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Targeted Endodontic Microsurgery: Trephine Bur and Endodontic Microsurgery Carbide Bur Root End Appearance After Resection in Porcine Teeth

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Targeted Endodontic Microsurgery Trephine Bur and Endodontic Microsurgery Carbide Bur Root End Appearance After Resection in Porcine Teeth.

ABSTRACT

Aim: The introduction of stent-guided trephines in endodontic surgery has allowed clinicians precise and predictable osteotomy and root end resections, especially in anatomically challenging scenarios. While the effects of trephines on bone has been reported in dental literature, little information is available on the effect trephines have on dentin. This *in situ* animal study investigates and compares the surface appearance of root ends resected by highspeed Lindemann carbide burs and stent-guided slow speed trephine burs. **Methodology:** Contralaterally matched porcine blocks containing the second and third mandibular premolars were selected for this study. Pre-operative 40 x 40 mm Cone Beam Computed Tomography (CBCT) studies were taken for surgical preparation and fabrication of targeted endodontic microsurgery (TEMS) guides. A total of fifty-two mesial roots were divided into two groups; 26 roots received endodontic microsurgery (EMS) using a highspeed Lindemann bur, while the contralateral side received TEMS using a slow speed trephine. The burs were only used on one experimental block (two roots) and always started on the mesial root of the second premolar. The roots were analyzed under a surgical operating microscope and stereomicroscope for the presence of dentinal defects. **Results:** Of the 52 roots examined, 10 (19.23%) had dentinal defects. The TEMS group (n = 1, 3.85%) had a significantly lower number of roots with defects than the EMS group (n = 9, 34.62%) (p = 0.01). Additionally, there was no significant difference in the number of defects found between the first and second root resection with the same bur. **Conclusions:** This *in situ* study demonstrates that both Lindemann and trephine burs can be used multiple times without detrimental effects on dentin. More importantly, trephine root end resections create less dentinal defects when compared to root end resections performed by Lindemann burs on porcine teeth.

Keywords: Targeted Endodontic Microsurgery, Lindemann bur, trephine, root end resection, dentin defect

INTRODUCTION

Persistent bacterial infection is the primary cause of root canal treatment (RCT) failure (1). Non-surgical retreatment (RETX) can often address persistent apical periodontitis (2). However, in cases where root canal anatomy has been significantly altered (ledge, perforation, separated instrument), or in cases where an extra-radicular biofilm has developed, retreatment may not be able to control the bacterial assault (3). Further, anatomical restrictions, the presence of an extensive apical lesion, newly cemented esthetic crowns, and the presence of high-quality initial RCT may suggest endodontic microsurgery (EMS) as a treatment of choice (4).

The surgical operating microscope (SOM), ultrasonic root-end preparation, biologically active materials, and direct access to the infection make EMS more successful than non-surgical retreatment and antiquated apicoectomy techniques (5,6,7). Targeted endodontic microsurgery (TEMS) enhances EMS allowing for safe and efficient access to previously prohibitive surgical sites. Cone-beam computed tomography (CBCT), and computer aided design/computer-aided manufacturing (CAD/CAM) produce surgical guides that interact with rotating trephine burs to carryout osteotomy, root end resection and biopsy in a single step (8). Osteotomy site and dimensions are predetermined and result in desirable access and visibility throughout the surgery, overcoming challenges that cause some clinicians to avoid EMS (9). However, if

TEMS is to become a more prevalent intervention, the specialty must ensure that trephine root-end resections do not induce dentin defects (8,10,11,12).

Dentinal defects present visually as incomplete lines that interrupt the integrity of the dentin on the root end surface. They do not typically stain with methylene blue dye or cause a tactile catch with a probe (13). They can extend from the outer root surface toward the root canal or from the inside of the root canal toward the outer root surface (13). Postsurgical dentin defects can have negative consequences for EMS outcomes, as they have been implicated in longitudinal vertical root fractures (14,15,16,17).

Ideal osteotomy instruments should preserve healthy bone and minimize heat generation (18). EMS carbide burs, such as the Lindemann bone bur, create a smooth resection surface that aids in the detection of cracks and anatomical entities (14). TEMS is reported to achieve a smooth root end resection in a single step with minimal heat generation (8).

