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Mineral Trioxide Aggregate (MTA) on Pulp Capping: Scientific Analysis of the Last 5 Years

Agregado Trióxido Mineral (MTA) no Capeamento Pulpar: Análise Científica dos Últimos 5 Anos

Agregado de Trióxido Mineral (MTA) en recubrimiento pulpar: Análisis Científico de Los Últimos 5 años

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Oliver Renê Viana de Jesus
Undergraduate Dentistry Student
Institution: Maurício de Nassau University Center/Uninassau
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0001-4129-2367
E-mail: vianawork@hotmail.com

Bárbara Sttephanny Silveira Santos
Undergraduate Dentistry Student
Institution: Tiradentes University/Unit
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0004-0108-3271
E-mail: babisttephanny@gmail.com

Stephanie Cardoso Costa
Undergraduate Dentistry Student
Institution: Maurício de Nassau University Center/Uninassau
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0001-5787-3182
E-mail: stephaniecardosoc@hotmail.com

Anna Karolliny Costa Bertoldi
Undergraduate Dentistry Student
Institution: Tiradentes University/Unit
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0000-4001-4536
E-mail: karollbertoldi@gmail.com

Walter Bertoldi Neto
Undergraduate Dentistry Student
Institution: Tiradentes University/Unit
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0006-2685-9464
E-mail: walterbertoldi737@gmail.com

Guilherme Santos da Silva
Undergraduate Dentistry Student
Institution: Maurício de Nassau University Center/Uninassau
Address: Pedrinhas – Sergipe, Brazil
Orcid ID: 0009-0005-4648-8720
E-mail: guilhermendes1001@gmail.com

Hugo Michael Celestino da Silva
Undergraduate Dentistry Student
Institution: Maurício de Nassau University Center/Uninassau
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0002-7024-509X
E-mail: hugomichael073@gmail.com

Cecília Bezerra de Meneses Corbal Guerra
Master's student in Dentistry
Institution: Federal University of Sergipe/UFS
Address: Aracaju – Sergipe, Brazil
Orcid ID: 0009-0008-9105-6697
E-mail: ce.guerra92@hotmail.com

Erik Vinícius Barros Guedes
Master's student in Dentistry
Institution: University of São Paulo/USP
Address: Aracaju – Sergipe, Brazil
Orcid ID:0000-0001-8052-6261
E-mail: erikbarros@usp.br

ABSTRACT

Direct pulp capping treatment is a conservative treatment based on placing a biologically active material in contact with the exposed pulp, resulting in the development of a hard dentin bridge thus preserving pulp vitality. Most dentists considered that there was a low probability of successful pulp capping due to contamination of the pulp tissue. Over time, the procedure has shown a high clinical success rate in patients who meet the criteria for this treatment. This study aims to provide an integrative analysis of numerous articles published regarding pulp capping with Mineral Trioxide Aggregate. The positive aspects of this material on pulp protection is the priority of this study. To sustain an integrative literature review, 64 bibliographic articles published in English and Portuguese from PubMed, ScienceDirect, Journal of Endodontics, Science Direct, Wiley Online Library, Google Scholar and Elsevier were filtered. After the final review, only 22 studies were included due to compatibility with the objective proposed in the study. The studies reviewed indicate the outstanding potential of MTA and increase new studies to keep documenting its effectiveness. It's possible to affirm that contemporary endodontic analyses support and approve using MTA as a capping element.

Keywords: Dental Pulp Capping, Endodontics, Regenerative Endodontics.

RESUMO

O tratamento de capeamento pulpar direto é um tratamento conservador baseado na aplicação de um material biologicamente ativo em contato com a polpa exposta, resultando no desenvolvimento de uma ponte de dentina dura, preservando assim a vitalidade pulpar. Alguns dentistas consideraram que havia uma baixa probabilidade de sucesso do capeamento pulpar devido à contaminação do tecido pulpar. Com o tempo, o procedimento tem apresentado alto índice de sucesso clínico em pacientes que atendem aos critérios para esse tratamento. Este estudo tem como objetivo fornecer uma análise integrativa de numerosos artigos publicados sobre capeamento pulpar com Agregado Trióxido

Mineral. Os aspectos positivos deste material na proteção pulpar são a prioridade deste estudo. Para sustentar uma revisão integrativa da literatura, foram filtrados 64 artigos bibliográficos publicados em inglês e português provenientes das bases de dados PubMed, ScienceDirect, Journal of Endodontics, Science Direct, Wiley Online Library, Google Scholar e Elsevier. Após a revisão final, apenas 22 estudos foram incluídos por compatibilidade com o objetivo proposto no estudo. Os estudos revisados indicam o excelente potencial do MTA e incentivam novas análises para continuar documentando sua eficácia. É possível afirmar que as análises endodônticas contemporâneas apoiam e aprovam o uso do MTA como elemento de capeamento.

