



Review Article

A Bibliometrics and Scientometrics Study of Mineral Trioxide Aggregate Material for Irreversible Pulpitis

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ABSTRACT

Background/purpose: Mineral Trioxide Aggregate (MTA) has become integral in endodontics, particularly in addressing irreversible pulpitis due to its notable biocompatibility and sealing properties. This bibliometrics and scientometric study aims to systematically analyse the literature to identify critical trends, influential publications, and emerging research areas.

Materials and methods: Publications were acquired online from the PubMed and Scopus databases on December 7th, 2023. Then, studies were screened based on title and abstract and irrelevant studies were eliminated. The publication output was then analyzed using Google Sheet, R package's Bibliometrix (Biblioshiny), and VOSviewer.

Results: From 136 studies, 60 studies were included. The study highlights a substantial annual growth rate of 18.02%. Collaboration emerges as a prominent feature, with an average of 4.78 co-authors per document and 21.67% of collaborations being international, with India standing out as the most prominent contributing country. Recent trends indicate a surge in investigating diverse conditions, exploring advanced material combinations, and a growing interest in decision-making frameworks within endodontic practices. Several topics are still less developed, including other materials, decision-making frameworks, special consideration for specific patient populations, and the role of medical informatics.

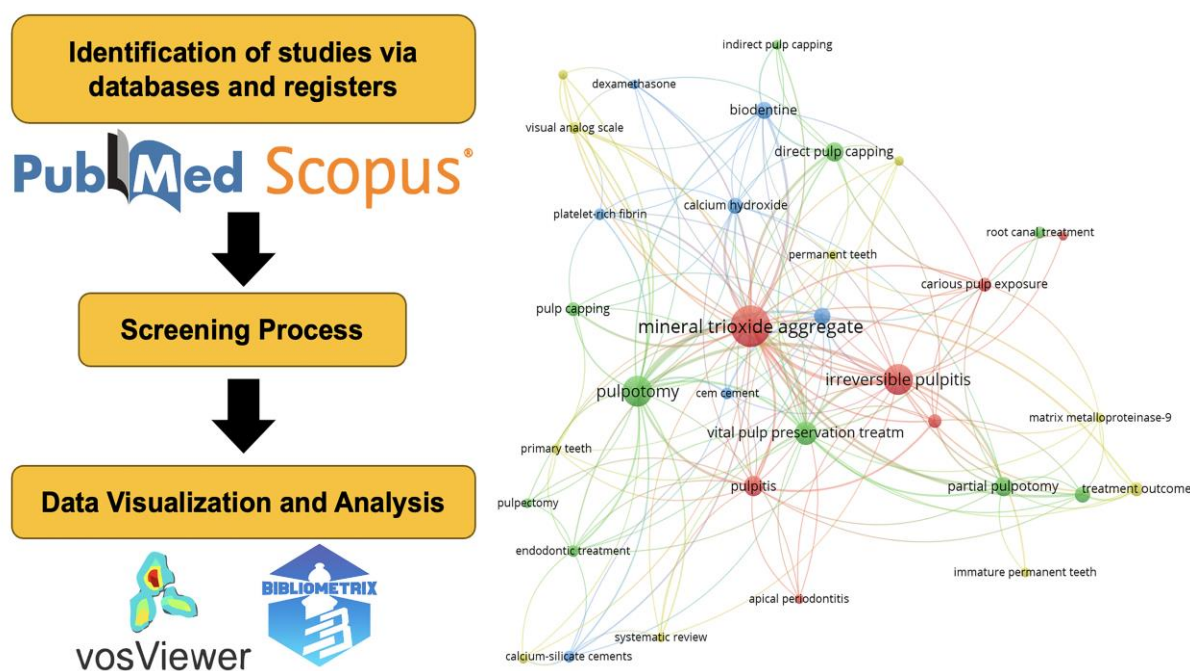
Conclusion: This study elucidates the dynamic evolution of research priorities in MTA and irreversible pulpitis, emphasizing key trends and areas for further exploration and development.

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GRAPHICAL ABSTRACT



Introduction

Untreated dental caries constitutes a global health concern and present a significant economic burden [1]. According to the Global Burden of Disease (GBD) 2017 report, among 328 diseases, dental caries in permanent teeth ranked first in prevalence [2]. The failure of dental caries treatment may result in the dissemination of bacteria and their byproducts into the dental pulp, hence inducing inflammation of different intensity levels [3]. Based on the pulp's presumed healing ability, pulpal inflammation is classified as reversible or irreversible [4]. Per the diagnostic terminology recommended by the American Association of Endodontists (AAE) Consensus Conference, irreversible pulpitis is characterized as a clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing and that root canal treatment is indicated [4]. Root canal treatment, or endodontic treatment, entails extracting these anatomical components, disinfecting and shaping, cleaning, and decontaminating the hollows using irrigating solutions and small files. The decontaminated

canals are then filled with obturation [5]. Several materials have been used for root-end filling material and as pulp capping material. In the mid-1990s, new cement, mineral trioxide aggregate (MTA), began to undergo testing as a pulp capping material [6]. MTA is a Portland cement-based material with superior resistance to leakage [7] and better long-term outcomes in pulp capping than calcium hydroxide [8]. It has become integral in endodontics, particularly in addressing irreversible pulpitis due to its notable biocompatibility and sealing properties [9, 10]. MTA has several strengths, including its biocompatibility, sealing ability, and ability to promote tissue regeneration [11, 12]. However, MTA also has some limitations, including its high cost, long setting time, and potential discoloration of teeth [13–16]. Subsequently, it is also still rarely for being used, especially in our country, Indonesia. Bibliometric study in this field is essential because it may provide a quantitative analysis of the research output, trends, and impact of MTA in dentistry, especially in irreversible pulpitis cases.

