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ORIGINAL ARTICLE

Surface integrity of root ends following apical resection with targeted trephine burs

ABSTRACT

Aim: *Targeted endodontic microsurgery may be performed utilizing trephine burs. The purpose of this study was to determine if guided resection using trephine burs produces cracks or fractures within the root.*

Methodology: *Twenty maxillary anterior and twenty mandibular molar mesial roots from extracted teeth were cleaned, shaped, and obturated. Roots were resected with either targeted trephine burs or multipurpose burs. Resected root ends were analyzed using light microscopy with a fluorescent filter and a dental operating microscope. Teeth were graded based on the presence, extent, and location of cracks.*

Results: *One (10%) anterior trephine-resected root demonstrated cracks, while three (30%) anterior multipurpose bur-resected roots had cracks. These findings were not statistically different (P=0.264, Chi-square=1.25). No molar teeth had detectable cracks. There was no significant difference between the groups with regards to crack formation.*

Conclusions: *Analysis of the samples supports the use of trephine burs in targeted endodontic microsurgery.*

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Introduction

The surgical removal of root ends, or root end resection, is a treatment for teeth that have undergone non-surgical root canal therapy without successful resolution of the apical pathosis. The goal is to eliminate periapical pathologic tissues and irritants in order to promote healthy tissue regeneration. By removing the last 3-4 mm of the root, one can eliminate the majority of accessory canals and apical ramifications where resistant bacteria may reside (1, 2).
In recent decades, the introduction of the dental operating microscope, piezoelectric ultrasonics, and more biocompatible root end filling materials has led to improved success rates in endodontic root end surgery. A meta-analysis of the literature found that endodontic microsurgery using modern techniques had a success rate of 91.6% (3). Despite these outcomes, anatomical challenges and restrictive access to the root end deter many skilled endodontists from tackling more challenging cases. Results of a web-based survey reported that 34.3% of responding endodontists were referring at least some endodontic surgeries to oral surgeons (4). Mandibular and maxillary posterior teeth present many of the greatest challenges due to anatomical considerations such as the thickness of the buccal plate, decreased visibility and access, shallow vestibules, and proximity to vital structures such as the inferior alveolar nerve, the greater palatine artery, and the maxillary sinuses (5).
With the advent of cone beam computed tomography, improved treatment planning can be accomplished in three dimensions. In the field of implant dentistry, CBCT has been used in combination with CAD/CAM software and 3-dimensional printing to guide precision implant placement, ensuring proper angulation while avoiding vital structures (6). These same technologies can likewise be used to guide precision endodontic surgeries. With the use of a CBCT scan and CAD/CAM software, a surgical guide can be created to aid in the osteotomy and root end resection while maintaining adequate access to the desired root, thereby overcoming many of the challenges of endodontic microsurgery.
Using these technologies, osteotomy size, bevel angulation, and the level of apical root end resection can be virtually planned. In a preclinical study, Pinsky et al. found that osteotomies performed utilizing CBCT and CAD/CAM surgical guides were able to localize the root apices more precisely and consistently than freehand osteotomies (7). Strbac et al. reported on the use of a surgical guide and piezoelectric ultrasonic instruments to remove cortical bone to gain access to the root apex (8). Ahn et al. presented a case report in which a CAD/CAM surgical template was utilized to guide an anchor drill, localizing the apex of a mandibular molar through thick cortical bone (9). Depending on the surgical site, the custom designed surgical guides can be supported by mucosa, teeth, bone, or with a combination technique which can lend additional support in soft tissue retraction.
Recently, Giacomino et al. described a technique they termed targeted endodontic microsurgery (TEMS) in which root end resection is performed utilizing a 3-dimensionally printed guide directing a surgical trephine bur (10). A recent study comparing TEMS with traditional endodontic microsurgery found that TEMS reduces surgical time and the amount of over-resection of the root (11). In addition, Popowicz et al. report on two cases in which they utilized the cortical plate harvested with the trephine bur during tissue grafting procedures (12). A case report by Antal et al. presented the use of custom trephine burs with a TEMS surgical guide (13). Unlike conventional trephine burs with somewhat wider cutting ends, the authors designed the custom burs with uniform diameters. Since the cutting action of trephine burs is different from currently utilized instruments, the mechanical effects of a TEMS resection technique on root ends are currently unknown. Such effects could include creation and/or propagation of dentinal cracks, which could affect the prognosis of such procedures. The purpose of this research was to evaluate any such effects.

