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THE EFFECT OF SMEAR LAYER REMOVAL ON ENDODONTIC OUTCOMES

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ABSTRACT

THE EFFECT OF SMEAR LAYER REMOVAL ON ENDODONTIC OUTCOMES

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Introduction: A layer of organic and inorganic debris referred to as the smear layer is produced during mechanical instrumentation of the root canal system. The combination of ethylene-diamine-tetraacetic-acid (EDTA) and sodium hypochlorite (NaOCl) has been shown to effectively remove the smear layer. To date, no prospective controlled *in vivo* studies have been published examining the effect of smear layer removal on endodontic outcomes in permanent teeth. **Objective:** This randomized, prospective, double-blinded clinical trial compared the endodontic outcomes of teeth where the smear layer was either removed or left intact. A secondary analysis assessed the influence of covariate factors on healing. **Methods:** Subjects meeting study inclusion criteria were randomly assigned to one of two irrigation groups. Root canals were instrumented in a standardized manner followed by a final irrigation of either 1ml of 17% EDTA or 1ml of 0.9% sterile saline. Clinical and radiographic evaluations were completed no earlier than 12- months post-treatment to assess outcomes. A modified periapical index (PAI) score (1-5) was used for radiographic analysis. Data were analyzed using Fisher's exact test ($\alpha < 0.05$). **Results:** For this interim analysis of 243 subjects, no significant difference in outcome was found between groups ($p = 0.57$). Pre-operative necrosis ($p = 0.01$) and a pre-operative apical lesion ($p < 0.0001$) were the only covariates found to affect healing rates. **Conclusions:** Within the limitations of this *in-vivo* clinical study, removal of the smear layer did not affect endodontic outcomes.

TABLE OF CONTENTS

LIST OF TABLES.....	v
LIST OF FIGURES.....	vi
CHAPTER 1. Introduction.....	1
CHAPTER 2. Materials and methods.....	6
CHAPTER 3. Results.....	10
CHAPTER 4. Discussion.....	16
CHAPTER 5. Conclusions.....	20
REFERENCES.....	21

LIST OF TABLES

Table 1. Covariate Factors Evaluated.....	12
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LIST OF FIGURES

Figure 1. The Healed Rates of the Irrigation Protocols.....	13
Figure 2. Pre-Operative Response to Cold and Healed Rates.....	14
Figure 3. Pre-Operative Radiolucency and Healed Rates.....	15

CHAPTER 1: Introduction

The first researchers to mention the presence of a layer of debris from grinding on tooth surfaces coined the term “smear layer” [1]. They noticed this substance remained when cutting on calcified tissue with either hand or rotary files. In 1975, McComb & Smith performed a study where they observed dentinal walls on the inside of teeth they had split open. Using a scanning electron microscope (SEM), they observed a noteworthy difference between an uninstrumented canal and an instrumented canal wall. They noted that the inner walls of canals that had been not been instrumented had “generally a smooth, sound, and clean dentin surface and open dentinal tubules, often with fingerlike projections of dentin pointing toward the canal” [2]. However, when they observed canals that had been instrumented, they observed something quite different. They found dentinal walls that were “completely obscured by this smeared layer” comprised of not only dentin, but necrotic and viable tissue, including remnants of amputated odontoblastic processes, pulp tissue, cytoplasmic and organelle enzymes, lamina limitans, and even fragments of predentin [2, 3]. Even at this time, researchers were asking about the significance of the smear layer and what its removal meant for the successful outcome of endodontic therapy. Other researchers were also using SEM to observe the presence of the smear layer. It appeared amorphous, irregular, granular or particulate, and was very tenacious [4, 5, 6, 7]. This “smear layer” was largely ignored after its discovery until the early 1980s [8] and the overall impact of the presence or the absence of the smear layer had not yet been established. When the smear layer is generated either by low-speed hand filing, or by 400,000 rpm high-speed burs, the layer is heavily burnished and the debris formed can be densely packed into the dentinal tubules anywhere from 40 μm to 110 μm deep, forming “smear plugs” [6, 9]. With the irregularities of the internal dentinal walls, as well as the variation of instrumented and un-instrumented areas, the thickness of the smear layer can vary greatly, but

in the canal space itself, it was generally observed to be 1-2 μm thick [6]. Contributing factors to the thickness of the smear plug can vary depending on the sharpness and speed of the instrumentation which causes it, and also whether the dentinal walls were wet or dry when they were cut [10]. The tubular packing of dentinal debris was originally thought to be mainly due to the physical forces generated by the action of burs and endodontic instruments [11, 6]; however, in 1989, Aktener and Cengiz showed that tubular compaction of dentinal debris was actually due to capillary action as the result of adhesive forces between the dentinal surface and the debris [9].

