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Stereomicroscope Analysis of Lindemann versus Zekrya Carbide Bur Root-End Resections in Fresh Ex Vivo Porcine Mandibles

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ABSTRACT

Introduction: Root-end resection has been reported to cause craze lines, cracks and fractures which have been termed "dentinal defects" in the literature. These defects may propagate into vertical root fractures which can significantly reduce endodontic microsurgery success rates. Limited evidence exists comparing dentinal defect induction rates of different root-end resection burs. The purpose of this *in situ* animal parts study is to determine and compare the rate of dentinal defects caused by Lindemann and Zekrya highspeed burs during root-end resection.
Methods: Twelve porcine mandibles were acquired for this study and sectioned into 24 contralaterally matched segments containing second and third mandibular premolars. Pre-operative 40 x 40 mm Cone Beam Computed Tomography scans were obtained for surgical preparation and to verify adequate root development. Two board-certified endodontists performed osteotomy and resected mesial roots of both premolars in the segment using a highspeed Lindemann bur (n=24). The contralateral premolar mesial roots were resected using a highspeed Zekrya bur (n=24). The root ends were then analyzed under a stereomicroscope for the presence of dentinal defects.
Results: Of the 48 root ends examined, 4 (8.33%) had dentinal defects. A related samples McNemar test showed no significant difference in the number of dentinal defects created between the Lindemann (n = 1, 4.17%) and Zekrya (n = 3, 12.50%) groups ($p > 0.05$). **Conclusions:** This *in situ* study revealed that porcine root-end resections with highspeed carbide burs may result in dentinal defects with no difference in the number of dentinal defects in roots resected with Lindemann and Zekrya burs.

KEY WORDS

Endodontic microsurgery, Lindemann bur, Zekrya bur, root-end resection, dentinal defect, stereomicroscope

INTRODUCTION

When non-surgical root canal therapy fails to eliminate periradicular pathology, endodontic microsurgery (EMS) is often indicated as the treatment of choice (1-3). During EMS, the apical portion of the root is resected to remove the etiology of the disease and to prevent reinfection (4). The main objective of root-end resection, cavity preparation and filling is to create an environment that encourages regeneration of alveolar bone, periodontal ligament and cementum (4).

Apical root resection may cause root-end craze lines, cracks, and fractures (5-9), which have been described as "dentinal defects" in the literature (10, 11). Defects can compromise the apical seal (6, 12) and may create a path for bacterial reinfection (9). In a prospective EMS clinical study, teeth with dentinal defects had a significantly lower success rate (32%) than teeth without dentinal defects (97%) (11). Further, dentinal defects may propagate into vertical root fractures (13-15), which can lead to persistent periapical disease and associated morbidity of pain, swelling, bone loss and eventual tooth loss (13, 14).

The rate of dentinal defect generation during root-end resection may vary depending on the resection bur choice. While many studies have investigated the probability of different orthograde or retrograde treatment modalities to cause dentinal defects, very few have compared the dentinal defect rates of different resection burs. There is no "gold standard" root-end resection bur, however the Lindemann bur has been recommended in surgical textbooks (16). In a study investigating the impact of various root resection burs on extracted teeth root ends, Morgan and Marshall compared a Lindemann bur, a Zekrya multipurpose bur and a #57 straight fissure bur (7). In this study, the Lindemann group had the highest number of cracks (11/12) and the Zekrya multipurpose group had the least number of cracks (6/12), although the difference was not statistically significant. Additionally, the authors reported that the Zekrya multipurpose bur yielded the smoothest root-end surfaces and cut with less vibration, which they proposed would cause less patient discomfort relative to the other burs tested. The Lindemann bur is designed for aggressive cutting of hard tissue or bone structure while efficiently removing debris (17). On the other hand, the Zekyra bur has more flutes than the Lindemann bur and the manufacturer states that it is ideal for separating and removing roots (17). The aggressive nature of the Lindemann bur with its fewer flutes may tend to induce more dentinal defects compared to the Zekrya bur *(possible figure here to show stereomicroscope photo of tips of both burs to show difference in # of flutes).*

When investigating dentinal defects, the experimental model choice is important. *In vitro* studies on extracted teeth may prove unreliable because of defects generated from the trauma of the extraction process and/or subsequent dehydration during storage (18). Additionally, lack of support from the surrounding periodontium may lead to defects that would not arise if the experiment was performed on the tooth in its native environment (19). One study compared ultrasonic root-end preparation on extracted teeth to the same treatment on cadaver teeth and found significantly fewer cracks on the *in situ* cadaver teeth (6). It is therefore recommended to investigate dentinal defect rates using experiments performed *in situ* or *in vivo* rather than *in vitro* on extracted teeth (6).

