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Microfiltración corono apical de *Enterococcus faecalis* en dientes endodonciados

Corono-apical microfiltration of Enterococcus faecalis in endodontic teeth

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Palabras claves:
E. faecalis, conductos radiculares, reinfección endodóntica, técnicas de obturación

Resumen

Introducción. El uso de agentes antimicrobianos y la aplicación de una buena técnica en la obturación del sistema de conductos son fundamentales para el éxito en los tratamientos endodónticos, ya que previenen el ingreso, proliferación y migración de las bacterias desde el interior de los conductos hasta los tejidos periapicales. **Objetivo.** La presente revisión bibliográfica tiene como objetivo analizar la microfiltración corono apical de *Enterococcus faecalis* en dientes endodonciados, así como, determinar su prevalencia en el sistema conductos radiculares con tratamiento endodóntico, además de, identificar materiales y técnicas utilizadas en endodoncia y, por último, describir las causas del fracaso endodóntico. **Metodología.** Se realizó una búsqueda exhaustiva en las bases de datos Science Direct, PubMed y Scopus, seleccionando 57 artículos científicos entre ellos experimentales, descriptivos y observacionales publicados desde el 2013 a 2023. **Resultados.** La mayoría de los autores destacan a *E. faecalis* como el principal microorganismo prevalente en dientes con fracaso endodóntico, debido a su capacidad de sintetizar proteínas que le permiten sobrevivir en condiciones adversas dentro de los túbulos dentinarios, sin embargo, recientes resultados de los estudios experimentales in vitro integran a *Propionibacterium, Actinomyces*. **Conclusión.** Se concluye que, una buena preparación químico-mecánica de los conductos radiculares, utilizando NaClO al 5,25% con EDTA al 17%, más la aplicación de la técnica de obturación termoplastificada, la cual proporciona un completo sellado en la porción apical, y finalmente realizando una restauración temporal con excelente adaptación marginal, anticipan un 90% del éxito en el tratamiento endodóntico. **Área de estudio general:** Odontología. **Área de estudio específica:** Endodoncia. **Tipo de estudio:** Artículos originales.

Keywords:
E. faecalis, root canals, endodontic reinfection, obturation techniques.

Abstract

Introduction. The use of antimicrobial agents and the application of a good technique in the obturation of the canal system are fundamental for the success of endodontic treatments since they prevent the entry, proliferation, and migration of bacteria from inside the canals to the periapical tissues. objective. This

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literature review aimed to analyze the coronoapical microleakage of Enterococcus faecalis in endodontically treated teeth. as well as to determine the prevalence of E. faecalis in the root canal system with endodontic treatment, to identify materials and techniques used in endodontics and, finally, to describe the causes of endodontic failure. Methodology. A comprehensive search was performed in Science Direct, PubMed, and Scopus databases, selecting 57 scientific articles among experimental, descriptive, and observational published between 2013 and 2023, according to the PRISMA 2020 protocol. Results. Most authors highlight E. faecalis as the main microorganism prevalent in teeth with endodontic failure due to its ability to synthesize proteins that allow it to survive in adverse conditions within the dentinal tubules; However, recent results of in vitro experimental studies integrate Propionibacterium, Actinomyces. Conclusion. It is concluded that a good chemical-mechanical preparation of root canals, using NaClO at 5.25% with EDTA at 17%, plus the application of the thermoplastic obturation technique, which provides a complete seal in the apical portion, and finally performing a provisional restoration with excellent marginal adaptation, anticipates a 90% success rate in endodontic treatment.

Introduction

Corona-apical microleakage in root canals of endodontically treated teeth shows a predominance of bacteria of the genus Enterococcus faecalis, facultative anaerobes that are naturally part of the oral bacterial flora and the gastrointestinal tract, which based on several studies have been classified as potential pathogens in humans, as they cause 12% of nosocomial infections such as: urinary tract, infectious endocarditis, intra-abdominal infections; it is argued that this is due to its ability to survive in arid environments, as it is detected in water, food, plants, animals such as birds and insects. (1)

Current studies carried out with the aid of electron microscopy, complemented with histochemical analysis, sampling and cultures have confirmed the prevalence of Enterococcus faecalis at 32% and discovered new bacterial species in periapical tissues of cases that report failure to conventional endodontic treatment. Canalda & Brau (2), confirm the findings ofRuksakietet al. (3), where they recognized the genus Actinomyces

with a predominance of 31.8%, followed by Propionibacterium 22.7%, Streptococcus 18.2% and finally the presence of Staphylococcus with 13.6%.

