In vitro analysis of efficiency and safety of a new motion for endodontic instrumentation: TF Adaptive

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_Introduction

The introduction of the nickel-titanium (NiTi) alloy in endodontics was a significant improvement, allowing good results in terms of cleaning and shaping of root canals, while reducing operative time and minimising iatrogenic errors.[1,2] Owing to the superior mechanical properties of the NiTi alloy, it was possible to use endodontic instruments of greater tapers in continuous rotation to increase the effectiveness and rapidity of the cutting.[3] However, several studies reported a significant risk of intracanal separation of NiTi rotary instruments.[4–7] Although multiple factors contribute to file separation, cyclic fatigue has been proven to be one of the leading causes.[8] Fatigue failure usually begins with the formation of microcrack at the surface of the file that arises from surface irregularities. During each loading cycle, microcracks develop, deepening until complete separation of the file occurs.[9] All endodontic files show some irregularities on the surface and inner defects as a consequence of the manufacturing process, and the distribution of these defects influences fracture strength of the endodontic instruments.[10,11]

NiTi instruments have traditionally been used with a continuous motion, but in recent years a new approach to the use of NiTi instruments in a reciprocating motion has been introduced.[12] In Yared's study,[12] only one F2 ProTaper NiTi rotary instrument Dentsply (York, PA) was used for canal preparation in a clockwise (CW) and counter-clockwise (CCW) movement. The CW and the CCW rotations used by Yared were four-tenths and two-tenths of a circle, respectively, and the rotational speed was 400 rpm.[12] The concept of using a single NiTi instrument to prepare the entire root canal is interesting, and it is possible because reciprocating motion is thought to reduce instrumentation stress, and new instruments have recently been introduced based on these concepts (e.g. WaveOne, DENTSPLY Tulsa Dental Specialties). Literature data has demonstrated that reciprocating motion can extend cyclic fatigue resistance of NiTi instruments compared with continuous rotation.[13–15] Moreover these positive results have been an initial step for further studies because many different reciprocating movements and many different instrument designs can be used in clinical practice, thus affecting the overall results.

More recently, a new instrumentation technique (TF Adaptive) has been developed by Axis | SybronEndo, aimed at combining the advantages of both continuous rotation and reciprocation. More precisely TF Adaptive uses Adaptive Motion, a patented, undisclosed motion provided by a new endodontic motor, the Elements Motor (Axis | SybronEndo, Coppell, TX) that automatically adapts to instrumentation stress (Fig. 1). When the TF Adaptive instrument is not (or very lightly) stressed, the movement can be described as an interrupted continuous rotation, allowing optimal cutting efficiency and removal of debris, since cross-sectional and flute designs are meant to perform at their best in a CW motion. On the contrary, while negotiating the canal, owing to increased instrumentation stress and metal fatigue, the motion of the TF Adaptive instrument changes into reciprocation with specifically designed CW and CCW angles. Moreover, these angles are not constant, but vary depending on the anatomical complexities and the intra-canal stress. This adaptive motion is therefore meant to reduce the risk of intra-canal failure without affecting performance, by the Elements Motor automatically selecting the best movement for each clinical situation.

The TF Adaptive technique is a three-file technique designed for all canals, with differences between small, difficult canals and large, easy ones, allowing in both cases an adequate taper an increased apical preparation size. The number of instruments in the sequence may vary, depending on the canal anatomy. An instrument is used only when apical enlargement is needed due to a larger original canal dimension and/or enhanced final irrigation techniques are required (Fig. 2). More precisely, TF Adaptive is an intuitive system designed for efficiency and ease of use. The colour-coded system is based on a traffic light: start with green, continue or stop with yellow, and stop with red. Once straight-line coronal access has been achieved, apical patency and a glide path are established using a #8 hand file, followed by a #10 hand file and continued up to a #15 hand file at least.

Based on tactile perception, if the clinician finds it difficult to take a #15 K-file to working length, then the canal size is deemed to be small and the small pack (single colour band) and its instrument sequence is used. If it is loose then the medium/large pack (double colour bands) is used. TF Adaptive files are used with the Adaptive Motion mode in the Elements Motor and are slowly advanced in the canal with a single controlled motion until the file engages dentine, then completely withdrawn from the canal. Files must never be forced apically, and a pecking motion should be avoided. Following withdrawal, the file flutes are wiped clean of debris and the previous step is repeated using the file the clinician started with until working length is achieved. If some brushing action is needed it can also be performed by selecting the TF (continuous rotation) mode in the motor. The same steps are repeated using the next instruments in the sequence.

Since Twisted Files (TF) and TF Adaptive files have different operative sequences and different sizes, in the present study a single-file technique was chosen, using a #25.06 file, which is available in both TF and TF Adaptive files.

The aim of this study was two-fold: to evaluate whether the Adaptive Motion had any effect on safety (measured by in vitro resistance to cyclic fatigue) and on the cutting ability (measured by in vitro instrumentation time) of TF instruments compared with traditional continuous rotation.

_Material and methods

Forty TF #25.06 NiTi instruments were randomly divided into four groups (n = 10 each). All of the instruments had been previously inspected using an optical stereomicroscope at 20x magnification for morphological analysis and for any signs of visible deformation. If defective instruments were found, they were discarded.

