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Retrograde Instrumentation of Surgically Resected Roots Using Controlled Memory Files: A Human Cadaver Study



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ABSTRACT

Introduction: The purpose of this study is to evaluate the amount of residual obturation material of retroinstrumented surgically resected roots using controlled memory files and to evaluate the incidence of adverse treatment outcomes. **Methods:** Thirty maxillary anterior teeth in human cadavers were selected, and nonsurgical root canal treatment was performed on these teeth. A standardized 4-mm osteotomy and a 3-mm root resection with as close to 0° bevel as possible were made on each tooth. A microsurgical diamond tip was used to create a 1- to 2-mm starting point for each retropreparation. A 25/06 and 30/06 VTaper 2H were bent at about 90° angle to mimic the clinical and anatomic restrictions and used to create a retropreparation to a depth of 14 mm. Micro-computed tomography scans were taken and analyzed for volume and percentage of residual obturation material at 5 and 10 mm. In addition, the incidences of instrument separation and crack and ledge formation in the teeth were recorded. **Results:** The median volume of residual obturation at 5 and 10 mm was 0.18 mm³ (interquartile range, 0.36 mm³) and 1.97 mm³ (interquartile range, 1.99 mm³), respectively. The overall incidence of file separation during retropreparation was 13.33% (4/30). Among the cases analyzed with micro-computed tomography, none showed crack or ledge formation. **Conclusions:** Retroinstrumentation of surgically resected roots using controlled memory files cleans the canal effectively with relatively low adverse treatment outcomes. Although this novel technique is limited in application, it is a safe and effective way to achieve a deep, clean retropreparation. (*J Endod* 2020;46:1317–1322.)

KEY WORDS

Apicoectomy; osteotomy; root canal therapy; X-ray microtomography

Endodontic surgery is a viable treatment option to preserve the natural dentition. Although every step in the procedure is important, one of the main challenges involved in surgical endodontics is the retrograde instrumentation of the root canal system. This critical step may affect the outcome of surgical treatment because the most common reason for nonsurgical and surgical endodontic failure is the persistence of intraradicular bacteria and their by-products^{1,2}. The goal of retrograde instrumentation is to remove the obturation material, infected tissues, and irritants from the root canal system and create a space that can be properly sealed³. Anything less undermines the biological basis for successful endodontic treatment⁴. Throughout history, various retrograde instrumentation methods have been introduced and evaluated. Traditionally, the root-end preparation was achieved by use of surgical burs in a handpiece. However, this technique has disadvantages including inadequate canal preparation, limited access, and risk of perforation of the palatal wall⁵. In addition, the osteotomy may need to be enlarged greatly to allow sufficient access for the handpiece and bur.

One of the advancements in modern endodontic surgery was the introduction of surgical ultrasonic tips that allowed for more centered and deeper root-end preparations. However, numerous studies have reported an increased incidence of cracks on resected roots after ultrasonic instrumentation^{6–8}. In addition, a majority of the ultrasonic tips can penetrate to only a depth of 3 mm into the canal. Indications for longer retropreparations include grossly and inadequately cleaned and obturated canals and missed canals. A recent randomized controlled trial evaluating the outcome of endodontic microsurgery revealed 9 times greater chance of failure if the quality of the root filling was inadequate⁹. Although ultrasonic tips

SIGNIFICANCE

A novel technique using controlled memory files for retrograde instrumentation in endodontic microsurgery may be a viable technique that can safely and effectively debride the canal system and can achieve deep, clean retropreparations.

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can be as long as 9 mm, they require a larger osteotomy or preparation of a keyhole to accommodate the longer tip¹⁰. However, the diameter of an ideal osteotomy is recommended to be limited to 4 mm¹⁰, and the removal of healthy facial or buccal bone may result in slower and incomplete healing¹¹. Moreover, ultrasonic tips are very efficient in cutting dentin, and if not used carefully, they can result in root perforations, off-axis preparation, and decreased residual dentin thickness. Therefore, there is a need for alternative techniques that allow for safe, deep retropreparations of the canal while preserving as much bone as possible.

