Outcomes of Primary Endodontic Therapy Provided by Endodontic Specialists Compared to Other Providers

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OUTCOMES OF PRIMARY ENDODONTIC THERAPY PROVIDED
BY ENDODONTIC SPECIALISTS COMPARED
TO OTHER PROVIDERS

by

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A Thesis submitted to the Faculty of the Graduate School, Marquette University, in
Partial Fulfillment of the Requirements for the Degree of Master of Endodontics

Milwaukee, Wisconsin

May 2016

ABSTRACT
AN OUTCOMES COMPARISON OF PRIMARY ENDODONTIC THERAPY PROVIDED BY ENDODONTIC SPECIALISTS WITH OTHER PROVIDERS

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Introduction: The objective of this study was to compare the outcomes of initial non-surgical root canal therapy (NSRCT) for different tooth types provided by both endodontists and other providers. **Methods**: Using an insurance company database, 487,476 initial NSRCT procedures were followed from the time of treatment to the presence of an untoward event indicated by Current Dental Terminology (CDT) codes for retreatment, apical surgery, or extraction. Population demographics were computed for provider type and tooth location. Kaplan-Meier survival estimates were calculated for 1, 5, and 10 years. Hazard ratios for provider type and tooth location were calculated using the Cox proportional hazards model. Analyses were performed using SAS 9.4 (Cary, NC). **Results**: The survival of all teeth collectively was 98% at 1 year, 92% at 5 years, and 86% at 10 years. Significant differences in survival based on provider type were noted for molars at 5 years, and for all tooth types at 10 years. The greatest difference discovered was a 5% higher survival rate at 10 years for molars treated by endodontists. This was further evidenced by a hazard ratio of 1.394 when comparing other provider's success to endodontists within this ten-year molar group. **Conclusions**: These findings show that survival rates of endodontically teeth is high at ten years post treatment regardless of provider type. Molars treated by endodontists after 10 years have significantly higher survival rates than molars treated by non-endodontists.

ACKNOWLEDGEMENTS

Jacob C. Burry, D.D.S

I would like to thank the faculty of the Marquette University School of Dentistry Endodontics Program for their tireless commitment to educating the future leaders of the endodontic community.

In particular, I'd like to thank Dr. Sheila Stover and Dr. Lance Hashimoto for their generosity, patience, and genuine care for residents of the program. Together they have created a very special environment ripe for learning.

I'd also like to thank Dr. Pradeep Bhagavatula for his guidance and instrumental role in the development, and completion of this thesis.

I must also give love and thanks to my wife Katie. I have pulled this poor lady across the country numerous times in pursuit of my dreams. She has been my rock during times of turmoil, and an ever-flowing fountain of support. We are finally ready to pack up our little Rowan and ride back into the western sunset.

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Nonsurgical Root Canal Therapy

The specialty of endodontics is directed towards the elimination and prevention of apical periodontitis (1). A prevalent malady, half of adults over fifty years of age will experience the disease, and nearly 2% of randomly sampled teeth will demonstrate evidence of apical periodontitis (2-4). Despite the widespread nature of the disease, the exact cause of apical periodontitis went unknown for many years. In a groundbreaking study utilizing normal and gnotobiotic rats, it was discovered that bacterial contamination of the root canal system resulted in development of apical periodontitis (5). Based on these findings, a similar study was conducted on a primate model utilizing macaca monkeys. Nine monkeys were used in this study. Within this animal sample, 78 teeth were devitalized in an aseptic fashion. Fifty-two of these canals were then inoculated with bacteria indigenous to the oral cavity of the specimens while the remaining canals were sealed to prevent bacterial contamination. The monkeys were then left undisturbed for 6 months post inoculation. The animals were sacrificed, and their tissues processed. Analysis of the processed specimens showed that 47 of the 52 contaminated teeth demonstrated positive radiographic evidence of apical periodontitis. Cultures of these radiographic lesions yielded high levels of anaerobic bacteria (6).

Several years prior to this publication, a beautifully designed human study was completed via the observation of 27 necrotic yet virgin and caries free teeth. Of these 27 teeth, 19 had apical lesions consistent with apical periodontitis. Bacterial analysis of these teeth showed that 18/19 teeth with apical lesions were contaminated with bacteria, while none of the teeth without lesions were infected (7). The results of these three

studies proved the now universally accepted relationship between bacterial infection and the development of apical periodontitis.

The link between bacterial infection of the root canal system and apical periodontitis has had a tremendous impact on endodontic clinical strategies directed towards its management. Mechanical removal of infected tissues coupled with chemical killing of bacteria are both crucial goals of nonsurgical root canal therapy (NSRCT). This "chemomechanical" debridement of the infected root canal system is of paramount importance when attempting to eliminate the bacteria responsible for causing apical periodontitis. This debridement also serves to remove any residual organic substrate within the root canal system which may aid in any future growth and development of surviving organisms (8).

Following chemomechanical debridement, traditional NSRCT requires obturation or filling of the cleansed root canal systems. The goal of canal obturation is to generate a dense three dimensional fill of all evacuated canal space and accessory canals which will help to prevent further intrusion of new bacteria or growth of residual bacterial (9). A dense fill of this nature terminated at the appropriate working length has been shown clinically to produce superior results (10). Obturation techniques satisfying these criteria help push the successful healing of initial NSRCT to 76%-86% (10, 11).

Recent documentation of intracanal and extra radicular biofilm development and its relationship to apical periodontitis has improved our understanding of the disease process. Although this discovery has improved our etiologic knowledge of apical periodontitis, it has introduced more complexities regarding its clinical management, and shed light on potential causes of failure (12). Despite these complexities, root canal

therapy is extremely cost effective compared to other strategies and has allowed the retention of billions of teeth (4).

