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The top 100 most cited papers in the first 100 years of calcium hydroxide as a dental material (1920-2020): a bibliometric analysis

Os 100 artigos mais citados nos primeiros 100 anos do hidróxido de cálcio como um material dentário (1920-2020): uma análise bibliométrica

Los 100 artículos más citados en los primeros 100 años del hidróxido de calcio como material dental (1920-2020): un análisis bibliométrico

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Abstract
Celebrating the centenary of calcium hydroxide (CH), the aim of this study was to analyze the 100 most-cited papers on this biomaterial. The bibliometric analysis was conducted in the Web of Science Core Collection (WoS-CC) database. Title, authorship information, study design, year, journal, number of citations, CH use, and fields of Dentistry were extracted. The number of citations in the WoS-CC, Scopus, and Google Scholar databases was cross-matched with the Spearman correlation. From the 1,596 papers identified, a list was compiled with the 100 most-cited papers. The number of citations in WoS-CC ranged from 78 to 384 (mean: 131.4). The main CH uses were: intracanal dressing (61%), and pulp protection (29%). The fields of Dentistry with most studies on CH were Endodontics (62%) and Operative Dentistry (30%). The most frequent study design was laboratory studies (44%). Three hundred and thirty-five authors from 29 countries were identified. The United States of America (USA) was the leading country with 23 articles. Dag Ørstavik was the author with the most papers and citations (9 papers; 1,118 citations). Most papers were published between 1991 and 2015 and in the Journal of Endodontics (38%). A very strong positive correlation was observed among the number of citations in the databases. The 100 most-cited papers were published mainly by European journals or from USA, with laboratory and multifaceted interventional designs. The present study celebrated the centenary of CH, highlighting the role and importance of this biomaterial in Dentistry.
Keywords: Bibliometrics; Biomedical and dental materials; Calcium hydroxide; Databases; Scholarly communication.

Resumo

Celebrando o centenário do hidróxido de cálcio (HC), o objetivo desse estudo foi analisar os 100 artigos mais citados sobre esse biomaterial. A análise bibliométrica foi realizada na base de dados *Web of Science Core Collection* (WoS-CC). Título, informações sobre autoria, desenho do estudo, ano, periódico, número de citações, uso do HC e áreas da Odontologia foram extraídos. O número de citações nas bases de dados WoS-CC, Scopus e Google Scholar foi cruzado com a correlação de Spearman. Dos 1.596 artigos identificados, foi compilada uma lista com os 100 artigos mais citados. O número de citações no WoS-CC variou de 78 a 384 (média: 131,4). Os principais usos do HC foram: medicação intracanal (61%) e proteção pulpar (29%). As áreas da Odontologia com mais estudos sobre HC foram Endodontia (62%) e Dentística (30%). O desenho de estudo mais frequente foi laboratorial (44%). Trezentos e trinta e cinco autores de 29 países foram identificados. Os Estados Unidos da América (EUA) foram o país líder com 23 artigos. Dag Ørstavik foi o autor com mais artigos e citações (9 artigos; 1.118 citações). A maioria dos artigos foi publicada entre 1991 e 2015 e no *Journal of Endodontics* (38%). Foi observada uma correlação positiva muito forte entre o número de citações nas bases de dados. Os 100 artigos mais citados foram publicados principalmente por periódicos europeus ou dos EUA, com desenhos laboratoriais e de intervenções multifacetadas. O presente estudo comemorou o centenário do HC, destacando o papel e a importância deste biomaterial odontológico.

Palavras-chave: Bibliometria; Materiais biomédicos e odontológicos; Hidróxido de cálcio; Bases de dados; Comunicação acadêmica.

Resumen

Celebrando el centenario del hidróxido de calcio (HC), el objetivo de este estudio fue analizar los 100 artículos más citados sobre este biomaterial. Análisis bibliométrico se realizó en la base de datos *Web of Science Core Collection* (WoS-CC). Se extrajo título, información de autoría, diseño del estudio, año, revista, número de citas, uso de HC y áreas de la Odontología. Se cruzó número de citas en las bases de datos WoS-CC, Scopus y Google Scholar con la correlación de Spearman. De los 1.596 artículos identificados, se compiló una lista de los 100 artículos más citados. El número de citas en WoS-CC osciló entre 78 y 384 (media: 131,4). Los principales usos del HC fueron: medicación intracanal (61%) y protección pulpar (29%). Las áreas de la Odontología con más estudios sobre HC fueron Endodoncia (62%) y Odontología Restaurativa (30%). El diseño de estudio más frecuente fue el de laboratorio (44%). Se identificaron 335 autores de 29 países. Estados Unidos fue el país líder con 23 artículos. Dag Ørstavik fue el autor con más artículos y citas (9 artículos; 1118 citas). La mayoría de los artículos se publicaron entre 1991 y 2015 en el *Journal of Endodontics* (38%). Se observó una correlación positiva muy fuerte entre el número de citas en las bases de datos. Los 100 artículos más citados fueron publicados principalmente por revistas europeas o estadounidenses, con diseños de laboratorio e intervenciones multifacéticas. El presente estudio conmemoró el centenario del HC, destacando el papel y la importancia de este biomaterial dental.

Palabras clave: Bibliometría; Materiales biomédicos y dentales; Hidróxido de calcio; Base de datos; Comunicación académica.

1. Introduction

The use of calcium hydroxide as a dental material marked its centenary in 2020. In 1920, when Hermann (1920) introduced a calcium hydroxide mixture that induced bridging of an exposed pulp with reparative dentine, a new era in the treatment of exposed pulps began (Stanley & Pameijer, 1997). In addition to inducing hard tissue deposition and promoting the healing of pulp tissue because of its biological and antimicrobial properties (achieved by the dissociation and diffusion of Ca^{2+} and OH^- ions) (Holland *et al.*, 1999; Siqueira Jr & Lopes, 1999), calcium hydroxide has been indicated in many other clinical situations (Pereira *et al.*, 2000; Rafter, 2005; Nair *et al.*, 2008; Mohammadi & Dummer, 2011).

Several papers have been published describing the use of calcium hydroxide as a direct pulp capping agent in the form of a powder or aqueous paste (Faraco Jr & Holland, 2001; Laurent *et al.*, 2012), as a chemical component of protective liners (Schedle *et al.*, 1998; Min *et al.*, 2008), as an intracanal medicament (Siqueira Jr & Uzeda, 1997; Galler *et al.*, 2015), as a pulp-dressing for pulpotomy (Mejàre & Cvek, 1993; Sonmez *et al.*, 2008), and as a chemical component of luting agents (Breeding *et al.*, 1992) and root canal sealers (Lee et al., 2002; Neelakantan *et al.*, 2015). The wide range of calcium hydroxide-containing dental materials designed for different clinical approaches and the role of this chemical component as a multipurpose dental biomaterial has been researched (Pereira *et al.*, 2000; Rafter, 2005; Nair *et al.*, 2008; Mohammadi & Dummer, 2011). Stanley and Pameijer (1997) suggested that calcium hydroxide should be considered “Dentistry's friend” because of its remarkable

properties. During the 100 years since its introduction to Dentistry, and with its expanded clinical use, the properties and applications of calcium hydroxide have been widely studied (Rosa *et al.*, 2019; Bedran *et al.*, 2020; Cushley *et al.*, 2021).

The impact of research studies and the development of a field can be quantified through a bibliometric analysis. Bibliometric studies have been conducted in various fields of health sciences since 1987 (Garfield, 1987; Rosenberg *et al.*, 2005; Yanbing *et al.*, 2020). This scientific method was initiated in Dentistry by Richard Niederman and his research team (Niederman & Badovinac, 1999; Sun *et al.*, 2000; Kim *et al.*, 2001; Yang *et al.*, 2001) in the late 1990s and early 2000s. From then on, with increasing emphasis on the number of citations of a given paper, which has been considered one of the measures of scientific merit (Eyre-Walker & Stoletzki, 2013; Shekhani *et al.*, 2017), special attention has been placed on citation analysis to recognize the contributing journals (Ahmad *et al.*, 2019; Perazzo *et al.*, 2019), researchers (Santos *et al.*, 2021), as well as the current status and research trends in different dental specialties (Faggion Jr *et al.*, 2017; Tarazona *et al.*, 2018), thematic fields (Adnan & Ullah, 2018; Baldiotti *et al.*, 2021) and materials (Lorusso *et al.*, 2020; Chen *et al.*, 2021).

