Systematic Review Of The Published Literature On Success And Failure Rates Of Nonsurgical Endodontic Treatment

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SYSTEMATIC REVIEW OF THE PUBLISHED LITERATURE ON SUCCESS AND FAILURE RATES OF NONSURGICAL ENDODONTIC TREATMENT

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ABSTRACT

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Purpose: The aim of this study was to conduct a systematic review of the literature on treatment results in non-surgical Endodontic therapy. This included researching and defining inclusion and exclusion criteria and applying these criteria to identified relevant publications. The overall goal was to analyze the available literature and synthesize these results in an effort to inform the profession on the success and failure rates in non-surgical root canal therapy.

Materials and Methods: Inclusion and exclusion criteria were established in an effort to systemically review and formulate an evidence-based understanding of treatment results in non-surgical root canal therapy. A comprehensive literature search was conducted using using PubMed and the Cochrane database using the search terms root canal therapy, apical periodontitis, success, failure, and treatment outcome and was restricted to January 2009 through December 2011. Articles were reviewed and analyzed according to the inclusion/exclusion criteria.

Results: A review of the abstracts for these 330 publications resulted in 51 publications articles to be examined more closely for relevance and inclusion. From this, no publication met all defined inclusion/exclusion criteria.

Discussion: Defining a set of criteria for how success is defined in practice is vital to the field of Endodontics. It is important to define, establish and incorporate a standardized methodology in the way research is conducted on Endodontic treatment results. This is necessary for the application of research to the practice of evidence-based Endodontics.

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INTRODUCTION

Among Endodontic specialists, the chances of achieving a successful result in initial non-surgical endodontic treatment are generally considered good with estimates as high as 97% (Salehrabi & Rotein, 2004); however, at a more scientific level it is apparent that treatment results depend in part on how success is defined and evaluated, which varies considerably among clinicians and researchers (Swartz et al., 1983). Further, factors including but not limited to the type and severity of disease, the type and location of the affected root canal (Ray & Trope, 1995), the instrumentation and technology used in treating and assessing the status of the affected root canal (Figini et al., 2008), and the expertise of the treating clinician (Alley et al., 2004) all potentially impact treatment success or failure. The lack of a consistent method for evaluating treatment results in the case of non-surgical root canal therapy makes reliable data on both the results and related prognostic factors scarce. In turn, defining and implementing evidence-based practice within the specialty of Endodontics can be difficult. Hence, the goal of this thesis is to achieve an evidence-based understanding of treatment success rates for non-surgical root canal therapy.

On a practical level, the definition of evidence-based dental practice is incorporating systematically evaluated evidence, tools, and resources into one's daily practice (Bader et al., 1999). In recent years, the field of dentistry has made an effort to make these resources available for clinicians and has emphasized the importance of evidence-based practice within the profession (Bader et al.). Yet, true achievement of evidence-based practice within the field of Endodontics is difficult to attain when the

available ‘evidence’ is unreliable because of methodological issues plaguing the research base. To work towards the true practice of evidence-based Endodontics, valid and reliable data on treatment results is needed so that dental professionals can be properly informed on the potential success of root canal therapy and factors to consider in the treatment planning process. With new technology being added to the field of Endodontics, it is important to state how one evaluates Endodontic success, which should be updated regularly. For instance, technological advancements such as cone beam technology (CBCT) is one new method for evaluating treatment success that provides radiographic images far more precise and complex than that provided in a conventional radiograph (Liang et al., 2007). Knowledge on what constitutes evidence-based care within the field of Endodontics and how one is to reliably evaluate Endodontic treatments are critical for general dentists and dental specialists, including Endodontists, and crucial to the education of dental students and residents.

In 2008, the American Association of Endodontics (AAE) published an online ‘study guide’ that offered a list of articles relevant to Endodontic treatment results; however, it is just that, a bibliography list and mostly included dated publications with the dates cited ranging from 1956 to 2007 and with the majority of studies dating around 1980. In fact, although the specialty literature in Endodontics is abundant and rapidly growing in volume, very few high quality reviews have been published on Endodontic treatment results. Exceptions include but are not limited to the work of the Cochrane Collaboration, which conducted a systematic review to evaluate the benefits of single-visit versus multiple-visit in the Endodontic treatment of permanent teeth (Figini et al.). Another example is a series of three papers that assessed the evidence level of various

Endodontic treatment results (Mead et al, 2005; Paik et al., 2004; Torabinejad et al, 2005). Even with some available data, the general consensus among researchers that aim to review the treatment literature is that there are inherent limitations in the statements one can make about the results of Endodontic care because of weaknesses in research methodology.

