Top-cited Articles in Endodontic Journals

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Abstract

Introduction: The purpose of this study was to identify the 100 top-cited articles published in journals dedicated to endodontology and analyze their characteristics to describe the quality and evolution of research in the field of endodontology. **Methods:** The Institute for Scientific Information Web of Knowledge Database and the Journal Citation Report Science Editions were used to retrieve the 100 most cited articles published in journals dedicated to endodontics. The top-cited articles were selected and analyzed with regard to journals, authors, institution, country of origin, publication title and year, number of citations, article type, study design, level of evidence, and field of study. **Results:** The top 100 articles were cited between 87 and 554 times. These articles appeared in 4 different journals, with more than half in the *Journal of Endodontics*, followed by the journals *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*, the *International Endodontic Journal*, and *Endodontics & Dental Traumatology*. Forty-eight articles were published between 1990 and 1999. All articles were published in English and primarily originated from the United States (n = 52). The majority of articles were basic science articles (n = 55), followed by clinical research studies (n = 28) and nonsystematic reviews (n = 17). Uncontrolled case series with level IV of evidence and narrative reviews with level V of evidence were the most frequent types of study design. The main topics covered by the top-cited articles were microleakage and endodontic microbiology. **Conclusions:** This analysis of citation rates reveals useful and interesting information about scientific progress in the field of endodontics. Basic research and observational studies published in high-impact endodontic journals had the highest citation rates. *(J Endod 2011;37:1183–1190)*

Key Words

Bibliometrics, citation analysis, endodontics

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0099-2399/$ - see front matter

doi:10.1016/j.joen.2011.05.037

Citation analysis is the field of bibliometrics that uses citation data to quantify the impact of research as illustrated by the number of references that an article receives over time (1). Analysis of the most frequently cited articles is used to identify previous, current, and future research trends within specific topics and to pinpoint the most frequently occurring authors, journals, and institutions (2). Citation rates are assumed to reflect the impact of journal articles, although not necessarily their quality (3).

According to Eugene Garfield (4), founder of the Institute for Scientific Information (ISI) a "citation classic" is a publication that is highly cited in the ISI Web of Knowledge Database. The ISI database via the Science Citation Index Expanded (SCI) and the Journal Citation Reports contains more than 10,000 international journals and provides the complete bibliographical information of these indexed publications (5). SCI is a multidisciplinary index to the journal literature of the sciences. It fully indexes more than 6650 major journals across 150 scientific disciplines and includes all cited references captured from indexed articles.

The features of citation classics have been investigated in the fields of general medicine (6), ophthalmology (7), anesthesiology (8), otolaryngology (9), surgery (10), plastic surgery (11), pain (12), critical care medicine (13, 14), gynecology (15), and traumatology (16). It appears that the first citation analysis in dentistry was conducted in 2007, when Nieri et al (17) identified the most cited articles in periodontology.

Until now, no comprehensive study of the top-cited articles in the field of endodontics has been available. The purpose of this study was to identify the 100 top-cited articles published in journals dedicated to endodontology and to analyze their main characteristics to gain insight into the types of publications influential in this field of dentistry, both now and in the past.

Materials and Methods

The 100 top-cited endodontic articles published in endodontic journals were identified in January 2011 by using the ISI Web of Knowledge Database. In the subject category "Dentistry, Oral Surgery & Medicine" of the 2009 SCI, the following 4 journals had titles containing the term "Endodontic" or "Endodontology": *Australian Endodontic Journal*, *International Endodontic Journal*, *Journal of Endodontics*, and *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*. The journal *Dental Traumatology* (2001–2010) was also considered for inclusion, because it was known as *Endodontics & Dental Traumatology* (1987–2000) until 2001. A search was then performed on the Web of Science of each journal under "Publication Name," and results were sorted by the category "Times Cited." This provided a list of all articles appearing in a given journal ranked by citation count.

The 100 top-cited articles were selected and analyzed with regard to authors, institution, publication name, year of publication, and number of citations. Each article was further reviewed, and basic information was collected, including article type (basic science article, clinical research article, and review), clinical article subtype (clinical–randomized controlled trial, cohort study, case control, case series, case report), level of evidence for clinical articles, and field of study. When a study included experiments on extracted human teeth or on cells, it was considered basic. If the study was microbiological on samples taken from root canals, the material of the study was considered clinical because the research variables in the subject of the study referred to specific patients.