The authors are unaware of a bibliometric study that has analyzed the most cited papers on calcium hydroxide in Dentistry. Because of its importance to Dentistry, a bibliometric study was conducted to determine the main uses of calcium hydroxide, the Dentistry fields most predominantly used, study designs, and to celebrate its 100th anniversary. This study aimed to qualitatively and quantitatively analyze the 100 most cited papers on the use of calcium hydroxide in Dentistry.

2. Methodology

2.1 Search strategy

A bibliometric analysis, following the method described by Perazzo *et al.* (2019), Baldiotti *et al.* (2021), Santos *et al.* (2021), and Mattos *et al.* (2021), was conducted on April 13, 2021 to catalogue the 100 most cited papers on the use of calcium hydroxide in Dentistry. The Web of Science (http://www.webofknowledge.com) was the main database used. The Scopus (https://www.scopus.com) and Google Scholar (https://scholar.google.com.br) databases were also searched for further comparisons.

A broad search [AB=("Calcium Hydroxide" OR "Hydroxide, Calcium")] was conducted in the WoS Core Collection (WoS-CC). The category “Dentistry, Oral Surgery & Medicine” was selected to filter the journals. Conference papers and studies in which calcium hydroxide was not the main topic were excluded. No restrictions of language, type of paper, or year of publication were applied. The numbers of citations in the Scopus (https://www.scopus.com), and Google Scholar (https://scholar.google.com.br) databases were cross-matched. In the event of a tie, the highest WoS-CC citation density (number of citations per year) was considered, followed by the highest number of citations in Scopus.

2.2 Data extraction and bibliometric parameters

Two researchers (MBPC and PSS) collected the data together. Any disagreement was resolved through discussion and consensus with a third researcher (JRCJr). The following bibliometric parameters were recorded from each paper: authorship (author names and number), title, journal title, number of citations, citation density, study design, main uses of calcium hydroxide in the field of Dentistry over time (thematic field), institutions and countries (based on the corresponding author's affiliation), year of publication, and keywords.

2.3 Study design

The studies were classified as reviews (systematic or narrative); case reports/series; laboratory (*in vitro*, *in vivo*, or *ex vivo*); observational (cross-sectional, case-control, or cohort); interventional (clinical studies); or multifaceted interventional studies (clinical studies associated with laboratory tests).

2.4 Main uses of calcium hydroxide

The main uses of calcium hydroxide were subgrouped into intracanal dressing, pulp-capping agent, chemical component of root canal sealers, pulpotomy pulp-dressing, or chemical component of luting agent.

2.5 Fields of Dentistry

The fields of Dentistry (thematic field of the paper) were subgrouped into Endodontics, Operative Dentistry, Dental Traumatology, Pediatric Dentistry, and Prosthodontics.

2.6 Bibliometric networks

The VOSviewer software (Centre for Science and Technology Studies, University of Leiden) was used to create bibliometric networks (van Eck & Waltman, 2021). Collaborative density maps were created for co-authorship and keywords, and the items were linked to each other by considering the number of jointly authored articles. Each point in the density map has a color that indicates the density of items at that point (van Eck & Waltman, 2021). Colors scale from blue to yellow to red. The higher the number of items in the neighborhood of a point and the higher the neighboring items' weights, the closer the color is to red (van Eck & Waltman, 2021). Conversely, the lower the number of items in the neighborhood of a point, and the lower the weights of the neighboring items, the closer the color of the point is to blue.

2.7 Statistical analysis

Data analysis was carried out using the statistical software package for Windows (SPSS, version 24.0; IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of data distribution. The Spearman rank correlation coefficient test was used since the data were not normally distributed.

3. Results

Initially, 1,596 documents were identified in the WoS-CC. After organizing the list in descending number of citations, 3 conference papers and 21 papers not focused on the topic were excluded. Thus, the 100 most cited papers on the use of calcium hydroxide in Dentistry were obtained. Altogether, the *h*-index of these papers was 84, that is, 84 papers received at least 84 citations. The total number of citations was 13,141 and 12,834 when self-citations (2.34%) were excluded. The mean number of citations per paper was 131.41, ranging from 78 to 384. The first 11 papers in the 100 were cited more than 200 times.

The 100 most cited papers based on the number of citations at the WoS-CC section were shown in descending order in Table 1. The numbers of citations in Scopus, and Google Scholar were also listed. Strong positive correlations were found between the number of citations in WoS-CC and Scopus (rho = 0.962; $p < 0.001$) and between WoS-CC and Google Scholar (rho = 0.865; $p < 0.001$).

Table 1: List of the 100 most cited papers on calcium hydroxide.

Rank	Title of the paper	Number of citations (citation density[a])		
		WoS-CC*	Scopus	Google Scholar
1	Andreasen, J. O.; Farik, B. & Munksgaard, E. C. (2002). Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. *Dental Traumatology*, 18 (3), 134-7.	384 (20.21)	467 (24.58)	1074 (56.53)
2	Cvek, M. (1992). Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. *Endodontics and Dental Traumatology*, 8 (2), 45-55.	355 (12.24)	409 (14.10)	803 (27.69)
3	Sjögren, U.; Figdor, D.; Spångberg, L. & Sundqvist, G. (1991). The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. *International Endodontic Journal*, 24 (3), 119-25.	351 (11.70)	451 (15.03)	1028 (34.27)
4	Siqueira Jr, J. F. & Lopes, H. P. (1999). Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. *International Endodontic Journal*, 32 (5), 361-9.	350 (15.91)	459 (20.86)	1078 (49.00)
5	Shuping, G. B.; Ørstavik, D.; Sigurdsson, A. & Trope, M. (2000). Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. *Journal of Endodontics*, 26 (12), 751-5.	245 (11.67)	287 (13.67)	670 (31.90)
6	Evans, M.; Davies, J. K.; Sundqvist, G. & Figdor, D. (2002). Mechanisms involved in the resistance of Enterococcus faecalis to calcium hydroxide. *International Endodontic Journal*, 35 (3), 221-8.	240 (12.63)	290 (15.26)	730 (38.42)
7	Rafter, M. (2005). Apexification: a review. *Dental Traumatology*, 21 (1), 1-8.	229 (14.31)	291 (18.19)	751 (46.94)
8	Pitt Ford, T. R.; Torabinejad, M.; Abedi, H. R.; Bakland, L. K.; & Kariyawasam, S. P. (1996). Using mineral trioxide aggregate as a pulp-capping material. *Journal of the American Dental Association*, 127 (10), 1491-4.	229 (9.16)	337 (13.48)	742 (29.68)
9	Mohammadi, Z. & Dummer, P. M. H. (2011). Properties and applications of calcium hydroxide in endodontics and dental traumatology. *International Endodontic Journal*, 44 (8), 697-730.	211 (21.10)	268 (26.80)	608 (60.80)
10	Aeinehchi, M.; Eslami, B.; Ghanbariha, M. & Saffar, A. S. (2003). Mineral trioxide aggregate (MTA) and calcium hydroxide as pulp-capping agents in human teeth: a preliminary report. *International Endodontic Journal*, 36 (3), 225-31.	205 (11.39)	242 (13.44)	492 (27.33)
11	Peciuliene, V.; Reynaud, A. H.; Balciuniene, I. & Haapasalo, M. (2001). Isolation of yeasts and enteric bacteria in root-filled teeth with chronic apical periodontitis. *International Endodontic Journal*, 34 (6), 429-34.	205 (10.25)	233 (11.65)	576 (28.80)
12	Ruparel, N. B.; Teixeira, F. B.; Ferraz, C. C. R. & Diogenes, A. (2012). Direct effect of intracanal medicaments on survival of stem cells of the apical papilla. *Journal of Endodontics*, 38 (10), 1372-5.	196 (21.78)	228 (25.33)	418 (46.44)
13	Cox, C. F.; Sübay, R. K.; Ostro, E.; Suzuki, S. & Suzuki, S. H. (1996). Tunnel defects in dentin bridges: their formation following direct pulp capping. *Operative Dentistry*, 21 (1), 4-11.	192 (7.68)	232 (9.28)	433 (17.32)
14	Distel, J. W.; Hatton, J. F. & Gillespie, M. J. (2002). Biofilm formation in medicated root canals. *Journal of Endodontics*, 28 (10), 689-93.	191 (10.05)	217 (11.42)	505 (26.58)

