



Research trends regarding chemomechanical preparation and obturation of root canals in the Science Citation Indexed Endodontics Journals: Bibliometric analysis of 2001–2005 and 2016–2020

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Purpose: Articles published in the Australian Endodontic Journal, Journal of Endodontics, and International Endodontic Journal were analyzed in two different periods.

Methods: Articles published in two different 5-year periods, 2001–2005 and 2016–2020, on the issues mentioned above the journals were evaluated by two researchers. The extracted parameters were the first author's country, number of authors, national and international cooperation, type of study, number of citations, first author's department and study topics. They were analyzed with the Chi-square independence test over the years.

Results: Mechanical preparation studies increased, while obturation studies decreased in the second period ($p = 0.000$). An increase was observed regarding authors' number and national/international cooperation ($p = 0.000$). In vitro studies were significantly higher than clinical studies and animal experiments in both periods ($p = 0.003$). An increase was found in studies evaluating files' root fracture formation ($p = 0.000$), apical debris extrusion ($p = 0.000$), and irrigation activation devices/methods ($p = 0.005$) in 2016–2020. Studies on microleakage lost their popularity in 2016–2020 ($p = 0.000$). An increase was also observed in clinical and radiographic follow-up studies after root canal treatment in 2016–2020 ($p = 0.001$).

Conclusion: Research topics change with technological, mechanical, physical, and biological developments, and researchers need to keep up to date with these changes to increase their chances of study acceptance.

Keywords: Bibliometric analysis, endodontics, journal, root canal treatment.

Introduction

Bibliometric analysis is the quantitative measurement of the impact of scientific publications on other publications in its field (1). It guides researchers in identifying study

topics, researching existing ideas, and determining the methods to be used (1). In order to analyze the trends and impact of publications in-depth, the journal should be examined comprehensively using bibliometric meth-

Cite this article as: Ezentaş N, Uzunoğlu Özyürek E. Research trends regarding chemomechanical preparation and obturation of root canals in The Science Citation Indexed Endodontics Journals: Bibliometric Analysis of 2001–2005 and 2016–2020. Turk Endod J 2023;8:87-96.

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Submitted: March 13, 2023 Revised: June 09, 2023 Accepted: June 09, 2023

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ods and techniques (2,3). The development and focus of treatments and techniques in the same field could also be highlighted through bibliometric analysis (2-9). Therefore, bibliometric analysis has gained significant attention in the scientific community. In recent years bibliometric studies from various dental specialties such as pedodontics (4), prosthodontics (5), periodontology (6), orthodontics (7), as well as endodontics (2,8,9), gained popularity.

Endodontic treatment involves chemomechanical preparation of infected root canals followed by obturation with an inert filling material (10). The objectives of mechanical preparation are to remove remaining pulp tissue and microorganisms and to obtain a suitable form for further cleaning and filling (11). The purpose of chemical preparation is to contribute to removing debris, smear layer and microorganisms that mechanical methods cannot altogether remove and to provide lubricity to the root canals during the mechanical preparation (11,12). It aims to prevent re-infection of the root canals by obturating the root canals prepared chemomechanically (13). The complete implementation of all these steps is essential for a successful endodontic treatment. As a result, this leads to the emergence of research involving various clinical, biological, mechanical and materials science topics (9). Although endodontic treatment is a treatment which is clinically performed, it has been reported that the percentage of laboratory studies published in journals is higher than clinical studies (14). In addition to the study types, the types of subjects studied also attract the attention of researchers (2,15). The popularity of study topics varies over time, for example, studies evaluating micro-leakage of filling materials decreased abruptly in recent years (8,16,17), while studies considering vital pulp therapies or revascularization/regeneration procedures increased (18-20).

Recognizing the changing trends in study subjects will contribute to proper project planning in a rapidly changing world. For this reason, bibliometric studies are critical in identifying current study topics and guiding researchers in their new studies. Therefore, this study aimed to perform a bibliometric analysis of articles published in 3 endodontic journals indexed in the Science Citation Index (Australian Endodontic Journal (AEJ), Journal of Endodontics (JOE) and International Endodontic Journal (IEJ) on the mechanical, chemical preparation and obturation steps of root canal treatment and to guide researchers about current study topics. Furthermore, it is aimed to evaluate the changes in the 21st century more comprehensively by analyzing two different 5-year periods, 2001–2005 and 2016–2020.

Materials and Methods

The publications considering the “mechanical or/and chemical preparation and obturation” stages of endodontic treatment and published between 2001–2005 and 2016–2020 in the AEJ, JOE and IEJ, which included in the Scientific Citation Index, were evaluated bibliometrically. Journal websites were used during the evaluation. The publications were included according to inclusion criteria by two reviewers that repeated their evaluations 3 times for consistency. Inclusion criteria were as follows: Studies published in AEJ, JOE, and IEJ between 2001–2005 and 2016–2020; studies evaluating mechanical preparation, chemical preparation and obturation stages, studies using acrylic models and bovine teeth that simulate mature permanent teeth, studies with mature permanent human teeth, animal, clinical and in vitro studies. Exclusion criteria were as follows: studies using acrylic models and bovine teeth that simulate immature teeth, primary teeth, immature human teeth, retrospective follow-up studies without data on which materials are used in the treatment phase, case reports, reviews (systematic, narrative), editorials, opinion letters, announcements and news, conference reports, meta-analyze studies, in vitro, animal and clinical studies considering only medicament use during chemical preparation were excluded.