Over the years, the importance of performing a hermetic seal in the root canal system to prevent the multiplication and proliferation of bacteria has led to the creation and development of new materials and methods of endodontic obturation. Likewise, Cedeño et al. (4) in their study highlight that the anatomy of the canals is varied and complex, for this reason, standard disinfection protocols, especially with irrigants, greatly reduce the amount of bacteria in the root canal system.

Several in vitro clinical trials that have been carried out in Ecuador maintain that apical microleakage of E. faecalis occurs in 60% of cases as a result of inadequate obturation, however, there are few studies carried out in the country through which the extracted data can be analyzed, compared and corroborated. (5)

Recent research worldwide shows that 70% of failures in root canal treatments are caused by Enterococcus faecalis, a microorganism with a great capacity to invade dentinal tubules and survive in low-nutritional media.(6)(7) From this perspective, in 2017 Cancio et al.(8) performed an in vivo experiment, where root canal samples were obtained from teeth in which endodontic treatment failed and through the application of molecular techniques (PCR), E. faecalis was observed with a predominance of 77%.

Finally, the purpose is to analyze the corona-apical microleakage of E. faecalis in endodontically treated teeth, as well as to determine the prevalence of Enterococcus faecalis in the root canal system with endodontic treatment, in addition to identifying materials and techniques used in endodontics and, finally, to describe the causes of endodontic failure.

Methodology

A review was conducted using the PICO question: What is the relationship of corona-apical microleakage of Enterococcus faecalis in endodontically treated teeth? The components of this PICO question included: “P” (population); Microleakage, “I” (intervention); in endodontically treated teeth, “C” (comparison); Enterococcus faecalis, “O” (outcomes); relationship of corona-apical microleakage of E. faecalis in endodontically treated teeth. (9)

For the literature search, the words coronal microleak, apical microleak, Enterococcus faecalis, microleak in endodontics, endodontic techniques, endodontic failure were used, which were combined with Boolean operators "AND, OR, NOT" for a primary search of scientific articles in scientific databases (Table 1).

Table 1. Search equation used

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PubMed	Science Direct	Scopus
(("apical microleakage") OR ("coronal microleakage")) AND (("Enterococcus faecalis microleakage") OR ("endodontic microleakage") OR ("apical crown leakage")) AND (("endodontic techniques") OR ("endodontic failures"))	(("apical microleakage") OR ("coronal microleakage")) AND (("Enterococcus faecalis microleakage") OR ("endodontic microleakage") OR ("apical crown leakage")) AND (("endodontic techniques") OR ("endodontic failures")) AND NOT (resin leaks))	((“apical microleakage”) OR (“coronal microleakage”) AND ((“Enterococcus faecalis microleakage”) OR (“endodontic microleakage”) OR (“apical crown leakage”)) AND ((“endodontic techniques”) OR (“ endodontic failures”))

By corroborating the SJR (SCImago Journal Rank) and ACC (Average Citation Count) values of the scientific articles used, the impact factor of the journals where they have been published was identified, because it organizes them into 4 quartiles (Q), for this, quartile 1 (Q1) symbolizes the highest and most important impact factor and quartile 4 (Q4) the one with the lowest impact, but with great literary relevance. At the same time, the ACC reveals the average citation count of each scientific study and the year in which they have been announced, the ACC marks the amount that an article has been cited by other authors. Therefore, if an article has a greater number of citations by several authors, it acquires academic relevance; All these values certify the excellence in the literature with which the research work was prepared.