The bibliometric analysis itself is a study that focuses on investigating the subfield of information science that examines the meta-data around published materials [17]. The scientometric analysis is "a quantitative study of the research on the development of science" [18]. It is a technique to evaluate research impact and investigate citation relationships to map a specific knowledge area with trends extracted from the academic database. It is gradually becoming a research hub in numerous fields, including dental and oral science [19–26]. There has been no scientometric or bibliometric analysis of the research outputs in this field. Therefore, a series of scientometric and visual analyses were conducted to generate a comprehensive knowledge map for MTA in irreversible pulpitis to comprehend future research directions through bibliometric analysis. The objectives were to investigate the quantity distribution of studies based on the number of annual publications, predicting the trend, the authors, institutions, countries, journals with the most publications, and the most cited references. Using keyword analysis, this study also identifies the central theme, trending topic throughout the period, research gaps, and potential future research topics in this field.

Materials and Methods

Data sources and search strategy

The data was acquired online from the PubMed and Scopus databases [27]. To avert the bias caused by daily database updates, the search process were conducted on February 18th, 2024. Keywords utilized in this study were ("mineral trioxide aggregate" OR mta) AND "irreversible pulpitis." The initial search revealed 136 studies and 59 duplicated studies were removed. We restricted the literature to those written in English that had reached the final stage of publication, and only articles, reviews, and conference papers published in journals were considered, and then, we screened all the studies that met our requirements based on the title and abstract and eliminated any irrelevant studies. Sixty studies were downloaded and analysed in

total. The entire search strategy process is visualized in [Figure 1](#).

Data analysis

The publication output was then analysed using Google Sheet, R package's bibliometrics, and VOSviewer (version 1.6.18). Google Sheets was used to predict trends. The R package's bibliometrics utility is designed for quantitative scientometrics and informetrics. [28,29]. The Bibliometrix R package was initially installed and loaded with R Studio. The Biblioshiny application was initiated by entering Biblioshiny into the R console. Biblioshiny is a web application that gives non-programmers access to the R package Bibliometrix. Numerous tools Bibliometrix provides enable researchers to conduct in-depth bibliometric studies [30]. A bibliometric network, VOSviewer, was employed for the building. VOSviewer is visualization software that displays cluster analysis and has excellent data visualization [31–33]. This software enables data extraction, including authorship, journals, organizations, nations, and keywords. For viewing existing associations between bibliometric data, outputs are presented as overlapping circles [34].

Results and Discussion

Study characteristics

This study included 60 publications on MTA and irreversible pulpitis, spanning the timespan from 2008 to 2023. The data from 33 journals reveals a notable annual growth rate of 18.02%, indicative of the increasing scholarly interest in this subject. The documents exhibit an average age of 3.75 years, demonstrating the relevance of recent research. With an average of 25.72 citations per document and a total of 2025 references, these publications reflect a robust scholarly discourse. The study also unveils 240 authors contributing to this body of work, with a low incidence of single-authored documents (1 out of 60), suggesting a collaborative nature within the academic community. The collaborative landscape further reveals an average of 4.78 co-authors per document, with 21.67% of these collaborations being international.