The first 20 instruments were submitted to cyclic fatigue tests. Group 1 instruments were tested using Adaptive Motion, while Group 2 instruments were used in continuous rotation for control. The speed was set at 500 rpm for Group 2, in accordance with the manufacturer's guidelines. The speed of Adaptive Motion is presently undisclosed.

The cyclic fatigue testing device used in the present study has been used for studies on cyclic fatigue resistance previously.[16] The device consists of a mainframe to which a mobile plastic support is connected for the electric handpiece and a stainless-steel block containing the artificial canals. The electric handpiece was mounted on a mobile device to allow precise and reproducible placement of each instrument inside the artificial canal. This ensured 3-D alignment and positioning of the instruments to the same depth. The artificial canal was manufactured by reproducing an instrument's size and taper, thus providing the instrument with a suitable trajectory that respected the parameters of the curvature chosen. A simulated root canal with a 60-degree angle of curvature and 5 mm radius of curvature was constructed for instrument type. The centre of the curvature was 5 mm from the tip of the instrument, and the curved segment of the canal was approximately 5 mm in length. All instruments

Fig. 1_The TF Adaptive motor.

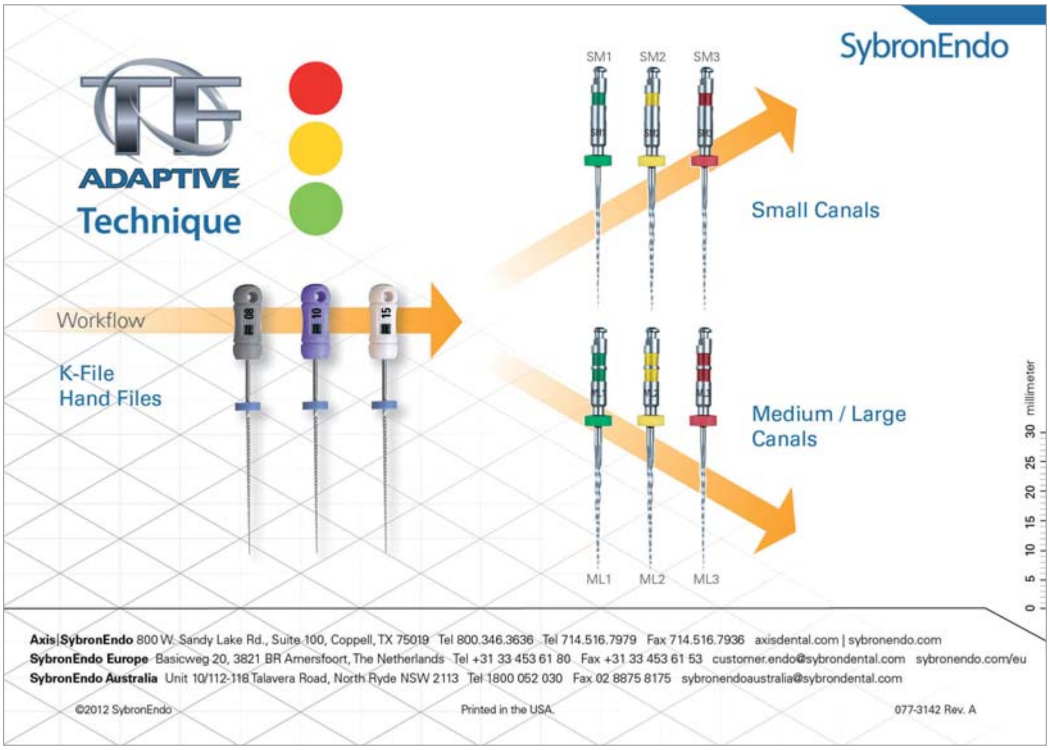


Fig. 2_The TF Adaptive workflow.

were rotated or reciprocated until fracture occurred. The time to fracture was recorded visually with a 1/100-second chronometer. Mean and standard deviations were calculated. All data was recorded and subjected to statistical evaluation with an analysis of variance test. (Statistical significance was set at $P < 0.05$.)

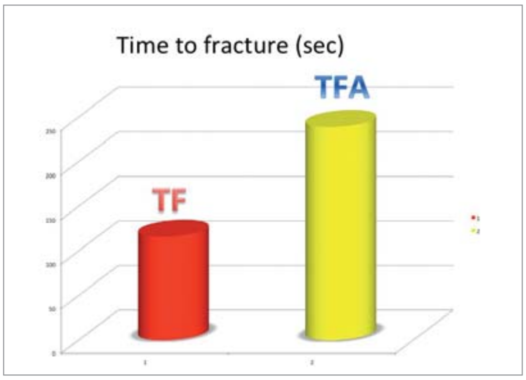
The other 20 instruments were randomly assigned to Group 3 (Adaptive Motion) and Group 4 (continuous rotation), and they were used to prepare a curved artificial canal in a transparent plastic block (SybronEndo preparation block) using a single-file instrumentation technique. Instrumentation time to reach working length was recorded visually with a 1/100-second chronometer. Mean and standard deviations were calculated. All data was recorded and subjected to statistical evaluation with an analysis of variance test. (Statistical significance was set at $P < 0.05$.)

