In vitro Comparison of Debris Removal Using Various Adjunct Irrigation Devices

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In vitro Comparison of Debris Removal Using Various Adjunct Irrigation Devices

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Introduction: The purpose of this in vitro study was to compare the debris removal effectiveness of EndoActivator, EndoUltra, PiezoFlow, Cavitron PEC Insert, EndoVac, and Max-i-Probe in human mandibular molars after instrumentation.
Methods: The mesial roots of 60 extracted mandibular molars were mounted in resin by using the K-Kube and then sectioned at 2 and 4 mm from the apex. The specimens were instrumented to size 40/.04 using a standard irrigation protocol. Specimens were randomly assigned to one of six adjunct irrigation treatment groups, disassembled for imaging and then reassembled prior to adjunct irrigation. Adjunct irrigation was accomplished according to manufacturer's recommendations. Specimens were again disassembled and imaged. The percentage of cleanliness for each canal and isthmus both before and following adjunct irrigation was calculated by using interactive software. Comparisons of canal and isthmus cleanliness before and after adjunct irrigation were made using paired t tests, and the groups were compared with repeated-measures analysis of variance ($P < .05$).
Results: The Cavitron PEC Insert performed significantly better than all the other adjunct devices with the exception of the EndoUltra. There were no statistically significant differences in canal and isthmus cleanliness at 2 and 4 mm from working length.
Conclusions: Final irrigation using the Cavitron PEC Insert significantly improves canal and isthmus cleanliness compared to EndoActivator, PiezoFlow, EndoVac, and Max-i-Probe needle irrigation.

The prevention and treatment of apical periodontitis is the goal of endodontic therapy (1). In order to facilitate this goal, the removal of debris and, even more importantly, the removal of bacteria from the root canal system is necessary (2,3). Debris consists of dentin shavings, toxins, residual pulp tissue, microorganisms, and biofilms (4,5). Several factors can complicate the process of debris removal, especially complex canal morphology. Isthmuses, accessory canals, fins, and deltas can all provide ideal locations for harboring both debris and bacteria (6). Mechanical instrumentation, although effective, is insufficient alone and will lead to decreased endodontic success (7,8). The addition of irrigation is essential to successful canal debridement (7-10).

To assist in properly debriding the root canal system, various adjunct irrigation devices have been introduced. Evidence suggesting that agitation increases the effectiveness of irrigation has led to the development of various adjunct devices (11,12) Cleaner canals and isthmuses have been produced by the addition of ultrasonic irrigation (13-15). The downside to ultrasonic use as an irrigation adjunct is the risk of procedural accidents such as perforations, zips, transporting the canal, or creating irregularly shaped canal preparations (16-18).

Ultrasonics work either by activating standing irrigant or by concurrently activating and delivering a volume of irrigant. The amount of residual bacteria is a function of the volume of irrigant used to chemically debride the canal (19). An increase in volume results in an increase in irrigation effectiveness. Thus, adjuncts which deliver irrigants as they are ultrasonically activated may be more effective at removing debris and bacteria than those which do not.

Two systems which activate standing sodium hypochlorite are the EndoActivator system (Dentsply, Tulsa, OK) and the EndoUltra system (Vista Dental Products, Racine, WI). Although both systems are cordless and battery powered, the EndoActivator is a sonic device, operating at less than 20,000 Hz, whereas the EndoUltra is an ultrasonic device, operating at greater than 20,000 Hz. The EndoActivator utilizes a plastic tip and the EndoUltra system utilizes a NiTi tip. The two constant flow irrigant systems are the PiezoFlow (ProUltra; Dentsply, Tulsa, OK) and the Cavitron PEC Insert (Dentsply, Tulsa, OK). EndoVac and Max-i-Probe were also selected for this study due to their needle-deep operation and to compare positive pressure irrigation to negative pressure irrigation. The purpose of this study was to compare the debris removal effectiveness of EndoActivator, EndoUltra, PiezoFlow, Cavitron PEC Insert, EndoVac, and side-ported needle irrigation with Max-i-Probe (Dentsply-Rinn, Elgin, IL) in the mesial roots of mandibular molars.

Material and Methods:

Specimen Preparation:

Mandibular mesial roots were selected for this study because they present a unique debridement challenge due to their high likelihood of isthmuses and fins. Specimen preparation closely followed that used by Dietrich et al (20). 60 mandibular molars were selected and stored in 0.5% chloramine-T. Only roots with curvatures less than 25 degrees were included in this study. Any teeth with decay or fractures below the Cemento-Enamel Junction, internal or external resorption, open apices, or previous root canal therapy were excluded. All cusps were flattened to provide reproducible reference points for working length (WL) determination and subsequent instrumentation and irrigation.