Palavras-chave: Capeamento da Polpa Dentária, Endodontia, Endodontia Regenerativa.

RESUMEN

El tratamiento de recubrimiento pulpar directo es un tratamiento conservador basado en la aplicación de un material biológicamente activo en contacto con la pulpa expuesta, dando como resultado el desarrollo de un puente dentinario duro, preservando así la vitalidad pulpar. Algunos dentistas consideraron que había una baja probabilidad de éxito en el recubrimiento pulpar debido a la contaminación del tejido pulpar. Con el tiempo, el procedimiento ha mostrado una alta tasa de éxito clínico en pacientes que cumplen los criterios para este tratamiento. Este estudio tiene como objetivo proporcionar un análisis integrador de numerosos artículos publicados sobre el recubrimiento pulpar con Agregado de Trióxido Mineral. Los aspectos positivos de este material en la protección pulpar son la prioridad de este estudio. Para respaldar una revisión integradora de la literatura, se filtraron 64 artículos bibliográficos publicados en inglés y portugués de las bases de datos PubMed, ScienceDirect, Journal of Endodontics, Science Direct, Wiley Online Library, Google Scholar y Elsevier. Tras la revisión final, sólo se incluyeron 22 estudios por compatibilidad con el objetivo propuesto en el estudio. Los estudios revisados indican el excelente potencial del MTA y alientan a realizar más análisis para seguir documentando su eficacia. Es posible afirmar que los análisis endodónticos contemporáneos apoyan y aprueban el uso del MTA como elemento de recubrimiento.

Palabras-clave: Recubrimiento de la Pulpa Dental, Endodoncia, Endodoncia Regenerativa.

1. INTRODUCTION

Dental caries is a common health problem in children and adolescents globally (Sheela et al., 2022) and minimally invasive treatment involves selective removal of caries, avoiding exposure of the pulp and endodontic treatment, however, it is common for caries lesions to reach deep areas of the dentin that are very close to the pulp chamber. When there is no exposure, but the proximity of the pulp tissue is evident, adequate pulp capping reduces irritation and induces the formation of reactive dentin (Vigil, 2023). If pulp exposure occurs during the cavity preparation without cavities, it is called mechanical exposure and is typically due to an accident during tooth preparation (Hoseinifar *et al*., 2020).

Traumatic pulp exposure can result from a sports injury or fall when the coronal part of the tooth is fractured. Several treatment options are available in the case of vital pulp exposure: direct pulp capping, partial and complete pulpotomy, up to pulpectomy, and endodontic treatment of the root canal (Hoseinifar *et al*., 2020). Direct pulp capping (DPC) is a successful method for maintaining pulp vitality. During the DPC, the exposed pulp tissue is covered with a pulp-capping material to preserve its function and biological activities and to protect it from additional injury (Hoseinifar *et al*., 2020).

Direct pulp capping (DPC) treatment is a conservative treatment strategy based on placing a biologically active material in direct contact with the exposed pulp, resulting in the development of a hard dentin bridge thus preserving pulp vitality (Vigil, 2023). Traditionally, most clinicians considered that there was a low probability of successful pulp capping due to contamination of the pulp tissue. Over time, the procedure has shown a high clinical success rate in patients who meet the criteria for this treatment, but there is still no consensus on the ideal biomaterial (Hoseinifar *et al*., 2020).

Long-term clinical studies have shown that success rates with calcium hydroxide pulp capping of carious exposures are highly variable, generally unpredictable, and often unsuccessful (Vigil, 2023). Bioceramic materials in endodontics can be considered a magnanimous entity that has changed the prognosis of many cases that were previously considered almost impossible (Vigil, 2023). This study aims to provide an integrative analysis of numerous articles published regarding pulp capping with Mineral Trioxide Aggregate (MTA). The effectiveness and positive aspects of this material on pulp protection are the priority of this study, with that said, it is possible to establish a strategy to collect the data from databases which is explicitly explained in the methodology topic.