Trephine burs have routinely been used for autogenous bone graft harvesting and removal of failed implants. In 1967, Brynolf utilized trephines to harvest bone, root end, and apical lesions from cadavers to compare histology with radiographic presentation (19). In clinical endodontics, specialized trephines have been used within root canal systems to remove dentin around separated instruments (20,21).

The purpose of this study is to investigate dentin defect profiles of porcine root ends resected with trephine and Lindemann carbide burs. The null hypothesis is stent-guided TEMS trephines, and freehand Lindemann burs do not induce dentinal defects during root-end resection.

MATERIAL AND METHODS

Sample Size Calculation

A non-inferiority power analysis was performed by a biostatistician using SAS version 9.4 (Statistical Analysis Software, Cary, NC). The results suggested a minimum total sample size of twelve pigs (*Sus scrofa*) (24 pairs; 48 teeth) to achieve 80% power and 5% significance.

Sample Selection

Thirteen mandibles (26 pairs; 52 teeth) from 18+ month-old female pigs were obtained from J and J Packing Company Inc, TX. Animals were sacrificed for reasons not related to this study. The mandibles were hemi-sectioned into contralaterally matched blocks containing the second and third premolars (Fig. 1a). Porcine teeth were selected for this study because the dentin is similar both in chemical composition and in microstructure to human teeth (22,23). They are also readily available and inexpensive in comparison to human cadaver models. A 40 x 40 mm preoperative CBCT scan at 68 kV and 5 mA was made on each experimental segment (3-D Accuitomo 170; J Morita USA, Inc, Irvine, CA) and read axial, coronal, and sagittal planes (i-Dixel 2.0; J Morita USA, Inc, Irvine, CA) to confirm canal development, anatomy, and maturity of apex (Fig. 1b-d). The mesial roots of the premolars were selected for surgical preparation based on canal morphology, resemblance to human roots, and their symmetry to the contralateral side. The experimental blocks were kept in a 100% humid environment during manipulation, transport, scanning, and storage, (storage/transport: 10% phosphate buffered saline (PBS) containers in a 0° C cooler, scanning/manipulation: gauze soaked/irrigation with room temperature sterile water). Next, the block pairs were randomly assigned (Randomizer.org) to receive TEMS or EMS such that the same intervention was carried out for both premolars on the respective side.

Surgical Preparation

Before surgery, all soft tissue was removed from the experimental blocks for ease of experimentation. For the TEMS group, a surgical guide accommodating a trephine of 4.25 mm inner diameter and 35 mm length (ACE Surgical Supply Co., Inc, Brockton, MA) was created within Blue Sky Plan 3 software (Blue Sky Bio, LLC, Grayslake, IL). The stent prescribed a trephine pathway that would resect the root end at a zero-degree bevel 4 mm from the apex with extension beyond the root for ease of core removal. An irrigation window was created in the guide port allowing direct access for copious sterile saline for lubrication and cooling, (Fig. 1e). A stereolithography file was produced and exported to a 3D printer (Objet 260 Connex3; Stratasys Ltd, Austin, TX), and were printed using MED610 resin (Stratasys Ltd, Austin, TX). An intimate fit was verified on the block sections before the surgical procedure. If the surgical guide did not fit, the guide was re-made until a proper fit was achieved.

Two board certified endodontists (BCEs) were randomly selected (Randomizer.org) to complete the assigned surgical procedure on contralaterally matched segments. A standardized armamentarium included: ProErgo (Zeiss Inc, Dublin, CA) microscope SOM, two handpieces; one highspeed surgical handpiece for EMS (Brassler, Savannah, GA), one electric handpiece (1,000 RPMS at maximum torque) for TEMS (Anthogyr SAS, Sallanches, France), a basic surgical instrument cassette (B&L Biotech, Inc., Fairfax, VA), carbide Lindeman bur (Pfingst & Co., Inc, South Plainfield, NJ), predetermined 35mm trephine bur (ACE Surgical Supply Co., Inc, Brockton, MA), caries indicator dye (To-Dye-For; Roydent, Johnson City, TN), and a 2-mm glass light guide transilluminator (AdDent, Danbury, CT). The experimental segments were fixed in a multi-vise attachment (Dremel, Racine, WI) that was affixed to the dental chair (Fig. 1f). Photographs were taken with DSLR camera through the SOM (Canon, Melville, NY) (Fig. 1g,h). The BCEs used the following instructions to prepare the root ends.

