A NAVAL POSTGRADUATE DENTAL SCHOOL ANALYSIS OF INITIAL ENDODONTIC TREATMENT

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MASTER'S THESIS

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ABSTRACT

A NAVAL POSTGRADUATE DENTAL SCHOOL ANALYSIS OF INITIAL ENDODONTIC TREATMENT

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Introduction: Initial, non-surgical endodontic treatment is associated with high healing rates and clinical success. The literature contains multiple studies examining outcomes of initial endodontic treatment. Multiple patient and treatment variables have been identified to affect outcomes. There is limited data evaluating endodontic outcomes of initial non-surgical root canal treatment in a military population. **Objective:** This retrospective study evaluated the outcomes of initial endodontic treatment performed by Navy endodontists and endodontic residents. Secondary analysis of covariate factors was performed to determine the effect on endodontic outcomes. **Methods:** Subjects that received initial NSRCT were enrolled at a 1 year follow-up examination. Retrospective clinical and radiographic data were obtained from initial endodontic treatment for each subject. A clinical and radiographic follow-up examination was performed. The endodontic outcome healed rate was determined from radiographic and clinical data. Pre-treatment, inter-appointment, and follow-up examination data were analyzed using Fisher's Exact test and odds ratios to evaluate the influence of covariate factors on endodontic outcomes. **Results:** This interim analysis evaluated 322 subjects. The overall healed rate was 63.4%. Healed was defined as the absence of a radiographic lesion and no clinical signs. A 93.5% functional rate was defined as the absence of clinical signs. Further analysis indicated a negative effect on outcome for those subjects presenting with covariate factors including: pre-operative sinus tract, periapical radiolucency, radiolucency 5mm or larger in diameter, diagnosis of pulp necrosis, irrigation without EDTA, or teeth restored less than 90 days following treatment. **Conclusion:** Interim analysis indicated a healed rate of 63.4% with a functional rate of 93.5%. Multiple covariate factors affected endodontic outcomes.

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I. INTRODUCTION AND REVIEW OF THE LITERATURE

Outcome studies of root canal treatment are prevalent throughout the dental literature. The criteria used to determine success or a favorable outcome varies from "retained in the dentition" (or a "functional" success) to more strict criteria including both the absence of periapical pathosis and a lack of clinical symptoms. Because time plays a factor in the healing of periapical pathosis (Fristad, 2004; Siqueira, 2008) some studies use a more loose criteria in defining success where the tooth has no symptoms but does have a lesion that has decreased in dimension since completion of treatment (Siqueira, 2008; Ng, 2011a).

Tooth retention has the least strict criteria for success, and several studies have reported endodontic outcomes based on this (Ng, 2011b; Dammaschke, 2003; Salehrabi, 2004; Chen, 2007; Stoll, 2005; Tilashalski, 2004). Ng, Mann, and Gulabivala prospectively evaluated initial non-surgical root canal treatment and non-surgical retreatment performed by post-graduate endodontic students for up to four years (Ng, 2011b). Tooth survival rate for both primary and secondary treatment was 95% (Ng, 2011b). Dammaschke *et al* evaluated the survival of root canal treated teeth performed by dental students. The overall survival rate was 85% (Dammaschke, 2003). Salehrabi and Rotstein evaluated root canal treatments completed by practitioners in a dental insurance network and reported a 97% survival rate of endodontically treated teeth after 8 years (Salehrabi, 2004). Chen *et al* reported 93% retention rate following a five year follow up (Chen, 2007). Tilashalski found an 81% retention rate after a minimum one year follow up (Tilashalski, 2004). Stoll, Betke, and Stachniss reported the 9 year cumulative survival probability of initial treatment to be 74% (Stoll, 2005). Setzer *et al* reported a 96% survival rate after 5 years in their study (Setzer, 2011).

An outcome classification similar to retention in the mouth is "functional." This classification was used in the Toronto Studies to denote teeth that are asymptomatic clinically, but may have any degree of periapical pathosis radiographically. In Phase 1 of the study, functional teeth totaled 97% with 4-6 year recall (Friedman, 2003), in Phase 2 it was 94% (Farzaneh, 2004), in Phase 3 it was 92% (Marquis, 2006), in Phase 4 it was 94% (Chevigny, 2008), and pooled results from Phases 1-4 found a functional rate of 95% (Chevigny, 2008).