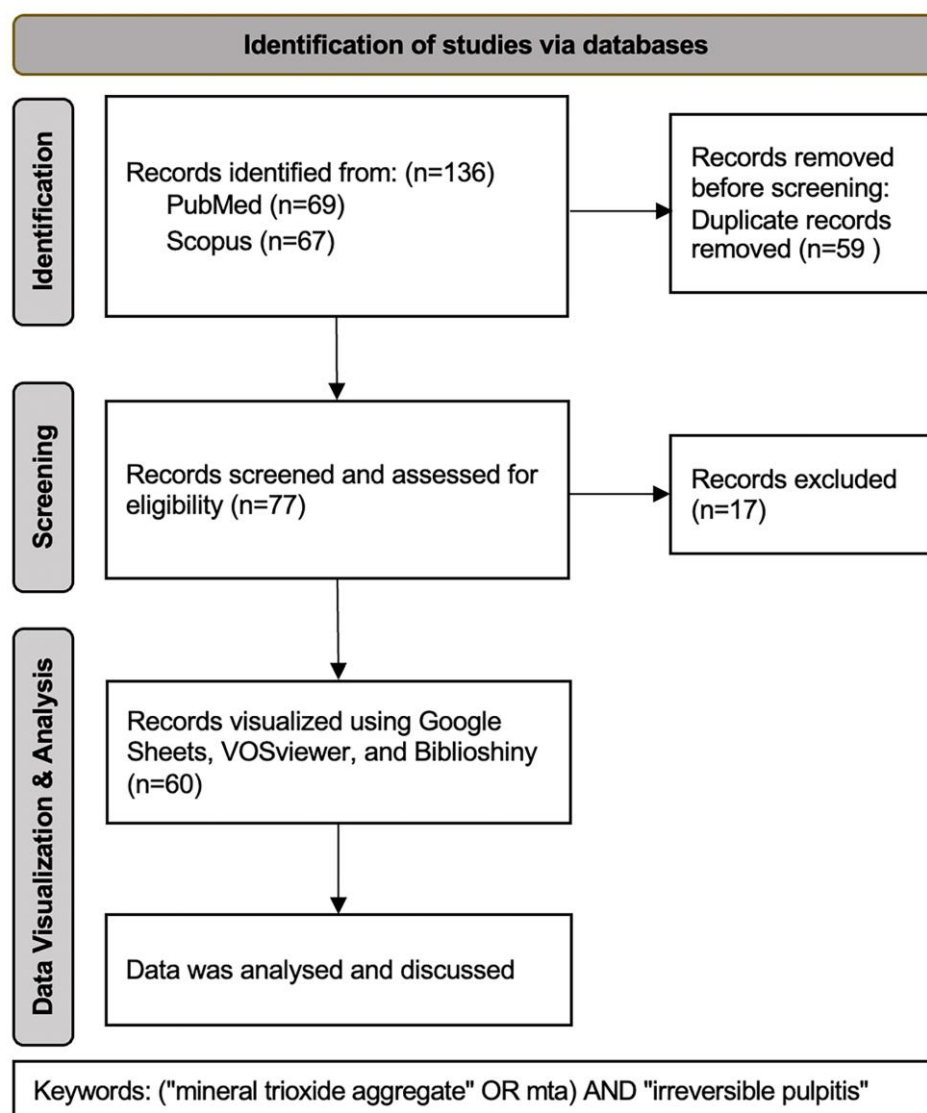


Figure 1: Flow diagram of literature searching and screening processes

Regarding document types, the majority consists of articles (54), followed by reviews (6).

Publication trends

The cumulative number of publications related to the subject of interest exhibits a discernible trend from 2008 to 2023. The data reveals a gradual rise, with 12 publications in 2023, 11 in 2022, and 10 in 2021, indicating an upward trajectory in research output. The trendline analysis, represented by an R-squared value of 0.71, underscores the moderate strength of the observed trend. Noteworthy spikes in publication counts are evident in 2017, where eight publications were recorded, contributing to an overall growth pattern. The earlier years, particularly 2014 and 2011, show a notable

absence of publications, highlighting potential gaps or shifts in research focus during those periods. This nuanced understanding of the temporal distribution of publications provides valuable context for interpreting the evolving research landscape on the chosen subject, offering insights into the research community's engagement and focus over the specified timeframe. A visualization of publication trends, the cumulative number of publications, and the trendline are provided in [Figure 2A](#).

Most influential publications

The article with the highest number of citations and citations per year is "Partial Pulpotomy in Mature Permanent Teeth with Clinical Signs Indicative of Irreversible Pulpitis: A Randomized

Clinical Trial", published in the Journal of Endodontics in 2017, accumulating a remarkable 120 citations and stands out with an impressive citation rate of 20 per year. This indicates a significant and enduring influence on the field and sustained interest and relevance. This article investigated the outcome of partial pulpotomy using MTA compared with calcium hydroxide in mature curiously exposed permanent molars. The result revealed that MTA partial pulpotomy sustained a success rate over the 2-year follow-up in mature permanent teeth clinically diagnosed with irreversible pulpitis. At the same time, more than half of the calcium hydroxide cases failed within two years [35]. The ten most influential publications based on the citations are explained in Table 1.

Other influential studies also examined various treatment approaches with several outcomes and comparisons. Two studies explored histological outcomes in irreversible pulpitis, one after MTA pulpotomy [36] and one after revascularization/regeneration procedures in immature permanent teeth, revealing the presence of loose connective tissue and collagen fibres in the canal space up to the coronal MTA plug [37]. Subsequent investigations focused on the efficacy of MTA pulpotomy for irreversible pulpitis, concluding that MTA pulpotomy was successful in clinical and radiography [38–40]. Another study compared pulpotomy outcomes using a calcium-enriched mixture (CEM) cement or MTA in molars with irreversible pulpitis, indicating excellent results with both biomaterials [41].

