Growth and Dissemination of Endodontic Knowledge

By

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ABSTRACT

Background: Endodontics is a relatively young clinical specialty that received formal recognition by the American Dental Association in 1963 and by the Commission of Dental Accreditation in 1975. Biological and technological advances have allowed endodontics to evolve into a scientifically based specialty that uses many meticulous methods both at the laboratory and clinical levels. The history, growth and impact of endodontics can be followed by studying the quantity and quality of published literature and comparing it to other dental specialties.

Purpose: The aim of this investigation was to use a variety of web based bibliometric tools and describe the growth and dissemination of endodontic knowledge both within and outside the specialty community. Specific aims included quantification of the entire endodontic literature, identification of types of research, analysis of publication patterns and discovery of who has supported and contributed to that knowledge. This overview of endodontic knowledge should provide information on how this may be enhanced in the future.

Methods: A series of specific questions were developed that covered many aspects of literature quantification. The value of the literature was assessed by the use of the Impact Factor and citation analysis. Search strategies were developed that could utilize databases such as MEDLINE, Web of Science, Journal Citation Reports and Scopus. Results were summarized using descriptive statistics and by further analysis using linear regression and correlation techniques.

Results: MEDLINE has indexed over 35,000 endodontically related papers since 1963. The two journals dedicated to the specialty, the Journal of Endodontics and

the International Endodontic Journal both publish more papers on endodontics than any other individual journal yet contain only around 20% of the all endodontic publications. The increase in the total number of research papers published each year in endodontics currently surpasses that in orthodontics and periodontics however, endodontics has fewer higher evidence-based studies compared to periodontics. Government funding was the highest for clinical trials and randomized controlled trials. When analyzing clinical publications within four clinical categories of etiology, diagnosis, prognosis and therapy, endodontics has considerably more papers relating to orthograde root canal therapy compared to any other clinical category. The total number of papers retrieved from the diagnosis clinical category was highest in papers that looked at Periapical disease and similar trends were observed in the prognosis category for papers relating to Endodontic surgery. The significance, of endodontic publications as judged by the Impact Factor has increased substantially over the last ten years when compared to orthodontics and periodontics. The number of citations for endodontic papers has begun to increase rapidly in 2002 especially in the endodontic journals themselves. The majority of endodontic research has originated from the United States, Brazil and England and from small rather than large institutions.

Dedication

The work presented in this master's thesis is dedicated to my late father

Mr. Rashmi S. Vora

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Definition of scientific terms

Articles: see publications
Basic research: a collective term for biological and technological research, previously known as scientific articles in JOE.
Case reports: isolated reports of techniques, anomalies, pathology and case series. This definition also applies to a section in JOE contents category.
Citations: references to the publications but not the actual publications.
Clinical articles: a section under the JOE contents category that represents clinical research.
Clinical literature: collective term for clinical articles, publications and research.
Clinical publications: publications relating to clinical decision-making.
Clinical research: prospective human outcome studies that did not result in tooth extraction for examination (apicoectomy root end specimens for histologic examination were allowed) and systematic reviews.
Contents sections: a list of contents sections in JOE that include clinical research and basic research.
Documents: information in the form of letters, obituaries, pamphlets and opinions, excluding journal publications.
Endodontic knowledge: a collective term for all endodontic publications from all study types.
Endodontic literature: see endodontic knowledge.
Endodontic publications: see endodontic knowledge.
Gold standard journal: a source title in endodontics that has shown a similar association to the quantity of literature retrieved using the PubMed search script.
Journal: see source title.
Laboratory research: research that involves the use of a tooth extraction and subsequent analyses to obtain results.
Literature: all information no matter how formally or informally recorded.
Papers: see publications.
Publications: all materials contained in journals that are of full-length, maybe subcategorized to type of publications, e.g. clinical trial
Reference: previously published work that is used to develop publications.
Review papers: a comprehensive publication of an author's opinion on a topic based upon selected publications.
Scientific articles: a section under the JOE contents category that represents laboratory research, which is subdivided into biological and technological research.
Scientific research: a collective term for the various study types that were selected in ISI MEDLINE search engine.
Search script: a search methodology used in MEDLINE constructed of collective MeSH terms.
Specific search script: a search methodology used in MEDLINE constructed of collective MeSH terms.
Search strategy: a search method devised to extract data from online databases.
Source title: the name of the journal printing a publication.

List of Abbreviations

AAE: American Association of Endodontists
ADA: American Dental Association
BS: Broad Sensitive
CC: Clinical Category
ECC: Endodontic Clinical Category
FROM: Citations from a journal
GEN: General Dental Journals
IF: Impact Factor
ISI: Institute for Scientific Information
JCR: Journal Citation Reports
MED: Medical Journals
MeSH: Medical Subject Headings
NS: Narrow Specific
SPEC: Specialty Dental Journals
TO: Citations to a journal
WoS: Web of Science

List of Journal Abbreviations

ADJ: Australian Dental Journal
AIM: Annals of Internal Medicine
AJD: American Journal of Dentistry
AJODO: American Journal of Orthodontics and Dentofacial Orthopedics
AM: Annals of Medicine
AO: Angle Orthodontist
AOB: Archives of Oral Biology
AOIM: Archives of Internal Medicine
ARM: Annual Reviews of Medicine
BDJ: British Dental Journal
BMJ: British Medical Journal
CMJ: Canadian Medical Journal
CR: Caries Research
DM: Dental Materials
Endo T: Endodontics and Dental Traumatology
IDJ: International Dental Journal
IEJ: International Endodontic Journal
IJOMS: International Journal of Oral and Maxillofacial Surgery
IJP: International Journal of Prosthodontics
IJPD: International Journal of Pediatric Dentistry
JADA: Journal of the American Dental Association
JAMA: Journal of the American Medical Association
JCDA: Journal of the Canadian Dental Association
JCP: Journal of Clinical Periodontology
JDR: Journal of Dental Research
JIM: Journal of Internal Medicine
JOE: Journal of Endodontics
JOMS: Journal of Oral and Maxillofacial Surgery
JOP: Journal of Periodontology
JPD: Journal of Prosthothetic Dentistry
JPR: Journal of Periodontal Research
LAN: Lancet
NEJM: New England Journal of Medicine
OD: Operative Dentistry
OOO: Oral Surgery, Oral Medicine, Oral Pathology
OOOOE: Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology

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Chapter 1- INTRODUCTION

The origins for endodontics date back to the 1930's.[1] The number of endodontic articles has increased in line with advances in clinical knowledge and technology. Growth of the endodontic literature affirms that the specialty is becoming an evidence-based discipline. The development of science, its growth, and its impact on the specialty can be studied using bibliometrics, which can also identify scientific areas where more research may be desirable.

History of the Endodontic literature

During the last eight decades, endodontics has included several eras (**Table I**) based on dominating scientific ideas such as disproving the focal infection theory[2, 3], providing evidence that indigenous oral bacteria causes periapical disease[4], introduction of nickel titanium instruments[5], development of biocompatible root filling materials[6] and the recent birth and enormous promise of regenerative endodontics.[7] The formal establishment of the specialty began in December 1942 when "a small group of practitioners and educators sent invitations to other colleagues to form an organization in which they could share common endodontic experiences and interests".[8] Endodontics then became established and 'organized' as a subject by the formation of the American Association of Endodontists in 1943. The AAE and its membership contributed to the bulk of knowledge through continuing education and conference meetings that are aimed to educate all dental professionals.[9] The first journal called the '*Journal of Endodontia*' was published in 1946 but discontinued in 1948.[10] Arrangements were then made with the Mosby

publishing company[10] to include a separate section for endodontics in their journal, Oral surgery, Oral medicine and Oral pathology. The American Dental Association recognized the specialty in 1963[8, 10] but it was not until 1975, that the first journal dedicated exclusively to endodontics was published, '*Journal of Endodontics'*. Endodontics grew internationally with the first edition of the '*Journal of the British Endodontic Society* 'being published in the spring of 1967 to be replaced by the current *'International Endodontic Journal'* in 1980.[11]

Initially most of the knowledge base of the specialty consisted of case reports and descriptions of procedures. The development of endodontic research programs was intended to help mature the specialty into an evidence based discipline.[9] Today, endodontics is a largely evidence-based specialty[12] rather than a technique based specialty and the absorption of new knowledge from other areas has increased enormously. New knowledge obtained from endodontic research has also been absorbed in by other specialties and disciplines.[13, 14]

American Association of Endodontists

The AAE is the primary source for continuing education in endodontics of both specialists and general dentists. The AAE is "dedicated to excellence in the art and science of endodontics and to the highest standard of patient care. The association inspires its members to pursue professional advancement and personal fulfillment through education, research, advocacy, leadership, communication and service". The AAE defines endodontics as "The branch of dentistry concerned with the morphology, physiology and pathology of the human dental pulp and periradicular

tissues. Its study and practice encompass the basic and clinical sciences including the biology of the normal pulp and the etiology, diagnosis, prevention and treatment of diseases and injuries of the pulp and associated periradicular conditions".[8]

Bibliometrics

All definitions for the various scientific terms used in this thesis are provided on page 5.

Bibliometrics is a component of library science that uses "statistical methods to analyze a body of literature to reveal historical development".[15] Bibliometric techniques include "word frequency, citation analysis and simple document counting, such as the number of publications by an author, research group, or country".[16]

Most evaluative bibliometric techniques use the *citations* of publications as their raw data. The number of citations of previously published work is an indicator of its subsequent recognition and impact in an area of study.[17, 18] Bibliometrics can also be used to identify funding emphasis, which in turn can affect research institution decisions such as hiring of scientists, promotion of scientists, and allow future successes in obtaining further funding. [19, 20 21]

Bibliometric analysis has been used extensively in evaluating medical progress in cardiology, emergency medicine[22], medical diagnosis[23] and other areas.[24] The dental literature has also been analyzed but to lesser extent.[25] Such analyses of the dental literature have been done to provide insight into the current scientific advancement of a particular field as well as indicate areas where new knowledge is headed.

Citation Analysis

References are used in articles to support the development of hypotheses, provide provenance for techniques and to compare old and new knowledge.[26] However, the majority of scientific papers are seldom cited in subsequent literature and only a few articles in a given discipline are heavily cited.[18, 27, 28] Articles that are cited more than 100 times are considered ''citation classics'' and are said to be of high impact.[29] Eugene Garfield first proposed Science Citation indices in 1955 to help researchers and academicians evaluate their work qualitatively through the use of citations.[30] In the 1960's, Thompson Reuters introduced the Impact Factor[31] and by 1975 the IF was published annually by ISI within the Journal Citation Reports.[31] "IF is a ratio between citations and recent citable items published".[31] It is calculated by dividing the number of current citations to articles published in a specific journal in the previous two-year period by the total number of articles published in the same journal in the corresponding two-year period.[31] IF has been given great importance in scientific communities over the last few decades as it is often perceived as an evaluative measure of journal quality. [19, 32]

The IF is only one evaluative citation index among many. Others include the h-index,[33] which measures citations of individual scientists, the Immediacy index which measures how quickly articles in a journal are cited and the Journal Cited Half life which is a measure of the rate of decline of citations to 50% of its initial value.[34]

Citation analysis is an important approach as it allows observation of the dissemination of knowledge and a comparison of the emphasis being given to different areas. It does not, in its present usage, establish the quality[32] of any

particular journal, any individual paper or any one scientist. Quality is difficult to assess and no mathematical model has yet been developed.

Bibliometric tools

Traditionally bibliometric tools were written indices that were constructed using complex mathematical formulas only within the reach of experts.[30] Today they are comprised of web based search engines and their corresponding databases. However there seems to be confusion between these terms in academic communities.[35] For the purposes and simplicity of this thesis, a distinction and classifications between search engines and databases were made. The classifications of search engines and databases used in this study are listed in **Figure A** shown below. In general, academic institutions will use a variety of search engines and subscribe to multiple databases that are offered by service providers. The National Center for Biotechnology Information (NCBI) Entrez retrieval system search engine, which does not require institutional subscription, includes PubMed that provides access to MEDLINE. NCBI Entrez offers many other databases that include molecular biology databases such as nucleotide and protein sequence information. For this thesis PubMed and MEDLINE will be used interchangeably. One of the more widely used databases is MEDLINE, which is a product of the United States National Library of Medicine (NLM) of the National Institutes of Health (NIH) that indexes the "biomedical literature from 1947 onwards, covering the disciplines of medicine, dentistry, nursing, veterinary medicine, health care services and the preclinical sciences.[36] Currently MEDLINE holds citations from approximately 5,400 worldwide

journals in 39 languages for current journals and 60 languages for older journals.

Search Engine	Discipline	Databases at U of M	Provider
NCBI Entrez	Medical/ health sciences	• MEDLINE	NIH and NLM
Ovid	Medical/ health sciences	• MEDLINE • Evidence Based Medicine Reviews (various) • Intl. Pharmaceutical abstracts • Nursing database	Wolters Kluwer
ISI	Multidisciplinary	• MEDLINE • Web of Knowledge • Web of Science • Journal Citation Reports • Current Contents Connect • BIOSIS Previews	Thompson Reuters
SciVerse	Multidisciplinary	• Scopus database	Elsevier

Figure A: Current University of Michigan database subscriptions

Data can be extracted by the use of Medical Subject Headings (MeSH terms), which are indexing terms used by NLM and consist of sets of naming descriptors in a hierarchical structure that permits searching at various levels of specificity.[37] The creation of MeSH headings was aimed at minimizing errors in literature retrieval compared to using keywords by providing standardized repeatable searching and by avoiding the problems of medical jargon and multiple synonyms for a particular category.[38] Staff and subject specialists who have expertise in various medical areas continually revise and update all MeSH vocabulary.[36] Endodontics [MeSH] was indexed by the NLM under Dentistry [MeSH] to include seven hierarchical descriptors **(Table A)**. MeSH terms can also be used in multiple search engines that may offer specific refining tools to extract specific information from MEDLINE. The

development of search strategy tools were aimed at improving the precision of searches.[38] PubMed, for example, offers the 'Clinical Queries" tool which is aimed at providing clinical end users with clinically relevant valid studies that can aid in decision-making.[38] It consists of a set of research methodology filters that classifies clinical studies into four clinical categories (CC) of etiology, diagnosis, prognosis and therapy **(Table G)**. A search can also emphasize *sensitivity* (a broad search, which will yield the largest number of relevant papers but also many irrelevant ones) or *specificity* (the irrelevant papers are weeded out, but pertinent ones may be missed). "For day-to-day clinical questions, a quick search that emphasizes *specificity* is usually most helpful".[38]

The Institute for Scientific Information is another search engine provided by Thompson Reuters and amongst other databases such as MEDLINE offers an exclusive citation database known as Journal Citation Reports[39] with data starting from 1997 onwards. The JCR offers many citation analyzing tools including, IF, Immediacy Index and Journal Cited Half Life. Another database offered by ISI is the Web of Science,[40] which provides access to other worldwide leading citation databases. Multidisciplinary coverage includes current and retrospective journal and proceedings data in the sciences, social sciences, arts, and humanities".[40] One of the major advantages of using WoS instead of MEDLINE is that the results filters are more specific and it is possible to extract data from the original search into sub-categories like institutions and countries of origin.

In 2004 Elsevier launched Scopus database that is utilized through the SciVerse search engine. Scopus is an abstract and citation database that contains peer reviewed literature and quality web sources to track, analyze and visualize research.[41] SciVerse offers many analytic tools for searching the Scopus database. The 'Citation Tracker' tool checks and tracks citation data including data for individual papers and the "Journal Analyzer" tool allows for searching journals in a specific field and obtaining data such as the number of citations a journal receives including self citations.[42]

Chapter 2- LITERATURE REVIEW

Bibliometric studies in Endodontics

To date, there has only been one paper published which has benchmarked the endodontic literature. Kim *et al*[43] conducted a bibliometric study aimed at identifying and quantifying the endodontic literature available between 1990 and 1998 to establish parameters for clinical decision-making. A search strategy was carried out using MeSH subject headings and specific methodologic filters to identify four clinical categories of information: etiology, diagnosis, prognosis and therapy. The results of the study showed that there were more articles published per year on orthograde root canal therapy than any of the other clinical categories and that overall the number of articles pertaining to etiology, diagnosis, therapy and prognosis increased significantly each year.[43]

Bibliometrics in other dental specialties

Bibliometrics has also been utilized in other areas of dentistry including dental specialties, where patterns of publication have helped authors to evaluate literature both quantitatively and qualitatively.

Orthodontic literature

Kanavakis *et al*[44] evaluated types of articles and authorship characteristics in the 3 orthodontic journals with the highest IF at the time—*American Journal of Orthodontics and Dentofacial Orthopedics* (AJODO), *Angle Orthodontist* (AO), and *European Journal of Orthodontics* (EJO) during 2 intervals of 5 years (1993-1997

and 1998-2002) and assessed the changes in their contents during these periods. The authors concluded that the contributions of articles from the United States and Canada to the AJODO and the AO were statistically higher than to the EJO. Conversely articles from Europe comprised more than 70% of the content of the EJO. An increased contribution of articles from East Asia and Oceania was noted in the second time period. Mavropoulos *et al*[45] also evaluated the orthodontic literature and concluded that most orthodontic journals are focusing largely on diagnosis and treatment evaluation while other topics, such as new techniques and new materials receive less emphasis. Many high-quality studies of orthodontic interest are published in high IF non-orthodontic journals possibly out of reach for many orthodontists.

Periodontic literature

Nieri *et al*[28] identified articles in periodontology published between January 1990 and March 2005 in four international periodontal journals: *Journal of Periodontology, Journal of Clinical Periodontology, International Journal of Periodontics* and *Restorative Dentistry* and *Journal of Periodontal Research*. A total of 55 'classic' (i.e. Cited at least 100 times) articles were identified. These were longer, used more images, had more authors and contained more self- references than less frequently cited articles. Overall classics had larger sample sizes, often dealt with etiology, pathogenesis and prognosis, but were rarely controlled or randomized clinical studies.

Pedodontic literature

Yang *et al*[15] conducted an analysis of the pedodontic literature between 1989 and 1998 by comparing data for pedodontics to six other disciplines. The authors conducted a strategic search using MeSH headings in Ovid MEDLINE using the MEDLINE database. Their main results showed that there was an average of 8097 dental articles published each year for the combined seven dental disciplines. Broken down by discipline then there were 327 articles per year for endodontics, 2765 articles per year for oral medicine, 1175 articles for orthodontics, 839 articles for oral surgery, 1233 articles for periodontics, 1353 articles for restorative dentistry and 404 articles for implant dentistry. Sixteen percent of the articles for the combined dental disciplines were limited to children (<12 years old) while the remaining 84% were limited to adolescents and adults (>13 years old). If the publications on children are of high clinical applicability, then pediatric dentists would need to read, digest and implement into clinical practice approximately 24 articles each week during their careers.