Extracted parameters were: The number of authors, the country of the first author, the first author’s department as endodontics or non-endo, national and international cooperation, study type (in vitro, clinical study, animal experiments, and combined studies), number of citations (Scopus database was used and citations numbers until January 01, 2021 were noted) and study topics. Studies were categorized according to headings as shown in Table 1. Studies involving experiments under two or more main categories were classified as combined studies. Studies involving two or more mechanical, chemical preparation or obturation steps were recorded as combined studies.

Statistical Analysis

SPSS V23 (IBM SPSS Statistics, Armonk, NY) software was used to evaluate the data. The trial version of GraphPad Prism V9 (GraphPad Software, La Jolla, California, USA) was used to prepare the graphics. The change in each parameter over the years was analyzed with the Chi-square independence test after the percentages were calculated and $p < 0.05$ was determined.

Results

Total and Included Article Numbers

The total and included number of articles and the distri-

Table 1. Subcategorization of the study topics

Mechanical preparation	Chemical preparation	Obturation
Fracture resistance of endodontic instruments	Smear layer removal	Microleakage
Shaping ability of endodontic instruments	Antimicrobial Efficiency	Strengthening effect of filling materials against root fractures
Root fracture/crack formation	Biocompatibility	Bond Strength
Debris extrusion	Activation methods and devices	Physicochemical properties of filling materials
Education	Tissue dissolution effect	Clinical and radiographic healing
Cleaning ability of endodontic instruments	Combination of 2 or parameters	Obturation quality
Other	Other	Root surface temperature change
		Biocompatibility
		Combination of 2 or parameters
		Other

Table 2. The total and included number of articles and the distribution of study topics

Journal name	Australian endodontic journal		Journal of endodontics		International endodontic journal		Overall per period		Total
Period	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005 and 2016–2020
Total number	97	182	837	1376	548	732	1482	2290	3772
Included articles	13	51	254	290	167	182	434	523	957
Mechanical preparation	4	22	81	155	79	86	164	263	427
							37.8%	50.3%	44.6%
Chemical preparation	1	21	65	70	36	62	102	153	255
							23.5%	29.3%	26.6%
Obturation	7	7	98	53	42	26	147	86	233
							33.9%	16.4%	24.3%
Combined	1	1	10	12	10	8	21	21	42
							4.8%	4.0%	4.4%

bution of study topics are shown in Table 2. A total of 957 articles were included in the study. In the first period (2001–2005), the total number of articles included in the study was 434, whereas in the second period (2016–2020), it was 523. Of the included articles, 427 were on mechanical preparation, 255 were on chemical preparation, and 233 were on obturation. Articles included were mainly published in JOE in both periods ($p = 0.000$). When the percentage of included studies is compared according to time intervals, it was observed that there was an increase in all journals between 2016 and 2020, and this increase was significant for AEJ and JOE ($p = 0.000$).

Authors Number

The number of authors was categorized as 1–3, 4–6, and 7-more. In the first period, 211 (48.6%), 205 (47.2%) and 18 (4.1%) studies were published with 1–3, 4–6, and 7-more authors, respectively. In the second period, this order was as follows: 91 (17.4%), 288 (55.1%), and 144 (27.5%). Studies performed with more authors increased

significantly in the second period compared to the first one ($p = 0.000$).

First Authors Country

Table 3 Shows the results of the countries quantity according to the first author's address. The top country was Brazil followed by the USA. While the percentage of included studies published by the USA and Germany decreased significantly in the 2016–2020 period, Brazil and Turkey increased ($p = 0.000$). The percentage of publications in the USA and Germany between 2001 and 2005 was found to be significantly higher than Brazil and Turkey ($p = 0.000$), but the opposite was found in the years 2016–2020 ($p = 0.000$).

First Authors Department

In both periods (308/434 vs. 373/523) first authors' department was endodontics, and there was no significant difference between these periods ($p = 0.905$).

Table 3. Countries of first authors of included manuscripts in different time periods in alphabetical order

