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**Cenário atual e tendências na pesquisa sobre perfuração radicular em
endodontia: uma análise baseada em métricas**

Florianópolis

2026

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endodontia: uma análise baseada em métricas**

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VALENTINA SCHMIDT COUFAL

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Este Trabalho de Conclusão de Curso foi julgado adequado para obtenção do título de
cirurgiã-dentista e aprovado em sua forma final pelo Curso de Odontologia da UFSC.

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Ao meu pai e minha mãe, pelo apoio incondicional
e por serem minha base em todos os momentos.
Essa realização carrega o nome de vocês.

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Um pouco sobre dentes, muito sobre gente -
(Anônimo, 2026)

RESUMO

Perfurações radiculares em endodontia são comunicações acidentais ou patológicas entre o sistema de canais radiculares e o periodonto, podendo causar inflamação, infecção, reabsorção óssea e até perda do dente se não tratadas adequadamente. O objetivo deste estudo foi realizar uma análise bibliométrica e altmétrica sobre perfuração radicular em endodontia. A busca foi realizada em março de 2025 na *Web of Science - Core Collection*. Conferências, editoriais e artigos não relacionados ao tema foram excluídos. Dois pesquisadores selecionaram os artigos e extraíram: número e densidade de citações, ano de publicação, desenho de estudo, temáticas sobre perfuração radicular (fonte dos dentes avaliados [humano ou animal], tipo de dentição [decídua ou permanente], grupo dental, localização, etiologia, diagnóstico, materiais para selamento, tipo de procedimento para manejo, sequelas e tempo de acompanhamento clínico), periódico e seu fator de impacto, país e continente, instituição, autores e palavras-chave. O desempenho altmétrico das publicações foi consultado no *Dimensions*. Redes colaborativas foram geradas no software *VOSviewer*. A relação entre os dados foi determinada pela correlação de *Spearman*. Foram incluídos 312 artigos. O artigo mais citado somou 719 citações. Pesquisas laboratoriais (n=168) foram o desenho de estudo mais frequente. Os estudos foram publicados entre 1970-2025. Procedimentos não cirúrgicos foram predominantes (n = 278). Os estudos envolveram principalmente a região de furca (n = 116), molares (n = 121), dentes permanentes (n = 278) e espécimes humanos (n = 236). O agregado trióxido mineral (MTA) (n = 175) foi o material mais utilizado. O *Journal of Endodontics* (n = 77) continha o maior número de publicações. O Brasil (n = 46) e a Universidade de São Paulo junto com a Universidade estadual Paulista (n = 9 cada) foram o principal país e instituição, respectivamente. O autor mais frequente foi Alhadainy HA (n = 8). A palavra-chave mais utilizada foi "Mineral Trioxide Aggregate" (51 ocorrências). O *Dimensions* mostrou maior interesse social nas publicações por leitores do Mendeley. O *VOSviewer* mostrou as principais interações entre os autores e entre as palavras-chaves. Ao longo desses 55 anos, a maioria dos estudos foram laboratoriais para avaliação de materiais para selamento da perfuração radicular, principalmente o MTA. O Brasil e suas instituições foram majoritários nesta pesquisa. Estudos clínicos multicêntricos e maior número de pesquisas em dentes decíduos são sugeridos.

Palavras-chave: perfuração radicular; endodontia; revisão bibliométrica; altmetria.

ABSTRACT

Root perforations in endodontics are accidental or pathological communications between the root canal system and the periodontium, which may cause inflammation, infection, bone resorption, and even tooth loss if not properly treated. The aim of this study was to perform a bibliometric and altmetric analysis on root perforation in endodontics. The search was conducted in March 2025 in the Web of Science - Core Collection. Conferences, editorials, and articles not related to the topic were excluded. Two researchers selected the articles and extracted: number and density of citations, year of publication, study design, themes (origin of the evaluated teeth [human or animal], type of dentition [deciduous or permanent], dental group, location, etiology, diagnosis, sealing materials, type of procedure, sequelae and follow-up), journal and its impact factor, country and continent, institutions, authors and keywords. The altmetric performance of the publications was consulted in Dimensions. Collaborative networks were generated using VOSviewer software. The relationship between the data was determined by Spearman correlation. A total of 312 articles were included. The most cited article had 719 citations. Laboratory studies (n = 168) were the most frequent study design. Non-surgical procedures were predominant (n = 278). The studies mainly involved the furcation region (n = 116), molars (n = 121), permanent teeth (n = 278) and human specimens (n = 236). Mineral trioxide aggregate (MTA) was the most commonly used material (n = 175). The journal *Journal of Endodontics* (n=77) contained the highest number of publications. Brazil (n = 46) and the University of São Paulo and the São Paulo State University (n = 9 each) were the leading country and institution. The most frequent author was Alhadainy HA (n = 8). The most commonly used keyword was “Mineral Trioxide Aggregate” (51 occurrences). Dimensions showed greater social interest in the publications of Mendeley readers. VOSviewer showed interactions among authors and keywords. Root perforations have been studied for 55 years. Most studies were laboratory, focusing on the evaluation of materials for sealing perforations, mainly MTA. Brazil and its institutions were predominant in this research. Multicenter clinical studies and a greater number of research on primary teeth are suggested.

Keywords: root perforation; endodontics; bibliometric review; altmetrics.

LISTA DE ABREVIATURAS E SIGLAS

AAS – Altmetric Attention Score

CBCT – Cone-Beam Computed Tomography

DOI – Digital Object Identifier

IF – Impact Factor

IRM – Intermediate Restorative Material/ Material Restaurador Intermediário

MTA – Mineral Trioxide aggregate/ Agregado de Trióxido Mineral

OSF – Open Science Framework

TCFC – Tomografia computadorizada de feixe cônico

UNESP – Universidade Estadual Paulista

USP – Universidade de São Paulo

VOSviewer – Visualization of Similarities Viewer

WoSCC – Web of Science Core Collection

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1. INTRODUÇÃO

Na odontologia, a endodontia é o ramo que se dedica à região pulpar do elemento dental e seus tecidos perirradiculares, abrangendo suas condições de normalidade e de alterações patológicas, que inclui seus aspectos etiológicos, diagnósticos, preventivos e terapêuticos (de Moor et al., 2013; American Association of Endodontists, 2020). Dentro desse contexto, há as perfurações radiculares que correspondem a uma comunicação entre o sistema de canais radiculares e os tecidos perirradiculares, sendo consideradas uma das intercorrências operatórias mais inoportunas na prática endodôntica (Nicholls, 1962; Associação Americana de Endodontistas, 2020).

Sua etiologia deriva-se de causas iatrogênicas sejam durante o tratamento endodôntico nas regiões de terço cervical, médio, apical e assoalho pulpar ou durante o preparo intrarradicular para pinos nas confecções de próteses dentárias. Também ocorre devido à causas não iatrogênicas, como as patológicas, que englobam reabsorções radiculares inflamatórias externas e internas e cárie extensas (Clauder, 2022). Dessa forma, o diagnóstico precoce é necessário para uma conduta imediata e apropriada, reduzindo os riscos de contaminação bacteriana, inflamação persistente, reabsorção óssea, comprometimento periodontal e possível perda dentária (Estrela et al., 2018).

Durante o diagnóstico dessas lesões, não existem sinais ou sintomas patognomônicos para as perfurações radiculares, o que torna os achados clínicos limitados e de baixa especificidade (Devine; Paisner; Dayo, 2025). Logo, exige-se uma abordagem clínica cuidadosa, como uma avaliação anatômica prévia por meio de exames de imagem, com as radiografias periapicais e tomografia computadorizada de feixe cônico (TCFC), o uso de microscopia operatória, localizadores apicais e instrumentação adequada com técnicas minimamente invasivas (Devine; Paisner; Dayo, 2025). A identificação precisa da localização, extensão e tempo de ocorrência é fundamental para a escolha do manejo clínico (Saed; Ashley; Darcey, 2016).

Diante disso, para um tratamento efetivo, prioriza-se o restabelecimento de um tecido periodontal saudável no local da perfuração, sendo portanto, fundamental um selamento eficaz, aliado ao uso de técnicas apropriadas, materiais

biocompatíveis aos tecidos adjacentes e acompanhamento clínico adequado (Clauder, 2022).

A revisão bibliométrica é um método quantitativo e retrospectivo que analisa e mapeia a produção científica sobre determinado tema, permitindo mensurar a produção acadêmica, identificar tendências, avaliar impacto e orientar estratégias para pesquisas futuras (Montazeri et al., 2023). De forma complementar, a altmetria destaca-se como ferramenta para avaliar o impacto das publicações a partir de suas interações no meio social, analisando o alcance e a influência dos artigos, permitindo compreender o desempenho atual de uma determinada temática ou assunto (Cenci et al., 2024; Lauer et al., 2024). Neste estudo, sua aplicação possibilitará uma compreensão mais ampla do desempenho científico e da influência social do tema perfuração radicular na endodontia.

