Endodontic Instrumentation

Does the Kinematics of the System Matter?

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About the Author

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Instrumentation, for the purposes of cleaning, shaping, and disinfecting the canals of a tooth, is one of the mainstays of modern endodontic treatment. We rely on instrumentation heavily to achieve these purposes. However, it has been shown that instrumentation (of any type) only cleans about 50% of the canal geometry. Yet, we enjoy a clinical success rate of somewhere higher than 90% of the teeth treated. The remainder of the cleaning and disinfecting is done by the irrigation solutions that we employ during endodontic treatment of the tooth. Naturally, it would be preferable if there were one type of instrument, or one movement of an instrument, that would clean, shape, and disinfect the canal to a greater degree than we are currently able to achieve. Unfortunately, to date, all instruments and instrument systems seem to clean the canal to about the same degree. Williamson et al. reported that there was no difference in cleaning ability of EndoSequence (Brasseler USA), ProTaper Universal, or ProFile GT (both from DENTSPLY Tulsa Dental Specialties [DTDS] and DENTSPLY Maillefer). Vaught et al. showed that comparisons between rotary Ni-Ti instruments and stainless steel hand instruments suggest that the manual technique with stainless steel instruments results in an equivalent cleaning ability, or performs even better with significantly less residual debris.

A HISTORICAL BACKGROUND

Originally in the 19th and early part of the 20th century, hand instruments were the only choice. In 1889, William Rollins developed the first endodontic handpiece for automated root canal preparation. This automated handpiece used full rotation and to lessen instrument breakage, the rotational speed was limited to 100 rpm. The next improvement appeared in 1928 when the Austrian company W&H (Burmooos, Austria) brought out the “Cursor filing contra-angle.” This handpiece used a combined rotational and vertical motion of the file. Eventually, endodontic handpieces became popular in Europe with the marketing of the Racer handpiece (W&H) in 1958 and the Giromatic (Micro-Mega) in 1964. The Racer handpiece worked with a vertical motion, the Giromatic with an equal reciprocal 90° rotation. All the endodontic instruments were made of stainless steel at this time. In the 1980s, sonic and ultrasonic handpieces were introduced to the dental marketplace and are still being used in various degrees today. The late 1980s to the early 1990s saw the introduction of the first rotary Ni-Ti files and corresponding handpieces to drive them. Currently, the greatest number of commercially available Ni-Ti files utilized to shape root canals are driven in continuous rotation. However, reciprocation, defined as any repetitive back-and-forth motion, has been clinically used to drive stainless steel files since 1958. From inception, most reciprocating handpieces used an equal 90° reciprocation both clockwise (CW) and counterclockwise (CCW). Throughout time, most reciprocating systems have reduced the envelope of motion to 30° arcs of reciprocation. Currently, the M4 (AxisSybronEndo), Endo-Eze AET (Ultradent Products), and the Endo-Express (Essential Dental Systems) use small, equal, 30° angles of CW/CCW reciprocation.

In 2008, Dr. Ghassan Yared indentified the unequal CW/CCW angles that would enable a single reciprocating 25/08 ProTaper file to shape a canal. Although this specific reciprocation technique stimulated considerable attention, the ProTaper F2 file was never designed to be used in this manner. In 2011, both WaveOne (DTDS and DENTSPLY Maillefer) and RECIPROC (VDW) were launched as single-file shaping techniques that used the unequal reciprocation method. In February of 2015, Essential Dental Systems launched the Tango-Endo system. It is a 2-instrument system using a small 45° angle of equal reciprocation. The instruments are asymmetrical, flat-sided vertical cutting reamers that cut in both CW and CCW directions. The more vertically oriented the cutting edges are (flutes and flats), the less likelihood of causing taper lock and consequently torsional breakage of the instruments in the root canal. These Tango-Endo instruments are specifically designed to be used in the Tango-Endo reciprocating handpiece. The handpiece is a 4:1 reduction with a 45° equal arc of...
reciprocal motion (Figure 2). Since the instruments are designed as modified reamers, they widen or enlarge an existing hole. That is exactly the situation that we have in endodontic treatment. We are widening the existing root canal in order to clean and shape it. The Tango-Endo instruments are specifically designed for maximal cutting efficiency and reduced instrument breakage when used in their equally 45° reciprocating motion handpiece.

It seems that dentists are currently using several methods of instrumentation to achieve debridement and shaping of the canal. We use hand instrumentation, continuous rotation, unequal reciprocation, equal reciprocation, or some combination of any of these to clean and shape the canal. The question is, which method is the best way to achieve our goal of cleaning and shaping? The answer is not so simple. There are a number of factors that must be considered in order to answer this question.