Country	AEJ		JOE		IEJ		Total		Percentage (%)	
	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005	2016–2020	2001–2005	2016–2020
Albania	0	0	0	1	0	0	0	1	0.00	100.00
Argentina	0	0	6	0	3	0	9	0	100.00	0.00
Australia	1	3	5	7	6	3	12	13	48.00	52.00
Belgium	0	0	0	2	6	2	6	4	60.00	40.00
Brazil	5	11	19	72	23	67	47	150	23.86	76.14
Canada	2	0	4	19	6	0	12	19	38.71	61.29
Chile	0	0	2	0	0	0	2	0	100.00	0.00
China	0	1	4	13	4	10	8	24	25.00	75.00
Colombia	0	0	0	0	1	2	1	2	33.33	66.67
Croatia	0	0	2	0	2	0	4	0	100.00	0.00
Egypt	0	1	0	2	0	7	0	10	0.00	100.00
France	0	0	12	2	5	0	17	2	89.47	10.53
Germany	0	2	10	7	21	6	31	15	67.39	32.61
Greece	0	2	7	4	2	1	9	7	56.25	43.75
Hong Kong	0	0	0	0	0	1	0	1	0.00	100.00
Hungary	0	0	1	0	2	0	3	0	100.00	0.00
India	0	3	0	6	0	2	0	11	0.00	100.00
Indonesia	0	0	1	0	0	0	1	0	100.00	0.00
Iran	2	2	0	3	1	1	3	6	33.33	66.67
Iraq	0	0	0	0	1	1	1	1	50.00	50.00
Israel	0	0	7	3	2	1	9	4	69.23	30.77
Italy	1	2	13	12	7	16	21	30	41.18	58.82
Japan	0	0	12	7	5	0	17	7	70.83	29.17
Jordan	0	1	0	0	0	0	0	1	0.00	100.00
Korea	0	0	5	13	3	1	8	14	36.36	63.64
Lebanon	0	1	0	2	0	0	0	3	0.00	100.00
Libya	0	0	0	1	0	0	0	1	0.00	100.00
Lithuania	0	0	0	0	0	1	0	1	0.00	100.00
Malaysia	0	1	0	0	0	0	0	1	0.00	100.00
Mexico	0	0	1	0	0	0	1	0	100.00	0.00
Myanmar	0	0	0	1	0	0	0	1	0.00	100.00
Netherlands	0	0	0	4	9	4	9	8	52.94	47.06
New Zealand	0	1	0	0	3	0	3	1	75.00	25.00
Norway	0	0	3	1	3	0	6	1	85.71	14.29
Paraguay	0	0	0	0	0	1	0	1	0.00	100.00
Poland	0	0	2	0	0	0	2	0	100.00	0.00
Portugal	0	0	0	3	0	0	0	3	0.00	100.00
Romania	0	0	0	1	0	0	0	1	0.00	100.00
Saudi Arabia	1	1	0	8	1	2	2	11	15.38	84.62
Serbia	0	0	0	1	0	0	0	1	0.00	100.00
Singapore	0	0	0	0	1	0	1	0	100.00	0.00
South Africa	0	0	0	5	1	1	1	6	14.29	85.71
Spain	0	3	4	11	3	9	7	23	23.33	76.67
Sweden	0	0	0	0	1	0	1	0	100.00	0.00
Switzerland	1	0	8	2	11	5	20	7	74.07	25.93
Taiwan	0	0	4	0	1	0	5	0	100.00	0.00
Thailand	0	1	4	2	0	0	4	3	57.14	42.86
Turkey	0	8	17	45	8	29	25	82	23.36	76.64
United Arab Emirates	0	0	0	2	0	0	0	2	0.00	100.00
United Kingdom	0	2	3	2	16	7	19	11	63.33	36.67
United States of America	0	5	98	26	9	2	107	33	76.43	23.57
Total	13	51	254	290	167	182	434	523	45.35	54.65

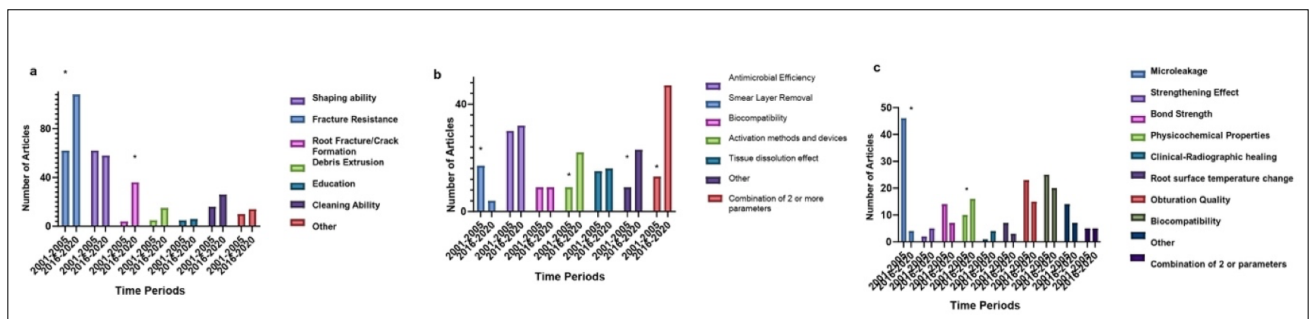


Fig. 1. The results of subcategories of mechanical preparation (a), chemical preparation (b) and obturation (c) studies. *revealed the difference between 2 periods regarding percentage of published studies ($p=0.05$, Chi-square tests)

National and International Cooperation

In the first period (209/434), 48% of the studies were performed with national cooperation, while in the second period (354/523), 68% of the studies were performed with national. This increase was statistically significant ($p = 0.000$). International cooperation is limited compared to national in both periods. However, a statistically significant increase also was observed for international cooperation in the second period (63/434 vs. 170/523) ($p = 0.000$).

Study Type

In the first period, 13 included studies were animal research, 12 were clinical studies, 407 were in vitro studies, and 2 were combined studies ($n = 434$). The second 4 were animal research, 39 were clinical, 479 were in vitro, and 2 were combined studies ($n = 523$). The percentage of clinical studies increased in the second period ($p = 0.001$), while the percentage of animal studies decreased ($p = 0.009$). In both periods, in vitro studies were the most preferred types ($p = 0.003$).