15	Jeeruphan, T.; Jantarat, J.; Yanpiset, K.; Suwannapan, L.; Khewsawai, P. & Hargreaves, K. M. (2012). Mahidol study 1: comparison of radiographic and survival outcomes of immature teeth treated with either regenerative endodontic or apexification methods: a retrospective study. *Journal of Endodontics*, 38 (10), 1330-6.	190 (21.11)	220 (24.44)	396 (44.00)
16	Haapasalo, H. K.; Sirén, E. K. & Waltimo, T. M. (2000). Inactivation of local root canal medicaments by dentine: an in vitro study. *International Endodontic Journal*, 33 (2), 126-31.	189 (9.00)	250 (11.90)	551 (26.24)
17	Laurent, P.; Camps, J. & About, I. (2012). Biodentine(TM) induces TGF-β1 release from human pulp cells and early dental pulp mineralization. *International Endodontic Journal*, 45 (5), 439-48.	184 (20.44)	228 (25.33)	460 (51.11)
18	Nair, P. N. R.; Duncan, H. F.; Pitt Ford, T. R. & Luder, H. U. (2008). Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. *International Endodontic Journal*, 41 (2), 128-50.	179 (13.77)	212 (16.31)	465 (35.77)
19	Holland, R.; Souza, V.; Nery, M. J.; Otoboni Filho, J. A.; Bernabé, P. F. & Dezan Júnior, E. (1999). Reaction of rat connective tissue to implanted dentin tubes filled with mineral trioxide aggregate or calcium hydroxide. *Journal of Endodontics*, 25 (3), 161-6.	170 (7.73)	212 (9.64)	479 (21.77)
20	Shabahang, S.; Torabinejad, M.; Boyne, P. P.; Abedi, H. & McMillan, P. (1999). A comparative study of root-end induction using osteogenic protein-1, calcium hydroxide, and mineral trioxide aggregate in dogs. *Journal of Endodontics*, 25 (1), 1-5.	166 (7.55)	209 (9.50)	495 (22.50)
21	Thibodeau, B. & Trope, M. (2007). Pulp revascularization of a necrotic infected immature permanent tooth: case report and review of the literature. *Pediatric Dentistry*, 29 (1), 47-50.	165 (11.79)	190 (13.57)	431 (30.79)
22	Faraco Jr, I. M. & Holland, R. (2001). Response of the pulp of dogs to capping with mineral trioxide aggregate or a calcium hydroxide cement. *Dental Traumatology*, 17 (4), 163-6.	164 (8.20)	192 (9.60)	467 (23.35)
23	Gomes, B. P. F. A.; Souza, S. F. C.: Ferraz, C. C. R.; Teixeira, F. B.; Zaia, A. A.; Valdrighi, L. & Souza-Filho, F. J. (2003). Effectiveness of 2% chlorhexidine gel and calcium hydroxide against Enterococcus faecalis in bovine root dentine in vitro. *International Endodontic Journal*, 36 (4), 267-75.	162 (9.00)	230 (12.78)	580 (32.22)
24	Chen, MY-H,; Chen, K-L.; Chen, C-A.; Tayebaty, F.; Rosenberg, P. A. & Lin, L. M. (2012). Responses of immature permanent teeth with infected necrotic pulp tissue and apical periodontitis/abscess to revascularization procedures. *International Endodontic Journal*, 45 (3), 294-305.	150 (16.67)	187 (20.78)	368 (40.89)
25	Hachmeister, D. R.; Schindler, W. G.; Walker 3rd, W. A. & Thomas, D. D. (2002). The sealing ability and retention characteristics of mineral trioxide aggregate in a model of apexification. *Journal of Endodontics*, 28 (5), 386-90.	150 (7.89)	185 (9.74)	408 (21.47)
26	Nerwich, A.; Figdor, D. & Messer, H. H. (1993). pH changes in root dentin over a 4-week period following root canal dressing with calcium hydroxide. *Journal of Endodontics*, 19 (6), 302-6.	148 (5.29)	182 (6.50)	413 (14.75)
27	Athanassiadis, B.; Abbott, P. V. & Walsh, L. J. (2007). The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. *Australian Dental Journal*, 52 (1 Suppl), S64-82.	143 (10.21)	185 (13.21)	476 (34.00)
28	Peters, L. B.; van Winkelhoff, A. J.; Buijs, J. F. & Wesselink, P. R. (2002). Effects of instrumentation, irrigation and dressing with calcium hydroxide on	143 (7.53)	170 (8.95)	395 (20.79)

	infection in pulpless teeth with periapical bone lesions. *International Endodontic Journal*, 35 (1), 13-21.			
29	Waltimo, T.; Trope, M.; Haapasalo, M. & Ørstavik, D. (2005). Clinical efficacy of treatment procedures in endodontic infection control and one year follow-up of periapical healing. *Journal of Endodontics*, 31 (12), 863-6.	135 (8.44)	153 (9.56)	361 (22.56)
30	Trope, M.; Delano, E. O. & Ørstavik, D. (1999). Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. *Journal of Endodontics*, 25 (5), 345-50.	135 (6.14)	164 (7.45)	414 (18.82)
31	Grigoratos, D.; Knowles, J.; Ng, Y. L. & Gulabivala, K. (2001). Effect of exposing dentine to sodium hypochlorite and calcium hydroxide on its flexural strength and elastic modulus. *International Endodontic Journal*, 34 (2), 113-9.	134 (6.70)	155 (7.75)	353 (17.65)
32	Siqueira Jr, J. F.; Rôças, I. N.; Favieri, A.; Machado, A. G.; Gahyva, S. M.; Oliveira, J. C. M. & Abad, E. C. (2002). Incidence of postoperative pain after intracanal procedures based on an antimicrobial strategy. *Journal of Endodontics*, 28 (6), 457-60.	133 (7.00)	161 (8.47)	384 (20.21)
33	Peters, L. B. & Wesselink, P. R. (2002). Periapical healing of endodontically treated teeth in one and two visits obturated in the presence or absence of detectable microorganisms. *International Endodontic Journal*, 35 (8), 660-7.	131 (6.89)	152 (8.00)	393 (20.68)
34	Lenherr, P.; Allgayer, N.; Weiger, R.; Filippi, A.; Attin, T. & Krastl, G. (2012). Tooth discoloration induced by endodontic materials: a laboratory study. *International Endodontic Journal*, 45 (10), 942-9.	130 (14.44)	149 (16.56)	289 (32.11)
35	Lee, K-W.; Williams, M. C.; Camps, J. J. & Pashley, D. H. (2002). Adhesion of endodontic sealers to dentin and gutta-percha. *Journal of Endodontics*, 28 (10), 684-8.	126 (6.63)	149 (7.84)	391 (20.58)
36	Accorinte, M. L. R.; Holland, R.; Reis, A.; Bortoluzzi, M. C.; Murata, S. S.; Dezan Jr, E.; Souza, V. & Alessandro, L. D. (2008). Evaluation of mineral trioxide aggregate and calcium hydroxide cement as pulp-capping agents in human teeth. *Journal of Endodontics*, 34 (1), 1-6.	124 (9.54)	144 (11.08)	283 (21.77)
37	Takita, T.; Hayashi, M.; Takeichi, O.; Ogiso, B.; Suzuki, N.; Otsuka, K. & Ito, K. (2006). Effect of mineral trioxide aggregate on proliferation of cultured human dental pulp cells. *International Endodontic Journal*, 39 (5), 415-22.	124 (8.27)	139 (9.27)	239 (15.93)
38	Witherspoon, D. E.; Small, J. C.; Regan, J. D. & Nunn, M. (2008). Retrospective analysis of open apex teeth obturated with mineral trioxide aggregate. *Journal of Endodontics*, 34 (10), 1171-6.	119 (9.15)	133 (10.23	279 (21.46)
39	Wu, D.; Fan, W.; Kishen, A.; Gutmann, J. L. & Fan, B. (2014). Evaluation of the antibacterial efficacy of silver nanoparticles against Enterococcus faecalis biofilm. *Journal of Endodontics*, 40 (2), 285-90.	118 (16.86)	156 (22.29)	268 (38.29)
40	Felippe, W. T.; Felippe, M. C. S. & Rocha, M. J. C. (2006). The effect of mineral trioxide aggregate on the apexification and periapical healing of teeth with incomplete root formation. *International Endodontic Journal*, 39 (1), 2-9.	118 (7.87)	144 (9.60)	360 (24.00)
41	Vera, J.; Siqueira Jr, J. F.; Ricucci, D.; Loghin, S.; Fernández, N.; Flores, B. & Cruz, A. G. (2012). One-versus two-visit endodontic treatment of teeth with apical periodontitis: a histobacteriologic study. *Journal of Endodontics*, 38 (8), 1040-52.	117 (13.00)	149 (16.56)	315 (35.00)
42	Huang, F-M.; Tai, K-W.; Chou, M-Y. & Chang, Y-C. (2002). Cytotoxicity of resin-, zinc oxide-eugenol-, and calcium hydroxide-based root canal sealers on human periodontal ligament cells and permanent V79 cells. *International Endodontic Journal*, 35 (2), 153-8.	116 (6.11)	135 (7.11)	308 (16.21)