Inconsistency in Endodontic treatment data was linked to inconsistent definitions of 'success' and 'failure' as it applies to Endodontic treatment results (Swartz et al.). The ultimate goal of root canal therapy is to eliminate the etiology of the infection and in turn, the pathology that causes the symptoms; that said, 'success' is not a black or white issue. Rather, it appears that ultimately the result of root canal therapy is best described according to a continuum ranging from complete success to complete failure. The outcome of root canal therapy falls along this continuum depending on the remaining pathology and/or symptoms experienced by the patient. A review of the literature revealed that just as 'success' is not simply defined in clinical practice, the same holds true for research investigations. The result of Endodontic treatment depends on numerous factors, many of which are frequently neglected in the available treatment studies. In turn, how one identifies the result of Endodontic therapy as a 'success' or 'failure' and how one evaluates this result vary, complicating the investigation of Endodontic treatment.

In 2009, Wu et al. discussed the challenges in Endodontic treatment research. Eleven systematic reviews on the results of root canal treatments published in the last decade were identified and reviewed. The publication highlighted the limitations of several reviews of Endodontic treatment results. Most importantly, researchers do not

consistently use the same method to determine treatment result. In a review article completed by Ng et al. (2007), 57% of the studies identified used both clinical and radiographic findings to determine treatment results. In 47% of the studies reviewed, results were based on radiographic findings alone. Further, the criteria used to evaluate the radiographic findings varied from complete resolution reduced apical periodontitis lesions at recall.

Wu and colleagues also noted the limitations of periapical radiographs for diagnosing post-treatment apical periodontitis and stated that these limitations were not discussed in any of the systematic reviews they evaluated. Most previous studies used conventional radiographic measures to identify the presence of periapical pathology (Liang et al.). In some instances, in cases labeled as 'healthy radiograph,' per conventional radiographic measures, periapical pathology was actually present when evaluated using CBCT; hence, use of conventional radiograph may overestimate the rate of Endodontic treatment success. The majority of published Endodontic studies utilize conventional dental radiograph because it has been the standard for the field and to date CBCT technology is not readily available to all practitioners. That said, CBCT is considered a more descriptive diagnostic tool because the radiographic beam makes one rotation around the patient's head and reconstructs millions of two-dimensional scans into one three-dimensional object. This not only provides for a more detailed 2D object but also allows the viewer to rotate the 3D object and see around anatomical landmarks that could not be seen using conventional dental radiographs.

Consistent with the advanced CBCT technology, Liang et al. found that treatment results varied depending on the use of conventional periapical radiographs and CBCT.

Liang and colleagues noted that more periapical lesions were found using CBCT radiographs but that the proximity of the root canal filling material to the apex along with the density of the obturation material was very different than that found using conventional radiography. Liang's data showed that density and apical extent of root filling were identified as predictors of treatment results when using conventional radiographs while CBCT focused on the quality of coronal restoration and density of root canal filling material for clinical significance. Liang pointed out how these predictors differed between CBCT and conventional radiograph and how they may influence clinical findings.

Though CBCT technology provides clear advantages compared to conventional radiograph and is gaining popularity within the field, it is not without limitations. For instance, although the radiation dose for CBCT is less than a medical CT exam (Lofthag-Hansen et al., 2007), the dental CBCT exams still deliver 5x greater radiation than conventional radiographs (European Commission). Another limitation for CBCT would be patient selection. For example, the FDA has recommended limiting CBCT to adults, and excluding children, due to the higher degree of radiation associated with CBCT (Lofthag-Hansen et al.).

Finally, the cost or the patient's anticipated expenses associated with CBCT are far greater than conventional dental radiographs. The financial obligation of CBCT, the complexity of using the technology, and the continual changing radiographic advancements all represent reasons why this technology has not been adopted as a standard of practice. Consequently, though CBCT may be preferred, this method is not typical in the majority of published Endodontic treatment research.