The Sackett initial and updated rules of evidence, as described by the Oxford Centre for Evidence-Based Medicine (18), were used to categorize the type of study design as well as to evaluate the level of evidence. Journal articles were categorized

by field of research where possible. Field of research was defined by subspecialty for clinical articles including endodontic microbiology, success and failure studies, traumatic dental injuries, irrigants, intracanal dressing, restoration, retrograde materials, physicochemical properties of the dentin pulp complex, pulp capping, and obturation. Basic science articles were categorized in 13 categories including leakage, canal instrumentation, obturation, irrigants, intracanal dressing, mineral trioxide aggregate (MTA), physicochemical properties of the dentin pulp complex, radiology, smear layer, bleaching, root canal anatomy, endodontic microbiology, and restoration.

The country of origin was defined by the address provided for the first author, whereas the addresses of additional authors were noted to establish the number and origin of collaborating institutions. A single-institution origin was scored in cases in which all contributing authors came from the same research institution, irrespective of their department.

Results

The 100 articles are listed in Table 1 in descending order of the number of citations they received. The most cited article received 554 citations, and the least cited article received 87 citations. The mean number of citations per article was 146.

Journals and Publication Dates of Top-cited Articles

Among the 100 top-cited articles, there were 54 articles from the *Journal of Endodontics*, 23 from the journal *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* (OOO), 17 from the *International Endodontic Journal*, and 6 from *Endodontics & Dental Traumatology* (Table 2). Considering the wide field of thematology covered by the journal OOO, only articles relative to endodontics were included in this analysis.

The top-cited endodontic articles were published from 1965–2006, with 48 published between 1990 and 1999, 35 before 1990, and 17 after 1999 (Fig. 1). The year 1995 was the year with the greatest number of top-cited articles (n = 12), followed by 1990 (n = 8), 1993 and 1997 (n = 6), and 1972 (n = 5). In addition, 4 top-cited articles per year were published in 1987, 1988, 1994, and 2000.

Authors, Countries, and Institutions

Table 3 summarizes the top-cited authors who contributed to endodontic research and publications. The number of authors of the top-cited articles ranged from 1–8. The first author was M. Torabinejad, with lead authorship in 12 articles of the top 100 list. Twenty persons authored 3 or more of the top-cited articles, 15 articles appeared to be monographs, and 81 articles had between 2 and 5 authors.

According to their country of origin, the list of top-cited articles was led by the United States (n = 52), followed by Sweden (n = 13), Great Britain (n = 7), and Switzerland (n = 6) (Table 4). Australia and Norway contributed 3 articles each, and Brazil and The Netherlands both contributed 2 articles to the list.

The 17 leading institutions appear in Table 5. Loma Linda University in California produced the highest number of endodontic publications (n = 12), followed by the University of Umea (n = 9), University of Zürich (n = 5), and University of North Carolina (n = 5). Of the total articles, 55 came from individual institutions, 13 were from multiinstitutional collaboration within the same country, and 32 were the product of international collaborations.

Research Design, Field of Study, and Level of Evidence of Top-cited Articles

The majority of the articles (n = 55) concerned basic science research, 28 articles reported clinical experience, and 17 were review articles. Whenever the article dealt with 2 or 3 separately defined topics of interest, it was accordingly scored in 2 or 3 categories.

The most highly cited articles in endodontics were basic science articles (Table 6), evaluating coronal or apical leakage (n = 12), followed by studies outlining the applications and properties of MTA (n = 12). Next in the ranking were studies that introduced or assessed instrumentation systems and techniques (n = 10), irrigants (n = 8), and the physicochemical properties of the dentin pulp complex (n = 5). Among the top-cited endodontic leakage studies, 5 evaluated coronal leakage, 5 evaluated apical leakage, 1 assessed the sealing ability of MTA for the repair of lateral root perforations, and 1 studied the effect of entrapped air on the accuracy of the dye penetration microleakage test.

The majority of clinical articles (n = 13) represented various subspecialty areas, mainly endodontic microbiology (Table 6). Two success and failure studies evaluated factors that might affect the outcome of root canal therapy, and 1 study assessed the outcome of endodontic retreatment. In addition, 2 studies assessed the correlation between coronal restoration and prognosis of conservative root canal treatment.