Standard access openings were made in all teeth with Trans-metal and Endo Z burs after which a #10 K-flex file (Miltex, Inc, York, PA) was inserted until the tip of the file was visible at the apical foramen of the mesial roots. This measured distance was used to determine the working length by subtracting 1mm. Each mesial canal was instrumented at working length to size #20/0.06 Profile GT (Dentsply-Tulsa Dental, York, PA). A sponge was placed in the chamber and the access and distal root orifice were sealed with Cavit (3M ESPE, St Paul, MN). The distal roots were amputated after which Triad clear gel (Dentsply, Trubyte, York, PA) was used to seal the canal opening of the amputated distal root as well as the apical foramina on the remaining mesial root. This was done to prevent mounting resin from entering these areas as well as to provide a closed canal system to mimic in vivo conditions.

Specimen Sectioning:

All specimens were embedded in a custom metal K-Kube (21) to the occlusal table using Epoxicure resin (Buehler/Lake Bluff, IL). After the resin set, specimens were sectioned at 2mm and 4mm from WL using an Isomet low-speed saw with a 0.15mm thick, Series 15, high concentration wafering diamond blade (Buehler/Lake Bluff, IL) irrigated with Isocut Plus Fluid (Buehler/Lake Bluff, IL) and water according to the manufacturer's recommendations. Sectioned specimens were stored at room temperature at 100% humidity when not in use.

Canal Preparation:

Specimens were reassembled in the K-Kube and all external hex bolts firmly tightened. Specimens were accessed again, the sponge removed, and a #20 hand file was placed to WL in order to verify proper assembly. Coronal flaring was accomplished with #2-4 Gates Glidden drills (Dentsply, York, PA).

Pulp chambers were filled with 8.25% NaOCl. The canals were then prepared using Vortex Blue 0.04 rotary files (Dentsply, York, PA) in a crown-down fashion to a #40 master apical file size. 1mL of 8.25% NaOCl was used in between each file using a 30g side vented Max-i-probe needle (placed as deep as possible without binding, but not closer than 1mm from WL).

Adjunct Irrigation:

After final instrumentation, specimens were randomly divided into six treatment groups of 10 specimens per group.

In group 1, the EndoUltra cordless handpiece (Vista Dental Products, Racine, WI) was used according to the manufacturer's recommendations. The mesial canals and pulp chamber were filled with 8.25% NaOCl and each canal was activated with the EndoUltra equipped with a #15/0.02 NiTi activator tip. During activation the activator tip was slowly moved up and down in the canal to within 2mm of WL for a total activation time of 60 seconds per canal.

In group 2, the EndoActivator (Dentsply, York, PA) was used according to the manufacturer's recommendations. The mesial canals and pulp chamber were filled with 8.25% NaOCl and each canal was activated with an EndoActivator equipped with a #15/0.02 activator tip. During activation the activator tip was slowly moved up and down in the canal to within 2mm of WL for a total activation time of 60 seconds per canal.

In group 3, the ProUltra PiezoFlow was used according to the manufacturer's recommendations. The PiezoFlow needle was attached to a Satelec P5 Piezoelectric Ultrasonic Unit (Acteon, Mount Laurel, NJ) and set to 50% power. Each canal was activated by inserting the PiezoFlow needle to 75% of WL. 8.25% NaOCl was dispensed from a syringe attached to the device and was delivered at a flow rate of 10mL/min. During activation the needle was slowly moved up and down in the canal to the stopper setting, never binding the needle in the canal, for a total activation time of 60 seconds per canal.

In group 4, the Endo PEC Insert (Dentsply, Tulsa, OK) was used according to the manufacturer's recommendations. The PEC Insert was attached to a Cavitron Select SPS 30K Ultrasonic Scaler (Dentsply, Tulsa, OK) and set to 50% power. Flow rate was also adjusted to 50% (10ml/min). Each canal was activated with an Endo PEC Insert equipped with a #15 x 29mm endosonic file. Distilled water was dispensed from the PEC Insert during activation and the endosonic file was slowly moved up and down in the canal without binding to within 2mm of WL for a total activation time of 60 seconds per canal.

In group 5, the EndoVac Irrisafe passive irrigation tip (Acteon Group, Laurel, NJ) was used according to the manufacturer's recommendations. 8.25% NaOCl was dispensed from a syringe into the pulp chamber. Irrigation of each canal was performed with negative pressure using an EndoVac Irrisafe passive irrigation tip to WL for 60 seconds per canal.

