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Reciprocating Files in Endodontics

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ABSTRACT

The success of endodontics treatment depends on how well the canal is prepared and disinfected. Ideally the canal should be circumferentially prepared and infected dentin should be removed without weakening the root. Reciprocating files are designed to minimally remove the dentin and reduce the incidence of fracture of the files. This article discusses about the advantages of reciprocating files over conventional files and its uses. Many reciprocating files have been introduced. They reduce the fracture rate compare to continuous rotation files. These files are based on balanced force technique. They may have different or same degree of clockwise and counterclockwise degree of rotation. The degree of rotation is governed by the properties of material used for the manufacturing of the file. This article discusses about the reciprocating files and their effectiveness in preparing the canal.

Key words: Adaptive motion, Clockwise-counter clockwise, Reciprocating motion, Dentinal defects

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INTRODUCTION

As the old adage goes, what we remove is more important than what we fill in the canal, it holds good even today. The canal should be prepared thoroughly without undue removal of dentin and at the same time not retaining the infected dentin. Instrumentation goal should also include with maintaining the natural anatomy of the root canal to fill the canal imperviously to get a microbe tight seal. Rotary instruments are designed to work in clockwise rotation. Continuous rotary files are consider to be more prone to fracture because of torsion and fatigue through flexure. These disadvantages can be overthrown by reciprocating files which have differing degree of clockwise and counterclockwise rotation and not full rotation. This degree of clockwise and counterclockwise rotation is driven by the properties of the metal of the file [1-3].

Balanced force technique

While the balanced force technique primarily had the greater angle of rotation in counterclockwise against the spiral directions which are basically the key of balanced force to cut the root dentin, the greater angle in the reciprocating movement has to be inwards in line with the flutes beneficial to move a rotary into the canal. The balanced forces technique permits us to enlarge beyond the canal curvature without creating disagreeable results [1,4-6].

The cutting edges incline down a K-type file shaft at almost 45 degrees from the vertical axis. By standardized guidelines, the circumradius increases from the tip toward the handle and the flutes spiral clockwise. The result is simply that a load released by clockwise rotation pulls away from the operator moves the instrument apically and pulls away from the operator, while a load released by counterclockwise rotation moves the file out of the canal and pushes toward the operator. As a consequence of this, the operator may feel the total of all forces in the course of counterclockwise rotation, torque plus outward movement, while he or she feels only the torque portion of a clockwise rotation [2,3,7-10].

Reciprocating movement, in terms of switching the direction of rotation, seems to mimic the balanced force technique, which preserves the curvature of the root canal with minimal distortion. Reciprocation was introduced first in the year1964 by the Giromatic system (MicroMega). Reciprocating motion is a interrupted rotation, originally instrument moved in the direction of cutting (counterclockwise), followed by a minor rotation in the release direction (clockwise) [11-14].

In 2008 Yared, put forward the oscillatory and rotational movement, which enhances the resistance to flexural fatigue in a nickel-titanium instrument when compared to the continuous rotation movement, because the anti-clockwise rotation is greater than the hourly rotation (disengagement), resulting in a Screw compression

effect, with depletion of compression forces conducive to the occurrence of elastic deformation, and of torsional fracture by engaging of its tip. The alternation of tensile and compressive stresses duringthe continuous rotation of instruments may lead to cyclic fatigue failure [15-19].

The motors are preset with specific angles for clockwise(CW) and counter-clockwise (CCW) rotations for Reciproc. When the instrument rotates in the cutting direction it will move forward in the canal and engage dentine to cut it before the instrument will rotate in the opposite direction to ensure unlocking of the file. This movement contributes to maintain the instrument remain in the center of the root canal, being the cutting force equal on the concave and convex side of the curve [20-22].

Reciprocating files have cutting action in clockwise or counterclockwise rotation. Few systems cut counterclockwise (Reciproc – VDW; Reciproc Blue – VDW; Wave One – Dentsply Sirona; Wave One Gold– Dentsply Sirona; Pro Design R – Easy; Unicone–MK Life; X1 Blue File – MK Life), there are other systems with clockwise cutting action (Genius–Ultradent, Pro Design S–Easy). The angles of files rotation range from roughly 60° to 90° clockwise and 120° to 270° counterclockwise.

