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A new device to test cutting efficiency of mechanical endodontic instruments

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Background: The purpose of the present study was to introduce a new device specifically designed to evaluate the cutting efficiency of mechanically driven endodontic instruments.




Material/Methods: Twenty new Reciproc R25 (VDW, Munich, Germany) files were used to be investigated in the new device developed to test the cutting ability of endodontic instruments. The device consists of a main frame to which a mobile plastic support for the hand-piece is connected and a stainless-steel block containing a Plexiglas block against which the cutting efficiency of the instruments was tested. The length of the block cut in 1 minute was measured in a computerized program with a precision of 0.1mm. The instruments were activated by using a torque-controlled motor (Silver Reciproc; VDW, Munich, Germany) in a reciprocating movement by the "Reciproc ALL" program (Group 1) and in counter-clockwise rotation at 300 rpm (Group 2). Mean and standard deviations of each group were calculated and data were statistically analyzed with a one-way ANOVA test ($P < 0.05$).

Results: Reciproc in reciprocation (Group 1) mean cut in the Plexiglas block was 8.6 mm (SD=0.6 mm), while Reciproc in rotation mean cut was 8.9 mm (SD=0.7 mm). There was no statistically significant difference between the 2 groups investigated ($P > 0.05$).

Conclusions: The cutting testing device evaluated in the present study was reliable and easy to use and may be effectively used to test cutting efficiency of both rotary and reciprocating mechanical endodontic instruments.

Keywords: NiTi Instruments • Rotation • Reciprocation • Cutting Efficiency • Cutting Test

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Background

Endodontic nickel titanium (NiTi) rotary and reciprocating files are useful and safe instruments for canal preparation, allowing efficacious preparation of even severely curved root canals and decreasing the working time [1,2]. With advancements in technology, endodontic instruments today come in a variety of designs, each differing in cost, performance, and safety [3].

One important attribute is the cutting efficiency of an endodontic instrument. The cutting efficiency can be measured with several different techniques: it has been assessed in terms of changes in the dentin thickness removed and root canal volume [4], from weight loss of tooth samples [5] and resin blocks [6] after instrumentation, as a result of the debris generated during the preparation of extracted teeth [7], measuring the mass lost from a plexiglas plate by the instrument in cutting [8], measuring the maximum penetration depth of the instruments into the lumen of special plastic samples with a cylindrical canal [9], in terms of preparation time [10,11], and from direct evaluation by a clinician during preparation [12].

The ability of a file to efficiently remove dentin is a complex interrelationship of different parameters, including number of flutes, cross-sectional area and design, sterilization, chip removal capacity, helical and rake angle, tip design, metallurgical properties, and surface treatment of the instruments. All these characteristics have been found by previous studies to affect cutting efficiency [5,6,9,13–17].

In 2008, a new preparation technique with only 1 ProTaper F2 instrument in a reciprocating motion was proposed by Yared [18]. The use of reciprocating motion was shown to ultimately increase the lifespan of NiTi instruments in comparison with continuous rotation [19]. Recently, NiTi instruments were introduced to the market that used the reciprocation concept, claiming that the reciprocal motion would reduce the torsional stress by periodically reversing the rotation of the file, thus remaining under the plastic limit of the instrument [20].

Although extensive studies have been conducted on the cutting efficiency of hand and rotary endodontic instruments, clear standards for testing cutting effectiveness or sharpness of endodontic instruments have not yet been defined [1,14], and there is a need for standardization in testing the cutting efficiency of endodontic mechanical files. Therefore, the aim of the present study was to introduce a new device specifically designed to evaluate the cutting efficiency of mechanically driven endodontic instruments.

Material and Methods

Instruments

A total of 20 new NiTi reciprocating instruments 25 mm in length were used in the present study (Reciproc R25, VDW, Munich, Germany). Subsequently, the instruments were randomly divided into 2 subgroups of 10 instruments each, depending on which movement was selected on the torque-controlled endodontic motor used (Silver Reciproc; VDW, Munich, Germany). Group 1 was Reciproc R25 instruments activated using the program “Reciproc ALL”, since these instruments are designed to be used in this way. Group 2 was Reciproc R25 instruments activated using counter-clockwise continuous rotation at 300 rpm, because the flutes of this instrument are milled to cut in the counter-clockwise rotation. All the instruments were activated by using a 6:1 reduction hand-piece (Sirona Dental Systems GmbH, Bensheim, Germany).