A more stringent approach to evaluate endodontic treatment success is by evaluating the tooth in question with both clinical and radiographic measures. Using the absence of symptoms and resolution of the lesion for a successful outcome, results from Molander *et al* revealed an overall 70% "healed" rate. When including both the healed and those with a decreased size in radiolucency around the apex and clinically asymptomatic the percentage rose to 90% (Molander, 2007). Field *et al* dichotomized the Gutmann criteria into success and failure and reported 89% success in their study (Field, 2004). Peak *et al*, used criteria of definitely successful, probably successful, and failure. Relating their terminology to healed, healing, and not healed, they reported 57% healed, 28% healing, and 15% not healed (Peak, 2001). Data from Penesis *et al* indicates an overall 68% classified as healed (PAI ≤ 2), 83% as healed or

healing (PAI decreased) 17% not healed/healing (PAI the same or worse) (Penesis, 2008). Ng, Mann, and Gulabivala classified teeth based on the absence of clinical symptoms and either incomplete healing radiographically (lesion size reduction) or complete healing radiographically (no lesion) in a 2-4 year follow up study. The rate of complete healing was 83% and the rate of complete and incomplete healing was 89% during the course of the study (Ng, 2011a). The Toronto Studies had 4-6 year follow- ups with patients and dichotomized PAI scoring for an assessment of healed with PAI of 1 or 2, and PAI of 3, 4, or 5 as disease, but, additionally, allowed for tenderness to percussion to be included in the healed category. Phase 1 of the Toronto Studies reported a healed rate of 81% (Friedman, 2003), in Phase 2 it was 87% (Farzaneh, 2004), in Phase 3 it was 86% (Marquis, 2006), in Phase 4 it was 88% (Chevigny, 2008), and pooled results for Phases 1-4 gave a healed rate of 86% (Chevigny, 2008). Imura *et al* classified teeth as success with no clinical symptoms and no evidence of lesions radiographically. They found 94% success (Imura, 2007). Field *et al* reported an 89.2% success rate of single-visit treatment with follow up of at least six months and up to four years with both clinical and radiographic criteria for success (Field, 2004). A long-term outcome study was conducted by Cheung and Chan with success criteria being absence of clinical symptoms and no periapical lesion four years after the treatment, no extraction of the tooth, and no retreatment. Teeth were followed from 10 to 20 years with a success rate of 48% success rate (Cheung, 2003). Siqueira *et al* evaluated the outcome of teeth with apical periodontitis up to 4 years and found 76% healed, 19% healing, and 5% non-healed (Siqueira, 2008). Data from Chugal *et al* indicate 77% success and 23% failure at four year follow-up (Chugal, 2001). Marending *et al* reported an 88% success rate in patients with a minimum of 2.5 year follow-up (Marending, 2005). Hoskinson *et al* reported 77% success, 20.5% uncertain, and 2.5% failure after 4-5 years follow-up (Hoskinson, 2002). Bernstein *et al* found 80.9% success with a mean 3.9 year follow-up among 1300 patients from multiple clinics (Bernstein, 2012).

Outcome evaluation using only radiographic criteria has been used in studies. Setzer *et al* reported 46% rate of periapical lesions in cases with a follow-up of over five years (Setzer, 2011). Tavares *et al* discovered 67% of teeth were "healthy" radiographically in a cross-sectional population (Tavares, 2009). Fouad and Burleson reported a 68% success rate among a population of 531 patients (Fouad, 2003).

Factors for success have been evaluated to determine what pre-, intra-, and post-treatment factors contribute to endodontic success. Studies have evaluated many factors including presence of pulpal and periapical status, medical status, preoperative pain, periodontal health, intraoperative errors, restorative status following treatment, length of obturation, patency, number of treatment visits and tooth type.

Conflicting results regarding presence of periapical lesions associated with teeth prior to treatment have been found. Presence of a lesion had no significant effect on tooth retention according to Ng *et al* (Ng, 2011b) however it did affect retention according to Dammashcke *et* al (Dammaschke, 2003; Cheung, 2003) and periapical healing/success according to others (Ng,

2011a; Friedman, 2003; Farzaneh, 2004; Marquis, 2006; Imura, 2007; Chevigny, 2008; Bernstein, 2012; Fouad, 2003). Ng *et al* also reported that a smaller lesion was more likely to heal (Ng, 2011a). Siqueira *et al* evaluated if the size of the lesion had an impact on the outcome, and although smaller lesions were more likely to heal, there was no statistically significant association between lesion size and outcome (Siqueira, 2008). Chugal *et al* and Hoskinson *et al* had contrasting findings to Siqueira *et al* – finding there was a statistically significant increase in success as the lesion size decreased (Chugal, 2001).