Success or Survival

In endodontics, clinicians have debated for years the appropriate description of "success"(13). The efficacy of any dental treatment is of considerable importance to both clinicians and patients. This information guides clinical recommendations, and should lead to the most optimal treatment. According to Bergenholtz, success of a given therapy in medicine or dentistry is defined as attainment of an initial treatment goal, while failure would result from not attaining this goal. Applied to endodontics, this may represent a variety of objectives including retained tissue function, elimination of pathology, comfort, survival, etc. It is also important to consider the patient's vision of success as it very frequently does not parallel the clinician's definition. A patient's definition of success may lean more heavily on subjective categories such as comfort etc (14).

Large variations in in treatment design (protocols, materials, etc) and varying definitions of success within endodontic publications has introduced considerable confusion in the assessment of endodontic outcomes. The lack of standardized criteria for measuring outcomes in endodontic studies has resulted in erratic and conflicting reports on endodontic treatment prognosis (15). A universally accepted definition of successful/ efficacious endodontic treatment has proven elusive. Within the literature, two main categories to describe outcomes have developed. These categories are success and survival (14, 16)

Success in endodontics has been defined as free from both clinical symptoms and an absence of or reduction in the size of a preexisting lesion. Disease consequently would be relegated to any clinical situation in which these criteria are not met (16-19).

The second category used to describe outcomes of endodontic therapy is survival. Survival aka functional retention reflects the goal of tooth retention with asymptomatic function. This category ignores the disease process as a radiolucency may be associated with an asymptomatic endodontically treated tooth, yet deemed successful (16).

The categories of success and survival have contributed a considerable amount of ambiguity not only for clinicians trying to make appropriate clinical recommendations, but also for patients trying to determine whether a treatment is in their best interest. Patients and clinicians alike may not fully understand the differences between the two criteria (16, 20). This can lead to treatment recommendations and selection that are based on a perceived higher likelihood of attaining desired outcome goals than what is actually supported by research (17).

With the goal of endodontics being elimination and prevention of disease, many endodontists feel that success/ healing is a more appropriate method of evaluating endodontic outcomes. It is assumed that having a universally accepted definition of success based on healing will allow for more objective goal oriented treatment recommendations by clinicians (16). However, a frustrating reality of endodontics is the very intimate association of non-endodontic factors with endodontic outcomes. The placement and quality of the subsequent restoration is a major, and sometimes overriding contributor to the long term health, retention and function of endodontically treated teeth (21, 22).

Some clinicians feel we should avoid the terms success and failure all together, and instead utilize verbiage which reflects "healing of disease" or "ineffective" and "effective" treatments. This suggestion is based on the belief that using outcomes descriptions such as these would "reduce ambiguity and facilitate more insightful discussion with patients and other clinicians" (17, 21). Switching to these descriptors would also eliminate the requirement of a 4 year recall for outcomes studies, and hopefully reduce the number of retreatments which are initiated by clinicians who follow a clinical decision making protocol based on strict adherence to the current definitions of success (21, 23)

The battle between success and survival rages on, and therefore it is necessary to explore both definitions in an effort to fully appreciate the design of this study.

Success

When used to describe endodontic outcomes, the term success reflects the highest attainable and most desirable clinical result. Influential in the development of the criteria of success, Strindberg believed the only satisfactory post treatment sequelea requires a symptom free patient with the absence of a periapical radiolucency. Cases not satisfying these criteria are deemed failures (18).

These criteria provide the clinician with a simple yes or no cookbook to determine whether an endodontic procedure has been successful. A very important bit of information remains however. How much time does this healing require?

Periapical healing following endodontic therapy was found to be radiographically visible 89% of the time after the first year (24). Reit found that an extra three years was often required for lesions to fully resolve when incomplete healing was noted at the one

year recall date (25). Thus, the recommendation to anyone providing endodontic therapy was to get a one-year recall radiograph, and allow up to four years of healing time for questionable cases. Any case not satisfying the radiographic criteria set forth by Strindberg at the four year mark would be considered a failure and planned for additional treatment (24-26).

Numerous studies have been completed using these criteria to evaluate the success of endodontic therapy. Endodontic residents providing care for patients at the University of Toronto followed multiple groups of NSRCT patients for periods of 4-6 years. When the four different groups were pooled, a success rate of 82% for teeth with apical periodontitis was found. Patients without apical periodontitis had 93% success. For the entire sample, healing was 86% (10).

In a separate university based study, the success of endodontic therapy provided by Swedish pre-doctoral dental students was evaluated. A total of 635 teeth were recalled 8-10 years post treatment. Successful healing without a lesion was found in 96% of cases and in 86% of cases with a lesion. These numbers are higher than one would suspect considering the level of experience of the providers. A possible explanation may be found in the long treatment times typical of pre-doctoral endodontic therapy, and the associated extended irrigant contact time with canal walls (27) .

Evaluations of successful treatment in the classic literature are unique in that they include historic techniques which in many cases are no longer utilized. Seltzer and Bender evaluated the success of private practice endodontists in the 1960s. Even with the inclusion of silver point obturation, success was quite high in this study. Teeth without

apical lesions healed at a rate of 92%, while teeth with apical lesions healed at a rate of 72%. This is quite impressive considering the technology of the time (11).

Smith et. al. evaluated the success of endodontic therapy provided in a hospital setting. Similar to Seltzer and Bender's previously mentioned study, historical techniques were also included. In a five year follow up of 821 teeth receiving conventional root canal therapy, 84.29% demonstrated successful or progressive healing (28).

A more modern evaluation of specialist endodontic success was undertaken by Imura. This study involved the retrospective analysis of 2000 randomly selected cases from an endodontist over a 30 year period. Success rates for initial treatment was 94.0% and 85.9% for retreatment. No distinction was made in this study regarding the healing between cases with or without pre-operative lesions. Total success rate was based on criteria of the European Society of Endodontology, indicating successful cases were asymptomatic and healed or healing. An overall success of 91.45% is higher than some university based studies perhaps validating the belief that endodontists have higher rates of success than other dental providers (26, 29).

The endodontic literature is replete with studies evaluating success of treatment. Rates of healing from 56%-96% in these studies frustrate the astute clinician attempting to develop a meaningful understanding of prognosis (15, 27, 30). We have designated objective criteria to help us assign cases into either success (healed and healing) or disease (15). The conflicting reports of success are likely related to the fact that these "objective" criteria require assignment by a subjective observation. As we will see,

criteria based on pain and radiographic observation are difficult for clinicians to objectively assign value to (15).