2. THEORETICAL FRAMEWORK

Pulp capping, whether direct or indirect, helps in pulp regeneration, thereby preserving the vitality and functions of the pulp tissue. In direct pulp capping, a biocompatible material is placed over the exposed pulp tissue, overlaid by suitable restorative material to reestablish function and aesthetics (Sheela *et al*., 2022). Clinicians have preferred calcium hydroxide as a gold standard material for direct pulp capping (Sheela *et al*., 2022).

Mineral Trioxide Aggregate (MTA) was the first calcium silicate material (CSM) to be commercialized and since its approval, it has been utilized more frequently, with remarkably promising results. It can be applied in pulp capping, in the repair of root perforations or furcations, apexification, and root end fillings (Sheela *et al*., 2022). Despite the high clinical efficacy, some problems prevented dentists from using it in many cases, such as very long setting time and difficult manipulation (Vigil, 2023).

MTA (Mineral Trioxide Aggregate) was developed by Dr. Mahmoud Torabinejad in the 1990s and was first introduced to the market in 1998 (Sharma *et al*, 2022). It is a calcium silicate-based material, commonly used in dentistry. This compound generally includes the following components: Silicon Oxide (Si02), Calcium Oxide (CaO), Aluminum Oxide (Al_2O3), Mineral trioxide, Calcium Sulfate ($CaS0_4$) and Iron Oxide (Fe_20_3), (Sharma *et al*, 2022; Vigil, 2023).

One of the problems with this formulation is the possibility of pigmenting the tooth, which is why a new type of MTA was introduced onto the market, "White MTA", which uses titanium dioxide instead of iron oxide as a pigment (Sharma *et al*, 2022). For handling, MTA is mixed with distilled water or saline solution until consistency is suitable for clinical use. It can be applied using different techniques, such as the "sandwich" technique and the thin layer technique (Sharma *et al*, 2022; Vigil, 2023).

3. METHODOLOGY

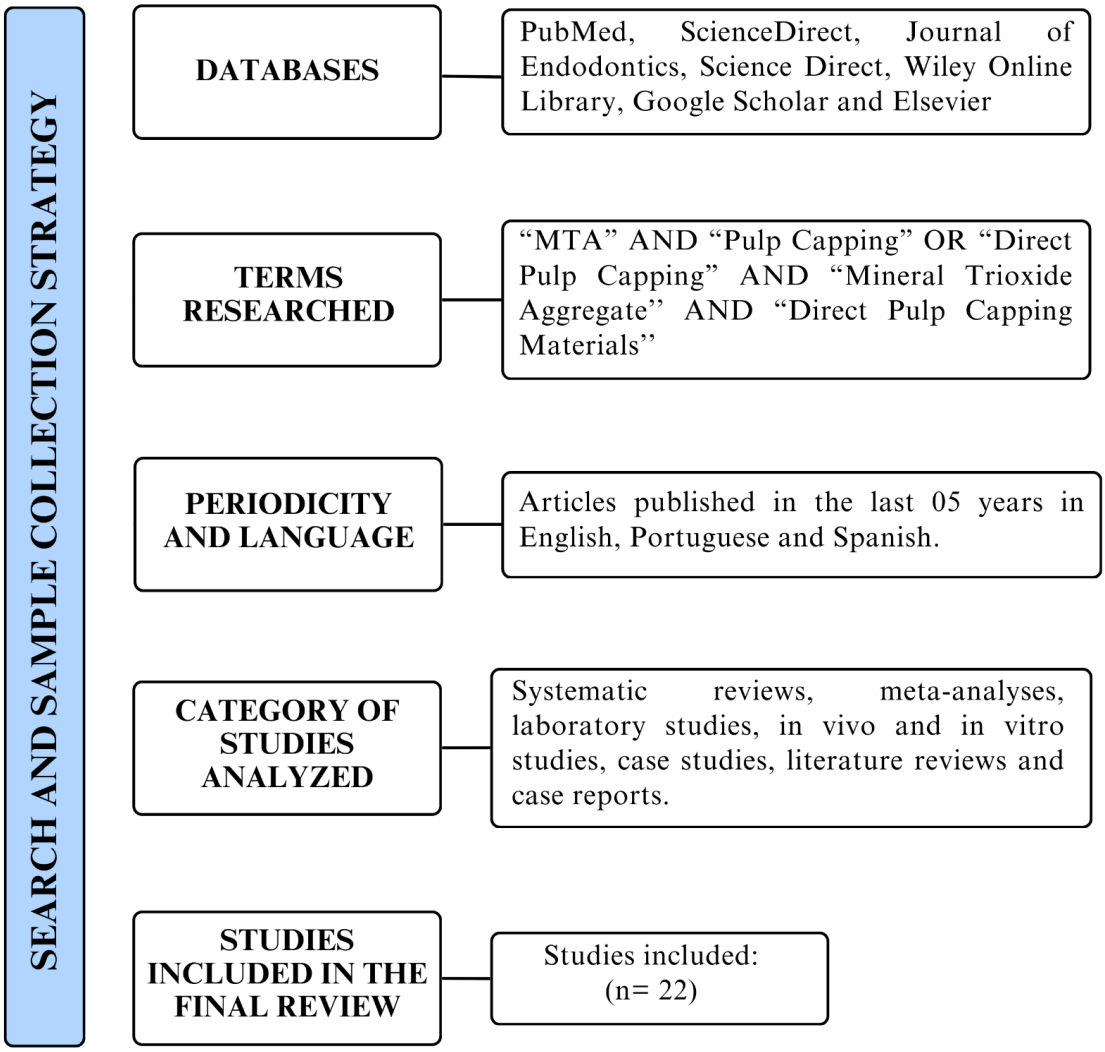
By integrating findings and perspectives from many empirical findings, a literature review can address research questions with a power that no single study has (Jesus *et al*., 2024). The goal of using an integrative review strategy is to overview the facts base, the principal studies regarding the theme, to critically examine, potentially reconceptualize and to expand on the theoretical foundation of the precise topic as it evolves (Jesus *et al*., 2024).