43	Fava, L. R. & Saunders, W. P. (1999). Calcium hydroxide pastes: classification and clinical indications. *International Endodontic Journal*, 32 (4), 257-82.	116 (5.27)	169 (7.68)	470 (21.36)
44	Hebling, J.; Giro, E. M. & Costa, C. A. (1999). Biocompatibility of an adhesive system applied to exposed human dental pulp. *Journal of Endodontics*, 25 (10), 676-82.	116 (5.27)	134 (6.09)	228 (10.36)
45	Mente, J.; Geletneky, B.; Ohle, M.; Koch, M. J.; Ding, P. G. F.; Wolff, D.; Dreyhaupt, J.; Martin, N.; Staehle, H. J. & Pfefferle, T. (2010). Mineral trioxide aggregate or calcium hydroxide direct pulp capping: an analysis of the clinical treatment outcome. *Journal of Endodontics*, 36 (5), 806-13.	115 (10.45)	137 (12.45)	251 (22.82)
46	Cox, C. F. & Suzuki, S. (1994). Re-evaluating pulp protection: calcium hydroxide liners vs. cohesive hybridization. *Journal of the American Dental Association*, 125 (7), 823-31.	115 (4.26)	129 (4.78)	221 (8.19)
47	Hilton, T. J.; Ferracane, J. L. & Mancl, L. (2013). Comparison of CaOH with MTA for direct pulp capping: a PBRN randomized clinical trial. *Journal of Dental Research*, 92 (7 Suppl), 16S-22S.	114 (14.25)	137 (17.13)	228 (28.50)
48	Safavi, K. E. & Nichols, F. C. (1993). Effect of calcium hydroxide on bacterial lipopolysaccharide. *Journal of Endodontics*, 19 (2), 76-8.	114 (4.07)	136 (4.86)	389 (13.89)
49	Ørstavik, D.; Kerekes, K. & Molven, O. (1991). Effects of extensive apical reaming and calcium hydroxide dressing on bacterial infection during treatment of apical periodontitis: a pilot study. *International Endodontic Journal*, 24 (1), 1-7.	114 (3.80)	146 (4.87)	330 (11.00)
50	Chávez de Paz, L. E.; Dahlén, G.; Molander, A.; Möller, A. & Bergenholtz, G. (2003). Bacteria recovered from teeth with apical periodontitis after antimicrobial endodontic treatment. *International Endodontic Journal*, 36 (7), 500-8.	111 (6.17)	125 (6.94)	282 (15.67)
51	Wigler, R.; Kaufman, A. Y.; Lin, S.; Steinbock, N.; Hazan-Molina, H. & Torneck, C. D. (2013). Revascularization: a treatment for permanent teeth with necrotic pulp and incomplete root development. *Journal of Endodontics*, 39 (3), 319-26.	110 (13.75)	127 (15.88)	269 (33.63)
52	Portenier, I.; Haapasalo, H.; Rye, A.; Waltimo, T.; Ørstavik, D. & Haapasalo, M. (2001). Inactivation of root canal medicaments by dentine, hydroxylapatite and bovine serum albumin. *International Endodontic Journal*, 34 (3), 184-8.	110 (5.50)	125 (6.25)	288 (14.40)
53	Erdemir, A.; Ari, H.; Güngüneş, H. & Belli, S. (2004). Effect of medications for root canal treatment on bonding to root canal dentin. *Journal of Endodontics*, 30 (2), 113-6.	109 (6.41)	130 (7.65)	302 (17.76)
54	Cehreli, Z. C.; Isbitiren, B.; Sara, S.; Erbas, G. (2011). Regenerative endodontic treatment (revascularization) of immature necrotic molars medicated with calcium hydroxide: a case series. *Journal of Endodontics*, 37 (9), 1327-30.	108 (10.80)	131 (13.10)	259 (25.90)
55	Sunde, P. T.; Olsen, I.; Debelian, G. J. & Tronstad, L. (2002). Microbiota of periapical lesions refractory to endodontic therapy. *Journal of Endodontics*, 28 (4), 304-10.	107 (5.63)	123 (6.47)	316 (16.63)
56	Dominguez, M. S.; Witherspoon, D. E.; Gutmann, J. L. & Opperman, L. A. (2003). Histological and scanning electron microscopy assessment of various vital pulp-therapy materials. *Journal of Endodontics*, 29 (5), 324-33.	104 (5.78)	115 (6.39)	238 (13.22)
57	Leksell, E.; Ridell, K.; Cvek, M. & Mejàre, I. (1996). Pulp exposure after stepwise versus direct complete excavation of deep carious lesions in young posterior permanent teeth. *Endodontics & Dental Traumatology*, 12 (4), 192-6.	104 (4.16)	115 (4.60)	246 (9.84)

58	Andreasen, J. O.; Munksgaard, E. C. & Bakland, L. K. (2006). Comparison of fracture resistance in root canals of immature sheep teeth after filling with calcium hydroxide or MTA. *Dental Traumatology*, 22 (3), 154-6.	103 (6.87)	133 (8.87)	290 (19.33)
59	Weiger, R.; Rosendahl, R. & Löst, C. (2000). Influence of calcium hydroxide intracanal dressings on the prognosis of teeth with endodontically induced periapical lesions. *International Endodontic Journal*, 33 (3), 219-26.	103 (4.90)	127 (6.05)	342 (16.29)
60	Siqueira Jr, J. F.; & Uzeda, M. (1997). Intracanal medicaments: evaluation of the antibacterial effects of chlorhexidine, metronidazole, and calcium hydroxide associated with three vehicles. *Journal of Endodontics*, 23 (3), 167-9.	102 (4.25)	123 (5.13)	333 (13.88)
61	Breeding, L. C.; Dixon, D. L.; Bogacki, M. T. & Tietge, J. D. (1992). Use of luting agents with an implant system: Part I. *Journal of Prosthetic Dentistry*, 68 (5), 737-41.	102 (3.52)	116 (4.00)	242 (8.34)
62	Neelakantan, P.; Sharma, S.; Shemesh, H. & Wesselink, P. R. (2015). Influence of irrigation sequence on the adhesion of root canal sealers to dentin: a fourier transform infrared spectroscopy and push-out bond strength analysis. *Journal of Endodontics*, 41 (7), 1108-11.	100 (16.67)	37 (6.17)	98 (16.33)
63	Hebling, J.; Giro, E. M. & Costa, C. A. (1999). Human pulp response after an adhesive system application in deep cavities. *Journal of Dentistry*, 27 (8), 557-64.	100 (4.55)	110 (5.00)	191 (8.68)
64	van der Sluis, L. W. M.; Wu, M. K. & Wesselink P. R. (2007). The evaluation of removal of calcium hydroxide paste from an artificial standardized groove in the apical root canal using different irrigation methodologies. *International Endodontic Journal*, 40 (1), 52-7.	99 (7.07)	124 (8.86)	256 (18.29)
65	Sheehy, E. C. & Roberts, G. J. (1997). Use of calcium hydroxide for apical barrier formation and healing in non-vital immature permanent teeth: a review. *British Dental Journal*, 183 (7), 241-6.	99 (4.13)	125 (5.21)	331 (13.79)
66	Siqueira Jr, J. F. & Uzeda, M. (1996). Disinfection by calcium hydroxide pastes of dentinal tubules infected with two obligate and one facultative anaerobic bacteria. *Journal of Endodontics*, 22 (12), 674-6.	98 (3.92)	124 (4.96)	284 (11.36)
67	Cotti, E.; Mereu, M. & Lusso, D. (2008). Regenerative treatment of an immature, traumatized tooth with apical periodontitis: report of a case. *Journal of Endodontics*, 34 (5), 611-6.	97 (7.46)	115 (8.85)	237 (18.23)
68	Min, K-S.; Park, H-J.; Lee, S-K.; Park, S-H.; Hong, C-U.; Kim, H-W.; Lee, H-H. & Kim, E-C. (2008). Effect of mineral trioxide aggregate on dentin bridge formation and expression of dentin sialoprotein and heme oxygenase-1 in human dental pulp. *Journal of Endodontics*, 34 (6), 666-70.	96 (7.38)	113 (8.69)	200 (15.38)
69	Schäfer, E. & Zandbiglari, T. (2003). Solubility of root-canal sealers in water and artificial saliva. *International Endodontic Journal*, 36 (10), 660-9.	96 (5.33)	114 (6.33)	285 (15.83)
70	Akimoto, N.; Momoi, Y.; Kohno, A.; Suzuki, S.; Otsuki, M.; Suzuki, S. & Cox, C. F. (1998). Biocompatibility of Clearfil Liner Bond 2 and Clearfil AP-X system on nonexposed and exposed primate teeth. *Quintessence International*, 29 (3), 177-88.	96 (4.17)	103 (4.48)	157 (6.83)
71	Ohara, P.; Torabinejad, M. & Kettering, J. D. (1993). Antibacterial effects of various endodontic irrigants on selected anaerobic bacteria. *Endodontics & Dental Traumatology*, 9 (3), 95-100.	96 (3.43)	117 (4.18)	268 (9.57)
72	Calt, S. & Serper, A. (1999). Dentinal tubule penetration of root canal sealers after root canal dressing with calcium hydroxide. *Journal of Endodontics*, 25 (6), 431-3.	94 (4.27)	133 (6.05)	278 (12.64)