The medical status of patients has been reported to be a significant variable on whether an endodontically treated tooth was retained or lost. Ng *et al* reported that coronary heart disease, thyroxin therapy and hormone replacement did not significantly impact periapical health or tooth loss, but diabetes and systemic steroid treatment were found to significantly contribute to a greater loss of the tooth but not to periapical health (Ng, 2011a; Ng, 2011b). Fouad and Burleson reported that diabetic patients were eight times less likely to have a successful outcome (Fouad, 2003). Marending *et al* reported that the immune status of patients had a significant effect on outcome, but smoking did not (Marending, 2005). Research by Bergstrom *et al* reported no significant difference between smokers and non-smokers with regard to periapical lesions or endodontic treatment (Bergstrom, 2004). Caplan's research indicated no significant difference on estimated survival between patients taking cardiac/hypertensive medications and those who were not (Caplan, 2002). Among an American Indian population Mindiola *et al* reported that both diabetes and hypertension were significantly associated with a decrease in tooth retention (Mindiola, 2006).

In regards to pulpal status, vital teeth have been associated with an increase in tooth survival (Stoll, 2005) and healing/success (Imura, 2007; Chugal, 2001; Hoskinson, 2002).

Teeth with pain prior to endodontic treatment have been reported to be significantly more likely to have an unfavorable outcome (Ng, 2011b; Stoll, 2005).

Procedural errors during treatment has been significantly associated with a decrease in tooth retention (Ng, 2011a), but conflicting effects on healing rates have been reported (Ng, 2011a; Imura, 2007; Song, 2011). Intraoperative complications were a significant factor in work done by Marquis (Marquis, 2006).

According to some studies, poor periodontal health of the treated tooth is associated with a significant decrease in tooth retention (Ng, 2011b; Setzer, 2011) while Fouad and Burleson reported it had no effect on success (Fouad, 2003).

Restorative factors may affect endodontically treated teeth. Lack of a definitive restoration of the tooth following endodontic treatment significantly increases the likelihood of tooth loss (Ng, 2011b; Dammaschke, 2003; Fouad, 2003) and healing (Imura, 2007) while a crown restoration significantly increases the likelihood of tooth retention (Ng, 2011b; Cheung, 2003), and restoration with appropriate retention and marginal adaptation increases healing (Ng,

2011a; Fernandez, 2013). Siqueira *et al* reported that while teeth with adequate permanent restorations did have a better outcome this was not a statistically significant factor (Siqueira, 2008). Caplan's research found a better estimated survival rate for teeth with crowns over those that were not crowned and for teeth with two proximal contacts over those with one or none (Caplan, 2002). A study by Mindiola *et al* reported a significant increase in tooth loss when a permanent restoration was not placed during the 90 days following completion of treatment and a 96.5% tooth retention if the permanent restoration was completed the same day as endodontic treatment (Mindiola, 2006). Tilashalski *et al* found that 50% of teeth extracted following root canal treatment did not have a permanent restoration placed following treatment (Tilashalski, 2004). A combination of adequate quality coronal restoration and endodontics have been shown to be less likely to have apical periodontitis (Gillen, 2011; Tavares, 2011).

Gutta percha filled beyond the terminal extent of the root (Ng, 2011b; Stoll, 2005; Ng, 2011a; Dammaschke, 2003; Song, 2011) and short of the radiographic apex have been associated with a decrease in tooth healing and/or survival in some studies (Stoll, 2005; Song, 2011; Imura, 2007), while a meta-analysis of 4 studies reported obturation length to have no statistical significance on success (Schaeffer, 2005). Chugal *et al* found the length of obturation evaluated radiographically did have a statistically significant effect on outcome based on apical status. In teeth with normal pulp and normal apical tissues an obturation 1.3mm short of the apex had a significantly better outcome than at 0.1mm short of the apex. Conversely, teeth with apical periodontitis had significantly greater success when the obturation was 0.7mm short of the apex compared to 1.8mm short of the apex (Chugal, 2003).