Materials and Methods

Extracted human maxillary anterior and mandibular molar teeth were collected with patients' consent under a protocol approved by the Dwight D. Eisenhower Army Medical Center Institutional Review Board. All extracted teeth were stored in 0.1% NaOCl for no longer than two months. Mesial roots were sectioned from the mandibular molars using a diamond-coated disc. Microscopic evaluation of the roots was performed and those roots with suspected cracks or surface defects were excluded from the study. Forty roots were divided into two groups. Each group (n=20) consisted of 10 maxillary anterior roots and 10 mandibular molar mesial roots. Group 1 served as the control group in which the roots would be resected with a multipurpose bur (Dentsply Maillefer, Johnson City, TN, USA) while Group 2 was the experimental group in which roots would be resected with the guided 5.1 mm trephine burs (BIOMET 3i, Palm Beach Gardens, FL, USA).

Utilizing a dental operating microscope, non-surgical root canal therapy was completed on all roots. Roots were wrapped in saline-soaked gauze to keep them moist during the procedure. Accesses were made with a 557 bur in a high speed handpiece. The working lengths were recorded by visually placing a size 10 K-file until it was visible at the apical foramen and subtracting 1 mm. Root canals were cleaned and shaped using Vortex Blue (Dentsply Sirona, York, PA, USA) rotary files utilizing a crown-down technique to a maximum apical file size of 35/.04 (molar roots) or 50/.04 (anterior roots). Irrigation with 8.25% sodium hypochlorite between each successive file and a final rinse of 5 ml 17% EDTA and 5 ml 8.25% NaOCl was performed in each canal. Following cleaning and shaping, each canal was obturated using gutta-percha and AH Plus sealer (Dentsply Sirona, York, PA, USA) utilizing the warm vertical compaction technique. Following non-surgical treatment, the dental operating microscope and methylene blue dye were used to inspect the roots for any cracks or dentinal defects sustained during instrumentation and obturation.

A custom jig was designed to include a three-dimensionally printed surgical guide fabricated in conjunction with the Army Dental Laboratory at Fort Gordon, Georgia (Figure 1). Roots were secured within the guide using polyvinyl siloxane (PVS). The guide was manufactured to split along its vertical dimension, allowing the teeth to be removed easily. The two halves of the guide were fastened together with a benchtop vise.

Group 1 control roots were resected using a multipurpose bur with continuous water spray. Burs were premeasured based on parameters of the surgical guide to ensure a complete resection. The resection was completed with a single pass of the multi-purpose bur in a mesial-distal direction to create a level plane. No