Surprisingly, 17% of the citation classics were review articles. Instrumentation was addressed in 3 articles, with one of them introducing the step-down technique. Three articles focused on microleakage, evaluating the clinical significance of leakage studies, the methods used for microleakage assessment, and the importance of coronal leakage in root canal treatment failure. Two top-cited articles reviewed the microbial flora involved in pulp pathology, and 2 reviewed the physicochemical properties of the dentin pulp complex. Additional topics included intracanal dressing, irrigants, root resorption, MTA, restoration, and smear layer (Table 6).

The levels of evidence of the 28 top-cited clinical articles are shown in Table 7. The most common designs were uncontrolled case series (n = 15) and narrative reviews (n = 17). Consistent with the distribution of study design type, a large number of studies were classified as providing level 4 (case series) and level 5 evidence (narrative reviews), whereas there were no randomized controlled trials.

Discussion

This study aimed to determine the published articles in endodontic journals that have exerted the most influence on endodontology, as signified by citations. Analysis of the most frequently cited endodontic articles not only provides a historical perspective on scientific progress in the field of endodontics but also reveals the trends in endodontic research. In medical literature, studying the number of times other authors reference an article is widespread (3, 8, 11, 13–16, 19). Although the number of citations that one article receives is not necessarily a measure of the quality of research, it reflects its recognition by the scientific community and the influence of the article in generating changes in practice, controversy, discussion, or further research.

The top 100 articles were cited between 87 and 554 times. This is similar to the number of references attributed to citation classics of periodontology, counting from the minimum of 100 to the maximum of 346 times (17). However, it is lower than what was observed in other larger medical fields such as orthopedic surgery, in which studies received from 353–1,748 citations (19), or general surgery studies, counting 278–1,013 citations (10). Indeed, citation rates differ for each specialty and might be dependent on the number of researchers working in a specific scientific field (4). A publication cited more than 400 times should be considered a classic, but in some fields with fewer researchers, 100 citations might qualify a publication (4).

TABLE 1. The Top 100 Cited Articles in Endodontology

Rank	Article	No. of citations
1	Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Pathol 1965;20:340–9.	554
2	Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515–30.	384
3	Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16:498–504.	370
4	Sundqvist G, Figdor D, Persson S, Sjögren U. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:86–93.	358
5	Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.	327
6	Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J 1997;30:297–306.	283
7	Molander A, Reit C, Dahlén G, Kvist T. Microbiological status of root-filled teeth with apical periodontitis. Int Endod J 1998;31:1–7.	267
8	Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod 1995;21:349–53.	264
9	Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995;28:12–8.	258
10	Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14:346–51.	248
11	Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggregate. J Endod 1999;25:197–205.	240
12	Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root end filling material. J Endod 1993;19:591–5.	238
13	Byström A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J 1985;18:35–40.	227
14	Nair PN, Sjögren U, Krey G, Kahnberg KE, Sundqvist G. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: a long-term light and electron microscopic follow-up study. J Endod 1990;16:580–8.	218
15	Torabinejad M, Ung B, Kettering JD. *In vitro* bacterial penetration of coronally unsealed endodontically treated teeth. J Endod 1990;16:566–9.	206
16	Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol 1984;58:589–99.	206
17	Sjögren U, Figdor D, Spångberg L, Sundqvist G. The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. Int Endod J 1991;24:119–25.	204
18	Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. J Endod 1997;23:77–85.	199
19	Orstavik D, Haapasalo M. Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules. Endod Dent Traumatol 1990;6:142–9.	195
20	Wu MK, Wesselink PR. Endodontic leakage studies reconsidered: part I—methodology, application and relevance. Int Endod J 1993;26:37–43.	192
21	Roane JB, Sabala CL, Duncanson MG Jr. The "balanced force" concept for instrumentation of curved canals. J Endod 1985;11:203–11.	190
22	Byström A, Sundqvist G. Bacteriologic evaluation of the effect of 0.5 percent sodium hypochlorite in endodontic therapy. Oral Surg Oral Med Oral Pathol 1983;55:307–12.	190
23	Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surg Oral Med Oral Pathol 1972;33:101–10.	190
24	Shipper G, Ørstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004;30:342–7.	184
25	Lee SJ, Monsef M, Torabinejad M. Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. J Endod 1993;19:541–4.	181
26	Glossen CR, Haller RH, Dove SB, del Rio CE. A comparison of root canal preparations using Ni-Ti hand, Ni-Ti engine-driven, and K-Flex endodontic instruments. J Endod 1995;21:146–51.	180
27	Andreasen JO, Borum MK, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors: 4—factors related to periodontal ligament healing. Endod Dent Traumatol 1995;11:76–89.	175
28	Yamada RS, Armas A, Goldman M, Lin PS. A scanning electron microscopic comparison of a high volume final flush with several irrigating solutions: part 3. J Endod 1983;9:137–42.	173
29	Saunders WP, Saunders EM. Coronal leakage as a cause of failure in root-canal therapy: a review. Endod Dent Traumatol 1994;10:105–8.	169
30	Sundqvist G, Johansson E, Sjögren U. Prevalence of black-pigmented bacteroides species in root canal infections. J Endod 1989;15:13–9.	160
31	Tronstad L. Root resorption: etiology, terminology and clinical manifestations. Endod Dent Traumatol 1988;4:241–52.	160
32	Torabinejad M, Pitt Ford TR, McKendry DJ, Abedi HR, Miller DA, Kariyawasam SP. Histologic assessment of mineral trioxide aggregate as a root-end filling in monkeys. J Endod 1997;23: 225–8.	153