Uses of greater taper

A complete elimination of pulp tissue, debris, cariogenic bacteria and infected dentin filings can be achieved by the componded cleaning effect of instrumentation with files and chemical irrigation. We can prepare a root canal by employing files of the same taper but with different apical tip diameters or different or graduating tapers. The concept behind variable or graduating tapers is that every subsequent file will only interlock a least possible aspect of the canal wall. Hence, frictional resistance is lessened and will need less torque to correctly run the file [23-26].

Continuous rotation files

Compressive and tensile stresses accumulate in one area because the file does not move axially (back and forth). These progressive stresses generate microstructural changes in the file. . Lately, a new kind of rotary motion, asymmetrical rotary motion, has been introduced. Asymmetrical rotational motion (waves of motion going along the active part of the instrument) is formed by contour features of the file, as well as having an off-centred cross section that is not related to endodontic motors. The offset designed files give rise to a mechanical wave of motion that disseminate along the entire length of the NiTi file which enhance cutting and removing the debris in comparison with a centered mass rotating instrument. Furthermore, this offset design reduces the taper lock or the screwing effect which causes instrument separation [11,27-29].

Passive and active fixed-taper NiTi files

Active instruments have active cutting blades similar to the K-FlexoFile, whereas passive instruments have a radial land between cutting edge and flute. Disadvantage of these systems is taper lock and the resultant screw effect. To reduce taper lock and the eventual screwing effect related to both passive and active fixed tapered Ni-Ti cutting instruments, EndoSequence (Brasseler USA) and BioRaCe (FKG Dentaire) produce file lines with alternating contact points. A negative or a "considerably neutral" rake angle brings about a scraping instead of cutting action. The optimal rake angle is slightly positive but not very much positive. An excessively positive rake angle will create digging and gouging in the dentin. Active instruments cut more effectively and more aggressively, and have a tendency to straighten the canal curvature (Figure 1) [13,29-31].

Reciprocating files

It may be defined as any repetitive up-and-down or back-and-forth motion. Instrument systems rotate in centric reciprocating motion, rotating at first counterclockwise (Reciproc 150°, Wave One 170°) to slice off dentin and clockwise (Reciproc 30°, WaveOne 50°) to remove it, so as to avoid the screw-in effect that happens with some continuous rotary systems. The angles of rotation were measured to be less than the degree required for fracture

Group	Rotary File	Enlargement Potential	Preparation Errors	Fracture Resistance	Clinical Performance
I Radial-landed 	ProFile[1], ProSystem GT[1], Quantec[2], Guidance[3], K3[2]	+, Depending on sizes, often time consuming	++ Low incidence, usually <150 µm canal transportation	+/- Fatigue + Torsional load, depending on system	++ Good, depending on treatment conditions. No difference between rotaries shown so far, except for inexperienced clinicians
II Nonlanded 	ProTaper[1], Pow-R[4], RaCe[5], Sequence[6]	+/-, Good with use of hybrid techniques	+/-, Overall more demanding of clinician's ability	+ Fatigue +/- Torsional load, depending on taper, handling	
III Others	LightSpeed & LSX[7], EndoEZE AET[8], Liberator[9]	Varies, + with LightSpeed	++ LightSpeed, - Other systems	Varies	Varies

++ Good + Adequate - Problematic +/- Undecided

Figure 1: Source: Colleagues for excellence published for the dental professional community by the american association of endodontists winter 2008 rotary instrumentation: An endodontic perspective [13].

of the instrument in case it binds to dentin that is the CCW reciprocating angle should be less than the elastic limit of the material used for each system, thus making for a safer technique. The reciprocating systems are used in a lateral brushing motion. The idea behind these systems is that there is a quick repetitive process of engagement and disengagement of the file with the wall of the root canal through the definite clockwise and counter clockwise movement as it effectively rotates through 360 degrees. This reduces load on the endodontic file and allows it to follow the canal without difficulty. Torsional stress is lowered by warding off binding of the file, and safety is enhanced. A reciprocating motion may reduce the effect of cyclic fatigue on NiTi rotary instrument life in contrast with rotational motion. It has been proposed that the increased resistance to fatigue occurs due to the release of reactionary stresses that get built within the material by reversing the direction of rotation. Te CW and CCW reciprocating angles are specifc for the endodontic reciprocating systems, and the CCW reciprocating angle should be smaller than the elastic limit of each system material [17,25,32-34].