An additional factor for consideration when evaluating published data on treatment results is the patient recall rate. The recall rate is the percentage of patients who attend a follow-up visit after the completed treatment. In a systematic review of 63 clinical studies, only 61% actually reported a recall rate and of those studies the recall rates were as low as 11% (Ng et al.). Research has consistently demonstrated that success rates may be overestimated in the case of low recall rates (Ostravik et al., 2004; Sathorn et al., 2005). A related consideration is the length of time to patient recall. In a study completed by Orstavik (1996), patients were recalled over a period of 4 years and though the success rate increased over time, the recall rate decreased over time. While it is possible that the increased success over time could be due to a gradual apical healing process, it is also possible that an increased number of patients with an unfavorable outcome did not present for follow up, hence the decreasing recall rate over time. Interestingly, Ortsavik's (1996) data revealed that more than 88% of cases that presented with favorable outcome at year four showed this favorable outcome at year one.

The inclusion of extractions and retreatments in defining the result of Endodontic treatment adds to the confusion of this literature. Wu and colleagues noted that of the eleven published systematic reviews between 1998 and 2007, none of them had discussed whether or not extractions or retreatments were identified as 'failed.' Despite Wu's recommendation for future research to consider an extraction or retreat as a 'failure' in treatment research, studies reviewed for the purpose of the current systematic review either did not provide such information or even included a retreated tooth as a 'success' (e.g., Suter et al., 2009). The inclusion of retreats as 'successful' outcomes is misleading and overestimates treatment success.

Finally, assuming the above listed factors are considered, researchers then must identify how to define a 'successful' outcome. As described, this definition varies considerably in the reviews examined by Wu and colleagues and also varied considerably in the literature examined for the purposes of the current review. Based on the extensive review completed by Wu and colleagues in their 2009 article, they stated that the use of the periapical index (PAI) scoring system developed by Orstavik et al. (1986) seems to be the accepted valid tool for evaluating treatment outcome (Orstavik, 1988). The PAI system was used in the 58 reviews examined by Wu et al., published between 1987 and 2008; since 2008, no outcome analysis system has been developed and validated. In the PAI system, outcome is rated on a scale of one to five (see Table 1). If a tooth has a radiographically healthy periapex, it is assigned a value of one. PAI values of two to five represent the increasing extent and severity of apical periodontitis upon follow-up radiograph.

Table 1: The Periapical Index System (PAI) (Ostravik et al., 1986)

PAI Score	Description
1.0	Periapical destruction of bone almost definitely not present
2.0	Periapical destruction of bone probably not present
3.0	Periapical destruction of bone is unclear from radiographic assessment
4.0	Periapical destruction of bone is probably present
5.0	Periapical destruction of bone is almost definitely present

While use of the PAI system is advised, there has been inconsistency among researchers in what PAI values denote a 'successful' result. When 'success' was limited to a PAI of one, the success rate was 26% compared to a success rate of 79% when the PAI value was limited to a one or a two (Orstavik et al., 2004). Wu et al. recommended that PAI scores of one or two, healthy or mild inflammation respectively, should be considered 'successful' in future research.

It is clear that future systematic reviews must heed the recommendations of prior researchers in order to contribute evidence-based data on the results of root canal therapy. Yet, to date, it appears that no published systematic review has comprehensively covered the clinical studies on treatment success and failure while also addressing the challenges present in the literature. Per Wu and colleagues, recommendations for how to address these challenges included: 1) Use the PAI system for evaluating outcome with scores of a

one or two being considered ‘successful;’ 2) Publish a recall rate of at least 50%; 3) Exclude retreatment cases from the calculation of initial successful treatment; and 4) During the recall appointment, should a tooth require retreatment or extraction it should be classified as ‘failure.’ It was also suggested that evaluation of treatment results be completed using CBCT as opposed to radiograph (Liang et al.; Wu et al.); however, studies using conventional radiograph have demonstrated excellent prognostic accuracy and therefore CBCT may not be a requirement for achieving high diagnostic accuracy (Fristad et al., 2004; Mead et al.).

Additional factors for consideration in evaluating treatment result data include: 1) whether or not the treatment was completed by a specialist; 2) the patient population (re: pediatric versus adult); and 3) type of treatment (re: surgical versus nonsurgical). In 1999, an examination of insurance claims through the Washington Dental Service showed that of 63,321 Endodontic procedures, general dentists completed 64.7% while Endodontists completed only 33.7%. Yet, success rates were notably higher when an Endodontic specialist performed the procedure versus a general dentist. In a survey of the survivability of teeth that underwent an Endodontic procedure, Endodontists experienced statistically significantly greater treatment success (98.1%) than general dentists (89.7%) (Alley et al.). The sum of data points to the impact of the level of the provider’s training on the result of root canal therapy.