The success of single-visit versus multi-visit root canal therapy has been studied by several authors. The question of how the number of visits affects the success rate is still not answered. Sathorn, Parashos, and Messer conducted a systematic review and meta-analysis with 3 studies meeting the inclusion criteria. With a follow up time from 1-5 years one appointment procedures had a minimal, although not statistically significant, increase (6.3%) in healing rate compared to multiple visit (Sathorn, 2005). Molander *et al* compared one versus two-visit endodontic treatment and while two-visit treatment had a higher success rate (10% higher) no statistically significant difference between the two modalities was reported (Molander, 2007). In a Cochrane Systematic Review with 12 studies meeting the final criteria, Figini *et al* found single-visit to be slightly more effective, although no significant difference between single vs multi-visit endodontic procedures was reported based on radiographic criteria for success. Also, those with necrotic pulps had a 38% better radiographic outcome in one visit compared to multiple visits (Figini, 2008). Penesis *et al* primary looked at radiographic criteria for healing based on PAI scoring at a one-year follow up. They found there was no statistical difference between one or two-visit treatments (Penesis, 2008). Imura *et al* reported one visit treatments had a statistically higher healing rate than multi-visit (Imura, 2007). Su, Wang, and Ye performed a systematic review with six studies meeting their inclusion criteria and found the number of visits had no significant effect on healing (Su, 2011).

Tooth position in the mouth has been reported to have significance on outcome in several studies and less influence in others. Friedman *et* al and Marquis *et al* found a significantly better outcome in teeth with one root over those with two or more (Friedman, 2003; Marquis, 2006). Field *et al* reported a better than 10% increase in success (statistically significant) when anterior teeth were treated compared to posterior teeth (Field, 2004). Similarly, the pooled results of the Toronto Study Phases 1-4 found a statistically significant increase in success in teeth with one root (Chevigny, 2008). Results from Bernstein *et al* indicate that molars and teeth with more than one canal are more likely to have adverse outcomes (Bernstein, 2012). Farzaneh *et al* reported that while teeth with at least 2 roots did have a worse outcome than those with 1 root, this result was not statistically significant (Farzaneh, 2004). Similarly, studies by Fouad and Burleson and Imura *et al* found no significant influence of tooth type (anterior versus posterior) on outcome (Fouad, 2003; Imura 2007). Studies by Ng *et al* reported that neither tooth (Ng, 2011a; Ng, 2011b) nor root type (Ng; 2011a) had a statistical significance on periapical health or tooth survival. Anterior teeth and mandibular molars were found to have a significantly higher survival probability according to Cheung and Chan (Cheung, 2003) while posterior teeth and teeth with two or three canals were reported to have a better survival rate in a study by Dammaschke *et al* (Dammaschke, 2003). Research by Lumley *et al* found that anterior teeth demonstrated both the best (central incisor) and worst (lateral incisor and canine) survival (Lumley, 2008). Results from a military study with at least 3 year follow up reported decreasing success rates from anterior to posterior teeth (Peak, 2001). Caplan's research indicates a significant difference on estimated survival rate of teeth based on tooth type with first molars and premolars having the best survival and second molars the least (Caplan, 2002).

Endodontic outcomes in specific patient subpopulations has been evaluated. Peak *et* studied outcomes in Britain among the Royal Air force. An 85% overall success rate was found after a minimum 12 month recall and a higher success rate reported among those obturated via cold lateral condensation (92%), obturation material to within 2 mm of the radiographic apex (88%), and those with periapical radiolucencies at time of treatment (87%) (Peak, 2001). Mindiola evaluated factors affecting outcomes following root canal treatment among an American Indian population (Mindiola, 2006). Lumley, Lucarotti, and Burke reported outcomes among patients who did not pay for their endodontic treatment (due to insurance coverage). In their study, primarily assessing time from non-surgical treatment to non-surgical retreatment, surgical treatment, or extraction they found that patients who did not pay for treatment had a statistically significant decreased probability of tooth survival. Other significant factors included amount paid annually for dental treatment and frequency of dental appointments. They reported an overall success rate of 96% after 1 year down to 74% after 10 years (Lumley, 2008).

Criteria for successful endodontic treatment varies greatly in the literature, as do the reported percentages of success. Success based on tooth survival ranges from 74% - 97% while criteria based on absence of symptoms and no periapical radiolucency ranges from 48-94%. There are several factors that may contribute to an adverse outcome such as the presence of a

lesion, lesions with a larger dimension, patients who are diabetic, a procedural error during treatment, multi-rooted teeth, and lack of a definitive restoration placed shortly after treatment.