Majority systems cut in a counterclockwise (Wave One–Dentsply Sirona; Wave One Gold–Dentsply Sirona; Pro Design R–Easy; Reciproc–VDW; Reciproc Blue–VDW Unicone–MK Life; X1 Blue File–MK Life), even though there are systems with clockwise cutting action (Genius–Ultradent, Pro Design S – Easy).

Cyclic fatigue

The cross-section that had the best resistance to cyclic fatigue was the double-S cross-section of Reciproc and Reciproc Blue. Different cross-sectional design of the instruments that is, Reciproc instruments have an S-shaped cross-section with two cutting blades whereas Reciproc blue (VDW GmbH, Munich, Germany), a thermally treated nickel—titanium instrument, s-shaped cross-section. Limiting the angle of rotation in the cutting direction under the tolerance limit of the instrument resulted in the development of a movement that could be defined as partial or unequal reciprocation, in which the angle of rotation in the cutting direction is more when compare to the angle of rotation in the opposite non-cutting direction [35-39].

Limiting the angle of rotation in the cutting direction to more than the angle of rotation in the opposite noncutting direction averts the taper lock phenomenon. Thus, torsional stress is reduced by limiting binding of the file, and safety is enhanced. Reciprocating movement in itself was able to increase the cyclic fatigue resistance of several NiTi instruments when compared to rotary motion. many factors significantly affect the cyclic fatigue resistance of files, anatomic variations, such as double curves in the root canal, are of particular importance. The irrigant did not have any influence on the cyclic fatigue on continuous or reciprocating files. The cross-sectional shape of the files might be another factor contributing to the cyclic fatigue resistances.

Debris removal

The different cross-sectional geometry may lead to increased space between the file and the dentinal walls, allowing more coronal flow of the dentinal debris. Files with triangular cross section like Protaper universal has better debris extrusion compared to Protaper next which has rectangular geometry [16,35].

Debris extrusion

The continuous rotating files showed better results than the reciprocating files. They produced less debris and smear layer, also multiple files preparation when compared to single file reciprocal systems. Amount of apical debris extruded can be related to the root canal anatomy, shape and number of root canals. Regardless of the systems used, all rotary file techniques lead to debris extrusion [40-43].

The number of instruments and the kinematics may contribute to debris extrusion during the instrumentation technique. Comparisons between single-file systems in continuous rotation and reciprocating motion showed less apical debris extrusion with continuous rotation systems [44-49]. While all staging techniques can cause apical extrusion of debris, the amount of debris extrusion in the periapical region may vary based on the method used. Wider angle of rotation in the cutting direction (counter-clockwise) of the WaveOne system with the lower depths of its grooves, this may explain the reduced performance in relation to debris removal during instrumentation. Few studies indicating that files with larger taper could be associated with greater levels of extrusion.

Maintenance of root canal anatomy

Creation of a glide path prior to instrumentation with any NiTi rotary or reciprocating motion is needed to maintain the normal anatomy of the canal. A glide path is produced when the file will enter from the canal orifice passing smoothly in a line by the entire length of the canal walls till the apical terminus in a easy, repeatable, and expected manner [50-53]. Preparations in curved canals showed remarkably more asymmetrical than straight canals. Regarding the centering ability, no single system was superior to the others regardless of canal anatomies [54-57].

Dentinal defects/cracks

Continuous rotation instruments generate more dentinal cracks in comparision to reciprocating motion, thus making them a better option [58-61]. The greater tapers rotary files with tend to generate more stresses into the root dentine when used for canal instrumentation, therefore contributing as one of the reason for crack formation in root dentin. M-wire and R-phase technologies NiTi files created lesser incidence of dentinal microcracks, particularly in the apical third.

Different types of reciprocatory movements' include

The term reciprocating motion includes several possible movements and angles, each of which may influence

the performance and resistance to failure of NiTi instruments. The original Giromatic handpiece (Micro Mega, Besanc¸on, France) and the more recent M4 motor (SybronEndo) have the same angles in CW and CCW, whereas the Tecnika motor (ATR, Pistoia, Italy), which was used, has a specific reciprocating movement with a CW angle that is approximately twice as large as that of the CCW.