The aim of the current study is to provide a systematic review of recent literature on the results of non-surgical root canal therapy. This review aims to improve upon the currently available reviews by addressing the limitations of previous research. The objectives included: 1.) To search the scientific literature published between January

2009 and December 2011 for publications on results in non-surgical Endodontic treatments; 2.) To review identified articles for inclusion in this review based on defined criteria; 3.) To analyze the available evidence; and 4.) To prepare and formulate the results on success and failure rates for non-surgical root canal therapy.

METHOD AND MATERIALS

Based on the recommendations of Wu and colleagues and limitations identified in the literature during the course of the current systematic review, strict inclusion and exclusion criteria were selected and applied in an effort to improve upon the current state of the literature on Endodontic treatment results (see Table 2 and Table 3). Before defining such criteria, it is noted that studies published between January 2009 and December 2011 were reviewed only. Additionally, longitudinal clinical studies, including randomized controlled clinical trials, cohort studies, retrospective observational studies, systematic reviews, and meta-analyses were considered eligible for inclusion in the present review in an effort to be considered an evidence-based review and hence, scientifically informative for the field of Endodontics; such studies are considered the highest levels of evidence (Torabinejad et al.). Studies were excluded that failed to meet one or more of the below inclusion criteria or that met one or more of the below exclusion criteria. These criteria were strictly applied in an effort to improve upon the work of previous researchers.

Table 2: Defined Inclusion Criteria

Inclusion Criteria
• Initial non-surgical root canal treatment • Use of a PAI score of one or two to denote success • Use of radiograph or CBCT for determination of PAI value • Published recall rate of at least 50% • Endodontic treatment and evaluation at recall completed by a specialist • Patient population 18 and older • RCT, quasi-RCT, cohort studies, retrospective observational studies, systematic reviews, or meta-analyses

Table 3: Defined Exclusion Criteria

Exclusion Criteria
• Failure to use PAI system for evaluating treatment result as a success or failure • No published recall rate or recall rate less than 50% • Endodontic treatment completed by student or general practitioner • Surgical root canal treatment performed on subject(s) in study • Extractions and retreats included in calculation of treatment result data • Pediatric cases included in data (re: younger than age 18) • International patient population and/or publication not available in English • Case study or general literature review

To ensure that all relevant studies were considered for this review, a broad search was completed in PubMed using the search terms root canal therapy, apical periodontitis, success, failure, and treatment outcome. The only restriction criterion was time period (re: January 2009 through December 2011). The PubMed search included high quality journals within the field including Endodontic Topics, International Dental Journal, International Endodontic Journal, Journal of the American Dental Association, Journal of the Canadian Dental Association, Journal of Endodontics, Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology, and the Journal of Dental Research. The search within PubMed also included searching within the Cochrane Library Database for previously published systematic reviews.

The abstracts of studies resulting from the search were reviewed and studies that based on the abstract alone obviously failed to meet defined inclusion criteria were then excluded. Full-text PDFs or reprints of all relevant or potentially relevant studies were obtained. The documents were reviewed again for relevance and to ensure all inclusion criteria were met. Irrelevant studies were excluded.

RESULTS

With the aforementioned search terms being applied in various combinations, this PubMed search produced 330 publications within the specified time period. A review of the abstracts for these 330 publications resulted in 51 articles to be examined more closely for relevance and inclusion. The original work for these 51 publications was obtained and reviewed. From this, no publication met all defined inclusion/exclusion criteria and were directly related to the research question. The below figures and tables describe the search process.