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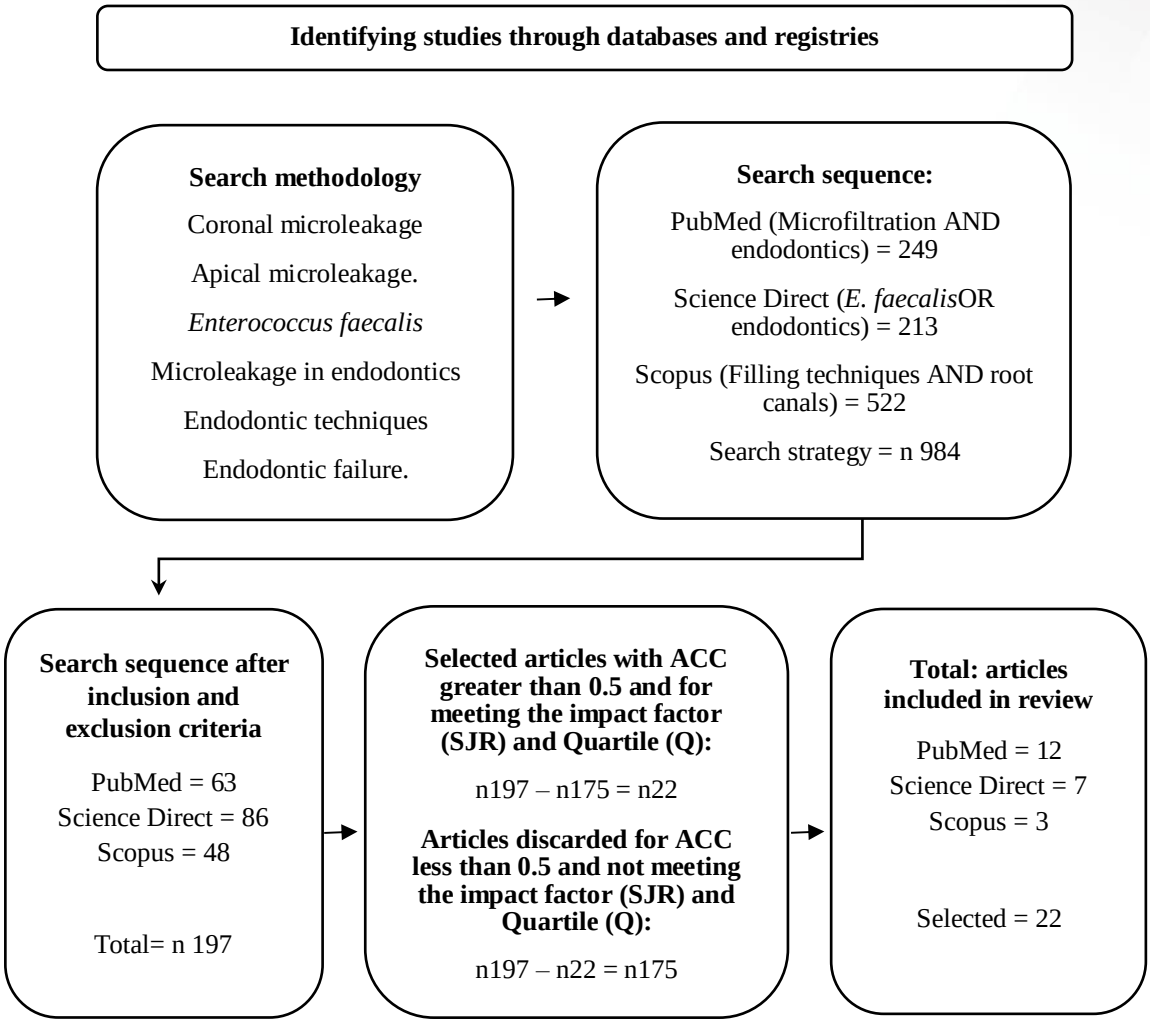

Figure 1. Flowchart

Once all the selection criteria were considered and after the first review, the 197 studies were compressed into a total of 22 scientific articles to carry out this study. Articles were selected without language restrictions and with a filter from the last 5 years; a descriptive, non-experimental research is proposed.

Results

Coronal-apical microleakage of E. faecalis in endodontically treated teeth

Bacteria and their byproducts are the main etiological factors of pulpal and periapical diseases. The stationary phase of bacterial growth is known to be among the mechanisms of resistance of bacterial biofilms to antimicrobials, although the starvation phase, induced by nutrient depletion, could be even more resistant to treatment.(10) Interest in the microbial composition and frequency of various microorganisms in endodontic

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infection has focused in recent decades on anaerobic bacteria due to their predominance in untreated teeth with necrotic pulps. Studies have shown that the periodontal microbiota can vary markedly in frequency and proportions in populations with different ethnic backgrounds. Geographical differences in the detection of bacteria in endodontic infections have also been observed.(11)

*E. faecalis*It is the species most frequently isolated and sometimes the only one found in root canals, however, the involvement of this species in the pathogenesis of endodontic infection is still not fully understood. Recent research indicates that E. faecalis in previously endodontically treated canals is probably of exogenous origin. A more likely explanation is that the normal microflora in a healthy individual prevents opportunistic enterococci from colonizing the oral cavity by competing for substrate and binding sites, as well as for the production of bacteriocins and hydrogen peroxide. (12)