**INSTRUMENT BREAKAGE**

The biggest problem we encounter with instrumentation is breakage of the Ni-Ti endodontic instruments in the root canal. Breakage of the Ni-Ti instruments occurs most often due to one of 2 different causes—either torsional stress due to taper lock or cyclic fatigue. In torsional instrument fractures, the more horizontally positioned the flutes of the instrument are, the easier it is for them to lock into the dentin of the canal wall. If the motion of the handpiece is (continuous) rotary, it tends to screw and lock the file into the wall of the canal. When the torque of the handpiece exceeds the proportional limit of the Ni-Ti file, separation occurs. This type of fracture is characterized by plastic deformation of the instrument, followed by breakage. Usually the last 3 to 4 mm of the instrument breaks off in the apical end of the canal. The broken piece is now threaded into the wall of the canal. This is a difficult situation to correct. Tzanetakis et al. have shown that only about one third of all apically broken Ni-Ti instruments are successfully removed or bypassed.

The second type of instrument breakage is caused by cyclic fatigue. Cyclic flexural fatigue is caused by mechanical loading and metal fatigue, and there is no macroscopic evidence of plastic deformation. Cyclic metal fatigue is a more important cause of instrument fracture in full rotary clinical practice. Repeated bending of instruments in curved canals causes metal fatigue, leading to instrument fracture. Each time an instrument completes one 360° rotation, it goes into both tension and compression during the course of that one rotation. Like a paper clip that is bent back and forth, it soon breaks. The degree of canal curvature and the rotational speed are important factors for metal fatigue of the instruments. The probability of cyclic fatigue fracture increases significantly as the angle of canal curvature increases.

The higher the rpm of the instrument, the more cycles of rotation per unit time it goes through. The more cycles it completes, the quicker the instrument will break. Consequently, the manufacturers generally recommend that rotary Ni-Ti systems should be run at relatively a low rpm (200 to 400 rpm) in order to prolong the life of the instrument. In addition, instruments with greater taper and diameter have a reduced lifespan due to cyclic fatigue. Fracture can also be affected by instrumentation sequence. Instrumentation sequences with various tapers seemed to be safer than a sequence that uses only a single taper, although using various tapers requires more instruments.

Reciprocal kinematics act differently when compared to rotary movement of the instrument with regards to instrument fracture. In a study done by Varela-Patina et al., the authors showed that the torsional fracture risk of the same ProTaper instruments when used under continuous rotation was significantly higher (52.14%/P = .001) compared with use under an alternating rotation (reciprocation). This can be explained by the fact that when preparing a curved root canal, alternating rotation prevents the flutes of the self-threading instrument from locking inside the root canal. Reported in other studies and reconfirmed in a study by You et al., when the endodontic file does not bind in the canal because of the reciprocal motion
of the handpiece, the torsional stress is drastically reduced, which leads to the assumption that the files may be used longer without fracture.

The literature is replete with studies of reciprocation and its effect on cyclic fatigue. However, we must clarify which type of reciprocation. Currently, there are 2 types of reciprocation being used on the market today. The first is static, stationary, or equal reciprocation. This is when the handpiece moves the instrument in equal degrees both CW and CCW (as an example, 30° CW and 30° CCW). In work reported by Shin et al., the authors compared ProTaper F2 instruments in stationary reciprocating and progressive reciprocating motions (Figure 3). The fatigue lives were compared with those under continuous rotation and a reciprocating operation with a forward 144° and backward 72° motion proposed by Yared. Shin et al. found that fatigue life increased with decreasing reciprocating amplitude. Operating in the stationary reciprocating mode increased fatigue life by 355% over that in the continuous rotation. They concluded that fatigue life increased with decreasing reciprocating amplitude in stationary reciprocation. In other words, keep the arc of reciprocating motion small.

The other reciprocal movement is uneven or progressive reciprocation. In this movement, one direction moves a greater amount of degrees than the other direction. In the WaveOne instruments, the CCW movement is greater than the clockwise CW movement. These instruments move 150° CCW and 30° CW. Three reciprocating cycles complete one reverse rotation and the instrument gradually advances into the canal. In effect, for every 3 reciprocating cycles, one rotary cycle is competed. Therefore, this movement is a hybrid movement of reciprocation and rotation.

Kiefner et al. found that when testing RECIPROC and Mtwo files (VDW) in progressive reciprocation, the reciprocating movement increased the cyclic fatigue resistance of the Ni-Ti instruments when compared to continuous rotation. Saber et al. demonstrated that decreasing the reciprocation range of WaveOne instruments resulted in an increased cyclic fatigue resistance with less canal transportation and more centered preparations but with longer preparation times. Confirming Saber et al.'s results, Gambarini et al. stated that if the clockwise angle of reciprocation was increased, which means that the angle of progression is driven more forward for each reciprocating cycle, it would reduce the resistance to cyclic fatigue. Gambarini et al. showed that movement kinematics (reciprocating movements in various angles) had a significant influence on the cyclic fatigue life of the tested Ni-Ti instruments. Many other recent papers all demonstrate that the reciprocating motion, either static or progressive, both increased the cyclic fatigue lifespan of Ni-Ti files when compared to continuous rotation. In simple terms, Ni-Ti instruments broke much less often in reciprocation than in rotation. Secondly, the smaller the arc of reciprocation, the more the Ni-Ti instruments were resistant to cyclic fatigue and breakages. Small back-and-forth movements cause less breakage of instruments. This is true for progressive reciprocation and static reciprocation. Lastly, on the topic of breakage and movement, Turker et al. concluded in their study that even if Ni-Ti is a better alloy for endodontic use, the cyclic fatigue resistance of stainless steel files when used for glide path preparation under reciprocating motion was significantly better than that of Ni-Ti rotary instruments. Since dimensions and design of the tested file were similar, this difference can be related to the different movement kinematics. Therefore, for glide path preparation, perhaps stainless steel instruments in reciprocation are a better choice.