EMS Protocol:

- Study preoperative CBCT scans
- Using the SOM create osteotomy on the mesial root of the second premolar with the supplied Lindemann bone bur in a high-speed handpiece (150,000 RPM) under copious irrigation
- Resect root approximately 3-4 mm from the apex with the effort to obtain a zero degree bevel
- Proceed to the mesial root of the third premolar and complete in a similar fashion using the same Lindemann bone bur
- Remaining root end is stained with caries and fracture detecting dye then rinsed with sterile water followed by transillumination and examined for dentin defects under the SOM
- Please record the presence of dentin defects (yes/no), extension (complete/incomplete), direction (buccolingual/mesiodistal/oblique), and location (pulpal wall/ elsewhere)

TEMS Protocol:

- Study preoperative CBCT scans
- Seat and confirm surgical guide fit

- Using the SOM complete osteotomy and root end resection on the mesial root of the second premolar with the supplied surgical guide and trephine bur in the electric handpiece (1,000 RPM at max torque) under copious irrigation
- Proceed to the mesial root of the third premolar and complete in a similar fashion using the supplied surgical guide and same trephine bur
- Remaining root end is stained with caries and fracture detecting dye then rinsed with sterile water followed by transillumination and examined for dentin defects under the SOM
- Please record the presence of dentin defects (yes/no), extension (complete/incomplete), direction (buccolingual/mesiodistal/oblique), and location (pulpal wall/ elsewhere).

Image Analysis

After surgical preparation, the bone inferior to the osteotomy site was removed with a new surgical carbide bur under copious irrigation with the SOM, which allowed for direct visualization of the root ends under the stereomicroscope (Fig. 1i). The resulting root end resections were viewed in random order through a Stemi 305 stereomicroscope under high-level illumination (Carl Zeiss, Oberkochen, Germany) and broadcasted live onto a 24-inch Full HD LED computer monitor (Hewlett-Packard, Palo Alto, CA). The blinded BCEs who had been previously calibrated by individual analysis of the root end resections evaluated the root ends together. Answers to the following questions were recorded. The presence of dentin defects (yes/no), extension (complete/incomplete), direction (buccolingual/mesiodistal/oblique), and location (pulpal wall/ elsewhere). Caries and fracture detecting dye and transillumination was used to examine and highlight irregularities, especially dentinal defects in the resected root surface. When there was disagreement between examiners the root end was re-evaluated until an agreement was reached. Photographs were taken with an Axiocam digital camera (Carl Zeiss, Oberkochen, Germany) at 24 x magnification (Fig. 1j-n).

Statistical Analysis

The association between categorical variables and treatment group was analyzed using Fisher's exact test for independence. The proportion of crack directions were compared using Z test. Significance was set to $p < 0.05$. Statistical analyses were performed using SAS version 9.4 (Statistical Analysis Software, Cary, NC).

RESULTS

Of the 52 roots examined, ten roots (19.23%) had dentinal defects. The TEMS group (n = 1, 3.85%) had a significantly lower number of roots with defects than the EMS group (n = 9, 34.62%) ($p = 0.01$). Among the 26 second premolars, none of the TEMS group (0%) had defects, while four in the EMS group (30.77%) had a defect ($p = 0.096$). Among 26 third premolars, one of the TEMS group (7.69%) had a defect, while five in the EMS group (38.46%) had a defect ($p = 0.16$). There were no significant differences in defects found between the second and third premolar. No significant differences were found between providers and the number of defects created, Provider 1 (15.00%) and Provider 2 (22.88%) ($p = 0.72$). The distribution of dentinal defects per treatment type, tooth, and provider is summarized in Table 1.

Dentinal defect outcomes are shown in Table 2. All ten roots with dentinal defects had only one defect. All ten defects were incomplete with regards to extension; 7 were in buccolingual direction, two mesiodistal, and one tooth had an oblique defect. While there was no significant difference in defect direction between TEMS and EMS ($p = 1.00$), there was a significant difference in overall defect direction buccolingual (70%) to mesiodistal (20%), (Z= -3.45, p=0.0006), and buccolingual (70%) to oblique (10%), (Z= -4.14, p<.0001).