73	Giuliani, V.; Baccetti, T.; Pace, R. & Pagavino, G. (2002). The use of MTA in teeth with necrotic pulps and open apices. *Dental Traumatology*, 18 (4), 217-21.	93 (4.89)	119 (6.26)	277 (14.58)
74	Mejàre, I. & Cvek, M. (1993). Partial pulpotomy in young permanent teeth with deep carious lesions. *Endodontics & Dental Traumatology*, 9 (6), 238-42.	92 (3.29)	92 (3.29)	188 (6.71)
75	Asgary, S.; Eghbal, M. J.; Parirokh, M.; Ghanavati, F. & Rahimi, H. (2008). A comparative study of histologic response to different pulp capping materials and a novel endodontic cement. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endododontics*, 106 (4), 609-14.	91 (7.00)	134 (10.31)	281 (21.62)
76	Huth, K. C.; Paschos, E.; Hajek-Al-Khatar, N.; Hollweck, R.; Crispin, A.; Hickel, R.; Folwaczny, M. (2005). Effectiveness of 4 pulpotomy techniques-randomized controlled trial. *Journal of Dental Research*, 84 (12), 1144-8.	91 (5.69)	98 (6.13)	214 (13.38)
77	Eldeniz, A.U.; Mustafa, K.; Ørstavik, D. & Dahl, J. E. (2007). Cytotoxicity of new resin-, calcium hydroxide- and silicone-based root canal sealers on fibroblasts derived from human gingiva and L929 cell lines. *International Endodontic Journal*, 40 (5), 329-37.	89 (6.36)	104 (7.43)	238 (17.00)
78	Waltimo, T. M.; Ørstavik, D.; Sirén, E. K. & Haapasalo, M. P. (1999). In vitro susceptibility of Candida albicans to four disinfectants and their combinations. *International Endodontic Journal*, 32 (6), 421-9.	88 (4.00)	115 (5.23)	305 (13.86)
79	Siqueira Jr, J. F.; Magalhães, K. M. & Rôças, I. N. (2007). Bacterial reduction in infected root canals treated with 2.5% NaOCl as an irrigant and calcium hydroxide/camphorated paramonochlorophenol paste as an intracanal dressing. *Journal of Endodontics*, 33 (6), 667-72.	87 (6.21)	98 (7.00)	232 (16.57)
80	Iwamoto, C. E.; Adachi, E.; Pameijer, C. H.; Barnes, D.; Romberg, E. E. & Jefferies S. (2006). Clinical and histological evaluation of white ProRoot MTA in direct pulp capping. *American Journal of Dentistry*, 19 (2), 85-90.	87 (5.80)	100 (6.67)	169 (11.27)
81	Sathorn, C.; Parashos, P. & Messer, H. H. (2005). Effectiveness of single- versus multiple-visit endodontic treatment of teeth with apical periodontitis: a systematic review and meta-analysis. *International Endodontic Journal*, 38 (6), 347-55.	86 (5.38)	108 (6.75)	258 (16.13)
82	Sathorn, C.; Parashos, P. & Messer, H. (2007). Antibacterial efficacy of calcium hydroxide intracanal dressing: a systematic review and meta-analysis. *International Endodontic Journal*, 40 (1), 2-10.	85 (6.07)	116 (8.29)	284 (20.29)
83	Kvist, T.; Molander, A.; Dahlén, G. & Reit, C. (2004). Microbiological evaluation of one- and two-visit endodontic treatment of teeth with apical periodontitis: a randomized, clinical trial. *Journal of Endodontics*, 30 (8), 572-6.	85 (5.00)	94 (5.53)	231 (13.59)
84	Kitasako, Y.; Inokoshi, S. & Tagami, J. (1999). Effects of direct resin pulp capping techniques on short-term response of mechanically exposed pulps. *Journal of Dentistry*, 27 (4), 257-63.	85 (3.86)	91 (4.14)	112 (5.09)
85	Galler, K. M.; Buchalla, W.; Hiller, K-A.; Federlin, M.; Eidt, A.; Schiefersteiner, M. & Schmalz, G. (2015). Influence of root canal disinfectants on growth factor release from dentin. *Journal of Endodontics*, 41 (3), 363-8.	84 (14.00)	110 (18.33)	179 (29.83)
86	Schuurs, A. H.; Gruythuysen, R. J. & Wesselink, P. R. (2000). Pulp capping with adhesive resin-based composite vs. calcium hydroxide: a review. *Endodontics & Dental Traumatology*, 16 (6), 240-50.	84 (4.00)	105 (5.00)	201 (9.57)
87	Portenier, I.; Waltimo, T.; Ørstavik, D. & Haapasalo, M. (2005). The susceptibility of starved, stationary phase, and growing cells of Enterococcus faecalis to endodontic medicaments. *Journal of Endodontics*, 31 (5), 380-6.	83 (5.19)	96 (6.00)	218 (13.63)