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TABLE 1. (*Continued*)

Rank	Article	No. of citations
33	Torabinejad M, Hong CU, Lee SJ, Monsef M, Pitt Ford TR. Investigation of mineral trioxide aggregate for root-end filling in dogs. J Endod 1995;21:603–8.	151
34	Spangberg L, Engström B, Langeland K. Biologic effects of dental materials: 3—toxicity and antimicrobial effect of endodontic antiseptics *in vitro*. Oral Surg Oral Med Oral Pathol 1973;36:856–71.	150
35	Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth: part I—time periods. J Endod 1987;13:56–9.	148
36	Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987;13:147–57.	147
37	Torabinejad M, Rastegar AF, Kettering JD, Pitt Ford TR. Bacterial leakage of mineral trioxide aggregate as a root-end filling material. J Endod 1995;21:109–12.	138
38	Koh ET, McDonald F, Pitt Ford TR, Torabinejad M. Cellular response to mineral trioxide aggregate. J Endod 1998;24:543–7.	135
39	Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod 2004;30:289–301.	130
40	Sundqvist G. Taxonomy, ecology, and pathogenicity of the root canal flora. Oral Surg Oral Med Oral Pathol 1994;78:522–30.	130
41	Sundqvist G. Ecology of the root canal flora. J Endod 1992;18:427–30.	124
42	Torabinejad M, Higa RK, McKendry DJ, Pitt Ford TR. Dye leakage of four root end filling materials: effects of blood contamination. J Endod 1994;20:159–63.	123
43	Jeansonne MJ, White RR. A comparison of 2.0% chlorhexidine gluconate and 5.25% sodium hypochlorite as antimicrobial endodontic irrigants. J Endod 1994;20:276–8.	122
44	Ciucchi B, Bouillaguet S, Holz J, Pashley D. Dentinal fluid dynamics in human teeth, *in vivo*. J Endod 1995;21:191–4.	120
45	Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 1989;15:512–6.	120
46	Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30:559–67.	114
47	Sattapan B, Nervo GJ, Palamara JE, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 2000;26:161–5.	114
48	Torabinejad M, Hong CU, Pitt Ford TR, Kettering JD. Cytotoxicity of four root end filling materials. J Endod 1995;21:489–92.	113
49	Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:756–63.	113
50	Standlee JP, Caputo AA, Collard EW, Pollack MH. Analysis of stress distribution by endodontic posts. Oral Surg Oral Med Oral Pathol 1972;33:952–60.	113
51	Goldman M, Pearson AH, Darzenta N. Endodontic success: who's reading the radiograph? Oral Surg Oral Med Oral Pathol 1972;33:432–7.	112
52	Nair PN, Henry S, Cano V, Vera J. Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after "one-visit" endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99:231–52.	111
53	Tay FR, Loushine RJ, Lambrechts P, Weller RN, Pashley DH. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. J Endod 2005;31:584–9.	110
54	Zehnder M. Root canal irrigants. J Endod 2006;32:389–98.	109
55	Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha: a retrospective clinical study. Endod Dent Traumatol 1992;8:45–55.	107
56	Rotstein I, Dankner E, Goldman A, Heling I, Stabholz A, Zalkind M. Histochemical analysis of dental hard tissues following bleaching. J Endod 1996;22:23–5.	105
57	Dorn SO, Gartner AH. Retrograde filling materials: a retrospective success-failure study of amalgam, EBA, and IRM. J Endod 1990;16:391–3.	104
58	Dederich DN, Zakariasen KL, Tulip J. Scanning electron microscopic analysis of canal wall dentin following neodymium-yttrium-aluminum-garnet laser irradiation. J Endod 1984;10:428–31.	104
59	Torabinejad M, Khademi AA, Babagoli J, Cho Y, Johnson WB, Bozhilov K, Kim J, Shabahang S. A new solution for the removal of the smear layer. J Endod 2003;29:170–5.	103
60	Helfer AR, Melnick S, Schilder H. Determination of the moisture content of vital and pulpless teeth. Oral Surg Oral Med Oral Pathol 1972;34:661–70.	102
61	Magura ME, Kafrawy AH, Brown CE Jr, Newton CW. Human saliva coronal microleakage in obturated root canals: an *in vitro* study. J Endod 1991;17:324–31.	101
62	Hancock HH 3rd, Sigurdsson A, Trope M, Moiseiwitsch J. Bacteria isolated after unsuccessful endodontic treatment in a North American population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:579–86.	100
63	Esposito PT, Cunningham CJ. A comparison of canal preparation with nickel-titanium and stainless steel instruments. J Endod 1995;21:173–6.	100
64	Brännström M. Sensitivity of dentine. Oral Surg Oral Med Oral Pathol 1966;21:517–26.	100
65	Baumgartner JC, Falkler WA Jr. Bacteria in the apical 5 mm of infected root canals. J Endod 1991;17:380–3.	99
66	Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy: a five-year retrospective study. Int Endod J 1993;26:321–33.	98
67	Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod 1992;18:332–5.	98