Jesus *et al*., (2024) express that this type of review often requires a more creative collection of data, as the objective is usually not to cover all articles ever published on the subject but rather to combine perspectives and understandings from distinct fields or research conventions.

During the undertaking of this research to elaborate an integrative review, the previous data selection was conducted using methodological techniques to simplify and filter the substantial content inserted inside the proscript investigation.

To sustain an integrative and qualitative literature/bibliographic review, 64 bibliographic articles published in English and Portuguese from PubMed, ScienceDirect, Journal of Endodontics, Science Direct, Wiley Online Library, Google Scholar and Elsevier were analyzed previously and filtered to compose the final review. After the final review, only 22 studies were included due to compatibility with the objective proposed in the study. The methodology is expressed in **Figure 1**, respectively.

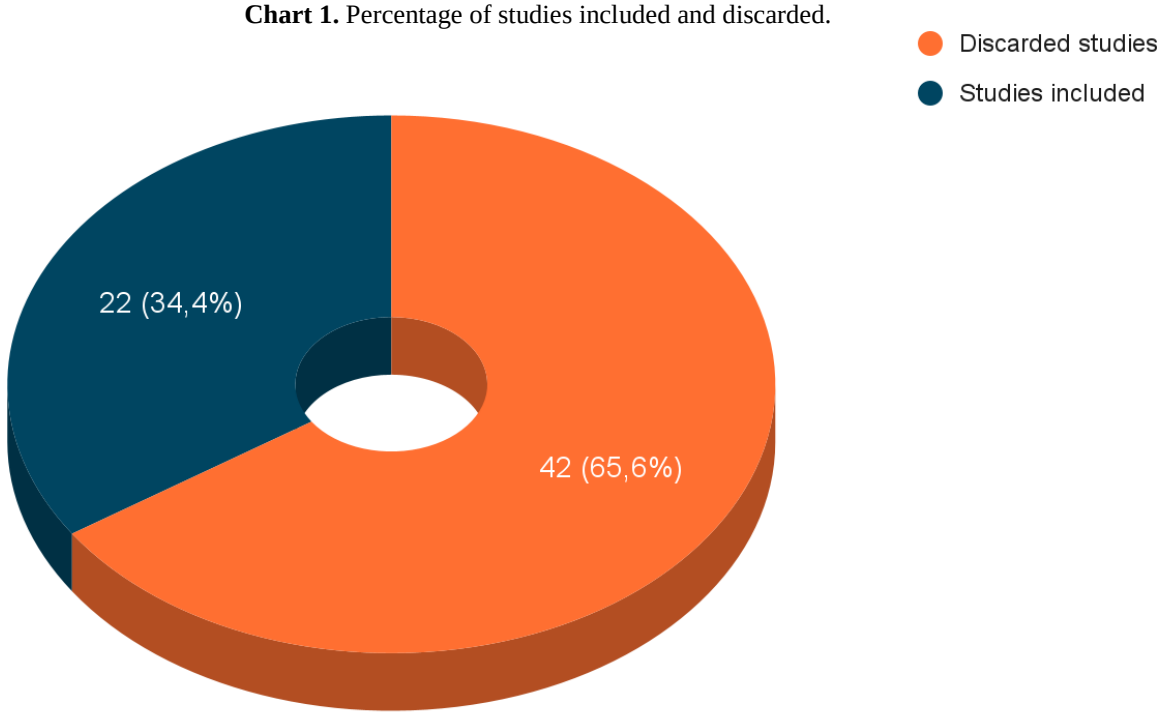
Figure 1. Data search methodology applied.