Oral and Maxillofacial Surgery literature

Kyzas[46] evaluated the oral and maxillofacial surgery literature by manually screening selected journals between 2004 and 2006 and categorizing the study types. Case series and isolated case reports accounted for the majority of the papers in comparison to randomized clinical trials and meta-analysis which accounted for less than 1% of the data analyzed. Lau *et al*[47] conducted a bibliometric study to examine the relationship between the apparent quality of research, in terms of

levels of evidence, and the journal IF. Similar to the results from Kyzas the majority of papers were case reports (47%), 20% animal studies, 11% laboratory studies, 8% technical notes, 5% tutorial articles, and 3% reviews articles. There was also a significant correlation between levels of evidence and journal IF. It was concluded that oral maxillofacial surgery is lacking in research from randomized clinical controlled trials and/ or systematic reviews and that most of the data available to clinicians for the two years studied were from case reports.

The Dental Hygiene literature

Haaland et al[48] mapped the dental hygiene literature and identified core journals that contributed to the majority of publications. Interestingly, the *Journal of Dental Hygiene* was the only dedicated journal within this clinical field. Most citations occurred within five core journals, the Journal of Dental Hygiene, the Journal of the American Dental Association, Journal of Periodontology, Journal of Dental Education, and Journal of Clinical Periodontology with MEDLINE providing the majority of the bibliometric data.

Dentistry Overall

An attempt has also been made to obtain a geographic world map of scientific production in dentistry[49] by analyzing published papers. Articles and reviews in dentistry, oral surgery & medicine category published from 1999 to 2003 were accessed through WoS database and data were analyzed quantitatively, qualitatively and socioeconomically. There were a total of 19,904 publications included in the final study, 19,248 original articles and 656 review articles. Conclusions from this

paper were that the USA, UK, Japan and Scandinavian countries were the most productive countries. Publications from Scandinavian countries were of high quality as measured by IF and citation rate, while the UK had one of the highest number of publications per researcher.

Chapter 3- STUDY AIMS

Purpose

The purpose of the investigation reported in this thesis was to use a variety of web based bibliometric tools to describe the growth and dissemination of endodontic knowledge both within and outside the specialty community. Specific aims included quantification of the entire endodontic literature, identification of types of research, analysis of publication patterns and discovery to who has supported and contributed to that knowledge. This overview of endodontic knowledge should provide information on how this may be enhanced in the future.

Specific Aims and Objectives

Experimental questions were defined for each of the aims of the study.

1) How much has the quantity of endodontic publications increased since ADA recognition of the specialty and what trends are occurring?
2) How does the quantity and types of publications in endodontics compare to that of periodontics and orthodontics?
3) What are the clinical publications in endodontics that can aid in decision-making?
4) Is there a difference in the number of publications for laboratory and clinical research when evaluated through a hand search for both endodontic source titles?
5) How does the Impact Factor compare in endodontics to that of periodontics and orthodontics?
6) Are there any correlations between the number of authors and length of published papers in the endodontic literature?
7) How often are endodontic articles cited in the general dental, specialty and medical literature and what are the patterns of self-citation?
8) Which dental institutions contribute the greatest number of publications in the disciplines of endodontics, periodontics and orthodontics?

Chapter 4- MATERIALS AND METHODS

In order to perform a bibliometric analysis on the endodontic literature, various methodological search strategies were to be developed that were accurate, logistic and repeatable. Quantification of endodontic knowledge was carried out using the MEDLINE database and the quality was measured using the JCR, Scopus and WoS databases. The flowchart-illustrated below gives a brief summary towards the methodological approaches that were undertaken to systematically retrieve data.

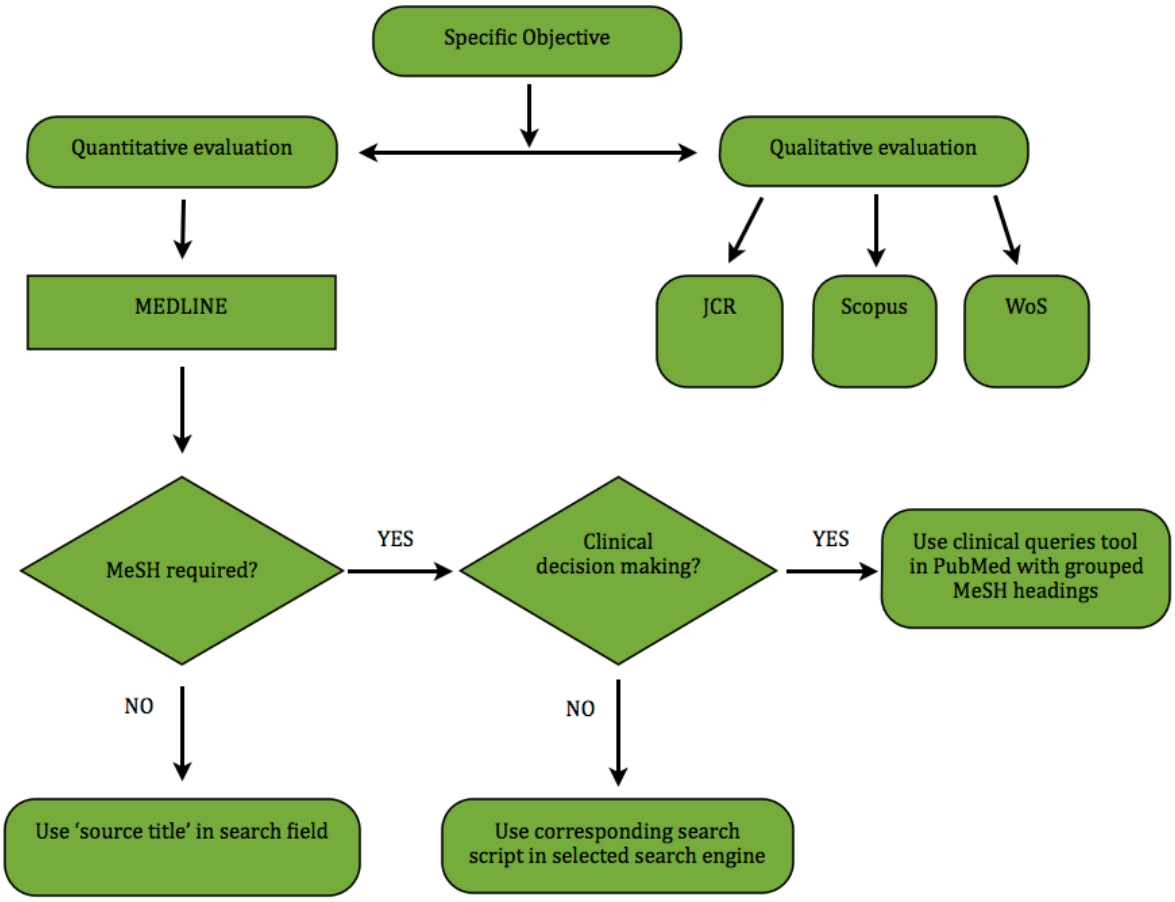


Figure B: Flow chart to show methodological approach for literature analysis

Development of a search strategy for using MEDLINE

Part 1- Comparison of search engines

MeSH headings were adapted to include those originally used by Kim et al.[43] This process yielded a total of twenty-eight MeSH terms that could correspond to the AAE definition of endodontics **(Table B)**.

A search strategy was then developed to utilize all the MeSH headings when combined.[38] Search scripts **(Table C)** were created so that standardized and repeatable searching could be carried out in three selected search engines that utilize the MEDLINE database. Search engines that were used included NCBI Entrez, Ovid Technologies and the Institute for Scientific Information. To utilize these search scripts, a simple cut and paste approach was taken into the respective search engines. Ovid MEDLINE and ISI MEDLINE require that the MeSH terms be abbreviated to indicate whether or not they should be exploded as part of the search. A unique feature to Entrez PubMed is that all MeSH terms are automatically exploded.

All search scripts were run in their respective search engines *with or without limits* of English language and a date range from 1950-2008. Time intervals were every six years from 1950 to 2008. The aim was to see the total number of papers retrieved for the entire period and if there were any differences in the three search engines for amount of data retrieved so that further complex searching can be carried out in a selected engine. For example ISI MEDLINE offers a user-friendly interface and various built in refining filters that can enhance specificity, such as extraction of

publication types and authors.

Findings

The results of the search strategy **(Figure S1/ Table S1)** show no apparent difference in the total number of publications retrieved using the Ovid MEDLINE, PubMed and ISI MEDLINE.

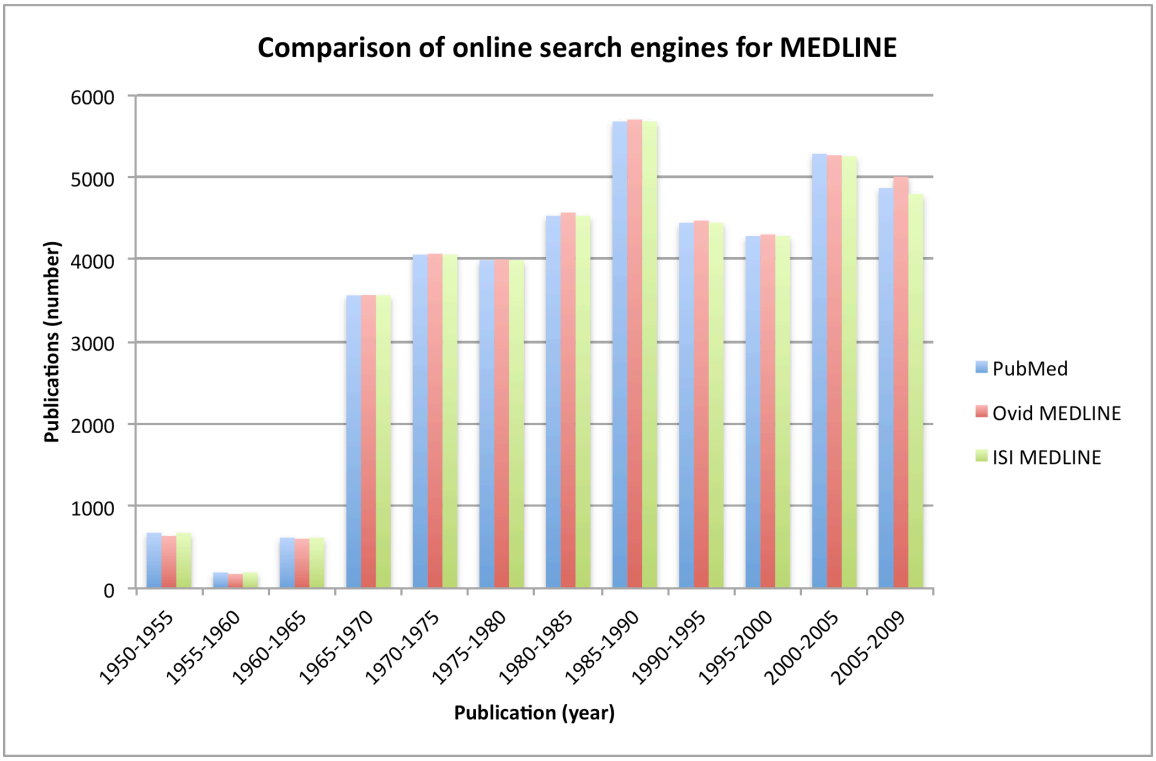


Figure S1: Comparisons between search engines for the number of publications

PubMed shows that there are a total of 35192 endodontic publications for the entire time period, out of which 24401 are published in the English language. When comparing both PubMed and ISI MEDLINE *with* limits of English language using the same time intervals, there is an enormous drop in the number of papers between periods 1965- 2000 in PubMed, compared to that of ISI MEDLINE. A random search was carried out which located errors in retrieval of foreign language papers in ISI

MEDLINE under English language **(Figure S2/ Table S1)**.

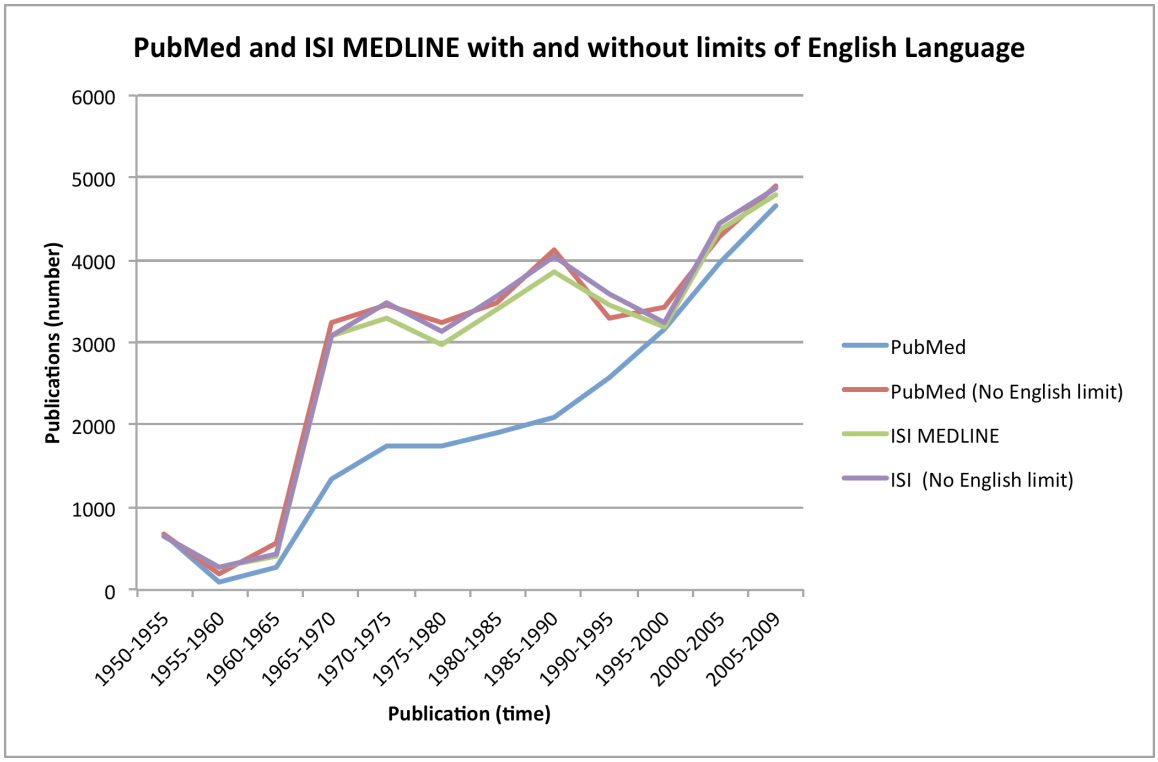


Figure S2: Comparisons between PubMed and ISI MEDLINE for English language

Part 2- Specific searching using MeSH

The previously described search method was intended to capture the bulk of the endodontic literature, however many papers may have been retrieved that were not of endodontic origin, mainly from the diversity of MeSH terms used in the original vocabulary. For example, Endodontics [MeSH] when exploded includes Dental Implantation, Endosseous, Endodontic [MeSH] under its hierarchical category **(Table A)**, which does not fit the original definition of the specialty. To make the retrieval of endodontic literature more specific and directed towards the definition, two MeSH terms from the original vocabulary were excluded due to considerable variation, Tooth Apex [MeSH] and Tooth Root [MeSH] respectively and Endodontics

[MeSH] was still included in the vocabulary however it was not exploded. In PubMed this requires inclusion of a tag [MeSH: noexp] following the heading and in ISI MEDLINE mh=Endodontics. When a MeSH term is not exploded, the more specific hierarchically indented descriptors are excluded. Four major headings were exploded in the final list and a total of fourteen specific MeSH headings (**Table D**) were established. New specific search scripts were then constructed **(Table E)** to include PubMed and ISI MEDLINE only.

Part 3- Grouping MeSH headings

It was also possible to group the specific MeSH headings except Endodontics [MeSH]. Grouping was aimed at retrieving papers that could be categorized into five "endodontic clinical categories" or ECC **(Table F)**. Each EEC was devised to mirror a typical scenario for an endodontist who may seek to retrieve papers as an aid for clinical decision-making.

Part 4- Accuracy of MeSH vocabularies compared to the gold standard journals

The greatest accuracy in literature retrieval would be expected in the specialist journals limited to endodontics; the Journal of Endodontics and the International Endodontic Journal. Searching the source title alone in MEDLINE should retrieve papers that are endodontically related regardless of the MeSH headings that are assigned to individual papers.

The aim here was to compare the number of papers retrieved at various individual time periods ranging from 1975-2006 in JOE and IEJ as well as searching using the original PubMed MeSH search script and eliminating either source title from the

results by using the Boolean '**NOT**' operator. This method would distinctly test the accuracy of the PubMed MeSH search script in retrieving endodontically related material against that of those retrieved by the two gold standard journals in endodontics, JOE and IEJ respectively. A formula was devised as follows for the search:

ST= (PMsc)- (PMsc NOT [ta])

ST is the number of papers obtained by using MeSH search strategy for that particular source title (IEJ or JOE). **PMsc** is the PubMed search script and **[ta]** is the handle for searching source titles in PubMed.

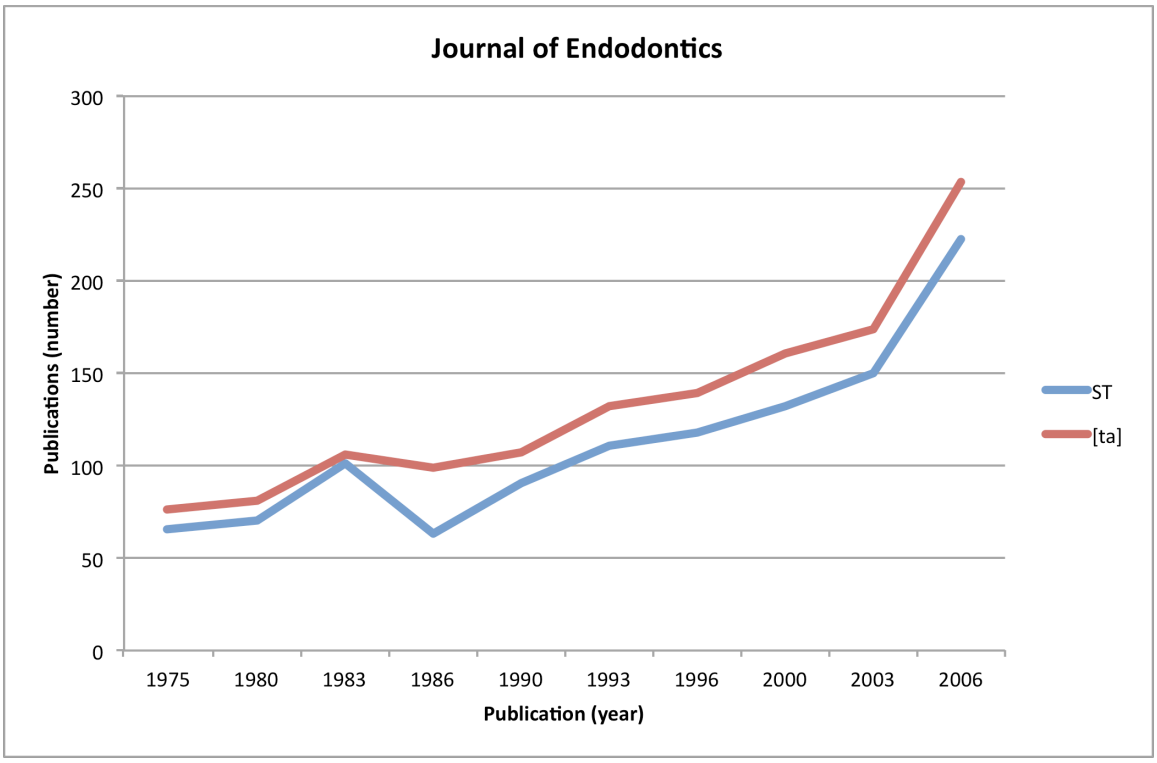


Figure S3: Comparisons between PubMed search script and JOE

Findings

The line graphs **(Figure S3 and S4/Table S2)** show that the number of papers retrieved by using all MeSH headings in PubMed are similar to those retrieved by searching the individual source titles. Of particular interest is the number of papers retrieved by the PubMed search script in JOE in 1986 using the MeSH search strategy. A similar drop in the total number of papers retrieved for IEJ was also noted in 1993.

