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Bioactive materials for pulpotomies in primary dentition: literature review

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ABSTRACT

There is a growing demand for increasingly biocompatible materials, especially for pulp therapies in children. In today's market, biomaterials such as mineral trioxide aggregate (MTA) and Biodentine have demonstrated high bioactive properties. However, no material has yet been identified that optimally meets all clinical requirements, due to factors such as biocompatibility, pulp repair potential, among others. The objective of this literature review was to determine the clinical and radiographic success rate of bioactive materials in pulpotomies, compared to the use of conventional materials. Additionally, the preferred final restorative material used after the application of the bioactive material was identified. PubMed, Scopus, ScienceDirect, Virtual Health Library, EBSCOHost, and ProQuest databases were used. The search included publications up to May 25, 2024, following PRISMA guidelines. Out of a total of 857 articles identified, twelve met the inclusion criteria and were selected for analysis. Subsequently, these studies underwent a control review to evaluate the results of pulp treatment: eleven were considered at the first year of follow-up and only one at the second year. The use of bioactive materials, such as Biodentine and calcium silicate cements, represents a significant advance in dentistry. These materials are easy to handle, set faster, and have a lower risk of discoloration than MTA.

Keywords: pulpotomy; primary tooth; biocompatible materials; pediatric dentistry.

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INTRODUCTION

Pulpotomy consists of removing the coronal pulp tissue and placing a suitable material to the remaining root pulp to keep it free from infection and inflammation (1). Its objective is to maintain a functional tooth with vital root pulp in the oral cavity, thus helping the tooth to exfoliate at the correct chronological moment (2). The success of this procedure depends not only on the correct diagnosis of inflamed pulp tissue without the presence of periapical lesions, but also on the tooth having at least two-thirds of its root length, in addition to the selection of an effective and biocompatible material (3).

Among the most popular material options is formocresol, which has been used for over 80 years because it has a direct pulp-fixing effect and is extremely bactericidal. It is based on the principle of mummification/devitalization. However, its use in dental treatments has generated mistrust due to its possible carcinogenicity, mutagenicity, cytotoxicity, and allergenicity; nevertheless, for this material to be toxic, it must be used in very high concentrations (4). In this context, some researchers have sought more biocompatible materials that have bioactive properties, provide a good seal, and allow for the repair of dental defects or communications between the root canal system and the periodontal ligament. This has led to the emergence of mineral trioxide aggregate (MTA) and Biodentine (3).

However, despite advances in the development of bioactive materials that seek to replace tissue lost mainly due to dental caries (5), an optimal material has not yet been found, as many factors must be considered, such as biocompatibility, pulp repair potential, and root filling potential, in order for it to meet all the requirements to be considered ideal (3).

Therefore, this literature review aims to determine the clinical and radiographic success rate of bioactive materials in pulpotomies compared to the use of conventional materials. For this purpose, articles referring to bioactive materials for pulpotomies in primary dentition have been searched and analyzed. It also aims to report on the preference for the final restoration material after use of the bioactive material.

MATERIALS AND METHODS

The PICO methodology was used, considering P (population): deciduous teeth with pulpotomy; I (intervention): bioactive dental materials; C (comparison): conventional dental materials; and O (outcomes): survival analysis.

The search strategy covered up to May 25, 2024, taking into account the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. A literature review was conducted by searching the PubMed, Scopus, ScienceDirect, Virtual Health Library (VHL), EBSCOHost, and ProQuest databases. The following MeSH descriptors were used in the search: "deciduous tooth," "tooth, deciduous," "dentition primary," "pulpotomy," "biomedical and dental materials," "dental materials," and "smart materials." The search was also performed by adding non-MeSH terms: "survival analysis," "survival," "survival rate," and "success rate," in addition to the Boolean operators AND and OR. Articles in English published in the last five years were included, resulting in the following final search expression: ("deciduous tooth" OR "tooth, deciduous" OR "dentition primary") AND (pulpectomy* OR "total pulpectomy") AND ("biomedical and dental materials" OR "dental materials" OR "smart materials") AND ("survival analysis" OR survival* OR "survival rate" OR "success rate").

The inclusion criteria were as follows: experimental studies applied to a population (comparative clinical trials [CCTs] and randomized controlled trials [RCTs]). Non-randomized clinical studies, experimental studies in animals, *in vitro* studies, letters to the editor, theses, review articles, laboratory studies, and procedural guidelines were excluded.