No previous study has evaluated the outcome of root canal treatments in an American military population. The primary purpose of this retrospective study was to evaluate the outcome of initial non-surgical root canal treatment performed by U.S. Navy Endodontists and residents. A secondary purpose was to report factors that affect the outcome of initial non-surgical root canal treatment.

II. MATERIALS AND METHODS

The materials and methods are described in the Walter Reed National Military Medical Center IRB approved protocol (IRBNet# 352272-14):

Inclusion Criteria: Adults (18 years or older) who received initial non-surgical orthograde endodontic treatment provided by an endodontic resident at NPDS or a Navy Endodontist. Treatment must have been completed in at least the twelfth month prior to a follow-up examination and an x-ray, taken at the final obturation appointment, must have been available for consideration as a study participant.

Exclusion Criteria: Patients whose record did not include a final treatment radiograph or whose treatment was completed less than the 12^{th} month prior to follow-up examination were excluded. Also excluded were patients who received non-surgical re-treatment, surgical treatment, or canal obturation using Resilon, carrier-based, silver points or a paste fill technique. Additionally, if any portion of the treatment was performed by any provider who was not a Navy endodontist or Navy endodontic resident, the patient was excluded.

Selection of Subjects: Study subjects were recruited from patients that were previously treated by residents at the NPDS Endodontic Clinic or Navy endodontists. Subjects were recruited from existing logbooks and records of former NPDS residents and from "walk in" and "sick call" patients reporting to the NPDS Endodontic Clinic for evaluation and/or treatment of a tooth.

Eligible patients were asked if they would like to hear more information about the study during their appointment. If they were interested they were given the study description and the consent forms by an investigator in a private room.

Consent Process: To avoid coercion, subjects were allowed to decline participation at any time. Once enrolled, they have the opportunity to withdraw at any time. No matter what was decided the follow-up evaluation was always completed. Patient consent was obtained by a Primary or Associate Investigator. Investigators were dressed in clinic attire without nametags to prevent coercion. Once all questions were addressed and answered the documents were signed and dated.

Study Design and Methodology: This was designed as an observational study combining clinical data obtained from a follow-up examination and retrospective information gathered from the subject record.

Preoperative, intraoperative treatment and follow-up data were collected. In the event that a patient had multiple treated teeth, each tooth was considered individually. The follow-up evaluations were performed by trained endodontic residents supervised by endodontists or by Navy endodontists.

Data Collection: Preoperative and final treatment radiographs were collected from the existing record. Preoperative data collected included: date of birth, gender, pulpal and apical diagnosis,

presence/absence of symptoms, tooth type (single versus multi-root), and existing medical conditions (smoker, coronary heart disease, diabetes).

Intraoperative treatment data gathered included: single vs. multiple treatment sessions, intracanal irrigants and medications, procedural complications, obturation fill length, periradicular status, and placement of an intraorifice barrier.

Follow-up data gathered included presence/absence of symptoms, apical diagnosis, presence of coronal restoration, presence of intracanal post, periradicular status, and the length of the follow-up period.

The subject number on all of these data gathering sheets was used to identify the subject on the master database list to de-identify the subjects.

The periradicular status of both post-treatment and follow-up radiographs was assessed by three board-certified endodontists following a calibration process. In order to avoid subjective bias during evaluation of the radiographs, the final treatment radiographs were viewed separately from the follow-up radiographs. Additionally, all radiographs were de-identified by assigning them random numbers of which the reviewers did not know the code. The periapical index (PAI) scoring method was used while viewing the images on either a single clinic light-box or a projector. The endodontists were calibrated using selected radiographs and a PAI standard reference. Evaluators scored the radiographs according to the PAI system as healed (scores 1 and 2), undetermined (score 3), or non-healing (scores of 4 and 5). Each evaluator scored the images independently and the final score was attained via forced-consensus in case of disagreement. In the case of multi-rooted teeth the worst PAI value was registered.

Data Analysis: Once the data were collected, the variables were analysed using the SPSS program to determine significant effects on treatment outcome. Forty seven variables were evaluated for effect on outcome. Statistical analysis was performed on the data including descriptive analysis, Fisher's Exact test and Odd's Ratios. See Table 1.

