrical and that appears to be ideal in conjunction with modern nickel-titanium (NiTi) files with a greater taper. Initially, this movement was limited to particular handpieces available on the market that was used with existing NiTi files to complete root canal instrumentation. Later on, specific files and proprietary motors were introduced into the market. The differences between reciprocating motion used for NiTi and stainless steel files are described and critically analyzed. **Conclusions:** A classification of the different mechanical reciprocating motions used is presented, thus enabling an easier understanding of these systems and anticipated future developments. *(J Endod 2015;41:1778–1783)*

Key Words

nickel-titanium instruments, reciprocation, review, root canal preparation, stainless steel instruments

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Reciprocating motion (RM) is a recent innovation in nickel-titanium (NiTi) instrumentation systems that claim to better resist instrument separation, thus permitting easier treatment and thereby shortening the learning curve for NiTi file systems. RM had been extensively used with stainless steel (SS) files in the development of endodontic mechanical instrumentation. However, RM applied to NiTi files has many differences from the one used with SS.

This article reviews the mechanical instrumentation of root canals (RCs) beginning with SS reciprocating files (RFs) and their evolution up to the latest applications of RM to greater taper NiTi files.

Literature Search Methodology

A search of the existing literature was performed on PubMed, Cochrane Library, Web of Science, and EMBASE electronic databases. The key words used were "Reciprocating"; "Reciprocation"; "Oscillating"; "Oscillation" combined with "Mechanical" AND "Preparation"; "Mechanical" AND "Instrumentation"; "Instruments"; "Files"; and "Technique." The research was limited to dental publications and articles written in English, and no time limits were given to the research. An additional hand search was extensively performed in the *Journal of Endodontics*; *International Endodontic Journal, and Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*; *Australian Endodontic Journal*; *British Dental Journal*; and *Journal of American Dental Association* with subject matter expertise by the citation of selected studies and available review articles. After the removal of duplicate articles, title review, and abstract selection, full-text articles were retrieved to verify that the topic was pertinent. Selected articles were reviewed by the authors, and inclusion criteria were that the articles should analyze any kind of oscillating or reciprocating endodontic instruments.

Evolution of Reciprocating Motion in Endodontics: Historic Perspective

The Early Era of Mechanical Instrumentation

Mechanical instrumentation of the root canal space has been an early objective of endodontic science, beginning in the 19th century when pioneers were trying to develop endodontic mechanical instruments (1). In 1912, Kerr Company had in its catalogue "K"-style rotary "broaches" made of carbon steel to be activated by treadle-type, foot-powered handpieces (1). The first endodontic motor in the market, introduced around 1925, can be considered the Endocursor (W&H, Burmoos, Austria), which allowed the use of conventional K or Reamer SS files with a complete 360° rotating motion combined with vertical strokes (1). The main problem with SS instruments was the intrinsic stiffness that did not permit the instruments in continuous rotation to enlarge the entire canal to the working length without avoiding procedural errors (2, 3).

Rotary SS root canal instruments, such as Gates Glidden and Peeso reamers, can be safely used only in the coronal and sometimes the middle third of relatively straight RCs (4–6). For this reason, RM that has the same reciprocating angle in both directions was successfully introduced. This type of reciprocation can be defined as *complete* *oscillating reciprocation* (Fig. 1), resembling the classic watch-winding movement used with manual SS files.

Different handpieces were manufactured initially in the 1960s including the Giromatic (MicroMega, Besancon, France), which was designed to reciprocate at 90°. The first files designed for this handpiece resemble a barbed-broach design (2); then, the same manufacturer dedicated other files (Giro-reamer and Giro-file) for this motor. Similar handpieces were the Intra-Endo 3 LD (KaVo, Biberach, Germany), which works with an alternating 80° horizontal rotational movement and the Dynatrak system (Dentsply DeTrey, Konstanz, Germany). Usually, these motors reciprocate at a higher speed between 3000 and 6000 reciprocations/min for greater efficiency. Contemporaneously, a sonic version of the handpiece to be used with similar instruments, such as the Micro Mega 1500 Sonic Air Endo System (7–9), was introduced.