Existem diferentes delineamentos de estudo sobre esse tema; contudo, análises que integrem bibliometria e altmetria ainda são escassas na literatura. Nesse contexto, este estudo tem como objetivo analisar, de forma abrangente, a produção científica acerca da perfuração radicular em endodontia por meio de uma revisão baseada em métricas.

2. REVISÃO DE LITERATURA

As perfurações radiculares são uma comunicação indesejável do canal radicular à área externa do dente (Associação Americana de Endodontistas, 2020). Sua etiologia dá-se majoritariamente por ações mecânicas causadas pelo operador durante os tratamentos endodônticos ou durante preparos radiculares para colocação de pinos intrarradiculares (Kvinnslund et al., 1989). Uma revisão sistemática estimou que essas perfurações iatrogênicas ocorrem entre 0,6% e 17,6% dos artigos avaliados (Sarao; Berlin-Broner; Levin, 2021). Elas decorrem também, mas com menor frequência, por questões patológicas, como em progressão de lesões cariosas (Fuss; Trope, 1996) e/ou reabsorções radiculares inflamatórias externas ou internas (Darcey; Qualtrough, 2013). A depender da severidade, quando não tratada, evoluirá para uma inflamação crônica, culminando em uma provável perda dentária (Estrela et al., 2018).

A importância desse tema para a comunidade científica torna-se evidente ao observar que 4,2% das exodontias de dentes submetidos a tratamento endodôntico estão relacionadas às perfurações radiculares (Touré et al., 2011). Além disso, um estudo na Finlândia demonstrou que essas ocorrências representaram 29% das lesões registradas nas ações jurídicas por negligência endodôntica, onde 70% desses dentes afetados foram extraídos e 80% dos casos eram evitáveis com boas práticas clínicas (Vehkalahti; Swanljung, 2020). Diante disso, enfatiza-se que as perfurações radiculares representam uma complicação endodôntica de impacto clínico e legal considerável, reforçando a necessidade de prevenção e manejo adequado (Estrela et al., 2018).

Nesse contexto, observou-se uma relação entre a etiologia da perfuração radicular provocada pelo operador e as diferentes localizações deste acidente operatório (Alhadainy, 1994). As perfurações no terço coronal da raiz geralmente resultam de falhas na abertura endodôntica ou na localização dos canais, provocando uma comunicação na região coronária ou na furca de dentes multirradiculares. Já as perfurações no terço médio são geralmente laterais, decorrentes da aplicação excessiva de força na curvatura durante a instrumentação, especialmente em raízes curvas de molares. E as perfurações do terço apical são causadas principalmente quando não se respeita a anatomia apical, provocando

bloqueios, desvios ou deslocamentos do canal até a perfuração (Alhadainy, 1994; Saed; Ashley; Darcey, 2016).

Diretrizes foram propostas para prevenir as perfurações radiculares durante os tratamentos endodônticos, sendo fundamental avaliar o alinhamento da coroa-raiz e as eminências ósseas pela palpação e exame radiográfico prévio (Deutsch; Musikant, 2004; Tsesis; Fuss, 2006). Foi constatado que as perfurações iatrogênicas dos dentes anteriores superiores ocorriam em face vestibular, sugerindo à má interpretação do operador na inclinação de acesso (Kvinnsland et al., 1989). Assim, orienta-se o uso do microscópio operatório junto da junção amelocementária do dente como referência para a localização dos orifícios dos canais radiculares (Krasner; Rankow, 2004; Tsesis; Fuss, 2006). Na instrumentação mecânica, o uso excessivo e agressivo de instrumentos rotatórios pode levar à perfurações apicais ou crestais (Abou-Rass; Frank; Glick, 1980). Como prevenção, recomenda-se os instrumentos de níquel-titânio mais flexíveis com irrigação adequada, especialmente em canais curvos (Hülsmann, Herbst e Schäfers, 2003).

As perfurações radiculares podem ser identificadas de diversas formas, dentre elas pelos sinais e sintomas clínicos, como o sangramento persistente no canal radicular, dor súbita durante o tratamento e a sensação de soltura do instrumento dentro do canal (Alhadainy, 1994). Existem também, os localizadores apicais que sinalizam com boa precisão a perfuração quando atingem no ligamento periodontal (Langaliya et al., 2024), os microscópios operatórios e os exames complementares, como as radiografias periapicais, que apesar de amplamente utilizados, apresentam limitações devido à sua natureza bidimensional (Estrela et al., 2018). Para superar essa barreira, a TCFC tem se mostrado mais precisa que as radiografias (Abdinian et al., 2020), embora seu uso deva ser criterioso em virtude da exposição à radiação ionizante, sendo indicada quando essa alterar o desfecho do caso clínico (Alhadainy, 1994; Estrela et al., 2018; Saed; Ashley; Darcey, 2016).

Alguns fatores influenciam no desfecho do tratamento, como a localização, o tamanho e o tempo de reparo. À vista disso, foi criada uma classificação sobre o prognóstico dessas perfurações (Fuss; Trope, 1996). Dessa forma, apresenta-se um bom prognóstico quando são recentes, pequenas e localizadas na região coronal ou apical da crista óssea. E com prognóstico questionável, quando são antigas, de grande extensão e situadas diretamente na região da crista óssea ou furca (Fuss; Trope, 1996). Essa região é denominada zona crítica, pois o íntimo contato com a

área gengival, associado ao maior tempo de exposição, implica em contaminação microbiana, gerando maiores alterações patológicas (Tsesis et al., 2010). Esses fatores devem ser levados em conta na prática clínica para o sucesso do tratamento (Fuss; Trope, 1996; Tsesis; Fuss, 2006).

Diante de uma perfuração, as opções disponíveis são reparo ou extração dentária (Saed; Ashley; Darcey, 2016). Quando possível o manejo, o procedimento não cirúrgico é a primeira escolha no tratamento das perfurações radiculares, apresentando taxas de sucesso superiores a 70%, conforme revisão sistemática (Siew; Lee; Cheung, 2015). A abordagem cirúrgica é indicada quando a primeira não for possível, há necessidade de intervenção periodontal, há incerteza quanto à natureza do defeito, há lesão subcrestal com sintomatologia ou patologia persistente e entre outras situações (Saed; Ashley; Darcey, 2016). Em alguns casos, ocorre a combinação de ambas as abordagens (Regan; Witherspoon; Foyle, 2005)

Além do exposto, há também as perfurações do tipo patológicas, que resultam das reabsorções radiculares ou cárie dental (Alhadainy, 1994). As reabsorções radiculares derivam da perda de dentina e cemento gradual devido à ação dos osteoclastos, classificando-as em inflamatórias internas ou externas. Suas causas ainda são desconhecidas, mas estão relacionadas com traumas, agentes clareadores, necrose pulpar, tratamento ortodôntico entre outros (Darcey; Qualtrough, 2013; 2013). As reabsorções internas são provenientes de uma inflamação no interior do canal radicular, autolimitadas, mas em alguns casos estende-se para uma comunicação externa. Já as reabsorções externas tendem a ser mais agressivas, propícias à uma perfuração radicular, sendo, portanto, imprescindível sua identificação para possível intervenção (Darcey; Qualtrough, 2013; 2013).

As lesões cariosas decorrem da ação microbiana que, quando ativa e não tratada, podem se estender para a região radicular provocando uma perfuração que exige diferentes métodos de tratamento (Saed; Ashley; Darcey, 2016). É comumente identificado em pacientes idosos, cuja qualidade e quantidade salivar são menores e estão associadas à maior quantidade de recessões gengivais (Regan; Witherspoon; Foyle, 2005).

Historicamente, há diversos materiais relatados na literatura para o reparo de perfurações radiculares, como amálgama, cimento óxido de zinco-eugenol, hidróxido de cálcio, guta-percha, cimento de ionômero de vidro, material restaurador

intermediário (IRM), cimento de fosfato de cálcio e entre outros (Kakani et al., 2015). Atualmente, a literatura científica sugere que as perfurações radiculares sejam tratadas com materiais que tenham melhores respostas biológicas, estabilidade e selamento (Holland et al, 2017). Assim, com o avanço das tecnologias, as biocerâmicas entraram com êxito no mercado da endodontia. Elas são materiais cerâmicos que possuem propriedades antibacteriana, antifúngica, biocompatibilidade, possuem excelente capacidade seladora e são, principalmente, bioativas —substâncias que interagem com os tecidos vivos de modo benéfico, podendo induzir a regeneração e ao reparo tecidual (Raghavendra et al., 2017).