Number of Citations

The number of citations was checked from the Scopus database until January 01, 2021. Studies had 100 and more citations from the first period (citation numbers 100-over: 76 vs. 0, 51-99: 106 vs. 9, 11-50: 210 vs. 183, 1-10: 41 vs. 277). Except for one article about mechanical preparation (21), all articles from the first period were cited at least once; while 54 articles from the second period were never cited until January 01, 2021. There are 76 articles with 100 or more citations, of which 31 were about mechanical preparation, 30 were about chemical preparation, and ten were related to obturation procedures. Five of them consisted of combined subjects.

Study Topics

Table 2 reveals the distribution of studies according to

their topics. The number of included studies was 957; 427 were categorized as mechanical preparation, 255 were categorized as chemical preparation, 233 were categorized as obturation, and 42 were combined at least two topics. Among these categorizations, mechanical preparation was the most popular ($p = 0.000$).

In the first period, the percentages of mechanical preparation and obturation studies were higher than those of chemical preparation studies ($p = 0.000$). In the second period, the percentage of mechanical preparation studies was higher than the percentages of chemical preparation and obturation studies ($p = 0.000$). The percentage of obturation studies decreased significantly in the second period compared to the first one ($p = 0.000$).

Subcategories Analysis

Fig. 1a reveals the results of subcategories of mechanical preparation studies. There was a significant increase in the percentages of studies considering root fracture/crack formation of file systems ($p = 0.000$), fracture resistance of files and debris extrusion potential of file systems in the second period compared to the first one ($p = 0.000$).

Fig. 1b reveals the results of subcategories of chemical preparation studies. There was a significant increase in the percentages of studies considering activation methods/devices ($p = 0.005$), more than two parameters ($p = 0.000$) and other topics such as penetration of irrigants to the dentinal tubules, their effect on postoperative pain and bond strength of filling materials to the canal walls in the second period compared to the first one ($p = 0.004$). On the other hand, the percentage of studies considering only smear layer removal decreased in the second period compared to the first one ($p = 0.000$).

Fig. 1c reveals the results of subcategories of obturation studies. There was a significant increase in the percentages of studies considering the physicochemical properties of filling materials in the second period compared to the first ($p = 0.010$). On the other hand, the percentage of studies

considering microleakage decreased in the second period compared to the first one ($p = 0.000$).

Discussion

This study aimed to revise and reveal the change in the main steps of the endodontic treatment research area, especially in the 21st century. For this purpose, three well-known endodontic journals were evaluated for two different periods. The number of included articles increased in the second period in all journals and was higher in JOE, followed by IEJ and AEJ, respectively. The total number of published articles plays a role also in the number of included articles, and the number of published articles was higher in JOE in both periods. This situation was considered natural because AEJ started its publication life later and published 3 times a year. Likewise, IEJ started its regular monthly publication life later than JOE. Previous bibliometric analysis preferred to review IEJ and JOE (2,8,9,22). However, in the current study, three journals in SCI were evaluated. It has been observed that the percentages of studies included in the second period from JOE and IEJ were decreased, while the percentage of studies included from AEJ was increased. It has been thought that AEJ continues to accept articles regarding endodontic treatment steps. At the same time, JOE and IEJ preferred to publish more recent topics such as apexification with bioceramic materials, vital pulp therapies, stem cells and regeneration (2,9,23).

The number of authors and national-international cooperations increased in the second period. While the authors preferred to work with researchers in their institutions and departments between 2001 and 2005, they tended to collaborate with researchers from different departments, institutions and countries in recent years (24). The increase in multi-author publications may result from the need for teamwork as research becomes more complex and multi-staged. With the increasing complexity of research, the increasing need for funding may also be effective in the increase in cooperation. It is claimed that as evidence-based practices gain importance, journals tend to publish multi-center studies with larger teams (24). A study by Beaver (25) in 2004 concluded that studies with multiple authors and collaborations are reliable. However, in multi-author studies, there is also a concern about the author's responsibilities. For this reason, some journal editors require a signed statement defining author responsibilities (24,26).

When the first author's country is evaluated, it has been determined that the USA, Brazil, Germany, Turkey and Italy are the countries with the most publications in both periods. While the number of publications included has decreased in the USA and Germany in the past 5 years,

it has increased in Brazil and Turkey. Considering that the manufacturing companies are primarily located in the USA and Germany and the pioneering experiments were carried out in these countries, it was considered natural that in the following years, there would be orientations to different fields (more current issues such as regeneration) and that the studies on the included topics were carried out in other countries at a later period. In a previous study (8), it was seen that Brazil became the leading publisher country by showing a significant increase in the number of articles published in recent years.