Table 1

Statistical Analysis Performed and Variables Evaluated

Analysis	*Variable*
Wilcoxon Rank Sum	Age Pre-op pain Pre-op electronic pulp test value Quantity of irrigant used Time from initial treatment to follow-up
Fisher's Exact Test Odd's Ratio	*Pre-operative variables* Gender Hypertension Smoker Coronary heart disease Diabetes Number of roots Pain Pain location by quadrant Pain location by tooth History of orthodontic treatment History of external resorption History of internal resorption History of bleaching Presence of restoration Open margin on restoration Caries Post present Probing depth (maximum) Bleeding on probing Mobility Cold sensitivity Percussion sensitivity Palpation sensitivity Sinus tract Swelling Radiolucency Size of radiolucency Intact lamina dura Pulpal diagnosis *Intra-operative variables* Electronic apex locator use for length Patency Calcium hydroxide use interappointment Procedural complications EDTA use as irrigant Intraorifice barrier placement Number of treatment sessions *Follow-up variables* Permanent restoration Intracanal post Open margin on restoration Tooth location/type Follow-up time Time from treatment to restoration placement

III. RESULTS

Enrollment for this interim analysis included 362 subjects. Forty subjects were excluded due to missing data or not meeting eligibility requirements leaving 322 subjects for descriptive and functional rate analysis. Fifty eight additional subjects were excluded from final analysis due to lack of diagnostic radiographs among those patients lacking symptoms leaving 264 patients for outcome analysis.

219 subjects (68%) were male, 103 subjects (32%) were female. Median age was 47, with a range from 19 – 84 years old. The median follow up time was 14 months with a range from 11.01 months – 10.3 years. Among the 264 patients for final outcome analysis, 168 (63.4%) were healed and 96 (36.6%) were non-healed. Eleven variables were found to significantly affect outcome and are listed in Table 2. 301 teeth (93.5%) were functional with 21 (6.5%) non-functional.

Table 2
Variables With Significant Effect On Outcome

Variable	p-Value	Odds Ratio (95% CI)
Sinus tract	<0.001	11.8
Radiolucency	<0.001	6.1
Lamina dura not intact	<0.001	4.6
Non-vital pulp	<0.001	3.2
Radiolucency ≥ 5mm	0.028	2.6
Time to restoration < 90 days	0.045	2.1
Palpation sensitivity	0.047	2.0
EDTA irrigation	0.018	1.9
Bleeding on probing	0.037	1.9
Age	0.021	*
Pre-op cold sensitivity	0.006	*
*could not be calculated because more than two groups were available for comparison		

IV. DISCUSSION

This study evaluated the outcome of initial non-surgical endodontic treatment with a minimum follow-up in the 12th month after initial treatment and found a healed rate of 63.4% (168/264). Criteria for successful endodontic treatment varies greatly in the literature, as do the reported percentages of success. Success based on tooth survival/functional success ranges from 74% - 97% (Stoll, 2005; Lumley, 2008; Salehrabi, 2004; Friedman, 2003) while criteria based on absence of symptoms and no periapical radiolucency ranges from 48-94% (Cheung, 2003; Imura, 2007). This outcome may have improved if longer term follow-ups were conducted. Studies with longer-term follow-ups have reported improved outcome. A 2011 study by Ng *et al* evaluated outcome at 1 year and 2 years following initial treatment and found an increase from 72% to 91% over that time (Ng, 2011a). Fristad *et al* reported an increase in healing of 9.8% between evaluation at 10-17 years and 20-27 years (Fristad, 2004). However, research by Lumley *et al* reported a decrease in success in initial non-surgical root canal treatment from one year (96%) to 10 years (74%) (Lumley, 2008).

The functional or clinical success rate was 93.5% (301/322). This is consistent with other studies reporting success in the ninety percent range (Ng, 2011b; Salehrabi, 2004; Chen, 2007; Setzer, 2011; Friedman, 2003; Farzaneh, 2004; Marquis, 2006; Chevigny, 2008). This study included percussion sensitivity as part of the criteria for classification as non-functional. This differs from the Toronto study where percussion sensitivity was not part of the criteria for non-functional as it may be due to factors not endodontic-related (Friedman, 2003). If percussion sensitivity were excluded from the non-functional criteria, the functional success would have been 98.1%.

Literature reporting outcomes in military populations is limited. Peak *et al* reported 57% healed rate and an additional 28% healing after a minimum 12 month follow up among the Royal Air Force in Britain (Peak, 2001).