Testing device

To eliminate variability due to possible different mechanical characteristics of dentine specimens, special Plexiglas plates (30×30×1 mm) created from the same original raw material were used. Each instrument has been used only once, and each plastic block was used to test 1 instrument from each of the 2 groups tested; thus, 10 blocks were used. Cutting efficiency of all instruments was determined by means of a specifically designed testing device manufactured for this study (Figure 1). It consisted of a main frame connected to a mobile plastic support for the hand-piece and a stainless-steel block containing the Plexiglas plates against which the cutting efficiency of the instruments was tested. The dental hand-piece was mounted to a mobile device connected to a fixed weight that used gravity to drive the horizontal instrument against the Plexiglas block in a precise and reproducible way (Figure 2). The same 150-gram weight was used to test all instruments. To prevent the instruments from slipping out the smooth surface of the plastic, a notch 1 mm in depth and width was created on the lateral wall of the 1-mm-thick Plexiglas. The plastic support for the hand-piece allowed for precise and simple 3-dimensional alignment and positioning of the instrument, as soon as it came perpendicularly into contact with the notch created on the wall of the Plexiglas specimen without bending. The cutting efficiency was tested 14 mm from the tip of the instruments to avoid deflection of the instrument when the weight was applied nearer to the tip, as reported in a pilot study. Furthermore, the coronal blades of the instruments at 15–16 mm from the tip were sharper and deeper and did not permit the instrument to remain stable during the test. Once everything was set-up, the motor of the testing device was switched on and the instrument removed material and actively penetrated (Figure 3). To permit removal of plastic debris

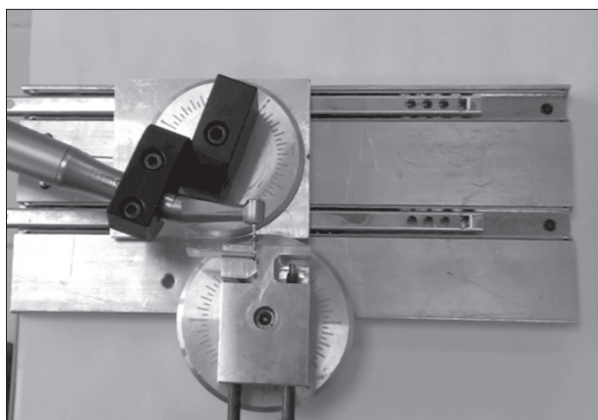


Figure 1. Testing device specially manufactured for the cutting test of the present study.

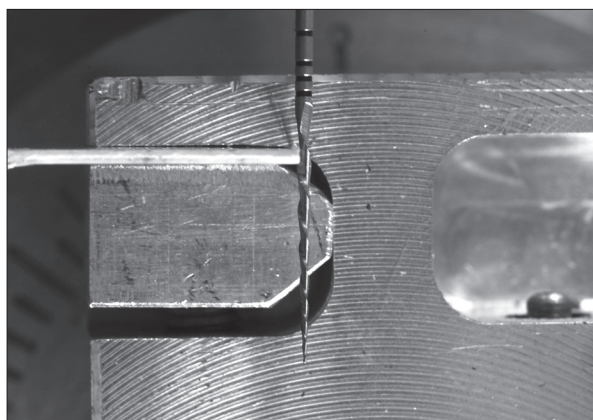


Figure 2. The instrument in contact with the Plexiglas block.