Two researchers performed the study selection process using the Rayyan tool, and a third researcher participated in deciding on elimination discrepancies. A spreadsheet (Microsoft ExcelTM, Microsoft Corporation) was used to collect the data, which contained the following information: year of publication, article title, author, country, objectives, study design type, population, sample, sample characterization (gender, age), sample selection, intervention performed (study groups, materials used), results (observation time, type of evaluation), and conclusions.

RESULTS

A total of 857 articles were found in the data sources used, which included PubMed (n = 5), Scopus (n = 105), ScienceDirect (n = 279), VHL (n = 15), EBSCOHost (n = 439), and ProQuest (n = 14). Forty-six duplicate studies were removed with Zotero reference manager. They were then uploaded to the Rayyan platform, where two researchers analyzed and reviewed the titles and abstracts, and then analyzed the full text. Of the remaining 811 articles, 782 were eliminated based on their titles and abstracts. Next, 29 articles were retrieved, of which those that met any exclusion criteria were removed. Finally, after a rigorous review process, 12 studies that met the inclusion criteria were obtained and used for the literature review (Figure 1).

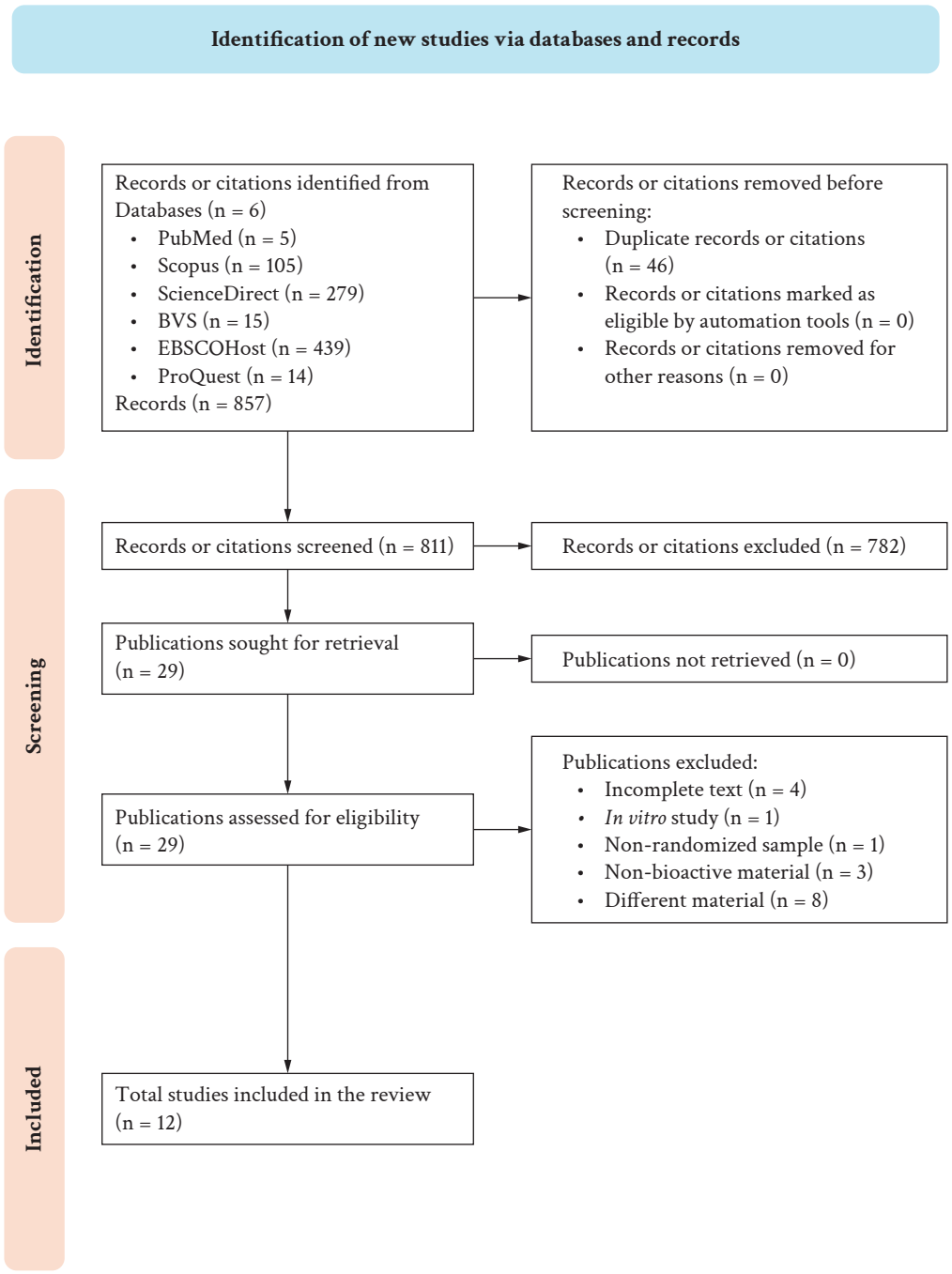

Figure 1. Flowchart of article selection and identification.