OTHER FACTORS TO CONSIDER
After instrument breakage, there are several other factors that should be considered when selecting an instrumentation...
system to use. One such factor is extrusion of debris into the periapical tissues. Studies examining the apical extrusion of debris have stated that all instrumentation techniques and instruments are associated with the extrusion of debris.\(^3,4\) In a study done by Tinoco et al,\(^5\) the authors stated that all instrumentation systems extruded bacteria beyond the orifice. However, reciprocating single-file systems tested extruded fewer bacteria apically than the conventional multifile rotary system. Dincer et al\(^6\) also showed that the use of a reciprocating single-file system resulted in the extrusion of significantly less debris compared with the full-sequence rotary Ni-Ti instruments and hand filing. On the other hand, Bürklein and Schäfer\(^7\) concluded that, once again, all systems caused apical debris extrusion. However, full-sequence rotary instrumentation was associated with less debris extrusion compared with the use of reciprocating single-file systems. Clearly, more studies need to be done concerning this issue. However, there are many studies\(^8,9\) that do show that both rotary and reciprocals systems reduced baterial counts to a similar level. This is a good result and explains the high clinical success rate of both types of systems in terms of bacterial removal from the canal and treatment outcome.

The popularity of using handpieces to power endodontic instrumentation has dentists concerned regarding the possibility of causing dentin microfractures and their possible consequence of vertical root fracture. It has been accepted by the dental community, because of the abundance of literature, that rotary endodontic instrumentation causes microcracks of the canal walls. Kansal et al\(^3\) reported that dentin cracks were initiated regardless of motion kinematics. However, their study\(^10\) showed the incidence of microfracture formation was less with reciprocating motion as compared to continuous rotation. Several other research groups have also shown that reciprocation may cause less microcracks than rotation.

The shaping ability of the endodontic instruments used in the canal is one of the most important factors to consider when determining which system or combination of instruments to use in order to clean and shape the canals. The study done by McRay et al\(^3\) stated that they do not recommend the use of one file system over the other (rotary ProTaper versus reciprocal WaveOne) when comparing centering ability and transportation. Both instrumentation systems appeared safe for endodontic treatment.\(^3\) Franco et al\(^3\) showed in a study that in order to compare apples to apples used the same FlexMaster Ni-Ti instruments (VDW) in rotation and reciprocation. The results showed that the reciprocating motion produced canals that were more centered when compared with the continuous rotation motion.\(^3\) Gergi et al\(^3\) demonstrated that no Ni-Ti system was able to completely instrument (clean and shape) the root canal system. However, they\(^3\) did demonstrate that reciprocation and adaptive motions cut dentin efficiently with no procedural errors. Many other studies in the literature also verify that reciprocal instrumentation produces well-shaped canals with limited procedural errors and do not differ substantially from canals shaped by Ni-Ti rotary instrument.

**Reference**

5. Yared G. Canal preparation using only one Ni-Ti rotary
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POST EXAMINATION QUESTIONS

1. It has been shown that instrumentation (of any type) only cleans about 28% of the canal geometry.
   a. True    b. False

2. Currently, the greatest number of commercially available Ni-Ti files utilized to shape root canals are driven in continuous rotation.
   a. True    b. False

3. Breakage of the Ni-Ti instruments occur most often due to one of 2 different causes: either torsional stress due to taper lock, or cyclic fatigue.
   a. True    b. False

4. Cyclic metal fatigue is a more important cause of instrument fracture in full rotary clinical practice.
   a. True    b. False

5. Instruments with greater taper and diameter have an increased lifespan due to no cyclic fatigue.
   a. True    b. False

6. Saber et al demonstrated that decreasing the reciprocation range of WaveOne instruments (DENTSPLY Tulsa Dental Specialties and DENTSPLY Maillefer) resulted in an increased cyclic fatigue resistance with less canal transportation and more centered preparations but with longer preparation times.
   a. True    b. False

7. Studies examining the apical extrusion of debris have stated that all instrumentation techniques and instruments are associated with the extrusion of debris.
   a. True    b. False
8. The greater the reciprocal arc of instrumentation, the less likelihood of instrument breakage.
   a. True  b. False
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