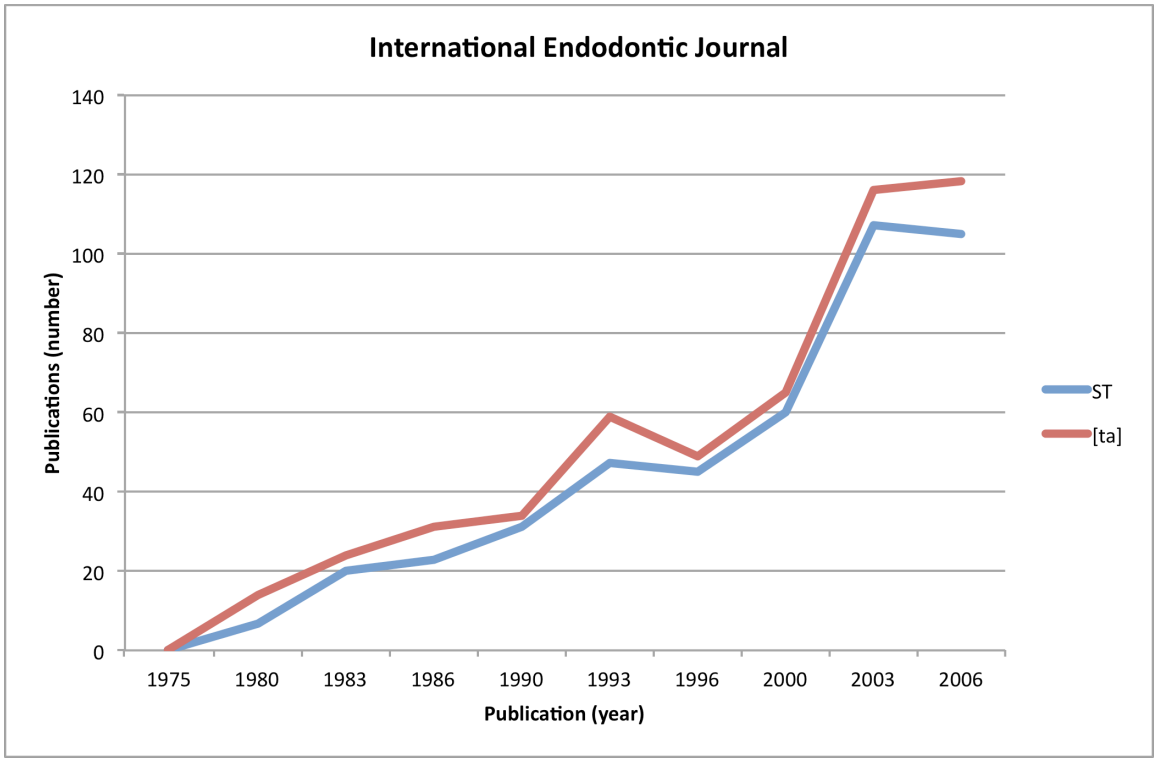


Figure S4: Comparisons between PubMed search script and IEJ

Development of a search strategy for using JCR and Scopus and WoS

These databases do not have index equivalents that are comparable and standardized like MeSH. Therefore to use these databases it was decided to directly use the source title as the "search type" and to use various filters in each to refine the retrieved data.

Overall findings from the search strategy

The main findings from this part of the study showed that there is no difference in utilizing MEDLINE from NCBI Entrez, Ovid Technologies and the Institute for Scientific Information search engines and that the MeSH search scripts are accurate and comparable to the quantity of data retrieved from searching either JOE or IEJ as source titles as the search type. Problems may arise from using the limits of English language in ISI MEDLINE search between 1965-2000 as an unexpected number of foreign language papers may be encountered. In general it seems that the MeSH search scripts may be more specific in retrieving endodontically related papers compared to the total number of papers retrieved by either source titles which may include other documents that include letters, opinions an obituaries.

Chapter 5- RESULTS

Aim and Objective 1

How much has the quantity of endodontic publications increased since ADA recognition of the specialty and what trends are occurring?

The original and specific ISI MEDLINE search script was used *without* English language and time frame 1950-2008 in MEDLINE. The total number of publications retrieved for the total time frame and individual years was recorded.

Ten source titles listed below were then selected within the "source titles" refining filter in ISI MEDLINE to yield the total number of endodontic publications in each source title. Journal selection was aimed at selecting core journals, in endodontics, periodontics, dental research and general dentistry.

Source titles
Journal of Endodontics
International Endodontic Journal
Oral Surgery, Oral Medicine, Oral Pathology
Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology
Journal of the American Dental Association
British Dental Journal
Endodontics and Dental Traumatology
Journal of Dental Research
Journal of Periodontology
Archives of Oral Biology

The results were tabulated and visualized by constructing column and line charts (Microsoft Excel for Mac 2011) followed by descriptive statistics.

Findings

When the raw data was plotted onto a histogram, two specific time periods could be visualized. The first is from 1964-1990, where there is a steady increase in the

number of papers followed by an immediate dramatic decrease at the end of 1989. The second spurt is seen from 1990-2005. **(Figure 1a/ Table 1a).** When the ADA recognized endodontics in 1963, there were a total of 799 papers published and by 2008 there were a total of 34063 papers published. Over the course of four decades there has been over a 40-fold increase in the amount of published endodontic literature retrieved from using MEDLINE.

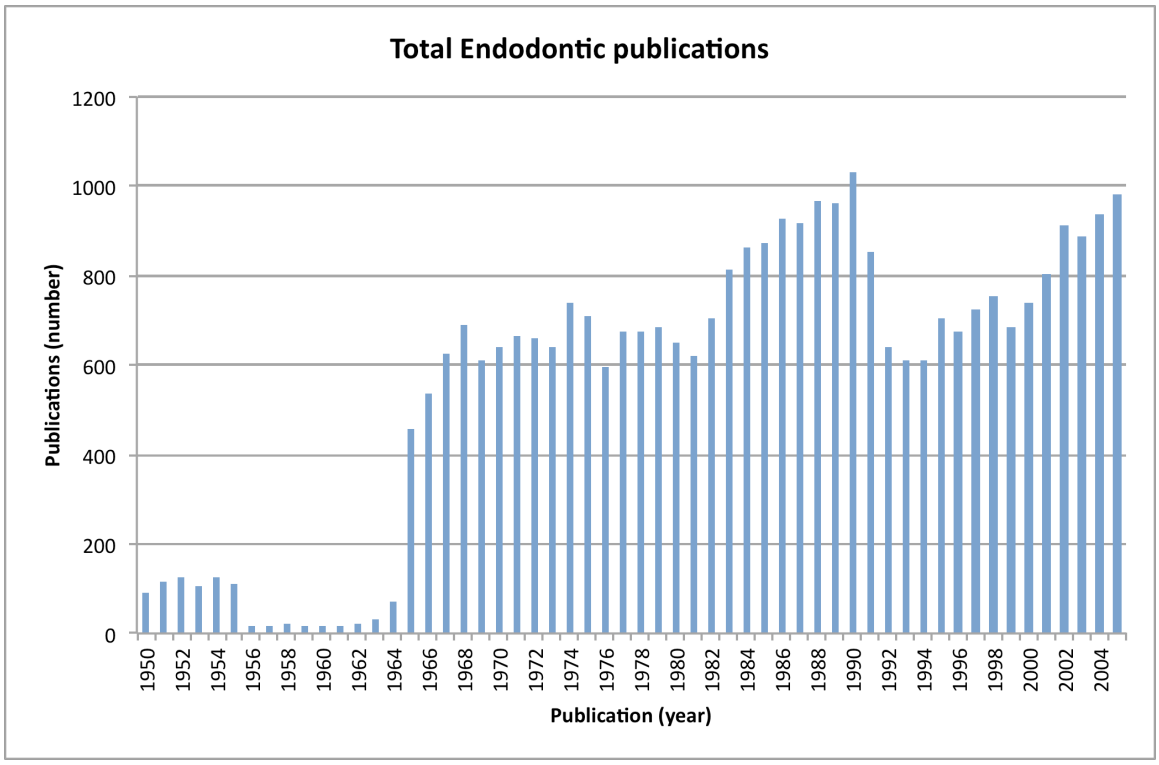


Figure 1a: Quantification of the entire endodontic literature

JOE and IEJ contributed the majority of publications to the source titles from the pool of 10 journals being considered. OOO (becoming OOOOE in 1996) has contributed to the majority of the earlier literature with papers published well before the birth of the JOE and IEJ **(Figure 1b)**.

The total number of papers retrieved from MEDLINE for the entire time period was 37168 **(Table S1)**. The total number of papers **(Table1b)** retrieved by all ten-

source titles was 10380. Therefore 27.9% of the endodontic literature is contributed from the ten selected source titles and JOE, IEJ and OOO/OOOE contribute to 18.53% of the total literature retrieved using this search methodology.

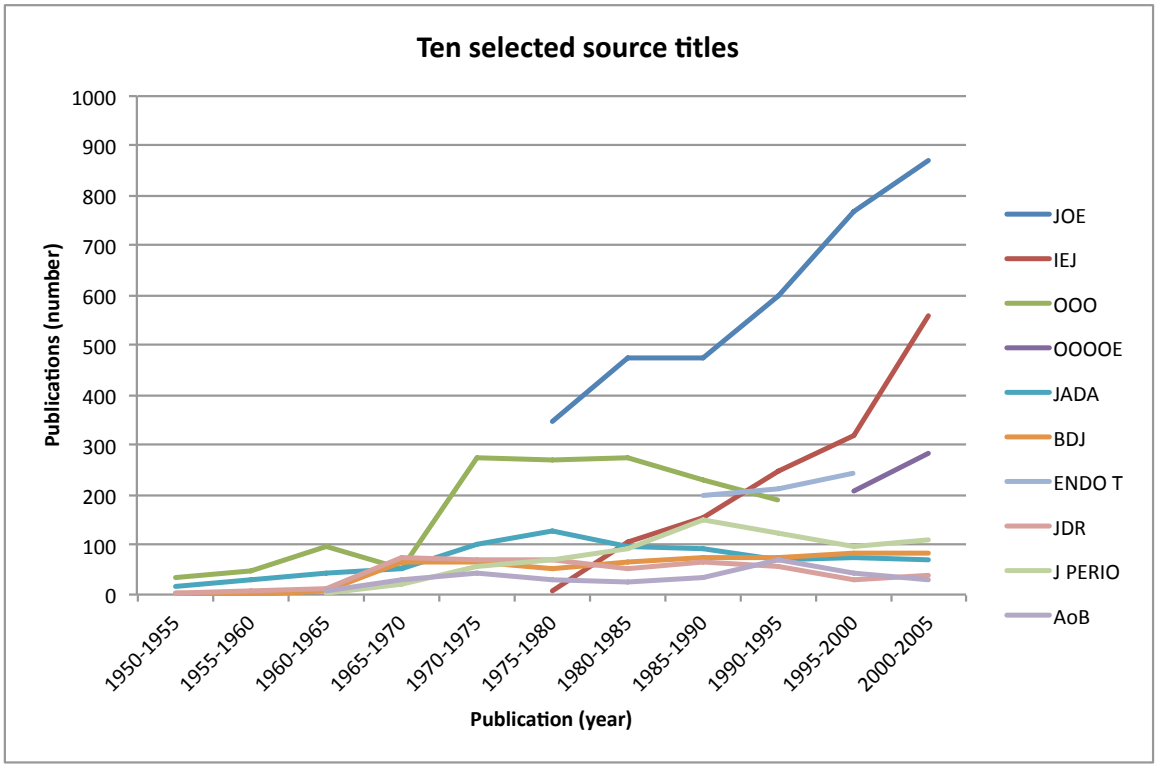


Figure 1b: Source titles contributing to the entire endodontic literature

When using the specific ISI MEDLINE search script with the same search limits, the total number of papers retrieved was 30162. This would mean that around 81.2% of papers from the original ISI MEDLINE search script are endodontically related with the remaining possibly having links to dental implants.

Aim and Objective 2

How does the quantity and types of publications in endodontics compare to that of periodontics and orthodontics?

ISI was utilized to access MEDLINE. The growth of scientific research publications in endodontics was compared to that of orthodontics and periodontics. The search utilized a combination of two journals in each specialty with the highest IF. Journals were selected based upon their IF scores in Journal Citation Reports 2008.

	Source titles	IF
Endodontics	Journal of Endodontics	2.727
	International Endodontic Journal	2.465
Periodontics	Journal of Clinical Periodontology	3.193
	Journal of Periodontal Research	2.038
Orthodontics	American Journal of Orthodontics and Dentofacial Orthopedics	1.442
	Angle Orthodontist	1.166

Combined journals were searched for each specialty using the Boolean operator '**OR**' together with English language. Journals were searched based upon the search strategy results discussed in *part 4*. An example of a typical search entry into the advanced search field in ISI MEDLINE would be SO=(J ENDOD) **OR** SO=(INT ENDOD J) AND Language=(("Eng")), for endodontics, where SO denotes the source title.

In order to then retrieve "scientific research" data, ISI MEDLINE offers a refining filter within the search results called "publication types". Various publication types were selected to correlate to scientific research that did not include reviews, case reports, letters or commentaries. The selected publication types were clinical trial (CT), comparative study (CS), controlled clinical trial (CCT), evaluation studies (ES), in vitro (IV), randomized controlled trial (RCT) and validation studies (VS). Two other publication type categories that were included as part of scientific research

were the following:

- Research support, US GOVN
- Research support NON-US GOVN

The latter two publication types would identify patterns for funding.

The subsequent results were then tabulated (Microsoft Excel for Mac 2011) and calculated to give a percentage increase for growth of scientific research in each specialty. Comparisons for the quantity of research publications were analyzed using analysis of variance (ANOVA). Line graphs were drawn to represent growth that comprised the scientific research for the entire period of 20 years in the three specialties. Column charts were drawn to show the number of publications for specific study types and research funding patterns.

Findings

When expressed as a percentage from the raw data, scientific research publications/year increased in all three areas at similar rates from 1989 to 1995 **(Figure2a/ Table 2a)**. Endodontic publications rose in 2008 to 581% of the 1989 count. Periodontal publications reached 190% and orthodontic articles 323%. Correlation between publication numbers and time was significant ($p>0.05$). When looking at study types, there were more controlled clinical trials in periodontics than in the other disciplines. Comparative studies were the greatest for endodontics and orthodontics. U.S. government funding support was greatest for periodontics **(Figure 2b/ Table 2b)**.

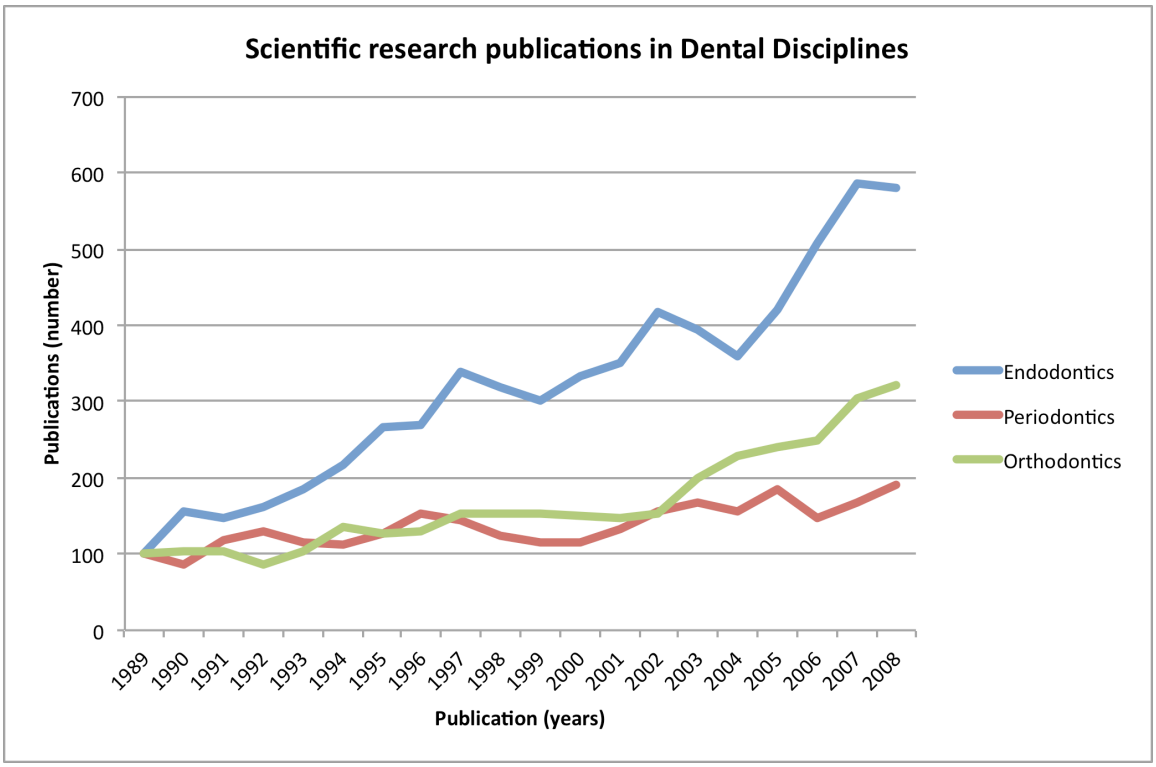


Figure 2a: Growth of scientific research

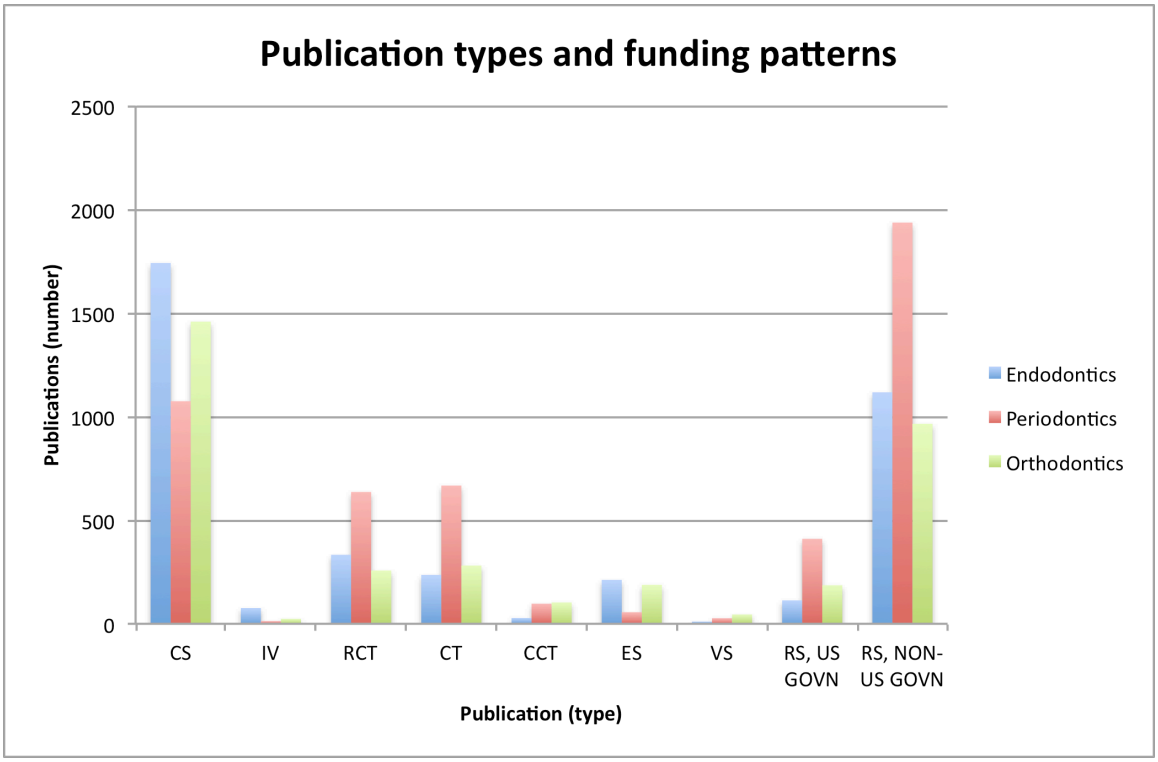


Figure 2b: Types of studies and funding patterns

Aim and Objective 3

What are the clinical publications in endodontics that can aid in decision-making?