Source: Prepared by the authors (2024)

Moreover, 65,6% of the studies analyzed previously weren't compatible with the research objective and proposal, and only 34,4% of the data were included, compatible and entirely examined to compose the investigation aim. The percentual concerning the studies, data collected inserted and discarded of the review was represented and expressed visually to better explain how the methodology worked during the sample collection and these numbers were formed and applied respectively in **Chart 1**, as this article can present:

Chart 1. Percentage of studies included and discarded.



Source: Prepared by the authors (2024)

4. RESULTS AND DISCUSSIONS

Vital dental pulp exposure may be caused by caries removal (caries exposure), cavity preparation where pinpoint exposure to the dental pulp (mechanical exposure), and accidental coronal pulp injury (traumatic exposure) (Nie *et al.*, 2021). Direct pulp capping (DPC) treatment is used when the vital asymptomatic pulp is visibly exposed due to caries or trauma, or due to a misadventure during tooth preparation or caries removal (Kunert & Lukomska-Szymanska, 2020). It includes the application of a biomaterial directly onto the exposed pulp, followed by immediate placement of a permanent restoration (Kunert & Lukomska-Szymanska, 2020).

According to Vigil (2023), the prerequisites before direct placement of the pulp capping material are a tooth with normal pulp or reversible pulpitis, results of percussion, palpation and periodontal probing tests must be within normal limits, the radiograph should show normal apical tissue, the pulp exposure site must be less than 1 mm in diameter and pulp hemorrhage must be stopped. Estrela *et al.*, (2023) discuss that among the materials well studied in endodontics clinical practice, calcium hydroxide, mineral trioxide aggregate, and new calcium silicate cement can be highlighted.

One of the basic principles for the selection of material is related to the benefits of its physicochemical, biological, and antimicrobial properties, likewise, the material that presents a larger number of these favorable properties would certainly contribute more toward the therapeutic process

(Estrela *et al.*,2023). MTA is another well-accepted and widely studied material in endodontics, being initially indicated for the sealing root perforations and retro-fillings (Estrela *et al.*,2023).

Panda *et al*., (2023) express that MTA is a bioactive and biocompatible self-setting hydrophilic calcium silicate cement that promotes the proliferation/differentiation of human dental pulp cells and shows calcified tissue-conductive activity, allowing for rapid dentine bridge construction and new hard tissue synthesis (Kunert & Lukomska-Szymanska, 2020).

Based on the results analyzed, it's possible to affirm that MTA is a remarkable material in modern dentistry, particularly, in endodontic treatment. MTA has been revealed to have several advantages, providing a firm seal on the treated area, helping to control bacterial infiltration and reducing the possibility of infection (Sharma *et al,* 2022).

MTA is resistant to erosion and does not degrade over time. Stimulates the formation of dentin and promotes the regeneration of pulp tissue (Hoseinifar *et al*., 2020). It is biocompatible and non-toxic, has high mechanical resistance and has excellent long-term stability (Sharma *et al,* 2022). Despite impediments regarding cost, long setting time and the possibility of causing darkening due to iron content, MTA continues to be a highly versatile dental material (Hoseinifar *et al*., 2020).

The desirable properties of MTA include excellent seal, high biocompatibility, low cytotoxicity, calcium ion release, and also its high alkalinity that provides its bactericidal properties. This material is not affected by contamination with blood or tissue fluids (Hoseinifar *et al*., 2020; Sharma *et al,* 2022; Sheela *et al.*, 2022). At present, several methods are available for pulp capping and MTA stimulates reparative hard tissue formation by sequestering growth factors and cytokines (Sheela *et al*., 2022).