The end results of shaping were similar to a classic manual approach (2, 10, 11); however, a higher incidence of root canal iatrogenic errors was observed (12–19). Recently, a system based on SS files used in complete rotation was commercialized as EndoFlash (KaVo, Biberach, Germany), but it exhibited poor results in terms of root canal preparation (20, 21) even though it showed adequate canal cleanliness (22). Nevertheless, it was rapidly replaced by the new torque control systems for NiTi rotary files, the EndoAdvance (KaVo) (23).

Contemporaneously with reciprocating handpieces, vertical stroke handpieces were introduced into the market. The Racer (Cardex, Klagenfurt, Austria) was released in 1958, with an amplitude of 1 to 2 mm vertically. The Canal Finder System, introduced by Lévy (24, 25), delivered a vertical stroke of 0.3 to 1 mm. The amplitude of the stroke was inversely related to resistance during instrumentation. If a forward motion (ie, toward the apex) was not possible (it would stop in the canal), a 90° degree horizontal rotational RM would replace the vertical stroke. With moderate resistance, the file had a forward motion plus RM, but if the torque became too strong, the handpiece would stop the file movement. Many similar handpieces with the same principle have been manufactured around that time, including the Excalibur (W&H), which mixed horizontal rotational movements with multilateral pendulum oscillations; the Canal-Leader 2000 (SET, Olching, Germany), which used a helicoidal motion combining vertical movements (0.4 to −0.8 mm) and horizontal rotations (20°−30°); the Endolift (Kerr/SybronEndo, Karlsruhe, Germany) in which the vertical and horizontal oscillations were unencumbered; the Endoplaner (Mikrona, Speitenbach, Switzerland) and the Intra-Endo 3-LDSY (KaVo) in which the horizontal rotational component was 360°; and the EndoPulse system (Société Endo Technique, Marseille, France), which represented the evolution of the Canal Finder, all using the same action.

The overall results regarding the shaping ability and its safety were generally inferior to SS manual root canal preparation (RCP), with a higher frequency of iatrogenic errors, including a tendency for canal straightening (26, 27). Better results in shaping capacity and procedural error incidence were found in the horizontal rotational oscillating Giromatic handpiece compared with others (28), and similar results to the control group prepared by hand instrumentation (29). The Canal Finder was considered useful to remove root canal filling materials (30). In general, reducing the amplitude of the movement toward a smaller oscillation with a higher frequency decreased the incidence of the iatrogenic errors and mechanical damages but often remained higher than SS manual preparation (31–42). It is worth noting that the sound has a frequency between 20 Hz and 20 kHz (43). In dentistry, a vibration is considered *sonic* when the frequency is >1500 Hz (1500 movements per second) and *ultrasonic* when it is >20 kHz (20,000 movements per second) (9, 44), but usually the successively introduced sonic handpieces had a smaller range of the movement compared with high frequency handpieces (eg, Excalibur). The other common observation after RCP with mechanical SS files was that increasing the size of the preparation risked a higher incidence of procedural errors (33–42, 45, 46).

Recently, a new instrument, the Self-Adjusting File (ReDent Nova Ltd, Ra'anana, Israel) was introduced into the market. The "net design" absent a solid metal core and with a sandpaper-like lattice surface gives the instrument the capacity to adapt its shape to the RC walls and to improve the shaping properties, hence the name Self-Adjusting File. The proprietary motor (ReDent Nova Ltd) enables a vertical RM of a 0.4-mm amplitude with a frequency of 3000–5000 vertical reciprocations/min under continuous irrigation (47–49).