88	Unemori, M.; Matsuya, Y.; Akashi, A.; Goto, Y. & Akamine, A. (2001). Composite resin restoration and postoperative sensitivity: clinical follow-up in an undergraduate program. *Journal of Dentistry*, 29 (1), 7-13.	83 (4.15)	91 (4.55)	184 (9.20)
89	Murray, P. E.; About, I.; Franquin, J. C.; Remusat, M. & Smith, A. J. (2001). Restorative pulpal and repair responses. *Journal of the American Dental Association*, 132 (4), 482-91.	83 (4.15)	87 (4.35)	142 (7.10)
90	Peng, W.; Liu, W.; Zhai, W.; Jiang, L.; Li, L.; Chang, J. & Zhu, Y. (2011). Effect of tricalcium silicate on the proliferation and odontogenic differentiation of human dental pulp cells. *Journal of Endodontics*, 37 (9), 1240-6.	81 (8.10)	85 (8.50)	135 (13.50)
91	Moretti, A. B. S.; Sakai, V. T.; Oliveira, T. M.; Fornetti, A. P. C.; Santos, C. F.; Machado, M. A. A. M. & Abdo, R. C. C. (2008). The effectiveness of mineral trioxide aggregate, calcium hydroxide and formocresol for pulpotomies in primary teeth. *International Endodontic Journal*, 41 (7), 547-55.	81 (6.23)	94 (7.23)	200 (15.38)
92	Bjørndal, L. & Thylstrup, A. (1998). A practice-based study on stepwise excavation of deep carious lesions in permanent teeth: a 1-year follow-up study. *Community Dentistry and Oral Epidemiology*, 26 (2), 122-8.	81 (3.52)	86 (3.74)	171 (7.43)
93	El-Meligy, OAS. & Avery, D. R. (2006). Comparison of apexification with mineral trioxide aggregate and calcium hydroxide. *Pediatric Dentistry*, 28 (3), 248-53.	79 (5.27)	100 (6.67)	225 (15.00)
94	Law, A. & Messer, H. (2004). An evidence-based analysis of the antibacterial effectiveness of intracanal medicaments. *Journal of Endodontics*, 30 (10), 689-94.	79 (4.65)	102 (6.00)	295 (17.35)
95	Pereira, J. C.; Segala, A. D, & Costa, C. A. (2000). Human pulpal response to direct pulp capping with an adhesive system. *American Journal of Dentistry*, 13 (3), 139-47.	79 (3.76)	82 (3.90)	134 (6.38)
96	Safavi, K. E. & Nichols, F. C. (1994). Alteration of biological properties of bacterial lipopolysaccharide by calcium hydroxide treatment. *Journal of Endodontics*, 20 (3), 127-9.	79 (2.93)	98 (3.63)	291 (10.78)
97	Sonmez, D.; Sari, S. & Cetinbaş, T. (2008). A Comparison of four pulpotomy techniques in primary molars: a long-term follow-up. *Journal of Endodontics*, 34 (8), 950-5.	78 (6.00)	88 (6.77)	179 (13.77)
98	Pinto, A. S.; Araújo, F. B.; Franzon, R.; Figueiredo, M. C.; Henz, S.; García-Godoy, F. & Maltz, M. (2006). Clinical and microbiological effect of calcium hydroxide protection in indirect pulp capping in primary teeth. *American Journal of Dentistry*, 19 (6), 382-6.	78 (5.20)	87 (5.80)	135 (9.00)
99	Souza Costa, C. A.; Lopes do Nascimento, A. B.; Teixeira, H. M. & Fontana, U. F. (2001). Response of human pulps capped with a self-etching adhesive system. *Dental Materials*, 17 (3), 230-40.	78 (3.90)	81 (4.05)	140 (7.00)
100	Schedle, A.; Franz, A.; Rausch-Fan, X.; Spittler, A.; Lucas, T.; Samorapoompichit, P.; Sperr, W. & Boltz-Nitulescu, G. (1998). Cytotoxic effects of dental composites, adhesive substances, compomers and cements. *Dental Materials*, 14 (6), 429-40.	78 (3.39)	84 (3.65)	162 (7.04)

*WoS-CC: Web of Science Core Collection
[a]Citation density = mean number of citations received per year
Source: Authors.

The 1990s and 2000s were the decades with the highest number of publications, with 29% and 56%, respectively. The oldest paper was authored by Ørstavik *et al.* (1991), a case report published in 1991 that has been cited 114 times (citation

density: 3.80). The most recent paper was authored by Neelakantan *et al.* (2015), a laboratory study published in 2015 that has been cited 100 times (citation density: 16.64).

The 100 most cited papers were published mainly in the *Journal of Endodontics* (38 papers; 4,589 citations), followed by the *International Endodontic Journal* (30 papers; 4,500 citations). The top 10 journals with the highest number of papers in the 100 most cited list are presented in Table 2. Researchers at the University of Oslo (Norway) authored the highest number of papers in the 100 most cited list (8 papers; 1,006 citations), followed by the University of Melbourne (Australia) with 5 papers (638 citations) (Table 3).

The number of authors ranged from one to 10 per paper. Papers with 3 to 4 (50%) and 1 to 2 (20%) authors were more frequent, followed by 5 to 6 (17%). A total of 335 authors appeared on the list of the 100 most cited papers. Most of the papers were from Europe (42 papers; 4,953 citations), while 23 papers (3,278 citations) were from the USA. Authors from all continents have published at least one paper (Figure 1). A VOSviewer density map (Figure 2) was created to detail the collaborative co-authorship among authors. The biggest cluster was that led by Ørstavik D and Haapasalo MPP, including 21 authors in total, demonstrating their influence in the scientific community. In addition, the top 10 authors with more papers in the top 100 list are shown in Table 4.

Table 2: Top 10 journals with the highest number of papers published on calcium hydroxide on the 100 most cited list.

Journal	Number of papers	Number of citations in WoS-CC	JCR 2020 Impact Factor
Journal of Endodontics	38	4,589	4.171
International Endodontic Journal	30	4,500	5.264
Dental Traumatology	10	1,704	3.333
Journal of the American Dental Association	3	427	3.634
Journal of Dentistry	3	268	4.379
American Journal of Dentistry	3	244	1.522
Pediatric Dentistry	2	244	1.874
Journal of Dental Research	2	205	6.116
Dental Materials	2	156	5.304
Operative Dentistry	1	192	2.440

Source: Authors.

The most cited paper in the WoS-CC was titled "Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture" (Andreasen *et al.*, 2002), authored by Andreasen JO, Farik B, and Munksgaard EC, published in 2002 in *Dental Traumatology*. This paper has been cited 384 times (citation density: 21.47). It was also the most cited in the Scopus database (467 citations) and Google Scholar (1074 citations). The paper with the highest citation density (mean number of citations per year) was a narrative review entitled "Properties and applications of calcium hydroxide in endodontics and dental traumatology" (Mohammadi & Dummer, 2011), authored by Mohammadi Z and Dummer PMH, published in 2011 in the *International Endodontic Journal*, with an average of 24.30 citations per year. This paper is the ninth most cited article in the top 100 list.

Most papers were laboratory studies (44%), followed by multifaceted interventional studies (22%); reviews (12%), being 2 systematic reviews and 10 narrative reviews; interventional studies (11%); case reports (7%); and observational studies (4%). Concerning the fields of Dentistry (thematic field), over half of the studies were on Endodontics (62%), 30% on Operative Dentistry, 4% on Dental Traumatology, 3% on Pediatric Dentistry, and 1% on Prosthodontics. On the issue of the main uses of calcium hydroxide made over time in dental research, 61% of the studies were on intracanal dressing, 29% on pulp capping agent, 5% on root canal sealers, 4% on pulpotomy pulp-dressing, and 1% on luting agents.

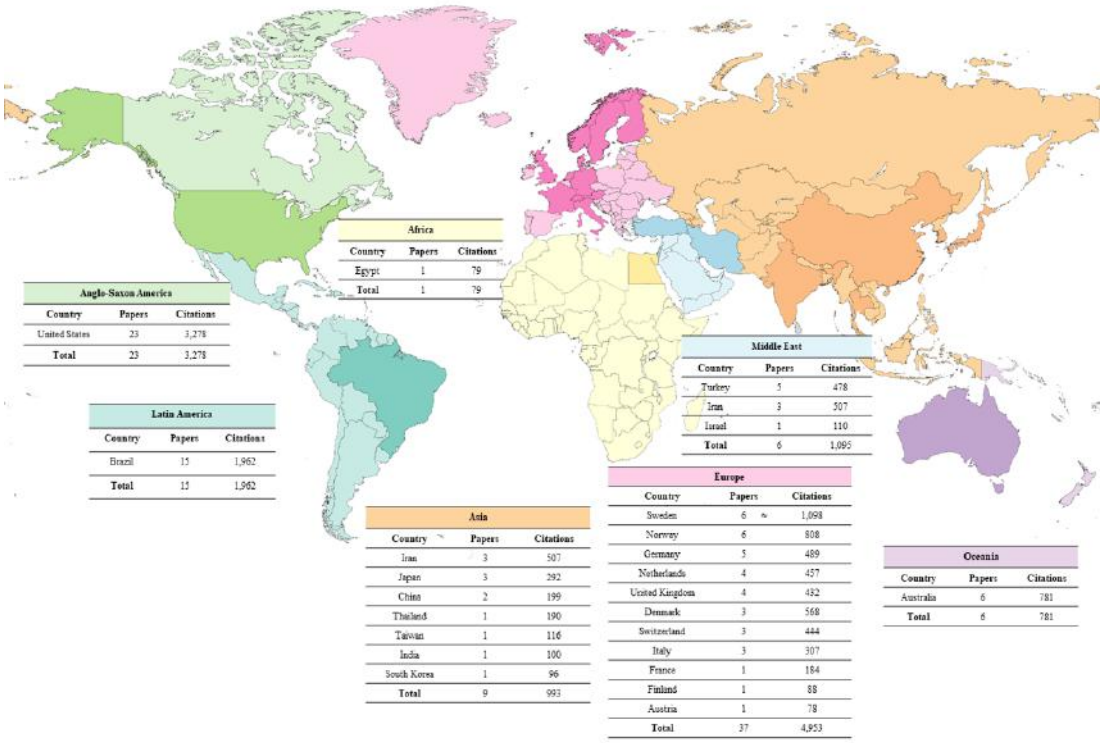
Table 3: Top 10 institutions with the highest number of papers published on calcium hydroxide on the 100 most cited list.