A pain free designation and radiographic evidence of healing are the primary factors currently used for evaluating endodontic treatment success. If healing isn't evident after four years in even the most questionable cases, the case is considered a failure (24, 25). There is concern however, that four years isn't enough time to assure healing will take place. A long term prospective study was done to monitor the healing of apical radiolucencies over time. Comparisons were made among initial radiographs and radiographs taken at 10-17 years and 20-27 years post treatment. The percentage of apical radiolucent lesions went from 49.8% of the total roots at the initial treatment to 16.6% after 10-17 years, and to 6.4% at 10 years later. Slow healing lesions were significantly associated with overextended filling material. This classic study proved late periapical healing does occur, and does cast some suspicion on the validity of the current recommended observation period (31).

The subjective nature of radiographic interpretation is likely one of the key contributors to the diverse findings of endodontic outcomes studies(15). It has been shown that radiographic interpretation varies considerably among differing practitioners as well as individually over time (32). The number and angulation of radiographs has great impact on the information a clinician can derive (33). In an attempt to address these concerns, the periapical index PAI was developed in an attempt to standardize radiographic impressions of healing (15, 34). The PAI unarguably reduces inter-examiner disagreement, but can also lead to incorrect categorization of disease in

situations where normal healing has resulted in a periapical scar which is free of inflammation (15, 35).

Although designed to be entirely objective, the criteria for endodontic success relies very heavily on the subjective assessment of conventional radiography. Bender and Seltzer showed that radiographic changes within bone cannot be seen until the bony cortex has been degraded by at least 7.1% or until mineralized bone loss passes 12.5% (36). In light of these findings, it is not unreasonable to think that pathologic bone changes may go unnoticed or in the case of active apical pathology, misdiagnosed as healed or healing (15, 36).

With the advent of cone beam computed tomography (CBCT), clinicians are now able to regularly visualize bony lesions that were undetectable with conventional radiography (37). Historical disagreements on and false impressions of success may be significantly reduced if clinicians were to adopt CBCT as the chief means of determining image based bony healing (38).

The desire to base endodontic treatment on successful healing of or prevention of pathology is a common desire among endodontic clinicians. Successful healing of endodontic treatment ranges from 56-96% (27, 30). Wide ranging study designs, materials used, clinician experience, and "leniency" or "strictness" of adherence to the criteria of success all seem to have a considerable influence on the documented success rates of NSRCT (15). While success is the gold standard, another category reduces the complexities of deciphering outcome.

Functional Retention/Survival

The classic outcome categorization of endodontically treated teeth based on radiographic interpretation, clinical signs and symptoms, and histologic assessment has resulted in a need for simpler standards for evaluating endodontic outcomes. A much simpler method of evaluation categorizes endodontically treated teeth as either functional and present or extracted (16, 39). Knowing how likely an endodontically treated tooth is to maintain function over time is of high value to patient and practitioner alike (39, 40).

Limiting the criteria to survival/functional retention or failure greatly simplifies analysis, and therefore allows researchers to undertake a more aggressive epidemiological study approach. This opens up the opportunity to analyze large patient populations over considerably longer periods of time. Although the findings offer less clinical specifics and clinical applicability than studies based on traditional success criteria, epidemiological studies can give robust outcomes comparisons and allow evaluation of the current medical/dental delivery system (39, 40).

In a United States study of unprecedented magnitude, Salehrabi and Rotstein evaluated the outcomes of 1,126,288 patients by analyzing insurance claims data from a large US based insurance company. Patients were represented from all fifty states. Retention of endodontically treated teeth was evaluated for eight years. Starting at the point of endodontic treatment, each case was monitored over time for untoward events (40). Untoward events represent pre-existing, post-endodontic/prosthetic, or endodontically derived complications necessitating the need for extraction (41). After eight years, 97% of the endodontically treated sample teeth were retained. Untoward

events leading to tooth extraction occurred most frequently within three years of initial endodontic therapy (40).

In another large scale study, 1,557,547 endodontically treated teeth in Taiwan were evaluated via records from the National Health Insurance Plan. The five year retention rate of this sample was 92.9%. Most untoward events in this study occurred within the first year following endodontic treatment (42).

In a well-known and frequently cited study, Lazarski et al. retrospectively analyzed 110,766 endodontically treated teeth using insurance data for patients in Washington State. As with the other epidemiologic studies discussed, treated teeth within the study sample had been treated by a combination of both specialists and general dentists. Dental codes associating extraction, retreatment, or periapical surgery again rounded out the categories of untoward events leading to a designation of failure. Treated teeth in this study were retained at a rate of 94.44% after an average follow up time of three and a half years (39).

Numerous smaller scale studies have evaluated functional retention of endodontically treated teeth. They represent provider skill levels from pre-doctoral students to specialists. A sampling of these studies showed retention rates from 74%-95% with follow up periods of four to ten years. They reflect smaller samples and less diverse practice behaviors. As a result, their value is limited, but it is interesting to compare the findings of these studies with the finding of the larger epidemiological works (39, 43-46).

Friedman carefully reviewed follow up studies of healing to offer the best evidence of outcomes. The chance of teeth without apical lesions to heal and remain

disease free after endodontic therapy is between 92-98%. Teeth with apical lesions will completely heal at a rate of 74-86% and be retained and functional at a rate of 91-97% (16). The retention rates of 92.9%-97% within the previously discussed large epidemiological studies strongly agree with this assessment and give an insightful impression of the value of endodontics.