There is validation from the randomized controlled trials developed by Edwards *et al.*, (2020) verifying that mineral trioxide aggregate performs better than calcium hydroxide for direct pulp capping of permanent teeth with complete root development following pulp exposure during caries removal, but not in cases of iatrogenic or traumatic exposures. This supports the European Society of Endodontology 2019 position statement on managing deep caries and exposed pulp (Edwards *et al*., 2020).

There are also indications that the excellence of mineral trioxide aggregate over calcium hydroxide for direct pulp capping becomes more pronounced over time (Edwards *et al.*, 2020). Cushley *et al.*, (2021) affirm that the preservation of pulp vitality is a critical factor in long-term tooth survival. A shred of evidence was applied in **board 1**, respectively, which explains with numerous articles, studies and analyses regarding how the MTA can be necessary and effective in endodontic treatment in contemporary dentistry.

Board 1. Retrospective results of evidence published between 2019 and 2024.

RESEARCH EVIDENCE COLLECTED	AUTHOR AND YEAR
The results suggest MTA to be effective for pulp capping.	Mickenautsch, 2019
MTA is a biocompatible material that has seen increased usage in recent years.	Gürcan & Seymen, 2019
MTA has suitable properties such as high sealing ability, high pH, optimal biocompatibility, prevention of bacterial leakage, and long-term stability.	Kermanshah, *et al*., 2020
There are indications that the superiority of mineral trioxide aggregate over calcium hydroxide for direct pulp capping becomes more pronounced over time.	Edwards *et al*., 2020
MTA performs better when employed as the direct pulp capping material.	Hoseinifar *et al*., 2020
MTA has proven to induce mineralization beneath exposed pulp and has the potential to maintain pulp vitality.	Kunert & Lukomska-Szymanska, 2020
MTA has proven to be a suitable choice for DPC material because of its good sealing ability and biocompatibility.	Nie *et al*., 2021
In a laboratory setting, MTA-HP promoted hDPSCs proliferation, mineralization and attachment, which may explain their *in-situ* success as endodontic biomaterials.	Abou Elreash *et al.*, 2021
MTA is better than calcium hydroxide in the long term.	Cushley *et al.*, 2021
The success rate of MTA is significantly higher than that of CH	Matsuura *et al*., 2021
MTA exhibited biocompatibility and supported cell activities toward regeneration potency.	Manaspon *et al*., 2021
The use of MTA over carious exposure to immature permanent teeth is commonly considered the appropriate and reasonable alternate treatment to root canal therapy or extraction.	Peskersoy; Lukarcanin; Turkun; 2022
MTA has given significantly better clinical, radiographic and histologic outcomes than other materials in different in vivo and in vitro direct pulp capping studies	Sharma *et al*, 2022
Direct pulp capping with MTA following hemorrhage control with the tested solutions offers a more predictable outcome compared to CH	Canoğlu *et al*., 2022
Extensive laboratory and clinical studies favored the use of MTA due to its excellent biocompatibility and sealing capabilities	Sheela *et al*., 2022
Stimulates the formation of dentin and promotes the regeneration of pulp tissue.	Vigil *et al*., 2023
Many *in vivo* studies have confirmed its good reparative dentin-forming ability	Saikia *et al*., 2023
MTA has several advantages including its antibacterial and biocompatibility properties, high pH, radiopacity, and its ability to aid in the release of bioactive dentin matrix proteins	Jha *et al*., 2023
Good potential to seal lateral and furcal root perforations, root-end fillings, pulp capping, pulpotomy, apexification and regenerative endodontic procedures.	Estrela *et al*., 2023
MTA is more effective than calcium hydroxide because of its higher mechanical strength, better adhesion to dentin, and lower water.	Gomez-Sosa *et al*., 2024

Source: Prepared by the author (2024)