Institution	Country	Number of papers	Number of citations in WoS-CC
University of Oslo	Norway	8	1,006
The University of Melbourne	Australia	5	638
The University of North Carolina	United States of America	4	680
The Academic Centre for Dentistry in Amsterdam (ACTA)	Netherlands	4	457
University of Copenhagen	Denmark	3	568
Nordic Institute of Dental Materials (NIOM)	Norway	3	515
Universidade Estadual Paulista (UNESP)	Brazil	3	434
The University of Alabama	United States of America	3	409
University of Basel	Switzerland	3	348
University of Connecticut	United States of America	3	280

Source: Authors.

A total of 460 keywords were identified, of which 320 appeared only once. The biggest nodes were “calcium hydroxide” (53 occurrences), “mineral trioxide aggregate,” and “sodium hypochlorite” (22 occurrences each), followed by “apical periodontitis” (20 occurrences). Figure 3 shows the VOSviewer density map of the co-occurrence of connected keywords, with at least one occurrence.

Figure 1: Worldwide distribution of the 100 most cited papers on calcium hydroxide.



Anglo-Saxon America

Country	Papers	Citations
United States	23	3,278
Total	23	3,278

Latin America

Country	Papers	Citations
Brazil	15	1,962
Total	15	1,962

Africa

Country	Papers	Citations
Egypt	1	79
Total	1	79

Middle East

Country	Papers	Citations
Turkey	5	478
Iran	3	507
Israel	1	110
Total	6	1,095

Asia

Country	Papers	Citations
Iran	3	507
Japan	3	292
China	2	199
Thailand	1	190
Taiwan	1	116
India	1	100
South Korea	1	96
Total	9	993

Europe

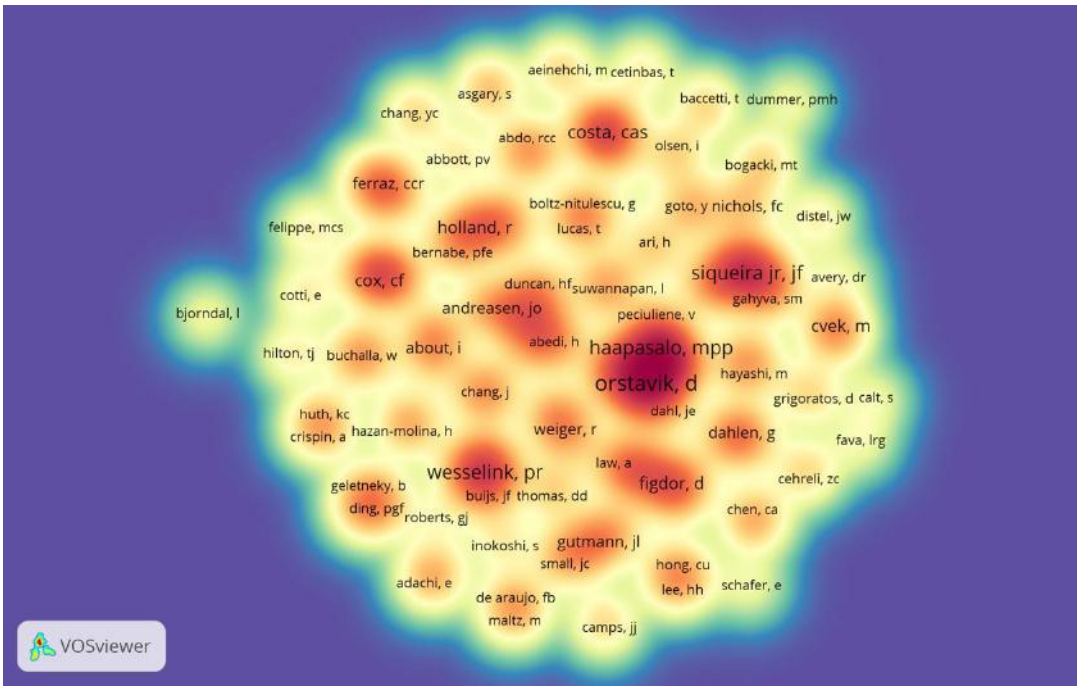
Country	Papers	Citations
Sweden	6	1,098
Norway	6	808
Germany	5	489
Netherlands	4	457
United Kingdom	4	482
Denmark	3	568
Switzerland	3	444
Italy	3	307
France	1	184
Finland	1	88
Austria	1	78
Total	37	4,953

Oceania

Country	Papers	Citations
Australia	6	781
Total	6	781

Source: Authors.

Figure 2: VOSviewer co-authorship density map demonstrating the existence of clusters of authors of the 100 most cited papers on calcium hydroxide.



Source: Authors.

Table 4: Bibliometric indicators of the first 10 authors with more papers published on calcium hydroxide on the 100 most cited list in WoS-CC.

Author	Country	Number of papers in the top 100 list	Number of citations in the top 100 list	Number of papers in WoS-CC	*h*-index
Orstavik, D.	Norway	9	1,188	148	46
Siqueira Jr, J. F.	Brazil	5	638	287	62
Haapasalo, M.	Norway	4	680	238	55
Wesselink, P. R.	Netherlands	4	457	187	54
Trope, M.	United States of America	3	568	140	44
Waltimo, T. M. T.	Switzerland	3	515	37	22
Costa, C. A. S.	Brazil	3	434	211	38
Figdor, D.	Australia	3	409	33	18
Cvek, M.	Switzerland	3	348	22	18
Holland, R.	Brazil	3	280	51	21

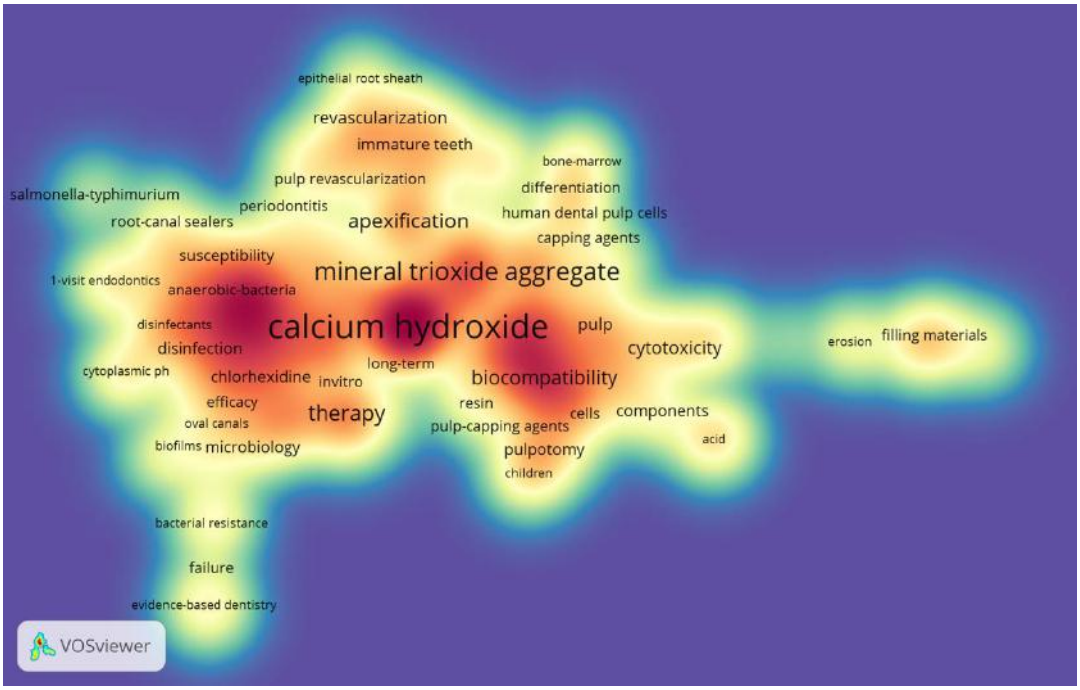
Source: Authors.