DISCUSSION

This *in situ* study investigated dentin defect profiles on porcine root ends resected with trephine and Lindemann carbide burs. Our results indicate that TEMS resected root ends had a statistically significant lower number of defects than the EMS group. Therefore, the null hypothesis was rejected.

To our knowledge, this is the first study to analyze the topography of root ends resected with trephine burs. It could be inferred that a trephine bur rotating at a slower speed (1000 RPMs) in a continual "pecking" motion could increase the likelihood of dentin defects; however, our results suggest the opposite. Stent-guided trephines appear to provide significant handpiece control producing a more uniform osteotomy and root-end resection, while root ends resected with Lindeman burs tended to have many different types of surface irregularities. These are perhaps due the aggressive nature of the Lindemann burs flutes—causing excessive vibration or the angle of resection and refinements in order to achieve a zero-degree bevel. These irregularities were noted in our findings but were not included in the nine dentin defects documented. It could also be assumed that utilization of the same bur for multiple osteotomy and root end resections would result in a higher amount of dentinal defects due to the inefficiency of the cutting flutes (Lindemann) or teeth (trephine) due to dulling. Our results indicate that while there was an increase in the dentin defects from premolar 2 to premolar 3 for both procedure types, this increase was not statistically significant.

The majority of research on dentinal defects is focused on different file types (22, 23, 24, 25) and ultrasonic root-end preparations (26, 27, 28). One *ex vivo* study described resected root ends and found 100% of the Lindeman bur resections had "root shattering," that was described as a fracture of the mesial or distal surface during resection (14). It was hypothesized that the burs large diameter and wide spacing between cutting flutes could be to blame for the fractures (14). The study concluded that, while shattering is not commonly encountered in clinical cases, it may be an indication that forces imparted on the root during resection may set up stresses that can lead to dentinal defects or fracture (14). Indeed, Tawil et als *in vivo* study questioned whether the strain of root end resection could increase the likelihood of dentinal defects (29). This study bridges the gap between laboratory and clinical research providing new insight into the relationship between root end resection and dentinal defects, as well as validates TEMS as a safe and predictable surgical intervention.

Although our study shows TEMS had a statistically significant lower number of dentinal defects than EMS, the clinical significance of dentinal defects created by root end resections has not been clarified. EMS maintains high success rates (2, 6) despite the use of Lindemann burs. While the identification of dentin defects at the resection plane is important, perhaps the depth of penetration of these defects is of greater importance to endodontic surgical failures. Further research into this idea is warranted.
It is worth mentioning that while porcine dentin is remarkably similar to human dentin (22, 23), some of the roots utilized in this study had unique projections (Fig. 1o). These dentin projections varied in size and thickness and could have led to vulnerabilities when resecting the root ends, potentially increasing the number of dentinal defects.

It has been suggested that *in situ* models with micro CT analysis be used as the gold standard in the evaluation and research of dentinal defects (30). The same study also found the absence of preexisting dentin defects in non-endodontically treated teeth (30), and similar conclusions have been made in other studies (23, 31). With that in mind, a similar model was used, which allowed us to demonstrate that the trephine and Lindemann burs root end resections were most likely the cause of the dentinal defects. While microCT would have given the study irrefutable evidence, time constraints, and the possibility of dentin dehydration—which can cause dentin defects (32) precluded its use. Another limitation to this study is experimental model does not truly replicate the clinical scenario. Teeth undergoing EMS or TEMS have had initial RCT, and in most cases, RETX. Both *in vitro* and clinical studies have shown a strong association between dentinal defects and RETX teeth (17, 22, 31). The implication that forces from resection could exacerbate pre-existing dentinal defects in RCT or RETX teeth is a valid one that also warrants investigation.

CONCLUSIONS

In summary, based on the parameters of this *in situ* study, we can conclude that TEMS trephine bur root end resections demonstrated statistically significant less dentinal defects when compared to root end resections performed with EMS and Lindemann burs on porcine teeth.