To look at clinical publications in endodontics, the 'Clinical Queries' tool in PubMed was utilized. A modified search from the original study by Kim et al[43] was used. Grouped MeSH **(Table F)** headings as described in *part 3* of the search strategy were utilized using the BOOLEAN "**OR**" character for each MeSH term included in each of the five endodontic clinical categories. An example of a search in the "Periapical" area would involve using Periapical Periodontitis [MeSH] "**OR**" Periapical Tissue [MeSH] in the clinical queries search filter. Each ECC was searched to also retrieve specific and sensitive data using further refining filters in the clinical queries tool. Search limits were English language and years 1966-2008. The year of 1966 was merely chosen as this represented the third era of our timeline **(Table I)**, specifically when Moller[50] and Kakehashi[4] studies revolutionized endodontic clinical microbiology.

The results were recorded (Microsoft Excel for Mac 2011) for the total literature retrieved within each endodontic clinical category. Descriptive statistics were utilized to analyze the data and columns charts for presentation.

Findings

The raw data is presented in **table 3** for the five endodontic clinical categories. In general the total number of papers yielding a sensitive search (n=20390) is far greater than that of a specific search (n=1860) for all five ECC's.

For the ECC's (both sensitive and specific searches), the Root Canal contained the

highest number of papers, 10460 (47.0%) and surgery was the least with a total of 1924 (8.65%) papers **(Figure 3a)**.

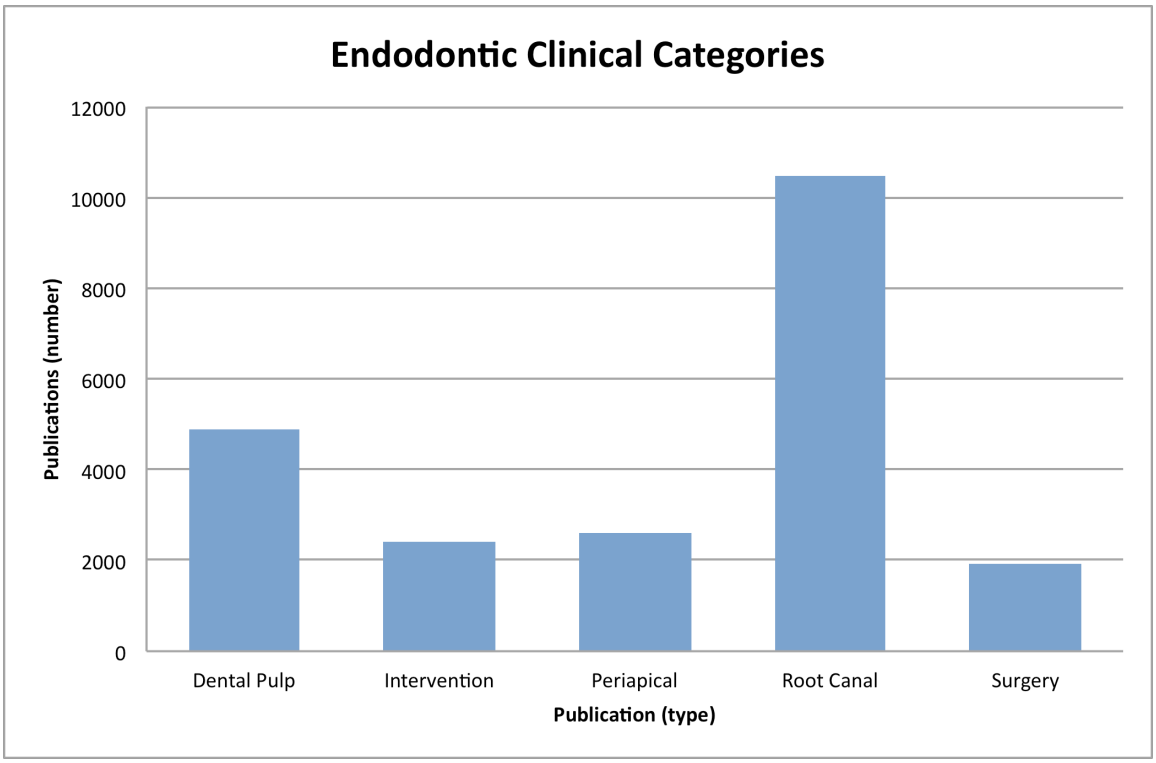
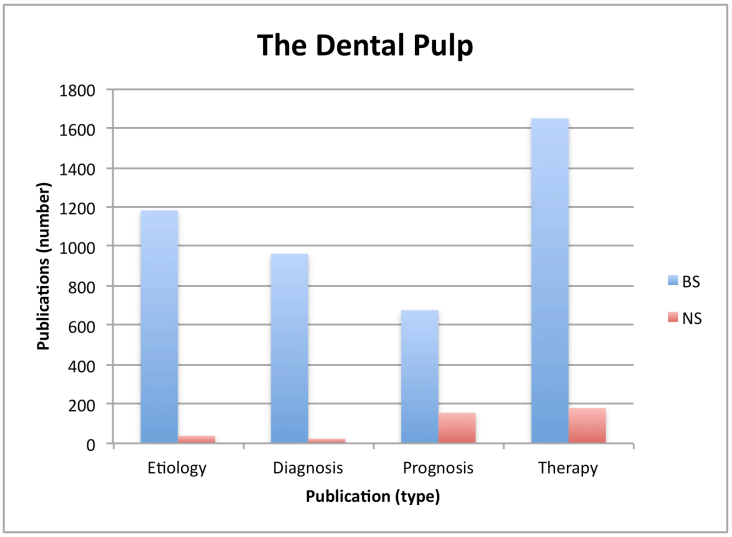
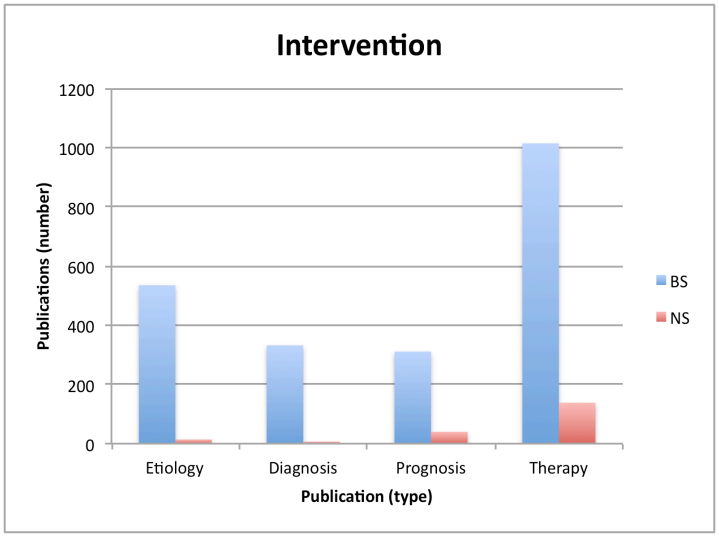


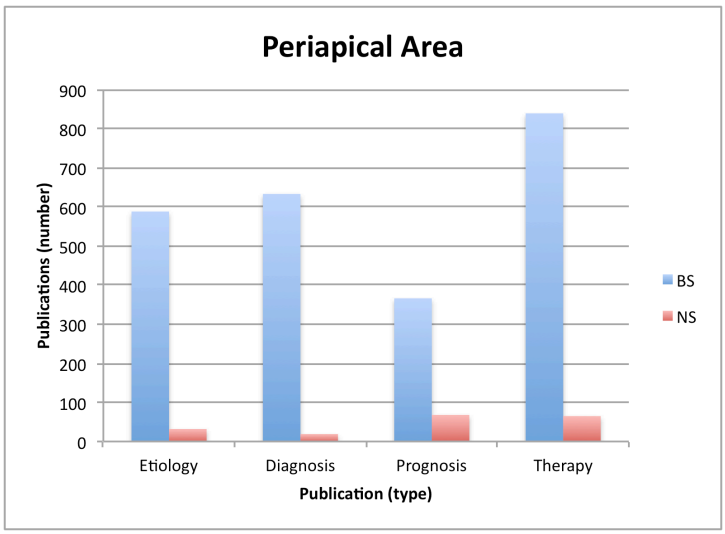
Figure 3a: Number of publications in each endodontic clinical category

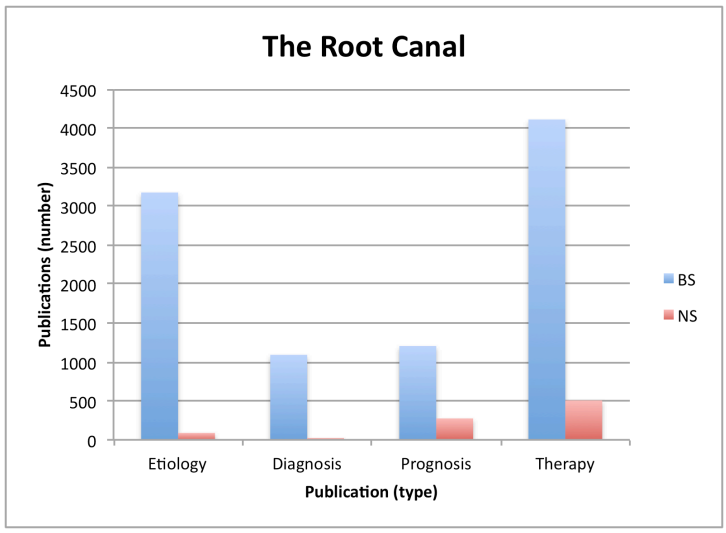
When looking at the clinical categories in each ECC **(Figure 3b)** for a sensitive search, therapy CC consistently yielded the highest number of papers in all ECC's. When disregarding all therapy CC's in each ECC and eliminating the root canal ECC completely, the CC of etiology contained the highest number of papers in the ECC of the dental pulp (41.9%) and diagnosis CC was the highest in the ECC of the periapical area (39.9%).

Of particular interest was the total number of papers retrieved for a specific search in prognosis CC for the ECC of surgery (56.72%). The number of papers for prognosis CC was generally high in all five ECC's for a sensitive search and the number of papers for the CC of diagnosis was the least for all five ECC's.









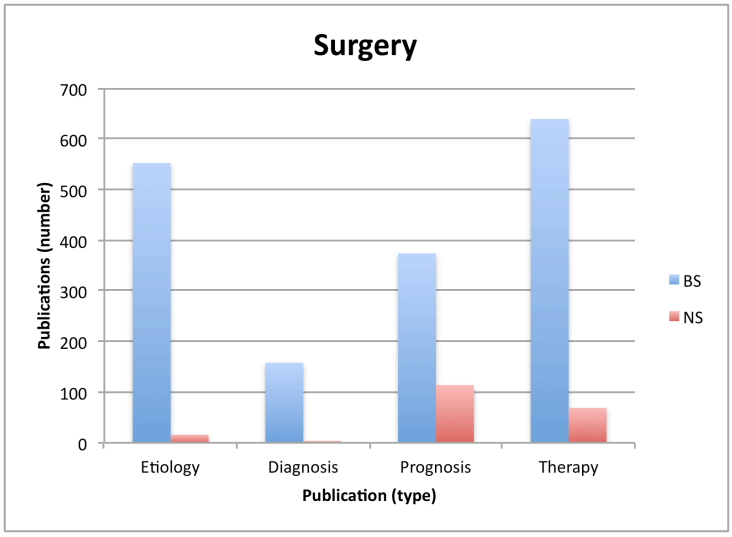


Figure 3b (i) to (v): Number of publications in each ECC for BS and NS searching

Aim and Objective 4

Is there a difference in the number of publications for laboratory and clinical research when evaluated through a hand search for both endodontic source titles?

A unique feature of accessing the Journal of Endodontics through the webpage of the American Association of Endodontists is that publications are traditionally split up into clinical articles, scientific articles and case reports. From May 2003 scientific articles now include sub-sections of biological and technological research and is known collectively as basic research and clinical articles as clinical research. For this thesis traditional content sections of JOE were used. The International Endodontic Journal is accessed through the University of Michigan Taubman Health Sciences Library electronic retrieval provided through a gateway into John Wiley & Sons. A disadvantage to this procedure is that the IEJ does not divide publications into specific scientific and clinical articles and therefore identifying relevant publications requires a hand search. The criteria used for the selection of publications to be included were laboratory research, clinical research and case reports. IEJ content sections were developed and based upon modification of the current Oxford guide for assigning levels of evidence.[51] The total number of publications that fit into each of the contents sections for JOE and IEJ were recorded per year and both source titles were examined from the first pioneer publication to 2005. The results were tabulated (Microsoft Excel for Mac 2011) and Pearson correlation (SPSS v.18, CSCAR online web access) was applied to compare the different types of research in both source titles.

Findings

Raw data obtained for JOE hand search is shown in **Table 4a**. When the data is plotted onto a line graph, it is apparent that the number of scientific articles surpasses that of clinical articles and case reports for the entire time period **(Figure 4a)**. There seems to be a steady rise in the number of scientific articles from 1980 with a dramatic increase from 2003. Clinical articles show a steady increase in the number of publications from 2004 and the patterns of publication for case reports seems relatively unchanged from 1980.

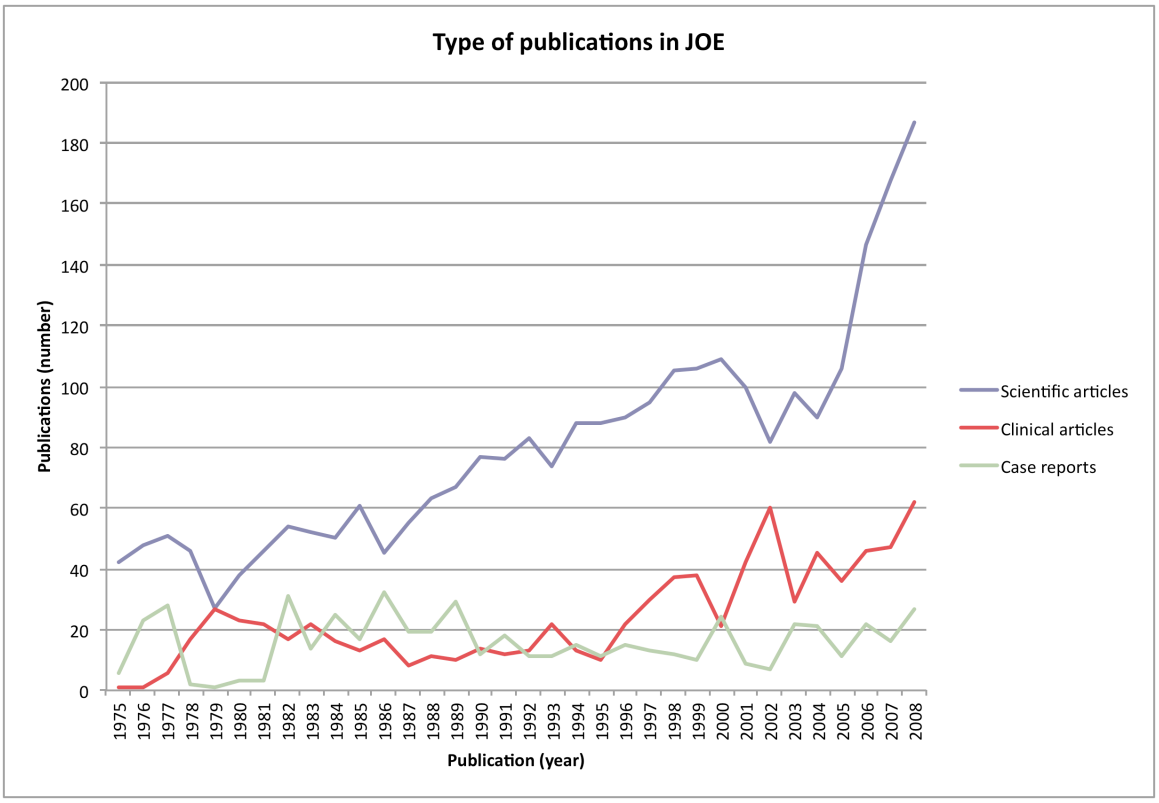


Figure 4a: Comparison of study types in JOE

Raw data obtained for IEJ hand search is shown in **Table 4b.** IEJ shows similar publishing patterns to JOE, in that the number of publications for laboratory research surpasses that of clinical research and case reports for the entire time

period **(Figure 4b)**. Published clinical research and case reports have shown similar trend trends with both showing an increase in 2000.