The primary aim of this *in situ* animal parts study is to determine and compare the rate of dentinal defects caused by Lindemann and Zekrya highspeed burs during root-end resection. The null hypothesis is that Lindemann and Zekrya carbide burs do not induce dentinal defects during root-end resection. The alternative hypotheses are that Lindemann and Zekrya carbide burs induce dentinal defects at either the same or different rates during root-end resection.

MATERIALS AND METHODS

Sample Selection

This study was approved by the United States Air Force 59th Medical Wing Institutional Animal Use and Care Committee. Twelve mandibles from mature female pigs were acquired from a meat packing company. Mandibles were denuded of soft tissue and hemi-sectioned into contralaterally matched block segments containing second and third premolars *(figure 1a: hemisected mandible block picture).* 40 x 40mm preoperative Cone Beam Computed Tomography (CBCT) scans were made for each segment using 3-D Accuitomo 170 (J. Morita Corp., Osaka, Japan) set at 68 kVp and 5 mA and 3D renderings were created via i-Dixel 2.0 software (J. Morita Corp.) to confirm canal development, anatomy and root apex maturity *(Fig. 1b-?: show a few slices of CBCT images that show pre-op CBCT).* Mesial roots of the 2nd and 3rd premolars were selected for surgical preparation because of their similarity to human premolars (19, 20). Experimental blocks were transported and stored in chilled containers of paraformaldehyde 4% solution in phosphate-buffered saline (PBS).

A priori power analysis was performed by a biostatistician. A minimum total sample size of 12 pigs (48 teeth, 24 matched pairs) with 10% group difference in the percent of cracks was calculated to achieve 80% power and 5% significance.

Surgery

The block segments containing the second and third premolars were randomly assigned to two experimental groups (n=12 segments which totaled 24 roots for each group). Group 1 underwent root resection with a Lindemann bone bur (Brasseler USA, Savannah, GA) and group 2 underwent root resection with a Zekrya surgical bur (Strauss Diamond Instruments, Palm Coast, FL). Contralateral segments were matched and one side was assigned to group 1 while the contralateral side segment was assigned to group 2, thus establishing a matched-pair experimental model. The same experimental bur was used for both premolars in a segment and then discarded after use on a single block segment.

The twelve block segment matched pairs (each block contained two premolars) were assigned evenly to two board-certified endodontists (BCEs). The BCEs reviewed all CBCT images prior to surgery and made measurements to determine root apex location within the block segment.

All surgical procedures were performed using an NL-4500 high-speed surgical handpiece (Brasseler USA, Savannah, GA) with the designated experimental bur using continuous 0.9% sodium chloride irrigation and visualization under a surgical operating microscope (PROergo, Carl Zeiss Microscopy, Wetzlar, Germany). The BCEs performed osteotomy followed by an approximately 3-4mm root-end resection with zero degree bevel (*maybe another figure here with a picture of the segment with osteotomy and resection completed)*.

Image and Data Analysis

After surgical intervention, the remaining bone inferior to the osteotomy sites was removed by the principal investigator to allow direct visualization of the root ends. The root ends were stained with caries indicator dye (To Dye for Caries and Facture Detector, Patterson Dental, St. Paul, MN) and rinsed with 0.9% sodium chloride irrigation. The resulting dyed root ends were viewed in random order through a Stemi 305 stereomicroscope (Carl Zeiss Microscopy, Wetzlar, Germany) with transillumination (Microlux Transilluminator Kit, Addent Inc, Danbury, CT). Staining alone of the root ends with methylene blue, as is custom, may be insufficient to highlight dentinal defects (8, 11). Rose and Svec recommended the combination of transillumination and caries indicator dye when investigating potential apical cracks caused by orthograde root canal treatment (19) based on findings from a study by Wright et al (21). Images were projected onto a 24-inch Full HD LED computer monitor (Hewlett-Packard, Palo Alto, CA). The BCEs separately analyzed the stained root ends at magnification levels ranging from 20-40x for the presence of dentinal defects. When disagreements occurred, the BCEs re-evaluated the root end together until they reached consensus. A dentinal defect was defined as any break in the dentin on the resected axial root surface. Photographs were taken with an Axiocam 305 digital camera (Carl Zeiss Microscopy, Wetzlar, Germany) between 20-40x magnification (*another figure with pictures of root ends, show some without dentinal defects and some with defects*). A related samples McNemar test was used to statistically analyze the data and significance was set to $P < 0.05$.

