Impact of Delayed Completion of Previously Initiated Therapy and Provider Type on Outcomes of Root Canal Treatment

Igor Sulim
Marquette University

IMPACT OF DELAYED COMPLETION OF PREVIOUSLY INITIATED THERAPY AND PROVIDER TYPE ON OUTCOMES OF ROOT CANAL TREATMENT

By

Igor Sulim, D.D.S.

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ABSTRACT

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Objective: The primary purpose of this study was to determine if the period of time between previously initiated therapy and the completion of non-surgical root canal treatment (NSRCT) influences long-term outcomes. The secondary purpose of this study was to determine if the provider type influences long-term outcomes in instances where NSRCT has been previously initiated.

Materials/Methods: Enrollment and claims data from Delta Dental of Wisconsin from 2002-2014 was analyzed. Teeth that received NSRCT within 6 months after completion of pulpal debridement or pulpotomy procedures (identified by Codes of Dental Procedures and Nomenclature) and within a continuous insurance coverage period were included. Teeth that did not receive definitive restorations within 180 days following completion of NSRCT were excluded. Teeth were followed from the time of treatment to the presence of a CDT code representing untoward events, which include retreatment, apicoectomy, or extraction. The impact of tooth location, age at time of NSRCT completion, and provider type on the outcome was also examined using Univariate and Multivariable Cox proportional hazards models. A total of 7,488 NSRCTs were included in the analysis.

Results: No statistically significant difference was found among the varying time intervals between initiation and completion of NSRCT. Molar teeth were associated with a greater risk of an untoward event than anterior teeth with an adjusted hazard ratio of 1.52 ($p<0.029$). An increase in the risk of failure was observed in teeth from patients that were 55 and older with an adjusted hazard ratio 2.15 ($p<0.001$). A significantly lower adjusted hazard ratio of 0.68 ($p<0.001$) was observed when treatment was initiated by a general dentist and completed by an endodontist when compared to treatment that was both initiated and completed by a general dentist.

Conclusion: Delayed completion of NSRCT after previously initiated therapy was not associated with unfavorable outcomes. Improved outcomes were noted when previously initiated therapy was completed by an endodontist.

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INTRODUCTION

Non-surgical root canal therapy (NSRCT) is considered the removal of inflamed or infected pulpal tissue due to caries, trauma, faulty restorations, or repeated procedures (1&2). This treatment may occur over multiple appointments due to provider preferences, patient factors, or due to time management limitations when facing endodontic emergencies. Root canals completed in multiple appointments can be tracked within an insurance database with a specific set of codes. The criteria for multiple appointments is met when the code for root canal completion is preceded by a code suggesting previously initiated therapy (PIT). According to the Glossary of Endodontic Terms, previously initiated therapy is defined as a clinical diagnostic category indicating that a tooth has been previously treated by partial endodontic therapy in the form of either a pulpotomy or a pulpectomy (3). A pulpotomy may be performed as an emergency procedure for pain relief and is defined by the Endodontist' Guide to CDT as the surgical removal of a portion of the pulp (4). When utilized as an emergency measure, pulpotomy treatment has been shown to be effective by demonstrating pain relief in 90% of patients 6 months following treatment (5). Pulpotomy treatment followed by permanent restorations has also been utilized as a definitive treatment modality in instances of carious pulpal exposures with overall success based on clinical and radiographic interpretation ranging from 72% - 99% (6&7). Additionally, pulpal debridement is defined as an appointment for the relief of acute pain prior to conventional root canal therapy which cannot be used when endodontic treatment is completed the same day (4). For the purpose of this study, only treatment that satisfies the criteria for multiple visit root canal therapy will be

included. Although many variables have been investigated in endodontic literature, the provider type and the specific period of time between appointments has yet to be examined as factors in determining the long-term success in instances where non-surgical root canal therapy has been previously initiated. Therefore, the two specific interests of this research study will be to examine the effect of provider type and how the period of time between previously initiated therapy and the completion of root canal treatment influences the long-term outcome of treatment.

LITERATURE REVIEW

Managing an endodontic emergency

Treatment of endodontic emergencies are often performed over multiple visits to ensure that the primary goal for both the patient and the provider is accomplished, which is managing pain in a swift and effective manner. Procedural interventions are the gold standard for managing emergency visits. Pulpotomies are performed as an emergency measure when there is inadequate time to clean and shape the root canal systems. If a pulpotomy is used as an interim treatment and is sealed with a temporary restorative material, the time until definitive treatment is performed in the form of complete endodontic therapy has been shown to be a factor in pain relief and absence of formation of periapical pathology (5). Studies have demonstrated that extended periods of time would allow for bacterial leakage which would result in inflammation of the remaining pulp (8&9). Bergenholtz exhibited that microleakage of bacteria is the primary cause of pulp inflammation due to failure of the restorative agent in providing a seal along the entire restorative interface (9). Due to the microleakage, bacterial byproducts are exposed to dentin and then initiate inflammatory reactions in the dental pulp.

A pulpectomy is another procedural intervention used as a first line of emergency treatment in managing endodontic emergencies. When time is inadequate, it is advised to perform complete cleaning and shaping of the largest canals and to at least partially debride smaller canals (10). A survey of Diplomates of the American Board of Endodontics found that respondents preferred pulpectomy over pulpotomy, for both vital and necrotic cases (11&12). In the same survey, more than 50% of endodontists preferred

complete instrumentation compared to pulpectomy-only procedures particularly in cases with initial diagnosis of pulpal necrosis (11&12). An updated survey was performed 13 years later and revealed that the preference for complete instrumentation in emergency cases has increased to 77% (13). This shift in philosophy can be seen in modern endodontic practices as technology has allowed endodontic providers to benefit from contemporary tools such as cone beam computed tomography, electronic apex locators, and surgical operating microscopes (14–18). These tools have helped facilitate the elimination of inadequate time as a factor in selecting pulpectomy and pulpotomy over complete instrumentation in the vast majority of emergency cases (19).

Patient Factors

Some patient factors may contribute to root canal treatment occurring over multiple appointments. Patients who cannot endure long treatment periods may not be suitable for single-visit endodontic therapy. Examples of these patients include those who struggle to stay open due to temporomandibular disorders and patients who cannot be reclined for long periods of time due to vertigo (20&21). These patients benefit from root canal treatment occurring over multiple visits which are shorter in duration compared to longer single-visit appointments. Financial considerations may also be a variable and a barrier that contributes to root canal therapy occurring over multiple visits. Pulpotomy and pulpectomy procedures can be viable alternatives to extraction for patients that desire to maintain a tooth with irreversible pulpitis but at the time of diagnosis cannot afford the recommended complete endodontic treatment (3).

Provider Preference for Multiple Visits

When time available for treatment and patient factors are not limiting root canal completion, a consensus among endodontists remains uncertain regarding single visit versus multiple visit treatment. This discrepancy can often be associated with the preoperative diagnosis of teeth being treated. A survey from 1980 of endodontists practicing in the United States indicated that endodontists felt comfortable treating most vital cases 67.1% of the time in one appointment (11&12). However, the same endodontic cohort was comfortable treating most necrotic cases in one appointment only 16.8% of the time. A decade later, those figures were comparable to a survey by Gatewood et al. which indicated that from the 568 questioned diplomates only 10.2% preferred to complete endodontic treatment in one visit on nonvital pulps in emergency cases (13). In 2002, a new study revealed that the preference for single visit root canal treatment had increased (22). The survey indicated that in vital cases root canal obturation was completed 55.8% of the time in one visit while necrotic cases were completed in one visit 34.4% of the time. When endodontists were questioned as to what was the reason for not performing single visit therapy in necrotic teeth with or without a lesion, the most common answer was "importance of intracanal medication" (23). Calcium hydroxide is considered the most common intracanal medicament (24). Its antimicrobial effect is related to the release of hydroxyl ions, which results in a highly alkaline environment that facilitates the elimination of several bacterial species commonly found in infected root canals (25–27). Several authors have advocated the importance of its use in multiple visit endodontic treatment (28&29).

In addition to biological considerations, a provider's personal preference for the number of visits often stems from personal experiences, anecdotal experiences from colleagues, and from what is taught during endodontic residency (30&31). A survey of 35 of the 50 post-graduate endodontic program directors in the United States revealed that a majority of the directors believed that there will be an equal chance of successful healing between one and multi appointment therapy for any case treated (31). This indicates that a large percentage of endodontic residency programs are teaching and practicing one appointment endodontic therapy. This trend is not uniformly followed in all parts of the world. In a survey of endodontists in Australia, 96% had a preference for multiple visit treatment over single visit root canal treatment even in cases where the preoperative diagnosis had no biological concerns. The primary factor for performing multiple visit treatment was operator preference over biologic or patient considerations (30).

