Cutting efficiency of 3 different instrument designs used in reciprocation

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Objective. This study examined the effect of flute number and cross-sectional area on the cutting efficiency of 3 reciprocating endodontic instruments twisted from rectangular stainless steel wire. 40/0.02 instruments at 25-mm length were compared.

Study design. Seventy-five anterior teeth were prepared, divided into 3 groups, and operated on with a reciprocating handpiece at 2500 rpm for 5 seconds at around 500 grams of force: Group 1, SafeSiders; Group 2, Dentsply K-Files; Group 3, Dentsply K-Reamers. Dentin generated was collected in weigh dishes. Cutting efficiency was determined by dentin weight. Statistical analysis was performed with 1-way ANOVA and the Student-Neuman-Keuls (SNK) multiple comparisons testing.

Results. SafeSider instruments produced a greater amount of debris than K-Files and K-Reamers (P < .026). K-Files and K-Reamers were not statistically different (P = .63).

Conclusions. Flute number had no effect on cutting efficiency. Cross-sectional area may be a determining factor on cutting efficiency. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:e82-e85)

The use of endodontic instruments dates back over 100 years. With advancements in technology, endodontic instruments today come in a variety of designs, each differing in cost, performance, and safety. One important attribute is the cutting efficiency of an instrument. Cutting efficiency can be measured with several different techniques.1-4 One accepted method is to measure by weight the amount of dentin cut by the instrument under a reproducible procedure.5-7

An instrument’s flute design may be a determining factor of its cutting efficiency.8 Two major classes of endodontic instruments are reamers and files. Files are generally machined or twisted tightly to exhibit flutes that run more horizontal to the cutting surface, whereas reamers exhibit flutes directed more vertically. At the same cutting length, files have a greater number of flutes than reamers, which may have an effect on cutting efficiency. Other parameters have been observed by previous studies to affect cutting efficiency, including surface treatment, cross-sectional area, sterilization, rake angle, tip design, and metallurgical properties.8-14 However, although extensive studies have been conducted on the cutting efficiency of rotary endodontic instruments, there is a need for studies investigating the cutting efficiency of reciprocating systems and flat-sided instruments.

This study investigates the role of flute number and cross-sectional area on the cutting efficiency of reciprocating stainless steel instruments. The effect of flute number is tested by comparing Dentsply K-Files with Dentsply K-Reamers, where K-Files have more flutes than K-Reamers. The effect of cross-sectional area is tested by comparing K-Reamers with SafeSiders, which incorporate a flat-sided design that decreases its cross-sectional area.

The null hypothesis of the study is that flute number and cross-sectional area have no effect on the cutting efficiency of reciprocating endodontic instruments.

MATERIALS AND METHODS

Seventy-five extracted, single-rooted, human anterior teeth were decoronated 10 mm from the apex using a diamond disc. The apex of each tooth was opened up to 30/0.02 using SafeSiders (Essential Dental Systems, South Hackensack, NJ) according to the manufacturer’s instructions. The teeth were placed in jars filled with distilled water, which were shaken vigorously for 10 seconds to loosen debris and to keep the teeth moistened. In a pilot study, tooth samples were also irrigated with 1 mL of distilled water with a 27-gauge irrigation
needle (Henry Schein, Inc., Port Washington, NY), allowing the water to escape out the apex. The extruded water contained no additional debris, verifying that the canals were free of fillings after being vigorously shaken.

Three types of instruments fabricated from the same alloy of stainless steel were tested: SafeSiders, K-Files (Dentsply Maillefer, Johnson City, TN), and K-Reamers (Dentsply Maillefer). Fig. 1 shows the design of the 3 instrument types; 25-mm instruments were used, each in size #40 with a taper of 0.02. All 3 instrument types were tested in reciprocating motion using an Endo-Express 4:1 reciprocating handpiece (Essential Dental Systems) operating at 2500 rpm. The rpm value was verified for accuracy using a digital laser tachometer (Neko Tools USA, Wenzhou, China). A total of 75 instruments were tested, 25 for each instrument type.

Samples were randomly assigned to 1 of the 3 instrument groups. For each tooth, a polystyrene weighing dish (Sigma-Aldrich, St. Louis, MO) was initially weighed in an ALC-80.4 analytical balance (±1 × 10^-4 g) (Accubal, Edgewood, NY). With the tooth positioned above the weighing dish, a 40/0.02 instrument was extruded through the apex with approximately 500 grams of force for 5 seconds. Any loosened debris was caught in the dish. The canal was irrigated with 1 mL of distilled water over 1 minute using a 27-gauge irrigating needle, making certain that any debris flushed out of the canal was caught in the dish. The instrument was flushed with distilled water and scraped along the edge of the dish to collect any debris that adhered to the instrument. The dish samples were dried for 24 hours at 37°C and reweighed. Two control groups were also added. Five dishes were weighed and filled with 1 mL of distilled water. They were dried for 24 hours at 37°C and reweighed. Another 5 dishes were weighed, kept at 37°C for 24 hours, and reweighed.

Cutting efficiency was evaluated by the increase in dish weight as a result of the debris generated. Data were analyzed using 1-way analysis of variance (ANOVA) and the Student-Neuman-Keuls (SNK) multiple comparisons testing at a significance level of P less than .05.

### RESULTS

Statistical analysis with 1-way ANOVA found a statistically significant difference among the 3 instrument types (P = .017). The mean debris weight generated and standard deviation for each experimental group are displayed in Table 1. SafeSiders was found to cut significantly more than K-Files and K-Reamers (P < .026), whereas K-Files and K-Reamers were not found to be significantly different (P = .63).