_Results

Adaptive Motion showed a significant increase ($p < 0.05$) in the time to fracture compared with continuous rotation. The mean time to fracture was 239 seconds (SD 11.5 seconds) for Group 1 and 116 seconds (SD 9.5 seconds) for Group 2. The mean instrumentation time was 11.5 seconds (SD 1.5 seconds) for Group 3 and 11.2 seconds (SD 1.5 seconds) for Group 4. Statistical analysis did not find significant differences ($p > 0.05$) between the two groups.

_Discussion

Although multiple factors contribute to file separation, cyclic fatigue has been demonstrated to be one of the leading causes.[17] Recently, the advancement in TF technology and the manufacturing process has allowed the production of a new generation of NiTi instruments, with better flexibility and greater resist-



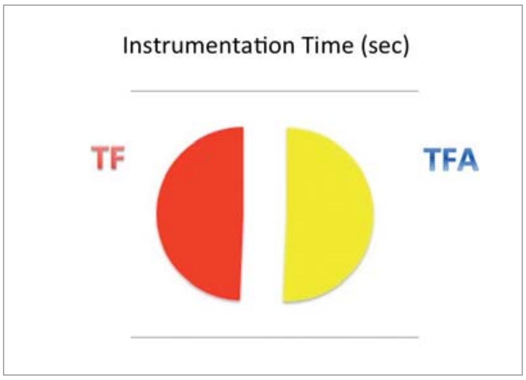


Fig. 3_Cyclic fatigue resistance of TF #25.06 used with Adaptive Motion (AD: yellow column) and continuous rotation (CR: red column).
Fig. 4_Cyclic fatigue resistance of TF #25.06 used with Adaptive Motion (AD: yellow column) and continuous rotation (CR: red column).

ance to cyclic fatigue.[18] Very few studies have been published so far about the effect of reciprocation on the lifespan of TF endodontic instruments, but they have all found very positive results: reciprocating motion extends cyclic fatigue life compared with continuous rotation.[19] However the term "reciprocating motion" includes several possible movements and angles, each of which may influence the performance and strength of the NiTi instruments.

In the present study, a new reciprocating motion (Adaptive Motion) was evaluated and compared with traditional continuous rotation, using TF instruments. The results of the present study clearly demonstrate that Adaptive Motion significantly extended the cyclic fatigue life of TF instruments compared with continuous rotation. Kinematics is among the many factors that may affect the lifespan of NiTi instruments because it determines the stress distribution that the instrument accumulates over time.

No statistically significant differences were found in the instrumentation time between TF used in the Adaptive Motion and continuous rotation. This is a positive finding because reciprocating motion is considered to be less effective in cutting (and in debris removal) compared with continuous rotation. This is easy to understand because the design has cutting angles and flutes that tend to remove debris in one direction of rotation, and a releasing angle (which is theoretically non-cutting or less cutting) with flutes that do not tend to remove debris in the opposite direction of rotation. In some marketing brochures, reciprocating single-file instrumentation techniques have been shown to reduce instrumentation time significantly, but these results are mainly due to one instrument being compared with a sequence of four to six instruments. The real advantage of kinematics regarding the reduction of instrumentation time of a single instrument has not yet been proven.

Although the angles are not disclosed by the manufacturers, visual inspection and video recordings show that Adaptive Motion is a reciprocating motion with cutting angles (CW angles in Adaptive Motion) much greater than those of WaveOne movements. As a consequence the TF Adaptive instrument works at a CW angle more often, which allows better cutting efficiency and removal of debris (and less tendency to push debris apically) because the flutes are designed to cut dentine and remove debris in a CW rotation. In this way, TF Adaptive takes advantage of the use of a motion that is more similar to continuous rotation for optimal cutting and debris removal. There are obviously some changes in the angles depending on canal anatomy (the more complex, the smaller the CW angle, or the larger the CCW angle), but they did not seem to influence the overall results in the present study significantly. On the contrary, these changes influenced resistance to metal fatigue, since TF instruments used with Adaptive Motion were found to have superior resistance to cyclic fatigue compared with the same TF instruments used in continuous rotation. Hence, we may conclude that Adaptive Motion has a positive effect on safety (measured by *in vitro* resistance to cyclic fatigue), while maintaining efficiency (cutting ability measured by *in vitro* instrumentation time) of TF instruments compared with traditional continuous rotation._

Editorial note: A complete list of references is available from the publisher.

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Prof. Gianluca Gambarini is a Professor of Endodontics at the Sapienza University of Rome's dental school in Italy. He is an international lecturer and researcher, and the author of numerous scientific articles, books and chapters in books. He has lectured extensively all over the world, and has been invited as a main speaker to the most significant international endodontic congresses in Europe, North and South America, Asia, the Middle East, Australia and South Africa. His research interests include endodontic materials and clinical endodontics. He is actively collaborating with a number of manufacturers all over the world to develop new technologies, operative procedures and materials for root-canal treatment.
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