O primeiro material biocerâmico estudado para o tratamento das perfurações radiculares foi o Agregado de Trióxido Mineral (MTA), um cimento à base de silicato de cálcio, que obteve melhor taxa de selamento e menor infiltração em relação aos materiais IRM e amálgama (Lee, Monsef & Torabinejad, 1993). Desde então, tem sido amplamente estudado para esse fim (Baroudi; Samir, 2016). Um estudo laboratorial concluiu que além de induzir uma osteogênese, o MTA também foi capaz de estimular a cementogênese, mostrando suas qualidades bioativas (Yildirim et al., 2005). Apesar de ser considerado um material de referência, ele apresenta limitações clínicas, como sua dificuldade de manuseio e seu tempo de presa ser em torno de 2-4 horas, o que compromete sua aplicação e estabilidade no selamento (Torabinejad and Chivian, 1999). Pode ocasionar também o escurecimento dental, comprometendo áreas estéticas (Baroudi; Samir, 2016; Saed; Ashley; Darcey, 2016).

Na tentativa de contornar esses impasses, novos biomateriais têm sido desenvolvidos, como por exemplo, o Biodentine. Ele é um cimento à base de silicato de cálcio, bioativo, com boa adesão mecânica aos túbulos dentinários, boa resistência à compressão e possui, de forma vantajosa, uma melhor consistência para a aplicação clínica e com um tempo de presa em torno de 45 minutos (Raghavendra et al., 2017). Além disso, uma revisão sistemática demonstrou que o Biodentine promove menor alteração cromática dentária quando comparado ao MTA (Slaboseviciute et al., 2021).

Outras biocerâmicas também têm sido investigadas, como por exemplo, os cimentos iRoot SP, iRoot Plus, EndoSequence Root Repair Material, Bioaggregate e a Mistura Enriquecida com Cálcio (Raghavendra et al., 2017; Kakani et al., 2015). No entanto, esses materiais ainda carecem de estudos de longo prazo e são

mencionados com menor frequência na literatura científica quando comparados ao MTA e suas variações disponíveis no mercado (Alghamdi e Aljahdali, 2019).

Junto aos materiais seladores, há uma discussão sobre a utilização de matrizes, que são biomateriais aplicados previamente na base da perfuração radicular, servindo como um arcabouço de sustentação para o material selador, sugerindo favorecer sua adaptação e estabilidade durante o reparo. Esses materiais também interagem com o tecido periodontal adjacente, contribuindo para a manutenção do espaço biológico e ambiente favorável à cicatrização (Rafter *et al.*, 2002).

Em menor escala, métodos alternativos podem ser empregados sem o uso de materiais seladores, através de abordagens cirúrgicas complementares, como por exemplo, apicectomia, hemissecção e bicuspidização, indicadas em casos selecionados conforme a localização e extensão da perfuração, o comprometimento periodontal e as condições clínicas do paciente (Regan; Witherspoon; Foyle, 2005; Arabaci; Çiçek; Güngör, 2012; Abu Hasna *et al.*, 2020). Porém, tais procedimentos são menos frequentes na literatura, refletindo a preferência pelo manejo conservador como primeira escolha terapêutica (Fuss; Trope, 1996; Saed; Ashley; Darcey, 2016).

Diante do exposto, destaca-se a importância do domínio desse tema por cirurgiões-dentistas, visto que, diante de perfurações radiculares decorrentes de iatrogenias ou de processos patológicos, torna-se imprescindível a adequada comunicação com o paciente quanto às condutas clínicas indicadas, às alternativas terapêuticas e ao prognóstico esperado (Estrela *et al.*, 2017).

3. OBJETIVO

3.1 Objetivo geral

Realizar uma análise bibliométrica e altmétrica sobre perfuração radicular em endodontia a fim de localizar as lacunas, tendências e avanços de conhecimento nessa área.

3.2 Objetivos específicos

- Indicar o número e densidade de citações dos artigos da base de dados Web of Science Core Collection;
- Avaliar os anos de publicações e a distribuição temporal dos estudos;
- Identificar os diferentes desenhos de estudos;
- Analisar as principais temáticas mais abordadas;
- Avaliar os periódicos com maior número de publicações e seus fatores de impacto;
- Observar os países e continentes com maior representatividade na temática;
- Identificar as instituições e autores mais recorrentes no mundo sobre essa temática;
- Expor as palavras-chave mais mencionadas;
- Realizar análise de tendências ao longo das décadas;
- Analisar o desempenho altimétrico sobre essa temática.

3. ARTIGO

Este trabalho encontra-se nas normas da revista "*Journal of Endodontics*" onde ele será submetido.

Current status and trends in research on root perforation in endodontics: a metrics-based analysis

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Current status and trends in research on root perforation in endodontics: a metrics-based analysis

Abstract

Introduction: This study conducted a bibliometric and altmetric analysis of the scientific literature on root perforations in endodontics, identifying trends and key characteristics.

Methods: The search was conducted in March 2025 in the Web of Science Core Collection. Conference papers, editorials, and unrelated studies were excluded. Two researchers independently selected articles and extracted data on number and density of citation, year of publication, study design, themes, journal and impact factor, country and continent, institutions, authors and keywords. Altmetric data were obtained from Dimensions. Collaborative networks were generated using VOSviewer. Relationships between data were determined by Spearman correlation. **Results:** A total of 312 articles were included. The most cited article had 719 citations. Laboratory studies were the most frequent design ($n = 168$). Publications ranged from 1970–2025. Non-surgical procedures were predominant ($n = 278$). The studies mainly involved the furcation region ($n = 116$), molars ($n = 121$), permanent teeth ($n = 278$) and human specimens ($n = 236$). Mineral trioxide aggregate (MTA) was the most investigated material ($n = 175$) and the most frequent keyword (51 occurrences). The Journal of Endodontics ($n = 77$), Brazil ($n = 46$), the University of São Paulo and the São Paulo State University ($n = 9$ each) and author Alhadainy HA ($n = 8$) had the highest number of publications. Dimensions showed greater social interest in the publications of Mendeley readers. **Conclusions:** Research has evolved over 55 years, with a predominance of laboratory studies focused on repair materials. Multicenter clinical studies and a greater number of research on primary teeth are suggested.

Keywords: Root perforation; Endodontics; Bibliometric review; Altmetrics.

Introduction

Endodontics is the specialty dedicated to the dental pulp and periradicular tissues, including both their normal state and pathological changes, including their etiological, diagnostic, preventive and therapeutic aspects (1, 2). Within this context, root perforations are defined as communications between the root canal system and the periradicular tissues, being regarded as one of the most unfavorable procedural complications in endodontic practice (2, 3).

Its etiology is associated with iatrogenic procedures that may occur during endodontic treatment or during intraradicular preparation for post placement in prosthodontic procedures, as well as from pathological processes, such as internal and external inflammatory root resorption and extensive dental caries (4). Thus, early diagnosis is crucial to enable prompt and appropriate intervention, minimizing the risks of bacterial contamination, persistent inflammation, bone resorption, periodontal involvement and eventual tooth loss (5).

During the diagnosis of these lesions, there are no pathognomonic signs or symptoms specific to root perforations, which makes clinical findings limited and of low specificity (6). Consequently, a meticulous clinical approach is necessary, involving preliminary anatomical evaluation through imaging examinations such as periapical radiography and cone-beam computed tomography (CBCT), in addition to the use of an operating microscope, apex locators and appropriate minimally invasive instrumentation techniques (4, 6). Precise determination of the location, extent, and timing of the perforation is crucial for guiding clinical management (7).

Accordingly, effective treatment prioritizes the reestablishment of healthy periodontal tissues at the perforation site, ensuring the absence of persistent inflammation (4). Therefore, effective sealing is essential, combined with the use of appropriate techniques, biocompatible materials for the adjacent tissues and adequate clinical follow-up (4, 5, 7).

Bibliometric review is a quantitative and retrospective method that analyzes and maps scientific production on a given topic, enabling the measurement of academic output, identification of trends, evaluation of impact, and guidance for future research strategies (8). Complementarily, altmetrics stand out as a tool for evaluating the impact of publications through their engagement in the social environment, analyzing the reach and influence of articles and providing insight into the current performance of a given field (9, 10). In this study, its application will enable a broader understanding of the scientific performance and social influence of root perforation in endodontics.

Different study designs have been employed to investigate root perforations in endodontics; however, analyses integrating bibliometrics and altmetrics on this topic remain scarce in the literature. In this context, this study aims to comprehensively analyze the scientific production on root perforations in endodontics through a metrics-based review.