Retrograde instrumentation with the use of hand files has been demonstrated, but only in select cases with sufficient bone destruction and access not restricted by anatomic factors¹². Improvements in metallurgy and instrument design have provided an opportunity for the clinicians to explore innovative treatment options. Recently, rotary instruments made from controlled memory nickel-titanium (NiTi) alloys have been introduced into the market. Unlike the traditional NiTi file systems, these rotary files can be bent and retain their controlled memory¹³. This new technology has made the files very flexible and resistant to cyclic fatigue. In addition, the properties of these files may decrease the risk of some instrumentation errors such as transportation, ledging, or root perforation¹⁴. To the best of our knowledge, there is no study in the literature evaluating the feasibility of using rotary files in endodontic surgery. The purpose of this study is to evaluate the amount of residual obturation material of retroinstrumented surgically resected roots using controlled memory files and to evaluate the incidence of adverse treatment outcomes including file separation, root fracture/cracks, and root perforation.

MATERIALS AND METHODS

Thirty maxillary anterior teeth within the maxillae of embalmed cadaver heads were used to maximize the replication of the clinical scenario. The inclusion criteria consisted of intact teeth with minimal dental caries and/or restorations, absence of periapical radiolucency, root length of at least 13 mm, and entire root within the maxillae. All cadaveric specimens were obtained through the Texas A&M College of Dentistry Anatomical Gift Program.

Nonsurgical Root Canal Treatment

Preoperative radiographs were taken on each sample, with working length established at 1 mm from the radiographic apex. Teeth were

instrumented with serial preparation to size 25/04. Copious irrigation with 3% NaOCl was used throughout, and canals were dried with paper points. After drying the canals, the teeth were obturated with gutta-percha and a resin sealer (2Seal easymiX; Roydent, Johnson City, TN). Postoperative radiographs were taken from 2 angles to check for the presence of a dense and homogenous obturation with no radiographic voids. No restoration was placed in the access cavity. The samples were then stored in 100% humidity for 7 days to allow for complete setting of the sealer.

Surgical Root Canal Treatment

A soft tissue flap was raised with a periosteal elevator to mimic the clinical scenario. A standardized 4-mm osteotomy was made with #4 round bur. Next, a 3-mm root resection with as close to 0° bevel as possible was made with a Lindemann bur (Meisinger, Neuss, Germany) (Fig. 1). Postoperative radiographs were taken to evaluate the root resection, and adjustments were made as necessary (Fig. 1, left). A microsurgical ultrasonic diamond tip (Obtura Spartan, Earth City, MO) was used to make 1- to 2-mm starting point for the retropreparation. A new 25/06 and 30/06 VTaper 2H (SS White, Lakewood, NJ) were bent at about 90° angle to mimic the clinical and anatomic restrictions (Fig. 2). The 2 files were used in an alternating fashion to advance down the canal incrementally. The file was run at a speed of 600 rpm and 440 g-cm on a ProMark Endo Motor (Dentsply Tulsa Dental, Tulsa, OK). The file was advanced incrementally and cleaned with a sponge after each insertion. The file was first advanced to a depth of 10 mm, and if no adverse event occurred, the file was advanced to a depth of 14 mm. Postoperative radiographs were taken to have a 2-dimensional evaluation of the retropreparation (Fig. 1, right). Copious irrigation with sterile

saline was used to remove debris after retropreparation.

Micro-Computed Tomographic Assessment of Residual Obturation Volume and Crack Formation

After retropreparation, each of the samples was scanned separately by using the micro-computed tomography (micro-CT) system (μ CT 35; Scanco Medical, Bassersdorf, Switzerland). The scan settings were as follows: voxel size of 20 μ m, 70 kV, 114 μ A. The experimental teeth were removed atraumatically from the maxillae of the embalmed cadavers by sectioning through the surrounding bone. Teeth were subjected to micro-CT scans. Analysis of the percentage of remaining obturation material was calculated by using Mimics Innovation Suite (v21; Materialise, Brussels, Belgium).

Using threshold and region growing tools, 2 masks (residual obturation and empty canal) were created at 5 mm and 10 mm from the apex, and their corresponding volumes were calculated. The percentage of residual obturation was calculated at each level (5 mm and 10 mm) by using this formula: Volume of residual obturation/Volume of residual obturation + Volume of empty canal (Fig. 3).

In addition, crack formation and ledge formation were assessed with this software by viewing the coronal, sagittal, and transaxial sections of each sample. Only the samples without file separation were scanned and analyzed with micro-CT.