In group 6, the 30-gauge Max-i-Probe (Dentsply, York, PA) was used (positive control). 4ml of 8.25% NaOCl was dispensed from a syringe equipped with a 30-guage Max-i-Probe needle. During irrigation the Max-i-Probe tip was rapidly moved up and down in the canal to WL for a total of 60 seconds per canal.

Method of Evaluation:

The amount of remaining debris present was evaluated while each specimen was disassembled. Evaluation occurred (a) immediately after instrumentation and prior to adjunct irrigation and (b) immediately following adjunct irrigation. Canals were dried with sterile paper points prior to disassembly and evaluation.

Images of the coronal aspects of each section were made using a digital camera and computer (Fig. 1). All images were made with a camera (Canon EOS Rebel T2i, Melville, NY) attached to a dental operating microscope (OPMI PROergo, Zeis, Oberkochen, Germany) at 20x magnification and a consistent working distance. Full color images were projected onto an iPad (Apple Inc., Cupertino, CA) and the outline of root canals, isthmuses and remaining debris were traced. Debris was defined as any material present on the canal walls and in the canal lumen or isthmus. The software program ImageJ (National Institutes of Health, Bethesda, MD) was used to calculate the area of the root canals, isthmuses and amount of remaining debris present.

In order to calculate the percentage of debris removed as a result of adjunct irrigation, the area of remaining debris immediately following adjunct irrigation was subtracted from the area of remaining debris immediately following instrumentation. This area was then divided by the area of remaining debris immediately following instrumentation to determine the percentage of remaining debris removed during adjunct irrigation.

Data Analysis:

The percentage of debris removed was compared by using repeated-measures analysis of variance and post hoc tests ($P < .05$).

Results:

The PEC Insert performed statistically better than all other irrigation adjuncts with the exception of the EndoUltra cordless handpiece (Fig. 2). However, the EndoUltra did not perform statistically better than the remaining four treatment groups. The PEC Insert removed an average of 80% of the remaining debris at 4mm from WL and 52% of the remaining debris at 2mm from WL. The average percentage of remaining debris removed by the other four adjuncts and Max-i-Probe needle irrigation at both 4mm and 2mm from WL was 35%.

Discussion:

The K-Kube was initially introduced by Klyn et al (21) in 2009. It is a custom-designed brass cube similar to one introduced by Bramante (22) with the addition of compression of the specimen components. This effectively eliminated the kerf created by the Isomet saw blades when the specimens were initially cut. The advantage of this technique is that each tooth was able to be disassembled to serve as its own control, reassembled for treatment, and then disassembled once again for final evaluation.

Previous studies compared the percent canal / isthmus cleanliness following instrumentation (prior to adjunct irrigation application) with canal / isthmus cleanliness following irrigation. It was determined that the addition of an irrigation adjunct resulted in statistically improved canal and isthmus cleanliness at all levels, regardless of technique used (21). Thus, it was not the aim of this study to compare canal / isthmus cleanliness pre- and post-irrigation adjunct. Rather, the aim was to determine which irrigation adjunct provided the greatest additional percentage of debris removal.

Previous studies by Howard (23) and Klyn (21) reported canal and isthmus cleanliness following instrumentation. Howard reported 92% canal cleanliness and 25% isthmus cleanliness following instrumentation. Klyn reported 94% canal cleanliness and 74% isthmus cleanliness following instrumentation. In the present study, canal and isthmus cleanliness of specimens following instrumentation and additional irrigation averaged 88% and 10% respectively. Variation in canal and isthmus cleanliness may be attributed to variations in isthmus width and length.

A major factor in cleanliness appears to be the volume of irrigant which reaches WL (19). Although not ultrasonically activated, “needle deep” irrigation with Max-i-Probe needles, and utilization of the EndoVac system, are two systems which aim to deliver irrigant directly to WL. The Max-i-Probe needles deliver irrigant to within 1ml of WL through a side-vent (17-18). The EndoVac system has been shown to deliver an average of 1.37ml of irrigant to WL in a 30 second timeframe when the canals are prepared to size #40/0.04 (15).

Although traditional needle irrigation alone is effective, the addition of sonic or ultrasonic activation appears to provide better irrigation in simulated canals (24), improved tissue removal (25), more vigorous irrigation of lateral canals (24), and additional removal of bacteria (26). Two handheld devices were chosen for this study, EndoActivator and EndoUltra. The EndoActivator utilizes a plastic tip which vibrates to activate standing irrigant whereas the EndoUltra utilizes a NiTi tip. One advantage of the EndoUltra, according to the manufacturer, are the NiTi tips which are designed to fit more easily to WL in curved canals. However, it has been suggested that ultrasonic tips which are allowed to oscillate freely facilitate debridement better than those which are in contact with canal walls (27).