4. Discussion

This bibliometric study aimed to identify and analyze the 100 most cited papers on the use of calcium hydroxide in Dentistry. This paper represents a celebration of the 100th anniversary since the first publication on calcium hydroxide in Dentistry, demonstrating the field's scientific progress to highlight its clinical importance, role, and current research trends.

The 100 most cited papers received a total of 13,141 citations in the WoS-CC. The most cited paper, by Andreasen *et al.* (2002), received a total of 384 citations. Even though it was published in 2002, this paper presented the fifth highest citation density. This paper is a laboratory study that aimed to test whether dentin in contact with calcium hydroxide would show a reduction in fracture strength over time. The results indicated that the fracture strength of calcium hydroxide-filled immature teeth was halved in about a year from the root filling. The impressive metrics of this study demonstrate its importance to the topic. In less broad research areas, papers with more than 100 citations can be considered highly cited papers, significantly influencing research and practice (Santos *et al.*, 2021; Van Noorden *et al.*, 2014). In the present study, 63 papers were cited at least 100 times, confirming the relevance of calcium hydroxide in dental science. In the 1990s, calcium hydroxide was called "Dentistry's friend" (Stanley & Pameijer, 1997) since this chemical component is/was considered a relevant multipurpose dental biomaterial (Rosa et al., 2019; Bedran *et al.*, 2020; Cushley *et al.*, 2021).

Figure 3: VOSviewer density map of co-occurrence of keywords.



Source: Authors.

Despite calcium hydroxide's centenary in Dentistry, the 100 most cited papers were published over only 30 years. Although the first scientific description of the use of calcium hydroxide in Dentistry was in 1920, the oldest paper among the 100 most cited, by Ørstavik *et al.* (1991), was not published until 1991, and 85% of the papers in the top 100 list were published during the 1990s or 2000s. While citations accumulate over time (Ahmad *et al.*, 2019; Feijoo *et al.*, 2014) with advances in scientific knowledge, the introduction of new concepts and analysis may be related in more recent studies (Baldiotti *et al.*, 2021; Mattos *et al.*, 2021) to increased interest. WoS-CC, the database adopted in this paper, retrieves publications from 1945, and papers published between 1920 and 1945 would not be retrieved. Furthermore, previous bibliometric studies (Ahmad *et al.*, 2019; Perazzo *et al.*, 2019) have also reported a tendency of the most cited papers to being published in the most recent three

decades (1990s-2010s). This may be because the internet and digital versions of scientific journals have contributed to the improved accessibility of papers published in recent years. Only in recent years have scientific journals digitized their older volumes. Also, peer-reviewers require that more recent papers are cited.

The introduction of mineral trioxide aggregate (MTA) in Dentistry in the 1990s, for instance, may also explain why the most cited papers are from recent decades. Studies evaluating the properties of MTA or its clinical success as a pulp-capping agent and in apexification models have often used calcium hydroxide as the control group. This hypothesis might be supported by analyzing the most frequent keywords. “Mineral trioxide aggregate” was the second most frequent keywords (22 occurrences), behind only “calcium hydroxide”, while MTA appeared 10 times.

The *Journal of Endodontics* and the *International Endodontic Journal* were identified as the scientific journals with the highest number of papers in the top 100 most cited list. Both journals are leaders in the field of Endodontics, the thematic field responsible for over half of the catalogued studies. In consequence, most of the papers used calcium hydroxide mainly as an intracanal dressing, pulp-capping agent, chemical component of root canal sealer, and pulp dressing agent for pulpotomy. In the past half century, the incorporation of new scientific knowledge on the protection of the dentine-pulp complex (da Rosa *et al.*, 2019; da Rosa *et al.*, 2018), such as approaches to the preservation of caries-affected dentine (Hernández *et al.*, 2014), the biomimetic aspects of restorative dental biomaterials (Zafar *et al.*, 2020), and the development of new products such as calcium silicate-based materials (Sadoon *et al.*, 2020), has occurred at a staggering pace, promoting a revolution in the field of new functional repair materials and pulp regeneration approaches in the 100 years since the introduction of calcium hydroxide in both adult and Pediatric Dentistry.

Considering the principles of evidence-based Dentistry, studies with higher levels of evidence such as systematic reviews and clinical trials are expected to be highlighted (Patil *et al.*, 2020). In the present analysis, two systematic reviews (171 combined citations) and eleven prospective clinical trials (1,062 combined citations) were compiled. However, laboratory and multifaceted interventional studies (an *in vivo* intervention associated with laboratory tests) were the most frequently observed study designs, followed by narrative reviews. These results were in accordance with previous bibliometric analysis that analyzed the most cited papers in Operative Dentistry (Feijoo *et al.*, 2014), Periodontology (Faggion *et al.*, 2017), and Cariology (Baldiotti *et al.*, 2021).

Regarding the continent, Europe shows the highest number of papers in the top 100 most cited list, as reported in previous bibliometric analysis (Perazzo *et al.*, 2019; Baldiotti *et al.*, 2021). The United States of America hosted the majority of papers at a country level, proportionally receiving a higher number of citations. These results might be explained by the quality of European and American institutions and researchers and the availability of research funding (Baldiotti *et al.*, 2021). However, despite the predominance of papers from Europe and from the USA, papers from all continents were retrieved, and less developed countries also contributed to knowledge on the topic, indicating the product's widespread use. Furthermore, the University of Oslo in Norway was the leading institution on the list of the 100 most cited papers, reflecting the prestige of the author with the highest number of publications, Dag Ørstavik.

Dag Ørstavik D and José Freitas Siqueira Jr. (the two most prolific authors), despite being from different countries (Norway and Brazil), conducted similar laboratory studies mainly on the antimicrobial and antibacterial properties of calcium hydroxide, either as intracanal dressing, pulp-capping agent, or root canal sealer. Likewise, Markus Haapasalo, the third most prolific author, worked in partnership with Dag Ørstavik on most of his papers identified in the top 100 list. Moreover, Paul Wesselink, the fourth on the 10 most prolific author list, performed two multifaceted interventional studies, assessing the effect of calcium hydroxide on the treatment of teeth with periapical lesions in one or two visits.

This study has limitations inherent to the research methodology applied. A bibliometric analysis focuses mainly on the crude analysis of citation rates, which may not directly reflect the quality of a paper, although the number of citations a paper

receives is considered one of the measures of scientific merit (Eyre-Walker & Stoletzki, 2013). In addition, despite the Web of Science being a reliable database, the exclusion of influential papers from other databases (e.g. PubMed) cannot be ruled out. However, despite its limitations, the present bibliometric study provides original data on worldwide scientific interest in the use of calcium hydroxide in Dentistry.

5. Conclusion

In conclusion, the 100 most cited papers on calcium hydroxide were published mainly by authors in European countries or the United States of America, with laboratory and multifaceted interventional designs and addressing topics mainly related to Endodontics and Operative Dentistry. The *Journal of Endodontics* published the majority of papers on the 100 most cited list.

Functional repair materials and pulp regeneration approaches represent the new frontier between conservative and endodontic therapy. Thus, based on current scientific literature on the protection of the dentine-pulp complex with the preservation of caries-affected dentine, and the current knowledge on the biomimetic aspects of restorative dental materials and regenerative endodontics; further investigation such as, reviews, case reports/series, laboratory, observational, interventional, and multifaceted interventional studies are needed in order to continue comparing calcium hydroxide-containing dental materials with new dental biomaterials under therapeutic approaches applied in modern Dentistry.

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