Methodology

The review protocol was registered in March 2025 on the Open Science Framework (OSF) under the following Digital Object Identifier (DOI): 10.17605/OSF.IO/P8453. This study is a quantitative bibliometric review, and its design was conducted in accordance with the METRICS guidelines (11).

An bibliographic search was conducted in the Web of Science Core Collection (WoSCC) database using the following search strategy: [ALL = (“Root perforation*” OR “Strip Perforation*” OR “Furcal Perforation*” OR “Furcation Perforation*” OR “Endodontic Perforation*” OR “Tooth Perforation*” OR “Teeth Perforation*” OR “Stripping perforation” OR “Root perforating” OR “Perforated root” OR “Root Canal Perforation”)].

The article selection was conducted by three independent researchers (V.S.C., A.O.R., L.M.A.) by examining titles, abstracts and, when needed, full texts. In cases of disagreement, a fourth reviewer (T.M.D.) was consulted. In selecting articles, inclusion and exclusion criteria were applied. All scientific articles on root perforation in endodontics indexed in the Web of Science Core Collection were included, regardless of language, location, or publication date, while non-scientific publications (e.g., conference abstract, letters, editorials and corrections) and studies unrelated to the topic or outside the endodontic context were excluded.

For each included article, the following data were extracted: number and density of citations, year of publication, study design, the journal and its 2024 impact factor (IF) (Journal Citation Reports), country and continent, institution of the corresponding author, authorship and keywords.

Additionally, thematic data about root perforation included were: (1) origin of the evaluated teeth (human or animal); (2) dentition type (permanent or deciduous); (3) dental group; (4) perforation location; (5) etiology; (6) diagnostic methods; (7) repair materials; (8) procedure type (surgical or non-surgical); (9) sequelae; and (10) clinical follow-up period.

The Visualization of Similarities Viewer (VOSviewer, version 1.6.17.0; Centre for Science and Technology Studies, Leiden University) was used to generate graphical representations of collaboration networks for authorship and keywords. Spearman's

correlation was used to assess the relationship between the number of citations and the year of publication, as well as between citation counts and journal IF. Data analysis was conducted using IBM SPSS Statistics for Windows (v24.0; IBM Corp).

The data were grouped into 11-year publication intervals according to the number of studies using Microsoft Excel (Microsoft Excel 2010; Microsoft Corp). The main characteristics and trends of each period were assessed based on study design, materials, diagnostic methods, journal, and country.

Altmetric data were obtained from the Dimensions database (dimensions.ai) using the same search strategy applied in WoS-CC and collected on the same day as the primary search by two independent researchers (V.S.C. and A.O.R.). The studies were then ranked in descending order according to the Altmetric Attention Score.

Results

The initial search in WoS-CC retrieved 548 documents. After selection, 312 studies were included and fully analyzed (Supplementary Figure 1). The articles accumulated a total of 7,746 citations, with self-citations accounting for 28.85%. The most cited study “Clinical applications of mineral trioxide aggregate” (12), received 719 citations and had the highest citation density (27.65) (Table 1). Spearman correlation analysis revealed a moderate negative correlation between citation count and publication year ($r = -0.752$; $p < 0.001$) and a weak positive correlation between citation count and journal IF ($r = 0.231$; $p < 0.05$).

The earliest WoS-CC-indexed study on root perforation in endodontics was published by Seltzer in 1970 (13). The most recent contributions include three studies published in 2025 (14-16). Despite a publication span exceeding 50 years, publication activity has increased markedly over the past ten years ($n = 160$), peaking in 2021 ($n = 24$) (Figure 1).

Most studies were laboratory ($n = 168$), followed by case reports ($n = 83$), observational studies ($n = 26$), literature reviews ($n = 24$), systematic reviews ($n = 7$), technical reports ($n = 2$), both laboratory and clinical study ($n = 1$) and clinical study ($n = 1$).

Regarding study objectives, the following themes were divided: evaluating biological and mechanical responses to sealing techniques, materials and irrigants in endodontic perforations ($n = 129$), technique description and/or clinical outcomes ($n = 85$), diagnosis of endodontic perforations ($n = 31$), scientific status ($n = 31$), evaluation of the prevalence of endodontic failures (including root perforations) associated with students and/or professionals ($n = 13$), clinical success of root perforations ($n = 13$), risk of root perforation ($n = 6$) and others ($n = 4$).

Most studies were conducted using human dentition (n = 236), followed by animal dentition (n = 49) and combined human and animal samples (n = 2). Permanent teeth were the most studied (n = 278), followed by primary teeth (n = 6) and mixed dentition (n = 3). Regarding tooth groups, molars accounted for the largest share (n = 121), followed by multiple tooth groups (n = 93), premolars (n = 36), incisors (n = 27) and canines (n = 3). Overall, 23 studies were not applicable to these analyses (literature reviews and laboratory studies — that did not use teeth in their analyses), 2 studies did not report dentition type and 9 did not report the tooth group.

Pulpal floor perforations were the most commonly reported location (n = 116), followed by multiple locations (n = 78), cervical (n = 30), middle (n = 21), apical thirds (n = 19) and extensive continuous perforations involving more than one root third (n = 8). This category was not applicable to 31 studies (literature reviews and laboratory studies — that did not use teeth in their analyses) and 9 studies did not report the perforation location.

The most frequently reported cause were simulated root perforations for experimental purposes (n = 160), iatrogenic events (n = 88), multiple etiologies (n = 13) and pathological causes (resorption or extensive caries) (n = 09). This category was not applicable to 29 studies (literature reviews and laboratory studies — that did not use teeth in their analyses) and 13 studies did not report the etiology.

Radiographic methods predominated (n = 55), followed by multiple diagnostic approaches (n = 47), tomographic imaging (n = 32), electronic apex locators (n = 12) and clinical examination (n = 6). This category was not applicable to 152 studies (literature reviews and laboratory studies without diagnostic assessment) and 8 studies did not report the diagnostic method.

Mineral trioxide aggregate (MTA) was the most frequently used material for perforation repair (n = 175), followed by bioceramics (n = 92) (Table 2). In 54 studies, biomaterial matrices were applied prior to placement of the sealing material. This category was not applicable to 68 studies (literature reviews; laboratory and observational studies focusing on the incidence or diagnosis of perforations; and case reports employing alternative repair approaches) and 4 studies did not report the material used.

Non-surgical procedures were the main approach (n = 101), followed by surgical approaches (n = 27) and combined methods (n = 17). This category was not applicable to 157 studies (in vitro laboratory studies; literature reviews; and observational studies that did not address this aspect) and 10 studies did not report the type of procedure.

Most studies conducted in humans reported complete success in the clinical outcome of root perforation repair (n = 76). Two studies reported total failure (100% of cases) (n = 2), whereas studies including multiple cases showed mixed outcomes (success and failures) with a predominance of favorable results (n = 15). This category was not applicable to 214 studies (in vitro studies; literature reviews; and observational studies that did not address clinical outcomes) and 5 studies did not report clinical outcomes.

Among humans studies, most did not report sequelae after perforation repair (n = 62), whereas some reported sequelae in all evaluated cases (n = 15) and some studies including multiple cases showed mixed findings, with a predominance of cases without sequelae (n = 12). Reported sequelae included tooth extraction, cervical gingival recession, persistent radiolucent lesions, dental and/or gingival discoloration, black space formation, need for clinical crown lengthening, hemisection, coronal and/or root fracture, persistent periodontal pockets and radicular cysts. This category was not applicable to 212 studies (in vitro studies; literature reviews; and observational studies that did not address clinical outcomes) and 11 studies did not report clinical outcomes.

Clinical follow-up periods were distributed as ≤ 6 months (n = 11), > 6 months to 1 year (n = 19), > 1 to 2 years (n = 22), > 2 to 5 years (n = 19), > 5 to 10 years (n = 12), and > 10 years (n = 5). This category was not applicable to 218 studies (in vitro studies; literature reviews; and studies without follow-up data) and 6 studies did not report follow-up time.

A total of 97 journals published articles on root perforation in endodontics, with the most prevalent being *Journal of Endodontics* (n = 77), followed by *International Endodontic Journal* (n = 25) and *Journal of Oral Surgery Oral Medicine Oral Pathology Oral Radiology* (n = 17) (Supplementary Table 1). The highest 2024 impact factors were observed for *Journal of Translational Medicine* (IF 7.5; n = 1), *International Endodontic Journal* (IF 7.1; n = 25) and *Journal of Dental Research* (IF 5.9; n = 1).

Overall, 42 countries contributed to the publications. Brazil was the most prevalent (n = 46), followed by the United States of America (n = 45) and Turkey (n = 36). Asia (n = 137), Europe (n = 58) and Latin America (n = 51) were the most represented continents (Figure 2). Publications were associated with 192 institutions, led by the University of São Paulo (USP) and São Paulo State University (UNESP) (n = 9 each), followed by Tel Aviv University and Cairo University (n = 7 each) (Supplementary Table 2). The dataset comprised 1,205 authors, with Alhadainy HA being the most prolific (n = 8) (Figure 3) (Supplementary Table 3).