Some factors evaluated in our study were intimately related to other factors evaluated and not discussed separately, including lamina dura not intact (related to radiolucency) and cold sensitivity (related to tooth vitality). Age was found to be a statistically significant value but the median ages between the healed and not healed groups differed by only 4 years (49 years old versus 45 years old) and is considered to not have clinical significance.

The greatest predictors for non-healing were presence of a sinus tract, radiolucency, and non-vital pulp. The presence of a sinus tract was reported by Ng *et al* to decrease odds for successful treatment by 48% and was a statistically significant variable (Ng, 2011a). Chugal *et al* reported a decrease of 36.3% in teeth with sinus tracts which was a significant factor in univariate analysis, but was found not to be significant using logistic regression (Chugal, 2001). Presence of a radiolucency is a prognostic factor for non-healing throughout the literature. Studies reporting a decrease in healing with presence of radiolucency include logistic regression

analyses by Chugal *et al*, Hoskinson *et al*, Friedman *et al*, Farzaneh *et al*, Marquis *et al*, Imura *et al*, Chevigny *et al*, Ng *et al,* and Bernstein *et al,* (Chugal, 2001; Hoskinson, 2002; Friedman, 2003; Farzaneh, 2004; Marquis, 2006; Imura, 2007; Chevigny, 2008; Ng, 2011a; Bernstein, 2012). Non-vital teeth have been reported to have a less favorable outcome in studies by Hoskinson *et al* and Imura *et al* (Hoskinson, 2002; Imura, 2007).

Other factors with significance were size of radiolucency, time to restoration, palpation sensitivity, EDTA irrigation and bleeding on probing.

Size of lesion was evaluated as a factor by dichotomizing lesions smaller than 5mm into one category and lesions 5mm and larger into another. This classification was also used by Siqueira *et al* (Siqueira, 2008). This study found that lesions of larger diameter were less likely to heal. This is consistent with logistic regression analyses by Chugal *et al*, Hoskinson *et al*, and Ng *et al* (Chugal, 2001; Hoskinson, 2002; Ng, 2011a) but inconsistent with findings of Siqueira *et al* where lesion size did not have statistical significance (Siqueira, 2008).

Literature looking at a specific time frame to restoration following treatment is limited. Time to restoration following treatment was dichotomized in this study into those restored less than 90 days after treatment and those restored 90 days or more after treatment. This is consistent with the restoration time frame used by Mindiola *et al* (Mindiola, 2006). This study found that delaying restoration of the treated tooth to 90 days resulted in a higher healed rate. This is in conflict with the findings of Mindiola that reported greater tooth loss when restored at 90 days or later. Factors that may contribute to this finding may relate to data not collected in this study such as the type of temporary restorative material used, the depth of restorative material placed or other unknown factors. Additionally, the p-value for this variable was 0.045 and may become not significant as more data is collected and/or logistic regression is performed on the final data set.

Another factor with a p-value nearing the 0.05 mark is palpation sensitivity. Research evaluating this factor's effect on outcome is limited. Orstavik *et al* reported an increase in palpation sensitivity among patients with chronic apical periodontitis compared to those with no apical periodontitis (Orstavik, 2004). This finding is intuitive as palpation sensitivity is diagnostic of apical periodontitis. Palpation sensitivity may be more likely among patients with apical radiolucencies needing non-surgical root canal treatment and for this reason may have been found to be significant. However, this may be found to lack statistical significance after more data is collected and/or logistic regression is performed.

Irrigation with EDTA was found to be associated with a better healed rate. Studies evaluating the influence of EDTA on outcome is limited. Ng *et al,* reported no significant effect of EDTA use on initial treatments, but that the use of EDTA did effect outcome in retreatments (Ng, 2011a). EDTA, when used to remove the smear layer, has been reported to promote

diffusion of antimicrobial medicaments (Orstavik, 1990; Foster, 1993), and sealer penetration (citation), which may account for the outcome found in this study.

Bleeding on probing was found to be statistically significant. No previous studies evaluating this factor were found. Further studies are needed to evaluate this finding.

IV. CONCLUSIONS

The outcome of initial non-surgical root canal treatment by Navy endodontists and residents was 63.4% healed rate with a 93.5% functional/clinical success rate. Factors with negative effect on outcome included presence of a sinus tract, presence and size of radiolucency, non-vital pulp, time to restoration following treatment, palpation sensitivity, irrigation with EDTA, and bleeding on probing.

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