Implants

Traditionally dentists have approached endodontically involved teeth with the goal of retaining the natural dentition. For teeth with a hopeless prognosis, the long standing options were extraction without replacement, or extraction with replacement via fixed partial or removal partial dentures. The introduction of implants in the late 1970's revolutionized the world of dentistry (47). Dental practitioners finally had what appeared to be a reliable third option for replacing both missing teeth and teeth with a poor prognosis (48, 49). Conspicuously missing from the literature however, are precise descriptions of what constitutes such a case. Current indications for endodontic therapy are beginning to conflict with the indications for implant placement (49). Additional concern arises in light of published unfounded recommendations to incorporate implant retained restorations in the treatment planning options for compromised teeth (50).

A systematic review of implant survival found that single tooth implants used to replace missing teeth had a survival rate of 97% at 4 years (51). When evaluated using the strict criteria of success, a functionally normal root canal–treated tooth will be categorized as a failure if a periapical radiolucency is associated with it (18, 26). This is not the case with implants, as they have an entirely differing set of criteria for success (52). The use of more lenient success criteria in implant studies may translate to higher

success rates, while stringent criteria employed in prognostic studies of root canals may lead to lower success rate (49, 53). Differing definitions of success for implants and endodontics makes direct comparison of the two options impossible (53).

A more lenient set of criteria for success related to implants compared to endodontic treatment may lead to higher perceived success than what is clinically producible (54). A 16-question survey was distributed to 648 dentists trained at University of Connecticut Dental School over the last 30 years to evaluate their understanding in the differing criteria of success used in endodontics and implant literature. A majority of respondents were unaware of difference between endodontic success criteria and the criteria of success for an implant. Older dentists were least likely to be aware of this difference. Within the sample surveyed there was a perception that implant outcomes are superior to endodontic therapy particularly when compared to retreatment. Information source was found to be predictive of survey responses among dentists. The more information dentists obtained from trade journals and dental sales representatives, the less likely they were to answer that the prognosis of root canal treatment of a necrotic pulp was the same or better than implant therapy (20).

Findings of this nature have prompted investigators to research the extent to which a clinician's level of knowledge affects their clinical decision making. Dentists without post graduate training have been shown to demonstrate a high level of disagreement with specialists regarding treatment plans involving extraction and placement of implants. General dentists seem to perceive implants as having a superior outcome when compared to endodontically treated teeth [55]. A considerable amount of disagreement exists among specialists as well. When presented with a case involving an

endodontically involved tooth, extraction and replacement was the preferred modality by 74% of periodontists, 64% of prosthodontists, and 65% of restorative dentists. These preferences were in sharp contrast to the endodontists, of whom only 30% preferred extraction (55).

The differing opinions of appropriate treatment for endodontically treated teeth are likely due to conflicting evidence within the literature. As stated earlier, comparing the two modalities is very difficult due to the differences in outcomes criteria for success (49). In an effort to objectively compare the two treatment options, Iqbal and Kim completed a systematic review and meta-analysis evaluating survival of endodontically treated teeth and single-tooth implants. The results indicated that the survival after average observation times of 5 years for single-tooth implants (96%) and 7.8 years for restored root canal teeth (94%) were not significantly different (53).

In another study, Doyle et al similarly found no significant difference in the rate of failure of single-tooth implants and restored endodontically treated teeth. Although the failure rates were similar over the course of ten years (6.1%), single-tooth implants required nearly five times as many post-operative interventions and had a longer average and median time to function following placement than restored root canal treated teeth (56).

Based on these findings, treatment planning for extraction and implant placement or restoration following endodontic therapy must be based on factors other than outcome (53). In order to gain informed consent for implant placement and restoration, a full understanding of the risks and benefits of treatment must be presented to and understood by the patient. Gordon Christensen recommended discussing cost, remaining tooth

structure, type of tooth, type of bone, occlusion, periodontal condition, functional requirements of the tooth following treatment, time required for treatment, esthetics, provider proficiency, patient expectations, and perceptions of treatment (47). No mention of obvious issues concerning systemic disease or related factors such as smoking were mentioned within this list (57, 58).

The general public has a limited knowledge of the rendering of dental treatment or how dentists gauge success. A focus group of patients regarding the lay public's impression of dental implants, it was discovered that most people see dental implants as a "panacea" for missing teeth, and considerably overestimated their function and longevity. At the same time, there was little concern regarding the skill/knowledge level of the provider placing the implant. The main concerns of the group centered on price and surgical related risks (59). Based on this research, it seems that of the recommendations suggested by Dr. Christensen, pricing and perceptions of treatment may be the most important factors in a patient's treatment decision making process.

To evaluate the cost differences between endodontics and single-tooth implants, a cost-benefit analysis was completed in the early 2000s showing that restored single-tooth dental implants were 70%-400% more expensive than restored endodontically treated teeth (60). In 2005, the average US cost of tooth extraction, implant placement, and restoration was $2,798-$3,060. The average US cost of endodontic treatment and restoration for the same period was $1,468-$1741 (47). In 2011, these prices had increased to $3,410-$3,701 for placement and restoration of a single tooth implant following extraction, and $1,840-$2,157 for root canal therapy and restoration of a natural tooth (61).

An analysis of cost effectiveness showed that retreatment and crown placement on a previously treated first molar was significantly more cost effective than both extraction and placement of an implant supported crown or fixed partial denture (54).

Regarding patient perceptions of treatment, it has been shown that many people have an inflated view of the prognosis of dental implants (59). Analysis of dental treatments rendered has shown that more affluent individuals have a 2.4 times greater odds of choosing implants compared to traditional root canal therapy. Males (1.3X), patients 47 years or older (6X), and Caucasian patients (2X) were all significantly more likely to choose implants over endodontic therapy. Only insured patients (1.6X) favored endodontic therapy. This is likely due to insurance coverage of root canal procedures compared to the general absence of coverage for implant therapy (60).

With all of the attention being placed on cost and perceptions of treatment etc., little attention has been given to functionality of implant supported restorations. Compared to endodontically treated contralateral counterparts, single-tooth implant supported crowns were found to have significantly lower maximum biting force, reduced area of occlusal and near contact, and reduced chewing efficiency. The untreated contralateral teeth had no significant differences in any of these categories when compared to their endodontically treated contralateral counterpart. Endodontically treated teeth therefore function identically to their untreated counterparts, while a significant decrease in chewing efficiency is noted with implant supported crowns (61).