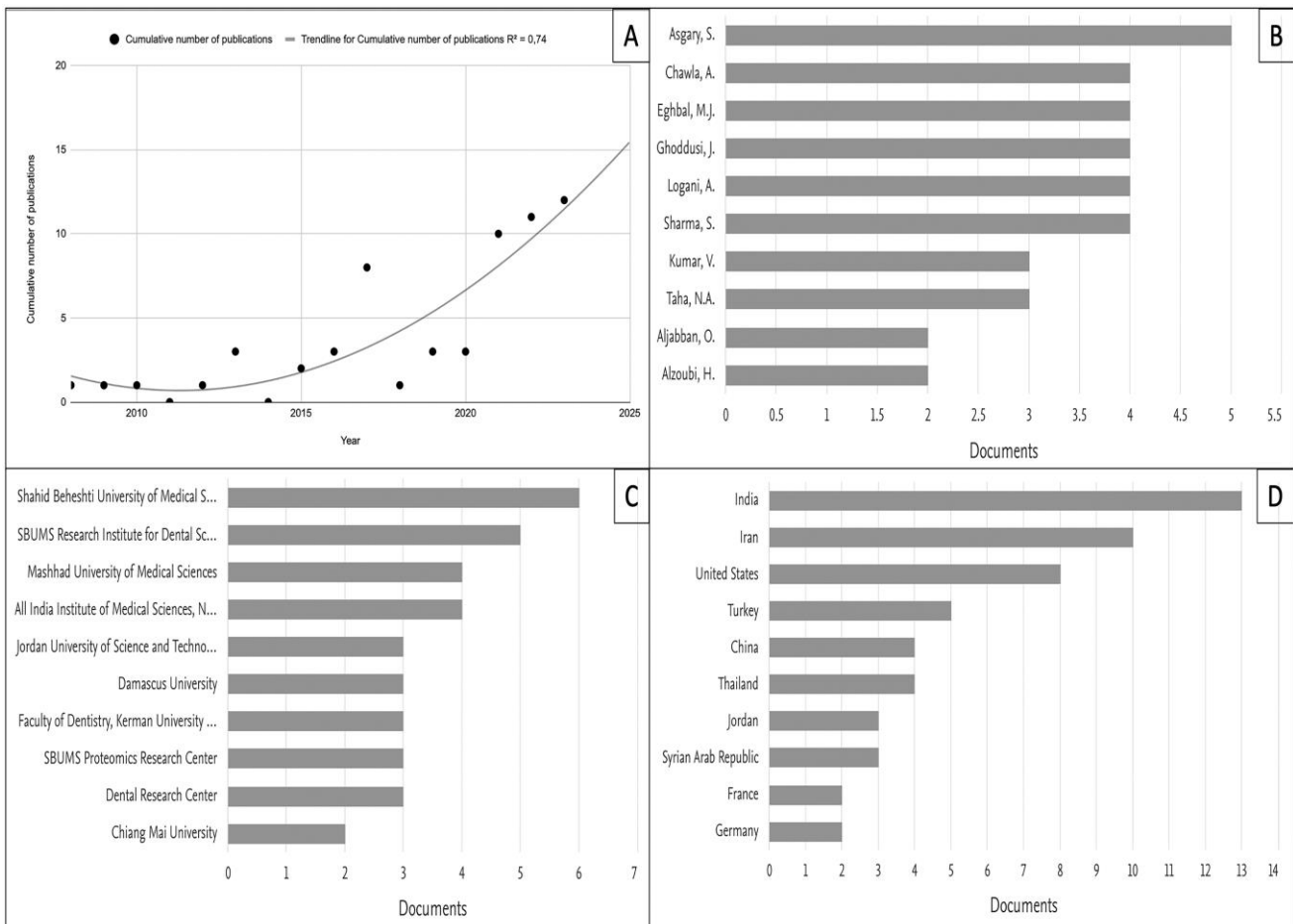


Figure 2: Publication trends and most productive authors, institutions, and countries. A) Publication trends, the cumulative number of publications, and its trendline. Create nodes for each year to represent the quantity of publications, and use curved lines to depict a trendline and predict the cumulative number of publications over time, B) most productive authors and each number of publications, C) most productive institutions and each number of publications, and D) most productive countries and each number of publications

Table 1: Most influential publications based on the citations

| Rank | Title | Journal | Year | Citations | Citations/ Year |
|------|---|----------------------------------|------|-----------|--------------------|
| 1 | Partial Pulpotomy in Mature Permanent Teeth with Clinical Signs Indicative of Irreversible Pulpitis: A Randomized Clinical Trial | Journal of Endodontics | 2017 | 120 | 20 |
| 2 | Histologic observation of a human immature permanent tooth with irreversible pulpitis after revascularization/regeneration procedure | Journal of Endodontics | 2012 | 118 | 10.727 |
| 3 | MTA pulpotomy of human permanent molars with irreversible pulpitis | Australian Endodontic Journal | 2009 | 110 | 7.857 |
| 4 | Assessment of Mineral Trioxide Aggregate pulpotomy in mature permanent teeth with carious exposures | International Endodontic Journal | 2017 | 100 | 16.667 |
| 5 | Treatment outcomes of pulpotomy in permanent molars with irreversible pulpitis using biomaterials: A multi-center randomized controlled trial | Acta Odontologica Scandinavica | 2013 | 84 | 8.4 |
| 6 | Treatment Outcomes of Mineral Trioxide Aggregate Pulpotomy in Vital Permanent Teeth with Carious Pulp Exposure: The Retrospective Study | Journal of Endodontics | 2017 | 81 | 13.5 |
| 7 | Mineral trioxide aggregate pulpotomy for permanent molars with clinical signs indicative of irreversible pulpitis: a preliminary study | International Endodontic Journal | 2017 | 77 | 12.833 |
| 8 | A review on vital pulp therapy in primary teeth | Iranian Endodontic Journal | 2015 | 67 | 8.375 |
| 9 | Outcomes of Direct Pulp Capping by Using Either ProRoot Mineral Trioxide Aggregate or Biodentine in Permanent Teeth with Carious Pulp Exposure in 6- to 18-Year-Old Patients: A Randomized Controlled Trial | Journal of Endodontics | 2018 | 66 | 13.2 |
| 10 | Partial pulpotomy with two bioactive cements in permanent teeth of 6- to 18-year-old patients with signs and symptoms indicative of irreversible pulpitis: a noninferiority randomized controlled trial | International Endodontic Journal | 2019 | 52 | 13.0 |

Finally, other studies focus on comparing ProRoot MTA and Biodentine, all revealing that both studies successfully treated it. At the same time, Biodentine exhibited a significantly lower frequency of discoloration compared to ProRoot MTA [42, 43].