Included studies were classified as *in vitro*, animal research, clinical studies and their combinations according to methodology. Most included studies were *in vitro* (laboratory) studies in both periods. Although *in vitro* studies are at the bottom of the evidence pyramid, they provide helpful information about future study designs and clinical applications. Advantages such as the absence of ethical problems and relatively easy, cheap and fast sample providing and preparation may explain the reasons for the tendency for *in vitro* studies (27). Extracted human teeth, bovine, pig teeth, simulated teeth made of acrylic resin or stainless steel, and cell culture methods were used in laboratory studies. Animal experiments provide more realistic data than *in vitro* tests. However, they cause a tremendous ethical debate (28). In the past 5 years, interest in animal experiments has decreased. *In vitro* studies provide preliminary data; however, neither *in vitro* nor animal experiments fully reflect clinical conditions. Therefore, clinical studies should also support the data obtained (29). Consistent with this, it was observed that clinical studies increased significantly in the second period. In 2015, Tzanetakis et al. (8) concluded that there was a decrease in clinical and *in vitro* studies published in IEJ and JOE over the years, while there was an increase in systematic reviews and meta-analysis studies. In the current study, systematic reviews and meta-analyses were excluded to avoid causing complexity in interpretation since the publications included in the current study can also be included in the meta-analyses.

The number of citations of an article shows its impact on the research area (1). This study's five most cited articles belong to 2001–2005. The first article has received 406 citations and assesses the shaping ability of files (30). The article with the second highest number of citations received 357 citations and evaluates the effectiveness of irrigation solutions in removing the smear layer (31). The third article has 350 citations, the fourth 293 and the fifth 283 citations. These articles deal with the effect of filling techniques on microleakage (32), the antibacterial activity of irrigation solutions (33), and the effect on the

smear layer (34), respectively. Articles with 100 or more citations are considered classics in their field (35). While 76 articles received 100 or more citations in 2001–2005, none reached this number in the last 5 years. It has been confirmed in previous studies that the publication year of the articles affects the number of citations (35–37). While citations measure one study's impact on others, it only partially reflects the quality and value of the work, and it takes about 20 years to determine the actual value of a publication (37). Furthermore, researchers often cite highly cited publications, which is called the “snowball effect” and causes older publications to receive more citations (1,38).

The main steps of endodontic treatment are mechanical preparation, chemical preparation of root canals and filling of prepared root canals. New materials and methods are being developed daily to improve the mechanical, chemical and filling stages and apply a more effective treatment (11–13). Since a complication during mechanical preparation might adversely affect the following stages, many studies have been carried out on this subject. It is aimed at reducing the rate of complications that may occur during adequate and ideal preparation. Consistent with this in the current study, it was found that the number of publications on mechanical preparation in both years was higher than the number of publications on other steps. As a result of the increase in commercially available file systems in the second 5-year period, a significant increase was observed in the number of publications related to mechanical preparation. One of the aims to be considered during mechanical preparation is preserving the original canal shape. Avoiding complications such as working length loss, ledge formation, and transportation when removing infected tissues is necessary. Therefore, the shaping ability of files is evaluated frequently in both periods. Besides preparation abilities, the resistance of files to separation during preparation was investigated many times. Separated instruments in root canals make it challenging to clean and obturate hermetically (39). There is increasing interest in fracture resistance studies to minimize this complication, which reduces treatment success (40,41). In recent years, researchers have focused on the importance of stress accumulation, crack and fracture formation on the root, and deformations on the files (42,43). Microcracks formed during mechanical preparation may progress and cause vertical root fractures and subsequent tooth extraction (44). Some debris generated during mechanical preparation may exit apically, causing inflammation in the periapical tissues and postoperative pain (45,46). The prevention of this condition, which negatively affects the success of treatment and patients' quality of life, has gained popular-

ity in the last 5 years and has been the focus of attention in many studies (47,48). As new systems are introduced to the market, it is understood that these kinds of studies will continue, and their acceptance possibility will be higher compared to conventional systems.

Mechanical and chemical preparation is treatment steps that are not independent. Irrigation solutions are needed to provide adequate disinfection in the root canal system, to remove microorganism and tissue residues that cannot be mechanically removed, to provide cleaning efficiency in inaccessible areas such as isthmuses and lateral canals, and to remove the smear layer that occurs during mechanical preparation (12,49). In recent years, irrigation activation methods and devices have gained popularity in improving the cleaning efficiency of chemical preparation. With these methods/devices, the contact and penetration of solutions to the dentinal tubules increased significantly (50). While the number of studies investigating the removal of the smear layer was relatively high in the first 5 years, many features of irrigation solutions have been evaluated simultaneously in recent years, such as their smear layer removal, microhardness, roughness and antibacterial effect (51,52). Complex studies that evaluated at least two properties of irrigation solutions have a higher chance of acceptance.

Considering the results of the current study, there has been a significant decrease in the number of studies on the root canal filling phase in the past 5 years. This result is likely due to increased treatment methods such as vital pulp therapy and regeneration in recent years with the common use of mineral trioxide aggregate (53). Journal editorial boards restricted the acceptance of microleakage studies due to their concerns about their reproducibility and inability to obtain results suitable for clinical conditions. There has been a severe decrease in publications on microleakage in the last 5 years (16,17). When the studies on the obturation step are examined, it has been observed that there has been an increase in the number of studies evaluating the physicochemical properties of the materials in the last 5 years. Root canal sealers are used with gutta-percha to obtain hermetic root canal obturation. Manufacturing new sealers with different ingredients or adding different contents, such as nanoparticles and chitosan, to the well-known sealers increased the number of studies that evaluated the physicochemical properties of sealers (54,55). Besides the physicochemical properties of filling materials, their contribution to the fracture resistance of endodontically treated teeth is widely investigated (56). In the past 5 years, the tooth-strengthening effect of filling materials has become one of the subjects of interest, and it has been observed that there has been an increase

in the number of studies on this subcategory. Between 2016 and 2020, clinical and radiographic follow-up studies have increased significantly. Clinical studies in which new materials and different filling methods are compared with traditional methods have gained importance (57,58). As previously mentioned, clinical studies are essential for developing new treatment methods and revealing their validity and reliability.