(*Continued*)

TABLE 1. (*Continued*)

Rank	Article	No. of citations
68	Bramante CM, Berbert A, Borges RP. A methodology for evaluation of root canal instrumentation. J Endod 1987;13:243–5.	98
69	Wu MK, De Gee AJ, Wesselink PR, Moorer WR. Fluid transport and bacterial penetration along root canal fillings. Int Endod J 1993;26:203–8.	97
70	Nair PNR. Light and electron microscopic studies of root canal flora and periapical lesions. J Endod 1987;13:29–39.	97
71	Pashley DH. Dentin permeability, dentin sensitivity, and treatment through tubule occlusion. J Endod 1986;12:465–74.	96
72	Torabinejad M, Smith PW, Kettering JD, Pitt Ford TR. Comparative investigation of marginal adaptation of mineral trioxide aggregate and other commonly used root-end filling materials. J Endod 1995;21:295–9.	95
73	Khayat A, Lee SJ, Torabinejad M. Human saliva penetration of coronally unsealed obturated root canals. J Endod 1993;19:458–61.	94
74	Meister F Jr, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg Oral Med Oral Pathol 1980;49:243–53.	94
75	Tronstad L, Asbjørnsen K, Døving L, Pedersen I, Eriksen HM. Influence of coronal restorations on the periapical health of endodontically treated teeth. Endod Dent Traumatol 2000;16:218–21.	93
76	Haïkel Y, Serfaty R, Bateman G, Senger B, Allemann C. Dynamic and cyclic fatigue of engine-driven rotary nickel-titanium endodontic instruments. J Endod 1999;25:434–40.	93
77	Wang JD, Hume WR. Diffusion of hydrogen ion and hydroxyl ion from various sources through dentine. Int Endod J 1988;21:17–26.	93
78	Spangberg L, Langeland K. Biologic effects of dental materials: 1—toxicity of root canal filling materials on HeLa cells *in vitro*. Oral Surg Oral Med Oral Pathol 1973;35:402–14.	93
79	Pashley DH. Clinical considerations of microleakage. J Endod 1990;16:70–7.	92
80	Mader CL, Baumgartner JC, Peters DD. Scanning electron microscopic investigation of the smeared layer on root canal walls. J Endod 1984;10:477–83.	92
81	Stanley HR, Lundy T. Dycal therapy for pulp exposures. Oral Surg Oral Med Oral Pathol 1972;34:818–27.	92
82	Peciuliene V, Reynaud AH, Balciuniene I, Haapasalo M. Isolation of yeasts and enteric bacteria in root-filled teeth with chronic apical periodontitis. Int Endod J 2001;34:429–34.	91
83	Griffee MB, Patterson SS, Miller CH, Kafrawy AH, Newton CW. The relationship of Bacteroides melaninogenicus to symptoms associated with pulpal necrosis. Oral Surg Oral Med Oral Pathol 1980;50:457–61.	91
84	Pinheiro ET, Gomes BP, Ferraz CC, Sousa EL, Teixeira FB, Souza-Filho FJ. Microorganisms from canals of root-filled teeth with periapical lesions. Int Endod J 2003;36:1–11.	90
85	Torabinejad M, Handysides R, Khademi AA, Bakland LK. Clinical implications of the smear layer in endodontics: a review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:658–66.	90
86	Sen BH, Wesselink PR, Türkün M. The smear layer: a phenomenon in root canal therapy. Int Endod J 1995;28:141–8.	90
87	Goerig AC, Michelich RJ, Schultz HH. Instrumentation of root canals in molar using the step-down technique. J Endod 1982;8:550–4.	90
88	Shuping GB, Orstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. J Endod 2000;26:751–5.	89
89	Thompson SA. An overview of nickel-titanium alloys used in dentistry. Int Endod J 2000;33:297–310.	89
90	Madison S, Wilcox LR. An evaluation of coronal microleakage in endodontically treated teeth: part III—*in vivo* study. J Endod 1988;14:455–8.	89
91	Senia ES, Marshall FJ, Rosen S. The solvent action of sodium hypochlorite on pulp tissue of extracted teeth. Oral Surg Oral Med Oral Pathol 1971;31:96–103.	89
92	Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. J Endod 2005;31:97–100.	88
93	Siren EK, Haapasalo MP, Ranta K, Salmi P, Kerosuo EN. Microbiological findings and clinical treatment procedures in endodontic cases selected for microbiological investigation. Int Endod J 1997;30:91–5.	88
94	Love RM. Enterococcus faecalis: a mechanism for its role in endodontic failure. Int Endod J 2001;34:399–405.	87
95	Thompson SA, Dummer PM. Shaping ability of ProFile.04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals: part 1. Int Endod J 1997;30:1–7.	87
96	White RR, Hays GL, Janer LR. Residual antimicrobial activity after canal irrigation with chlorhexidine. J Endod 1997;23:229–31.	87
97	Foreman PC, Barnes IE. Review of calcium hydroxide. Int Endod J 1990;23:283–97.	87
98	Safavi KE, Spangberg LS, Langeland K. Root canal dentinal tubule disinfection. J Endod 1990;16:207–10.	87
99	Goldman M, Simmonds S, Rush R. The usefulness of dye-penetration studies reexamined. Oral Surg Oral Med Oral Pathol 1989;67:327–32.	87
100	Brannstrom M. The hydrodynamic theory of dentinal pain: sensation in preparations, caries, and the dentinal crack syndrome. J Endod 1986;12:453–7.	87