Pearson regression analysis (SPSS v.18) shows that there is a correlation between the number of scientific articles and clinical articles in JOE (r=0.70). Similar correlations are also evident in IEJ with laboratory and clinical research (r=0.70).

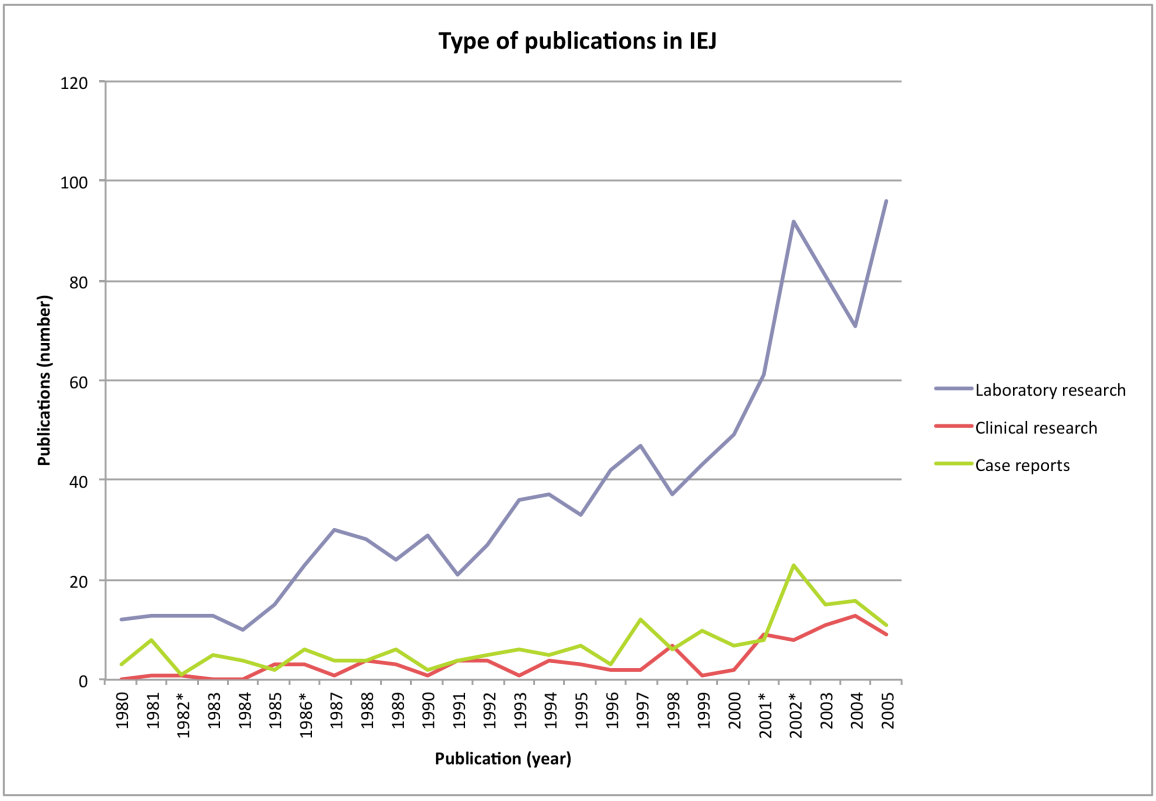


Figure 4b: Comparison of study types in IEJ

When comparing the total number of publications for laboratory research to that of case reports, there was a correlation in IEJ (r=0.815), however there was no correlation in JOE (r=0.189) for the number of scientific articles to case reports. Similar patterns were also seen when comparing correlations for the total number of publications for clinical research and case reports, there was a correlation in IEJ (r=0.666) however there was no correlation in JOE (r= -0.104) for clinical articles

and case reports. Overall it appears that the number of case reports in JOE is declining relative to the number of scientific and clinical articles that are published per year.

Aim and Objective 5

How does the Impact Factor compare in endodontics to that of periodontics and orthodontics?

Journal Citation Reports 2008 was utilized from 1998-2008 using the sub-category selection of 'Dentistry, Oral Surgery & Medicine'. Two source titles were selected to represent each dental specialty (as per *chapter 2*) based upon the highest IF given in 2008. IF for both source titles in each specialty were combined.

The data from all three specialties were tabulated, represented graphically (Microsoft Excel for Mac 2011) and compared using descriptive statistics.

Findings

The raw data is shown in **Table 5** to compare the growth of the IF in the three dental specialties.

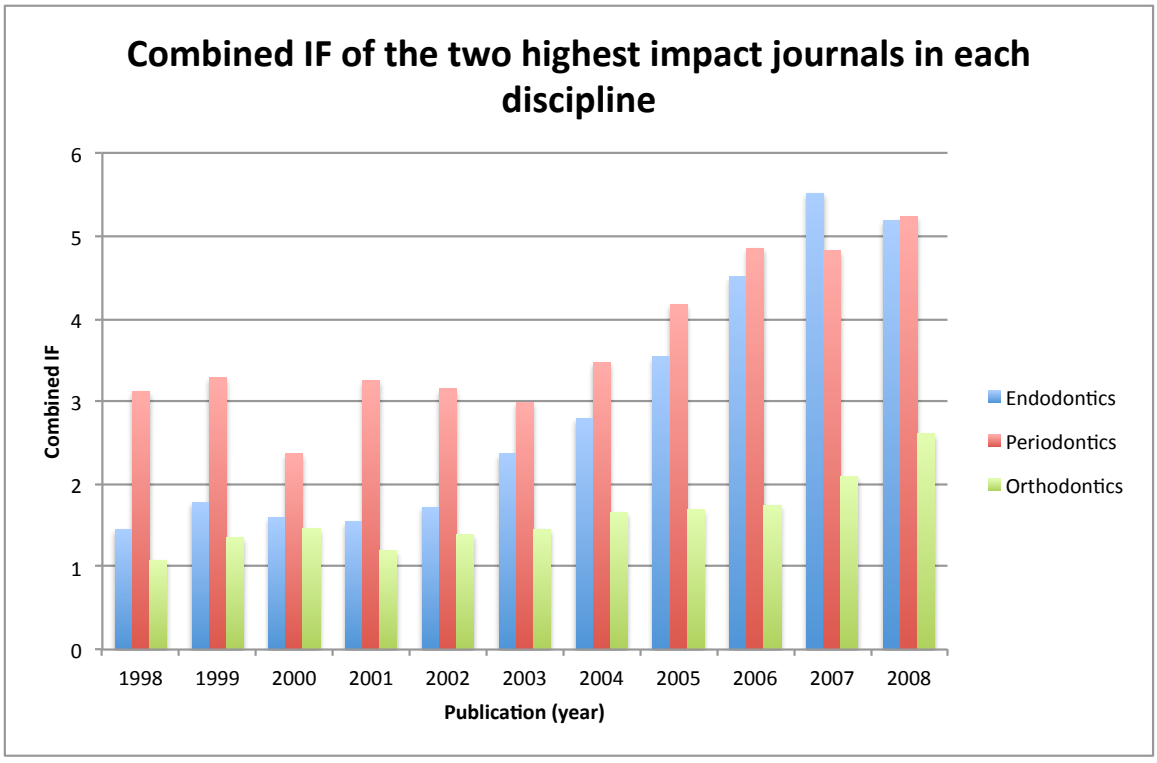


Figure 5a: Combined IF for dental disciplines

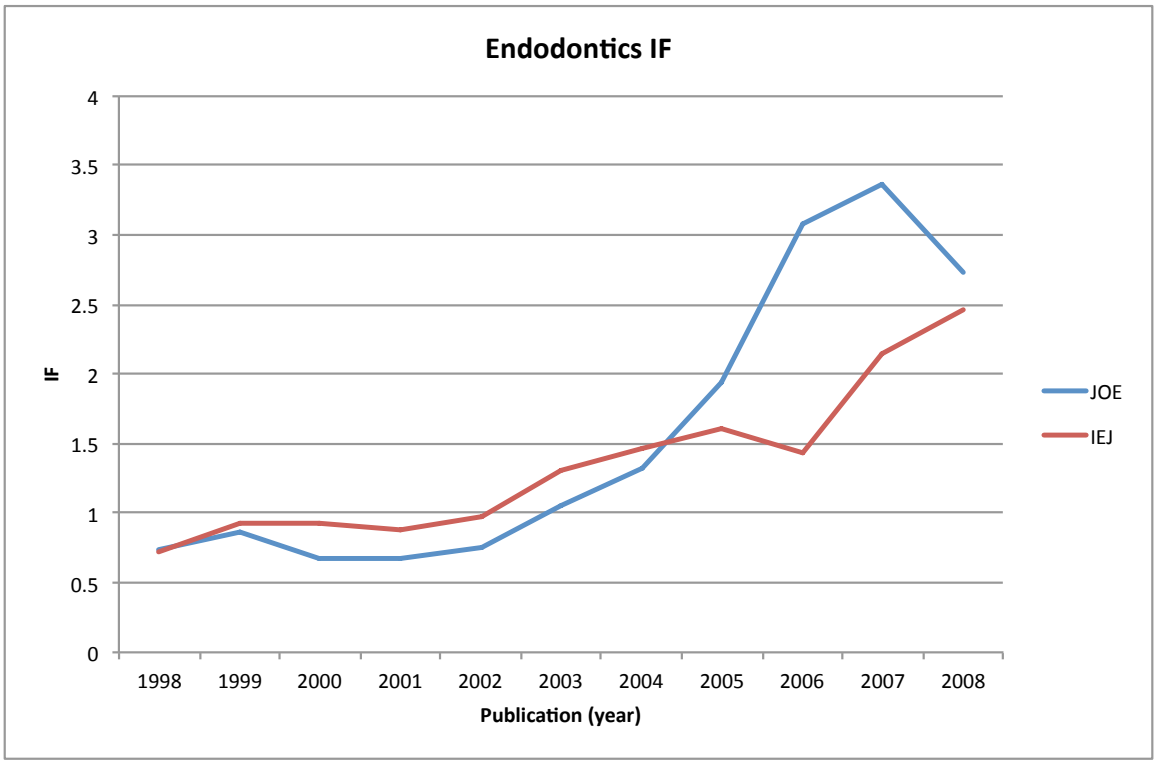


Figure 5b: Comparison for IF in JOE and IEJ

When plotted as a column chart for the combined source titles in each dental discipline, the raw data shows that the IF of endodontics has increased considerably to that of orthodontics and has surpassed that of periodontics in 2007 **(Figure 5a)**. When looking at the IF for only endodontic source titles **(Figure 5b)**, the IF of IEJ was higher than that of JOE up to 2004 and then the IF of JOE rose significantly up to the end of 2007. The IEJ also had a significant drop in its IF in 2006.

Aim and Objective 6

Are there correlations between the number of authors and length of published papers in the endodontic literature?

The Scopus database was used. JOE and IEJ were hand searched online individually as a source title in the search field. The time frame was from the pioneer publication of both JOE and IEJ up to 2008. Default settings were applied for the "Document Type".

The results window reveals the number of papers, which was recorded. Manual searches of the number of authors and pages per paper were also recorded for each individual year up to 2008. The data was analyzed by using descriptive statistics, and linear regression (SPSS v.18, CSCAR online web access) to compare the two groups.

Findings

The data was tabulated **(Tables 6a and 6b)** and represented on a scatter plot to identify any correlations **(Figures 6a and 6b)**.

Linear regression showed a strong correlation between the number of pages and the number of authors for both source titles with time. R^2 values were 0.925 and 0.956 for JOE and IEJ respectively. The β1 for the slope was 0.869 for JOE and 1.603 for IEJ, indicating that over the time periods examined, as the number of authors increases by 1, the predicted number of pages increases by 1.6 for IEJ and 0.9 for JOE.

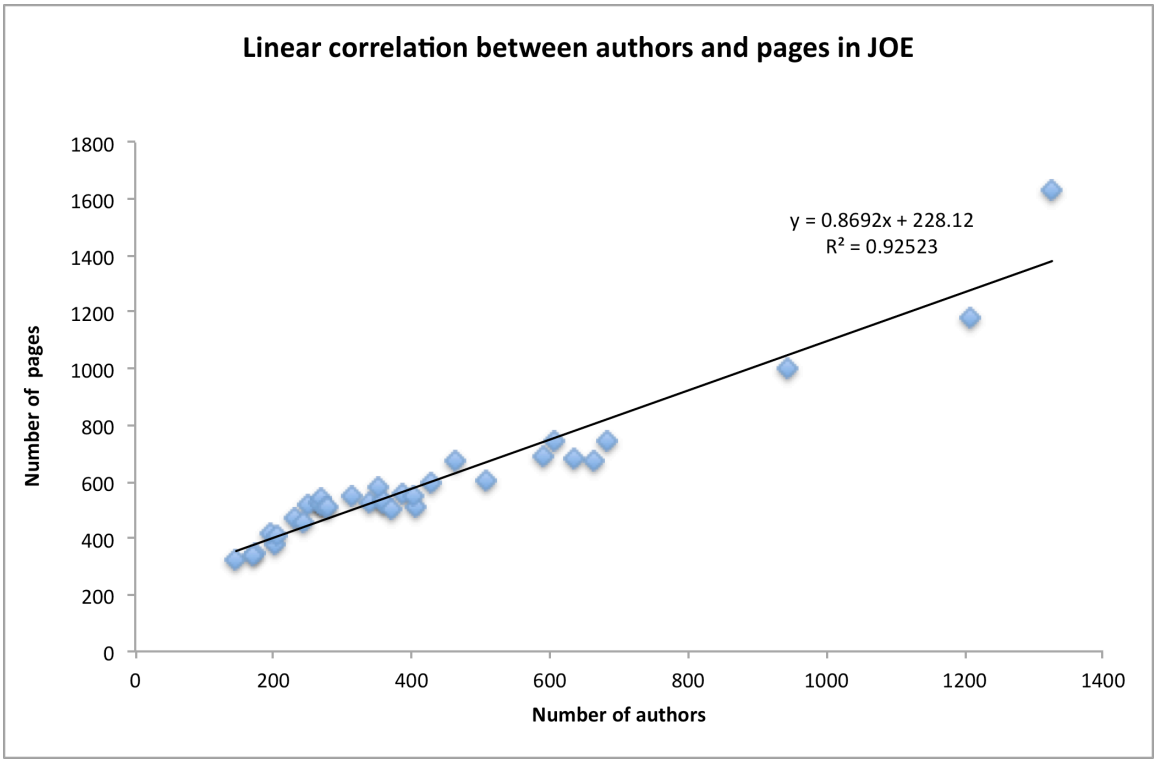


Figure 6a: Correlations between author and length of papers for JOE

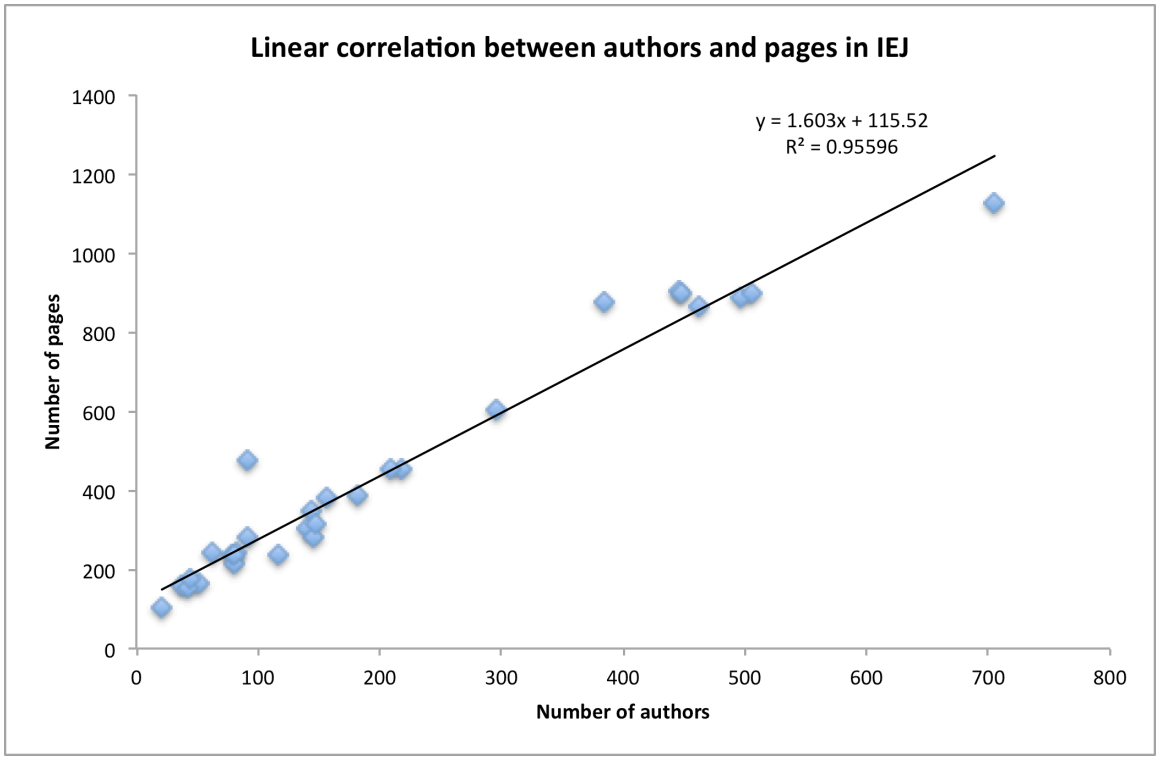


Figure 6b: Correlations between author and length of papers for IEJ

Aim and Objective 7

How often are endodontic articles cited in the general dental, specialty and medical literature and what are the patterns of self-citation?

The Scopus database was used. A list of top ten general dental, specialty dental and medical journals was collected based upon the IF ranking in JCR 2008 **(Table H)**.

JOE and IEJ were used as dedicated endodontic journals from which endodontic citations were to be investigated. When looking for endodontic citations in other source titles, a denotation of (FROM) was given. This denotation merely meant, "citations from JOE or IEJ are cited in other source titles". In order to find FROM citations in JOE and IEJ, each source title was searched individually using 'all document types' and individual years with a range of eleven years, 1998-2008. This part of the search then yielded the total number of publications for a particular year. All the results are then selected and inputted into the 'Citation Tracker' tool. The citation overview now displays all the individual publications cited for a particular year from either JOE or IEJ and also the total number of FROM citations, which was recorded. The total number is selected and data for the ten selected source titles is obtained from using the refining filters.

It was also possible to see how many citations either the JOE or IEJ received. This part of the study was given the "TO" denotation, meaning that "citations to the JOE or IEJ from other source titles" including self-citations. The Scopus "Journal Analyzer" tool was used. Either JOE or IEJ were searched as source titles and the results window reveals the total number of publications, TO citations and self-citations for individual years from 1998-2008. All the results were then tabulated

and depicted graphically (Microsoft Excel for Mac 2011) and compared using descriptive statistics.

Findings

The raw data in **Tables 7a** and **7b** show the number of citations in general dental, specialty dental and medical journals of JOE and IEJ respectively.