Most productive authors

Saeed Asgary from SBUMS Research Institute for Dental Sciences, Tehran, Iran stands out as the most prolific author with five publications, followed closely by Amrita Chawla, Ajay Logani, and Sidhartha Sharma from All India Institute of Medical Sciences, New Delhi, India; Mohammad Jafar Eghbal from SBUMS Research Institute for Dental Sciences, Tehran, Iran; and J. Ghoddsi from Mashhad University of Medical Sciences, Mashhad, Iran, each with four publications. Vijay L. Kumar from Punjab Agricultural University, Ludhiana, India, and Nessrin Ahmad Taha from Jordan University of Science and Technology, Irbid, Jordan, each contributed three publications. Ossama Aljabban and Hasan Alzoubi from Damascus University, Damascus, Syrian Arab Republic, authored two publications each. The ten most productive authors are visualized in Figure 2B.

Asgary's influential article, "MTA pulpotomy of human permanent molars with irreversible pulpitis," published in the Australian Endodontic Journal in 2009, garnered significant recognition with 110 citations. This study investigated the histological success of MTA as an alternative treatment for the treatment of irreversible pulpitis in human teeth [36]. Furthermore, the manuscript highlights Asgary's most recent contribution, "Selection of the best endodontic treatment option using data mining: A decision tree approach," published in the Saudi Endodontic Journal in 2023. This study aimed to evaluate the relationship of data mining algorithms in longitudinal data of postendodontic pain and treatment allocation to predict the best treatment option with the patients who underwent MTA pulpotomy who were included in this study.

Most productive institutions

Shahid Beheshti University of Medical Sciences (Iran) is a central hub for this research, contributing six documents. At the same time, the SBUMS Research Institute for Dental Sciences (India) closely follows with five. Mashhad University of Medical Sciences (Iran) and All India Institute of Medical Sciences, New Delhi (India), demonstrate notable engagement with four documents each, underlining the global nature of this academic exploration.

The international perspective is further emphasized by the contributions from Jordan University of Science and Technology (Jordan); Damascus University (Syrian Arab Republic); Faculty of Dentistry at Kerman University of Medical Sciences (Iran); SBUMS Proteomics Research Center (Iran); and Dental Research Center (Iran), each with three documents. Last, Chiang Mai University (Thailand) contributes two articles to the body of research. The ten most productive institutions are visualized in Figure 2C. Notably, the most influential and newest articles from Shahid Beheshti University of Medical Sciences, the most productive institution, were the same as Saeed Asgary from SBUMS Research Institute for Dental Sciences articles. This suggests a symbiotic relationship between prolific authors and influential institutions in advancing knowledge in this field.

Most productive countries

India emerges as the predominant contributor, with 13 documents indicating a substantial and sustained commitment to advancing knowledge in this field. Iran closely follows with ten documents, underscoring its significant role in shaping the global discourse on the subject. The United States, with eight documents, reflects a notable presence in the research landscape, while Turkey, China, and Thailand contribute five, four, and four documents, respectively, demonstrating diverse international engagement. Jordan and the Syrian Arab Republic each provide three documents, further highlighting the collaborative efforts from the Middle East. France and Germany contribute two documents each, contributing to the collective global knowledge on the specified subject. This comprehensive overview of country-

wise contributions underscores the widespread and collaborative nature of research efforts, portraying a rich tapestry of global involvement in advancing understanding within this research domain. The ten most productive countries are visualized in [Figure 2D](#).

India's article "Comparative evaluation of platelet-rich fibrin, mineral trioxide aggregate, and calcium hydroxide as pulpotomy agents in permanent molars with irreversible pulpitis: A randomized controlled trial" [44] published in *Contemporary Clinical Dentistry* in 2016 stands out with 34 citations, reflecting its substantial impact on the field. In addition to these impactful works, India's most recent contribution, "Comparative evaluation of the effectiveness of calcium silicate-based materials with or without platelet-rich fibrin as a pulpotomy medicament in human permanent teeth with irreversible pulpitis: A randomized clinical trial," published in *Endodontology* in 2023, [45] highlights the nation's on-going commitment to advancing research and clinical practices in the field.

Trend topics

In the earlier years, from 2008 to 2015, there was a substantial focus on foundational concepts such as "apexogenesis," "dental cements," and "revascularization." During this period, exploring innovative materials like "cem cement" and "calcium-enriched mixture" gained momentum, laying the groundwork for subsequent investigations. In addition, the attention to "clinical outcomes" underscores a growing emphasis on assessing the effectiveness of endodontic interventions. Towards 2016 and beyond, topics like "mineral trioxide aggregate" and "pulpotomy" surged in popularity, reflecting a significant shift towards these advanced materials and treatment modalities. The rise of "direct pulp capping," "deep caries," and "irreversible pulpitis" in the later years indicate an evolving landscape with a heightened focus on specific clinical scenarios, treatment approaches, and their respective outcomes.