Vertical (in-out) only reciprocation like Racer (Cardex, Austria) and Self-Adjusting file (ReDent Nova, Israel)[50].

Complete reciprocation-Horizontal: There is no completion of any rotations and also no vertical movements [51-53]. Giromatic (MicroMega), M4 Safety hand piece (Sy-bronEndo). This type of reciprocation can be defined as complete oscillating reciprocation, similar to the classic watch-winding movement used with manual SS files [54-57].

Complete reciprocation with vertical oscillations: Canal-Finder (Fa. Societe Endo Technique, Marseille, France) introduced by Lévy. Reciprocating handpieces, vertical stroke handpieces were introduced. The range of the stroke was inversely related to opposition during instrumentation [58-61]. If a forward motion (i.e., toward the apex) was not possible (it would stop in the canal), a 90 degree horizontal rotational RM would substitute the vertical stroke.

Partial reciprocation: Complete rotations completed, dependent on dissimilar angles of reciprocation. Edge One Fire (EdgeEndo) and Wave-One Gold (Dentsply Sirona [46].

Hybrid reciprocation [23,24,30]: TF Adaptive System (Sybron-Endo) that can interrupt continuous rotation (CR) (600° CW cutting motion) with 50° CCW movement depending on whether undue torsional stresses are detected. The innovative automatically adapts to instrumentation stress. Studies have reported higher fatigue resistance than Reciprocating files. T. F Adaptive files significantly produced the least transportation and a better centering ratio.

Bacterial reduction [21,36]: Both single-file reciprocating systems and rotary systems were effective in reducing more than 95% of endotoxin contents from root canals that were primarily infected with no significant statistical differences between them found in the baseline samples. In addition, different tip sizes and tapers has been reported to result in similar bacterial counts [56].

Maintenance of root canal anatomy [45]: The amount of dentine to be removed in cervical and medium thirds should be sufficient enough to allow irrigating solutions to access and reach the apical third. At the apical third, particularly at the foramen, preparation should not cause iatrogenic errors like deviation or zipping and even perforations. Centering ability of file is determined by instrument design (taper, flexibility and cross-section).

Dentinal defects/cracks [38,44,49]: The total volume of dentin removed from root canals is significantly greater with NiTi engine driven systems when as opposed to hand filing, this may furthermore increase the chances of formation of the defects. The taper of files used for canal preparation could contribute to the formation of dentinal cracks. The greater the taper, the more root dentin is removed and the greater the chances of root fracture to occur.

Effect of preparation with reciprocating instruments on canal length [7,10,11]: Working length (WL) reduction is greater immediately after coronal flaring as oppose to late coronal flaring prior to apical preparation. It is highly recommended to check the WL at least two times during root canal shaping; an initial check is recommended during canal scouting. A second check of the WL is recommended after canal flaring, prior to preparation of the apical portion of the root canal, because the high likelihood for WL to undergo significant changes [24,25].

Clinical efficiency [8,12,13]: The rotary shaper files cut largely in the coronal two thirds, whereas the rotary finishers cut largely in the apical third. However, the reciprocating file continues to cut along its entire length, with file engagement increasing as canal penetration continues. Thus, as the tip reaches the apical two thirds, the coronal part is still being shaped. As a result, the file may work against itself in extracting debris from the tooth [1].

It has been reported that the greater the cross-sectional area is, the more flexural and torsional stiffness, in this way, file design (cross-sectional shape, diameters of core, etc) will significantly affect the torsional and bending (hence, fatigue) resistance.

Waveone

These files have left handed threads instead of usual right handed threads and reversed helix so CCW rotations engage the file whereas CW rotation disengages the file the tips are modified (non-cutting) to follow canal curvature precisely. The variable pitch flutes along the length of the instrument significantly improve safety. CCW rotation facilitates forward movement of the instrument, engaging and cutting the dentine. CW movement disengages the instrument from the dentine even before it can lead to taper lock into the canal [14-16].

As the instrument begins to rotate in one direction (usually the larger angle) it cuts and becomes engaged into the canal wall then it disengages in the reverse direction (usually with the smaller angle) and the stresses are eventually reduced [29].

Another advantage of forward reciprocating motion over continuous rotation is that it may reduce root canal irregularity [17].