For many years, it has been known that bacteria are a key component in how pulpal and periapical pathology develop [12, 13, 14]; it is for this reason that adequate cleaning and shaping of a root canal system is so critical for removing bacteria and their byproducts as completely as possible. What complicates this task is the extreme complexity and diversity of the root canal system, as well as the fact that mechanical instrumentation alone is incapable of effectively cleaning the entire root canal system [15, 16]. In fact, bacteria and their byproducts are not even confined to the root canal space itself. Bacteria and the toxins they produce have been found in the dentinal tubules up to two-thirds of the thickness of the root in infected root canal systems [17]. Researchers have shown that a myriad of factors, such as the type of bacteria, the amount of bacteria, the duration of exposure, and the presence or absence of the smear layer, can all have an influence on the depth and bacterial penetration into the dentinal tubules. It is even possible that the smear layer itself may be infected and may protect the bacteria already present in the dentinal tubules [18].

Various methods and solutions have been used over the years to remove the smear layer; ethylene diamine tetra-acetic acid (EDTA) has been shown to be highly effective. EDTA is a chelating agent which acts on the inorganic components of the smear layer, causing

decalcification of dentin and exposure of collagen fibrils. Using another irrigant, such as sodium hypochlorite (NaOCl) dissolves the collagen leaving the openings to the dentinal tubules exposed [6, 19]. When used as a lone irrigant, sodium hypochlorite is a very effective rinse for dissolving pulpal remnants and even pre-dentin resulting in a superficially clean canal; but it is ineffective at removing the inorganic hard tissue portion of the smear layer which is firmly embedded along the canal wall and into the dentinal tubules [5, 6]. Irrigant combinations such as EDTA and sodium hypochlorite have been found to be very effective at eliminating biofilms of *Enterococcus faecalis* [20], and the combined use of 5% NaOCl and 15% EDTA showed a greater antimicrobial effect than with NaOCl alone in one study [21]. Other research showed 25% citric acid and 17% EDTA both removed the smear layer effectively, while a combination of 17% EDTA with a final rinse of 5.25% NaOCl produced the best results according to Yamada [5].

The smear layer has been shown to inhibit the penetration of intracanal disinfectants into dentinal tubules [22] and compromise the seal of obturating materials in dye leakage tests [23]. While EDTA is highly effective at removing the smear layer, there are noted concerns about its potential to erode the dentin. One study found that irrigation with 2.5% NaOCl followed by 17% EDTA removed the smear layer with no significant alteration to the dentin structure when the chelating agent was applied for seven minutes. Three and five-minute application times resulted in partial removal of smear layer; at one minute, the removal of smear layer was negligible [24]. Contrastingly, other studies evaluated contact time and the effect of EDTA on smear layer removal and the structure of dentin. McComb and Smith produced the cleanest canals after EDTA was sealed in the canal for 24 hours [2]. Another study, the experiment performed investigated one-minute or ten-minute applications of EDTA followed by 10 mL of 5% sodium hypochlorite. This study found that 1 minute of rinsing with

EDTA effectively removed the smear layer, leaving open tubules and a clean dentinal surface, while a ten-minute rinse with EDTA produced excessive peritubular and intertubular dentinal erosion and larger tubule openings [25]. Additionally, the optimal volume of an EDTA rinse was studied and it was established that 1 ml of 17% EDTA with a contact time of one minute, followed by a final rinse of 3 ml of 6% NaOCl is just as effective as 10 ml 17% EDTA in removal of the smear layer [26].

Interestingly, some studies have shown that the removal of the smear layer produced an increase in apical microleakage [23, 27]. The smear layer can be thought of as a way to occlude the dentinal tubules. Once it is removed, it increases the permeability of the dentin by creating an additional pathway for pathogenic bacteria to leak into the tubules [28, 8].

Due to the perpetual pursuit of safer procedures and more effective outcomes, various materials continue to be tested. As recently as 2009, Spanó & Silva compared 15% EDTA, 10% citric acid, 10% sodium nitrate, apple vinegar, 5% acetic acid, 5% malic acid, and sodium hypochlorite as possible agents to remove the smear layer and found that 15% EDTA followed by 10% citric acid were the most successful [29].

Maleic acid is a mild organic acid found to possess similar smear layer removing qualities when used as an acid conditioner in restorative dentistry [30]. One study compared the effectiveness of 17% EDTA and 7% maleic acid, followed by 2.5% NaOCl as a final irrigant in the removal of the smear layer. They found that there was no significant difference between the irrigants in the coronal and middle third of instrumented canals and that both combinations efficiently removed the smear layer. However, in the apical third, maleic acid outperformed EDTA significantly and completely removed the smear layer on the root canal walls leaving the tubules patent. In EDTA-treated specimens, moderate amounts of smear layer remained, and in some areas, peritubular dentinal erosion was found. Final irrigation with 7%

maleic acid was more efficient than 17% EDTA in the removal of smear layer from the apical third of the root canal system; a crucial area for disinfection [31]. However, under scanning electron microscope, a different study found that 17% EDTA more efficiently removed the smear layer than 7% maleic acid at all root levels [32].