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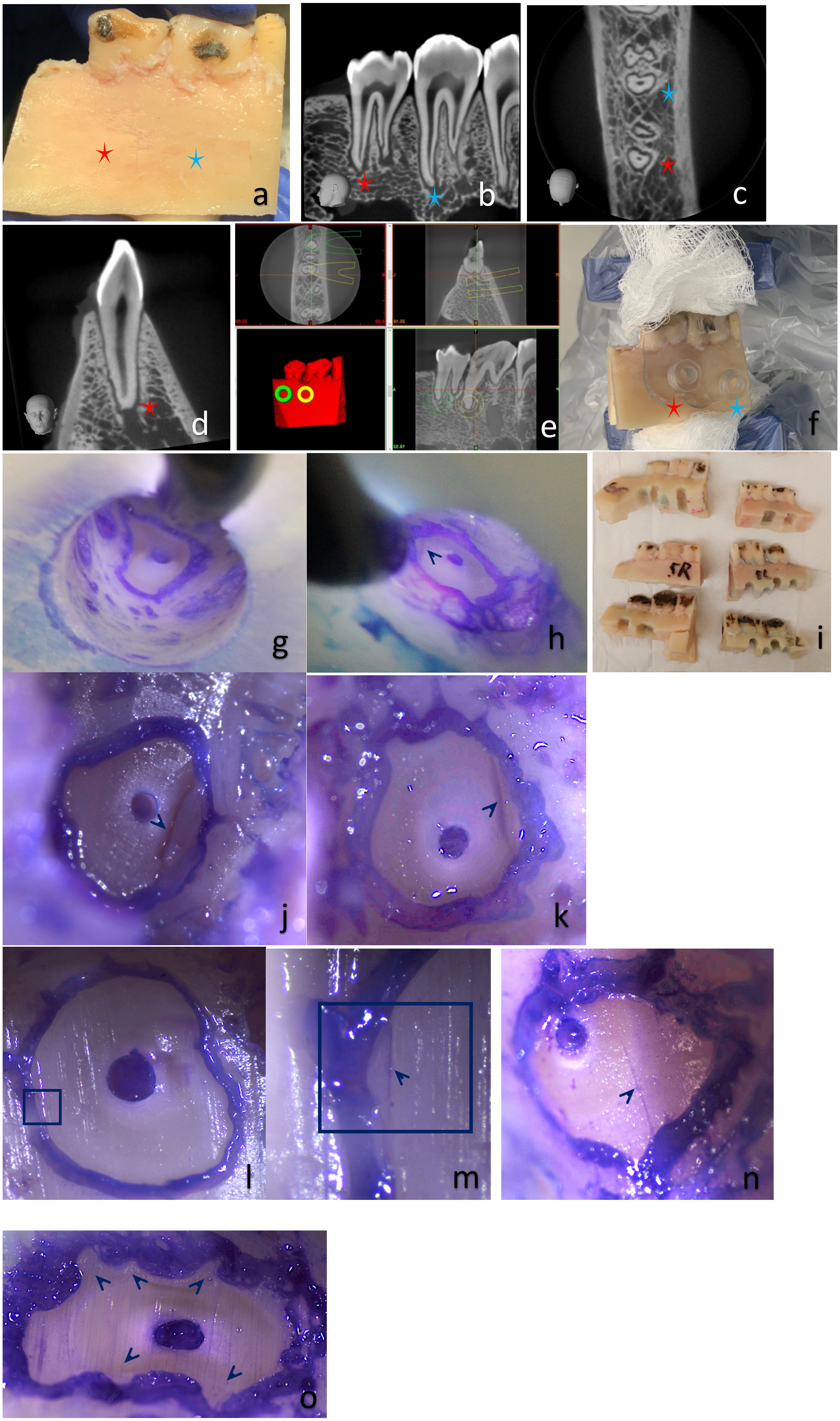
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Figure 1. (a) Example of experimental block section, mesial root of second premolar (red star), mesial root of third premolar (blue star). (b-d) CBCT of experimental block in sagittal (b), axial (c), and coronal plane (d). (e) Prescribed trephine pathway for TEMS procedure. (f) Example of experimental set-up. (g) Examination under SOM of TEMS root resection. (h) Examination under SOM of EMS root resection. Note possible fracture (dark gray arrow). (i) Experimental block sections with bone inferior to the osteotomy site removed. (j-l) Images of dentinal defects from EMS root resections (x24 magnification), (dark gray arrows). (m) Higher magnification (x64) of the dentinal defect found (l)(dark gray square). (n) Image of dentinal defect from TEMS root resection (x24 magnification). (o) Image of the unique root projections on porcine premolar (dark gray arrows).