In recent years, there has been a noticeable uptrend in the investigation of specific conditions, such as "acute irreversible pulpitis"

and "asymptomatic irreversible pulpitis," indicating a keen interest in understanding and managing different states of pulp inflammation. The exploration of combination or comparison with other advanced materials continues with a focus on "bioceramic," "epoxy resin-based root canal sealer," and "calcium-silicate cements," suggesting a trajectory towards refining endodontic materials; furthermore, including "decision trees" points towards a growing interest in exploring decision-making frameworks within endodontic practices in recent research. All the trend topic keywords are visualized in [Figure 3](#). Subsequently, the trend topics of only the main theme keywords are visualized in [Figure 4B](#).

Main themes and study gaps for future investigation

The main themes in the MTA and irreversible pulpitis research can be categorized into four domains. Firstly, there is a significant emphasis on understanding the disease process, as evidenced by keywords such as "apical periodontitis," "irreversible pulpitis," "deep caries," and "pain." These terms underscore the researchers' focus on unravelling the pathological conditions, associated symptoms, and consequences of irreversible pulpitis and its impact on dental health. Secondly, the exploration of various clinical procedures is evident through keywords like "direct pulp capping", "full pulpotomy", "partial pulpotomy", "pulpectomy", "root canal treatment", and "vital pulp preservation treatment". This category highlights the keen interest in diverse treatment modalities and approaches to managing irreversible pulpitis. The third category centres around materials, with keywords including "biodentine," "calcium hydroxide," "calcium-enriched mixture", "calcium-silicate cements", "mineral trioxide aggregate", and "platelet-rich fibrin". Researchers have delved into investigating the properties and applications of these materials for addition or comparison in MTA and irreversible pulpitis research. Lastly, some keywords represent broader scopes, encompassing methodological considerations, the

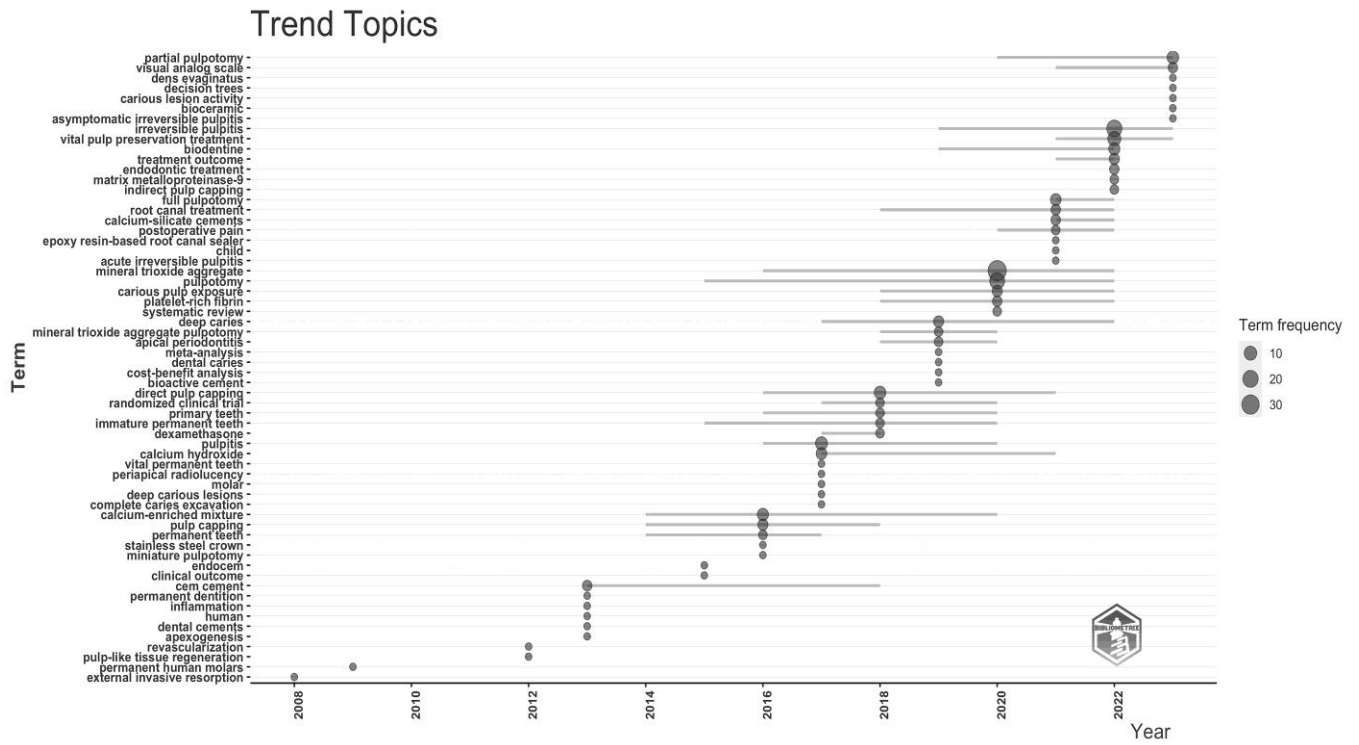
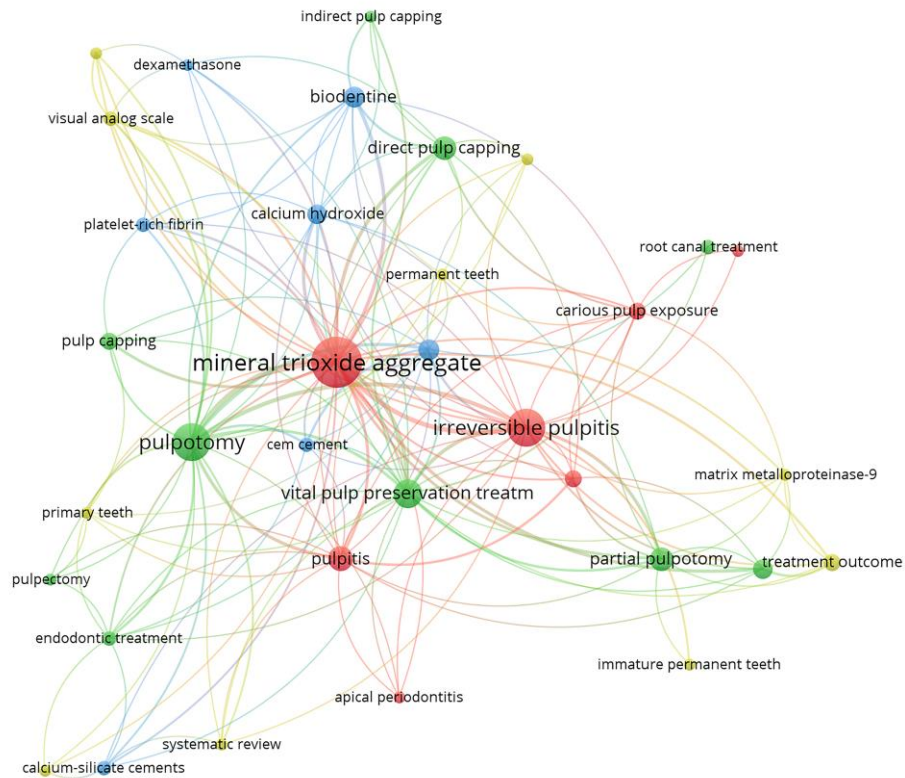