To date, there have been no *in-vivo* studies investigating the intentional removal of the smear layer in a root canal system in adult teeth and its effect on healing outcomes from non-surgical endodontic therapy. The purpose of this double-blinded, randomized, controlled clinical trial is to investigate, 1) the effect of smear layer removal from the root canal system on healing outcomes and 2) the impact of potential contributing factors other than the methodology of non-surgical root canal therapy on healing outcomes.

CHAPTER 2: Materials and methods

Materials and Methods adapted from Fleming, A. 2020 Thesis Manuscript

The Institutional Review Board (IRB) at the Walter Reed National Military Medical Center (WRNMMC), Bethesda, Maryland, approved this study, WRNMMC IRB #352491, “The Effect of Smear Layer Removal on Endodontic Outcomes.” WRNMMC also provided funding. Since the inception of this study, the Material and Methods section of this manuscript has been modified from the initial approved protocol.

The Endodontics Department at the Naval Postgraduate Dental School (NPDS) serves all active duty military, their dependents, retired military, as well as foreign military members and other categories of eligible beneficiaries. Inclusion criteria for patients to be enrolled were as follows: patients must be 18 years or older, in good health (American Society of Anesthesiology health status classification I or II), require initial, one-appointment non-surgical root canal therapy, and must agree to return for a 1-year follow-up examination.

Patients with a history of periodontal disease, previously initiated or previously treated root canal therapy, active antibiotic use or presenting with an acute apical abscess, were ineligible to participate in this study. Those patients who were allergic to any medication or dental material used in the study, including latex or gutta percha, and subjects who reported being pregnant, were also excluded from participation.

Once consented and enrolled, subjects were randomly assigned to one of two treatment groups. Orthograde and angled pre-operative periapical radiographs were exposed. Medical conditions, clinical symptoms, diagnostic and treatment data were collected using standardized data collection forms.

All treatment was provided by NPDS endodontic residents using dental operating microscopes and overseen by an Endodontic Department faculty member. With the exception of the irrigation variable, either 17% EDTA or 0.9% sterile saline, a standardized treatment protocol was utilized regardless of group assignment. Subjects were anesthetized and the tooth to be treated was isolated with rubber dam and Oraseal[®] caulking adhesive (Ultradent Products, South Jordan, UT). Straight-line access was established using #2 round or #557 carbide burs (Henry Schein, Melville, NY) and EndoZ burs (Dentsply Sirona, Tulsa, OK). Coronal flaring was created using #2, #3, and #4 Gates Glidden drills (SybronEndo Corporation, Orange, CA). Canal working lengths were established using a Root ZX[®] (J Morita, Irvine, CA) and confirmed radiographically. A glide path was created using 0.02 taper #10, #15, #20 FlexoFile[®] (Dentsply Sirona, Tulsa, OK) stainless steel files to working length. The canals were cleaned and shaped with 0.04 Vortex Blue[™] (Dentsply Sirona, Tulsa, OK) rotary files using a crown down technique to at least a master apical file size #35 with .04 taper. Recapitulation was performed with 0.02 taper #10 Flex-o-Files to working length and irrigated with 8.25% NaOCl, delivered from a 30-gauge side vented irrigation tip between all file sizes for a total intraoperative irrigation volume not exceeding 2 ml. The canals were dried with sterile paper points (Henry Schein, Melville, NY).

To blind providers to the final irrigation solutions, each was given a syringe containing either 17% EDTA or 0.9% saline, labeled “irrigant A” or “irrigant B.” The clinician delivered 1 ml of the test irrigant 1 mm short of working length over 1 minute per canal, after which identical treatment for all subjects resumed.

A final rinse of 3 ml of 8.25% NaOCl per canal was performed and the canals were dried with sterile paper points (Henry Schein, Melville, NY). A System B[®] (Kerr Corporation, Brea, CA) plugger that bound within the canal 5-7 mm short of working length was selected.

Working length was confirmed using a 0.04 taper master gutta percha cone (Diadent, Burnaby, BC, Canada). Roth 801 sealer (Roth International LTD, Chicago, IL) was delivered into the canal and the walls coated. The master cone was seated to working length and the canal was obturated with gutta percha using a continuous wave technique. The canal was backfilled using a thermoplasticized backfill technique. Alcohol-soaked cotton pellets were used to clean the chamber prior to temporizing the access with a sterile cotton pellet and Fuji Triage® (GC America Inc., Alsip, IL) or Cavit™ Temporary Filling Material (3M ESPE Dental, St Paul, MN). A post-operative radiograph was exposed using an XCP® (Dentsply Rinn, York, PA) device with Blu-Mousse® (Parkell Inc., Edgewood, NY) bite registration material in order to reproduce the vertical and horizontal angles of the original radiograph at the one-year follow-up appointment. Subjects were instructed to return to their referring dentist for the permanent restoration.