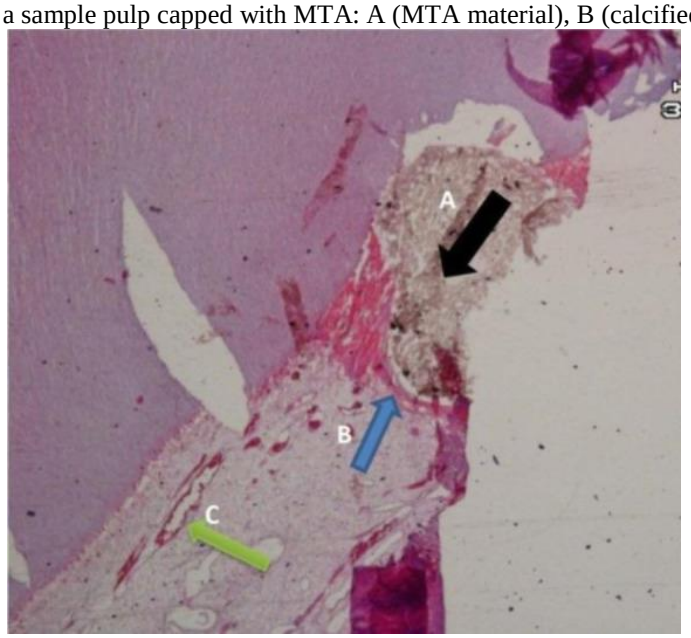
The endodontic history encompasses the several stages of root canal therapeutic procedures, characterizing the differences observed over time of various endodontic materials proposed (Estrela *et al*., 2023). Since MTA is a calcium silicate cement, new materials with similar compositions have been proposed with additional characteristics that allow an improved clinical application, which facilitates handling and manipulation and minimizes coronal discoloration. To achieve this, the new calcium silicate cement (also named bioceramics) forms a colloidal structure after hydration and sequentially develops into a hard structure (Estrela *et al*., 2023).

The advantages that have been described in the literature of the new calcium silicate cements are related to their physicochemical and biological properties, including excellent sealing possibility, due to their physicochemical interaction with the local environment, and high biocompatibility. Similarly, they

have advanced compressive strength and dentin-like physical characteristics (Sheela *et al*., 2022; Jha *et al*., 2023; Estrela *et al*., 2023).

Various studies on pulpotomy with MTA in exposed teeth or teeth with irreversible pulpitis have shown good results expressing a great prognosis, demonstrating the efficacy of the technique (Peskersoy et al., 2022). Furthermore, numerous histopathological analyses were developed over the past few years, making it possible to confirm the tissue viability already consulted during the review, as shown in **Figure 2**, Hoseinifar *et al*., (2020) registered an image of a specimen pulp capped with the MTA material and exemplifies the advantages and the potential of Mineral trioxide aggregate (MTA) on pulp capping.

Figure 2. Pathologic image of a sample pulp capped with MTA: A (MTA material), B (calcified bridge), C (pulp hyperemia).



Source: Hoseinifar *et al*., (2020).

During the execution of this article, it was evident that MTA is a positive material applied in dental practice, even with a few limitations reported by studies. Biologically, this material it's efficient when associated with procedures of the human pulp. Every single piece of evidence inserted on board 1 has shown how the viability of this material is important. Authors like Hoseinifar *et al.*, (2020), Edwards *et al*., 2020, MICKENAUTSCH 2021, Sheela 2022 and Estrela et al., (2023) brought to the newest discoveries concerning MTA as a significant matter in endodontic applications. Every study reviewed captured important evidence and the last 5 years confirm that Mineral Trioxide Aggregate is still positive to dentistry.

5. CONCLUSION

MTA when compared to calcium hydroxide results in much lesser pulpal inflammation and a qualitatively better dentine bridge. Both these factors contribute to the higher success rate of MTA in

endodontic approaches. The studies reviewed indicate the outstanding potential of MTA and increase new studies to keep documenting its effectiveness. It's possible to affirm that contemporary endodontic breakdowns support and approve using MTA as a capping element.

REFERENCES

ABOU ELREASH, A. et al. A laboratory study to test the responses of human dental pulp stem cells to extracts from three dental pulp capping biomaterials. **International Endodontic Journal**, v. 54, n. 7, p. 1118-1128, 2021.

CANOĞLU, Ebru; GÜNGÖR, H. Cem; UYSAL, Serdar. Direct pulp capping of primary molars with calcium hydroxide or MTA following hemorrhage control with different medicaments: randomized clinical trial. **Pediatric Dentistry**, v. 44, n. 3, p. 167-173, 2022.

CUSHLEY, S. et al. Efficacy of direct pulp capping for management of cariously exposed pulps in permanent teeth: a systematic review and meta-analysis. **International endodontic journal**, v. 54, n. 4, p. 556-571, 2021.