Outcomes of Single versus Multiple Visit Treatment

In 2016, an updated Cochrane Review article was published comparing single versus multiple visit treatment of permanent teeth. The article included 25 randomized clinical trials that encompassed 3,751 participants (32). Several outcome factors were examined which included: radiographic failure, flare up incidence, sinus tract formation, and incidence of complications. Each of these examined variables demonstrated no statistically significant difference when single visit treatment was compared to multiple visit treatment. Overall, the authors concluded that there is no evidence to suggest that one visit treatment regimen is superior to multiple visit root canal treatment. These

findings are consistent with an additional systematic review which included 47 clinical trials (33). The findings indicated that neither single visit endodontic treatment nor multiple visit treatment were superior when compared to the other in regard to healing or success rate. Additionally, an absence of postoperative pain could not be shown between either treatment methods.

Due to the absence of difference between the treatment modalities, Wong et al. suggested that there may be several advantages of single visit therapy (33). By reducing the number of visits, single visit treatment becomes more comforting, convenient, and safer for patients. Single visit treatment reduces episodes of pain and anxiety that may arise at each appointment and may be safer in regard to reduced risks associated with local anesthetic. Also, in patients with premedication considerations single visit treatment will reduce the need for repeated use of antibiotics. It offers busy patients with time restrains the ability to complete treatment in one sitting. The benefits are also discussed for the operator. Single appointment treatment reduces the number of appointments; thereby, facilitating clinicians to manage time more efficiently by having less wasted time in scheduling and with missed appointments and by reducing material resources needed for treatment (34). The possibility for introducing iatrogenic errors such as ledging, perforation, stripping, and extrusion of irrigants are also reduced due to the minimization of exposure to instrumentation procedures. Lastly, in single visit treatment there is a reduced need for a provisional restoration between appointments; therefore, there is less potential for bacterial contamination through leakage.

However, it should be noted that root canal treatment completed in one visit must follow contemporary endodontic principles: 1) use of aseptic technique; 2) cleaning the

canals thoroughly and mechanically with the aid of chemical agents; 3) shaping the root canals for ease of obturation; 4) obturation to achieve a tight seal of the root canals; and 5) proper restoration of the tooth to prevent coronal leakage (33). These principles are an update to the key to endodontic success that was first described by Gutmann (35).

Prognostic Factors in Longitudinal Studies

Traditionally, if adhering to proper standard of care measures and techniques, primary endodontic therapy has been shown to be very successful. Longitudinal studies have shown successful treatment ranging from 91% - 97% (36-40). A multitude of factors have been examined including: effect of provider training, timing of full coverage restoration from endodontic therapy, patient age, tooth location, and presence of crown. Burry et al. found that molars treated by endodontists have significantly higher survival rates than molars treated by non-endodontists 10 years after completion of treatment (40). Core/post placement followed by full coverage restoration completion within 60 days significantly decreased the risk for untoward events (41). Untoward events have previously been defined as a composite measure of extraction, retreatment, or apical surgery (36). Additionally, Yee et al. demonstrated an increase in adjusted hazard ratios associated with an increase in age of the patient at the time of treatment (40). In regard to definitive restoration, incidence of extraction was shown to increase by more than 4-fold if no definitive restoration was placed following NSRCT (36). Similarly, it was shown that endodontically treated teeth without full coronal coverage were lost at a rate six times greater than fully covered teeth (42).

From an extensive literature review, only a few research articles were found that directly examined the influence of the period of time between appointments as a factor in determining the long-term success in instances where root canal therapy was completed over multiple appointments. The reason for the limited amount of research is likely due to the difficulty of designing prospective or randomized clinical studies that would intentionally delay treatment that is considered a standard of care. As result, the best study design to examine this variable is an incorporation of a retrospective study. A previous retrospective study by Wong et al. followed the sequelae of delayed root canal therapy by comparing prompt treatment with delayed treatment (43). In the study, prompt root canal treatment completion was defined as period of time less than 4 months. This was an estimated time patients using the military dental care system would have root canal therapy completed as part of a comprehensive treatment plan. The delayed treatment group was further categorized into a delayed root canal filling group and an incomplete root canal therapy group. The results of the study indicated that teeth receiving incomplete root canal therapy had a higher incidence of extractions (56%) than either the delayed root canal filling group (3%) or prompt treatment group (2%). There was no statistical difference between the delayed root canal filling group which had an average of 578 days between treatment and the prompt treatment group which had an average 45 days between treatment.

Prognostic Factors in Prospective Cohort Studies

When reviewing the success rate of root canal therapy, three main categories of prognostic factors have been examined: preoperative factors, intraoperative factors, and

postoperative factors. Variables included in the preoperative factors are: age, gender, tooth location, number of roots, signs and symptoms, apical periodontitis, and pulp vitality. Intraoperative variables included: number of treatment sessions, obturation technique, voids in obturation, sealer extrusion, complications, and the use of a temporary seal. Postoperative factors included: presence or absence of a temporary restoration and placement of a post. A Toronto study project consisting of several prospective cohort studies was performed to address these prognostic factors (44–46). The Phase I study demonstrated that the main prognostic factor in initial endodontic treatment is the preoperative presence of a periapical radiolucency (44). This was the only variable that was statistically significant among all other preoperative, intraoperative, and postoperative factors. Phase II of the study examined the prognostic factors associated with orthograde retreatment with some additional factors examined in the preoperative, intraoperative and postoperative categories. The results were similar to Phase I in which previously root canal treated teeth with a periapical radiolucency had a statistically significant lower healing rate (45). Additionally, it was shown that teeth without a preoperative perforation had statically significant success compared to those with preoperative perforations. A retrospective study of 2,000 cases performed by Tsesis et al. identified the prevalence of perforations (47). The study found that approximately 2.3% of treated teeth had perforations with large perforations having associations with significantly more pathological changes compared to small perforations. Phase III of the Toronto Study project was an extension of the original studies and was used to corroborate previously identified outcome predictors by using an increased sample size which contributed to an increased statistical power. Multivariate analysis identified the

presence of a preoperative radiolucency and the presence of intraoperative complications as significant outcome predictors in initial therapy (46). Intraoperative complications were further discussed to include: perforations, calcified canals that could not be negotiated, and file breakage. A study by Iqbal et al. examined 4,865 endodontic resident cases and determined the incidence of instrument separation was 1.93%, which was similar to the rate determined in the phase III study (2.79%) (48). Complications are important treatment outcomes as they may interfere with the elimination of infection and may promote the progression of infection.

Role of Bacteria in Endodontic Infection

A classic study by Kakehashi et al. demonstrated how microbial colonization of the root canal system plays an essential role in the pathogenesis of periradicular lesions (49). Within the study there was a comparison between conventional and germ-free rats that had dental pulps exposed to the oral cavity. The findings demonstrated that periradicular lesions occurred only in conventional rats and not in the germ-free ones. Similarly, a study was performed on devitalized monkey teeth, which was able to display that uninfected pulps showed absence of pathological changes while infected dental pulps were seen to induce periradicular lesions (50). The important role of bacteria was further confirmed by Sundqvist (51) by demonstrating that bacteria was found in root canals of pulpless teeth with periradicular bone destruction. With the understanding of the significance of bacteria in the root canal system, it is critical to understand the importance of a biofilm and its role in endodontic infection. A biofilm is defined as a highly organized structure consisting of bacterial cells enclosed in self-produced extracellular

polymeric matrix (52&53). Free-floating bacterial cells in the planktonic state have physiological properties that are substantially different than the sessile bacterial cells found in the biofilm state (54&55). Microbes within a biofilm can be 1000-fold more resistant to host defenses and antimicrobial agents due to the protection by their matrix; thereby, making microbial biofilms found in the root canal systems highly resistant to disinfecting agents used in endodontic treatment (56). Therefore, an essential principle in endodontic treatment is the ability to remove the microbiota found in root canal systems and to disrupt the formation of microbial biofilms.

Intraradicular endodontic infections can be organized into three separate categories: primary, secondary, or persistent infection. These categories are dependent on when the participating microorganisms established themselves in the root canal (57). Primary infection results from the initial pulpal inflammation and proceeds to root canal infection. Primary endodontic infections are polymicrobial with several predominate species including: *Bacteroides, Peptostreptococcus, Prevotella, Prophyromonas, Treponema, Fusobacterium, Camphylobacter, and Eubacterium* (58–62). Infection within the root canal system is a dynamic process in which selective pressures occur that favor the establishment of some species and inhibit others (57). In the initial phases of pulpal infection, facultative bacteria dominate (58). However, after oxygen is depleted due to the progression of pulpal necrosis and consumption by facultative bacteria an anaerobic environment develops. As time progresses, the anaerobic conditions become more pronounced, particularly in the apical third. This creates a change in the microbial flora that favors anaerobic bacteria over facultative bacteria.