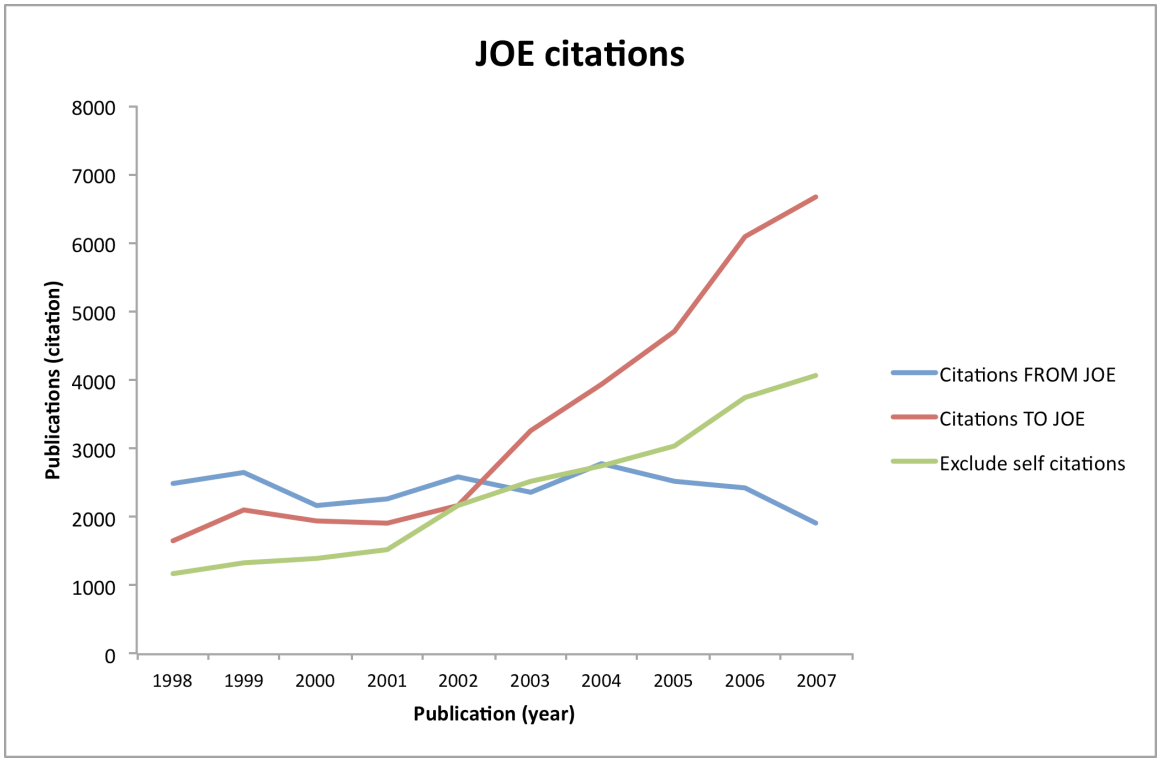


Figure 7c: Citation patterns for JOE

For the general dental journals, 'Dental materials' and the 'American Journal of Dentistry' cited JOE the most within the ten-year period, with an average of 22.0 and 18.3 citations per year respectively. A similar tend was also observed with IEJ.

For the dental specialty journals, the 'Journal of Periodontal Research' and 'Operative Dentistry' cited JOE the most within the ten-year period, with an average of 11.4 and 11.7 citations per year respectively. The Journal of Oral and Maxillofacial

Surgery cited the IEJ 4.7 times from 1998-2007. For the medical journals, only JOE was cited in the 'Annals of Internal Medicine' in 2000 and 2005. No medical citations were retrieved for IEJ.

The raw data for the total number of TO citations and self-citations for JOE and IEJ are shown in **Table 7c**.

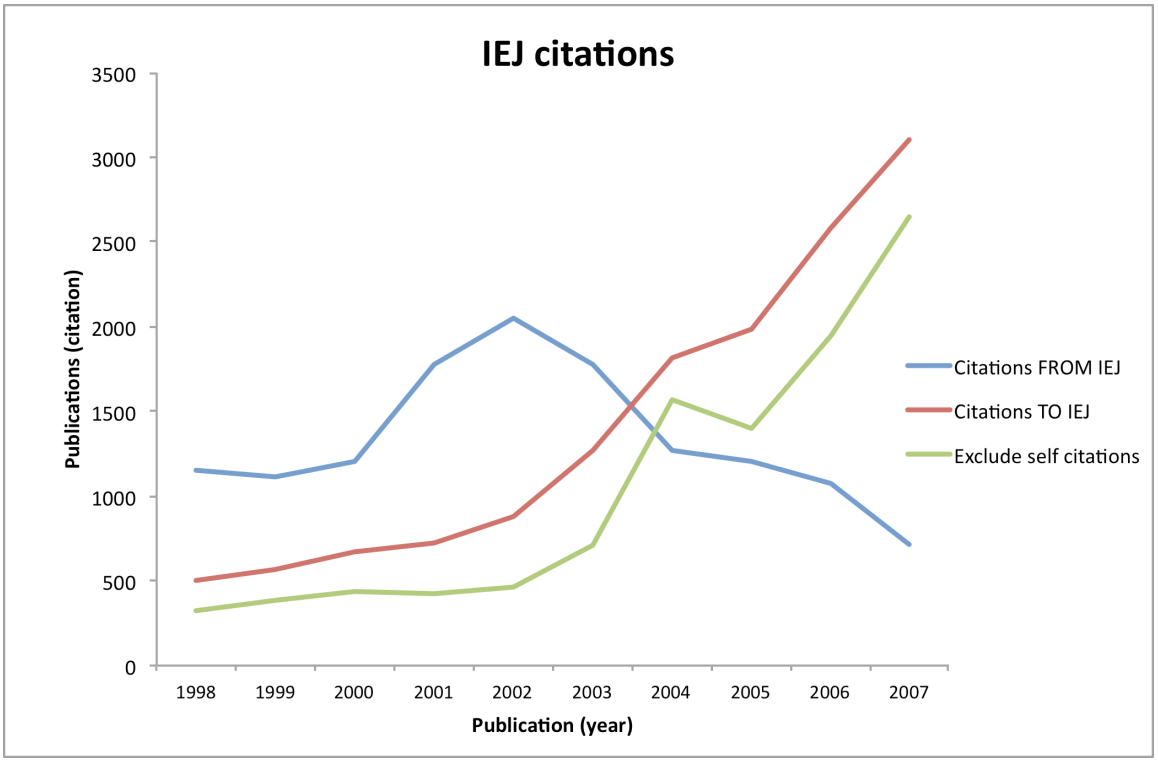


Figure 7d: Citation patterns for IEJ

The total number of TO citations for both source titles including self-citations has been increasing dramatically since 2002 with both showing similar trends. It can also be seen that JOE has more self-citations from 2002 onwards compared to that of IEJ with almost 40% of citations in 2008 coming from self-citations. The number of FROM citations in JOE seems to be generally uniform for the entire time period unlike the number of FROM citations in IEJ, which was over two thousand in 2002 and then dramatically decreased up to 715 in 2007. In general the IEJ is being less

cited over the years in other source titles compared to that of JOE.

Aim and Objective 8

Which dental institutions contribute the greatest number of publications in the disciplines of endodontics, periodontics and orthodontics?

The Web of Science database was used with search limits set for all years. Within each specialty of endodontics, orthodontics and periodontics, the total number of papers was retrieved when combining the two highest IF journals in each specialty. Institutions and countries of origin of literature for each specialty were ranked in the top twenty from the WoS refining filters.

Findings

Raw data was directly taken from the WoS results pages and tabulated to rank the top twenty institutions and countries contributing to the dental literature in endodontics, periodontics and orthodontics **(Tables 8a and 8b)**.

Medical College of Georgia ranked number one for the most endodontic publications and The University of Michigan ranked first for the total number of orthodontic publications and 14th for endodontic publications.

Most of the publications are from authors residing in the United States and Brazil. England makes significant contributions to both the endodontic and periodontic literature where as Canada and Japan make significant contributions to the orthodontic literature.

Chapter 6- DISCUSSION

The current research appears to be the first broad bibliometric study to evaluate the endodontic literature both quantitatively and qualitatively. Overall, endodontics has grown substantially since ADA recognition of the specialty and evidence from citation analysis shows an increase in literature quality.

Development of search strategies was essential to help answer the eight questions proposed in this thesis and two bibliometric search analogies were used. The first involved the use of MEDLINE database for quantification of the endodontic literature and the second, the use of citation databases of JCR and Scopus to determine literature quality. A few studies in dentistry have used MEDLINE[25, 28, 43] to extract data with the use of MeSH headings however only limited number dental specialties have used citation databases to analyze the quality of their literature.[28]

A major limitation to this thesis includes the lack of standardization between search engines in extracting information from various databases,[52, 53] lack of classifications between defining search engines and databases and the lack of standardization of scientific terms in academic communities. Development of search strategies and scientific definition of terms were aimed to account for such errors by formulating search methodologies that were repeatable and paralleled the original AAE definition of the specialty. MeSH headings offer a type of standardization that is consistent with many search engine service providers offering MEDLINE, however the end user must be relatively proficient in utilizing MeSH headings otherwise the search results will lack specificity. The use of other databases such as EMBASE and Cochrane database may also prove useful in further quantifying the endodontic

literature including the analysis of papers outside the English language and the so called "gray literature" which includes information beyond that of published journals[54] such as conference proceedings, reports and doctoral thesis. In general, doctoral theses may contain the best information based upon the original scientific investigation undertaken and published data out of a thesis maybe more geared towards trends and politics of publishing. Evaluating literature quality also poses many challenges due to the variations in methods available and citations are continuously changing when new publications are circulated[21] into the dental field. For example the IF is dependent on the total number of citations divided by the total number of publications of a source title, which does not reflect the true publication pattern of an individual scientist. Therefore a scientist who may frequently appear other than the primary investigator or research coordinator in many publications may falsely allege that she/ he publishes high impact work. Further analyses using other scientific indices such as the h-index[16, 33] may be helpful to evaluate endodontic authors for the quality of published research, which may also aid to identify trends in authorship patterns and group research interests. The analysis of citations has also shown to have many variations between databases.[52] In this thesis, citations were evaluated using Scopus database, however it would be interesting to see if endodontic citation patterns are similar or different in other citation databases such as Google scholar or JCR. Further dissemination of citation patterns can allow for further comprehensive comparisons between endodontics and other dental specialties.

Comparisons between PubMed and ISI MEDLINE in extracting data from MEDLINE

were aimed at testing the validity of retrieval for the total number of publications together with or without the limits of English language. The drop in the number of publications in PubMed using English language was expected, however ISI MEDLINE retrieved many foreign language papers under limits of English language. This was an essential finding and lead to the use of ISI MEDLINE *without* the use of English language limits for quantification of the entire endodontic literature in chapter 1 of the results. This potential error may pose problems for literature searching in ISI MEDLINE for the end-user when a specific search is needed for a publication outside of the English language, however the significance may be questionable for the data presented in this thesis as the majority of papers in endodontics (70%) are published in English language. The study conducted by Kim *et al*[43] looked at the endodontic literature with Endodontics [MeSH] being exploded into a PubMed search. When using the ISI MEDLINE specific search script, it was shown that 18% of the endodontic literature retrieved using the original ISI MEDLINE search script may be related to implants. It would be interesting to view individual titles of these publications and understand their relevance to endodontics. Moreover, the integration of implants into endodontics maybe more embedded into the specialty that we once thought. The analogy behind comparing MeSH vocabulary to the gold standard journals was aimed at evaluating the accuracy of the MeSH vocabulary. The results showed that the PubMed MeSH search script is more specific in retrieving papers possibly indicating that some papers maybe indexed in the JOE or IEJ that do not have identifiable MeSH subject headings[55] or inconsistencies may exist at NLM when papers are indexed with MeSH headings. However the trend lines

support that there is a consistent pattern for data retrieval between using the PubMed MeSH search script and the two gold standard endodontic journals. These results gave confidence in using source titles to extract data when MeSH headings were not indicated or could not be used in other databases such as JCR, Scopus and WoS. This search strategy also proved useful when searching for literature in orthodontics and periodontics.

When the entire literature was quantified, particular trends were evident that could be correlated with the chronological era presented in **Table I**. The end of the second world war demarcated the start of the baby boomer generation where an increase in birth rate ultimately led to the development of better socioeconomic growth, discovery of new technologies and collaboration of pioneers from many countries to ultimately help us better understand endodontic science through research. Of particular interest is the extension of this growth well into the 1980's. We classified this period as the scientific era, where the majority of instrumentation techniques and materials science research were developed, including the addition of RadioVisioGraphy (Trophy Radiologie, Toulouse, France) and nitinol to endodontics.[5] In the early 1990s, there was a sudden drop of about 40% in publications. Possible reasons for this may be attributed to the great recession of 1990[56] where employment rates declined especially in white collar professions such as finance, insurance and real estate.[57] This in turn may have led to a decrease in the number of endodontic treatments that sequentially affected the output of scientific research publications. The regenerative era is a relatively new potential in endodontic research. Initial studies have shown promising results when looking at

pulp re-vascularization. Re-vascularization techniques are not new,[58] however better technologies have refined experimental animal models and subsequent human trials[59] have shown great potential for specific cases. Pulp regeneration from the implantation of scaffolds and generation of living pulp tissue still poses multiple challenges, thus the regenerative era still needs to be defined within the endodontic community.

To look at scientific publications, ISI MEDLINE was utilized as it offers many refining filters that can specifically retrieve papers under particular scientific research categories. We selectively picked nine scientific research categories from the publication types in ISI MEDLINE that could be used to retrieve a scientific research paper. A random hand search was also carried out to verify that the papers retrieved did not include isolated case reports or reviews. The growth of endodontic scientific research was surprising when compared to orthodontics and periodontics in which both are well known to have substantial amount of literature. However, endodontics and orthodontics lack higher-level evidence[51] studies when compared to that of periodontics, where correlations between oral pathogenic bacteria and cardiovascular disease have long been established[60, 61] possibly explaining government funding support. Many older[1] and recent studies[62, 63] in endodontics have tried to identify a link between endodontics and systemic disease and have found no substantial evidence that the presence of a chronic asymptomatic periapical lesion of endodontic origin can lead to a decrease in mortality.[64, 65]

To look for clinical literature in endodontics was a challenging task as a classification of what denotes clinical literature has no standardization in the

endodontic literature.[66] It was therefore decided to split up the clinical literature into clinical publications, clinical articles and clinical research. Standardizations for these terms were difficult for this part of the thesis as terms can be easily mismatched and meanings inferred upon incorrectly. JOE has always published in sub-sections in which papers are categorized into content sections of scientific articles, clinical articles, case reports, reviews or letters, however there are certain discrepancies for the types of studies included into these categories. The IEJ however has no such classification, so a classification was established based upon modification using the Oxford center for EBD.[51] Interestingly the number of papers that were classified as clinical research were very low in the 25 years hand searched in the IEJ, compared to the number of clinical articles in the JOE irrespective of the total publication counts in both source titles. In general both source titles seemed to publish significantly more scientific articles and laboratory based research of low-level evidence[51] and the JOE consistently contained papers in their 'clinical articles' section, which were not actual clinical based research studies.[67] Within the medical literature the Consolidated Standards of Reporting Trials (CONSORT) was established in 1993 to help provide some type of standardization for the reporting of clinical trials.[68] Both the JOE[69] and IEJ[66] have released statements supporting CONSORT guidelines and now adhere to these strict criteria for authors submitting clinical publications under the category of a CONSORT clinical trial.

Four studies[25, 43, 70, 71] have looked at clinical publications by the use of the clinical queries tool in PubMed. The clinical queries tool was established to help clinicians retrieve relevant clinical publications in the four CC of etiology, diagnosis, prognosis

and therapy.[38] Kim *et al*[43] has evaluated clinical publications in endodontics by this method and found that the majority of articles pertained to therapy. Our aim was to modify this method by categorizing each MeSH heading into an ECC and also not to include Endodontics [MeSH] from the specific MeSH vocabulary. Endodontics [MeSH] was removed, as it did not relate to any of the EEC's that were being tested. The number of papers in the root canal ECC and the CC of therapy exceeded that of all other CC in all ECC's, therefore from a clinical point of view, clinicians have significantly more resources that can guide them through root canal procedures in everyday practice. The number of publications relating to etiology and diagnosis were low which is similar to the results of Kim *et al*[43] however the two CC were more evident in the ECC of the dental pulp and periradicular tissues respectively. Overall, with the use of this search strategy it seems that endodontics lacks studies relating to evaluation and causation of disease. Of particular interest was the specific search for prognostic publications in "surgery". Many of these studies are European studies where excellent recall rates provide powerful data.[64, 72] Prognostic studies in endodontics are of importance as they provide data to evaluate the extent of our inventions to controlling periapical disease. Epidemiological studies in endodontics have shown interesting patterns, where multi-casual inference has helped explain certain clinical conditions such as the presence of an endodontically treated tooth with no coronal seal[73] and the absence of clinical or radiographic symptoms. Epidemiology has also helped to evolve new criteria for the evaluation of treatment when comparing endodontics to modern endosseous implants.[74] Such criteria have helped to distinguish between the clinical terms of 'success' and

'survival' in the dental community that were previously leading to false claims about the treatment outcome in endodontics.

When looking at journal quality, scientists and public look upon the citation analysis of IF, which has gained popularity as the gold standard for evaluating quality of, published literature. IF of more than 7500 of the world's most highly cited, peer reviewed journals in about 200 fields of science are produced yearly by the Thomson Reuters Journal Citation Reports. The list grew from 600 journals in 1964 to 2400 in 1972, and every year the number of journals indexed in the database increases by 200.[32] The IF is viewed upon with importance in the scientific community in that applying a specific number to assess the quality of source titles is a simple and easy task.[75] However, the outcome is that governments use such bibliometrics to rank universities and research institutions.[19, 20] "These practices can compel scientists to submit their papers to journals at the top of the IF ladder and circulate progressively through the journals ranks when they are rejected."[20] This can waste time for editors and those who peer-review papers and it is disappointing for scientists, regardless of the stage in their career.[20] In general larger journals have larger IF,[32] therefore comparing dentistry journals, especially specialty journals such as JOE, JCP and AJDO to that of medical journals has no significance of the quality of research. Overall articles should be evaluated individually against levels of evidence[12] together with the personal experience of the reader, not collectively in journals in which they are published. Endodontic program directors also give importance to high IF journals and highly cited papers.[18] The astute program director should personally evaluate the classic and

current literature based upon study design and findings and confer this information to graduate residents.