A follow-up examination was conducted no sooner than 12 months following completion of treatment. Providers reviewed health histories and recorded clinical data including results from diagnostic testing on standardized follow-up data collection forms. A follow-up periapical radiograph was taken using the positioning device previously created at the treatment appointment.

All radiographs were assessed using a modified PAI scoring technique, described by Ørstavik [33]. PAI scoring was conducted by 3 calibrated, board-certified endodontists. Coronal restorations of the immediate post-operative radiograph and the 1-year follow-up radiograph were masked to eliminate reviewer bias. Radiographs were coded, randomized, and individually projected onto a screen in a dark room. Radiographs were scored individually; when there was disagreement, a forced consensus was initiated. A PAI score of 1 or 2 was considered healed while a PAI score of 3, 4 or 5 was considered non-healed. All data were

entered into SPSS Statistics (IBM, Armonk, NY). R software was used for statistical analysis (Core Team 2021)

Separate pulpal and apical diagnoses were made based on diagnostic testing conducted during the follow-up exam.

Outcome assessment. Data from the treatment and follow-up exam were utilized to determine the endodontic outcome. Subjects classified as “healed” were asymptomatic with an absence of a radiographic lesion at the time of follow-up, while “non-healed” subjects were symptomatic with or without a radiographic lesion.

Sample size was established by estimating an 80% healed rate at 12-months adding in a 40% projected drop-out rate. In order to assess the true healed rate to within 5 percentage points, a power analysis recommended a total 440 subjects, with 220 per test group. A Fisher’s exact test ($\alpha < 0.05$) was used to perform all statistical comparisons.

CHAPTER 3: Results

This interim analysis reports that a total of 342 subjects have been enrolled in the study. 24 subjects were enrolled since the last interim analysis. Eleven subjects did not complete the NSRCT at NPDS, resulting in 311 subjects who were eligible for follow-up. 252 subjects completed the follow-up examination for a follow-up rate of 81%. A total of 51 subjects with a completed follow-up were unable to be analyzed due to extraction ($n = 15$) or deviation from protocol ($n = 36$). The most common protocol deviation was due to multiple appointment treatments, others included surgical root canal treatment, missed canals, use of a sealer not included in the protocol and a known use of EDTA. The remaining 211 subjects were analyzed. As shown in Figure 1, 72% of subjects assigned to the 0.9% sterile saline group healed while 64% of subjects assigned to the 17% EDTA group healed. Comparison of the two irrigation protocols demonstrated no significant difference between groups ($p = 0.53$). Covariate factors that were evaluated as potentially affecting healing are listed in Table 1. Because of the limited number of subjects evaluated, healed rates were derived by combining data from the two groups for all covariate analyses. A pre-operative necrotic pulpal diagnosis, and the presence of a pre-operative radiolucency were the only covariates significantly influencing healed rates (Figures 2-3). For teeth with a pre-operative response to cold (Figure 2), 78% with a non-lingering response (R/NL), and 77% with a lingering response (R/L), were considered vital. 58% of teeth exhibited no pre-operative response to cold (NR) and were considered necrotic. Pooling healed rates of teeth testing as vital compared to healed rates of those testing as necrotic revealed a significant difference in response to cold ($p = 0.01$). As shown in Figure 3, 79% of those subjects without a pre-operative radiolucency healed, whereas 57% of those subjects with a pre-operative radiolucency healed. This represented a significant difference according to Fisher's Exact Test ($p < 0.0001$).

At previous interim analyses, diabetes was evaluated as a possible covariate factor in the healing outcomes of patients. In this current analysis, diabetes was not shown to play a significant role in the outcomes between the two irrigants tested.

Table 1. Covariate Factors

Gender	History of ortho treatment	Pre-op/Post-op lamina dura
Tooth position	History of external resorption	Presence of pre-op radiolucency
Tooth type	History of bleaching	Pre-op pulpal diagnosis
Pre-op/Post-op diabetes	History of internal resorption	Pre-op apical diagnosis
Pre-op/Post-op HTN	Pre-op/Post-op post	Patency
Pre-op/Post-op smoker	Pre-op/Post-op caries	Procedural complications
Pre-op/Post-op coronary heart disease	Pre-op/Post-op cold sensitivity	Intra orifice barrier
Pre-op/Post-op pain	Pre-op/Post-op mobility	Obturation fill length
Pre-op/Post-op EPT results	Pre-op/Post-op bleeding on probing	Post treatment apical diagnosis
Pre-op/Post-op palpation	Pre-op/Post-op restoration	Post treatment pulpal diagnosis
Pre-op/Post-op percussion	Pre-op/Post-op probing depths	Time elapsed between initial treatment and permanent restoration
Pre-op/Post-op sinus tract	Pre-op/Post-op open margin	Follow-up apical diagnosis
Pre-op/Post-op swelling		