The decision to have an implant placed versus pursue endodontic therapy and restoration of a natural tooth is up to the patient. It is the clinician's responsibility to deliver information which will allow the proper choice for the individual (47). Restored

single tooth implants and restored endodontically treated teeth have similar survival rates over time (53, 56), and this requires that the clinician base their treatment recommendations on factors other than outcome (49). Due to the drastically different nature of the treatments, the debate between which of them is superior is irrelevant. We instead should be comparing retention of a functional organ to a prosthetic device (16). It is important that future efforts are made to provide both patients and practitioners with the information to make appropriate treatment decisions (49).

Failure

Equally important to the understanding of success and survival of endodontic therapy is an adequate knowledge of the factors associated with failures. The success of endodontic therapy relies heavily upon the preoperative status of the tooth. Indeed, this may be the most influential factor related to the long term survival of teeth requiring endodontic treatment (27, 39).

Great effort has been put forth to gain an adequate insight on the prognostic determinants of root canal treated teeth. In a military group practice with all dental specialties represented, 116 extracted teeth with previous endodontic treatment were analyzed to determine the causes of failure and subsequent extraction. Prosthetic failures (failure of the placed restoration or an inability to further restore the tooth) were responsible for 59.4% of failures. Periodontal failures (periodontal compromise was extensive enough to preclude continued periodontal or prosthodontic therapy) was responsible for 32% of failures. Endodontic failures (vertical root fractures, zips/strips, and resorption) made up the remaining 8.6% of failures. Endodontic failures occurred significantly earlier than failure of prosthodontic or periodontal origin (21).

These findings were similar to the findings of several other studies. These studies found failures of endodontically treated teeth to be related to prosthetic issues 43.5%-61.4% of the time (39, 41, 62, 63), periodontal issues 4.6%-40.3% of the time (41, 63, 64), and endodontic issues 10.7%-21.5% of the time (41, 62-64). The evident trend from this data suggests problems relating to prosthetic restoration of endodontically treated teeth are the leading cause of their extraction (21, 39, 41, 62, 63, 65).

Endodontically related problems have been shown to be responsible for a minority of untoward events leading to extraction (21, 41). However, a host of pre, intra, and post-operative factors have been linked to failure of endodontically treated teeth. Numerous studies have shown that tooth vitality and the presence of pre-operative radiographic lesion results in significantly diminished prognosis (10, 11, 27, 28, 43). This is likely due to the considerable difficulties is eliminating deeply entrenched biofilms and residual bacteria from the intricate anatomy of the pulp space (8, 12).

The primary intra-operative variable that has been shown to be significantly associated with failure of endodontically treated teeth is the use of a rubber dam (66). Rubber dams have been proven to reduce the spread of bacteria during dental procedures by 90%-98% (67). Several surveys based studies have shown that general dentists always utilize rubber dams during endodontic treatment 44%-47% of the time (68, 69). It was also found that 15% of General dentists never use a rubber dam for root canal procedures. Interestingly reported use of rubber dams "always" by endodontic specialists was 100% (68, 69).

Post-operative factors relating to endodontic treatment failure center on obturation. The ideal endpoint/length of root obturation has been determined to be

between .5-1mm from the apex of the tooth (70). Deviations in length either short or long have been shown to significantly decrease the prognosis of endodontically treated teeth (27, 28, 71, 72). The quality of obturation and in some cases obturation technique has also been shown to effect prognosis (10, 73). With ideal obturation consisting of a dense three dimensional fill (9), a lack of density or voids (particularly in the apical and middle third) have been associated with increased endodontic failure (30, 43).

Prosthetic problems leading to the failure of endodontic teeth can be related to either the preoperative condition of the tooth, or the failure to adequately restore it. During operative procedures, removal of each respective tooth surface equates to roughly a 20% decrease in cuspal stiffness. Thus an MOD restoration will on average reduce a tooth's stiffness by at least 60%. Investigation of occlusal access preparations has shown endodontic accesses to be associated with an additional 5% decrease in cuspal stiffness (74). One study evaluating fractures of endodontically treated teeth found that 83% of fractured endodontically treated teeth had three or more restored surfaces (75).

Several options are available to restore endodontically treated teeth. In a systematic review which consisted of one study, one researcher advocated the utilization of intra-coronal restorations to restore endodontically treated teeth believing this restorative option provided as much long term protection as full or cuspal coverage (76). Had the criteria for inclusion been broader, this researcher may have found that the general consensus is quite contrary to his findings.

After a 20 year retrospective study, it was found that amalgam restorations without cuspal coverage were not adequate for coronal restoration of endodontically treated teeth. MOD restorations were lost 73% of the time. This study concluded that

cuspal coverage was critical to the long-term prognosis of endodontically treated teeth (77). These findings were again confirmed in a systematic review and meta-analysis where it was found that greater healing of apical periodontitis will be seen when adequate root canal therapy is combined with adequate restorative treatment (22). A separate systematic review produced the same finding (78).

During their large scale epidemiologic study, Salehrabi and Rotstein concluded that of the 3% of teeth that were lost following endodontic treatment, 85% didn't have a full coverage restoration (40). Aquilino et.al. found that root canal treated teeth without crowns were lost at a six times greater rate than their uncrowned counterparts (79). Based on the findings of these studies, full coverage protection of endodontically treated teeth has a considerable influence on their long term prognosis.

Other factors effecting the failure rate of endodontically teeth have been explored as well. Proximal contacts and a history of trauma were significantly related to the loss of root canal filled teeth over a 6-8 year follow up period. Teeth with one or no proximal contacts were three times more likely to be lost (78, 80). Variations in the finding of the significance of age, filling material, smoking status, gender, tooth type, and education level on the failure rate of endodontic treatment require that these variables be looked at in greater detail (10, 29, 64, 65, 78, 80, 81).