Figure 1: Original search process

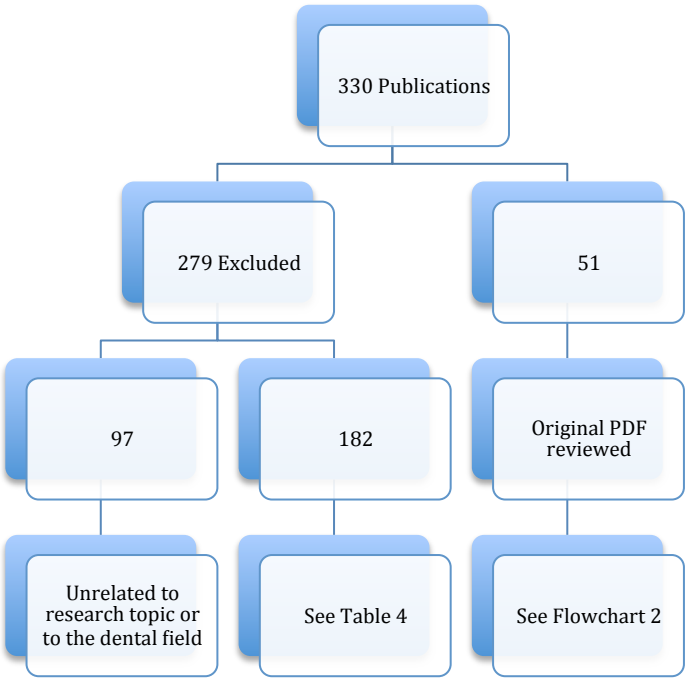

Table 4: Reasons for Exclusion of Publications Based on the Review of Abstracts in Original Search

Reasons for Exclusion:
• Animal Study (7) • Crown Evaluation (5) • Ethics (1) • Foreign Language Only (4) • Instrumentation (7) • Microbiology (11) • Pain Management (12) • Pediatric (36) • Periodontal (8) • Prosthodontics (1) • Retreatment (18) • Systemic Complications Following Treatment (5) • Surgical (32) • Tissue Regeneration (14) • Tooth Discoloration (2) • Tooth Reattachment (19)

Figure 2: Review of 51 PDFs from the Original Search

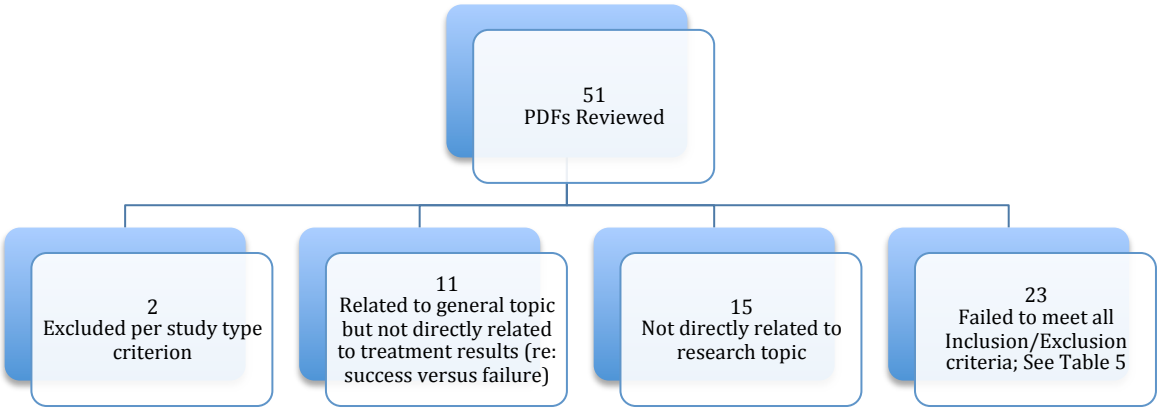

Table 5: Reasons for Exclusion of 23 Publications Directly Reviewed

Reason(s) for Exclusion
• Cheung & Liu (2009) – Treatment/evaluation not completed by specialist • Cuje et al. (2010) – Did not use PAI; treatment completed by generalist • Del Fabbro & Taschieri (2010) – Did not use PAI • Gilbert et al. (2010) – Treatment completed by generalist • Gillen et al. (2011) – Did not use PAI consistently; did not report who completed treatment; recall rate not considered • Gomez-Polo et al. (2010) – Did not use PAI; treatment not completed by specialist • Gunduz et al. (2011) – Did not report who completed treatment/evaluation • Fu et al. (2011) – Included retreatment • Mente et al. (2009) – Did not use PAI exclusively • Ng et al. (2011a) – Did not use PAI; treatment not completed by specialist • Ng et al. (2011b) – Did not use PAI; treatment not completed by specialist • Nixdorf et al. – Did not use PAI; included surgical treatments • Ozkurt et al. (2010) – Treatment/evaluation not completed by a specialist • Peciuliene et al. (2009) – Study type; did not include US practitioners • Ravanshad et al. (2010) – Did not use PAI • Ricucci et al. (2011) – Treatment/evaluation not completed by specialist • Setzer et al. (2011) – Included retreatments • Su et al. (2011) – Did not use PAI consistently; treatment not completed by specialist • Suter et al. (2009) – Included retreatments • Stockhausen et al. (2011) – Did not use PAI • Tsesis et al. (2009) – Included surgical cases • Wu et al. (2011) – Did not use PAI • Zmener & Pameijer (2010) – Did not report who performed treatment