ProTaper Next (PTN) (Dentsply Sirona) is a rotary root canal-shaping system made up of of M-Wire NiTi, having a bilateral symmetrical rectangular cross-section, with an offset from the central axis of rotation (except in the

last 3 mm of the instrument (D0–D3), allowing it to go through a rotational situation known as precession or swagger. In terms of mechanical properties, ProTaper files have a convex, triangular cross-section and due to variable taper along their cutting blade as well as the presence of sharp edges (with positive cutting angles around 60° in size), they have a tendency to remove more dentin from the external wall of the curved canals. Such a tendency for proceeding in a straight path, in combination with lower flexibility than WaveOne Gold, explain further deviation from the canal curvature.

There are many variations of rotary motion, which includes complete reciprocation (oscillation), partial reciprocation (rotational effect), and hybrid reciprocation (combined movements). Hybrid reciprocation could be fixed or flexible (i.e., they can move from one kind of reciprocation to the other in the canal depending upon mechanical resistance and torque) [11,12]. Also, the angle of clockwise and counterclockwise rotation varies with different files. This situation might also influence the cyclic fatigue resistance of reciprocating files [18].

The hand files have reverse-cut triangular flutes and the rotary files have clockwise 'U-blade' flutes. The push-pull movement of a file requires the more horizontal flute orientation to pull cleaved dentin from the canal. Once these horizontal flutes are engaged with a rotary or reciprocating motion, their ability dramatically reduces because they are removing very less dentin while engaging the tooth far more. Greater engagement does not necessarily mean greater efficiency.

Left-leaning flutes; hence, the cutting direction for both is clockwise. One difficulty that can occur with this design is the transportation of dentin debris into the apical area, instead of moving debris coronally. Clinically, frequent careful removal of debris from the cutting blades with a moist gauze is suggested. Angle of rotation clockwise is less than anticlockwise to avoid screwing in effect.

Generation of NiTi files

First generation: NiTi files in usually have passive cutting radial lands and constant tapers of 4 and 6 per cent along the length of their active cutting blades. The main drawback of this generation of NiTi rotary instruments is the need for more files to reach these goals and difficulty. eg. LightSpeed Endodontics (1992), Profile-Dentsply (1993), Quantec-SybronEndo (1996), and GT system-Dentsply (1998) [8,15,16].

Second generation

They have active cutting edges and thus require fewer instruments to prepare a canal fully. Many second generation systems had positive rake angles which had considerable cutting efficiency. NiTi files of this type are ProTaper rotary files, K3 system, Mtwo, Hero Shaper, EndoSequence, and BioRaCe.

Third generation

Recently, a new NiTi wire (termed M-Wire) has been developed through a proprietary thermomechanical processing procedure and showed significantly improved cyclic fatigue resistance on endodontic rotary instrument products (GT series X and ProFile Vortex [Dentsply Tulsa Dental, Tulsa, OK]) in comparison with those made of regular superelastic NiTi alloys. According to the latest study on the metallurgical characterization of M-Wire), M-Wire contains all 3 crystalline phases, including deformed and microtwinned martensite, R-phase, and austenite.

Fourth generation

The use of reciprocating motion was shown to ultimately increase the life span of NiTi instruments in comparison with continuous rotation The recommendation for single use has the extra benefit of reducing instrument fatigue, which is an even more significant with WaveOne files, as one file does the work traditionally performed by three or more rotary NiTi files [33].

Fifth generation: Offset cross-sectional design

The offset designed files form a mechanical wave of motion that distributes along the entire length of the NiTi file which better preparation and bring out the debris in contrast with a centered mass rotating instrument. Moreover, this offset design decreases the taper lock or the screwing effect which can lead to instrument separation [11-13].

Combined movements (centric rotary + reciprocating)/ adaptive motion

When the amount of stress on the file is minimal, the file uses continuous rotation. Once it runs upon dentin and a load is applied, its motion changes to reciprocating. The idea behind this is that this adaptive motion and twisted file design improves the flexibility of the instrument and permits the file to adapt to intracanal torsional forces, based on the amount of pressure load on the file [3,4,6,17-19].

Eccentric rotary motion

Few systems, because of the characteristics of their instruments, spin eccentrically or asymmetrically (i.e., the rotational axis is off-center). The file design has an asymmetric cutting axis. An eccentric NiTi file can cut marginally outside of its central axis of rotation and needs lesser torque because the flutes while cutting can disengage through the axis of the canal, and all cutting edges are not engaged simultaneously [7,19-21].