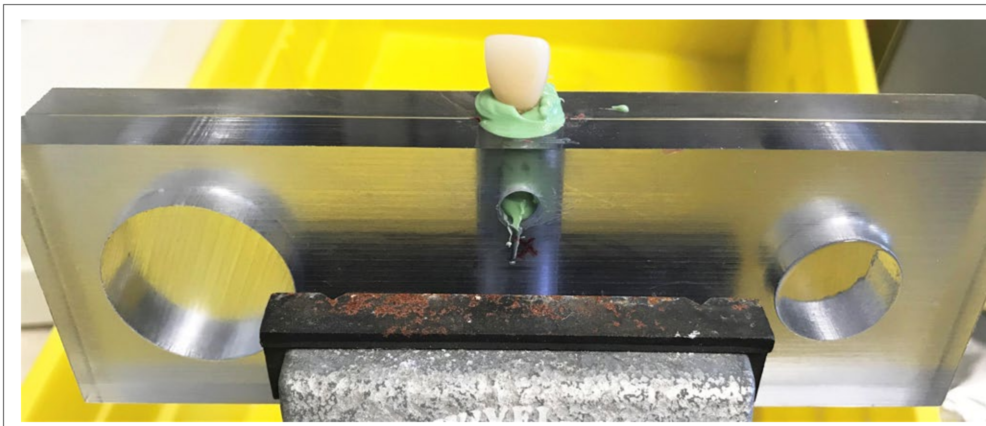
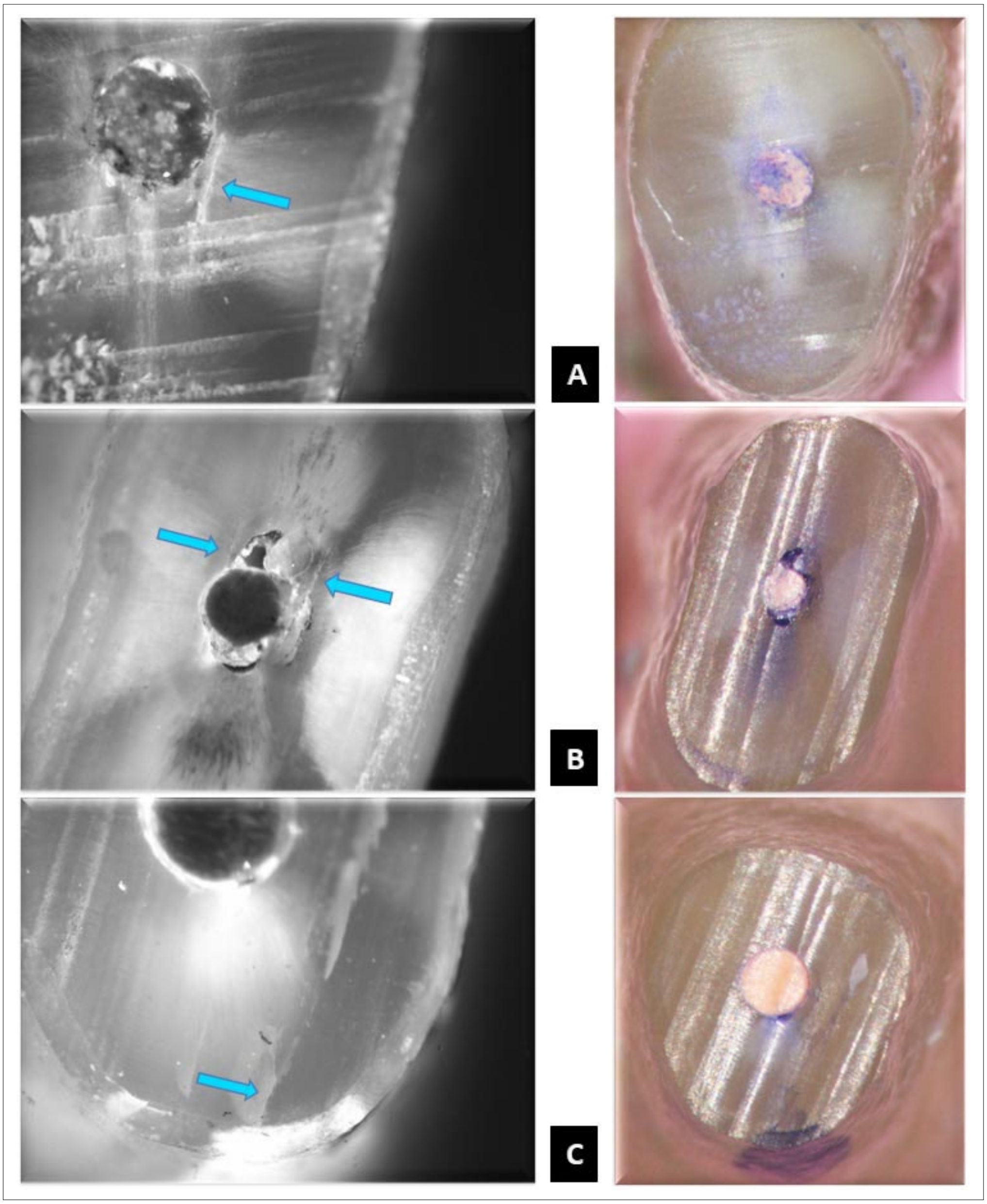


Figure 1. Custom-designed experimental jig with tooth in place.

Figure 2.
A) Microscopic image of a maxillary anterior root end following resection with a trephine bur showing transverse striations and an incomplete crack confined to the dentin, with corresponding photograph.
B) Microscopic image of a maxillary anterior root end following resection with a multipurpose bur showing characteristic striations and incomplete cracks radiating from the canal outward, with corresponding photograph.
C) Microscopic image of a maxillary anterior root end following resection with a multipurpose bur showing characteristic striations and an incomplete crack radiating from the external root surface inward, with corresponding photograph.



additional smoothing was performed. Group 2 experimental roots were resected using a 5.1 mm diameter trephine bur utilizing an electric handpiece (W&H, Dental Werk Bürmoos GmbH, Austria) rotating at the manufacturer's recommendation of 1000 rpm with maximum torque and continuous water irrigation. The root ends were resected with intermittent pressure from the bur from buccal to lingual. Following each resection, the root was removed from the PVS material and immediately placed in 100% humidity in appropriately labeled containers for future observation.

Root surfaces were observed with light microscopy and analyzed by four blinded observers who were calibrated to interpret the microscopic images. In cases of disagreement, consensus was achieved following a discussion categorizing each tooth. Analysis of the root surface was based on three categories, from least to most severe: 0-no cracks, 1-incomplete cracks (originating from the root canal and radiating into the dentin, originating

Table 1
Analysis of the root surface from least to most severe

Method of Resection	Tooth Type	Number of Teeth with Defects	Category of Defects
Multipurpose Bur	Anterior	3/10	1 (i), 1(e), 1 (id)
	Molar	1/10	d
Trephine Bur	Anterior	1/10	1 (c)
	Molar	1/10	d

0=No cracks, 1=incomplete cracks (originating from the root canal and radiating into the dentin or originating from the root surface radiating into the dentin, or confined to dentin), and 2=complete cracks (from the root canal to the root surface). Cracks and defects were further subcategorized as follows: (i) for internal, (e) for external, (c) for confined, and damage to cementum exposing dentin was identified with a (d).

from the root surface radiating into the dentin, or confined to dentin), and 2-complete cracks (from the root canal to the root surface or from the root surface to another root surface). Cracks were further subcategorized by location as follows: (i) internal, (e) external, and (c) confined. Damage to cementum that resulted in exposed circumferential dentin was identified with a (d). Chi-square analysis was performed to compare the groups.