There were two systematic reviews completed during the defined time period (re: January 2009 through December 2011) and directly related to treatment outcome in the case of non-surgical root canal therapy. These reviews, and the reasons for exclusion, are listed above in Table 4 (re: Gillen et al., 2011; Su et al., 2011). Though these publications failed to meet defined inclusion/exclusion criteria, because they were published as a 'systematic review,' which represents the highest level of research evidence (Torabinejad et al.), these publications are summarized below.

Analysis of Article 1

- Gillen BM, Looney SW, Gu LS, Loushine BA, Weller RN, Loushine RJ, Pashley DH, Tay FR. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: A systematic review and meta-analysis. J Endod 2011; 37(7):895-902.

  Purpose

  Evidence has consistently demonstrated a positive correlation between the result of root canal therapy and the quality of the root filling (Nair, 2006; Sjogren et al., 1997). Gillen et al. cited successful treatment results ranging from well above 90% to 75% depending on the presence of preoperative apical periodontitis. Yet, in samples with a high occurrence of apical periodontitis and inadequate root fillings, favorable outcomes have been as low as 40 to 65%, emphasizing the need for an adequate coronal seal for proper healing to take place (Frisk et al., 2008; Madison & Wilcox, 1988; Sunray et al., 2007). Gillen and colleagues compared the impact of the quality of a root filling to the quality of a coronal restoration on the result of root canal

therapy.

Materials and Methods

An exhaustive literature search was completed using the broad search terms "coronal restoration," "root canal," "periapical status," and "quality." Nine articles that examined the impact of the quality of root filling, quality of coronal restoration, or both on the success of root canal treatment were selected.

Inclusion and Exclusion

Inclusion criteria were as follows: clinical study, sample size given, success determined by radiographic and/or clinical criteria, evaluated quality of root filling, evaluated quality of coronal restoration, evaluated periapical status, reevaluation completed at least 1 year following the initial treatment, and the overall success rate provided or could be calculated from raw data.

Exclusion criteria were as follows: evaluation of non-Endodontically treated teeth, systemic disease present and possibly associated with treatment outcome, quality of coronal restoration not provided, no association between quality of coronal restoration and Endodontic treatment result, poor quality of the overall Endodontic treatment result, and could not establish contributors to poor treatment result.

There were differences among the studies selected that were thought to possibly confound the association between the root canal treatment and the absence of apical peridodontitis. These were identified as covariates and included: whether evaluation was completed radiographically only or radiographically and clinically; calibration status of evaluators; whether or not the 5-point PAI system was used for the radiographic assessment of the periapical status; and evaluation of both the quality of

the seal and root length versus evaluation of root length only. Data was divided into categories according to these dichotomous characteristics and percentages of teeth without apical periodontitis were calculated for each category (re: adequate restoration and adequate root filling; adequate restoration and inadequate root filling; inadequate restoration and adequate root filling). Odds ratios from this data were calculated and logistic regression models were determined.

Primary Results

- Comparison of the groups adequate restoration (AR) and adequate root treatment (AE) versus AR and inadequate root treatment (IE) produced an odds ratio of 2.734; 95% confidence interval (CI), 2.61-2.88 ($P < .001$).
- Comparison of the groups AR + AE versus inadequate restoration (IR) and AE produced an odds ratio of 2.808; 95% CI, 2.64-2.97 ($P < .001$).
- Use of the 5-point PAI in evaluating outcome did significantly impact outcome determination.

Conclusions

- Apical periodontitis healing increased with both adequate root filling and adequate coronal restoration. This points to the importance of the Endodontist and restorative dentist working closely together and coordinating patient care in a concerted effort to produce optimal treatment outcomes.
- Despite poorer clinical outcomes, there was no significant difference in the odds of healing with adequate root filling but inadequate restoration versus inadequate root filling but adequate restoration.
- Variations in participants, interventions, study design and evaluation

techniques, and statistical heterogeneity made comparison of previous studies difficult.