Self-adjusting file (SAF)

The SAF is a file which is hollow designed as a compressible, fragile-walled pointed cylindrical either 1.5 or 2.0 mm in diameter made up of 120- mm-thick nickel-titanium lattice. It is operated with a special RDT handpiece-head and an irrigation pump (either the VATEA pump or the all-in-one EndoStation unit) that delivers a continuous flow of irrigant through the hollow file. This instrument is driven with reciprocational vibratory handpieces. It adapts itself to the shape of a canal both longitudinally and along the cross-section [19,20].

CONCLUSION

Regardless of the instruments used for canal preparation the canal has to be prepared the canal circumferentially and ideal amount of dentin must be removed to remove as much as infection possible by canal preparation. The debris should not be taken beyond the apex to avoid post-operative pain. Reciprocating files have the advantage of reduced file separation and better circumferential canal preparation and reduced chances of unprepared surfaces on the walls of the canal. No instrument is ideal for root canal preparation. The astute clinical should choose the best system suitable depending upon the anatomy, working length, status of the pulp and canal. Studies have shown that the fatigue resistance of reciprocating files is more than continuous rotation files and the chances of fracture will be eventually less, but there is more extrusion of debris with reciprocating files.

CONFLICT OF INTEREST

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REFERENCES

1. Van der Vyver PJ, Jonker C. Reciprocating instruments in Endodontics: A review of the literature: Clinical review. South African Dent J 2014; 69:404-409.
2. Gavini G, Santos MD, Caldeira CL, et al. Nickel–titanium instruments in endodontics: a concise review of the state of the art. Br Oral Res 2018; 32.
3. Tomson PL, Simon SR. Contemporary cleaning and shaping of the root canal system. Prim Dent J 2016; 5:46-53.
4. Junior EC, Da Fonseca TS, Da Frota MF, et al. Cleaning capacity of hybrid instrumentation technique using reamer with alternating cutting edges system files: Histological analysis. Contemp Clin Dent 2014; 5:203.
5. Ruddle CJ, Machtou P, West JD. The shaping movement 5th generation technology. Dent Today 2013; 32:94.
6. Buchanan LS. The standardized-taper root canal preparation–Part 1. Concepts for variably tapered shaping instruments. Int Endod J 2000; 33:516-529.
7. Shivakumar AT, Kalgeri SH. Peregrination of endodontic tools-past to present. J Int Clin Dent Re Organization 2016; 8:89.
8. Kuzekanani M. Nickel–titanium rotary instruments: Development of the single-file systems. J Int Soc Prev Community Dent 2018; 8:386.
9. Walsch H. The hybrid concept of nickel–titanium rotary instrumentation. Dent Clin 2004; 48:183-202.
10. Ye J, Gao Y. Metallurgical characterization of M-Wire nickel-titanium shape memory alloy used for endodontic rotary instruments during low-cycle fatigue. J Endod 2012; 38:105.
11. Venkateshbabu Nagendrababu BD, Ahmed HM. Shaping properties and outcomes of nickel-titanium rotary and reciprocation systems using micro-computed tomography: A systematic review. Quintessence Int 2019; 50.
12. Özyürek T, Yılmaz K, Uslu G. Effect of adaptive motion on cyclic fatigue resistance of a nickel titanium instrument designed for retreatment. Restor Dent Endod 2017; 42:34-38.
13. Peters OA. Rotary Instrumentation: An Endodontic Perspective. AAE Colleagues for Excellence Series 2008.
14. Bergmans L, Van Cleynenbreugel J, Wevers M, et al. Mechanical root canal preparation with NiTi rotary instruments: Rationale, performance and safety. Am J Dent 2001; 14:324.
15. Peters OA, Paqué F. Current developments in rotary root canal instrument technology and clinical use: A review. Quintessence Int 2010; 41.
16. Ruddle CJ. Finishing the apical one third: Endodontic considerations. Dent Today 2002; 21:66-73.
17. Mittal S, Kukreja N, Chaudhary D, et al. Sword of endodontist: A Review. Dent J Adv Studies 2014; 2:118-124.
18. Shen Y, Zhou HM, Zheng YF, et al. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013; 39:163-172.
19. Nasseh A. Three dimensional anatomic cleaning and shaping. Dent Today 2017; 36:1.
20. Van Der Vyver P. The waveone reciprocating endodontic system. Int Dent 2013; 3:6-20.
21. Webber J, Machtou P, Pertot W, et al. The WaveOne single-file reciprocating system. Roots 2011; 1:28-33.
22. Zubizarreta-Macho Á, Albaladejo Martínez A, Falcão Costa C, et al. Influence of the type of reciprocating motion on the cyclic fatigue resistance of reciprocating files in a dynamic model. BMC Oral Health 2021; 21:1.
23. Plotino G, Grande NM, Testarelli L, et al. Cyclic fatigue of reciproc and WaveOne reciprocating instruments. Int Endod J 2012; 45:614-618.
24. Yared G. Reciproc blue: The new generation of reciprocation. Giornale Italiano Endod 2017; 31:96-101.
25. Dagna A, Gastaldo G, Beltrami R, et al. Debris