Results

Inspection of the roots with methylene blue and the dental operating microscope did not reveal any cracks or defects resulting from the instrumentation and obturation of the teeth. Following apical root resection, the majority of teeth did not have any defects that could be identified by light microscopic analysis. Results are listed in Table 1. All cracks observed were category 1. Representative examples can be found in Figure 2. One (10%) anterior trephine-resected root demonstrated cracks, while three (30%) anterior multipurpose bur-resected roots had cracks, one of which also demonstrated damage to the cementum. These findings were not statistically different (P=0.264, Chi-square=1.25). No molar teeth in either group had detectable cracks. One molar from each group demonstrated damage to the cementum with no associated cracks. No significant difference in crack or defect prevalence between the trephine and multi-purpose bur groups was observed when combined molar and anterior teeth were analyzed (P=0.292, Chi-square=1.11).

Discussion

Surface integrity of the resected root end was evaluated based on crack production and external root surface damage. The trephine bur gave the most uniplanar resection, leaving only minor mesial-distal, transverse striations in some cases, while the multi-purpose bur produced more cracks as well as the characteristic buccal-lingual striations shown in Figure 2. Such striations from fissure bur resections have been described previously (11). In order to maintain consistency within the study, only one pass of the bur through the root end was allotted in each group. The favorable results of the trephine bur resection might be attributed to the surgical guide which limited bur movement.
Another factor which may have contributed to its smooth cutting and efficiency is the engineering of the bur with end cutting teeth. One distinct difference with the resection produced by the trephine bur was the concave surface that it created due to the bur's cylindrical shape. This may expose additional dentinal tubules at the periphery of the root surface. The significance of this difference and whether it poses a threat to long term success is unknown. Future studies may be performed to inspect these areas for residual biofilms. If desired, the root

surface can be smoothed following the initial resection. The term microcrack may be more suitable to describe the defects seen as they could not be stained with methylene blue dye or observed with a dental operating microscope. These defects could only be observed using a high powered light microscope at 40x magnification with the aid of a fluorescent light filter which reduced white light exposure. Since some in vitro studies have shown that instrumentation and obturation of root canals may cause cracks and induce stresses within root dentin (14-18), it is possible that, immediately prior to resection, the inspection of the roots with methylene blue and the dental operating microscope inappropriately identified the roots as intact. With this in mind, one possible explanation for the microcracks only occurring within anterior teeth in this study could be related to the larger diameter files resulting in excessive stresses being applied to the roots.

The custom jig used in this study attempted to replicate an in vivo environment where the roots would only have physiologic mobility while providing a surgical guide for the bur to cut with minimal deviation. The PVS material used in this study did not limit the cutting efficiency of the trephine bur and provided adequate stability to the root during resection. One limiting factor in the model was the absence of a lesion as would be common in most clinical scenarios. However, in order to stabilize the root within the guide, PVS material needed to fully encompass the root. This method was chosen to enable reproducibility within the study, minimizing variables such as bone loss and lesion size. The teeth in this experiment were stored in a 0.1% NaOCl solution since a previous study demonstrated that this concentration was safe for storing extracted teeth without affecting their hardness values (19), but it is still possible that the cracks identified in this study may have been affected by the ex vivo storage of the roots. Even with the confounding factors inherent in an extracted tooth model of this type, if significant differences were found between the resections with the trephine bur and resections with the multipurpose bur, it would have increased concerns when utilizing this promising surgical approach. While no significant differences were observed in this preliminary investigation, further studies utilizing a cadaver or in vivo model are appropriate. Many different methodologies have been employed to evaluate the creation or presence of radicular microcracks, including endoscopy, scanning electron microscopy, infrared thermography, and micro-computed tomography (20). In future studies, these additional techniques should be considered to evaluate crack formation during trephine bur resection.

Conclusions

Under the conditions of this study, there was no significant difference in crack production by root end resections utilizing either multi-purpose burs or trephine burs. The results of this study support the use of trephine burs for root end resections in targeted endodontic microsurgery.

Clinical Relevance

This study found that targeted endodontic microsurgery (TEMS) using trephine burs does not appear to increase the risk of dentinal microcracks or other defects compared to traditional techniques of root resection.

Conflict of Interest

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

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