Combining IF for each source title in each dental specialty was aimed at comparing the quality in growth of publications. The results need to be interpreted with caution, as the combining of IF is not an accurate mathematical model to measure quality of research in a particular discipline as bias can arise from which source titles are selected and included. For example Periodontology 2000 was not included as one of the two highest IF for periodontics as the first publication was in 1993. Results show that the IF of endodontics has increased dramatically since 2001 when compared to periodontics and orthodontics. However the IF of the two gold standard endodontic journals showed interesting patterns. The IF of JOE superseded that of the IEJ in 2005 and both JOE and IEJ show an increase in the number of TO citations from the results using Scopus. Such dramatic IF changes in JOE may be attributed to the eagerness of editors to confer upon authors to cite multiple references per publication. In general it appears that the number of citations including self-citations is on the rise, especially in JOE, which is ultimately leading to an increase in IF. The results from this can also be correlated with the results from the linear regression when comparing the number of authors and pages in JOE and IEJ. In general both source titles are showing and increase in one page per addition of one author to a paper. If this is the case, then the addition of an author can ultimately lead to an increase in the number of citations per paper hence the increase in IF of endodontics when looking at both JOE and IEJ IF combined. Several authors also tend to cite previous papers in the same journal and editors may cite

editorials. Some journals have been known to try to manipulate the IF by writing to authors asking them to add references to articles published in that journal.[76] Pressures of publishing may be another contributing factor to the quality of research due to competitions for the number, types and funding support of research projects. Publications in languages other than English can also have detrimental effects on citation rates. [53]

When comparing the quality of JOE and IEJ publications against levels of evidence,[51] the hand search shows that if strict criteria are adapted then many studies fall into publications that are primarily comprised of laboratory based experiments (*chapter 4*). However when adopting loose criteria as regarded in the sections of JOE, more clinical articles become evident regardless of the fact that JOE publishes substantially more papers than the IEJ per year. The adoption and selection experimental criteria can vary results substantially and can have an impact on the overall message that can be inferred to public, university research communities and private institutions.[77]

Endodontic citations were also evaluated in ten top IF general dental, specialty dental and medical journals. DM has cited JOE and IEJ the most within the last ten years. Materials science has a large role in endodontic research, and will continue to do so especially with the aim of looking into more biocompatible materials.[6] JADA and BDJ also tend to cite both source titles as these are common dental journals that are at the reach of general dentists and are part of professional organizations such as the ADA and the British Dental Association respectively. Within specialty journals, on average OD tended to cite JOE and IEJ frequently however JPD cited JOE

an average of eleven times compared to IEJ at four times. It would be interesting to see the titles of the publications in JPD that are citing JOE so frequently. The lack of citations in medical journals can be explained by the lack of knowledge between any correlations of periapical disease and systemic disease.

Overall it appears that the methods of measurement for research quality are so broad that a definitive conclusion on the overall quality of endodontic research cannot be established. Standardizations for research quality should be established between both endodontic source titles for what exactly contributes a laboratory research category or a clinical research category, perhaps by also engaging a consensus between with the AAE and the European Society of Endodontics (ESE). If both organizations work closer together then multi centre worldwide studies could be carried out that can offer many advantages for the types of research and educational resources that can be offered to dental professionals.

The majority of endodontic research originates from the United States and Brazil possibly explained by the vast number of endodontic specialty training programs and the existence of the AAE. Of particular interest would be to review the research priorities from the AAE and to see how much funding is donated and which institutions are at the top end of receiving such support. Canada has also contributed to the wealth of endodontic knowledge with research publications from the current graduate endodontic program at the University of Toronto together with occasional funding from the continuing educational body of the Canadian Academy of Endodontics.[78] A new pilot program has also commenced at the University of British Colombia in 2009. Endodontics has also evolved in Europe with England

being the third top publishing country for research in endodontics.

The future for endodontics is bright. Collectively, endodontics has developed and evolved to become a fully self-sufficient dental specialty and is considered a separate faculty from restorative dentistry. The role of the endodontium and its management is the precursor for successful tooth rehabilitation, which has been reported in numerous publications[74] consistent with all studies types. The modern role of implants have challenged this phenomenon and the AAE has acted to help correct false disseminations through research[79, 80] and position statements[79] to general dentists and the public. Future endodontists must adhere to these principles and not let false information succumb our profession into a plague of tooth extractions, which once was a treatment of choice during the focal infection era. Educational research should continue to be a forefront in endodontics, where endodontists can participate in helping to deliver the most recent best evidence to the world.

More laboratory-based studies also need to be implemented into human trials and outcomes should be evaluated to identify if significant improvements are being made compared to traditional techniques. For example, the evolution of the 'regenerative era' needs to implement ideas into clinical settings where outcomes can be evaluated and tested. Ultimately the question to be asked "is the treatment outcome of a tooth undergoing regenerative techniques different to that of traditional techniques and is this treatment option cost effective to the patient?"

Other questions also need to be addressed that include the significance of pulpitis and systemic disease,[62] which may in turn increase government supported funding

if correlations become evident. Diagnosis has always been difficult in endodontics due to variations in presentation of periapical disease. Advancements in diagnosis could include early analysis of dentinal fluid specimens[81] from cavity preparations that may give insight into the status of pulpal inflammatory changes, where early intervention from drug and gene based approaches may eliminate the need for future pulp extirpation. Other advancements may include local drug based therapies[82] through the use of nanotechnology especially in cases of persistent periapical disease or in the immunocompromised patient. Such molecular based approaches are full of exciting potential, however like regenerative endodontics, the complete knowledge of all cellular events including all cell signaling cascades and the timing of each specific individual pathway remains a mystery. Ultimately, we need to understand the entire system as a whole before dental pulp and teeth are grown successfully in vivo.

Improvements in visual technologies include the advent of cone beam computed tomography to evaluate periapical disease[83] where three dimensional images are reconstructed to provide multi-planar views of the root canal system with superior image resolutions. Three-dimensional technology is currently being implemented into many medical applications and could be introduced into endodontics as real time endodontics, where the practitioner can visualize every portion of the root canal system during treatment. Other ideas from medical applications include the use of robotics to perform root canal treatments and apical surgeries. The use of biological materials derived from natural resources[84] may prove to be more biocompatible and offer better alternatives for healing. Nitinol technologies will

most likely remain as a standard for rotary endodontics as it offers many advantages as well as being relatively cheap to manufacture. The ongoing search for improvements in metallurgy for canal instrumentation and compactable plastics for root canal obturation continue to be exhaustive, however no recent developments have shown any improvements in the overall outcomes to traditional root canal treatment.[85] Other possible routes to root canal instrumentation that are being evaluated include the use of lasers and photo-activated disinfection.[86] The application of minimal mechanical techniques has been studied before[87] however, with the advent of newer technologies, it may drive endodontics into another era. Certainly the future will provide a new series of treatment options to the patient beyond that of traditional mechanical techniques.

Finally, database search methodologies like the ones presented in this thesis may be used as algorithms in computer web based programs at endodontic training institutions. Such programs could help endodontists, general dentists, students and public to retrieve any type of information relating to endodontics best suited to the scientific interest of the end-user.

Conclusions

- There has been a considerable increase in the amount of literature since ADA recognition of the specialty.
- JOE, IEJ and OOO/OOOE contribute to 18.53% of the total endodontic literature.
- The growth of scientific research publications in endodontics in is far superior compared to that of orthodontics and periodontics.
- Endodontics lacks level high evidence studies specifically those of clinical and randomized clinical trials.
- Government funding is the highest in periodontics.
- There are more clinical publications relating to the clinical categories of therapy when compared to that of etiology, diagnosis and prognosis in endodontics.
- Combined IF of endodontics is similar to that of periodontics.
- The number of authors and the number of pages per paper are increasing over time for both endodontic source titles.
- Both JOE and IEJ cite many papers per article, however both are being less cited by other source titles.
- Both JOE and IEJ participate in self-citations with a considerable increase in JOE.
- The endodontic literature has a very limited impact in the medical literature.
- Majority of research originates from US, Brazil and England.

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Appendices

Appendix 1 Presentations

"DIFFERENCES IN NUMBER AND TYPE OF RESEARCH PUBLICATIONS IN DENTAL DISCIPLINES".

Poster presentation:

- The University of Michigan Research Day, February 2010: *First prize*
- American Association of Dental Research (AADR) meeting in March 2010.

Appendix 2 Tables corresponding to figures

Endodontics [MeSH]

⇒ Dentistry

- ♦ Endodontics
  - ▪ Apicoectomy
  - ▪ Dental Implantation, Endosseous, Endodontic
  - ▪ Dental Pulp Capping
  - ▪ Pulpectomy
  - ▪ Pulpotomy
  - ▪ Root Canal Therapy
    - → Apexification
    - → Dental Pulp Devitalization
    - → Root Canal Obturation
      - ○ Retrograde Obturation
    - → Root Canal Preparation
  - ▪ Tooth Replantation

Table A

Medical Subject Headings

MeSH Headings	
Apicoectomy	**Periapical Tissue**
Dental Pulp Necrosis	**Pulpitis**
Dental Pulp Calcification	**Pulpotomy**
Dental Pulp Capping	**Pulpectomy**
Dental Pulp Test	**Root Canal Therapy**
Dental Pulp Diseases	**Root Canal Preparation**
Dental Pulp Exposure	**Root Canal Obturation**
Dental Pulp Devitalization	**Root Canal Irrigants**
Dentin, Secondary	**Root Canal Filling Materials**
Endodontics	**Retrograde Obturation**
Gutta-percha	**Tooth, Nonvital**
Periapical Abscess	**Tooth Replantation**
Periapical Periodontitis	**Tooth Apex**
Periapical Granuloma	**Tooth Root**

Table B

Search scripts for MEDLINE

PubMed *search script*

Apicoectomy[MeSH] OR Dental Pulp Necrosis[MeSH] OR Dental Pulp Calcification[MeSH] OR Dental Pulp Capping[MeSH] OR Dental Pulp Test[MeSH] OR Dental Pulp Diseases[MeSH] OR Dental Pulp Exposure[MeSH] OR Dental Pulp Devitalization[MeSH] OR Dentin, Secondary[MeSH] OR Endodontics[MeSH] OR Gutta-percha[MeSH] OR Periapical Abscess[MeSH] OR Periapical Periodontitis[MeSH] OR Periapical Granuloma[MeSH] OR Periapical Tissue[MeSH] OR Pulpitis[MeSH] OR Pulpotomy[MeSH] OR Pulpectomy[MeSH] OR Root Canal Therapy[MeSH] OR Root Canal Preparation[MeSH] OR Root Canal Obturation[MeSH] OR Root Canal Irrigants[MeSH] OR Root Canal Filling Materials[MeSH] OR Retrograde Obturation[MeSH] OR Tooth, Nonvital[MeSH] OR Tooth Replantation[MeSH] OR Tooth Apex[MeSH] OR Tooth Root[MeSH]

Ovid MEDLINE *search script*

exp Apicoectomy OR exp Dental Pulp Necrosis OR exp Dental Pulp Calcification OR exp Dental Pulp Capping OR exp Dental Pulp Test OR exp Dental Pulp Diseases OR exp Dental Pulp Exposure OR exp Dental Pulp Devitalization OR exp Dentin, Secondary OR exp Endodontics OR exp Gutta-percha OR exp Periapical Abscess OR exp Periapical Periodontitis OR exp Periapical Granuloma OR exp Periapical Tissue OR exp Pulpitis OR exp Pulpotomy OR exp Pulpectomy OR exp "Root Canal Therapy" OR exp "Root Canal Preparation" OR exp "Root Canal Obturation" OR exp "Root Canal Irrigants" OR exp "Root Canal Filling Materials" OR exp Retrograde Obturation OR exp Tooth, Nonvital OR exp Tooth Replantation OR exp Tooth Apex OR exp Tooth Root

ISI MEDLINE *search script*

mh:exp=Apicoectomy OR mh:exp=Dental Pulp Necrosis OR mh:exp=Dental Pulp Calcification OR mh:exp=Dental Pulp Capping OR mh:exp=Dental Pulp Test OR mh:exp=Dental Pulp Diseases OR mh:exp=Dental Pulp Exposure OR mh:exp=Dental Pulp Devitalization OR mh:exp=Dentin, Secondary OR mh:exp=Endodontics OR mh:exp=Gutta-percha OR mh:exp=Periapical Abscess OR mh:exp=Periapical Periodontitis OR mh:exp=Periapical Granuloma OR mh:exp=Periapical Tissue OR mh:exp=Pulpitis OR mh:exp=Pulpotomy OR mh:exp=Pulpectomy OR mh:exp=Root Canal Therapy OR mh:exp=Root Canal Preparation OR mh:exp=Root Canal Obturation OR mh:exp=Root Canal Irrigants OR mh:exp=Root Canal Filling Materials OR mh:exp=Retrograde Obturation OR mh:exp=Tooth, Nonvital OR mh:exp=Tooth Replantation OR mh:exp=Tooth Apex OR mh:exp=Tooth Root

Table C

Specific Medical Subject Headings

Specific MeSH headings	
Apicoectomy	Pulpotomy
Dental Pulp Test	Pulpectomy
Dental Pulp Capping	Root Canal Therapy (**explode**) → Apexification → Dental pulp Devitalization → Root canal obturation → Retrograde obturation
Dental Pulp Diseases (**explode**) → Dental pulp calcification → Dental Pulp Exposure → Dental Pulp Necrosis → Dentin, Secondary → Pulpitis → Tooth, Nonvital	Root Canal Irrigants
Endodontics (**no explode**)	Root Canal Filling Materials (**explode**) → Gutta-Percha
Periapical Periodontitis (**explode**) → Periapical abscess → Periapical Granuloma	Retrograde obturation
Periapical Tissue	Tooth Replantation

Table D

Specific Search Scripts for MEDLINE

Specific PubMed *search script*

Apicoectomy[MeSH] OR Dental Pulp Test[MeSH] OR Dental Pulp Capping[MeSH] OR Dental Pulp Diseases[MeSH] OR Periapical Periodontitis[MeSH] OR Periapical Tissue[MeSH] OR Pulpotomy[MeSH] OR Pulpectomy[MeSH] OR Root Canal Therapy[MeSH] OR Root Canal Irrigants[MeSH] OR Root Canal Filling Materials[MeSH] OR Retrograde Obturation[MeSH] OR Tooth Replantation[MeSH] OR Endodontics[MeSH:noexp]

Specific ISI MEDLINE *search script*

mh:exp=Apicoectomy OR mh:exp=Dental Pulp Capping OR mh:exp=Dental Pulp Test OR mh:exp=Dental Pulp Diseases OR mh=Endodontics OR mh:exp=Periapical Periodontitis OR mh:exp=Periapical Tissue OR mh:exp=Root Canal Therapy OR mh:exp=Root Canal Irrigants OR mh:exp=Root Canal Filling Materials OR mh:exp=Retrograde Obturation OR mh:exp=Tooth Replantation OR mh:exp=Pulpotomy OR mh:exp=Pulpectomy

Table E

MeSH headings categorized into ECC

The dental pulp

→ Dental Pulp Diseases [MeSH] (explode)

Intervention

→ Dental Pulp Test [MeSH]

→ Dental Pulp Capping [MeSH]

→ Pulpotomy [MeSH]

→ Pulpectomy [MeSH]

Periapical area

→ Periapical Periodontitis [MeSH] (explode)

→ Periapical Tissue [MeSH]

Root canal

→ Root Canal Therapy [MeSH] (explode)

→ Root Canal Irrigants [MeSH]

→ Root Canal Filling Materials [MeSH] (explode)

Surgery

→ Apicoectomy [MeSH]

→ Tooth Replantation [MeSH]

→ Retrograde obturation [MeSH]

Table F

Definitions for clinical categories

Category	Definition
Etiology	Content pertained directly to causation of disease or condition
Prognosis	Content pertained directly to the prediction of the clinical course of the natural history of a disease with the disease existing at the beginning of the study
Diagnosis	Content pertained directly to the evaluation of a disease process, usually through comparing methods of arriving at a diagnosis
Therapy	Content pertained directly to therapy, prevention or rehabilitation

Data extracted from Haynes RB et al[38]

Table G

Top ten general dental, specialty dental and medical journals

General dental journals (sorted via descending IF:)

1. Journal of dental research (3.142)
2. Dental materials (2.941)
3. Caries research (1.993)
4. Journal of the American dental association (1.849)
5. Archives of oral biology (1.379)
6. American journal of dentistry (1.130)
7. Journal of the Canadian dental association (0.929)
8. British dental Journal (0.916)
9. International dental journal (0.672)
10. Australian dental Journal (0.573)

Specialty dental journals (sorted via descending IF:)

1. Journal of clinical periodontology (3.493)
2. Journal of periodontal research (2.038)
3. International journal of oral and maxillofacial surgery (1.487)
4. American journal of orthodontics and dentofacial orthopedics (1.442)
5. International journal of prosthodontics (1.374)
6. Journal of oral and maxillofacial surgery (1.241)
7. Angle orthodontist (1.166)
8. Journal of prosthothetic dentistry (1.139)
9. Operative dentistry (1.089)
10. International journal of pediatric dentistry (1.072)

Medical Journals (Medicine, General & Internal), (sorted via descending IF:)

1. New England Journal of medicine (50.017)
2. Journal of the American Medical Association (31.718)
3. Lancet (28.409)
4. Annals of internal medicine (17.457)
5. British medical journal (12.827)
6. Annual reviews of medicine (10.985)
7. Archives of internal medicine (9.110)
8. Canadian medical journal (7.464)
9. Annals of medicine (5.435)
10. Journal of internal medicine (5.412)

Table H

Historical Events in Endodontics

1940's: (Establishment of Endodontic Literature)

- 1941, Robinson et al confirms anachoresis in inflamed pulps.
- 1943, Birth of the American Association of Endodontists (AAE) in Chicago, Illinois.
- 1946, the Journal of Endodontia was first introduced by Dr. Balint Orban
- 1948, Limited section in OOO dedicated to endodontics followed by the discontinuation of the Journal of Endodontia

1950's: (Establishment of Endodontic Literature)

- 1956, Birth of the American Board of Endodontics (ABE)
- 1955 Kuttler defined apical anatomy especially the CDJ.
- 1958 Ingle proposed instrument standardization
- 1959, introduction of Sargenti paste

1960's (Bacterial Revolution)

- 1960, Bender et al refuted the focal infection theory, indicating that a bacteremia was not detectable by culture ten minutes after intentional instrumentation beyond the apex, refuting the focal infection theory.
- 1961, Ingle proposed instrument standardization
- 1963, The American Dental Association (ADA) recognized Endodontics as a specialty of dentistry.
- 1963, Zeldow and Ingle showed better success rates at two years following a negative root canal culture.
- 1965, Kakehashi et al proved that indigenous oral bacteria are the result of periapical disease following bacterial contamination of the pulp & root canal space.
- 1966 Moller developed new culture based techniques.
- 1966, Torneck disproved the hollow tube theory originally put forward by Rickert & Dixon in 1931.
- 1966, online indexing of MEDLINE
- 1967 Schilder publishes "Filling root canals in three dimensions"

1970's (Standardization and development)

- 1970, Weine et al introduced the stepback technique for canal preparation, (initially developed by Clem 1969).
- 1975, Birth of the Journal of Endodontics
- 1976, ADA specification 28 established, standardizations for files and reamers.
- 1977, Yee et al introduced thermoplasticized injectable gutta-percha, Obtura.
- 1978, Ben Johnson introduced carrier based obturation (case report)
- 1978, Oynick presented histological evidence of a superior root end material, Super EBA

1980's (Scientific Era)

- 1980, First publication of the International Endodontic Journal, UK.
- 1981 Bystrom showed the effects of NaOCl and instrumentation on reducing bacterial counts compared to saline irrigation.
- 1981 Moller identified specific bacteria in the infected root canal with improved culture methods.
- 1981, Delvanis disproves anachoresis in unfilled canals
- 1982, Goerig introduced the crown down technique for canal preparation
- 1984, Montagense et al, start of the OHIO STATE anesthetic studies
- 1985, Roane introduced the balance force technique.
- 1988, Walia et al introduced Ni-Ti to endodontics
- 1989 Development of RadioVisioGraphy (RVG) in France

1990's (Technological Era)

- 1993 Introduction of Profile rotary instruments and merger of Quality Dental Products with Tulsa Dental Products.
- 1993 First published study on MTA used for retro filling in SRT
- 1994 Kobayashi introduced the ratio method for determining canal length
- 1998 ADA issued a statement that all endodontic programs must incorporate formal microscope training for NSCRT and SRT.