As evidenced by the present study and in accordance with many others, the majority of articles originated from academic institutions in the United States (8, 10, 11, 15, 19). This can be explained by the large size of the American scientific community and higher research budgets (20). A large proportion of articles (n = 45) resulted from multicentered collaborations, with 32 being international in nature.

TABLE 2. Journals in Which the Top 100 Cited Endodontic Articles Were Published

Rank	Journal	No. of articles
1	*Journal of Endodontics*	54
2	*Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*	23
3	*International Endodontic Journal*	17
4	*Endodontics & Dental Traumatology*	6

The most active institute in production of endodontic top-cited articles was the Loma Linda University in California, producing 12 top-cited articles during the period 1990–2003, which coincides with the advent of MTA into endodontics.

The most highly cited articles in endodontics were in the field of basic science. On the contrary, the majority of citation analysis in medicine reports the dominance of clinical rather than basic science articles (8, 11, 19). The dominance of basic research in endodontics results from ethical concerns prohibiting comparison of treatment efficacy or materials in humans. This has also occurred as a result of the nature of root canal treatment and lack of comparative treatment modalities similar to it (21). Nevertheless, basic endodontic research is particularly important to ensure the effectiveness of new materials or modified techniques. The integration of knowledge from new basic research into endodontic practice offers the potential to address major clinical issues.

The subject areas of the articles showed some interesting trends and reflected major advances in endodontics during the last 50 years. The first top citation classic article, published by Kakehashi and colleagues in 1965, demonstrated that pulp necrosis and periapical bone destruction only develop in normal and not in germ-free rats when the pulp chambers are kept open to the oral cavity. At second position, Zach and Cohen measured the intrapulpal temperature increase induced by the application of standardized heat stimuli to the external tooth surface in an animal study. Finally, the third most cited article addressed factors affecting the long-term results of endodontic treatment.