A total of 557 author keywords were identified, with “Mineral Trioxide Aggregate”

(51 occurrences), “Root Perforation” (39 occurrences) and “MTA” (30 occurrences) being the most frequent. “Biodentine” has gained prominence in recent years (Figure 4).

Temporal trends in root perforation research, showing increased publication output and sustained predominance of laboratory studies. Materials evolved from amalgam, calcium hydroxide and gutta-percha to MTA and other bioceramic materials. Diagnostic approaches progressed from clinical and conventional radiography to multimodal strategies, with growing use of tomography. The Journal of Endodontics emerged as the main publication venue after the 1990s, while geographic contributions shifted from early dominance by the United States to broader participation from countries such as Brazil, Turkey and India (Table 3).

According to Dimensions, 45 studies presented altmetric data—which integrates citations, social media mentions, and patents (17, 18). Engagement was highest among Mendeley readers, X users and patents. The article with the highest altmetric performance was “Root perforations: aetiology, management strategies and outcomes. The hole truth.” (7), with an Altmetric Attention Score (AAS) of 15, with 219 Mendeley readers, 12 mentions on X and one blog citation (Table 4).

Discussion

Root perforation is a complication associated with endodontic treatment that may significantly compromise prognosis of the tooth (6). This study aimed to perform a bibliometric analysis of the literature on root perforations in endodontics. The findings indicate a predominance of laboratory studies, mainly published in the Journal of Endodontics, with Brazil as the leading contributor.

The most cited article was “Clinical applications of mineral trioxide aggregate” (12), which also presented the highest citation density. Its impact was attributed to establishing MTA as an effective and innovative material in dentistry, describing its properties, clinical indications and applications, as well as to the prominent scientific influence of its author, Torabinejad, in modern Endodontics (19). A moderate negative correlation was observed between citation count and year of publication, indicating that older articles tended to receive more citations due to longer exposure in the literature. Conversely, a weak positive correlation was found between citation count and journal IF, suggesting that higher-impact journals increased study visibility, although with limited influence on citation counts.

Most studies were laboratory and had the objective of “evaluating biological and mechanical responses to sealing techniques, materials, and irrigants in endodontic root perforations”, supporting the development of evidence-based dental materials and improving

the understanding of repair outcomes and prognosis (20). However, these findings require validation through clinical trials given their importance for clinical decision-making (21). In this review, only one clinical trial was identified, likely due to ethical constraints but also to the difficulty in standardizing samples and clinical protocols, given the multifactorial nature of root perforations (21, 22). Hence, multicenter studies are warranted to strengthen the evidence base.

A predominance of studies in human permanent teeth and a scarcity in primary teeth highlight an important gap in the literature. This may be explained by the physiological features of primary teeth, including physiological root resorption, proximity to the permanent successor and behavioral challenges in pediatric patients, which restrict laboratory and clinical investigations (23).

Most root perforations were simulated, followed by iatrogenic events. Although undesirable, root perforations still occur clinically and require effective therapeutic and technological approaches, which are developed and tested in laboratory studies, explaining the predominance of simulated perforations (24). The pulpal floor was the most common site, and molars the most frequently involved teeth. This pattern likely reflects the predominance of laboratory studies, where perforations are simulated—mainly at the pulpal floor—to evaluate sealing materials under standardized and easily reproducible conditions (25).

Radiographic methods represent the primary approach for detecting root perforations and remain the central role for diagnosis, treatment and follow-up. Although, data indicate a trend toward combining diagnostic approaches, such as electronic apex locators and tomographic imaging, improving reliability and accuracy (4, 6, 7).

MTA was the most commonly used material, reflecting the shift from traditional materials to bioceramic cements and its establishment as the reference standard for perforation repair, frequently employed as a control in studies evaluating new materials (26). Its prominence was also evident among author keywords, with “Mineral Trioxide Aggregate” being the most prevalent term, corroborating previous bibliometric reviews (27, 28). In recent years, “Biodentine” has emerged as a growing keyword, likely due to its favorable handling, shorter setting time and lower discoloration potential (29, 30). In addition to material selection, some studies have reported the use of biomaterial matrices; however, their application remains under evaluation, with some studies suggesting that they help prevent extrusion of sealing materials and promote stability (31, 32), while others show no significant difference (33, 34).

The preferred approach for treating root perforations was a non-surgical method, based on conservative endodontic principles aimed at preserving dental and periodontal structures (35). This approach has become safer and more predictable with the use of technologies such as the operating microscope and ultrasonic instrumentation (36). Therefore, in human studies, the majority reported clinical success in root perforation repair, with most cases presenting no sequelae, reflecting advancements in endodontic treatments and sealing materials, in agreement with a previous systematic review reporting success rates exceeding 70% for non-surgical methods (37).

A follow-up period of 1–2 years was predominant, which is considered adequate for initial assessment in the absence of symptoms, although longer follow-up is recommended to confirm long-term stability, particularly in surgical cases or those with radiographic lesions (38).

The Journal of Endodontics was the most prevalent journal due to its specialization in the field (39), while the Journal of Translational Medicine had the highest impact factor despite a single publication, likely due to its multidisciplinary scope (40).

Brazil ranked first in number of publications, corroborating previous bibliometric reviews (41, 42). It also led in contributing institutions, with USP and UNESP ranking highest. Around 15% of endodontic publications are linked to Brazilian researchers, consolidating the country as a major center of research in recent decades (43). At the continental level, Asia accounted for the highest number of studies, followed by Europe, while African publications were limited to Egypt and only three studies originated from Oceania. This pattern highlights geographic disparities and the need to expand research in these regions.

The temporal trend observed in this review suggests growing scientific interest in root perforations alongside technological and biomaterial advances in Endodontics. The increase in publications after the introduction of MTA likely reflects its impact on perforation management and prognosis. Similarly, the growing use of CBCT demonstrates the incorporation of advanced imaging methods into endodontic practice, contributing to more accurate diagnosis (44). Additionally, the increasing contribution of emerging countries may reflect greater governmental investments in science and technology, expanding research productivity and publication output (43).

Three articles overlapped between the bibliometric and altmetric rankings, indicating that some publications achieve both high scientific impact and digital visibility. Nevertheless, altmetric analysis from Dimensions showed that, although studies on root perforations receive

some online attention, their overall digital impact remains limited. Higher engagement on Mendeley likely reflects its widespread use among researchers, consistent with previous studies (45, 46). This may be explained by the specialized nature of the topic.

Some limitations should be considered when interpreting the results. The bibliographic search was restricted to the Web of Science database. This choice is supported by methodological guidelines, which report that most bibliometric reviews rely on a single database, mainly due to technical constraints related to data export and compatibility with software such as VOSviewer (11).

Scientific production on root perforation has grown markedly, with a predominance of laboratory studies and MTA as the main material, alongside increasing interest in bioceramic cements. However, research remains geographically concentrated, with Brazil emerging as a leading contributor, and important gaps persist. These include the need for broader geographic representation, multicenter clinical trials in humans and a greater number of studies focused on primary dentition. This highlights the need to strengthen clinically oriented and globally distributed research to enhance the translation of evidence into practice.

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Tables

Table 1. Top 10 most cited articles on root perforations in endodontics.

Bibliometric ranking	
Citation WoS-CC	Article
719	Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggregate. <i>J Endod</i> . 1999;25(3):197-205. doi:10.1016/S0099-2399(99)80142-3.
501	Lee SJ, Monsef M, Torabinejad M. Sealing ability of mineral trioxide aggregate for repair of lateral root perforations. <i>J Endod</i> . 1993;19(11):541-4. doi:10.1016/S0099-2399(06)81282-3.
383	Mohammadi Z, Dummer PM. Properties and applications of calcium hydroxide in endodontics and dental traumatology. <i>Int Endod J</i> . 2011;44(8):697-730. doi:10.1111/j.1365-2591.2011.01886.x.
233	Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. <i>Oral Surg Oral Med Oral Pathol Oral Radiol Endod</i> . 1995;79(6):756-63. doi:10.1016/S1079-2104(05)80313-0.