One of the limitations of this study is the exclusion of studies that evaluate the effects of intracanal medicaments used for chemical preparation, such as calcium hydroxide pastes and chlorhexidine gluconate gels. There is a recent interest in studies investigating single-visit treatments in the literature, and studies show no difference in success compared to multi-visit treatments (59,60). Multi-visit studies were not included, considering that medicaments could affect parameters such as antimicrobial efficacy, postoperative pain, and bonding of filling materials to canal walls. Retrospective studies that did not provide information about treatment procedures and materials were excluded. Another limitation is that the number of citations is determined according to a single database and up to a fixed date. Present results could be different from the presented ones. Although there are many journals in the field of endodontics, only the publications in AEJ, JOE, and IEJ were examined in this study. Since these three journals are the leading journals in the endodontic literature (22,61), these journals were preferred. However, the publications in the field of endodontics are not only published in these three journals but also many different journals included in the Scientific Citation Index.

Within the limitations of this study, an increase in scientific publications has been observed with technological developments and globalization. In the past 5 years, while interest in mechanical and chemical preparation steps has continued, there has been a severe decrease in the number of studies on obturation. Researchers need to follow the recent literature. Information about subjects that gained popularity in the literature, subjects that need to be further researched and clarified, and information about previous studies in the research area might guide researchers to conduct innovative, repeatable and reliable studies with higher acceptance chances. Although there are many in vitro studies in the literature, it has been observed that the tendency to perform clinical studies is low. More clinical studies are needed to evaluate the validity and reliability of the findings obtained under laboratory conditions. The publication value of more comprehensive studies involving different expertise steps will likely increase. For this reason, it may be beneficial to take a collaborative approach while forming research teams.

Authorship Contributions: Concept: N.E., E.U.O.; Design: N.E., E.U.O.; Supervision: E.U.O.; Materials: N.E., E.U.O.; Data: N.E., E.U.O.; Analysis: N.E., E.U.O.; Literature search: N.E., E.U.O.; Writing: N.E., E.U.O.; Critical revision: E.U.O.

Acknowledgements: Authors are grateful to Dr. Sevilay Karahan for statistical assistance.

Source of Funding: None declared.

Conflict of Interest: None declared.

References

- Ahmad P, Elgamel HAM. Citation classics in the Journal of Endodontics and a comparative bibliometric analysis with the most downloaded articles in 2017 and 2018. *J Endod* 2020; 46: 1042–51. [\[CrossRef\]](#)
- Khan AS, Ur Rehman S, Ahmad S, et al. Five decades of the International Endodontic Journal: bibliometric overview 1967-2020. *Int Endod J* 2021; 54: 1819–39. [\[CrossRef\]](#)
- Cartes-Velázquez R, Delgado CM. Bibliometric analysis of articles published in ISI dental journals, 2007–2011. *Scientometrics* 2014; 98: 2223–33. [\[CrossRef\]](#)
- Feldens CA, Kramer PF, Feldens EG. Exploring the profile of articles on traumatic dental injuries in pediatric dental journals. *Dent Traumatol* 2013; 29: 172–7. [\[CrossRef\]](#)
- Thornton K, Lee DJ, Yuan JC, et al. An analysis of prosthodontic research productivity: geographic, economic and collaborative perspective. *J Prosthodont* 2012; 21: 73–8.
- Geminiani A, Ercoli C, Feng C, et al. Bibliometrics study on authorship trends in periodontal literature from 1995 to 2010. *J Periodontol* 2014; 85: e136–43. [\[CrossRef\]](#)
- Hui J, Han Z, Geng G, et al. The 100 top-cited articles in orthodontics from 1975 to 2011. *Angle Orthod* 2013; 83: 491–9. [\[CrossRef\]](#)
- Tzanetakis GN, Stefopoulos S, Loizides AL, et al. Evolving trends in endodontic research: an assessment of published articles in 2 leading endodontic journals. *J Endod* 2015; 41: 1962–8. [\[CrossRef\]](#)
- Ordinola-Zapata R, Peters OA, Nagendrababu V, et al. What is of interest in endodontology? A bibliometric review of research published in the International Endodontic Journal and the Journal of Endodontics from 1980 to 2019. *Int Endod J* 2020; 53: 36–52. [\[CrossRef\]](#)
- Ng YL, Mann V, Rahbaran S, et al. Outcome of primary root canal treatment: systematic review of the literature – part 2. Influence of clinical factors. *Int Endod J* 2008; 41: 6–31. [\[CrossRef\]](#)
- European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *Int Endod J* 2006; 39: 921–30. [\[CrossRef\]](#)
- Zehnder M. Root canal irrigants. *J Endod* 2006; 32: 389–98. [\[CrossRef\]](#)