RESULTS

Only the samples in which file separation did not occur (26/30) were subject to micro-CT scans and analysis. In addition, 2 samples were not included because of poor image



FIGURE 1 – (Left) Periapical radiograph after nonsurgical root canal treatment, osteotomy, and 3-mm root resection. (Right) Periapical radiograph after retrograde instrumentation with remaining obturation material visible.



FIGURE 2 – (Left and right) Controlled memory file at about 90° angle to mimic the clinical and anatomic restrictions.

quality. In total, 24 samples were scanned and analyzed.

Among the 24 scanned specimens, volumetric analysis revealed a median percentage of residual obturation material to be 6.65% (interquartile range, 11.54%) and 28.41% (interquartile range, 28.47%) at 5 mm and 10 mm, respectively (Table 1).

In terms of absolute volume of residual obturation material in mm³ following the experimental protocol, the median volume and interquartile range at 5 mm were 0.18 mm³ and 0.36 mm³, respectively. At 10 mm, the median volume was 1.97 mm³, and the interquartile range was 1.99 mm³.

Among the total 30 specimens, the overall incidence of file separation during retropreparation was 13.33% (4/30). Three of the files separated at the junction of the cutting flutes and shank and one where a 4-mm segment of the file separated (Fig. 4). All 4 file

separations (100%) were retrievable. Three files separated at the junctions of the cutting flutes and shank and were retrieved using a hemostat. One separated at 4 mm, which was irrigated out (Table 2). In evaluating the 24 scanned samples, the incidence of crack formation was 0% (0/24), and the incidence of ledge formation was 0% (0/24) (Table 2).

DISCUSSION

The goal of this study was to evaluate the amount of residual obturation material of retroinstrumented surgically resected roots using controlled memory files and to evaluate the incidence of adverse treatment outcomes. To the best of our knowledge, this is the first study to look at the feasibility of using rotary files in endodontic surgery. The rationale for the introduction of a novel retrograde instrumentation technique is biological. It is

well-documented that pathogenic bacteria and their by-products are the main cause of endodontic failure and persistence of periapical disease¹⁵. In addition, numerous studies have evaluated the efficacy of various techniques for gutta-percha and obturation material removal during nonsurgical retreatment procedures. The overwhelming consensus is that no instrumentation system or technique can effectively remove all obturation material^{16–20}. The inability to completely remove all obturation material provides a potential etiology of future failure because bacteria and biofilm may persist in these untouched areas²¹.

With the High Success Rate of Endodontic Microsurgery, Is There Room for Improvement?

A recent long-term outcome study of endodontic surgery revealed a healing rate of