189	Malkondu Ö, Karapinar Kazandağ M, Kazazoğlu E. A review on Biodentine, a contemporary dentine replacement and repair material. <i>Biomed Res Int.</i> 2014;2014:160951. doi:10.1155/2014/160951.
186	Gandolfi MG, Taddei P, Tinti A, Prati C. Apatite-forming ability (bioactivity) of ProRoot MTA. <i>Int Endod J.</i> 2010;43(10):917-29. doi:10.1111/j.1365-2591.2010.01768.x.
177	Main C, Mirzayan N, Shabahang S, Torabinejad M. Repair of root perforations using mineral trioxide aggregate: a long-term study. <i>J Endod.</i> 2004;30(2):80-3. doi:10.1097/00004770-200402000-00004.
126	Fuss Z, Trope M. Root perforations: classification and treatment choices based on prognostic factors. <i>Endod Dent Traumatol.</i> 1996;12(6):255-64. doi:10.1111/j.1600-9657.1996.tb00524.x.
121	Guneser MB, Akbulut MB, Eldeniz AU. Effect of various endodontic irrigants on the push-out bond strength of Biodentine and conventional root perforation repair materials. <i>J Endod.</i> 2013;39(3):380-4. doi:10.1016/j.joen.2012.11.033.
119	Holland R, Filho JA, de Souza V, Nery MJ, Bernabé PF, Junior ED. Mineral trioxide aggregate repair of lateral root perforations. <i>J Endod.</i> 2001;27(4):281-4. doi:10.1097/00004770-200104000-00011.

Table 2. Materials used for the sealing of root perforations in endodontics.

Materials	Number of times used
MTA	175
Bioceramics	92
Amalgam	29
Resin-modified glass ionomer cement	26
Zinc oxide–eugenol cement	22
Gutta-percha	22
Conventional glass ionomer cement	15
Portland cement	12
Calcium hydroxide	12
Composite resin	10
Resin cement	06
Temporary filling cement	05
Biomaterials	05
Compomer	02
Dentin adhesive	02
4-META/MMA-TBB resin	02
Indium Foil	01
Theracal LC	01
Polydopamine-coated bioactive glass	01

Table 3. Publication trends on root perforation research in endodontics over the years.

Decades	1970-1980	1981-1991	1992-2002	2003-2013	2014-2025
(Number of articles)	(n=03)	(n=16)	(n=40)	(n=81)	(n=172)
Study design	Laboratory (1) Case report (1) Literature review (1)	Laboratory (9) Case report (4) Observational study (2)	Laboratory (28) Case report (8) Literature review (3)	Laboratory (43) Case report (26) Observational study (7)	Laboratory (87) Case report (44) Observational study (16)
Materials	Calcium hydroxide (2) Gutta-Percha (2) Amalgam (1) Zinc oxide-eugenol cement (1)	Amalgam (7) Gutta-Percha (6) Calcium hydroxide (5)	Amalgam (14) Resin-modified glass ionomer cement (14) MTA (8)	MTA (64) Zinc oxide-eugenol cement (11) Bioceramic materials (10)	MTA (101) Bioceramic materials (79) Gutta-Percha (10)
Diagnostic method	Clinical (1)	Radiographic (4) Multiple methods (2)	Radiographic (8) Electronic apex locator (2) Multiple methods (2)	Radiographic (19) Multiple methods (11) Tomographic (3)	Multiple methods (32) Tomographic (29) Radiographic (24)
Scientific journal	Journal of the American Dental Association (1) Journal of Dental Research (1) Journal of Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology (1)	Journal of Endodontics (11) International Endodontic Journal (2) Journal of Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology (2)	Journal of Endodontics (23) International Endodontic Journal (4) Journal of Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology (2)	Journal of Endodontics (24) International Endodontic Journal (11) Journal of Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology (6)	Journal of Endodontics (19) International Endodontic Journal (19) Case Reports in Dentistry (10)

Countries	United States of America (3)	United States of America (11)	United States of America (18) Israel (4) Brazil (3) Egypt (3) United Kingdom (3)	Brazil (16) United States of America (9) Türkiye (8)	Türkiye (28) Brazil (26) India (24)
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Table 4. Top 10 most cited articles on root perforations in endodontics.

Altmetric ranking		
AAS	Article	Mentioned by
	Saed SM, Ashley MP, Darcey J. Root perforations: aetiology, management strategies and outcomes. The hole truth. Br Dent J. 2016;220(4):171-80. doi:10.1038/sj.bdj.2016.132.	219 Mendeley 12 X users 1 Blog
	Mohammadi Z, Dummer PM. Properties and applications of calcium hydroxide in endodontics and dental traumatology. Int Endod J. 2011;44(8):697-730. doi:10.1111/j.1365-2591.2011.01886.x.	1127 Mendeley 3 X users 1 Wikipedia page 1 News
	Siew K, Lee AH, Cheung GS. Treatment outcome of repaired root perforation: a systematic review and meta-analysis. J Endod. 2015;41(11):1795-804. doi:10.1016/j.joen.2015.07.007.	314 Mendeley 2 Blogs 1 X user
	Kakani AK, Veeramachaneni C, Majeti C, Tummala M, Khiyani L. A review on perforation repair materials. J Clin Diagn Res. 2015;9(9):ZE09-13. doi:10.7860/JCDR/2015/13854.6501.	174 Mendeley 1 News
	Lodiene G, Kleivmyr M, Bruzell E, Ørstavik D. Sealing ability of mineral trioxide aggregate, glass ionomer cement and composite resin when repairing large furcal perforations. Br Dent J. 2011;210(5):E7. doi:10.1038/sj.bdj.2011.198.	107 Mendeley 7 X users
	Shemesh H, Cristescu RC, Wesselink PR, Wu MK. The use of cone-beam computed tomography and digital periapical radiographs to diagnose root perforations. J Endod. 2011;37(4):513-6. doi:10.1016/j.joen.2010.12.003.	170 Mendeley 1 Clinical guidelines sources
	Haghanifar S, Moudi E, Mesgarani A, Bijani A, Abbaszadeh N. A comparative study of cone-beam computed tomography and digital periapical radiography in detecting mandibular molar root perforations. Imaging Sci Dent. 2014;44(2):115-9. doi:10.5624/isd.2014.44.2.115.	44 Mendeley 1 Patents
	Lee SJ, Monsef M, Torabinejad M. Sealing ability of mineral trioxide aggregate for repair of lateral root perforations. J Endod. 1993;19(11):541-4. doi:10.1016/S0099-2399(06)81282-3.	422 Mendeley 1 Clinical guideline sources
	Behnia A, Strassler HE, Campbell R. Repairing iatrogenic root perforations. J Am Dent Assoc. 2000;131(2):196-201. doi:10.14219/jada.archive.2000.0147.	73 Mendeley 1 Patents



Gandolfi MG, Taddei P, Tinti A, Prati C. Apatite-forming ability (bioactivity) of ProRoot MTA. *Int Endod J.* 2010;43(10):917-29. doi:10.1111/j.1365-2591.2010.01768.x.

197 Mendeley
2 Patents

Figures

Figure 1. Distribution of the number of publications on the topic over the years.

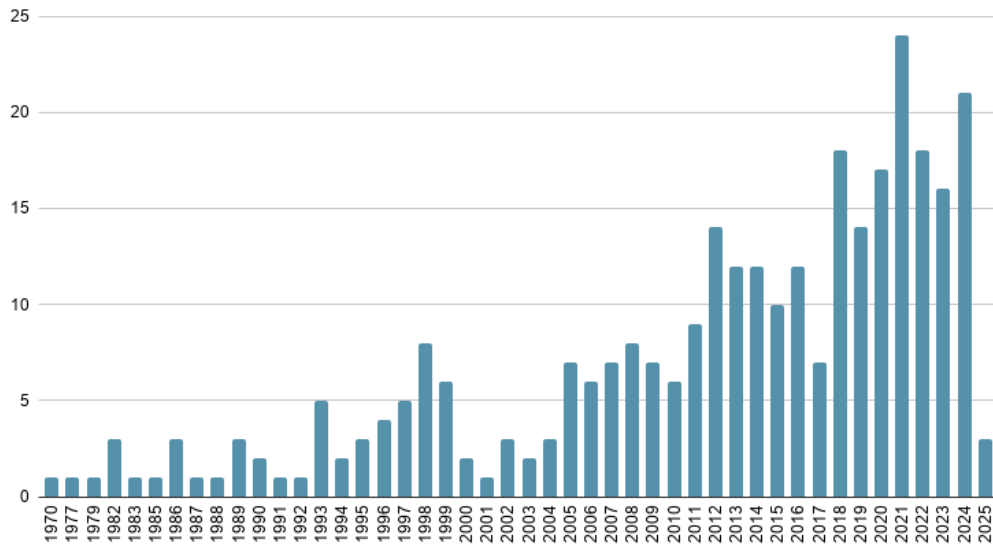


Figure 2. Global distribution of publications by country and continent.