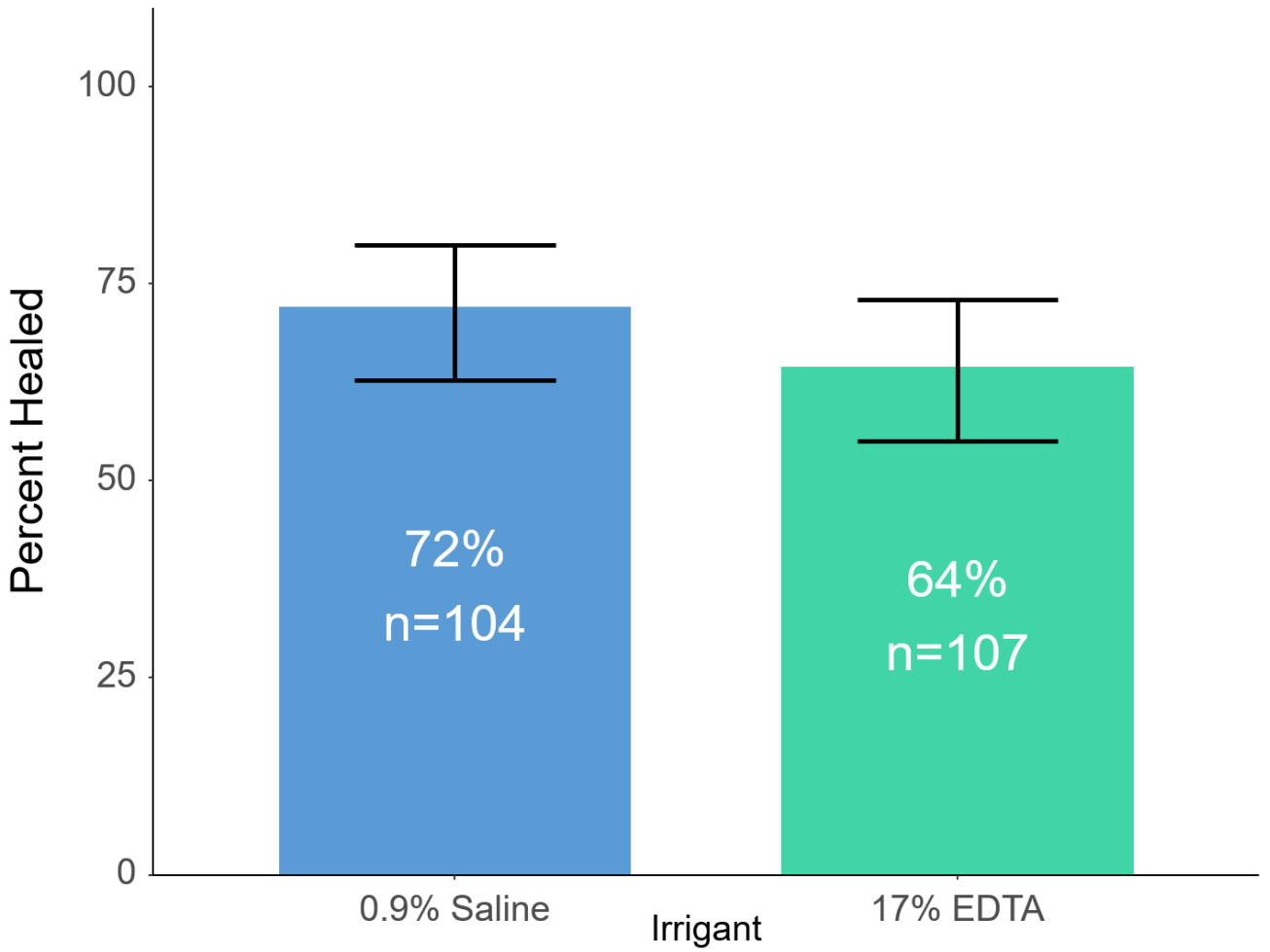


Figure 1. *Comparison of the Irrigation Protocols on Healed Rates.* The graph shows the number of subjects, the healed rate, and 95% confidence intervals of subjects in the two irrigation protocols for this interim analysis. Fisher's Exact Test revealed no significant difference in healed rate between groups ($p = 0.53$).