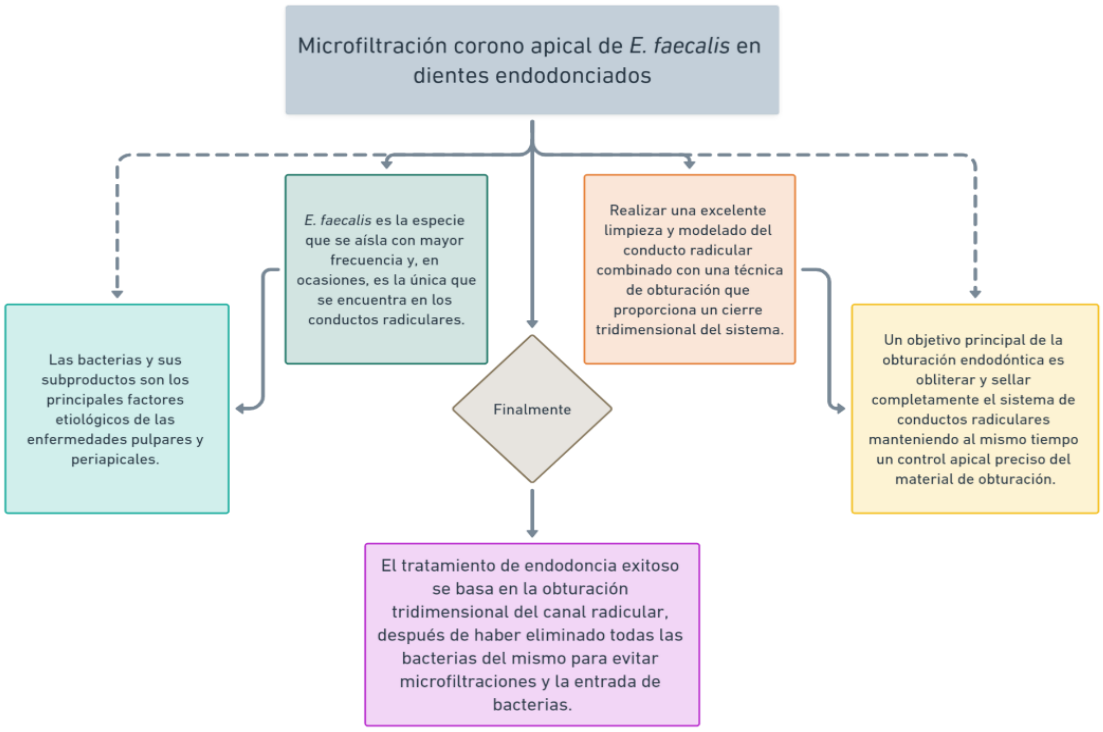

Figure 2. Apical coronal microleakage in endodontically treated teeth caused by E. faecalis

Prevalence of E. faecalis in endodontically treated root canal systems.

Enterococci are gram-positive cocci that can occur singly, in pairs, or in short chains. They are facultative anaerobes and have the ability to grow in the presence or absence of oxygen. Of the Enterococcus species, E. faecalis is the most frequently detected in oral infections. In addition, it is associated with different forms of periradicular disease and is

more likely to be found in cases of persistent infections than in primary endodontic infections.(13)

*E. faecalis*It is a prevalent microorganism in persistent endodontic infection and the most commonly used microorganism to determine the antibacterial efficacy of treatment agents or regenerative endodontic procedures. In addition, it has the ability to form a biofilm and invade dentinal tubules.(14)Penetration into dentinal tubules is the most important resistance mechanism of E. faecalis against antibacterial agents in endodontics.(15)

A single treated root canal with persistent infection may harbor a similar amount of bacteria as untreated root canals with primary infection; however, microbial diversity decreases after treatment in persistent infection. Conditions in untreated necrotic root canals favor Gram-negative anaerobic bacteria, and there is evidence that only one to three species, mainly Gram-positive cocci or rods, can be isolated from failed endodontic treatments.(16)