Analysis of Article 2

- Su Y, Wang, C., Ye L. Healing rate and post-obturation pain of single- versus multiple-visit endodontic treatment for infected root canals: A systematic review. J Endod 2011: 37(2): 125-32.

  Purpose

  In recent years, the necessity of multiple-visit for the completion of root canal treatment has been questioned in favor of a single-visit treatment. Research has not found significant differences in bacteria presence in single-visit versus multiple-visit treatments (Kvist et al., 2004). Furthermore, technological advancements have facilitated single-appointment treatment and other advantages including time, cost effectiveness, patient preference, and reduced infection risk between appointments, all make a single-visit root canal treatment increasingly appealing and accepted (Jurcak et al., 1993). Conclusions from previous studies and systematic reviews that have examined results in single-visit versus multiple-visit root canal treatment are limited due to small sample sizes and variability in treatment results due to the presence of vital versus non-vital pulp prior to treatment. Su and colleagues examined differences in results between single-visit and multiple-visit root canal treatments only in teeth with infected canals.

  Materials and Methods

  A computerized literature search was completed in the following databases:

MEDLINE (1966 – 2010), the Cochrane Library (2010), EMBASE (1984 – 2010), SCI (1995 – 2010), and CNKI (1982 – 2010). Only RCTs and quasi-RCTs that compared root canal therapies in single-visit versus multiple-visit in patients with infected canals were included for review. Broad search terms, used in various combinations, included: Endodontics, root canal therapy, pulpotomy, pulpectomy, dental, pulp, diseases, devitalization, obturation, visit, and appointment. References cited in identified articles were examined and all relevant articles in the Journal of Endodontics, Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics, and the International Journal of Endodontics were hand-searched. Ten RCTs were included in the review; six of these studies compared the healing rate of teeth treated in single-visit versus multiple-visit and five studies compared post-obturation pain in teeth treated in single-visit versus multiple-visit.

Inclusion and Exclusion

Inclusion criteria were as follows: permanent teeth with infected root canals or radiographic evidence of apical periodontitis; no previous Endodontic treatment on selected teeth; outcome measures were radiographic evidence of 'healing' and incidence of pain; 'healed' teeth were observed for at least one year.

Exclusion criteria were as follows: studies that were not RCTs or quasi-RCTs; failed to compare single-visit and multiple-visit root canal treatment in infected canals within the same study; no data on the healing rate or presence of pain; pulp status was not identified as vital or necrotic; the specific Endodontic procedure was not identified.

Primary measures of treatment results included long-term success and the

presence or absence of complications subsequent to treatment. Endodontic treatment results were assessed by the healing rate after one year as evaluated according to radiographic assessment of the size of periapical radiolucency and a clinical exam of signs and symptoms, which were scored as present or not present. Complications were defined as post-obturation pain, and a flare-up was defined as uncontrollable post-operative pain or increased swelling. All cases were scored as 'healed' or 'not healed' and 'pain' or 'no pain.' Cases identified as 'healed' were completely healed per radiographic and clinical evidence; 'not healed' included failures and cases where healing was uncertain. Cases classified as 'pain' included slight, moderate, strong, or severe pain.

Primary Results

- There was no significant difference in the healing rate for root canal treatment in teeth with an infected canal in a single-visit treatment versus multiple-visit treatment.
- Based on an aggregation of the available data, the healing rates for single-visit versus multiple-visit treatments were 80.1% and 80.0% respectively.
- Post-operative pain, as perceived by the patient, was significantly less in patients with a single-visit treatment versus a multiple-visit treatment.
- The difference in pain, as perceived by the patient, seven to ten days following completed treatment was not significantly different in those with a single- versus multiple-visit treatment.

Conclusions

- Authors concluded that with the use of effective instrumentation, adequate

irrigation, and complete obturation, single-visit Endodontic treatment can produce a successful result.

- Short-term pain following obturation was significantly less in a single-visit treatment than in multiple-visit treatment.
- The healing rate for infected teeth was similar for root canal treatments completed in a single-visit and those completed over the course of multiple-visits.
- Because of the limited number of studies available for review, these results should be interpreted with caution.