Figure 3: Trend topics throughout the entire publication period. The provided visual representation depicts the chronological progression of term usage patterns as observed by chronological analysis

A



B

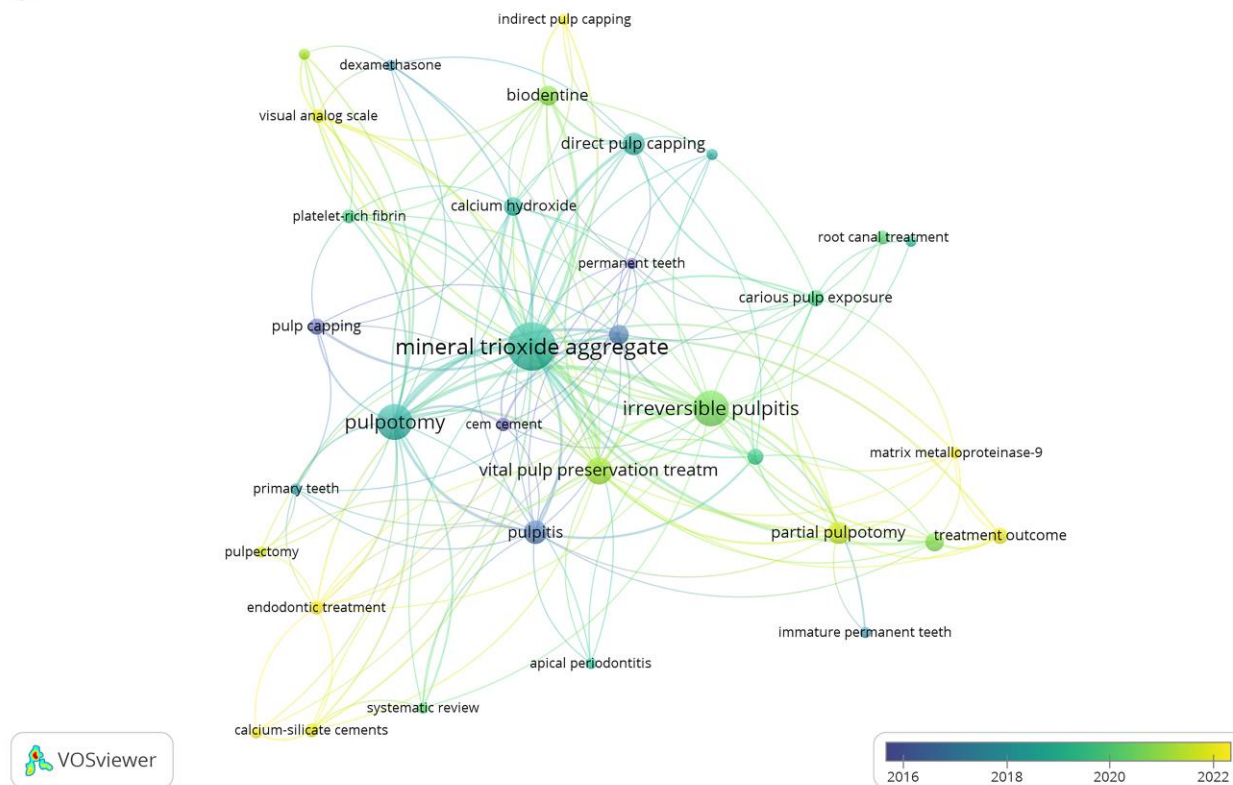


Figure 4: Network and overlay visualizations of main themes. A) Network visualization of most prominent keywords. Different colours represent co-occurrence clusters of the author's keyword. The size of the circle is proportional to the occurrence of the keyword, while the thickness is proportional to the strength of co-occurrence and B) overlay visualization of most prominent keywords. The colour of the circle represented the average publication year of its keyword