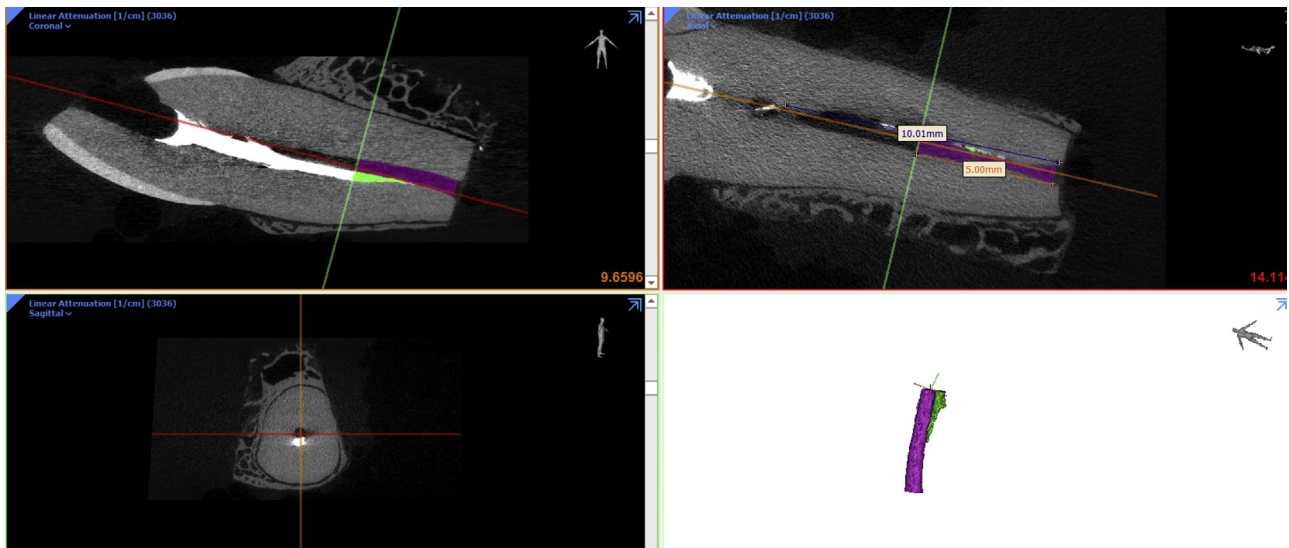


FIGURE 3 – Example of micro-CT analysis using threshold and region growing tools to differentiate and calculate residual obturation material versus empty canal. Green represents remaining obturation material. Fuchsia represents clean canal. Lower left image is the view used to analyze for crack initiation.

TABLE 1 - Median, Interquartile Range, and Overall Range of Percentage and Volume (in mm³) of Residual Obturation at 5 and 10 Millimeters from the Apex

Percentage of residual obturation	Root level from resection	
	5 mm	10 mm
	Median: 6.65%	Median: 28.41%
	IQR: 11.54%	IQR: 28.47%
	Range: 0.00%–30.57%	Range: 0.00%–68.66%
Volume of residual obturation	5 mm	
	5 mm	10 mm
	Median: 0.18 mm ³	Median: 1.97 mm ³
	IQR: 0.36 mm ³	IQR: 1.99 mm ³
	Range: 0.00–0.91 mm ³	Range: 0.00–4.13 mm ³

IQR, interquartile range.

91.6% at 1 year and 91.4% healed rate at 5 years, respectively. However, at 10 years this rate dropped significantly to 81.5%²².

Furthermore, von Arx et al²² reported that maxillary incisors were 1 of 3 tooth groups that contributed to virtually all failures; maxillary premolars and mandibular molars were the other tooth groups included in the failures. What could be contributing to these failures? Failure to thoroughly clean and debride the root canal system are the most significant potential reasons for failure after endodontic surgery²³. Therefore, the proposed technique has a biological rationale. The success rate for surgery increases when nonsurgical orthograde retreatment is completed before the apical surgery²⁴. This novel technique provides an avenue to effectively re-treat the canal system in a retrograde fashion, removing more of the etiologic factors of failure than a 3-mm retropreparation. Our hope is that this technique will contribute to an even higher and longer-term success rate in endodontic surgery.

Therefore, the primary outcome measurement was the volume and percentage of residual obturation material in the canal following this novel technique. The results showed a median volume of residual obturation material of 0.18 mm³ and 1.97 mm³ at 5 mm and 10 mm, respectively. In addition, the median percentage of residual obturation

was 6.65% and 28.41% at 5 and 10 mm, respectively. Micro-CT analysis reported 0% incidence of crack or ledge formation.

Because this study represents a novel technique, there is no direct comparison in terms of previous studies, methodologies, and results.

In traditional nonsurgical retreatment, every attempt is made to remove as much of the previous obturation material as possible. A technique for achieving this objective is to use a rotary endodontic file that is larger than the existing preparation size²⁵. However, this concept may not be applicable when rotary files are used for retropreparation. When the file is used in this technique, it will inevitably remove less material as the file progresses coronally because of the reverse taper of the file relative to the previously prepared canal. This explains this study's finding that more material remained at 10 mm from the apex compared with 5 mm from the apex. The potential drawback of enlarging the canal with rotary instruments is the increased risk of crack initiation or propagation²⁶. Although it has been known that no technique can completely remove the remaining obturation material^{16–20}, every attempt should be made to clean the canal as well as possible to remove potential etiologic factors for treatment failure.

The incidence of instrument separation was 13.33% (4/30), with all being retrievable

using a hemostat. In orthograde endodontics treatment, a review of the literature indicates an incidence range of 1.3%–10.0%²⁷. However, in a retrospective study, of the 28 separated rotary NiTi instruments, 18 separated in retreatment cases, whereas 10 separated during initial treatment²⁷. Therefore, the chance of file separation may be higher when removing existing filling materials. In this study, 2 separations occurred in lateral incisors and 2 in canines. The palatally inclined anatomic position of these teeth increased the amount of stress on these files and likely contributed to the separation. Although the incidence of separation in this study is higher than previously reported file separation in orthograde endodontic treatment, the mere incidence of file separation alone may not be an outcome predictor. In this study, all the separated instruments were easily retrievable and therefore unlikely to affect the treatment outcome.