evaluation after root canal shaping with rotating and reciprocating single-file systems. J Funct Biomater 2016; 7:28.

26. Uzun I, Güler B, Özyürek T, et al. Apical extrusion of debris using reciprocating files and rotary instrumentation systems. Nigerian J Clin Pract 2016; 19:71-75.
27. Saberi EA, Ebrahimipour S, Saberi M. Apical debris extrusion with conventional rotary and reciprocating instruments. Iranian Endod J 2020; 15:38-43.
28. Berutti E, Paolino DS, Chiandussi G, et al. Root canal anatomy preservation of WaveOne reciprocating files with or without glide path. J Endod 2012; 38:101-104.
29. Christofzik D, Bartols A, Faheem MK, et al. Shaping ability of four root canal instrumentation systems in simulated 3D-printed root canal models. PloS One 2018; 13:e0201129.
30. Aidasani GL, Mulay S, Mehta VP, et al. Dentinal defects in endodontically treated teeth using NiTi rotary vs reciprocating endodontic instruments-A systematic review. J Clin Diagn Res 2017; 11.
31. Pawar AM, Thakur B, Kfir A, et al. Dentinal defects induced by 6 different endodontic files when used for oval root canals: An *in vitro* comparative study. Restorative Dent Endod 2019; 44.
32. Sawant K, Pawar AM, Banga KS, et al. Dentinal microcracks after root canal instrumentation using instruments manufactured with different NiTi alloys and the SAF system: A systematic review. Appl Sci 2021; 11:4984.
33. Robinson JP, Lumley PJ, Cooper PR, et al. Reciprocating root canal technique induces greater debris accumulation than a continuous rotary technique as assessed by 3-dimensional micro–computed tomography. J Endod 2013; 39:1067-1070.
34. Berutti E, Chiandussi G, Paolino DS, et al. Effect of canal length and curvature on working length alteration with WaveOne reciprocating files. J Endod 2011; 37:1687-1690.
35. Martinho FC, Gomes AP, Fernandes AM, et al. Clinical comparison of the effectiveness of single-file reciprocating systems and rotary systems for removal of endotoxins and cultivable bacteria from primarily infected root canals. J Endod 2014; 40:625-629.
36. Machado ME, Nabeshima CK, Leonardo MF, et al. Influence of reciprocating single-file and rotary instrumentation on bacterial reduction on infected root canals. Int Endod J 2013; 46:1083-1087.
37. Villela Laurindo F, Poli de Figueiredo JA. Reciprocating versus Rotary instruments: A review. Revista Odont Ciência 2016; 31.
38. Monga P, Bajaj N, Mahajan P, et al. Comparison of incidence of dentinal defects after root canal preparation with continuous rotation and reciprocating instrumentation. Singapore Dent J 2015; 36:29-33.
39. Li SH, Lu Y, Song D, et al. Occurrence of dentinal microcracks in severely curved root canals with ProTaper Universal, WaveOne, and ProTaper Next file systems. J Endod 2015; 41:1875-1879.
40. Alsilani R, Jadu F, Bogari DF, et al. Single file reciprocating systems: A systematic review and meta-analysis of the literature: Comparison of reciproc and WaveOne. J Int Soc Prev Community Dent 2016; 6:402.
41. Jin SY, Lee W, Kang MK, et al. Single file reciprocating technique using conventional nickel–titanium rotary endodontic files. Scanning 2013; 35:349-354.
42. Roane JB, Sabala CL, Duncanson MG. The "balanced force" concept for instrumentation of curved canals. J Endod 1985; 11:203-211.
43. Çapar ID, Arslan H. A review of instrumentation kinematics of engine-driven nickel–titanium instruments. Int Endod J 2016; 49:119-135.
44. Espir CG, Nascimento-Mendes CA, Guerreiro-Tanomaru JM, et al. Counterclockwise or clockwise reciprocating motion for oval root canal preparation: a micro-CT analysis. Int Endod J 2018; 51:541-548.
45. Grande NM, Ahmed HM, Cohen S, et al. Current assessment of reciprocation in endodontic preparation: a comprehensive review—part I: historic perspectives and current applications. J Endod 2015; 41:1778-1783.
46. Giuliani V, Di Nasso L, Pace R, et al. Shaping ability of WaveOne primary reciprocating files and ProTaper system used in continuous and reciprocating motion. J Endod 2014; 40:1468-1471.
47. Silva EJ, Villarino LS, Vieira VT, et al. Bending resistance and cyclic fatigue life of Reciproc, Unicone, and WaveOne reciprocating instruments. J Endod 2016; 42:1789-1793.
48. Al-Obaida MI, Merdad K, Alanazi MS, et al. Comparison of cyclic fatigue resistance of 5 heat-treated nickel-titanium reciprocating systems in canals with single and double curvatures. J Endod 2019; 45:1237-1241.
49. Pedrinha VF, da Silva Brandão JM, Pessoa OF, et al. Influence of file motion on shaping, apical debris extrusion and dentinal defects: A critical review. Open Dent J 2018; 12:189.
50. Ferreira F, Adeodato C, Barbosa I, et al. Movement kinematics and cyclic fatigue of NiTi rotary instruments: A systematic review. Int Endod J 2017; 50:143-152.
51. Silva EJ, Tinoco JM, Tinoco EM, et al. Bending resistance and cyclic fatigue life of a new single-file reciprocating instrument WaveOne Gold. Eur Endod J 2016; 1:1.
52. Higuera O, Plotino G, Tocci L, et al. Cyclic fatigue resistance of 3 different nickel-titanium