impact of therapeutic agents, and a comprehensive evaluation of treatment success. Terms such as "randomized clinical trial", "systematic review", "visual analog scale", "dexamethasone", "immature permanent teeth", "postoperative pain", "matrix metalloproteinase-9", and "treatment outcome" reflect a multifaceted exploration beyond disease processes, procedures, and materials. Entire main theme keywords and their cluster were provided in [Figure 4A](#).

However, several topics are still less developed, as evidenced by the infrequent occurrence of keywords, including decision-making frameworks represented by "decision trees" with the number of occurrences (n)=1, along with "survival analysis" (n=1), and "cost-effectiveness analysis" (n=1), warrant further exploration to establish evidence-based practices and evaluate the economic considerations associated with various endodontic approaches. Special

consideration for specific patient populations, such as "HIV-positive patients", (n=1), is essential to tailor endodontic care to diverse condition groups. Investigating the psychological aspects ("mentality") (n=1) and "quality of life" (n=1) related to endodontic treatments can provide valuable insights into patient experiences and the psychosocial impact of interventions. Moreover, exploring the role of "medical informatics" in endodontics can lead to integrating advanced technologies to enhance diagnostic precision and treatment planning.

Decision trees, a recent entrant in the field, were explored in only one study, specifically focusing on their application to optimize treatment modalities for minimizing posttreatment pain [46]. Similarly, survival analysis made a solitary appearance in a retrospective study examining the success rate of pulpectomy in primary molars under general anesthesia [47]. Subsequently, cost-effectiveness analysis remains unexplored

within the current scope of research and only appears in a suggestion for future investigation by Li *et al.*'s study [48]. Similarly, a specific study on HIV-positive patients exists only as a case report [49]. Moreover, psychological aspects and quality-of-life concerns related to endodontic treatments were addressed in just one study. [50]. The same holds for medical informatics, with only one study investigating the application of data mining techniques in selecting optimal endodontic treatment options [46]. This collective insight lays the groundwork for future research endeavours to fill these critical gaps and advance the field.

Limitation of study

While this bibliometric exploration sheds light on the exciting developments at the MTA intersection and irreversible pulpitis research, it is essential to acknowledge certain limitations that may affect the generalizability of our findings and the scope of this study. Initially, our analysis relies heavily on the availability and accessibility of published research articles and academic literature, potentially excluding valuable insights from non-peer-reviewed sources. Second, it is also crucial to consider the possibility of publication bias, where positive or significant results may be overrepresented due to the bias toward publishing such studies. Finally, the dynamic nature of scientific research means that newer developments or emerging trends may not be fully captured in this snapshot analysis.

Conclusion

This bibliometrics and scientometrics analysis provides valuable insights into the evolving research landscape on MTA and irreversible pulpitis. The study reveals a growing scholarly interest, with an annual growth rate of 18.02%, emphasizing the significance of recent contributions to the field. Collaboration is a hallmark, with an average of 4.78 co-authors per document, and international collaborative efforts are noteworthy at 21.67%. The temporal distribution of publications indicates a nuanced progression, with spikes in 2017 and notable shifts in focus during earlier years, highlighting

potential research gaps. The most influential publication, "Partial Pulpotomy in Mature Permanent Teeth with Clinical Signs Indicative of Irreversible Pulpitis: A Randomized Clinical Trial," underscores the enduring impact of specific studies on the field. Saeed Asgary from SBUMS Research Institute for Dental Sciences, Iran, emerges as the most prolific author; Shahid Beheshti University of Medical Sciences, Iran, stands out as a leading institution, while India prominently emerges as a leading country contributor, showcasing the collaborative nature of impactful research.

Based on the trend topics, there was a substantial focus on foundational concepts of innovative material explorations in the earlier years. The later years indicate an evolving landscape with a heightened focus on specific clinical scenarios, treatment approaches, and their respective outcomes. In recent years, there has been a noticeable uptrend in the investigation of particular conditions, indicating a keen interest in understanding and managing different states of pulp inflammation. Subsequently, the exploration of a combination or comparison with other advanced materials was also conducted. Furthermore, nowadays, there is a growing interest in exploring decision-making frameworks within endodontic practices in recent research. Subsequently, based on the main themes, the primary exploration of previous study is focused on understanding the disease process, various clinical procedures, and other addition or comparison materials. Several topics are still less developed, including different materials, decision-making frameworks, special consideration for specific patient populations, and the role of medical informatics [46]. These observations underscore the evolving nature of research priorities in the field, highlighting areas of progress and indicating avenues for further exploration and development.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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