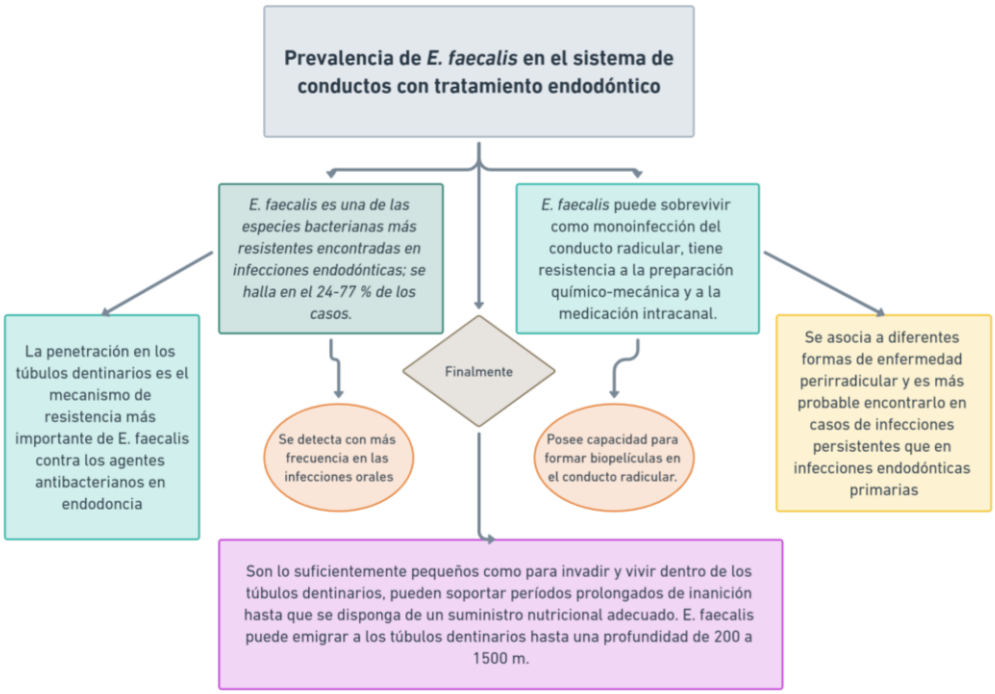

Figure 3. Prevalence of Enterococcus faecalis

Causes of endodontic failure

Root canal treatment failure can be attributed to several factors, but microleakage through the root canal system is one of the main ones.Milani et al.[17]It is believed that most failed cases of root canal treatment are due to leakage of fluid from inflamed areas and periapical tissue into improperly filled canals. Poor filling quality, over- and under-extension of the root canal filling, and leakage between the materials and the dentin surface of the root canal or within the filling materials are often the main causes of failure in root canal treatments.[18]

The success of endodontic treatment depends primarily on the effective removal of bacteria and their byproducts from the root canal system. Anatomical complexity such as isthmuses, lateral canals, and dentinal tubules may represent an obstacle to achieving this goal. In this context, bacteria remaining in the root canal at the time of root filling cause persistent infection and treatment failure, so to achieve adequate disinfection, mechanical instrumentation must be supplemented with chemical irrigation methods. Effective root canal disinfection is crucial for the success of regenerative endodontics because infection can interfere with stem cell activity and regeneration as well as the repair process. (19)

Lack of adhesion of gutta-percha to the filling material and adequate sealing of the apical canal are responsible for almost 60% of root canal failures.[20]In this sense, the study by Samson et al.[21]on endodontic success and failure suggests that apical percolation of periradicular exudates into incompletely filled canals is the main cause of endodontic failures. It would seem safe to assume that noxious products leaking from the apical foramen act as inflammatory irritants.

Bhandiet al.[22]They followed teeth with endodontic treatment for 5 years and concluded that 63% of the failures of such treatments are due to coronal microleakage, defined as the passage of liquids and bacteria through the temporary restoration material and the dentin wall. As one of the main etiological agents of human dental caries, the virulence of S. mutans as a dental pathogen resides mainly in its capacity to cause infections.[23]

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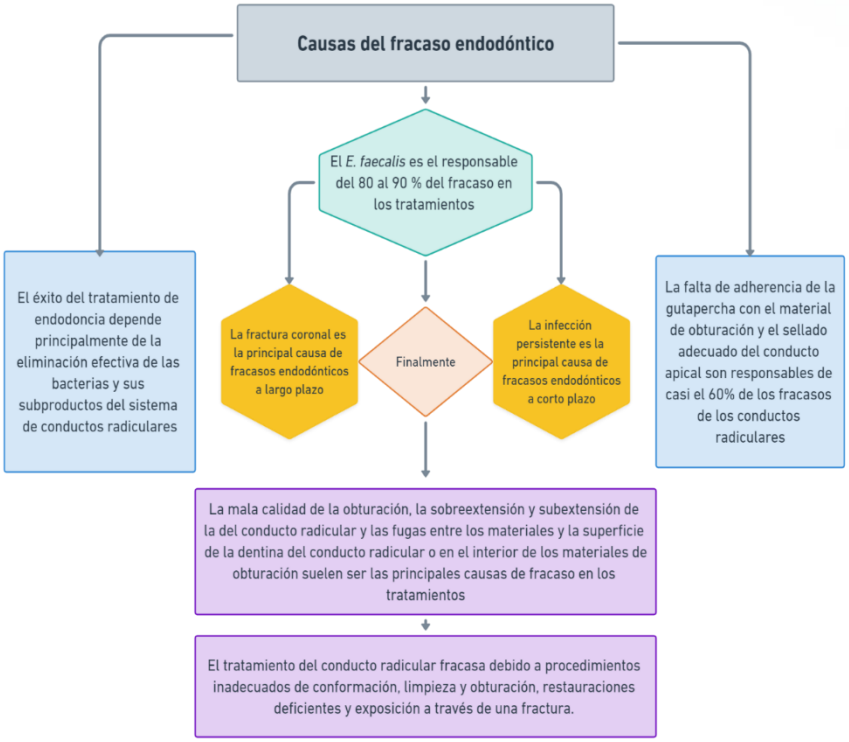