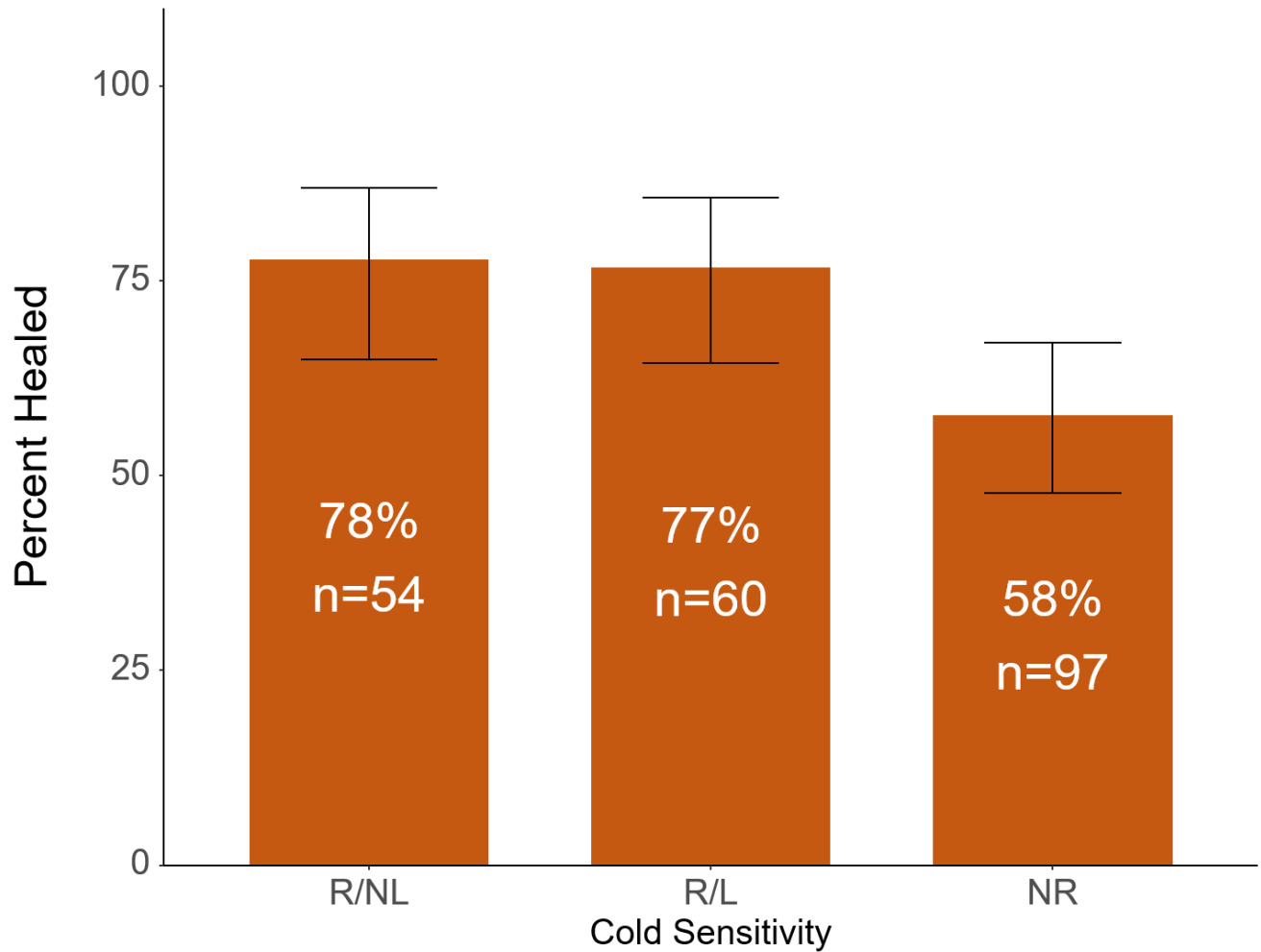


Figure 2. Comparison of Pre-Operative Response to Cold on Healed Rates. The graph shows the number of subjects, the healed rate, and 95% confidence intervals of subjects with a pre-operative response to cold. Teeth with a non-lingering response (R/NL) or lingering response (R/L), were considered vital. Teeth with no response to cold (NR), were considered necrotic. Fisher’s Exact Test revealed a significant difference between pooled healed rates of vital teeth compared to necrotic teeth ($p = 0.01$).