Persistent infections are caused by microorganisms from a primary infection that resisted intracanal antimicrobial procedures and managed to endure periods of nutrient deprivation in a prepared canal. In comparison, secondary infections are caused by microorganisms that were not present in the primary infection but that were introduced into the root canal system at some time during or after endodontic intervention (57). Bacterial entry can occur in three different manners: during treatment, between appointments, after root canal filling. During treatment, the main causes of microbial introduction are the result of remnants of dental plaque, calculus, or caries on the tooth crown; leakage of the rubber dam; or contamination of endodontic instruments, irrigating solutions, or other intracanal medications. Between appointments, microorganisms can enter the root canal system by loss or leakage of temporary restorative materials; fracture of the tooth structure; or through teeth left open for drainage. After root canal obturation, microorganisms can penetrate the root canal by loss or leakage of temporary or permanent restorative materials, preparation of posts or other intracanal restorations without the rubber dam, fracture of the tooth structure, recurrent decay that exposes the root canal filling material, or delay in the placement of permanent restorations. Clinically, persistent and secondary infections are indistinguishable. Numerous studies have identified the bacteria found in persistent and secondary infections which commonly include*: Enterococci, Actinomyces,* fungi (such as *Candida*), *Lactobacilli,* and *Streptococci* (63–67). The most predominate bacteria found in these infections is *E. faecalis.* It has been shown that *E. faecalis* is highly resistant to a variety of intracanal medicaments, and the overall eradication of the bacteria by conventional means has been shown to be very difficult (68–71).

Biofilm removal is typically accomplished with a chemomechanical approach in which endodontic instrumentation is combined with a variety of root canal irrigants (72). Sodium hypoclorite (NaOCl) is the most common and potent irrigant used in endodontic disinfection (73&74). It has antimicrobial properties and the ability to dissolve both necrotic and vital tissues (75&76). During endodontic treatment, NaOCl is used in concentrations that may range from 0.5 to 6% (75&77). Additionally, a recommended irrigation sequence involves the use of NaOCl and Ethylenediaminetetraacetic acid (EDTA) which is a chelating agent (78). It has been shown that a combined application of 17% EDTA and 2.5% NaOCl substantially reduces the intracanal biofilm quantity (79). This protocol's efficacious ability comes from removing both organic and inorganic debris while also disrupting microbial biofilms.

Temporary Materials

Temporary materials in endodontics are used during and after treatment to provide a tight seal over the access cavity. This is done to prevent reinfection into the root canal system. Currently, the most common temporary materials for short and long-term temporization include: Cavit, IRM, and variations of glass ionomer cements (80). Endodontic literature is replete with studies demonstrating the limiting capacity of temporary materials for preventing microleakage (81&82). A study utilizing IRM as a temporary material demonstrated that in coronally sealed canals medicated with calcium hydroxide recontamination occurred after 17 days (83). A study performed by Balto (84) demonstrated that all the provisional materials tested in completed root canals failed to prevent coronal leakage when used for an average of 30 days. This raises the question

whether there is a specific period of time between previously initiated therapy and completed root canal treatment that will increase the risk for failure. Many studies have investigated the long-term outcomes of multiple visit root canal treatment; however, the influence of specific time interval periods between appointments has yet to be examined as a contributing variable.

MATERIALS AND METHODS

The data for this study was obtained from the electronic insurance claims record and enrollment database for Delta Dental of Wisconsin, which included patient encounters that occurred between January 1, 2002 and December 31, 2014. From the total patient encounters, 488,617 initial NSRCT procedures were completed on permanent teeth. Data was then obtained from the database following specific inclusion and exclusion criteria parameters. Only teeth that received NSRCT within 6 months after completion of pulpal debridement or pulpotomy procedures (identified by Codes of Dental Procedures and Nomenclature) and were within a continuous insurance coverage period were included in the study. Teeth that did not receive definitive restorations within 180 days following completion of NSRCT were excluded. A total of 7,448 NSRCTs were included in the analysis. Teeth were followed from the time of treatment to the presence of a CDT code representing untoward events, which include retreatment, apicoectomy, or extraction. NSRCT procedures were considered successful until a lapse in the patient's enrollment status or the presence of a CDT code for an untoward event.

Several variables were analyzed including: age of patient at the time of NSRCT, tooth location, and provider type. Provider types were general dentists, other dental specialists, and endodontists whom graduated from an American Dental Association accredited endodontic residency program. Subcategories based on provider types were then analyzed for each initial treatment rendered and each definitive treatment completed. Combinations of types of providers were also examined in which one type of provider initated treatment and a different type of provider completed treatment. Various time interval periods from initial endodontic intervention to definitive endodontic treatment

were examined. Additionally, the time interval between completed NSRCT and placement of definitive restoration was examined.

Definitive restorations were categorized into two groups: other restorations and full coverage restorations. Other restorations were permanent restorations identified by CDT codes which included: single surface amalgams/multiple surface amalgams, single surface composite/multiple surface composites, core build ups, and both prefabricated and indirectly fabricated post and cores. Full coverage restorations identified by CDT codes included all-ceramic crowns, cast metal crowns, and porcelain fused to metal crowns.

Following the set forth variables, the insurance information was analyzed using SAS 9.4 software. Due to an inadequate sample size, other dental specialists were combined with the general dentists category for statistical analysis. Hazard ratios were calculated using a univariate Cox proportional hazards model. From this data, adjusted hazard ratios were calculated using a multivariable Cox proportional hazards model to simultaneously account for numerous variables and predictors. A p-value of <0.05 as the level of significance was utilized. Kaplan-Meier survival estimates were calculated at 1,3,5, and 10 years following the completion of definitive endodontic intervention and placement of a definitive restoration to the end of the continuous enrollment period or presence of an untoward event.

This project has Marquette University's Intuitional Review Board's approval with protocol number HR-1946

RESULTS

Variable	All (N = 7488)
Age at restoration	
[0,30]	1428 (19.1%)
(30,45]	2372 (31.7%)
(45,55]	2145 (28.6%)
(55,120]	1543 (20.6%)
Tooth Location	
Anterior	667 (8.9%)
Premolar	2014 (23.7%)
Molar	5605 (67.4%)
Time from PIT to NSRCT	
(0-1] wks	929 (19.1%)
(1-2] wks	1052 (21.6%)
(2-4] wks	1223 (25.1%)
(4-8] wks	891 (18.3%)
>8 wks	779 (16.0%)
Time from NSRCT to Restoration	
(0-2] wks	1965 (26.2%)
(2-8] wks	3691 (49.3%)
>8 wks	1832 (24.5%)
PIT Provider	
Endodontist	338 (4.5%)
General Dentist	7150 (95.5%)
NSRCT Provider	
Endodontist	2457 (32.8%)
General Dentist	5031 (67.2%)
Provider type(s)	
General Dentist (PIT) & General Dentist (NSRCT)	4874 (65.1%)
General Dentist (PIT)) & Other Specialist (NSRCT)	152 (2.0%)
General Dentist (PIT)) & Endodontist (NSRCT)	2124 (28.4%)
Endodontist (PIT) & Endodontist (NSRCT)	333 (4.4%)
Restoration type	
Other	4552 (60.8%)
Crown	2936 (39.2%)

Table 1: Descriptive summary of variables based on number of cases

Univariate Cox Proportional Hazards	HR	95% Cl	p-value
Tooth location			
Pre-molar vs. Anterior	1.30	[0.88, 1.92]	0.184
Molar vs. Anterior	1.31	[0.92, 1.88]	0.136
Age at restoration			
(31,45] vs. [<=30]	1.41	[1.02, 1.96]	0.037
(46,55] vs. [<=30]	1.66	[1.21, 2.31]	0.002
(>55] vs. [<=30]	2.05	[1.47, 2.86]	<0.001
PIT provider			
General Dentist vs. Endodontist	1.52	[0.93, 2.48]	0.097
NSRCT provider			
General Dentist vs. Endodontist	1.37	[1.12, 1.68]	0.002
Weeks from PIT to NSRCT			
Time from PIT to NSRCT	0.99	[0.98, 1.00]	0.265
(1-2] Wks vs. (0-1] Wks	1.16	[0.88, 1.52]	0.286
(2-4] Wks vs. (0-1] Wks	1.13	[0.87, 1.48]	0.358
(4-8] Wks vs. (0-1] Wks	0.99	0.73, 1.33]	0.921
>8 Wks vs. (0-1] Wks	0.95	[0.69, 1.30]	0.736
Weeks from NSRCT to Restoration			
(2-8] Wks vs. (0-2] Wks	1.02	[0.81, 1.27]	0.888
>8 Wks vs. (0-2] Wks	1.08	[0.84, 1.40]	0.535
Restoration type			
Crown vs. Other	0.85	[0.71, 1.03]	0.092