### DISCUSSION

This study compared the cutting efficiency of 3 types of stainless steel endodontic instruments size #40 with a 0.02 taper and 25-mm length. SafeSiders, Dentsply K-Files, and Dentsply K-Reamers were chosen for this study because of their similarities in manufacturing process. Studies observed a significant difference in cutting efficiency between machined and twisted instruments. The 3 instruments tested circumvent this variable as they are all twisted from a rectangular stainless steel wire.

SafeSiders demonstrated a greater cutting efficiency than either K-Files or K-Reamers. This may be attributable to the smaller cross-section of the SafeSider as a result of the integration of a flat side. According to Cumps and Pertot, a smaller cross section creates more space between the instrument and the canal walls. This extra space allows for more debris collection, which facilitates easier removal. Larger cross sections may not provide enough space for debris to be displaced. As such, the debris impedes the instrument from cutting more dentin. The flat-sided feature may also increase cutting efficiency by introducing another cutting edge. However, this conclusion can neither be confirmed nor denied by this study.

Dentsply K-Files and K-Reamers were found to exhibit comparable cutting efficiency on dentin. At ISO size #40, both the Dentsply K-Files and K-Reamers are

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Cross-section</th>
<th>No. Flutes</th>
<th>Mean ± SD, mg</th>
<th>SNK</th>
</tr>
</thead>
<tbody>
<tr>
<td>SafeSiders</td>
<td>Square with ground flat</td>
<td>16</td>
<td>1.53 ± 0.36</td>
<td>A</td>
</tr>
<tr>
<td>K-File</td>
<td>Square</td>
<td>24</td>
<td>1.28 ± 0.33</td>
<td>B</td>
</tr>
<tr>
<td>K-Reamer</td>
<td>Square</td>
<td>15</td>
<td>1.32 ± 0.27</td>
<td>B</td>
</tr>
</tbody>
</table>

SNK, Student-Neuman-Keuls multiple comparisons testing.
fabricated from the same alloy of rectangular wire. The main difference between the 2 instruments lies in the extent in which the wire is twisted. K-Files are wound more tightly, resulting in flutes that are directed more horizontally than flutes found in K-Reamers. Accordingly, K-Files have more flutes than K-Reamers at the same cutting length. However, this disparity in flute number did not seem to significantly affect cutting efficiency.

Measures were taken to ensure that the dentin collected and weighed accurately represented the filings generated solely from the 40/0.02 instrument after initial preparation of the tooth samples. Neither of the control groups exhibited any change in weight, signifying that the weigh dishes did not fluctuate in weight under heat, nor did the distilled water affect the weight of the dish. After initial preparation, samples were placed in a jar of distilled water and vigorously shaken to remove all loose debris from the canals. After instrumentation with the 40/0.02, the samples were irrigated to flush debris out of the canal; 1 mL of distilled water was found to be an adequate amount to ensure complete removal of filings as the final water drops contained no captured debris. Test instruments were flushed with distilled water after testing and scraped along the edge of the weigh dish to collect filings that adhered to the instrument. Although this was not able to remove all of the attached debris, the amount remaining was deemed too insignificant to compromise the results of the data.

All instruments were operated under reciprocal cutting, whereby the cutting flutes oscillate back and forth about an axis that is parallel to the direction of cutting. Under this system, cutting efficiency improves as the angle between the cutting edge and the long axis of the instrument decreases. This would seem to favor reamers over files, as reamers exhibit flutes that are more vertical than those found in files. The results of this study do not support this supposition.

The amount of dentin weight removed observed in this study ranged between 0.5 and 2.6 mg. These values are within the range of values found in other cutting efficiency studies that evaluated the removal of dentin weight, from 0.25 to 6.77 mg. A study by Vinothkumar et al. on nickel-titanium rotary endodontic instruments observed mean weight removal values between 3.7 and 4.7 mg. However, because each study differed considerably in experimental protocol, direct comparisons of the results cannot be made.

This study examined the cutting efficiency of endodontic instruments by operating them on tooth samples. Other studies discouraged testing with teeth because of their variable hardness and water content, instead choosing to evaluate the weight removal of Plexiglas blocks or bovine bone. The use of Plexiglas allows for different instruments to be tested on identical samples, eliminating variations in hardness that may influence results; however, Plexiglas does not exhibit the same properties as dentin and thus does not provide clinically relevant data. Bovine bone specimens could be standardized in shape and orientation, as well as exhibiting comparable hardness to dentin. Still, cutting into bone does not reproduce the action of instrumenting a root canal. To compensate for any variations in hardness and moisture content among tooth samples, this study tested 25 samples for each instrument group.

Certain variables that were not controlled or examined may have influenced the results. All tooth samples were initially opened up using the SafeSiders system. K-Files and K-Reamers tested on teeth prepared with their respective systems may show a different degree of cutting efficiency. Furthermore, the instrument rpm was set according to the instructions of the SafeSiders manufacturers. K-Files and K-Reamers may display a greater cutting efficiency at a different rpm. Another variable may be the smear layer produced during instrumentation, which remains after the water rinse. Studies have reported smear layer thicknesses between 0.9 and 3.0 µm. The amount of dentin contained in the smear layer is less than 1.5% of the amount of dentin removed during instrumentation. As such, any differences in smear layer thickness produced by the different instrument types would have a negligible effect on the results of the study.

CONCLUSIONS
The results of this study conclude that SafeSiders stainless steel 40/0.02 instruments exhibit a greater cutting efficiency on dentin than K-Files and K-Reamers of the same size and taper. K-Files and K-Reamers display a similar cutting efficiency. Cross-sectional area may be a determining factor on cutting efficiency. Pitch length does not seem to have an effect on cutting efficiency.

REFERENCES
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