reciprocating instruments in artificial canals. J Endod 2015; 41:913-915.

53. Pedullà E, Grande NM, Plotino G, et al. Cyclic fatigue resistance of two reciprocating nickel–titanium instruments after immersion in sodium hypochlorite. Int Endod J 2013; 46:155-159.
54. De-Deus G, Vieira VT, da Silva EJ, et al. Bending resistance and dynamic and static cyclic fatigue life of Reciproc and WaveOne large instruments. J Endod 2014; 40:575-579.
55. Iacono F, Pirani C, Arias A, et al. Impact of a modified motion on the fatigue life of NiTi reciprocating instruments: A Weibull analysis. Clin Oral Invest 2019; 23:3095-3102.
56. Keskin C, Inan U, Demiral M. Effect of interrupted motion on the cyclic fatigue resistance of reciprocating nickel–titanium instruments. Int Endod J 2018; 51:549-555.
57. de Souza Carvalho M, Junior EC, Garrido AD, et al. Histological evaluation of the cleaning effectiveness of two reciprocating single-file systems in severely curved root canals: Reciproc versus WaveOne. Eur J Dent 2015; 9:80-86.
58. Gergi R, Arbab-Chirani R, Osta N, et al. Micro–computed tomographic evaluation of canal transportation instrumented by different kinematics rotary nickel-titanium instruments. J Endod 2014; 40:1223-1227.
59. de Moura JD, da Silveira Bueno CE, Fontana CE, et al. Extrusion of debris from curved root canals instrumented up to different working lengths using different reciprocating systems. J Endod 2019; 45:930-934.
60. Nouri H, Amini K, Jahromi MZ. Comparison of full rotation and reciprocating movements in regaining apical patency during endodontic retreatment. Dent Res J 2021; 18.
61. Gambarini G, Rubini AG, Al Sudani D, et al. Influence of different angles of reciprocation on the cyclic fatigue of nickel-titanium endodontic instruments. J Endod 2012; 38:1408-1411.