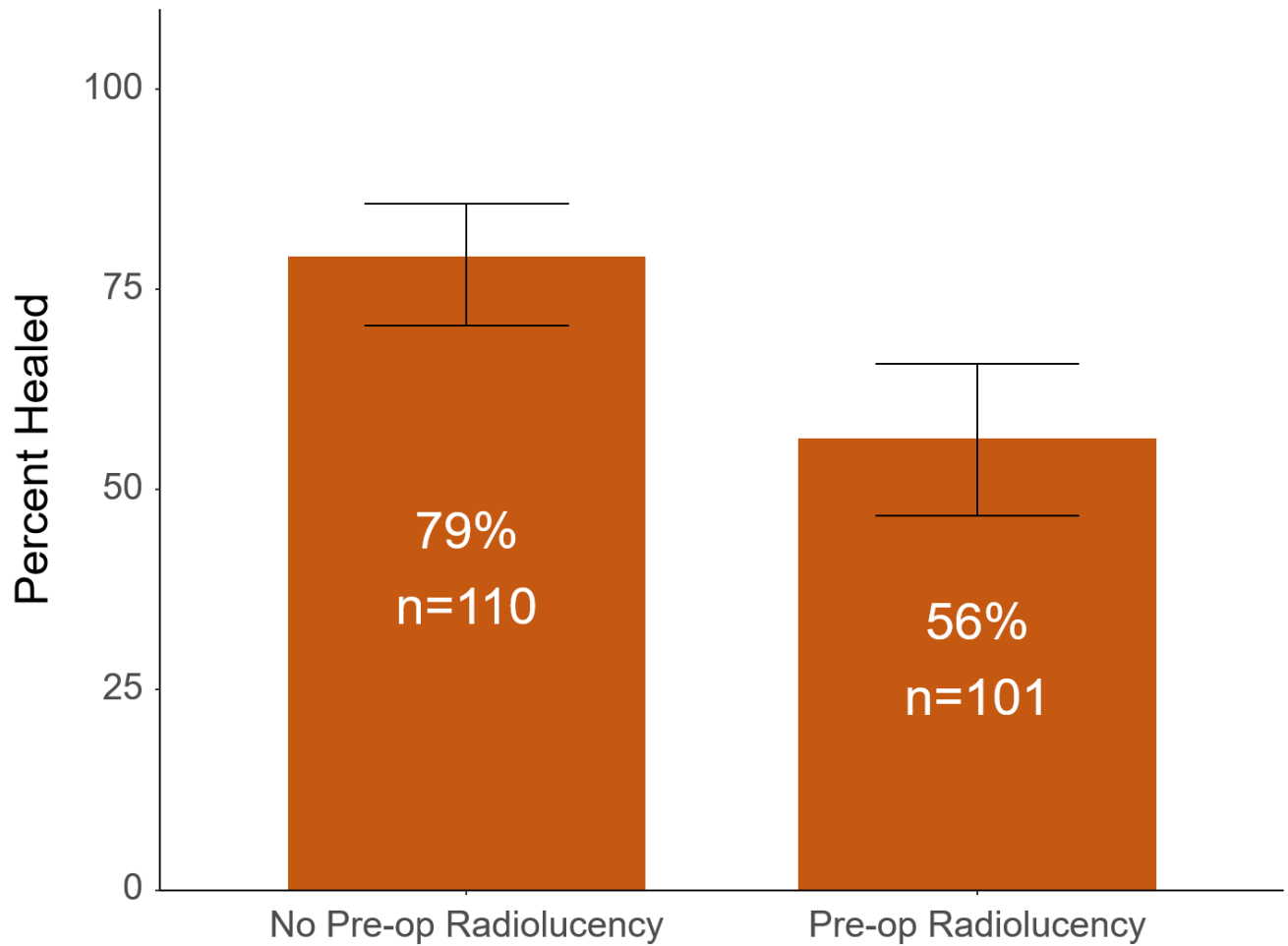


Figure 3. *Comparison of Pre-Operative Radiolucency on Healed Rates.* The graph shows the number of subjects, the healed rate, and 95% confidence intervals of teeth presenting with a pre-operative radiolucency. Fisher’s Exact Test revealed a significant difference in healed rates between teeth with no pre-operative radiolucencies when compared to teeth presenting with a pre-operative radiolucency ($p < 0.0001$).

CHAPTER 4: Discussion

The literature is currently lacking with regards to randomized, double blinded, prospective clinical trials assessing the single variable of smear layer removal on endodontic outcomes in permanent teeth. Studies evaluating the effects of smear layer removal have focused on singular effects within the limitations of *in vitro* studies. Studies in favor of removal report the release of trapped bacteria within and beneath the smear layer [2], increased ability to improve the seal between obturation material and tooth structure [34, 35], decreased microleakage [36] and enhanced ability of intracanal medicaments to diffuse through the dentin [37]. *In vitro* studies in favor of not removing smear layer cite an increase in apical microleakage [38, 39], or an increase in dentinal erosion resulting from the combined use of EDTA and NaOCl [40]. Then the smear layer was left intact, bacterial leakage has been shown to increase [8, 38, 39], and bacterial counts within dentinal tubules were found to be reduced [41].