Figure 4. Causes of endodontic failure

Discussion

Control of coronal-apical microleakage of E. faecalis in endodontically treated teeth represents a challenge for most endodontic procedures, since it requires appropriate cleaning and modeling of the root canal, in addition to a filling technique that facilitates a three-dimensional sealing of the canals, and thus reduces the formation of spaces that generate communication with the external environment and consequently cause reinfection. From this deduction, the authors[(1)(11) (14)(15)]They agree that performing a correct obturation technique will greatly reduce the filtration of persistent microorganisms that remain in the dentinal tubules or in the complex morphology of the root canal.

On the other hand, according to the studies[(4)(8)(18)(19)]Currently there are several methods to verify the microfiltration of bacteria, to mention a few: infiltration of dyes and fluids, measurement bystereomicroscope, isotope markers, computed tomography (CBCT), bacterial filtration, the latter being the most widely used technique.conservative, effective, providing a high level of precision, while the radiographic method shows a low degree of reliability.

Coronal apical microleakage in endodontically treated teeth is caused in 90% of cases by the invasion of Enterococcus faecalis in the root canals, however, there are several strains

that can survive the endodontic procedure such as Actinomyces, Propionibacterium, Streptococcus and Staphylococcus. Based on this premise, the authors[6][8][17][20]They confirm that E. faecalis, an opportunistic anaerobic pathogen, has the ability to survive in environments with scarce nutrients and a high alkaline pH and, as interesting characteristics, it presents a high resistance to antimicrobial agents, which makes it a pathogen resistant to root canal treatment.

In disagreement, the authors[4][11][16]They emphasize that E. faecalis is not a habitual colonizer of the oral cavity, since it is mainly found in the human intestine, thus the question of how this pathogen manages to intervene in root canal infections arises. In accordance with the above, several studies[2][13][14][23]They state that E. faecalis has not been shown to be involved in periapical lesions when compared with teeth with root canal treatment without lesions, and they also argue that, despite being present, it is not the most dominant species in retreatment cases.

The purpose of endodontic materials is to serve as a barrier to prevent communication of the periapical area with the outside environment and to eliminate any microorganisms within the root canal. However, multiple authors[6][11][22]They argue that with the materials and methods currently used in endodontics it is not feasible to achieve a complete and permanent sealing of the root canal system. In agreement with this, in vitro and animal studies[4][7][10][12]They show that no material meets the requirements for proper sealing of the duct system.

An ideal endodontic sealant should present antimicrobial properties as well as produce a hermetic seal of the root canals, various authors[3][11][20]They state that calcium silicate-based materials have superior sealing capabilities to others. In disagreement, the authors[4][6][14][22]14 investigated that a bioceramic sealant provides a complete coronal seal in endodontically treated teeth, compared to other materials examined in endodontics.

In this perspective, the authors point out that the Thermafil obturation technique produces a superior apical seal when compared to the lateral condensation method and Obtura II. Likewise, the authors[3][12][18][19][21]agree based on in vitro experiments that the lateral condensation technique lacks replication of the complex morphology of root canals and their homogeneity. However, some authors[11][17][22]They disagree because based on their studies, the lateral condensation technique is the most widely used method due to its long-term advantages, ease of use, predictability, and mastery in material placement.

Conventional irrigation and disinfection techniques of the root canal system have been able to eliminate 90% of bacteria. Based on this premise, the authors[7][19][20][21][22]They agree that irrigants with their antibacterial capacity help to eradicate microorganisms and consider that 5.25% sodium hypochlorite and 2% chlorhexidine are highly effective.

However, in vitro studies[1][3][19][23]Using five irrigating solutions, they claim that the most potent agents are 5% NaOCl and 17% EDTA. In support of this claim, the authors[2][4][13][18]They found that irrigation with sodium hypochlorite in combination with the ethylenediaminetetraacetic acid17% present less coronal microleakage after obturation.