A great number of factors can lead to the failure of endodontic treatment. It is difficult in some situations to determine why a particular case failed. Most failures of endodontically treated teeth are not related to the endodontic treatment itself. Failure usually results from prosthetic or periodontal inadequacies (21, 41). Adequate endodontic treatment with an adequate restoration significantly increases the long term

prognosis of endodontically treated teeth (22). The importance of a good coronal restoration can't be underestimated, because it is possible for initially successful cases to become failures following recontamination of the root-canal system through ineffective temporary or permanent restorations (82).

Specialists and Generalists

Recent estimates place the number of root canal procedures performed within the United States at 15.1 million annually. Of these, general dentists complete 72% of cases, while endodontists are responsible for the remaining 28% (83). Endodontist have been found to perform more molar root canal therapy, conventional retreatment, and surgical endodontic procedures than general dentists who provide endodontic treatments. General dentists provide more root canal therapy on anterior and premolar teeth, and complete more pulp caps than endodontists (84).

In an effort to gain insight on the treatment protocols of general dentists, Savani mailed surveys regarding endodontic therapy to 2000 general dentists. The 479 returned surveys showed that 84% of responding dentists provided root canal therapy. Of this 84%, 99% provided anterior treatment, 95% premolar treatment, and 62% molar treatment. 18% of the respondents provided retreatment. New technologies such as NiTi rotary instrumentation were more likely to be adopted by clinicians with less than ten years of experience. These less experienced dentists were also more likely to use a rubber dam than their mentors with 20 or more years in practice. Rubber dam use for all endodontic procedures was reported to be at 60% (85). This is higher than other recent

studies, which has placed rubber dam use by general dentists during endodontic procedures at 44%-47% (68, 69).

Regardless of the obvious preference of most general dentists to treat their own endodontic cases, endodontists still hold a high level of esteem amongst general practitioners. 94% of general dentist have positive perceptions of endodontists. They are more likely to refer cases out to endodontists they feel are partners in patient care, endodontists who refer back for restorative treatment, endodontists who have timely follow-up reports and images, and endodontists who can be flexible in regards to scheduling accommodation (85).

Few studies have been done directly comparing general dentists and dental specialists. Fortunately, the medical profession evaluated the differences between general practitioner and specialist care. The link isn't direct, but perhaps their findings can be applied to the dental profession.

Dentists evaluating the appropriate treatment for a periapical lesion operate along a continuum. A large lesion is frequently felt to be a worse situation, and therefore carry a worse prognosis than a small lesion. This grading appears to be based more on personal values than science, and will greatly effect treatment recommendations (86). In a study of treatment suggestions for a particular condition, physicians' treatment recommendations were compared to an analytic model representing the optimal treatment strategy. The study found that majority of physicians opted not to treat vs. following the optimal strategy. This decision was believed to be based on the avoidance of risk to the patient, rather than a true understanding of ideal treatment (87, 88).

In medicine, it has been shown that specialists when compared to general practitioners depend primarily on professional sources of information such as journals and professional meetings when informing themselves on risky therapies (89). A similar discovery was made during a recent study conducted in Iowa (90). As such, it may be that specialists can offer a higher level of care because they are more aware of the risks, and therefore more comfortable with providing the appropriate treatment [84].

Dental based studies have also shown that increased exposure to trade journals and dental sales representatives reduces a dentist's likelihood of knowing the correct literature supported prognosis of root canal treatment for necrotic teeth compared to implant therapy (20). Several studies have shown that general dentists and even some specialists have a much higher perception of the prognosis of implants compared to retreatment or initial treatment of a necrotic tooth (91, 92).

Specialty affiliation also seems to have considerable impact within dentistry. In one study, general dentists, prosthodontists, endodontists, oral surgeons, and periodontists were presented with patient scenarios with varying degrees of endodontic involvement and complexity. 250 randomly selected clinicians from each specialty were given 5 endodontically related radiographs and scenarios. Each clinician selected from several treatment options including: no treatment, extraction with no replacement, extraction with implant, extraction with removal prosthesis, root canal and restoration, root canal retreatment, apicoectomy, root canal treatment and apicoectomy, consultation required, and other. Significant variations were evident in the decisions made by practitioners from different specialties and general practice. This was particularly evident in treatment strategies for previously endodontically treated teeth. In these cases,

extraction and implant placement became a more commonly chosen option among all practitioners except endodontists (93). Differences in specialty training and experience strongly influence endodontic decision making, however endodontists in multiple studies have shown the highest level of agreement among groups (93, 94). However common these disagreements are, interdisciplinary discussion can reduce the levels of disagreement and result in superior outcomes for the patient (55). Overall, graduate level training tends to direct practitioners towards maintenance of the natural dentition (95).

Through continued cultural stigmatization, the perception of endodontic therapy remains very negative because in the eyes of the lay public, root canals are linked to pain (96). Even in light of higher fees and potential procedurally related pain, patients receiving care from endodontists are significantly more satisfied with their treatments than treatments by general dentists, and have indicated that treatment time was the key reason for the satisfaction. Increased knowledge, skill, and proficiency are certainly related to this finding (97).

In a goal oriented world, outcomes should be the true advocate for proper treatment. At present, there is a tremendous lack of evidence confirming or denying the value of endodontic specialists compared to generalists relating to outcome. This information would be extremely valuable to patients, third party payers, and clinicians with their patient's best interest in mind. As early as the mid-1980s, a gradual shift in dentist's referral patterns was being noted. General dentists began treating teeth that previously would have been referred out (98). This trend began prior to the ubiquitous adoption of rotary NiTi file systems and mass marketing efforts of prominent dental suppliers. It is likely more pronounced in the present day.

Lazarski et al determined that endodontists have roughly the same rate of success as general dentists, but attain this similar outcome treating cases of considerably higher difficulty. This study also found that extraction rates following endodontic surgery were significantly higher 25%-49% for treatments provided by general dentists as compared to 7-11% when treatment was completed by endodontists. (39).