13. Tomson RM, Polycarpou N, Tomson PL. Contemporary obturation of the root canal system. *Br Dent J* 2014; 216: 315–22. [\[CrossRef\]](#)
14. Fardi A, Kodonas K, Gogos C, et al. Top cited articles in endodontic journals. *J Endod* 2011; 37: 1183–90. [\[CrossRef\]](#)
15. Adnan S, Ullah R. Top-cited articles in regenerative endodontics: a bibliometric analysis. *J Endod* 2018; 44: 1650–64. [\[CrossRef\]](#)
16. Editorial Board of the Journal of Endodontics. Wanted: a base of evidence. *J Endod* 2007; 33: 1401–2. [\[CrossRef\]](#)
17. De-Deus G. Research that matters – root canal filling and leakage studies. *Int Endod J* 2012; 45: 1063–4. [\[CrossRef\]](#)
18. Abuelniel GM, Duggal MS, Kabel N. A comparison of MTA and Biodentine as medicaments for pulpotomy in traumatized anterior immature permanent teeth: a randomized clinical trial. *Dent Traumatol* 2020; 36: 400–10.
19. Taha NA, Khazali MA. Partial pulpotomy in mature permanent teeth with clinical signs indicative of irreversible pulpitis: a randomized clinical trial. *J Endod* 2017; 43: 1417–21. [\[CrossRef\]](#)
20. Awawdeh L, Al-Qudah A, Hamouri H, et al. Outcomes of vital pulp therapy using mineral trioxide aggregate or biodentine: a prospective randomized clinical trial. *J Endod* 2018; 44: 1603–9. [\[CrossRef\]](#)
21. Dearing GJ, Kazemi RB, Stevens RH. A comparison of the machining efficiency of two brands of stainless steel endodontic hand files. *J Endod* 2005; 31: 873–6. [\[CrossRef\]](#)
22. Mishra L, Pattnaik P, Kumar M, et al. A bibliometric analysis of two PubMed-indexed high-impact factor endodontic journals: a comparison of India with other countries. *Indian J Dent* 2016; 7: 121–5. [\[CrossRef\]](#)
23. Shamszadeh S, Asgary S, Nosrat A. Regenerative endodontics: a scientometric and bibliometric analysis. *J Endod* 2019; 45: 272–80. [\[CrossRef\]](#)
24. Barão VA, Shyamsunder N, Yuan JC, et al. Authorship, collaboration, and funding trends in implantology literature: analysis of five journals from 2005 to 2009. *Implant Dent* 2011; 20: 68–75. [\[CrossRef\]](#)
25. Beaver Dd. Does collaborative research have greater episodic authority? *Scientometrics* 2004; 60: 399–408.
26. Kassirer JP, Angell M. On authorship and acknowledgments. *N Engl J Med* 1991; 325: 1510–2. [\[CrossRef\]](#)
27. Sadan A. The significance of in vitro studies. *Quintessence Int* 2007; 38: 13.
28. Wataha JC. Principles of biocompatibility for dental practitioners. *J Prosthet Dent* 2001; 86: 203–9. [\[CrossRef\]](#)
29. Markowitz K, Roberts E, Strickland M. Dental products and evidence-based dentistry. *Quintessence Int* 2019; 50: 402–11.
30. Peters OA, Schönenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. *Int Endod J* 2001; 34: 221–30. [\[CrossRef\]](#)
31. Torabinejad M, Khademi AA, Babagoli J, et al. A new solution for the removal of the smear layer. *J Endod* 2003; 29: 170–5. [\[CrossRef\]](#)
32. Shipper G, Ørstavik D, Teixeira FB, et al. 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. [\[CrossRef\]](#)
33. Gomes BP, Ferraz CC, Vianna ME, et al. In vitro antimicrobial activity of several concentrations of sodium hypochlorite and chlorhexidine gluconate in the elimination of enterococcus faecalis. *Int Endod J* 2001; 34: 424–8.
34. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. *J Endod* 2002; 28: 17–9. [\[CrossRef\]](#)
35. Ahmad P, Dummer PMH, Chaudhry A, et al. A bibliometric study of the top 100 most-cited randomized controlled trials, systematic reviews and meta-analyses published in endodontic journals. *Int Endod J* 2019; 52: 1297–316.
36. Feijoo JF, Limeres J, Fernández-Varela M, et al. The 100 most cited articles in dentistry. *Clin Oral Investig* 2014; 18: 699–706. [\[CrossRef\]](#)
37. Ahmad P, Dummer PMH, Noorani TY, et al. The top 50 most-cited articles published in the International Endodontic Journal. *Int Endod J* 2019; 52: 803–18. [\[CrossRef\]](#)
38. Lefavre KA, Shadgan B, O'Brien PJ. 100 most cited articles in orthopaedic surgery. *Clin Orthop Relat Res* 2011; 469: 1487–97. [\[CrossRef\]](#)
39. Madarati AA, Hunter MJ, Dummer PM. Management of intracanal separated instruments. *J Endod* 2013; 39: 569–81. [\[CrossRef\]](#)
40. Pedullà E, Lizio A, Scibilia M, et al. Cyclic fatigue resistance of two nickel-titanium rotary instruments in interrupted rotation. *Int Endod J* 2017; 50: 194–201. [\[CrossRef\]](#)
41. Topçuoğlu HS, Topçuoğlu G, Kafdağ Ö, et al. Effect of two different temperatures on resistance to cyclic fatigue of one Curve, EdgeFile, HyFlex CM and ProTaper next files. *Aust Endod J* 2020; 46: 68–72. [\[CrossRef\]](#)
42. Rödiger T, Krämer J, Müller C, et al. Incidence of microcracks after preparation of straight and curved root canals with three different NiTi instrumentation techniques assessed by micro-CT. *Aust Endod J* 2019; 45: 394–9.
43. Zuolo ML, De-Deus G, Belladonna FG, et al. Micro-computed tomography assessment of dentinal microcracks after root canal preparation with TRUShape and self-adjusting file systems. *J Endod* 2017; 43: 619–22. [\[CrossRef\]](#)
44. Ceyhanli KT, Erdilek N, Tatar İ, et al. Comparison of ProTaper, RaCe and Safesider instruments in the induction of dentinal microcracks: a micro-CT study. *Int Endod J* 2016; 49: 684–9. [\[CrossRef\]](#)
45. Toyoğlu M, Altunbaş D. Influence of different kinematics on apical extrusion of irrigant and debris during canal preparation using K3XF instruments. *J Endod* 2017; 43: 1565–8. [\[CrossRef\]](#)
46. Tanalp J, Güngör T. Apical extrusion of debris: a literature