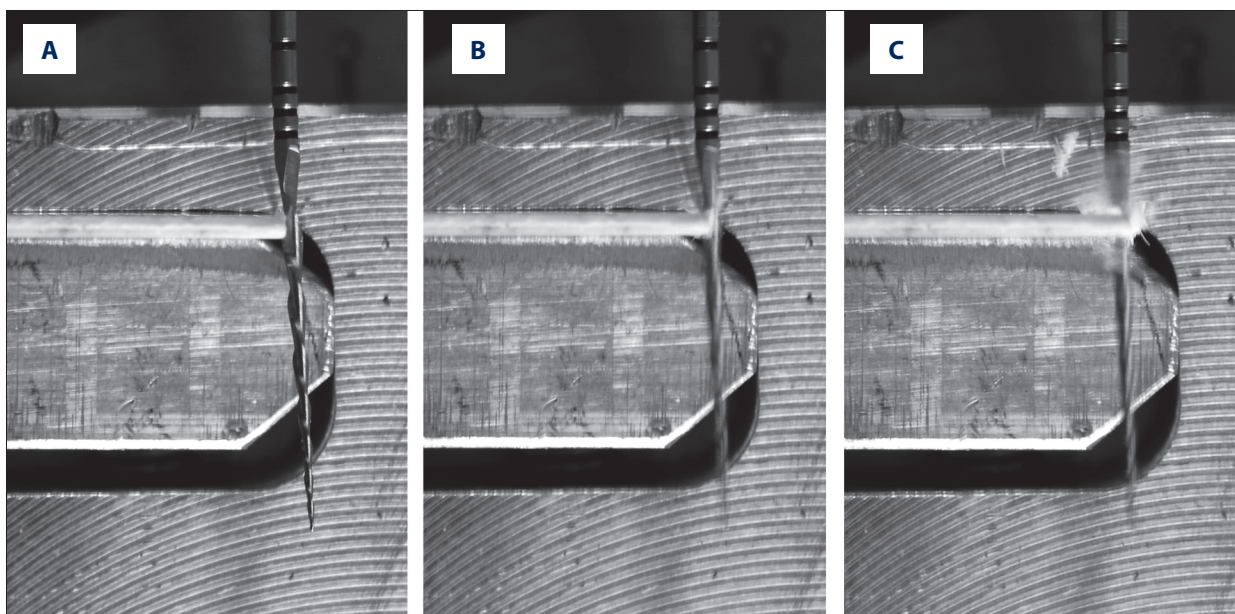


Figure 3. The instrument during progressive cutting of the Plexiglas block.

created by the instrument during the test, an air compressor was attached and used during all the experiment (Figure 4). Each instrument was tested in linear cutting unidirectional lateral motion. The maximum penetration depth of the instruments was the criterion for cutting efficiency and the basis for the comparison as a function of time.

Data calculation and statistical analysis

The precise length of the plastic block cut in 1 minute was measured in mm for all groups tested using a computerized program (Adobe Photoshop CS4) with a precision of 0.1 mm. The 1-mm notch was subtracted from the length obtained. Mean and standard deviations of each group were calculated and data were statistically analyzed with a one-way ANOVA test with significance set at 95% confidence interval.

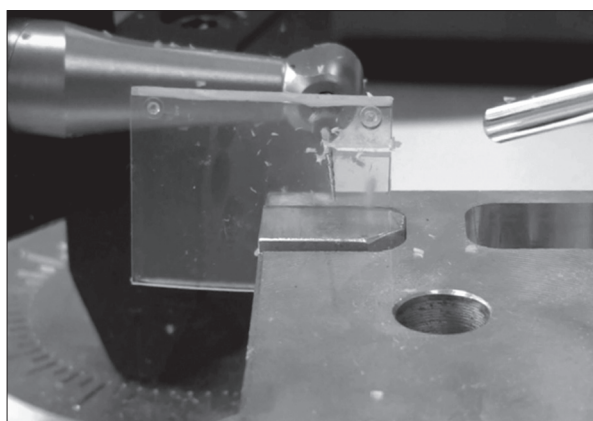


Figure 4. The testing device with the air compressor (on the right) that permits removal of plastic debris created by the instrument during the test.

Table 1. Cutting depth in plastic blocks of the two groups in mm.

	Group 1	Group 2
Mean	8.6	8.9
SD	0.6	0.7

Results

For all groups, the mean maximum penetration depths and standard deviations are given in Table 1. Reciproc R25 instruments used with their proprietary reciprocating movement (Group 1) cut the Plexiglas block to a mean depth of 8.6 mm (SD=0.6 mm), while Reciproc R25 instruments used in counter-clockwise rotation cut the Plexiglas block to a mean depth of 8.9 mm (SD=0.7 mm). There was no statistically significant difference between the 2 groups investigated ($P>0.05$). No errors occurred during the test and all the instruments were operated without any interruption or repetition of the test.