The main cause of endodontic failure is the presence of microorganisms, which are capable of causing extraradicular and intraradicular reinfection. Based on this, the authors[3][5][12][17]They agree that the main pathogen causing contamination of treated root canals is Enterococcus faecalis due to its ability to form biofilms resistant to endodontic irrigants and intracanal medications.

An inadequate obturation technique, underextension and overextension of the root canal, as well as leakage between the filling material and the dentin wall of the root canals, are causes of endodontic retreatment. The authors[4][5][13][18][20]Accordingly, they point out that complete disinfection of the root canal system and proper application of endodontic sealants are crucial to avoid failure in endodontic therapy.

Conclusions

- *E. faecalis*Opportunistic pathogen is prevalent in root canals due to its potent virulence factors. Thermoplastic obturation technique presents effective results in preventing microleakage compared to other endodontic techniques. Finally, the findings affirm that the two main reasons are given by an incomplete obturation of the root canal system and corona-apical microleakage of Enterococcus faecalis.

Conflict of interest

The authors declare that there is no conflict of interest in relation to the submitted article.

Authors' contribution statement

All authors contributed to writing, reviewing, and editing the research. Lead author who developed the research: CVA, Collaboration in reviewing and verifying results: MLV and VGH, development of the manuscript: CVA and MLV. All authors have read and agree with this version of the manuscript.

Bibliographic References

1. Prada I, Micó-Muñoz P, Giner-Lluesma T, Micó-Martínez P, Collado-Castellano N, Manzano-Saiz A. Influence of microbiology on endodontic failure. Literature review. Med Oral Pathol Oral and Cir Bucal. 2019;24(3): e364–72.Available from: https://pubmed.ncbi.nlm.nih.gov/31041915/

2. Canalda Sahli C, Brau Aguadé E. Endodontics: clinical techniques and scientific bases Aguagé. Spain-Elsevier 2019.

3. Ruksakiet K, Hanák L, Farkas N, Hegyi P, Sadaeng W, Czumbel LM. Antimicrobial Efficacy of Chlorhexidine and Sodium Hypochlorite in Root Canal Disinfection: A Systematic Review and Meta-analysis of Randomized Controlled Trials. J Endod. 2020;46(8):1032-1041.e7. Available from: https://www.sciencedirect.com/science/article/pii/S0099239920303083

4. Cedeño Delgado MJ, Pinos Robalino PJ, Segovia Palma PI. Root canal system obturation. A review of the literature. 2020 Jan 31;4(1):253–66.

5. Arellano DL.In vitro comparison of coronal-apical microleakage of Enterococcus faecalis with three different obturation techniques: lateral, vertical and stem, in single-rooted premolars [Doctoral thesis; PDF]. [Quito]: USFQ; 2017 December.23p.

6. Alfadda S, Alquria T, Karaismailoglu E, Aksel H, Azim AA. Antibacterial Effect and Bioactivity of Innovative and Currently Used Intracanal Medications in Regenerative Endodontics. J Endod. 2021 Aug 1;47(8):1294–300. Available from: https://pubmed.ncbi.nlm.nih.gov/34033820/

7. Kelmendi T, Koçani F, Kurti A, Kamberi B, Kamberi A. Comparison of Sealing Abilities Among Zinc Oxide Eugenol Root-Canal Filling Cement, Antibacterial Bioceramic Paste, and Epoxy Resin, using Enterococcus faecalis as a Microbial Tracer. Med Sci Monit Basic Res. 2022;28: e936319. Available from: https://pubmed.ncbi.nlm.nih.gov/35771490/

8. Cancio V, Carvalho Ferreira D de, Cavalcante FS, Rosado AS, Teixeira LM, Braga Oliveira Q. Can the Enterococcus faecalis identified in the root canals of primary teeth be a cause of failure of endodontic treatment? Acta Odontol Scand. 2017;75(6):423–8. Available from: https://pubmed.ncbi.nlm.nih.gov/28580816/

9. Page MJ, Mckenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 statement: an updated guideline for the publication of systematic reviews E. Revista Española de Cardiología. 2021;74(9):790–9. Available from: https://www.revespcardiol.org/es-declaracion-prisma-2020-una-guia-articulo-S0300893221002748

10. An HJ, Yoon H, Jung HI, Hoon D. Comparison of Obturation Quality after MTA Orthograde Filling with Various Obturation Techniques. J Clin Med. 2021. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8074131/