Regarding the field of study, the subject of microleakage in the basic science category and endodontic microbiology in clinical research represent areas of significant interest within the field of endodontics. Whereas microbiology, irrigants, and canal instrumentation showed a stable publication rate over time, there was a reasonable increase in articles concerning MTA during 1986–1995, when this material was first introduced into clinical practice, and in leakage studies during 1991–2000. However, some important articles might not be readily listed as citation classics because their research topic has become such common knowledge after publication that it is no longer cited.

In general, there was no positive relationship in endodontic research between number of citations and level of evidence. Observational studies with level IV of evidence and narrative reviews with level V of evidence were the most frequent types of study design. Our findings on the dominance of uncontrolled case series are consistent with previously published data evaluating the success and failure of initial nonsurgical root canal treatment (21), surgical endodontics (22), or retreatment of "failed" nonsurgical root canal therapy (23). This trend has been observed in the literature of other surgical subspecialties, including obstetrics and gynecology (15) and rehabilitation (20). The overrepresentation of narrative reviews among highly cited articles has also been reported in several studies (17, 24). One possible explanation could be that authors of subsequent articles prefer to cite these reviews instead of the referenced original articles.

There are obvious limitations to this type of study. As indicated by similar studies in other fields of dentistry, this survey was limited to journals featuring a wide spectrum of endodontic research with the term "endodontology" or "endodontic" in their titles (17). Consequently, important endodontic articles in general dental journals were excluded from the list, possibly excluding work that has been influential in endodontics. For example, the description of the dental pulp stem cell properties published in the *Journal of Dental Research* by Gronthos et al (25) in 2002 has been cited 320 times and could be classified at the top of endodontic classics with respect to received citations. The study

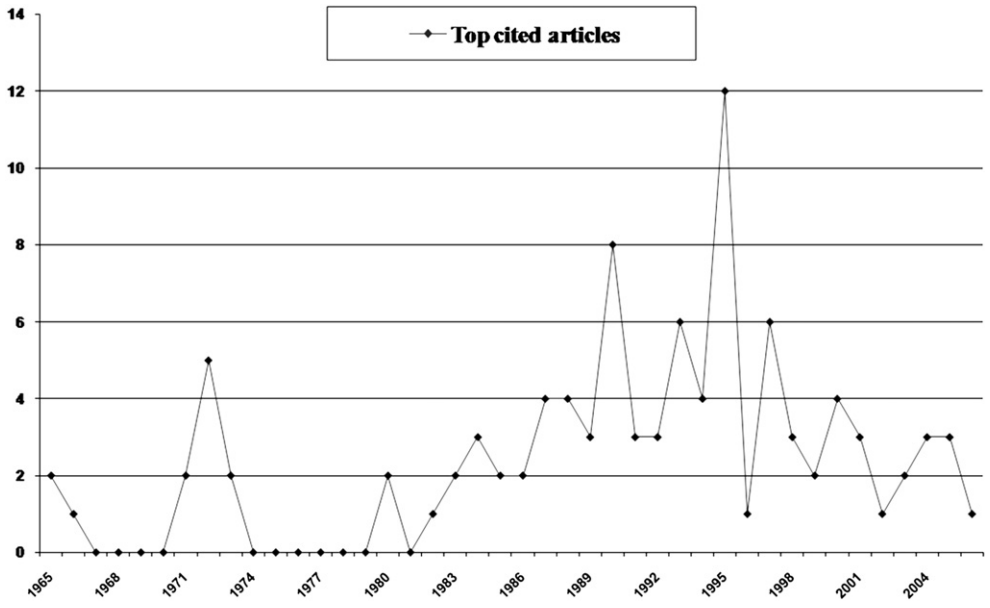

Figure 1. Pattern of distribution of top-cited articles.

TABLE 3. Authors of the Top-cited Articles

Author	No. of citation classics	No. of articles	
		As first author	As co-author
Torabinejad M	16	12	4
Ford TRP	10	1	9
Sundqvist G	10	4	6
Sjögren U	6	3	3
Pashley DH	4	2	2
Spangber L	4	2	2
Hong CU	4		4
Kettering JD	4		4
Trope M	4		4
Baumgartner JC	3	2	1
Lee SJ	3	1	2
Nair PNR	3	3	
Goldman M	3	2	1
Orstavik D	3	1	2
Wesselink PR	3		3
Figdor D	3		3
Haapasalo M	3		3
Langelan K	3		3
McKendry DJ	3		3
Messer HH	3		3