Since increased volume of irrigant as well as sonic/ultrasonic activation have been shown to improve irrigation, we evaluated two devices which not only activate irrigants but also deliver a high volume of irrigant during the process. The two devices were the the Cavitron PEC Insert and the ProUltra PiezoFlow. The PEC Insert allows easy conversion of any Cavitron unit into an endodontic irrigation device. The Cavi-endo files, which fit into the insert, are used to facilitate apical cleansing. The ProUltra is a piezoelectric ultrasonic tip with a relatively large lumen through which irrigants are delivered. Although it is effective at delivering irrigant, the large size of the tip lumen prevents its insertion any closer than about 75% of WL and, due to its size, is not as effective at ultrasonically activating irrigants as the Cavitron PEC Insert.

In the present study, the Cavitron PEC Insert was found to be the most effective irrigation adjunct. It is important to note that the Cavitron PEC Insert was effective while only utilizing sterile water instead of high concentrations of NaOCl. This can be attributed to the large volume of irrigant delivered during ultrasonic activation along with the small needle size. Further, the Cavitron PEC Insert tip vibrates vigorously, effectively facilitating irrigant delivery in all directions. A limitation to the Cavitron PEC Insert is the requirement to have a Cavitron unit available for use.

Conclusions:

The results of this study demonstrated that the Cavitron with a PEC Insert removed statistically more debris following instrumentation than the other irrigation adjuncts tested with the exception of the EndoUltra cordless handpiece. The effectiveness of the Cavitron PEC Insert can be attributed to the volume of irrigant it delivers as well as the vigor to which the needle vibrates and ultrasonically activates the irrigant. However, no currently available irrigation adjunct consistently removes all debris from canals and isthmuses (15,19,21,28). The results of this study support those of previous studies which found factors important in removing debris and bacteria are the depth and volume of irrigation along with ultrasonic activation.

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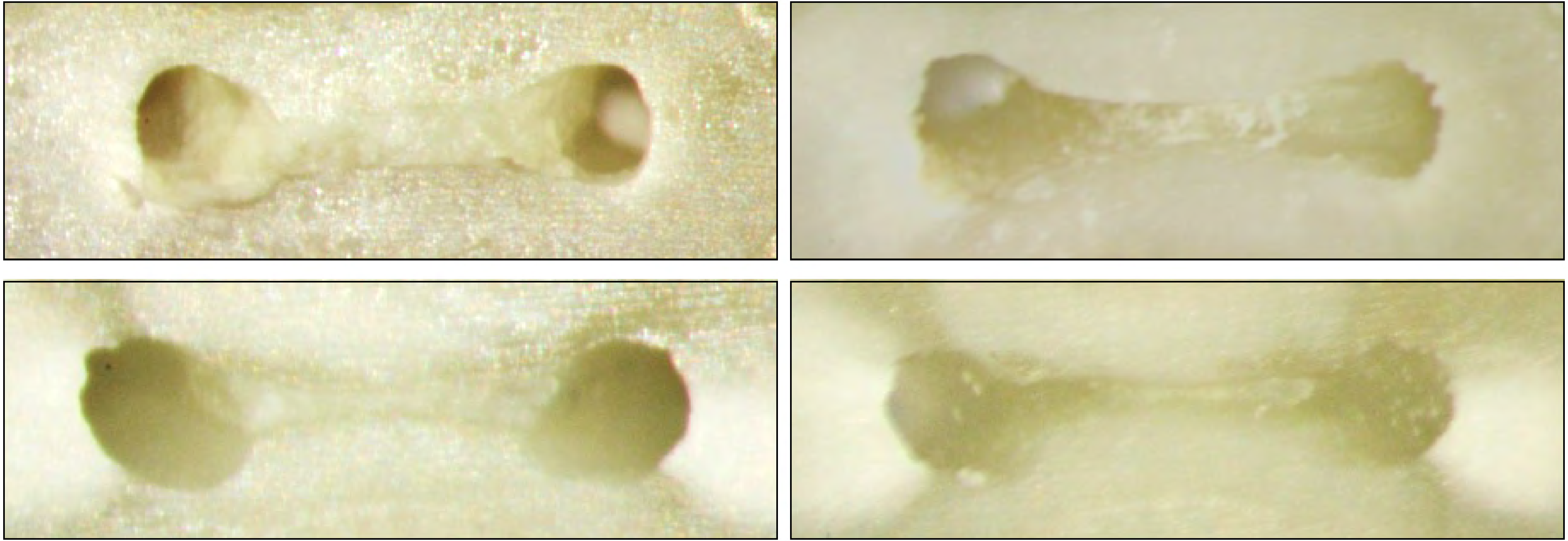