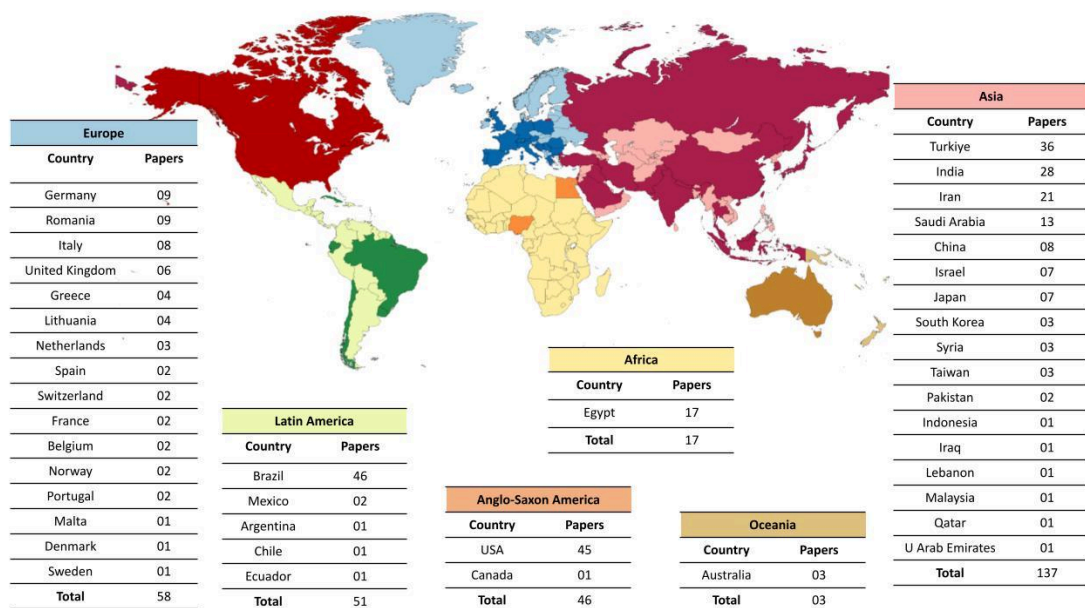


Figure 3. Frequency of authorship (three or more publications) and co-authorship relationship. Circle size reflects the number of publications; color indicates the year of publication; and line thickness represents the strength of co-authorship connections.

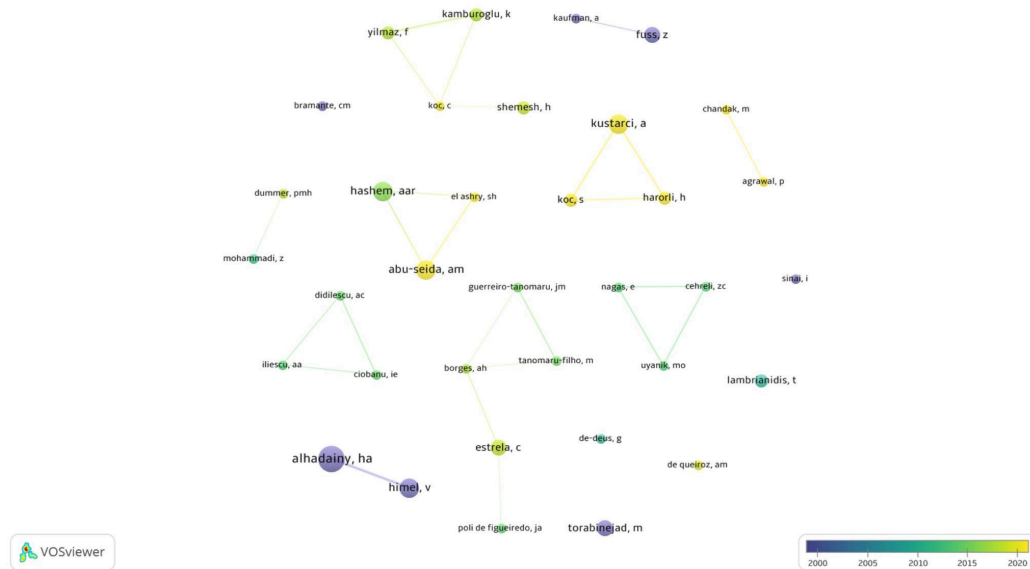
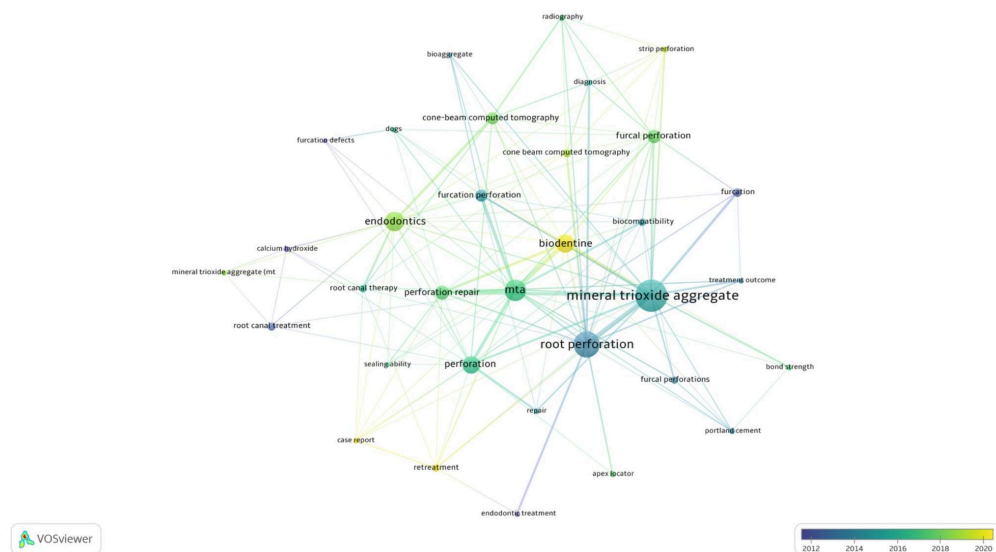


Figure 4. Prevalent keywords (four or more occurrences) and their network. Larger nodes with highlighted font represent terms that appeared most frequently, whereas smaller nodes with smaller labels represent less frequent keywords. Lines connecting the nodes indicate co-occurrence of these terms in the same studies.



Supplementary tables and figures:

Supplementary Table 1. Main journals with the highest number of publications on root perforations in endodontics

Journal Titles	Number of Articles	Impact Factor 2024
Journal of Endodontics	77	3.6
International Endodontic Journal	25	7.1
Oral Surgery Oral Medicine Oral Pathology Oral Radiology	17	1.9
Case Reports in Dentistry	10	0.9
Giornale Italiano Di Endodonzia	08	0.8
ENDO-Endodontic Practice Today	08	0.0

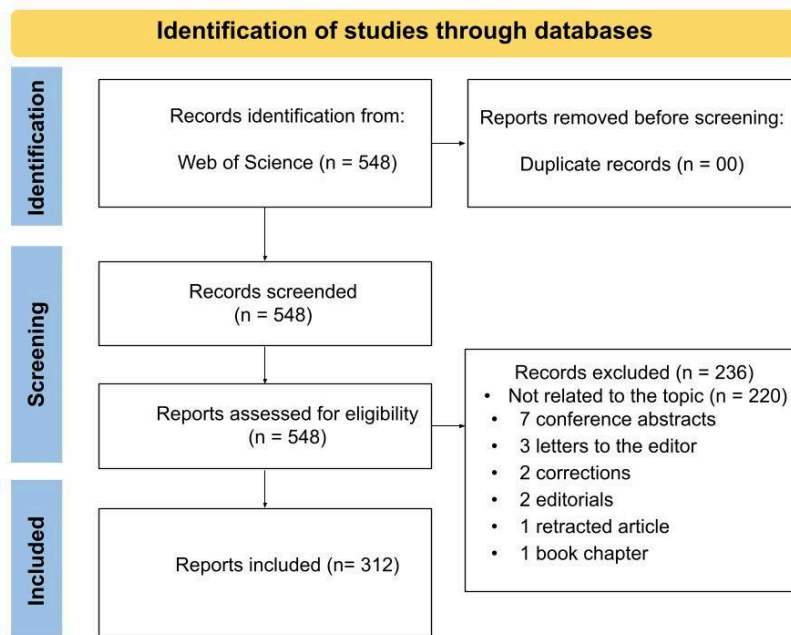
Supplementary Table 2. Leading institutions with the highest number of publications on root perforation in endodontics

Institutions	Countries	Number of Articles
University of São Paulo	Brazil	09
São Paulo State University	Brazil	09
Cairo University	Egypt	07
Tel Aviv University	Israel	07
University of Tennessee System	United States of America	06
Ankara University	Türkiye	06
Akdeniz University	Türkiye	05
Carol Davila University of Medicine and Pharmacy	Romania	05
Hacettepe University	Türkiye	05

Supplementary Table 3. Main authors with the highest number of publications on root perforations in endodontics

Authors	Number of Articles	Number of Citations
Alhadainy HA	08	215
Kustarci A	06	26
Himel V	06	123
Abu-seida AM	06	73
Hashem AAR	06	136
Estrela C	05	97
Fuss Z	05	194
Torabinejad M	05	1711

Supplementary Figure 1. Flowchart of article selection.