Only one study has been specifically directed towards comparing the outcomes of endodontic treatment provided by general dentists with the treatment provided by trained endodontists. This study involved the review of 3,500 charts from three different practices. From these charts, 350 cases met the inclusion criteria. Analysis of these cases after a study mandated five year recall period showed that treatments provided by general dentists survived 89.1% of the time, while cases treated by endodontists survived a significantly higher 98.1% of the time. A non-significant, but fascinating finding of this study related to one of the general dentists. This provider referred out at a twice the rate as the other two providers, and had fewer than half as many failures associated with his practice (99).

In light of the lack of research comparing the outcomes of classically trained endodontists with the outcomes of other provider types, the aim of this study was to compare the survival rates of endodontic therapy over time as it relates to provider type and tooth type.

Materials and Methods

Data for this study was obtained from the electronic claims and enrollment database of Delta Dental of Wisconsin. Claims analysis was based on claims data

representing 13,329,249 patient encounters between January 1, 2000 and December 31, 2013. Dental insurance claims were searched for CDT procedure codes D3310, D3320, and D3330 which were considered to be triggering events. The end of study period and loss of continuous dental insurance coverage were treated as censoring events. This query produced 487,476 initial NSRCT procedures performed over the 14-year time period. For each of these procedures, information regarding provider type/specialty status and tooth number was collected. The title of endodontist was given only to clinicians who had completed an American Dental Association accredited U.S. endodontic residency program. It was decided to include all non-endodontic specialists into the broader category of other providers. As with Lazarski et al, success was determined by the absence of untoward events (39). Cases were followed and considered successful until either enrollment was broken, or until CDT codes representing extraction, retreatment, or apical surgery were encountered. Once a case met either of these two criteria, the case was eliminated from the sample. Cases were further subdivided into 1, 5, and 10 year follow up intervals to aid in the comparison of survival over time.

Analysis

Insurance claims analysis was completed by the Biostatistics department at the Medical College of Wisconsin. Survival estimates were computed for provider type and tooth location. Kaplan-Meier survival estimates were calculated for 1, 5, and 10-year survival of endodontically treated teeth. Hazard ratios for provider type and tooth type

were calculated using the Cox proportional hazards model. Analyses were performed

using SAS 9.4 (Cary, NC).

Results

Of the 487,476 procedures, endodontists completed 153,315 cases (31.5% of the

total). These cases consisted of 15,832 anteriors (10.3%), 27978 premolars (18.2%), and

109,505 molars (71.4%). Other-providers completed 334,161 cases (68.55% of the

total). These cases consisted of 68,600 anteriors (20.5%), 107,279 premolars (32.1%),

and 158,282 molars (47.3%). The survival/absence of untoward events for all teeth

collectively was 98% at one year, 92% at five years, and 86% at ten years. The median

follow-up time for all cases was 2.43 years

At the one-year interval, no significant difference in survival was noted between

providers or for tooth type. Anterior teeth treated by both endodontists and other

providers had 98% survival, premolars had 99% survival, and molars survived at a rate

of 98% (Table 1).

At the five-year interval, no significant differences in survival were found

between treated anterior teeth and premolars. Anterior teeth and premolars treated by

both endodontists and other providers had a survival rate of 95%. A significant

difference in molar survival was discovered. Molars treated by other providers survived

at a rate of 91%, while molars treated by endodontists had a 93% survival rate (p<.0001)

(Table 1).

Time Interval Group (years)	Tooth type	Provider Type	Time (years)	Cases	Survival Distribution Function Estimate	Lower 95% Confidence Limit	Upper 95% Confidence Limit
1	Anterior	Other Provider	1.00	48986	0.98	0.98	0.99
		Endodontist	1.00	11354	0.98	0.98	0.98
	Premolar	Other Provider	1.00	77670	0.99	0.99	0.99
		Endodontist	1.00	20225	0.99	0.98	0.99
	Molar	Other Provider	1.00	113742	0.98	0.98	0.98
		Endodontist	1.00	79649	0.98	0.98	0.98
5	Anterior	Other Provider	5.00	16424	0.95	0.95	0.95
		Endodontist	4.90	3582	0.95	0.94	0.95
	Premolar	Other Provider	5.00	27044	0.95	0.94	0.95
		Endodontist	4.99	6698	0.95	0.94	0.95
	Molar	Other Provider	5.00	38358	0.91	0.91	0.91
		Endodontist	5.00	25712	0.93	0.93	0.94
10	Anterior	Other Provider	9.88	3066	0.91	0.90	0.91
		Endodontist	9.62	596	0.92	0.91	0.93
	Premolar	Other Provider	9.99	5475	0.91	0.90	0.91
		Endodontist	9.89	1222	0.90	0.89	0.91
	Molar	Other Provider	9.98	7406	0.84	0.84	0.85
		Endodontist	9.99	4605	0.89	0.89	0.89

Table 1: Summary of survival estimates for endontically treated teeth based on provider type and tooth type.
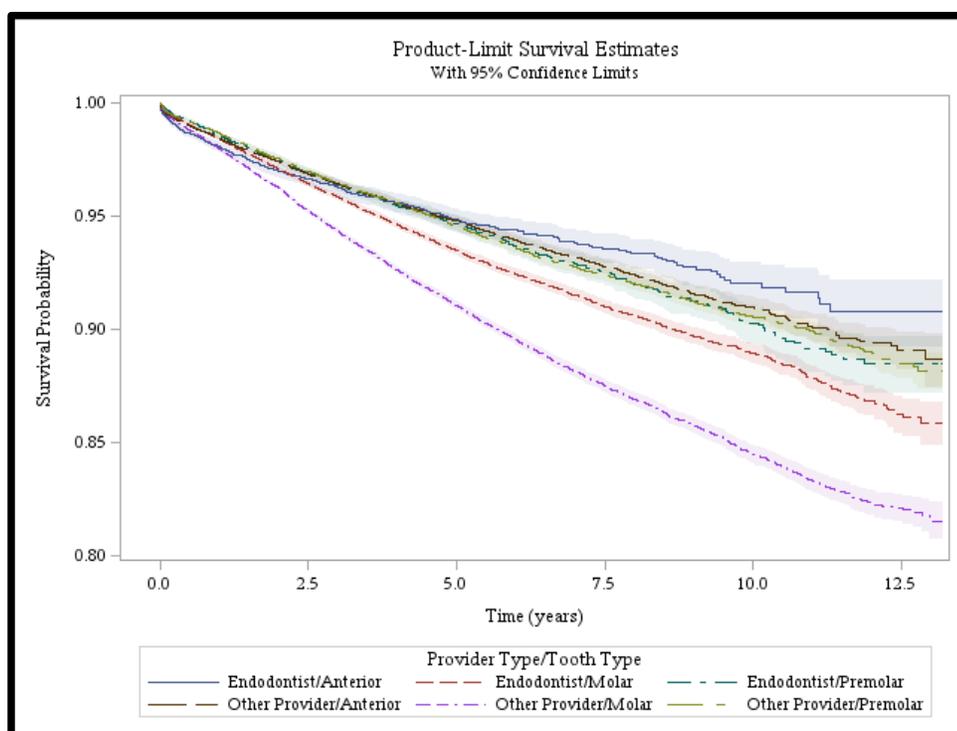
Figure 1: Product limit survival estimates of endodontically treated of different tooth type treated by endodontists and other providers