TABLE 5. Institutions of Origin with 2 or More Top-cited Articles in Endodontics

Institution	No. of articles
Loma Linda University, California	12
University of Umea	9
University of Zürich	5
University of North Carolina	5
University of Texas Health Science Center	4
Tufts University School of Dental Medicine, Boston	3
University of Connecticut Health Center	3
University of Florida College of Dentistry, Gainesville	3
University of Melbourne	2
University of Oslo	2
Karolinska Institute	2
Academic Centre for Dentistry Amsterdam (ACTA)	2
University of Wales College of Medicine, Cardiff	2
Indiana University School of Dentistry	2
Medical College of Georgia, Augusta	2
Marquette University School of Dentistry, Milwaukee	2
Walter Reed Army Medical Center, Washington	2

of Byström and Sundqvist (26) in 1981 was published in the *Scandinavian Journal of Dental Research* and investigated the efficacy of mechanical root canal instrumentation, and the research of Bouillaguet et al (27) in 2003, published in *Dental Materials*, which assessed the bond strength between adhesive systems and root canal dentin, received 251 and 154 citations, respectively, and were both excluded from this study. Other articles published in the *Journal of Dentistry* have been cited 235 times or more and obviously would also qualify as endodontic citation classics (28, 29). This is equally true for the article of Bergenholtz et al (30) in 1982 that described bacterial leakage around dental restorations. This article was published in the *Journal of Oral Pathology* and has received 261 citations. Finally, the classic studies of Bender and Seltzer (31, 32) published in 1961 in the *Journal of the American Dental Association* that compared direct and roentgenographic observations of experimental bone lesions were not included in this study although they received 130 and 92 citations, respectively. This list of examples of classic endodontic articles originally published in journals outside the field of endodontics is by no means comprehensive, and there are other such articles that were not examined in this study. Nevertheless, the 4 journals selected feature the highest impact factor in the field of endodontics because they are generally accepted as reference journals for endodontists and attract a large scientific readership.

Second, the use of citations involves problems and challenges such as the lack of correction for self-citations, lack of counting possible citations in book chapters, and preference of peers to cite review articles or articles from the journal in which they seek to publish their own work (33). Nevertheless, citation counts provide the best recognition of the quality of a single work and offer the best measure of the originality and impact of an author (10).

One other limitation of using the total citations an article has accumulated as a measure of impact is that older publications and older journals are favored. Time can have multiple effects on an article's

TABLE 4. Countries of Origin of the Top 100 Cited Articles in Endodontics

Country	No. of articles
United States	52
Sweden	13
United Kingdom	7
Switzerland	6
Australia	3
Norway	3
Brazil	2
The Netherlands	2
Canada	1
China	1
Denmark	1
Finland	1
France	1
Germany	1
Iran	1
Israel	1
Korea	1
Mexico	1
New Zealand	1
Turkey	1

TABLE 6. Categorization of Articles on Basis of Type and Field of Study

Field of study	Clinical	Basic	Review
Endodontic microbiology	13	2	2
Irrigant	3	8	1
Success and failure studies	3		
Traumatic dental injuries	2		
Restoration	2	1	1
Intracanal dressing	2	2	1
Pulp capping	1		
Retrograde materials success/ failure	1		
Obturation	1	2	
Physicochemical properties of dentin pulp complex	2	5	2
Leakage		12	3
Canal instrumentation		10	3
MTA		12	1
Root canal anatomy		2	
Smear layer		2	2
Bleaching		1	
Root resorption			1
Radiology		1	

TABLE 7. Study Design of the Top 100 Cited Articles in Endodontics

Study design	No. of articles
Randomized controlled trial	0
Cohort study	1
Nonrandomized controlled cohort	4
Case control study	8
Case series	15
Case report	0
Review	17

citation ranking. With time, each article has greater chances of being cited. Therefore, the group of highest ranking articles can be dominated by some of the oldest. Under this spectrum, it has been reported that the true impact and eminence of an article cannot be accurately assessed for at least 2 decades (8).

To the best of our knowledge, this is the first report of the top-cited articles in endodontics. Despite limitations, this citation analysis reveals useful and interesting information about scientific progress in this field of dentistry. Microbiology remains the primary cited topic of endodontic literature, suggesting that research interests emphasize the crucial role of bacteria in endodontic pathology. Basic research and observational studies published in high-impact English language endodontic journals constitute the most common type of highly cited publications.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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