Table 2: Univariate cox proportional hazard results

Multivariate Cox Proportional Hazards	aHR	95% Cl	p-value
Tooth Location			
Pre-molar vs. Anterior	1.31	[0.88, 1.94]	0.185
Molar vs. Anterior	1.49	[1.03, 2.15]	0.033
Age at restoration			
(30,45] vs. [0,30]	1.38	[0.99, 1.91]	0.054
(45,55] vs. [0,30]	1.64	[1.19, 2.27]	0.003
(55,120] vs. [0,30]	2.06	[1.47, 2.88]	<0.001
PIT provider			
General Dentist vs. Endodontist	1.30	[0.77, 2.17]	0.323
NSRCT Provider			
General Dentist vs. Endodontist	1.43	[1.15, 1.78]	0.001
Provider Type(s)			
General Dentist (PIT Provider) & Endodontist (NSRCT Provider) vs. General Dentist (PIT Provider) & General Dentist (NSRCT Provider)	0.68	[0.55, 0.85]	<0.001
Weeks from PIT to NSRCT	0.99	[0.98, 1.01]	0.336
Weeks from NSRCT to Restoration	1.00	[0.99, 1.02]	0.660
Restoration type			
Crown vs. Other	0.81	[0.67, 0.99]	0.035

Table 3: Multivariable cox proportional hazard results

Within the 7,448 encounters where endodontic treatment was completed with a definitive restoration following previously initiated therapy 5,049 (67.4%) were molars, 1,772 (23.7%) were premolars, and 667 (8.9%) were anteriors (Table 1). Molar teeth were associated with a greater risk of an untoward event than anterior teeth as shown by the adjusted hazard ratio of 1.49, p = 0.033 (Table 3). There was no statistically significant difference between the failure rate of anterior and premolar teeth, p = 0.185 (Table 3).

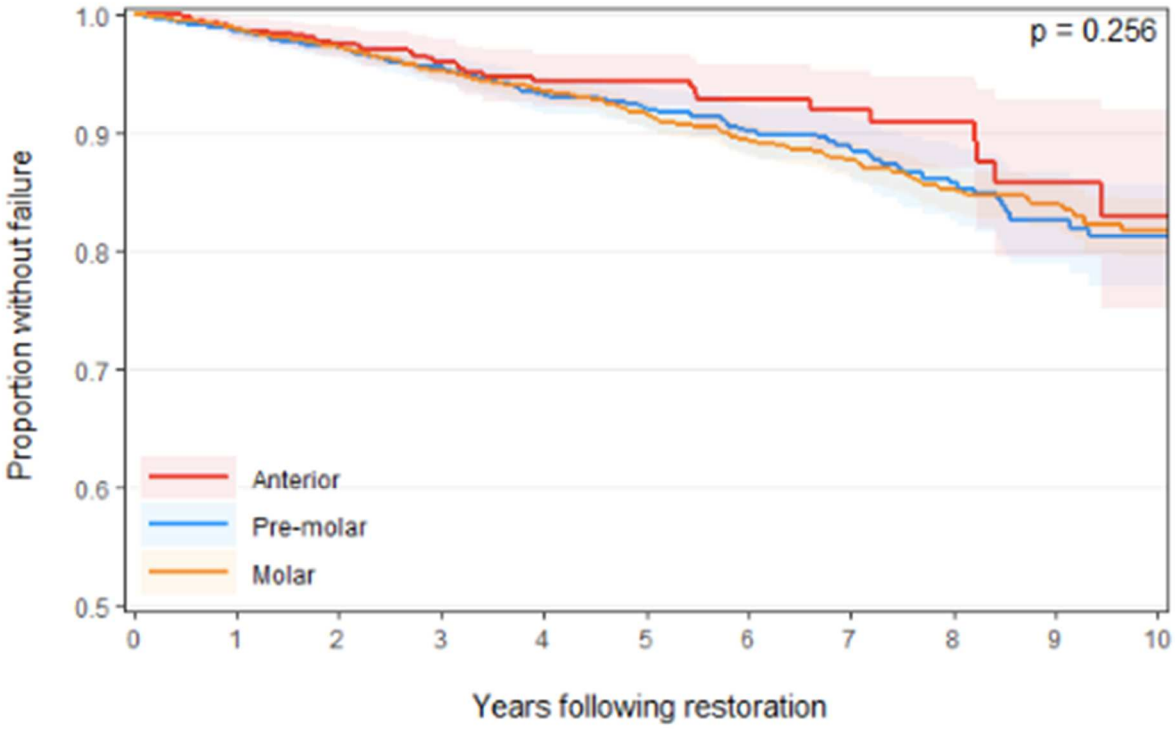

Figure 1: Survival estimates of endodontically treated teeth based on tooth location

Year	Survival	N events	N at risk
Anterior			
0	100% [100.00%, 100.0%]	0	667
1	98.8% [97.9%, 99.7%]	7	538
3	96.0% [94.2%, 97.8%]	12	339
5	94.4% [92.2%, 96.7%]	5	197
10	83.1% [75.1%, 91.9%]	9	18
Pre-molar			
0	100% [100.00%, 100.0%]	0	1772
1	98.6% [98.0%, 99.1%]	23	1440
3	95.6% [94.5%, 96.7%]	37	933
5	92.1% [90.4%, 93.8%]	28	511
10	81.3% [77.0%, 85.7%]	30	71
Molar			
0	100% [100.00%, 100.0%]	0	5049
1	98.8% [98.5%, 99.1%]	54	4092
3	95.2% [94.5%, 95.9%]	125	2612
5	91.6% [90.6%, 92.7%]	75	1448
10	81.9% [79.4%, 84.4%]	82	181

Table 4: Survival estimates of endodontically treated teeth based on tooth location

The mean age at the time of NSRCT was 43.6 years with a standard deviation of 13.7. Age was further classified into age groups with ages ≤ 30 years having 1,428 (19.1%) cases, ages 31-45 years with 2,372 (31.7%) cases, ages 46-55 years with 2,145 (28.6%), and over 55 years of age with 1,543 (20.6%) of cases (Table 1). The survival rates for endodontically treated teeth for the age group ≤ 30 years were 99.0% at 1 year, 96.8% at 3 years, 94.9% at 5 years, and 85.2% at 10 years. Survival rates for the age group 31– 45 years were 99.0% at 1 year, 95.9% at 3 years, 92.6% at 5 years, and 82.4% at 10 years. Survival rates for endodontically treated teeth for the age group 46 – 55 years were 98.6% at 1 year, 94.9% at 3 years, 91.3% at 5 years, and 82.8% at 10 years. Survival rates for endodontically treated teeth for the age group >55 years were 98.4% at 1 year, 94.1% at 3 years, 89.8% at 5 years, and 76.2% at 10 years (Table 5). There was a statistically significant increase in the risk of failure in teeth from ages 46-55 years and

>55 years when compared with ≤ 30 years with adjusted hazard ratios of 1.73 and 2.15 respectively (Figure 2, Table 3