11. Vula V, Stavileci M, Ajeti N, Vula V, Kuçi A, Meqa K. Evaluation of Apical Leakage After Root Canal Obturation with Glass Ionomer, Resin, and Zinc Oxide Eugenol Sealers Combined with Thermafil. Med Sci Monit Basic Res. 2022 Jun 15;28: e936675. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9208302/

12. Saatchi M, Shokraneh A, Navaei H, Maracy MR, Shojaei H. Antibacterial effect of calcium hydroxide combined with chlorhexidine on Enterococcus faecalis a systematic review and meta-analysis. J Appl Oral Sci. 2021;22(5):356–65. Available from: https://pubmed.ncbi.nlm.nih.gov/25466470/

13. Manoj Kumar Pulyodan, Sunil Paramel Mohan, Dhanya Valsan, 1 Namitha Divakar, Shabna Moyin and ST. Regenerating A Monoblock to Obturate Root Canalsvia a Mineralising Strategy. Natl Libr Med. 2020;1–10. Available from: https://pubmed.ncbi.nlm.nih.gov/30190589/

14. Reiznautt CM, Ribeiro JS, Kreps E, Lo W, Lacerda H De, Peralta SL, et al. Development and Properties of Endodontic Resin Sealers with Natural Oils. J Dent. 2021; 104:1–7. Available from: https://pubmed.ncbi.nlm.nih.gov/33248212/

15. Kitagawa H, Kitagawa R, Tsuboi R, Hirose N, Thongthai P, Sakai H, et al. Development of endodontic sealers containing antimicrobial-loaded polymer particles with long-term antibacterial effects. Dent Mater. 2021;37(8):1248–59. Available from: https://pubmed.ncbi.nlm.nih.gov/33972098/

16. Combrinck R. Modulation of Virulence in Enterococcus faecalis Cells Surviving Antimicrobial Photodynamic Inactivation with Reduced Graphene Oxide-Curcumin: An Ex Vivo Biofilm Model. Photodiagnosis Photodyn Ther. 2022; Available from: https://pubmed.ncbi.nlm.nih.gov/31899382/

17. Milani A, Firuzi S, Barhaghi M, Shahi S, Abdollahi A. Evaluation of Sealing Ability of Mineral Trioxide Aggregate Mixed with Propylene Glycol as A Root Canal Sealer: A In Vitro Study. J Dent Res [Internet]. 2019; Available from: https://pubmed.ncbi.nlm.nih.gov/31303874/

18. Amanda P, Ivo da P, Carlos J, Rodrigues A, Ricardo M, Gomes B. Pathogenic Potential of Enterococcus faecalis Strains Isolated from Root Canals After Unsuccessful Endodontic Treatment. Clin Oral Investigative. 2021; Available from: https://pubmed.ncbi.nlm.nih.gov/33559751/

19. Augusto R. Lima, Tridib Ganguly, Alejandro R. Walker, Natalia Acosta PA, Francisco1, Roberta Pileggi, José A. Lemos BPFAG, Jacqueline, Abranches.

Phenotypic And Genotypic Characterization of Streptococcus Mutans Strains Isolated from Endodontic Infections. J Endod. 2020;98104. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7686129/

20. Ghorbanzadeh R, Assadian H, Chiniforush N, Parker S, Pourakbari B, Ehsani B, Modulation of virulence in Enterococcus faecalis cells surviving antimicrobial photodynamic inactivation with reduced graphene oxide-curcumin: An ex vivo biofilm model. Photodiagnosis Photodyn Ther. 2020 Mar 1;29. Available from: https://pubmed.ncbi.nlm.nih.gov/31899382/

21. Samson E, Kulkarni S, C SK, Likhitkar M. An In-Vitro Evaluation and Comparison of Apical Sealing Ability of Three Different Obturation Technique - Lateral Condensation, Obtura II, and Thermafil. J Endod. 2013;5(2):35–43.

22. Bhandi S, Mashyakhy M, Abumelha AS, Alkahtany MF, Jamal M, Chohán H. Complete Obturation—Cold Lateral Condensation Vs. Thermoplastic Techniques: A Systematic Review of Micro-Ct Studies. J Funct Biomater. 2021;1–15. Available from: https://pubmed.ncbi.nlm.nih.gov/34300930/

23. Kooanantkul C, Shelton RM, Camilleri J. Comparison of obturation quality innatural and replica teeth root-filled using different sealers and techniques. Clin Oral Investigative. 2023;27(5):2407–17. Available from: https://pubmed.ncbi.nlm.nih.gov/36738319/

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