- review of an inherent occurrence during root canal treatment. *Int Endod J* 2014; 47: 211–21. [\[CrossRef\]](#)
47. Relvas JB, Bastos MM, Marques AA, et al. Assessment of postoperative pain after reciprocating or rotary NiTi instrumentation of root canals: a randomized, controlled clinical trial. *Clin Oral Investig* 2016; 20: 1987–93. Erratum in: *Clin Oral Investig* 2016; 20:1995. [\[CrossRef\]](#)
48. Gambarini G, Di Nardo D, Miccoli G, et al. The influence of a new clinical motion for endodontic instruments on the incidence of postoperative pain. *Clin Ter* 2017; 168: e23–7.
49. Chubb DWR. A review of the prognostic value of irrigation on root canal treatment success. *Aust Endod J* 2019; 45: 5–11. [\[CrossRef\]](#)
50. Gu LS, Kim JR, Ling J, et al. Review of contemporary irrigant agitation techniques and devices. *J Endod* 2009; 35: 791–804. [\[CrossRef\]](#)
51. Souza MA, Hoffmann IP, Menchik VHS, et al. Influence of ultrasonic activation using different final irrigants on antimicrobial activity, smear layer removal and bond strength of filling material. *Aust Endod J* 2019; 45: 209–15.
52. Eldeniz AU, Erdemir A, Belli S. Effect of EDTA and citric acid solutions on the microhardness and the roughness of human root canal dentin. *J Endod* 2005; 31: 107–10.
53. Guerrero-Gironés J, Forner L, Sanz JL, et al. Scientific production on silicate-based endodontic materials: evolution and current state: a bibliometric analysis. *Clin Oral Investig* 2022; 26: 5611–24. [\[CrossRef\]](#)
54. Wong J, Zou T, Lee AHC, et al. The potential translational applications of nanoparticles in endodontics. *Int J Nanomedicine* 2021; 16: 2087–106. [\[CrossRef\]](#)
55. Versiani MA, Abi Rached-Junior FJ, Kishen A, et al. Zinc oxide nanoparticles enhance physicochemical characteristics of Grossman sealer. *J Endod* 2016; 42: 1804–10.
56. Tan M, Chai Z, Sun C, et al. Comparative evaluation of the vertical fracture resistance of endodontically treated roots filled with Gutta-percha and Resilon: a meta-analysis of in vitro studies. *BMC Oral Health* 2018; 18: 107. [\[CrossRef\]](#)
57. Barborka BJ, Woodmansey KF, Glickman GN, et al. Long-term clinical outcome of teeth obturated with Resilon. *J Endod* 2017; 43: 556–60. [\[CrossRef\]](#)
58. Chybowski EA, Glickman GN, Patel Y, et al. Clinical outcome of non-surgical root canal treatment using a single-cone technique with endosequence bioceramic sealer: a retrospective analysis. *J Endod* 2018; 44: 941–5. [\[CrossRef\]](#)
59. Su Y, Wang C, Ye L. Healing rate and post-obturation pain of single- versus multiple-visit endodontic treatment for infected root canals: a systematic review. *J Endod* 2011; 37: 125–32. [\[CrossRef\]](#)
60. Wong AW, Zhang C, Chu CH. A systematic review of nonsurgical single-visit versus multiple-visit endodontic treatment. *Clin Cosmet Investig Dent* 2014; 6: 45–56.
61. Kolahi J, Khazaei S, Iranmanesh P, et al. Altmetric analysis of the contemporary scientific literature in Endodontology. *Int Endod J* 2020; 53: 308–16. [\[CrossRef\]](#)