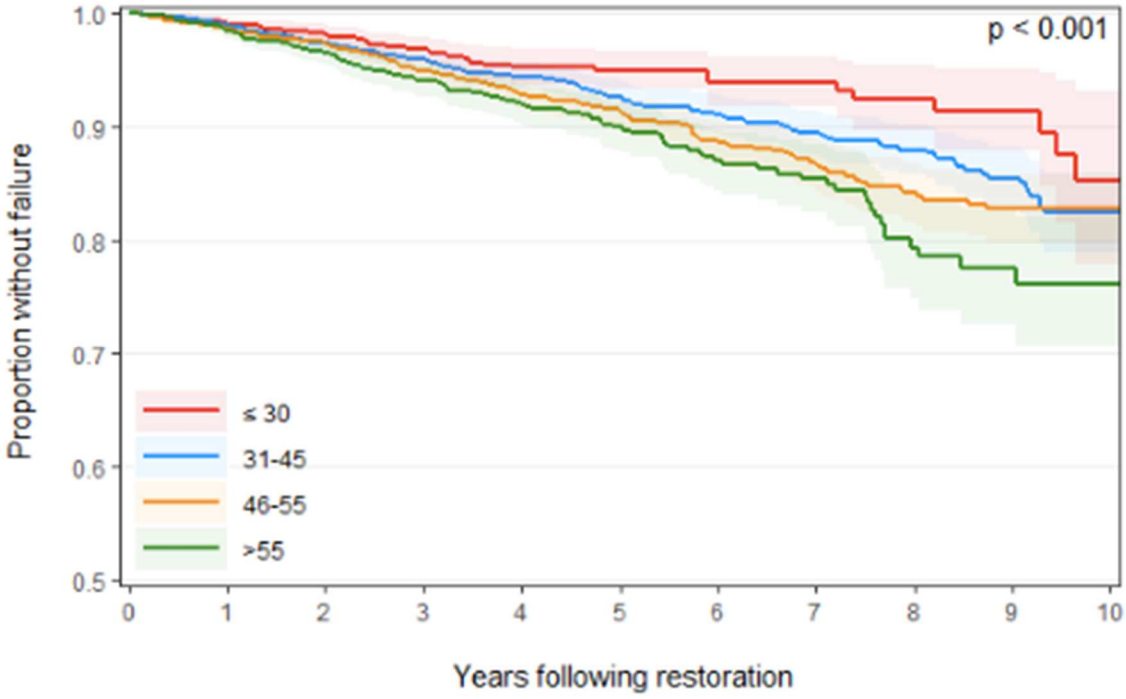

Figure 2: Survival estimates of endodontically treated teeth based on age

Year	Survival	N events	N at risk
Age ≤30			
0	100% [100.00%, 100.0%]	0	1428
1	99.0% [98.4%, 99.6%]	12	1052
3	96.8% [95.6%, 98.0%]	18	576
5	94.9% [93.3%, 96.6%]	9	274
10	85.2% [77.9%, 93.1%]	8	28
Age 31-45			
0	100% [100.00%, 100.0%]	0	2372
1	99.0% [98.5%, 99.4%]	22	1910
3	95.9% [95.0%, 96.8%]	51	1269
5	92.6% [91.2%, 94.0%]	35	751
10	82.4% [79.0%, 86.0%]	42	119
Age 46-55			
0	100% [100.00%, 100.0%]	0	2145
1	98.6% [98.1%, 99.1%]	28	1824
3	94.9% [93.8%, 96.0%]	58	1251
5	91.3% [89.8%, 92.9%]	38	728
10	82.8% [79.9%, 85.8%]	43	91
Age >55			
0	100% [100.00%, 100.0%]	0	1543
1	98.4% [97.8%, 99.1%]	22	1284
3	94.1% [92.7%, 95.5%]	47	788
5	89.9% [87.9%, 92.0%]	26	406
10	76.2% [70.7%, 82.1%]	28	32

Table 5: Survival estimates of endodontically treated teeth based on age

The number of previously initiated treatments performed by an endodontist was 338 (4.5%) and the number completed by general dentists was 7,150 (95.5%) (Table 1). There was no statistically significant increase in risk of failure when the provider type for previously initiated therapy was a general dentist with an adjusted hazard ratio of 1.30 (p =.323) (Table 2, Figure 3). The number of NSRCTs completed by an endodontist was 2,457 (32.8%) and number of NSRCTs completed by a general dentist was 5031 (67.2%) (Table 1). There was a statistically significant increase in failure rate when NSRCT provider was not an endodontist. This was observed in both the univariate Cox

proportional hazard with a ratio of 1.37 (p = 0.002) and the adjusted hazard with a ratio of 1.43 (p<0.001) (Table 2, Table 3, and Figure 4).

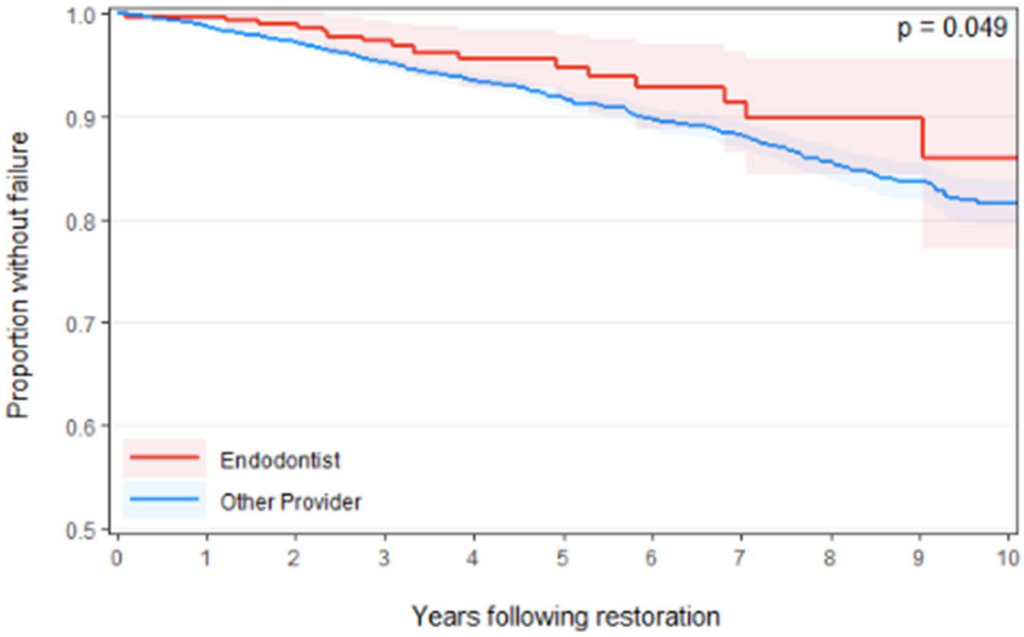

Figure 3: Survival estimates of endodontically treated teeth based on previously initiated therapy provider type

Year	Survival	N events	N at risk
Endodontist			
0	100% [100.00%, 100.0%]	0	338
1	99.7% [99.1%, 100.0%]	1	284
3	97.3% [95.3 %, 99.3%]	6	189
5	94.7% [91.5%, 98.0%]	4	107
10	85.9% [77.3%, 95.6%]	5	6
General Dentist			
0	100% [100.00%, 100.0%]	0	7150
1	98.7% [98.4%, 99.0%]	83	5786
3	95.3% [94.7%, 95.9%]	168	3695
5	91.8% [91.0%, 92.7%]	104	2049
10	81.7% [79.5%, 83.8%]	116	264

Table 6: Survival estimates of endodontically treated teeth based on previously initiated therapy provider type

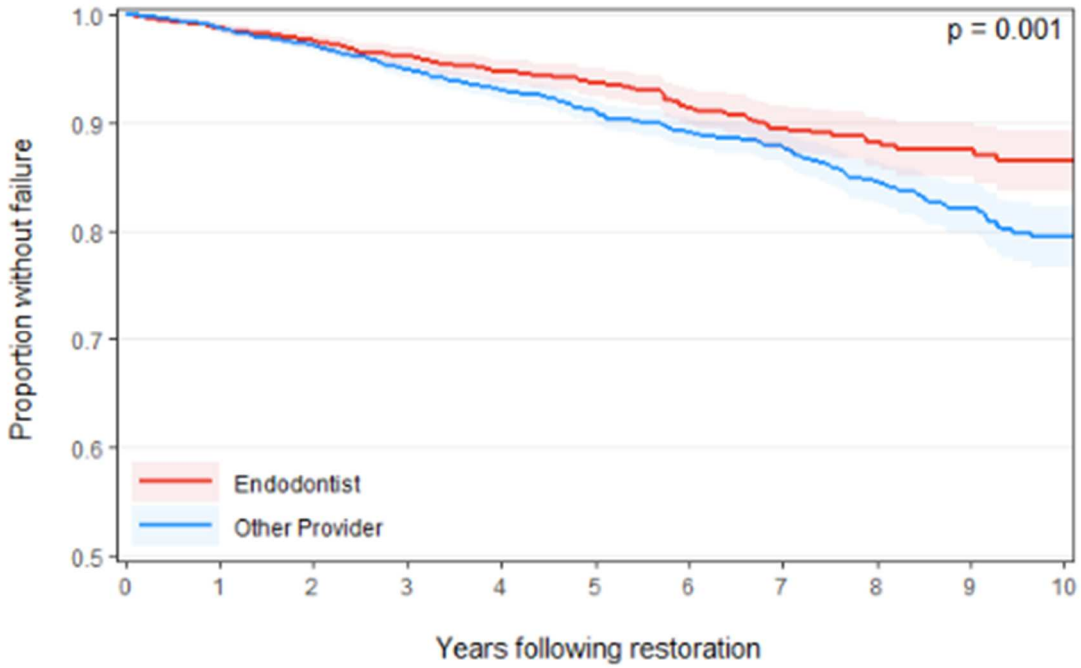

Figure 4: Survival estimates of endodontically treated teeth based on NSRCT provider type