4. CONSIDERAÇÕES FINAIS

A produção científica sobre perfuração radicular em endodontia apresentou crescimento progressivo ao longo das últimas décadas, especialmente nos últimos dez anos, com predomínio de estudos laboratoriais voltados à avaliação de materiais seladores, sendo o MTA o material mais investigado e com crescente número de estudos envolvendo diferentes cimentos biocerâmicos. Além disso, nota-se uma concentração das publicações em determinadas regiões e países, tendo o Brasil e suas instituições como destaque. No que se refere à altmetria, apenas parte dos artigos apresentou dados altmétricos, com impacto digital limitado e maior engajamento no gerenciador de referências Mendeley. Apesar dos avanços observados, persistem lacunas na literatura, o que reforça a necessidade de maior representatividade geográfica nas publicações, ensaios clínicos multicêntricos em seres humanos para ampliar as amostras, bem como maior número de estudos voltados à dentição decídua, a fim de fortalecer pesquisas com enfoque clínico e maior distribuição global, aprimorando a aplicação das evidências na prática clínica.

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ANEXOS

ANEXO 1 – ATA DE APRESENTAÇÃO



UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE CIÊNCIAS DA SAÚDE
CURSO DE ODONTOLOGIA
DISCIPLINA DE TRABALHO DE CONCLUSÃO DE CURSO DE ODONTOLOGIA

ATA DE APRESENTAÇÃO DO TRABALHO DE CONCLUSÃO DE CURSO

Aos 06 dias do mês de maio de 2026, às 08:00 horas, em sessão pública no auditório da graduação desta Universidade, na presença da Banca Examinadora presidida pelo Professor Aurélio de Oliveira Rocha e pelos examinadores:

- 1 - Lucas Menezes dos Anjos,
 - 2 - Jarde Dorigon dos Santos,
- a aluna Valentina Schmidt Coufal

apresentou o Trabalho de Conclusão de Curso de Graduação intitulado:

Cenário atual e tendências na pesquisa sobre perfuração radicular em endodontia: uma análise baseada em métricas, como requisito curricular indispensável à aprovação na Disciplina de Defesa do TCC e a integralização do Curso de Graduação em Odontologia. A Banca Examinadora, após reunião em sessão reservada, deliberou e decidiu pela APROVAÇÃO do referido Trabalho de Conclusão do Curso, divulgando o resultado formalmente ao aluno e aos demais presentes, e eu, na qualidade de presidente da Banca, lavrei a presente ata que será assinada por mim, pelos demais componentes da Banca Examinadora e pelo aluno orientando.

Presidente da Banca Examinadora	 Documento assinado digitalmente AURELIO DE OLIVEIRA ROCHA Data: 06/05/2026 10:05:47-0300 CPF: ***.303.844-** Verifique as assinaturas em https://v.ufsc.br
Examinador 1	 Documento assinado digitalmente Lucas Menezes dos Anjos Data: 06/05/2026 11:27:23-0300 CPF: ***.792.005-** Verifique as assinaturas em https://v.ufsc.br
Examinador 2	 Documento assinado digitalmente JARDEL DORIGON DOS SANTOS Data: 08/05/2026 10:22:58-0300 CPF: ***.598.619-** Verifique as assinaturas em https://v.ufsc.br
Aluno	 Documento assinado digitalmente VALENTINA SCHMIDT COUFAL Data: 12/05/2026 12:40:55-0300 CPF: ***.515.129-** Verifique as assinaturas em https://v.ufsc.br

ANEXO 2- NORMAS DA REVISTA

Essential title page information

- *Title*. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
- *Author names and affiliations*. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
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Structured Abstract

A structured abstract, by means of appropriate headings, should provide the context or background for the research and should state its purpose, basic procedures (selection of study subjects or laboratory animals, observational and analytical methods), main findings (giving specific effect sizes and their statistical significance, if possible), and principal conclusions. It should emphasize new and important aspects of the study or observations.

Abstract Headings.

Introduction, Methods, Results, Conclusions.

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly

established in the field may be eligible. These keywords will be used for indexing purposes.

Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

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

Original Research Article Guidelines

Title Page.

The title describes the major emphasis of the paper. It must be as short as possible without loss of clarity. Avoid abbreviations in the title because this may lead to imprecise coding by electronic citation programs such as PubMed (eg, use sodium hypochlorite rather than NaOCl). The author list must conform to published standards on authorship (see authorship criteria in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals at (www.icmje.org)). Include the manuscript title; the names and affiliations of all authors; and the name, affiliation, and full mailing address (including e-mail) of the corresponding author. This author will be responsible for proofreading page proofs and ordering reprints when applicable. Also highlight the contribution of each author in the cover letter.

Abstract.

The Abstract concisely describes the purpose of the study in 250 or fewer words. It must be organized into sections: Introduction, Methods, Results, and Conclusions. The hypothesis is described in the Abstract Introduction. The Abstract describes the new contributions made by this study. The Abstract word limitation and its wide distribution (eg, PubMed) make it challenging to write clearly. This section is written last by many authors. Write the abstract in past tense because the study has been completed. Provide 3-5 keywords.

Introduction.

The introduction briefly reviews the pertinent literature in order to identify the gap in knowledge that the study is intended to address and the limitations of previous studies in the area. Clearly describe the purpose of the study, the tested hypothesis, and its scope. Many successful manuscripts require no more than a few paragraphs to accomplish these goals; therefore, do not perform extensive literature review or discuss the results of the study in this section.

Materials and Methods.

The Materials and Methods section is intended to permit other investigators to repeat your experiments. There are 4 components to this section: (1) detailed description of the materials used and their components, (2) experimental design, (3) procedures employed, and (4) statistical tests used to analyze the results. Most manuscripts should cite prior studies that used similar methods and succinctly describe the essential aspects used in the present study. A “methods figure” will be rejected unless the procedure is novel and requires an illustration for comprehension. If the method is novel, then you must carefully describe the method and include validation experiments. If the study used a commercial product, the manuscript must either state that you followed manufacturer’s protocol or specify any changes made to the protocol. If the study used an in vitro model to simulate a clinical outcome, describe either experiments made to validate the model or previous literature that proved the clinical relevance of the model. The statistical analysis section must describe which tests were used to analyze which dependent measures; P values must be specified. Additional details may include randomization scheme, stratification (if any), power analysis as a basis for sample size computation, dropouts from clinical trials, the effects of important confounding variables, and bivariate versus multivariate analysis.

Results.

Only experimental results are appropriate in this section; do not include methods, discussion, or conclusions. Include only those data that are critical for the study, as defined by the aim(s). Do not include all available data without justification; any repetitive findings will be rejected from publication. All Figures, Charts, and Tables must be cited in the text in numerical order and include a brief description of the major findings. Consider using Supplemental Figures, Tables, or Video clips that will be published online. Supplemental material often is used to provide additional information or control experiments that support the results section (eg, microarray data).

Figures.

There are 2 general types of figures: type 1 includes photographs, radiographs, or micrographs; type 2 includes graphs. Type 1: Include only essential figures and use composite figures containing several panels of photographs, if possible. Each panel must be clearly identified with a letter (eg, A, B, C), and the parts must be defined in the figure legend. A figure that contains many panels counts as 1 figure. Type 2: Graphs (ie, line drawings including bar graphs) that plot a dependent measure (on the Y axis) as a function of an independent measure (usually plotted on the X axis). One example is a graph depicting pain scores over time. Use graphs when the overall trend of the results is more important than the exact numeric values of the results. A graph is a convenient way to report that an ibuprofentreated group reported less pain than a placebo-treated group over the first 24 hours, but pain reported was the same for both groups over the next 96 hours. In this case, the trend of the results

is the primary finding; the actual pain scores are not as critical as the relative differences between the NSAID and placebo groups.

Tables.

Tables are appropriate when it is critical to present exact numeric values; however, not all results need be placed in either a table or figure. Instead of a simple table, the results could state that there was no inhibition of growth from 0.001%-0.03% NaOCl, and a 100% inhibition of growth from 0.03%-3% NaOCl (N55/group). If the results are not significant, then it is probably not necessary to include the results in either a table or as a figure.

Acknowledgments.

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