Table 1. Distribution of Variables by Surface Anatomy

			Intact (n= 42)		Dentinal defects (n= 10)	
Variables	**n**	**%**	**n**	**%**	**n**	**%**
Treatment Type						
TEMS	26	50	25	96.15	1	3.85
EMS	26	50	17	65.38	9	34.62
Tooth						
PM2	26	50	22	84.62	4	15.38
PM3	26	50	20	76.92	6	23.08
Provider						
1	20	38.5	17	85.00	3	15.00
2	32	61.5	25	78.13	7	21.88

Table 2. Summary of Dentinal Defects Outcomes

Outcomes	**n**	**%**
Extension of Defect		
Complete	0	0
Incomplete	10	100
Direction of Defect		
Buccolingual	7	70*
Mesiodistal	2	20
Oblique	1	10
Location of Defect		
Pulpal Wall	0	0
Elsewhere	10	100

*Statistically significant.
Z test analyzed if there was statistically significant difference of dentinal defects in a buccolingual direction compared to mesiodistal and oblique direction, ($Z=-3.45$, $p=0.0006$) ($Z=-4.14$, $p<.0001$) respectively.

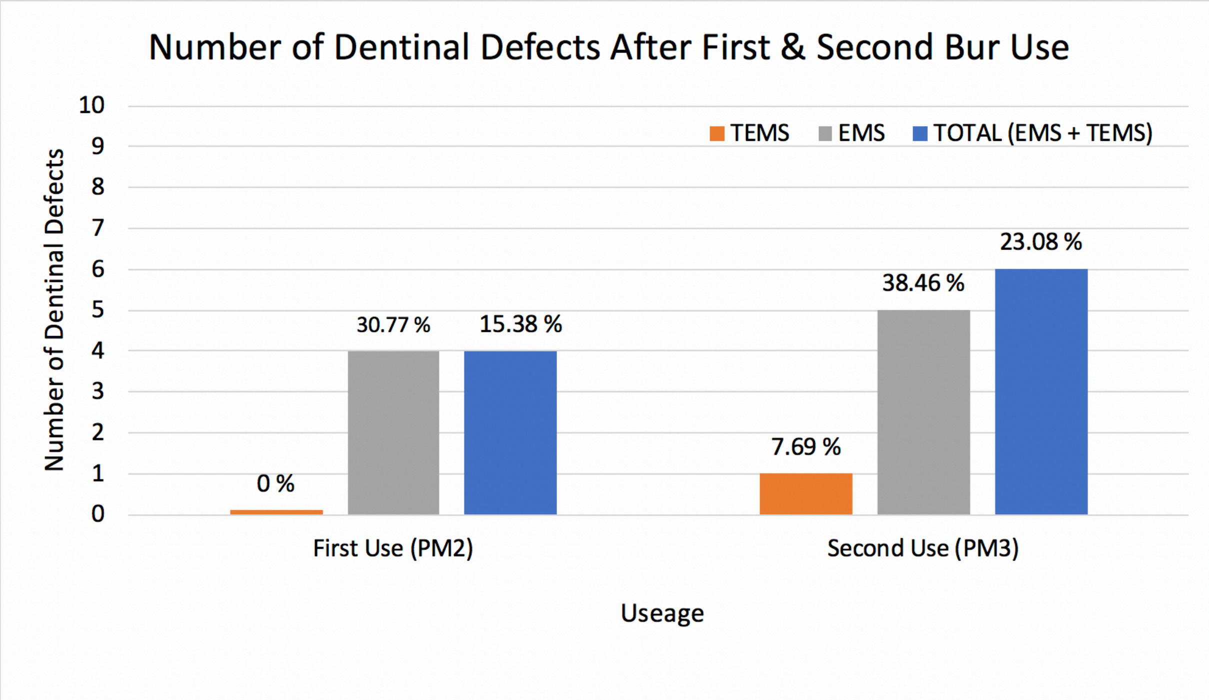

Figure 2. A column graph showing individual and total number of dentinal defects identified after first and second bur use by procedure. The second premolar (PM2) represents first bur use, and third premolar (PM3) second bur use. Tests for the association of dentinal defects between first use and second use determined using Fisher's extact test (p=1.00 for both PM2 and PM3, p=0.73for total). No signficant difference noted.