Year	Survival	N events	N at risk
Endodontist			
0	100% [100.00%, 100.0%]	0	2457
1	98.7% [98.3%, 99.2%]	28	2008
3	96.1% [95.2 %, 97.0%]	45	1307
5	93.7% [92.5%, 95.0%]	26	744
10	86.5% [83.7%, 89.4%]	34	97
General Dentist			
0	100% [100.00%, 100.0%]	0	5031
1	98.7% [98.4%, 99.1%]	56	4062
3	95.0% [94.3%, 95.7%]	129	2577
5	91.1% [90.0%, 92.2%]	82	1412
10	79.5% [76.7%, 82.3%]	87	173

Table 7: Survival estimates of endodontically treated teeth based on NSRCT provider type

Three main combinations of provider types were categorized when previously initiated therapy provider type and NSRCT provider type were combined. A general

dentist for previously initiated therapy provider combined with a general dentist for NSRCT consisted of 4,874 (65.1%) of cases, a general dentist for previously initiated therapy combined with an endodontists for NSRCT consisted of 2,124 (28.4%) of cases, and an endodontists for previously initiated therapy combined with an endodontists for NSRCT consisted of 333 (4.4%) of cases (Table 1).

When compared by combination of provider types the survival rates for a general dentist for previously initiated therapy combined with a general dentist for NSRCT were 98.7% at 1 year, 94.9% at 3 years, 91.0% at 5 years, and 79.1% at 10 years (Table 8). The survival rates for a general dentist for previously initiated therapy combined with an endodontist for NSRCT were 98.6% at 1 year, 95.9% at 3 years, 93.6% at 5 years, and 86.6% at 10 years. The survival rates for an endodontist for previously initiated therapy combined with an endodontist for NSRCT were 99.7% at 1 year, 97.4% at 3 years, 94.6% at 5 years, and 85.6% at 10 years. A statistically significant lower adjusted hazard ratio of 0.68 ($p<0.001$) was observed when treatment was initiated by a general dentist and completed by an endodontist when compared to treatment that was both initiated and completed by general dentists (Table 3, Figure 5).

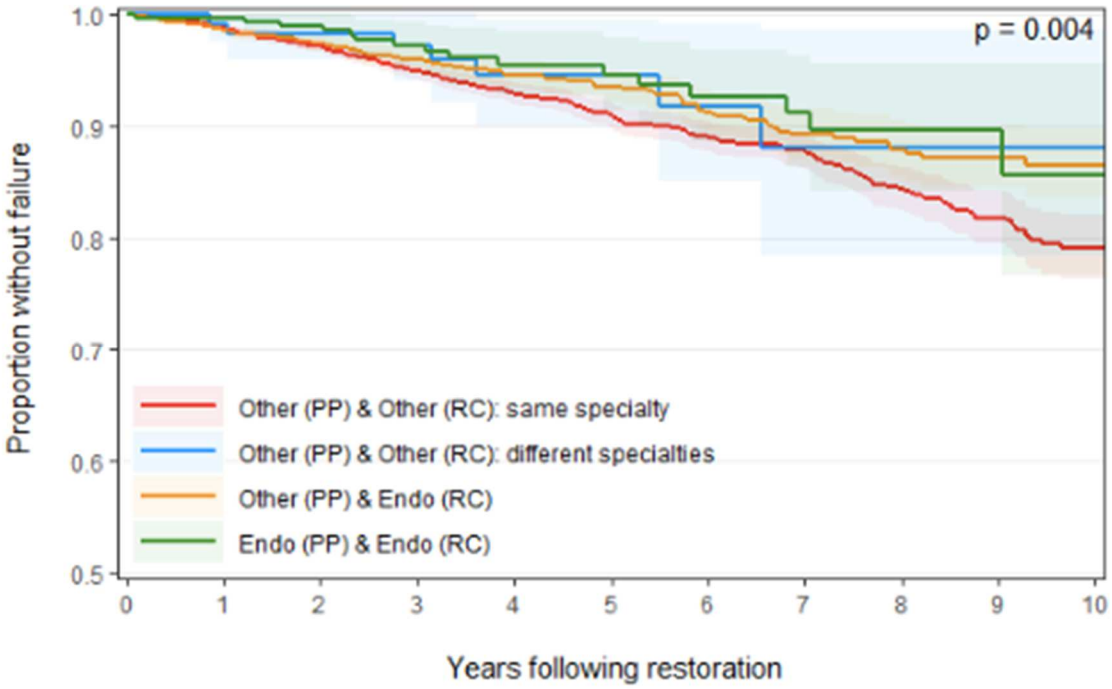

Figure 5: Survival estimates of endodontically treated teeth based on a combination of provider types for previously initiated therapy and NSRCT

Year	Survival	N events	N at risk
General Dentist (PIT) & General Dentist (NSRCT)			
0	100% [100.00%, 100.0%]	0	4874
1	98.7% [98.4%, 99.1%]	55	3942
3	94.9% [94.2%, 95.6%]	127	2792
5	91.0% [89.9%, 92.1%]	80	1372
10	79.1% [76.3%, 82.1%]	85	164
General Dentist (PIT) & Other Specialist (NSRCT)			
0	100% [100.00%, 100.0%]	0	152
1	99.2% [97.6%, 100.0%]	1	115
3	97.2% [94.1%, 100.0%]	2	82
5	94.6% [90.0%, 99.4%]	2	38
10	88.0% [78.5%, 98.6%]	2	8
General Dentist (PIT) & Endodontist (NSRCT)			
0	100% [100.00%, 100.0%]	0	2124
1	98.6% [98.1%, 99.1%]	27	1729
3	95.9% [95.0%, 96.9%]	39	1121
5	93.6% [92.2%, 95.0%]	22	639
10	86.6% [83.7%, 89.6%]	29	92
Endodontist (PIT) & Endodontist (NSRCT)			
0	100% [100.00%, 100.0%]	0	333
1	99.7% [99.1%, 100.0%]	1	279
3	97.2% [95.2%, 99.3%]	6	186
5	94.6% [91.4%, 97.9%]	4	105
10	85.6% [76.7%, 95.6%]	5	5

Table 8: Survival estimates of endodontically treated teeth based on a combination of provider types for previously initiated therapy and NSRCT

Five different categories of time intervals between initiation and completion of root canal therapy were examined (Table 9, Figure 6). The first period of time examined was 0 - 1 weeks and consisted of 1,558 cases (20.8%); the survival rates were 98.6% at 1 year, 95.8% at 3 years, 92.4% at 5 years, and 82.7% at 10 years. The second time interval

examined was 1 - 2 weeks and consisted of 1,593 cases (21.3%); the survival rates were 98.4% at 1 year, 95.0% at 3 years, 91.3% at 5 years, and 80.5% at 10 years. The third time interval examined was 2 - 4 weeks and consisted of 1,869 cases (25.0%); the survival rates were 98.8% at 1 year, 95.1% at 3 years, 91.8% at 5 years, and 81.1% at 10 years. The fourth time interval examined was 4 - 8 weeks and consisted of 1,313 cases (17.5%); the survival rates were 98.9% at 1 year, 95.0% at 3 years, 92.1% at 5 years, and 83.1% at 10 years. The last time interval examined was greater than 8 weeks and consisted of 1,155 cases (15.4%); the survival rates were 99.2% at 1 year, 96.2% at 3 years, 92.6% at 5 years, and 82.5% at 10 years. No statistically significant difference was observed at 1,3,5, or 10 years with an adjusted hazard ratio of 0.99 (p = 0.347) (Table 3).