EDWARDS, David Christopher et al. MTA or calcium hydroxide for direct pulp capping in fully developed permanent teeth: a systematic review. **Endodontic Practice Today**, v. 14, n. 2, 2020.

ESTRELA, Carlos et al. Mechanism of action of bioactive endodontic materials. **Brazilian dental journal**, v. 34, p. 1-11, 2023.

GOMEZ-SOSA, Jose Francisco et al. Determining Factors in the Success of Direct Pulp Capping: A Systematic Review. **The Journal of Contemporary Dental Practice**, v. 25, n. 4, p. 392-401, 2024.

GÜRCAN, Aliye Tuğçe Tanyeri; SEYMEN, Figen. Clinical and radiographic evaluation of indirect pulp capping with three different materials: a 2-year follow-up study. 2019.

HOSEINIFAR, Razieh et al. Histological Evaluation of Human Pulp Response to Direct Pulp Capping with MTA, CEM Cement, and Biodentine. **Journal of Dentistry**, v. 21, n. 3, p. 177, 2020.

JESUS, Oliver Renê Viana de et al. Surgical efficacy of bone grafts and GTR on endodontic microsurgery: An overview of bone regeneration technology applied in magnification. **Research, Society and Development**, v. 13, n. 3, p. e10013345212-e10013345212, 2024.

JHA, Shruti et al. Comparative Evaluation of Effectiveness of TheraCal LC, MTA, and Calcium Hydroxide in Direct Pulp Capping in Primary Molars: Randomized Clinical Study. **International Journal of Clinical Pediatric Dentistry**, v. 16, n. Suppl 2, p. 213, 2023.

KERMANSHAH, Hamid et al. Direct pulp capping with ProRoot MTA alone and in combination with Er: YAG laser irradiation: A clinical trial. **Journal of Lasers in Medical Sciences**, v. 11, n. Suppl 1, p. S60, 2020.

KUNERT, Marta; LUKOMSKA-SZYMANSKA, Monika. Bio-inductive materials in direct and indirect pulp capping—a review article. **Materials**, v. 13, n. 5, p. 1204, 2020.

MANASPON, Chawan et al. Human dental pulp stem cell responses to different dental pulp capping materials. **BMC Oral Health**, v. 21, n. 1, p. 209, 2021.

MATSUURA, Takashi et al. Long-term clinical and radiographic evaluation of the effectiveness of direct pulp capping materials: A meta-analysis. **Dental Materials Journal**, v. 40, n. 1, p. 1-7, 2021.

MICKENAUTSCH, Steffen. Clinical effect of MTA cement for pulp capping [November 09, 2019]. **Journal of Minimum Intervention in Dentistry**, v. 14, n. 5, p. 106-109, 2021.

NIE, E. et al. Effectiveness of Direct Pulp Capping Bioactive Materials in Dentin Regeneration: A Systematic Review. Materials 2021, 14, 6811. 2021.

PANDA, Pratima et al. Analysis of Pulp Tissue Viability and Cytotoxicity of Pulp Capping Agents. **Journal of Clinical Medicine**, v. 12, n. 2, p. 539, 2023.

SAIKIA, Debanga et al. Evaluation of Indirect Pulp Capping Using MTA, Light-cured Calcium Silicate, and Propolis in Primary Teeth: A Clinical and Radiographic Study Using VistaScan. **International Journal of Clinical Pediatric Dentistry**, v. 16, n. 5, p. 686, 2023.

SHARMA, Vivek et al. Evaluation of Endosequence Root Repair Material and Endocem MTA as direct pulp capping agents: An in vivo study. **Australian Endodontic Journal**, v. 48, n. 2, p. 251-257, 2022.

SHEELA, Soumya et al. Synthesis and biocompatibility evaluation of PCL electrospun membranes coated with MTA/HA for potential application in dental pulp capping. **Polymers**, v. 14, n. 22, p. 4862, 2022.

VIGIL, Patricia Alduain. Capeamento pulpar direto em dentes permanentes: eficácia do Hidróxido de cálcio vs MTA vs Biodentine. Revisão sistemática integrativa. Tese (Mestrado em Medicina Dentária) - Instituto Universitário de Ciências da Saúde. Gandra, maio de 2023.

PESKERSOY, Cem; LUKARCANIN, Jusuf; TURKUN, Murat. Efficacy of different calcium silicate materials as pulp-capping agents: Randomized clinical trial. **Journal of dental sciences**, v. 16, n. 2, p. 723-731, 2021.