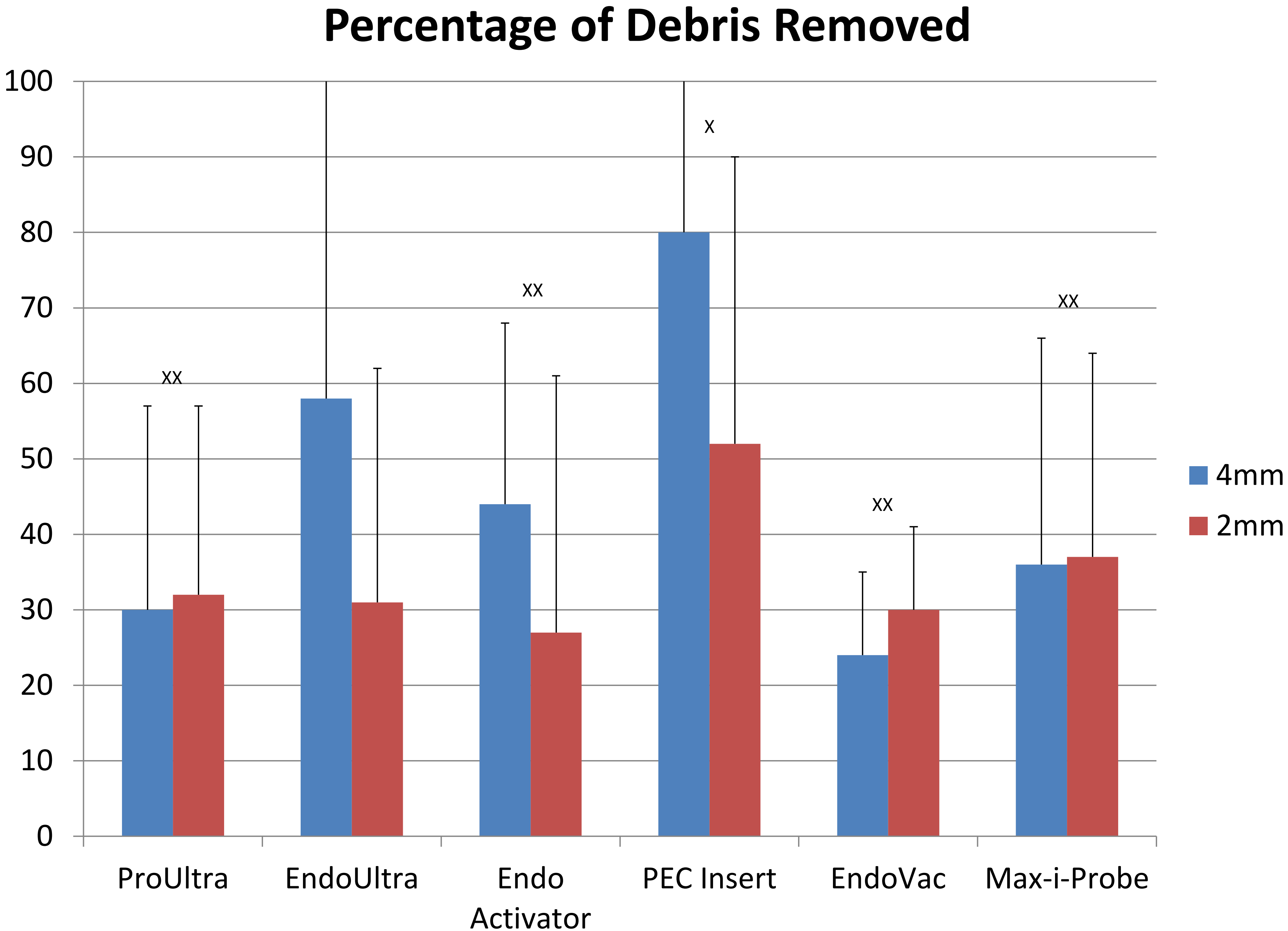
Percentage of Debris Removed
100
90
80
70
60
50
40
30
20
10
0
xx
xx
x
xx
xx
ProUltra
EndoUltra
Endo Activator
PEC Insert
EndoVac
Max-i-Probe
4mm
2mm