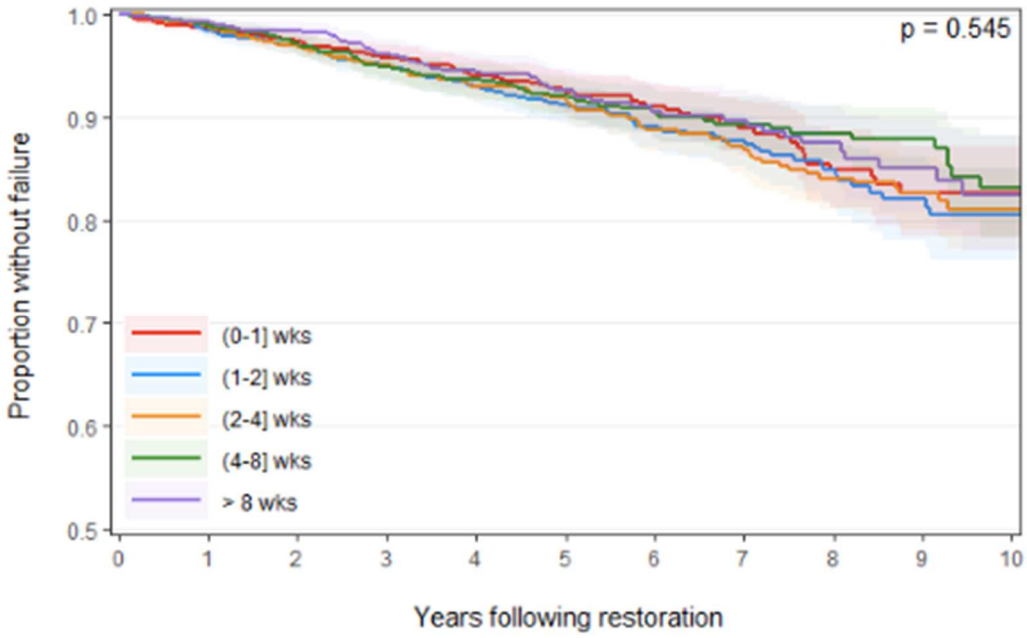

Figure 6: Survival estimates of endodontically treated teeth based on varying time intervals between previously initiated therapy and NSRCT

Year	Survival	N events	N at risk
(0-1) wks			
0	100% [100.00%, 100.0%]	0	1558
1	98.6% [98.0%, 99.2%]	20	1257
3	95.8% [94.7%, 97.0%]	29	796
5	92.4% [90.6%, 94.2%]	21	431
10	82.7% [78.4%, 87.2%]	22	54
(1-2) wks			
0	100% [100.00%, 100.0%]	0	1593
1	98.4% [97.7%, 99.0%]	23	1289
3	95.0% [93.7%, 96.2%]	38	841
5	91.3% [89.4%, 93.1%]	26	465
10	80.5% [76.1%, 85.1%]	28	61
(2-4) wks			
0	100% [100.00%, 100.0%]	0	1869
1	98.8% [98.3%, 99.3%]	20	1539
3	95.1% [93.9%, 96.2%]	50	996
5	91.8% [90.1%, 93.5%]	27	544
10	81.1% [77.2%, 85.2%]	36	59
(4-8) wks			
0	100% [100.00%, 100.0%]	0	1313
1	98.9% [98.3%, 99.5%]	13	1066
3	95.0% [93.6%, 96.4%]	35	689
5	92.1% [90.2%, 94.1%]	17	396
10	83.1% [78.2%, 88.3%]	18	58
>8 wks			
0	100% [100.00%, 100.0%]	0	1155
1	99.2% [98.7%, 99.8%]	8	919
3	96.2% [94.8%, 97.6%]	22	562
5	92.6% [90.4%, 94.8%]	17	320
10	82.5% [77.1%, 88.2%]	17	38

Table 9: Survival estimates of endodontically treated teeth based on varying time intervals between previously initiated therapy and NSRCT

Three time intervals between completion of root canal therapy and placement of definitive restoration were examined (Table 10, Figure 7). The first period of time examined was 0 - 2 weeks and consisted of 1,965 cases (26.2%); the survival rates were 98.8% at 1 year, 95.7% at 3 years, 92.6% at 5 years, and 81.7% at 10 years. The second period of time examined was 2 - 8 weeks and consisted of 3,691 cases (49.3%); the survival rates were 98.7% at 1 year, 95.4% at 3 years, 92.3% at 5 years, and 81.8% at 10 years. The third period of time examined was greater than 8 weeks and consisted of 1,832 cases (15.9%); the survival rates were 98.7% at 1 year, 94.9% at 3 years, 90.8% at 5 years, and 82.0% at 10 years. No statistically significant difference was observed at 1,3,5, or 10 years with an adjusted hazard ratio of 1.00 (p = 0.592) (Table 3).

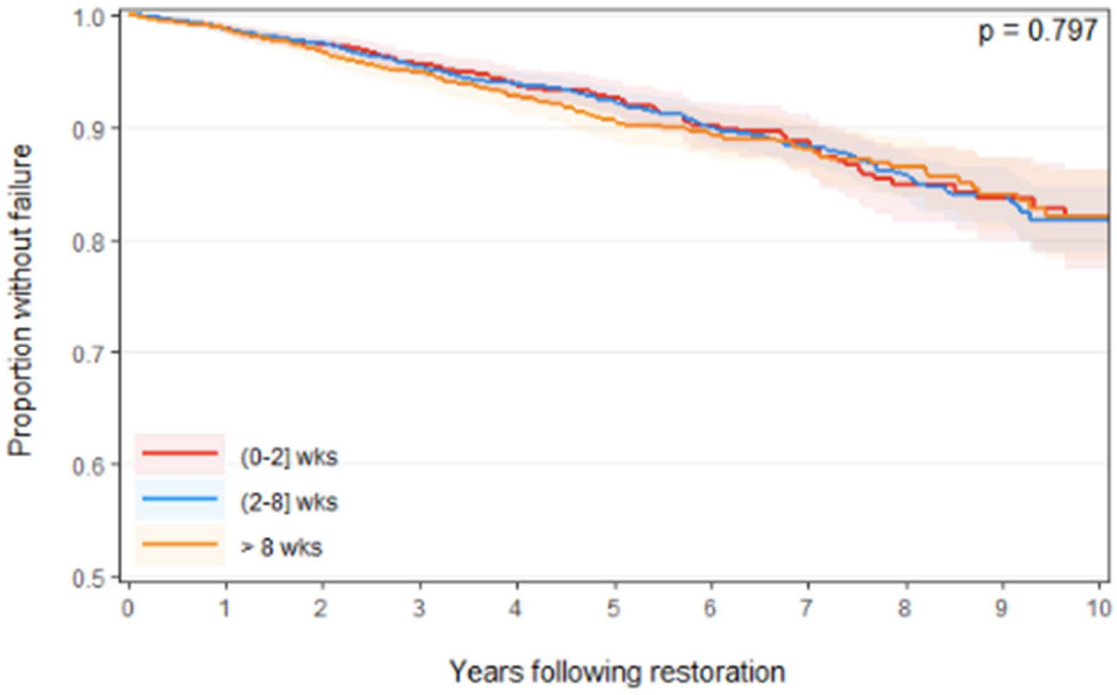

Figure 7: Survival estimates of endodontically treated teeth based on varying time intervals between NSRCT completion and placement of definitive restoration

Year	Survival	N events	N at risk
(0-1) wks			
0	100% [100.00%, 100.0%]	0	1965
1	98.8% [98.3%, 99.3%]	20	1532
3	95.7% [94.6%, 96.7%]	41	975
5	92.6% [91.0%, 94.2%]	24	531
10	81.7% [77.3%, 86.3%]	31	59
(2-8) wks			
0	100% [100.00%, 100.0%]	0	3691
1	98.7% [98.3%, 99.1%]	43	3035
3	95.4% [94.6%, 96.2%]	83	1948
5	92.3% [91.1%, 93.5%]	50	1091
10	81.8% [78.9%, 84.8%]	64	131
>8 wks			
0	100% [100.00%, 100.0%]	0	1832
1	98.7% [98.2%, 99.3%]	21	1503
3	94.9% [93.8%, 96.1%]	50	961
5	90.8% [89.0%, 92.6%]	34	534
10	82.0% [78.2%, 86.1%]	26	80

Table 10: Survival estimates of endodontically treated teeth based on varying time intervals between NSRCT completion and placement of definitive restoration

DISCUSSION

The primary objective of this study was to determine if the period of time between previously initiated therapy and the completion of root canal treatment influences long-term outcomes. Currently, there is no clinical guideline to recommend a time interval between root canal appointments. Therefore, dental providers advise patients to complete root canal therapy within several weeks of initiating treatment. This interval period stems from the use of intracanal medicaments, patient/provider preferences, and the ability of temporary restorative materials to prevent coronal leakage (3,23,28–30, 80–84). Despite the available endodontic literature, a consensus among dental professionals is lacking; hence, there is a need for more scientific evidence to support clinical decision making. The secondary purpose of this study was to determine if the provider type influences long-term success in instances where NSRCT has been previously initiated. Currently, there are no studies in endodontic literature that directly address this variable as a contributing factor in the long-term success of multiple visit root canal treatment.