At the ten-year interval, significant differences were found for all tooth types. Anterior teeth treated by other providers survived at 91% while anterior teeth treated by endodontist survived at a rate of 92% (p<.0001). Premolar survival was 91% for other providers and 90% for endodontists (p<.0001). Molar Survival was 84% for other providers and 89% for endodontists (p<.0001) (Table 1). Figure 1 graphically portrays the 1, 5, and 10-year product limit survival estimates for each tooth and provider type.

Cox model analysis found the only significant relationship between tooth type and provider type existed for molars at ten years. A hazard ratio of 1.394 was found when 10-year molar survival of teeth treated by other providers was compared with the same subset of teeth treated by endodontists (p<.0001)

Discussion

Survival trends of endodontically treated teeth are of considerable interest to providers, patients, and third party payers. Endodontic therapy has proven to be a very predictable and conservative method of retaining natural teeth. Large epidemiological studies provide a method for assessing the outcomes of the dental health system as a whole (39). No studies to date have directly compared long term survival rates of endodontically treated teeth as it relates to provider type and tooth type. The aim of this study was to explore this relationship.

The percentage of treatments provided by endodontists (31.45%) and treatments provided by other-providers (68.55%) in this study closely parallel ratios seen in previous observations of 28%:72% and 33.9%:66.1% (39, 83). The population studied was stratified to include only those patients with dental insurance. This is an important consideration because an insured patient population may present differing dental care access and expectations when compared with populations of uninsured patients. This would likely have an effect on outcomes, but to what extent is unknown. These results, therefore, should only be interpreted with respect to this population.

Use of insurance information on a scale such as that used for this project conveniently serves to minimize many potential sources of potential bias. At the same time however, data on such a scale makes important diagnostic/prognostic predictors of individual cases impossible (39). There is no way to reliably determine pre-procedural diagnosis as it relates to both the pulpal and periodontal condition of the treated patient. Restorability of the treated tooth and medical conditions that may predispose a person to endodontic failure are also not available. Final restoration and dental dam use have

proven to be vitally important in the long term success of endodontic treatment (22, 40, 66, 79). Such nuances are important to the planning, delivery, and long-term success of a selected treatment.

Despite the limitations of this study, the high long-term survival rates of endodontically treated teeth reconfirm the predictability of endodontic treatment provided by the dental health system as a whole. 1, 5, and 10-year survival rates of 96%, 92%, and 86% represent survival rates similar to those of previous studies (15, 16, 39). It is important to bear in mind that basing failure on untoward events yields a higher percentage of overall failure than what is actually present. The incorporation of non-surgical retreatment and apical surgery into the criteria for failure generates a higher number of failed cases, even though these teeth are receiving adjunctive therapies which may ultimately result in tooth retention and function. With the high success rates of these additional modalities, the true survival rate of our sample is likely higher than we are able to present. To what extent is impossible to determine using claims data

The large nature of the sample size in this study allowed for very small differences in survival to be determined as statistically significant between the two provider categories. Although several significant differences of 1-2% were discovered, these small differences could be considered by some as being clinically inconsequential.

A desirable finding in this study would have been to find identical survival rates between initial endodontic therapy provided by endodontists and other providers. This would indicate that the two groupings provide treatment of equivalent quality, and that practitioners practicing within the category of other providers are effectively referring

cases beyond their clinical ability. This result would indicate an effective system of endodontic care under the current dental health system.

This study's finding of similar survival rates between other providers and endodontic specialists at the 1 and 5 year post-procedural periods indicates that providers of all varieties provide effective short and medium-term endodontic outcomes. At ten years, anterior teeth and premolar teeth have similar survival rates among provider types as well. Molars treated by endodontists however, show the largest difference in survival when comparing the two groups (84% other providers vs. 89% endodontists). At 10 years, primary endodontic therapy provided by other providers when compared to endodontists is associated with a hazard ratio of 1.394 (95% CI. p<0001). This equates to a 39.4% higher hazard risk within this tooth population.

Endodontists on average treat teeth of all types that are of higher clinical difficulty than what is typically treated in other practice settings. To have similar or even higher success when completing cases of higher complexity is true testament to their additional training and skill. A more complete understanding of chemomechanical debridement, shaping, and obturation of intricate canal systems may lead to improved long term survival rates of highly difficult cases compared to other providers.

Conclusion

The dental health delivery system is highly effective at providing favorable endodontic outcomes. This study has shown that endodontists and other providers have similar 1, 5, and 10-year survival rates for anterior and premolar teeth. Long term survival of molars is higher when these teeth are treated by endodontists. With the

patient's best long term prognosis in mind, this finding may inspire non-endodontists to carefully re-examine their referral patterns related to the endodontic treatment of molars.

Future areas of research could include an evaluation of the time from completed endodontic therapy to final restoration, and whether this time period has any correlation to failure rate.

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