The purpose of this prospective randomized double-blinded clinical study was to investigate the influence of smear layer removal on endodontic outcomes during single-visit initial NSRCT. In an effort to minimize variability, a standardized protocol was established and followed by all providers treating enrolled subjects. Exact materials and techniques were provided as part of the protocol to maintain consistency between treated subjects. Calibration of endodontic providers was completed prior to participation in the study via PowerPoint presentation and written instructions were made available to practitioners during treatment for reference and guidance.

This interim analysis determined that removing the smear layer using a combination of 17% EDTA and 8.25% NaOCl did not lead to improved healed rates. The

results of this study are in agreement with another prospective outcome study [42]; our methodology differed with regard to initial treatments vs retreatments, so comparison may not be possible. Smear layer removal has been evaluated on a primary tooth model with findings advocating for the removal of the smear layer [43], and another study that reported no significant differences [44]. Differences noted between previous studies and our study include: primary vs. permanent teeth, citric acid vs. EDTA as the smear layer removal irrigant, multi-visit vs. single visit treatment, use of an intra-canal medicament vs. no medicament, obturation with zinc-oxide eugenol vs gutta percha, and multi-year vs. one-year follow-up. There are a number of additional variables and methodologies that make comparison very challenging.

The presence or absence of the smear layer was not found to be a statistically significant variable. Based on previous studies that have shown that apical pathosis is caused by intracanal bacteria [12], the reduction of intracanal bacteria when utilizing rotary instrumentation [45] and NaOCl [46, 47] may overshadow the effects of the smear layer's removal. Reduction of bacterial load from the canal both in the planktonic state and as part of a biofilm without a way to quantify how much of a smear layer is produced may indeed overshadow what potential minimal smear layer is being produced and its effect on healing. It has been reported that 35-56% of a canal's surface remains untouched during mechanical instrumentation [48] which could result in a relatively low production of smear layer covered surfaces within the canal. Mechanical instrumentation alone is not effective at removing pulp tissue but when combined with chemical irrigation it was found to significantly reduce canal debris and the bacterial load [49]. Various irrigation systems are available to aid in removing debris from the canal system and in this study syringe irrigation via a 30-gauge Max-i-probe syringe (Dentsply Sirona, Tulsa, OK) was placed 1 mm short of the working length [50, 51].

Positive pressure irrigation techniques are able to introduce large volumes of solutions into the canal system; however there are limitations, such as vapor lock [52]. When compared to negative pressure systems, neither method completely eliminated accumulated hard tissue debris [53]. These factors may contribute to our study's interim findings that removal of the smear layer may not be significant when evaluating outcomes.

In addition to the primary objective, covariate factors were analyzed to determine statistical influence on endodontic outcomes. Of those evaluated, the presence of a pre-operative necrotic pulpal diagnosis and a pre-operative radiolucency were found to be statistically significant in effecting healing rates. This is in agreeance with studies by Ng *et al* [42], Marquis *et al* [54], and Imura *et al* [55]. These studies found decreases in healed rates when pre-operative lesions were present and an increased healed rate when a pre-operative lesion was not present. Based on this interim analysis, these covariates were the only factors associated with a decreased endodontic outcome at this time.

The limitations of this interim analysis include: the reported sample size at this time, the length of time for follow-up, and the use of strict criteria during outcomes assessment, where only asymptomatic patients with a PAI score of 1 or 2 on follow-up were considered healed. A power analysis was completed prior to protocol approval in order to determine sample size. This analysis was completed assuming an 80% healed rate based on a previously published outcome study [42]. For this interim analysis, the sample size (211 evaluated subjects) is well below the sample size needed to have a sufficient power (440 subjects) and therefore the results of this study could potentially change as more subjects are enrolled and analyzed.

Ørstavik reported that at 12-months following completion of NSRCT

approximately 90% of teeth that will heal, will show signs of healing [33]. Healing was noted to continue past the 12-month mark and it could take up to four years for complete healing to be recorded. Due to the transient nature of the military population and the relatively high capture rate of that study the recall examination was set at no earlier than 12-months from completion of initial NSRCT. A longer recall time could likely result in an increased healed rate [56]. Loose healed rate criteria was not considered for this study which reduces the overall healed rate and places it lower than other published studies that did not use strict criteria during PAI scoring [42]. This study's classifications of "healed" or "non-healed" without a "healing" category is a limitation. Additional scoring systems have been compared against the PAI scoring system with higher intra- and inter-observer agreement values with other indexing assessments for periapical health assessed radiographically [57].

CHAPTER 5: Conclusions

The interim analysis of this prospective randomized double-blinded clinical trial reveals that the healed rate of single-visit initial non-surgical root canal treatment in permanent teeth was not significantly altered by the presence or absence of the smear layer.

Additionally, it was noted that necrotic teeth and teeth with a pre-operative radiolucency; negatively impacted healed rates. Based on these results, we cannot reject the null hypothesis at this time.

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