DISCUSSION

Treatment success can be based on a variety of factors including but not limited to symptom resolution, the healing of periapical tissues per radiograph, or even histologic evidence showing the absence of infected cells. Patients, on the other hand, may define success differently than practitioners. A patient's 'definition' of success may be the absence of pain or increased functionality of the tooth. Patients want treatment options that are proven to produce results in a timely and feasible manner that will last. The use of the PAI for evaluating treatment results has been advised because it is a reliable and valid way for denoting a healthy periapex and hence, quantifiable scientific evidence of 'successful' treatment results. Yet, in the research on Endodontic treatments, there is heterogeneity in how success is defined and how it is evaluated, creating problems for comparing studies and aggregating data. In turn, success rates and those factors linked to success remain unclear because the evidence itself can be contradictory, or at best inconsistent, from study to study.

This thesis set out to improve upon the current state of treatment results. The goal was to research an evidence-based definition of success, establish the parameters around evaluating whether or not studies adhered to this definition of success, and to evaluate the Endodontic treatment data in recent literature carefully according to this definition. Ultimately, the purpose was to provide evidence-based data on the success and failure rates of non-surgical root canal therapy and establish standardized criteria on how success should be defined. This was approached via a review of the literature on this topic and the inclusion and exclusion of identified articles according to defined criteria. This

search of the literature failed to identify a single study of adequate quality that met all inclusion/exclusion criteria and addressed the research question at hand. While frustrating, this finding is an important one as it highlights the gross limitations in the current research base.

On a professional level, the rise of implants makes now a particularly important time to firmly establish the potential results of Endodontic treatment. The introduction of implants has been a great addition to the field of dentistry. Several factors must be considered during the treatment planning for dental implants including the location of the implant, quality of the surrounding bone, periodontal status, restorability and systemic factors (Wood & Vermilyea, 2004). The lengthy treatment of properly placed implants, which can take up to 12 months to complete, must be fully understood by the patient especially when the tooth is located in an esthetic part of the patient's mouth. Another consideration that needs to be addressed is the finances involved in placing an implant. A 2005 insurance database concluded that single tooth implants cost approximately 75-90 percent more than similarly restored Endodontically treated teeth (Christensen, 2006). Several studies have been conducted that looked at the costs, restorability and overall life of the tooth. Ray and Trope demonstrated that when comparing a properly completed root canal with the placement of a permanent restoration versus an implanted tooth, there was no difference in the longevity of the tooth. In 2006, Doyle et al. compared 196 post-Endodontically treated teeth with 196 single-tooth implants. Both groups had failure rates of approximately 6 percent. Patients who received an implant experienced more post-operative complications, which was reflected in a poorer success rate. Scholz and d'Hoedt (1984) pointed out that the success of implants for children, up to 17 years of age,

was around 77%. In contrast, additional studies support the use of osseointegrated implants on children less than 18 years of age, and found that implants provide a versatile solution for traumatic injuries within minors (Ledermann et al., 1993). In sum, when deciding upon a treatment, the dental professional must be knowledgeable of the most recent data on evidence-based care so that in turn the professional and patient can discuss and weigh the pros and cons of each possible procedure. Reliable and valid data on Endodontic treatment results is crucial to the treatment planning completed by an Endodontist or by a general dentist when root canal therapy may be indicated.

Previous research has cited success rates of non-surgical root canal therapy from 94% to as high as 98% (Lazarski et al., 2001; Salehrabi & Rotstein). Endodontically treated teeth that result in complications are typically treated as a failure. In a review of 1.4 million dental patients who received an initial root canal treatment, only 0.47% required retreatment and only 0.45% later required surgery (White et al., 2006). Similarly, in another review, researchers cited a 1 in 500 chance for an initial root canal therapy to fail and require retreatment and subsequent surgery (Friedman & Mor, 2004). While at face value this data seems to point to the high probability of success in initial root canal therapy, the limitations of the reviewed literature may be impacting the interpretation of this data. Hence, to truly understand the meaning of research on the topic of Endodontic treatment and to use this information to inform treatment planning and clinical practice, these limitations must be addressed and improved upon. As previously stated, defining a set of criteria for how success is defined in practice is vital to the field of Endodontics. Dentistry currently has many challenges when comparing success rates of different procedures across different dental specialties. It is important to

define, establish and incorporate a standardized methodology in the way research is conducted. Once these parameters have been accepted within the field of Endodontics, more reliable research will be available to push the specialty to the next level.

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