The M4 Safety Handpiece (Sybron-Kerr, Orange, CA) is featured by a 30° horizontal rotational RM and a chuck that locks regular hand files. Initially, it was suggested for the entire RCP mounting Safety Hedstrom files (Sybron-Kerr); this system led to better and faster RCP than a step-back application (50, 51). The Endo-Gripper (Moyco/Union Broach; Montgomeryville, PA) and the NSK TEP-E10 R (Nakanishi Inc, Tokyo, Japan) were similar handpieces, with a 45° and 90° horizontal rotational motion, respectively.

Other systems with similar movements have been marketed to achieve a complete shaping of the RC; the Endo-Eze AET system (Ultradent Products Inc, South Jordan, UT) is featured by a 30° horizontal rotational RM as well as the Endo-Express SafeSiders (Essential Dental Systems, South Hackensack, NJ). These systems are equipped with

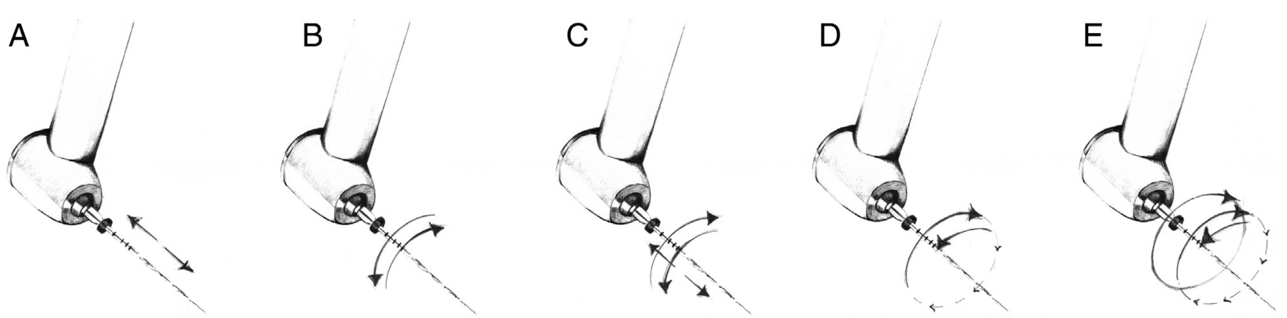

Figure 1. Different types of RM for endodontic instrumentation: (*A*) complete reciprocation with vertical oscillations (Racer and Self-Adjusting File), (*B*) complete reciprocation with horizontal rotational oscillations (Giromatic, Intra-Endo 3 LD, Dynatrak system, M4 Safety Handpiece, Endo-Gripper, NSK TEP-E10 R, Endo-Eze AET system, Tilos system, and Endo-Express SafeSider), (*C*) complete reciprocation with combined oscillations (Canal Finder System, Excalibur, Canal-Leader 2000, Endolift, Endoplaner, and EndoPulse system), (*D*) partial reciprocation with rotational effect (ATR Teknica, WaveOne, WaveOne Gold, and Reciproc), and (*E*) hybrid reciprocation (TF Adaptive/Elements motor).

dedicated files, square K-type files for the Endo-Eze, and modified Hedstrom files for the SafeSider. Recently, the Endo-Eze AET system has been upgraded with accessory NiTi instruments, named the Tilos system (Ultradent Products Inc), to have a hybrid NiTi/SS system used with the same RM. With these handpieces, depending on the speed of the motor, the frequency of oscillation is variable. Originally, a speed from 6000–12,000 rpm resulted in 3000–6000 oscillations per minute (52). The error concerning the angle of reciprocation increases according to the speed used (53).

The Endo-Eze system that has been ideated by Riitano (52) can be considered as a direct upgrade from the sonic handpiece Micro Mega 1500 Sonic Air that used the barbed broach–type Rispi instruments. This technique appears to be the first crown-down motor-driven approach proposed in the market (54). This is an important observation from a historic point of view considering that the first crown-down technique was described in 1880 by Talbot (55) and that the mechanical crown-down is a basic approach of many modern RCP techniques. Controversial results have been found in the literature using the Endo-Eze system. The quality of RCP in oval-shaped RCs was found to be better than for rotary NiTi files (56, 57), and it led to good results for different endodontic obturation techniques (58, 59). However, its limitations include the risk of iatrogenic errors such as apical zips and/or apical perforations in curved RCs (60).