RESULTS

Of the 48 root ends examined, 4 (8.33%) had dentinal defects present. Only one root (4.17%) in the Lindemann group had a dentinal defect compared to 3 roots (12.50%) in the Zekrya group, however the difference was not significant ($p > 0.05$). The distribution of dentinal defects per treatment group, tooth, and provider is summarized in *Table 1(need data table)*.

DISCUSSION

Given the clinical significance of persistent disease and poor outcomes linked to dentinal defects (6, 11-15), the purpose of this study was to determine if the trauma of root-end resection causes dentinal defects and whether different resection burs might induce defects at varied rates. A previous study compared a Lindemann bur, a Zekrya multipurpose bur and a #57 straight fissure bur during root-end resection (7) while another study compared an Er: YAG laser, a diamond-coated ultrasonic tip, and an unspecified plain tapered fissured carbide bur (5). Rates of root ends with cracks for these two studies were 72% and 83%, respectively. The current study confirmed Morgan and Marshall's findings of no significant difference in number of dentinal defects between the Lindemann and Zekrya groups, however a total of only 8% of roots in this study showed defects compared to the much larger rates found in the previous studies. This variance may be explained by the differences between the experimental models used. Both previous studies were performed *in vitro* on extracted teeth which has been shown to be unreliable when investigating dentinal defect rates (6, 18, 19). Conversely, the same research group that compared the Lindemann and Zekrya burs during root-end resection *in vitro* performed another study using only the Zekrya multipurpose bur during *in vivo* root resections of 25 maxillary teeth and found no root-end cracks (22). Other studies performed using either *in vivo* or *in situ* models produced results ranging from 0-10% (6, 9, 23), which are similar to the present study's findings.

In the current study, an *in situ* porcine experimental model was used to investigate the incidence of dentinal defects after root-end resection with Lindemann and Zekrya carbide resection burs. The null hypothesis that Lindemann and Zekrya carbide burs do not induce dentinal defects during root-end resection was rejected and the alternative hypothesis that these two resection burs induce defects at the same rate was supported instead. To our knowledge, this is the first study to compare dentinal defect induction rates between different carbide resection burs using an *in situ* experimental model.

One of the limitations of this study is that porcine teeth were used instead of human cadaver teeth. Porcine teeth were selected due to their relative inexpensiveness and ease of acquisition compared to cadaver teeth. Additionally, porcine dentin has similar microstructural and chemical properties to human dentin (20, 24). Rose and Svec also used porcine teeth in a study investigating apical root cracks (19). They hypothesized that the influence of human cadaver preservation chemicals may alter the properties of dentin, causing unknown variables during instrumentation and that using fresh unembalmed ex vivo animal mandibles may therefore yield more reliable results than experiments using preserved cadavers.

Another limitation of this study is that root resection was performed without prior orthograde root canal treatment. Performing root canal treatment before root-end surgery would have more closely simulated a true clinical scenario, however root canal instrumentation and obturation has been shown to cause dentinal defects (10) and the purpose of this study was to determine the impact of resection alone. Hence, the decision to perform resection on uninstrumented canals was made to avoid confounding variables.

De-Deus et al. suggested that micro-computed tomography (micro-CT) is an ideal imaging method to detect root dentinal defects (18). One of the advantages of this imaging method is that the specimen teeth can act as their own controls by comparing pre-operative micro-CT scans to post-operative scans to determine if post-operative defects were present pre-operatively (13). Despite clear benefits, micro-CT may not be the gold standard imaging method for dentinal defect detection. Shemesh questioned the sensitivity of micro-CT to reveal dentinal defects due to insufficient scanning resolution (25) which Tawil supposed may be the reason that some defects can be seen better with magnification combined with transillumination (26), which supports the imaging method used in the present study.

CONCLUSION

Under the conditions of this *in situ* animal parts study, it can be concluded that root-end resections with highspeed carbide burs may result in dentinal defects, as observed with stereomicroscope imaging. Moreover, there is no difference in the number of dentinal defects in roots resected with Lindemann and Zekrya burs.

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The opinions or assertions contained herein are the private ones of the author(s) and are not to be construed as official or reflecting the view of the DoD or USUHS.

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

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