Discussion

This study aimed to describe and evaluate a new device specifically designed to evaluate the cutting efficiency of endodontic mechanical instruments operated with different movements, including rotation and reciprocation. No errors were reported during the test. All the instruments were operated without any interruption or repetition of the test and maintained great stability on the Plexiglas plates during the entire time of the test, guaranteeing effective, easy, and reliable evaluation of the cutting properties of the instruments tested. Furthermore, the air-blowing permitted us keep the testing field free from plastic debris and to avoid their possible influence in the cutting efficiency of the instruments.

In the present study, each instrument was used to prepare only 1 plastic sample, because it has been suggested it is impossible to ensure that files maintain optimal efficiency after use [21–23]. Cutting efficiency of endodontic instruments was examined by operating them on plastic samples, as some studies discouraged testing with human teeth because of their variable hardness and water content [24,25]. Even if clear standards for testing cutting effectiveness or sharpness of endodontic instruments have not yet been defined [1,14], according to previous reports, the use of a testing device in combination with special plastic samples guarantee standardized experimental conditions, allowing direct comparisons of the cutting ability of different instruments [9]. The use of plastic allows for different instruments to be tested on identical samples, eliminating variations in hardness that may influence results; however, plastic does not have the same properties as dentin and thus does not provide clinically relevant data; admittedly,

it does not reproduce the action of instrumenting a root canal. The motion generated by the testing device did not reflect a clinical situation in which the endodontic instrument is required to cut inside a root canal while it rotates through reciprocation, for example, when enlarging curved root canals.

The Reciproc R25 demonstrated a high cutting efficiency both in reciprocation and in rotation, which can be explained by its cross-sectional design and more positive cutting angles. Previous studies have confirmed the observation that instruments with an “S-shape” cross-section with 2 sharp cutting edges (Mtwo and Reciproc) are associated with an enhanced cutting efficiency [9–11,26–31]. In addition to the cross-sectional design, the debris removal capability also determines the efficiency of mechanical instruments because the removal of cut dentin chips is important to reduce clogging of the cutting blades [1,14]. According to Camps and Pertot [32] a smaller cross section creates more space between the instrument and the canal walls. Because of their small core diameter, Reciproc instruments are characterized by an extra space between the canal walls and the instrument, which allows more debris collection and facilitates easier removal capability [27]. Larger cross-sections may not provide enough space for debris to be displaced and the debris impedes the instrument from cutting more dentin. Furthermore, it has been observed that cutting efficiency and cleaning effectiveness of mechanical NiTi instruments are closely related [1]. Recent studies have shown that Reciproc instruments and, in general, instruments with an “S-shape” cross-sectional design, showed better canal cleanliness [27,31,33].

From the results of the present study, the cross-sectional design had a greater influence on the cutting efficiency than the movement used. In fact, there was no difference between results when the same instrument was used with different movements. The high cutting efficiency reported for the “S-shape” cross-section with 2 sharp cutting edges, as previously mentioned, ensure a similar cutting efficiency in rotation and reciprocation. Another possible explanation of these results lays in the particular reciprocating movement used with the Reciproc instruments, which are used with a reciprocating motion that is 150° counter-clockwise, then 30° clockwise rotation at a speed of 300 rpm [20]. This guarantees that the instruments have a very fast movement, similar to the rotary files, and a much higher cutting angle (150°) than the releasing angle (30°), thus maintaining an effective cutting ability even if not in full rotation.

Although the cutting efficiency of a root canal instrument surely represents only 1 selection criterion, information on the cutting efficiency, and thus on the cleaning efficiency, may be useful in the selection of particular instruments [34]. Furthermore, in previous studies Reciproc instruments also demonstrated high fatigue resistance [35,36].

Conclusions

The cutting testing device described in the present study has demonstrated reliable and easy use and may be effectively

used to test cutting efficiency of both rotary and reciprocating mechanical endodontic instruments.

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