The Endo-Express handpiece and its dedicated SafeSiders instruments showed controversial results regarding RCP. The technique is claimed to be fast, safe, and effective in terms of cutting and root canal filling material removal (61–65). Other studies have reported the possibility of procedural errors caused by metal rigidity of SS, and the results were generally inferior when compared with NiTi instrumentation systems (66, 67).

Other studies assessed the transportation and centering ability of preparations with 90° horizontal rotational reciprocation (NSK TEP-E10R), concluding good overall results (68, 69). Even the use of a M4 handpiece to complete the entire root canal instrumentation exhibited a high prevalence of aberrations and errors, especially in curved root canal configurations (70). Better results were found with the use of an M4 with NiTi-modified Hedstrom files using Endo Gripper with K-flexo SS files (Dentsply Maillefer, Ballaigues, Switzerland) (71).

The Modern Use of SS Files Mounted on Reciprocating Handpieces

Although many of the systems are still in the market, the tendency is to limit the use of SS RFs to the first scouting phase of the RCP to obtain a glide path of the RC. This would minimize the adverse effects of SS files limited by their rigidity. Scientific reports about this kind of SS RF application are still lacking even if the clinical use of these files is widely diffused (72). Recently, special SS instruments called Pathfinders (SybronEndo, Glendora, CA) were introduced in small sizes (0.06- and 0.09-mm tip diameter) with a minimal taper (0.02 mm) and in 2 different metals: carbon steel (CS) and SS. These files are designed especially for the initial phase of canal negotiation in conjunction with a 30° complete horizontal rotational reciprocating handpiece (M4). The stiffer CS alloy should give a higher axial rigidity to the files, thus maintaining a high flexibility. One study showed an overall high fatigue resistance of small SS and CS files (73), which is even higher than that recorded for glide path NiTi rotary files (74–76); these results can be attributed to the different movements of the instruments. Although NiTi has a higher resistance to cyclic fatigue because of its superelasticity (77), the dynamic of the RM applied to these instruments seems to play a major role (78–80). The primary observations regarding SS or CS small files for scouting and negotiation of the RC seem promising, but studies are lacking on how they would behave in calcified and curved RCs (81).

Modern Reciprocation for NiTi Files with Greater Taper

The use of greater taper NiTi files has improved the overall quality of RCP even in the most challenging internal anatomy (1, 83). The main problem with the NiTi rotary instruments has been the fracture rate of these files (82). This “separation” problem can be attributed to its use in continuous rotation (77). In 2004, one study investigated the *endurance limit* (EL) of NiTi files (84); this can be defined as the level of torsional stress or strain at which the file can be subjected to a virtual infinite cycles without failure, where a cycle is intended as a loading stress or strain and releasing (85). This value will be a specific deflection angle (DA) characteristic of each instrument, and it will depend on the size and design features (85).

Virtually each time that a file is cutting dentin in rotation and is constricted inside the RC, there is a certain degree of torsional deformation that develops on its axis; if this deformation is maintained under the limits of the plastic deformation, there will be no structural changes. However, if this repeated cyclic axial deformation is accrued and it is exceeding the EL, the metal will fracture because of torsional fatigue. This mechanism of stress is added to the flexural fatigue that is developed within a curved RC (86). The idea to limit the angle of rotation in the cutting verse under the EL of the instruments led to the development of a movement that could be defined as partial or asymmetrical reciprocation (Fig. 1) with a rotary effect in which the angle of rotation in the cutting verse is higher than the angle of rotation in the opposite noncutting verse. This determines the final rotation of the instrument that will perform a complete turn for a certain number of reciprocating cycles. When first introduced (87), a motor was programmed with this kind of motion (ATR Teknica; ATR, Pistoia, Italy) together with files designed for rotary use (ProTaper F2; Dentsply Maillefer). The angles used were described as four tenths of a circle (144°) in the clockwise (CW) cutting verse and two tenths of a circle (72°) in the