The micro-CT analysis of this study revealed 0% incidence of crack or ledge formation. This provides a potentially advantageous outcome when comparing controlled memory endodontic rotary instrumentation versus ultrasonic instruments for use in retroinstrumentation. Ultrasonic instruments have been shown to have an increased incidence of crack propagation after retropreparation in endodontic surgery^{6,8,28}. The experimental procedure was performed with the teeth within the cadaver jaws; therefore, a true evaluation of transportation was not possible in this study because it was not feasible to take preoperative micro-CT scans. Transportation may be more likely with ultrasonic tips because they are very efficient in cutting dentin. It is reasonable to assume that ultrasonic tips, especially the longer instruments, could very quickly get off axis and may result in procedural errors.

Whereas this study is the first to propose this novel technique, there are limitations within our study. First, a preoperative scan was not possible because

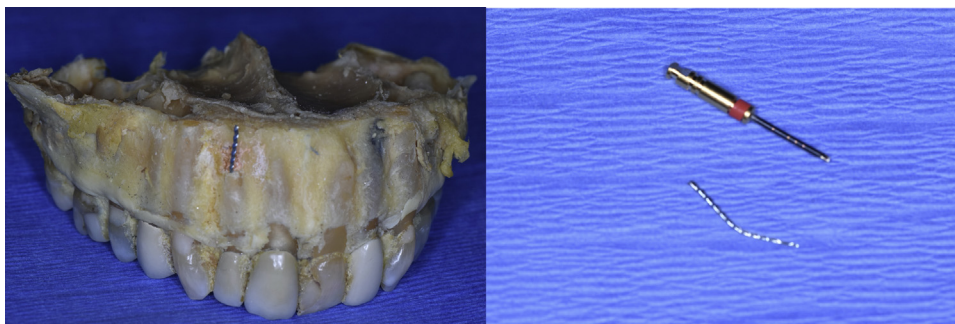


FIGURE 4 – Example of file separation on lateral incisor. File separated at junction of the cutting flutes. File was retrieved with a hemostat.

TABLE 2 - Number and Percentage of Adverse Events That Occurred during Retropreparation Are Reported on Basis of When They Were Discovered

Adverse events		Total number of cases evaluated
During experimental protocol	Incidence of file separation = 4* (13.3%)	30
During micro-CT analysis	Incidence of crack/ledge formation = 0 (0%)	24†

*All 4 files were retrieved. Three separated at junction of cutting flutes and shank and were retrieved with a hemostat. One separated at 4 mm, which was irrigated out.

†24 micro-CT scans taken. Scans taken only on teeth without file separation. Also, 2 samples were not included because of poor image quality.

the experiment was designed to mimic a clinical scenario as much as possible. Second, there was no control group. It was not meaningful to have a control group because no other technique was similar to this. Third, this technique is only feasible on anterior teeth because of anatomic restrictions. Fourth, additional studies are needed to evaluate the obturation and sealing ability of this novel retropreparation design. We discussed the idea of a reverse taper that this file creates relative to original canal morphology. We propose that future studies should evaluate the

sealing ability of various techniques: a gutta-percha cone and sealer, bioceramic material and sealer, and/or a combination of both.

In addition, we wanted to comment further on 2 samples that we were unable to include in the micro-CT analysis. One of the scans was blurry and appears to have been physically interrupted during the process, and the other did not include the entire tooth. Multiple attempts were made to have these samples re-scanned. However, these attempts were unsuccessful, and the 2019 Coronavirus disease pandemic closed access

to the scanner. The decision was made to move forward with the data from the 24 micro-CT scans we had.

CONCLUSION

Retroinstrumentation of surgically resected roots using controlled memory files is able to clean the canal effectively, with relatively low adverse treatment outcomes. Although this novel technique is limited in application, it is a safe and effective way to achieve a deep, clean retropreparation.

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The authors deny any conflicts of interest related to this study.

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