By using the Delta Dental of Wisconsin insurance database, the study was able to include a large patient base and was able to examine how different prognostic variables influence long-term outcomes. There are several advantages of this study that make the results beneficial for interpretation. Unlike many prospective studies that have limited follow-up periods and are underpowered due to limited sample sizes, this study has both a large patient population and long follow-up periods. This study is also shielded from biases since the data was collected for reasons other than the purpose of this study. By utilizing a large data set, it allows for a minimization of treatment variation by providers. Many prospective studies are performed in academic institutions, in which the data is

only representative of a particular patient population and treatment decisions made by only a handful of clinicians. In contrast, the data set from this study is a true representation of outcomes from endodontic treatment performed by clinicians all over the state of Wisconsin. This provides real-world outcomes and assessments than can be interpreted and applied to everyday clinical situations. Most importantly, due to the nature of the clinical question, only a retrospective study design may be used to address the primary objective of the study. Randomized clinical trials and prospective cohort studies are not possible study designs due to the unethical considerations they propose in the manner of intentionally delaying a treatment that is considered a standard of care.

The impacts of both tooth location and the age of the patient at the time of treatment were examined as variables to consider for long-term survival. The findings of the study indicated that molar teeth had an increased risk for untoward events when compared to anterior teeth. An increase in the age of the patient was also implicated as an increased risk for an untoward event. These findings are consistent with a previous study by Moore (85) that demonstrated similar findings for both variables. A possible explanation for the impact of tooth location exists: increased anatomical complexity of multi-rooted teeth may limit the providers ability to effectively chemomechanically debride the root canal system (55). Therefore, there may be an increased risk for persisting endodontic infections resulting in endodontic failure. An additional consideration is that posterior teeth are subject to more occlusal forces which may result in increased fractures necessitating in tooth extraction (86). As patients age, teeth become increasingly more calcified. A study by Bernick demonstrated that 90% of pulps of individuals over the age of 40 exhibited pulpal calcification whereas no calcification was

evident in individuals younger than 20 years of age (87). The increase in calcification with age may contribute to increased difficulty in treatment. It is also important to consider that the risk for periodontal disease increases with age (88). It is possible to consider that the increase in risk for untoward events in older patients is related to periodontal considerations as opposed to endodontic failure. In a study examining the failure of endodontically treated teeth, it was determined that periodontal failures resulted in 32% of failed cases (89).

This study also sought to evaluate the influence of provider type for previously initiated therapy and NSRCT completion. The results of the study demonstrated that the influence of provider type for previously initiated therapy was not statistically significant in affecting long-term outcomes. This indicates that pulpotomy and pulpal debridement treatments are effective treatment modalities regardless of provider type. This was in agreement with previous findings by Wong (43) that concluded that regardless of provider type palliative endodontic treatment was extremely effective. When examining the influence of provider type for NSRCT completion, it was determined that provider type was statistically significant in affecting long-term outcomes. At 10 years, 86.5% of NSRCTs completed by an endodontist survived while only 79.5% of NSRCTs treated by a general dentist survived. These findings were similar to two previous studies. The first study demonstrated a 5% higher survival rate at 10 years for molar teeth treated by endodontists when compared to all other providers (40). The second study demonstrated a 98.1% survival of teeth treated by an endodontist and an 89.1% survival of teeth treated by a general dentist at a five year follow up (90). These previous studies differed from Lazarski (36) which determined endodontists have similar rates of success when

compared to general dentists. It should be noted that in these studies there was no mention whether root canal therapy had been previously initiated. Therefore, there was an inclusion of both single and multiple visit treatments while the present study examined the influence of provider type on only multiple visit root canal treatment.

This was the first study that examined the combination of treatment providers between initiation and completion of NSRCT. It was shown that there is a statistically significant reduction in the adjusted hazard ratio for when treatment is completed by an endodontist compared to when treatment is completed by a general dentist regardless of the period of time between appointments. At 10 years, there was 7.5% increase in survival for all teeth that had treatment that was initiated by a general dentist and completed by an endodontist compared to treatment that was both initiated and completed by a general dentist. Key prognostic factors in endodontic treatment success have previously been identified as the preoperative presence of periapical pathology and intraoperative complications (44–46). From the findings in the study, there are several inferences that can be made. First, it is possible to infer that the instrumentation and irrigation protocols used by endodontists are more effective in limiting persistent and secondary endodontic infections. Enhanced understanding of the biological principles from advanced endodontic training may maximize the ability to disinfect the root canal system which would minimize the possibility of persisting endodontic infections. Additionally, endodontists are more likely to minimize the possibility of introducing secondary infections intraoperatively, as they are more likely to use rubber dams during treatment (91). A survey from 2015 revealed that only 47% of general dentists utilized rubber dams for all root canal procedures (92). A second inference that may be made

from the findings of the study is that endodontists are better adept at both managing and preventing intraoperative complications. Endodontist may be better equipped in managing these complications by having more training and more access to advanced armamentarium in the form of surgical operating microscopes and cone beam computed tomography (16–18). According to Vire, 8.6% of endodontic failures are a result of iatrogenic errors such as perforations, ledges, transportations, or separated instruments (89).

Additionally, various time interval periods between initiation and completion of NSRCT were examined to determine the influence on long-term outcomes. A maximum period of 180 days was utilized based on clinical findings from McDougal (5). The study demonstrated that 96% of temporary materials were structurally intact at 6 months while only 68% were at 12 months. The intention of this study was to examine a specific time frame in which a majority of multiple visit root canals would occur while minimizing the confounding influence of prosthetic failure in the form of an inadequate coronal restoration. The findings of this study indicated that there was no statistically significant difference between all the examined periods. At 10 years, the survival rates for all five interval periods was remarkably similar ranging from 80.5% to 83.1%. The lack of increase in the untoward event of extraction for delayed root canal completion was consistent with the study by Wong (43). These findings suggest that the increased risk for persisting and secondary infection in delayed root canal completion is low. Therefore, this implies that effective disinfection prior to obturation is critical to endodontic success.

Similarly, various time interval periods from NRSCT completion to placement of definitive restoration were examined. 180 days was also used a maximum period of

observation to minimize the influence of prosthetic failure. The findings of this study demonstrated that among the three examined periods of time there was no statistically significant difference. At 10 years, the survival rates ranged from 81.7% to 82%, suggesting a low probability that secondary endodontic infection was the source of failure in the period from NSRCT completion to placement of definitive restoration. The influence of the timing of definitive restoration following NSRCT completion in regard to microleakage is controversial in endodontic literature. Several in vitro studies have demonstrated how both temporary materials and obturation materials are unable to prevent bacterial leakage after 30 days and 60 days respectively (84&93). The clinical significance of this is questioned in several studies (94&95). Specifically, one study with a follow-up period of 3 years explored root canal filled teeth that were exposed to the oral environment without a proper restoration for a period of at least 3 months (95). The authors determined that well prepared and filled root canals were able to resist bacterial penetration even with long-standing oral exposures. It was suggested that the problem of coronal leakage may not be of great clinical importance as previously suggested in vitro. The conflicting reports illustrate the need for more research regarding this topic.

There are inherent limitations of the study that need to be addressed. The study can only evaluate data that was submitted to insurance. Therefore, the sample size of the study is likely not a true representation for the frequency of multiple visit root canal treatment. Many dental providers will complete root canal treatment over multiple visits, but it is not possible to ascertain from an insurance database the number of visits performed to complete treatment. As a result, this study likely focuses on cases of true endodontic emergencies in which palliative treatment was initiated in the form of a

pulpotomy or pulpal debridement. Furthermore, the main limitation in this retrospective study is the inability to examine preoperative, intraoperative, and postoperative variables. In particular, there is no possibility to determine the influence of preoperative diagnosis, use of intracanal medicament, or type of temporary material used between treatment appointments. Lastly, there is only an ability to determine survival as clinical and radiographic interpretation is not possible. There may be instances where teeth in the study have survived, but by contemporary interpretation would not be considered successful based on specific clinical and radiographic criteria for healing that is commonly used in prospective studies (44–46).

CONCLUSION

This was the first study that directly examined the influence of varying time intervals between initiation and completion of root canal therapy on the long-term outcome of treatment. Additionally, this was the first study that examined the influence of provider type on the outcome of treatment after root canal therapy was previously initiated. Within the limitations of the study, it was shown that delayed completion of NSRCT after previously initiated therapy was not associated with unfavorable outcomes. Improved outcomes were noted when previously initiated therapy was completed by an endodontist.

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