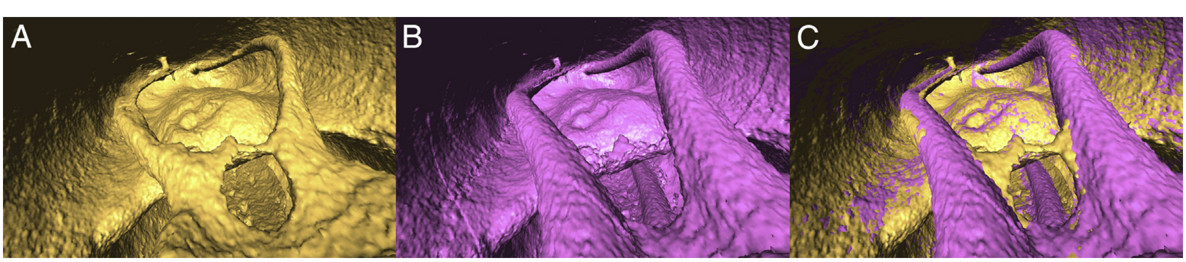

Figure 2. (*A*) Three-dimensional reconstruction of a micro–computed tomographic scan of a mesial root of a mandibular first molar before instrumentation. (*B*) Three-dimensional reconstruction of a micro–computed tomographic scan of the same mesial root after single-file reciprocating instrumentation. (*C*) Superimposition of pre- and postinstrumentation images showing the centering ability of this type of instrumentation technique.

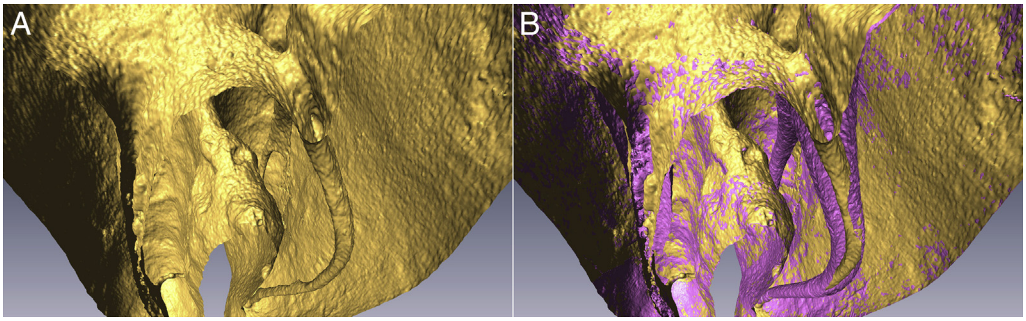

Figure 3. (*A*) Sagittal section of a 3-dimensional reconstruction of micro–computed tomographic scan of a mesial root of a mandibular first molar before instrumentation. (*B*) Superimposition of pre- and postinstrumentation (*pink*) 3-dimensional reconstructions showing the centering ability of this type of instrumentation technique.