2000's (Regenerative Era)

- 2000 Gronthos publishes first paper on isolation of human dental pulp cells
- 2001 Iwaya published the first case report for placing intracanal antibiotics to promote revascularization of open apex cases
- 2004 Banchs & Trope published the first successful revascularization technique with triple paste using a suggested protocol based upon experimental evidence
- 2004 Introduction of Resilon solid core obturation
- 2008, A consensus was established by the AAE for new definitions to describe clinical symptoms based upon subjective evidence
- 2008, Sonoyama, Discovery of apical stem cells, SCAP cells.

Table I

Total Endodontic publications

YEAR	Publications
1950	91
1951	115
1952	128
1953	107
1954	125
1955	110
1956	15
1957	17
1958	21
1959	15
1960	16
1961	18
1962	21
1963	30
1964	73
1965	459
1966	537
1967	624
1968	690
1969	611
1970	642
1971	666
1972	662
1973	638
1974	740
1975	710
1976	596
1977	673
1978	675

YEAR	Publications
1979	687
1980	650
1981	622
1982	704
1983	815
1984	865
1985	874
1986	926
1987	919
1988	966
1989	963
1990	1030
1991	853
1992	640
1993	611
1994	608
1995	705
1996	675
1997	725
1998	754
1999	684
2000	738
2001	802
2002	910
2003	889
2004	937
2005	979
2006	1056
2007	1126
2008	1324

(Data from ISI MEDLINE Week 4 June 2009)

Table 1a

Ten selected source titles

	JOE	IEJ	OOO	OOOOE	JADA	BDJ	ENDO T	JDR	J PERIO	AOB
1950- 1955			32		16	4		2		
1955- 1960			49		28	0		8		
1960- 1965			95		45	7		12	2	7
1965- 1970			50		53	65		76	22	29
1970- 1975			274		100	67		69	57	41
1975- 1980	347	7	271		126	51		69	68	29
1980- 1985	475	106	276		96	63		51	91	23
1985- 1990	475	155	228		91	76	197	65	150	36
1990- 1995	601	246	189		71	72	212	56	121	68
1995- 2000	767	319		207	75	84	243	31	97	44
2000- 2005	872	559		285	71	83		38	108	29

Total number of publications in endodontics from ten selected source titles.

Table 1b

Comparing scientific research publications in dental disciplines

RAW	Endodontics	Periodontics	Orthodontics
1989	42	110	74
1990	66	95	78
1991	62	129	77
1992	68	142	63
1993	78	128	76
1994	91	124	101
1995	112	141	95
1996	113	168	96
1997	142	157	113
1998	134	135	113
1999	126	128	114
2000	140	125	112
2001	148	146	109
2002	175	172	113
2003	166	184	147
2004	151	173	170
2005	176	202	178
2006	213	162	184
2007	246	186	224
2008	244	209	239

%	Endodontics	Periodontics	Orthodontics
1989	100	100	100
1990	157	86	105
1991	148	117	104
1992	162	129	85
1993	186	116	103
1994	217	113	136
1995	267	128	128
1996	269	153	130
1997	338	143	153
1998	319	123	153
1999	300	116	154
2000	333	114	151
2001	352	133	147
2002	417	156	153
2003	395	167	199
2004	360	157	230
2005	419	184	241
2006	507	147	249
2007	586	169	303
2008	581	190	323

Tables to show RAW data and % for scientific research publications

Table 2a

Number and types of scientific research publications in dental disciplines

	Endodontics	Periodontics	Orthodontics
Comparative studies	1741	1074	1458
In Vitro	76	13	24
Randomized Clinical Trial	333	636	257
Clinical Trial	236	667	281
Controlled Clinical Trial	28	97	103
Evaluation Studies	212	56	188
Validation studies	10	27	45
Research support, US GOVN PHS	113	410	186
Research support, NON-US GOVN	1117	1936	965

Table to show the raw data for the number and type of research including funding support

Table 2b

Number of clinical publications in endodontics

Dental pulp	Broad/ Sensitive	Narrow/ Specific
Etiology	1182	38
Diagnosis	962	24
Prognosis	676	155
Therapy	1649	179
Intervention	Broad/ Sensitive	Narrow/ Specific
Etiology	535	14
Diagnosis	332	7
Prognosis	311	40
Therapy	1014	138
Periapical	Broad/ Sensitive	Narrow/ Specific
Etiology	588	32
Diagnosis	633	19
Prognosis	366	68
Therapy	839	65
Root Canal	Broad/ Sensitive	Narrow/ Specific
Etiology	3174	89
Diagnosis	1091	10
Prognosis	1204	275
Therapy	4111	506
Surgery	Broad/ Sensitive	Narrow/ Specific
Etiology	552	16
Diagnosis	158	2
Prognosis	374	114
Therapy	639	69

Table to show the raw data for the total number of clinical publications retrieved from PubMed using the clinical categories filter.

Table 3

Types of studies (Hand Search)

JOE

Year	Scientific articles	Clinical articles	Case reports	Clinical aids	Review Papers
1975	42	1	6		
1976	48	1	23		
1977	51	6	28		
1978	46	17	2		
1979	27	27	1	1	
1980	38	23	3	2	
1981	46	22	3	1	
1982	54	17	31		
1983	52	22	14	6	
1984	50	16	25	6	
1985	61	13	17	3	
1986	45	17	32	6	
1987	55	8	19	4	
1988	63	11	19		
1989	67	10	29	1	
1990	77	14	12	3	
1991	76	12	18	4	1
1992	83	13	11	7	
1993	74	22	11	9	
1994	88	13	15	8	
1995	88	10	11	9	
1996	90	22	15	5	
1997	95	30	13	2	
1998	105	37	12	2	
1999	106	38	10	5	1
2000	109	21	24	3	1
2001	100	42	9	6	1
2002	82	60	7	1	1
2003	98	29	22		4
2004	90	45	21		4
2005	106	36	11		11
2006	147	46	22		9
2007	168	47	16		19
2008	187	62	27		8

Table to show the total number of papers in each year for each specific study type. Note that in JOE after 2003, scientific studies were sub categorized and biological and technological studies. For the purpose of this study both sub categories were combined

Table 4a

Types of studies (Hand Search)

IEJ

Year	Laboratory research	Clinical research	Case reports	Review Papers
1980	12	0	3	0
1981	13	1	8	1
1982*	13	1	1	6
1983	13	0	5	4
1984	10	0	4	10
1985	15	3	2	7
1986*	23	3	6	0
1987	30	1	4	1
1988	28	4	4	0
1989	24	3	6	2
1990	29	1	2	2
1991	21	4	4	0
1992	27	4	5	3
1993	36	1	6	2
1994	37	4	5	3
1995	33	3	7	1
1996	42	2	3	3
1997	47	2	12	1
1998	37	7	6	3
1999	43	1	10	5
2000	49	2	7	4
2001*	61	9	8	6
2002*	92	8	23	4
2003	81	11	15	6
2004	71	13	16	2
2005	96	9	11	1

Table to show the raw data for specific study types. * Denotes that the number of volumes increased in that particular year

Table 4b

Impact Factor in dental disciplines

Combined IF

YEAR	Endodontics	Periodontics	Orthodontics
1998	1.449	3.125	1.081
1999	1.784	3.291	1.354
2000	1.601	2.372	1.461
2001	1.547	3.254	1.194
2002	1.722	3.152	1.388
2003	2.368	2.989	1.452
2004	2.793	3.475	1.662
2005	3.539	4.172	1.694
2006	4.506	4.852	1.745
2007	5.519	4.824	2.098
2008	5.192	5.231	2.608

IF of JOE and IEJ

YEAR	JOE	IEJ
1998	0.731	0.718
1999	0.863	0.921
2000	0.668	0.933
2001	0.668	0.879
2002	0.748	0.974
2003	1.056	1.312
2004	1.323	1.47
2005	1.933	1.606
2006	3.077	1.429
2007	3.369	2.15
2008	2.727	2.465

Table 5

Authors and length of papers (JOE)

Year	# Papers	# Authors	# Pages
1975	99	202	377
1976	84	174	350
1977	101	195	421
1978	72	146	325
1979	74	169	336
1980	95	204	409
1981	103	230	472
1982	106	250	519
1983	104	242	459
1984	119	265	530
1985	105	269	522
1986	119	270	541
1987	105	274	509
1988	109	314	548
1989	123	338	527
1990	114	278	509
1991	122	359	529
1992	123	358	536
1993	136	352	582
1994	127	372	503
1995	125	406	514
1996	141	386	555
1997	145	429	594
1998	161	463	671
1999	173	589	693
2000	161	508	605
2001	166	401	553
2002	182	662	677
2003	183	634	686
2004	189	607	746
2005	180	682	745
2006	234	943	1005
2007	284	1206	1182
2008	331	1326	1632

Table 6a

Authors and length of papers (IEJ)

Year	# Papers	# Authors	# Pages
1980	14	21	106
1981	23	37	160
1982	26	51	163
1983	24	43	151
1984	25	45	178
1985	29	62	242
1986	31	80	216
1987	37	78	238
1988	47	91	474
1989	38	83	241
1990	34	80	238
1991	42	91	281
1992	40	116	237
1993	59	144	350
1994	51	140	302
1995	51	146	282
1996	49	148	315
1997	59	182	386
1998	54	157	381
1999	63	217	455
2000	65	208	452
2001	88	295	606
2002	129	446	902
2003	117	448	899
2004	107	385	874
2005	123	463	868
2006	128	497	889
2007	118	506	899
2008	143	705	1127

Table 6b

JOE citations in general, specialty dental and medical journals

GEN	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	AVG
JDR	13	12	8	16	16	7	15	13	16	13	12.9
DM	46	30	22	20	23	17	14	20	18	10	22.0
CR	0	3	5	0	3	0	1	0	1	1	1.4
JADA	24	20	14	17	14	20	17	14	14	7	16.1
AOB	9	9	8	9	5	2	7	5	6	6	6.6
AJD	26	37	22	21	16	16	22	13	8	2	18.3
JCDA	10	7	11	7	11	11	11	7	7	7	8.9
BDJ	12	16	11	9	10	3	16	5	7	5	9.4
IDJ	17	10	8	9	9	6	4	6	5	5	7.9
ADJ	18	12	7	9	13	9	8	10	5	1	9.2

SPEC	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	AVG
JCP	12	7	2	3	4	1	1	1	2	0	3.3
JPR	4	5	3	7	8	7	5	1	4	0	4.4
IJOMS	1	1	0	2	2	5	0	0	3	1	1.5
AJODO	2	1	3	4	1	1	0	1	4	1	1.8
IJP	9	3	3	7	6	4	6	2	3	1	4.4
JOMS	4	6	7	6	5	6	8	6	2	2	5.2
AO	1	1	0	4	2	0	3	1	0	1	6.5
JPD	30	20	3	11	10	9	10	9	8	4	11.4
OD	16	27	16	15	11	5	7	10	6	4	11.7
IJPD	5	6	3	3	3	4	0	1	3	2	3.0

MED	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	AVG
NEJM											
JAMA											
LAN											
AIM			1					2			0.3
BMJ											
ARM											
AOIM											
CMJ											
AM											
JIM											

Table 7a

IEJ citations in general, specialty dental and medical journals

GEN	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	AVG
JDR	7	2	5	7	9	9	7	3	7	1	5.7
DM	3	8	10	10	8	10	11	10	11	6	8.7
CR	0	0	0	5	1	0	1	0	0	1	0.8
JADA	6	8	5	10	11	9	5	2	6	2	6.4
AOB	1	3	2	2	5	10	3	4	3	2	3.5
AJD	5	10	13	11	15	11	9	7	5	3	8.9
JCDA	4	5	8	3	6	7	7	9	3	2	5.4
BDJ	8	3	10	9	14	10	8	8	5	6	8.1
IDJ	3	6	9	5	5	7	5	3	4	3	5.0
ADJ	6	9	8	8	12	9	10	8	5	0	7.5

SPEC	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	AVG
JCP	1	2	3	1	2	2	1	0	0	0	1.2
JPR	3	1	0	3	2	1	1	0	0	0	1.1
IJOMS	0	0	1	0	1	1	1	2	0	3	0.9
AJODO	0	0	4	1	2	0	0	1	0	0	0.8
IJP	1	1	3	0	3	0	1	2	1	0	1.2
JOMS	6	3	10	8	5	5	5	3	2	0	4.7
AO	0	3	1	1	0	0	1	0	1	1	0.8
JPD	2	2	6	4	7	4	2	4	6	0	3.7
OD	2	1	2	2	12	6	3	7	11	3	4.9
IJPD	1	4	3	0	4	3	1	1	1	1	1.9

MED	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	VGA
NEJM											
JAMA											
LAN											
AIM											
BMJ											
ARM											
AOIM											
CMJ											
AM											
JIM											

Table 7b

Citations and self citations in JOE and IEJ

	#Documents in JOE	Citations FROM JOE	Citations TO JOE	EX self citations TO JOE
1998	161	2498	1641	1176
1999	173	2660	2102	1333
2000	161	2176	1951	1387
2001	166	2268	1900	1519
2002	182	2581	2178	2178
2003	183	2361	3268	2531
2004	189	2786	3947	2741
2005	180	2532	4699	3051
2006	234	2415	6085	3742
2007	284	1914	6670	4059

	#Documents in IEJ	Citations FROM IEJ	Citations TO IEJ	EX self citations TO IEJ
1998	54	1157	501	324
1999	63	1111	564	380
2000	65	1202	677	438
2001	88	1778	729	425
2002	129	2054	884	459
2003	116	1783	1268	715
2004	107	1272	1818	1564
2005	123	1201	1985	1405
2006	128	1070	2587	1953
2007	118	715	3106	2647

Table 7c

Top publishing schools in Endodontics

Rank	Endodontics	Periodontics	Orthodontics
1	Med college Georgia	Gothenburg Univ.	Univ. Michigan
2	Univ. of Texas	Univ. Bern	Univ. Iowa
3	Univ. of Iowa	Forsyth Dent CTR	Univ. N Carolina
4	Univ. Sao Paulo	Acad CTR Dent Amsterdam	Univ. Washington
5	Loma Linda Univ.	Univ. Oslo	Univ. Illinois
6	Tel Aviv Univ.	Univ. Washington	Univ. Connecticut
7	Univ. Connecticut	Karolinska Inst.	UCSF
8	Univ. Pen	Univ. Pen	Baylor Coll. Dent
9	Univ. N Carolina	Univ. Lund	UCLA
10	Ohio State Univ.	Univ. Helsinki Univ. Texas	Univ. Florence Univ. Oklahoma
12	Baylor Coll. Dent Univ. Washington Univ. Univ. Zurich	Loma Linda Univ.	Univ. Oslo
13	Temple Univ. Univ. Melbourne.	Royal Dent College	NYU Univ. Texas
14	Univ. Michigan	Univ. Connecticut	Univ. Sao Paulo
15	Univ. Minnesota	Suny Buffalo	Harvard Univ.
16	Hebrew Univ. Jerusalem Oregon Health. Sci. Univ. Univ. Toronto	Harvard Univ.	Univ. Alberta Univ. Louisville
17	Acad CTR Dent Amsterdam	Univ. Michigan	Case Western USC
18	Univ. Hong Kong	Columbia Univ.	Ohio State Univ.
19	Univ. Maryland	UCL	Univ. Toronto
20	Marquette Univ.	Univ. Newcastle Upon Tyne	Univ. Florida

Table 8a

Top publishing countries in Endodontics

Rank	Endodontics	Periodontics	Orthodontics
1	USA (2591)	USA (2123)	USA (3961)
2	Brazil (483)	Sweden (775)	Japan (476)
3	England (371)	England (764)	Canada (356)
4	Japan (344)	Japan (556)	Turkey (352)
5	Turkey (258)	Germany (393)	England (261)
6	Germany	Netherlands	Brazil
7	Italy	Switzerland	Italy
8	Israel	Norway	Germany
9	France	Denmark	Sweden
10	Australia Canada Switzerland	Finland	S. Korea
12	China	Canada	Israel
13	Taiwan	Italy	Norway
14	Netherlands	Brazil	Netherlands
15	Sweden	Australia	Greece
16	Greece	Wales	Australia
17	S. Korea	Israel	China
18	Norway	Turkey	Denmark
19	Wales	France	Switzerland
20	Scotland	Spain	India

Table 8b

Database comparison

	PubMed	OVID	ISI
1950- 1955	676	638	655
1955- 1960	194	176	265
1960- 1965	617	604	457
1965- 1970	3564	3567	3391
1970- 1975	4059	4070	4066
1975- 1980	3992	4001	3868
1980- 1985	4531	4571	4556
1985- 1990	5679	5702	5568
1990- 1995	4447	4473	4815
1995- 2000	4285	4304	4080
2000- 2005	5286	5268	5447
TOTAL	37330	37374	37168

	PubMed/ ENG	PubMed/ NO ENG	ISI/ ENG	ISI/ NO ENG
1950-1955	676	676	655	655
1955-1960	96	194	265	265
1960-1965	285	572	412	424
1965-1970	1352	3242	3081	3081
1970-1975	1759	3454	3298	3474
1975-1980	1737	3236	2983	3134
1980-1985	1898	3492	3400	3550
1985-1990	2097	4134	3844	4048
1990-1995	2579	3307	3468	3578
1995-2000	3159	3441	3195	3253
2000-2005	3974	4287	4368	4435
2005-2009	4670	4900	4800	4869

Table S1

Comparing searches by using MeSH terms and source titles

JOE

	ST	[ta]
1975	66	76
1980	70	81
1983	101	106
1986	63	99
1990	91	107
1993	111	132
1996	118	139
2000	132	161
2003	150	174
2006	223	253

IEJ

	ST	[ta]
1975	0	0
1980	7	14
1983	20	24
1986	23	31
1990	31	34
1993	47	59
1996	45	49
2000	60	65
2003	107	116
2006	105	118

Table S2