counterclockwise (CCW) noncutting verse with a speed setting of 400 rpm. An *in vitro* fatigue test was reported in which the results were encouraging (88). The overall speed of this kind of rotational reciprocation is much lower than the speed used for oscillating reciprocation. Consequently, the rotating effect given by the difference between CW and CCW movements is important to maintain an adequate cutting efficiency and apical progression. It has been speculated that this kind of reciprocation can determine a dynamic of cutting that can resemble the action of the balanced force technique as described by Roane et al in 1985 (89). This dynamic contributes to maintain the instrument centered in the RC, being the cutting force equal on the concave and convex side of the curve (Figs. 2 and 3). The advantage of the limited torsional stress, which is developed on the shank of the files during the cutting action thanks to the limited rotation under the ideal limit of the DA specific for the file, permitted the development of a reciprocating single file (RSF). In an RSF, only one file is used after an initial canal negotiation phase performed by small (0.08- and 0.10-mm tip diameter) SS scouting files to determine the final shape of the instrumentation (90, 91). This approach can be risky for files used in complete rotation because if the file "wedges" in the root canal while rotating it will lead to fracture (87). This modified CW/CCW movement led to NiTi files specifically designed for use in partial reciprocation, such as WaveOne (Dentsply Maillefer) and Reciproc (Dentsply VDW, Munich, Germany). These files are used with different angles in cutting and noncutting verses (150°/30° for Reciproc with an average speed of 300 rpm and 170°/50° for WaveOne with an average speed of 350 rpm) that are predicated on their characteristic EL (92). Discrepancies between the movements that reciprocating motors propel to the files were recorded because variables, such as the delay between the 2 verses movement and the acceleration to reach the desired speed, could play an important role in the efficacy of the different instruments (93). Additional studies are needed to explore this variable. For commercial reasons, the cutting direction of these flute-designed NiTi files is in the CCW direction, but it is CW for all other rotary NiTi files (93). Both techniques are intended as single-instrument techniques in which after an initial scouting of the RC and a clinical evaluation of the average dimension, only an RSF is used to obtain the final shape. The RSF aims to obtain a basic shape of the RC in place of a series of different files; occasionally, it might be necessary to use additional instruments to clean the apical third and the fins of the RCs (94). An RSF is subjected to a certain amount of mechanical stress during use that is distributed among a series of different files. For this reason, manufacturers urge a single use for RSF techniques to prevent the increased risk of file separation in case of multiple usages (87). Recently, WaveOne has been upgraded to WaveOne Gold. The kinematics of this system are unchanged, but the section, size, and geometry of the files have been modified to make the file more flexible. The heat treatment of files has been changed from M-wire to gold alloy treatment, which allows a higher flexibility compared with NiTi and the M-wire alloy (95). Reciproc (Dentsply VDW) advertises that it can prepare the coronal and middle thirds of RCs, even without SS files for the scouting procedure and without the establishment of an initial glide path (96). This procedure seems to be clinically useful and safe even in complex canals (97), providing that the clinician adheres to the manufacturing instructions (98).

Another file system, the TF Adaptive with the dedicated motor Elements (SybronEndo), has been commercialized. The feature of this motor is that it changes the kinematics from an interrupted complete rotating movement (600° CW horizontal rotational motion and 0° CCW) to a partial reciprocation (370° in the cutting verse CW and 50° in the noncutting verse CCW) depending on the torsional stresses building up on the shaft of the file. It is claimed that the angles of RM change depending on the torque to which the file is subjected (99). The average speed of the RM is not declared by the manufacturer. This type of movement could be defined as hybrid reciprocation (Fig. 1).

Concluding Remarks

RM is defined as a repeated backward and forward (CW/CCW) movement (100); this reciprocal movement can be applied to many endodontic files, and it has been extensively used in endodontics for many years. There are many variations of RM (Fig. 1), including complete reciprocation (oscillation), partial reciprocation (rotational effect), and hybrid reciprocation (combined movements). Hybrid reciprocation can be fixed or flexible (ie, they can shift from one type of reciprocation to the other in the canal based on mechanical resistance and torque).

This kind of movement has been extensively used for the entire shaping phase with SS instruments. Nowadays, it is still possible to use this mechanical movement with SS files as a tool for initial scouting and glide path establishment phases of the treatment. The evolution of this movement and its application to NiTi instruments with greater taper seem to cover a promising role in the modern endodontic instrumentation of RCS; this is extensively reviewed in the second part of this article.

Acknowledgments

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