Description of the studies

A comprehensive review of the articles was conducted to determine their characteristics (Table 1).

Table 1. Characteristics of the selected articles.

Author	Year	Type of study	Intervention	Sample per group	Results
Abdelwahab et al. (6)	2024	RCT	G1: MTA (PDTM MTA White®) + PSC G2: MTA + RMGI G3: BC RRM® Fast Set Putty + RMGI G4: BC RRM® Fast Set Putty + PSC	n = 16	After 12 months, there were no statistically significant differences between the four groups in terms of clinical success rate.
Mushtaq et al. (7)	2023	RCT	G1: MTA G2: 3Mixtatin	n = 25	After 12 months, the overall success rates were 95.5% for MTA and 91.3% for 3Mixtatin.
Alqahtani et al. (8)	2023	RCT	G1: NeoMTA® G2: NeoPUTTY®	n = 35	At 12 months, clinical and radiographic success in the MTA group was 100% and 94.1%, respectively. In the NeoPUTTY® group, clinical and radiographic success was 97.1% and 92.8%, respectively. No significant differences were observed between the two groups.
Alnassar et al. (9)	2023	RCT	G1: MTA G2: BC Putty	n = 20	During the 12-month follow-up period, the success rate was 95% in the MTA group and 100% in the BC Putty group.
Hidalgo et al. (10)	2023	Randomized clinical trial with simple random sampling	G1: MTA G2: Biodentine	n = 15	Pain was detected only with Biodentine™ at 6 months and mobility at 12 months. Radiographically, after 12 months, periapical and interradicular lesions and internal resorption were evident in 13% of cases of teeth treated with Biodentine™. MTA induced pulp calcification in 13% of cases, unlike Biodentine™.
Hassanpour et al. (11)	2023	RCT	G1: TheraCal G2: MTA	G1 (n = 40) G2 (n = 42)	The overall success rates were 98.1% and 99.3% for TheraCal and MTA, respectively. No significant differences were observed between the two groups ($p > 0.05$).
Kiranmayi et al. (12)	2022	RCT	G1: Treated with bioceramic filler G2: MTA	n = 30	Over a 3-month period, success rates were 96.7% and 93.1% for the bioceramic and MTA groups, respectively; and over 6- and 12-month periods, success rates were 93.3% and 93.1%, respectively.
Eshghi et al. (13)	2022	RCT	G1: The remaining pulp was covered with 2 mm of MTA G2: 3 mm Biodentine	n = 26	There were no significant differences between MTA and Biodentine in terms of clinical and radiographic success rates. The survival rate in both pulp treatment methods was similar in symptomatic teeth.

G: group; RCT: randomized controlled trial; MTA: mineral trioxide aggregate; PSC: preformed steel crown; RMGI: resin-modified glass ionomer; TheraCal: resin-modified calcium silicate; PC: Portland cement.

Table 1. (*Continuation*).

Author	Year	Type of study	Intervention	Sample per group	Results
Vilella-Pastor et al. (14)	2021	RCT	G1: MTA G2: Biodentine	n = 45	A total of 84 pulpotomies were performed, with a total success rate of 99.4% and 97.2% for Biodentine and MTA, respectively, at 24 months. No statistically significant differences were found between the two groups.
Lima et al. (15)	2020	RCT	G1: Angelus MTA G2: Bio-C Pulpo	G1 (n = 34) G2 (n = 36)	Two teeth showed internal resorption in the Bio-C Pulpo group, one at one month and the other at three months of follow-up; and one tooth at six months of follow-up in the MTA Angelus group. However, this process was not detected at 12 months of follow-up in either group.
Öznurhan et al. (16)	2020	RCT	G1: ProRoot MTA G2: BIOfactor MTA	n = 12	No clinical or radiographic differences were observed at 1, 3, and 6 months, but at 12 months ProRoot MTA showed statistically better results in the clinical evaluation (p = 0.047).
Meslmani et al. (17)	2020	Randomized clinical trial	G1: MTA G2: PC	n = 30	The radiographic success rate of MTA after 12 months was 96.7%, while that of PC was 93.3%. There were no significant differences between the two groups.

G: group; RCT: randomized controlled trial; MTA: mineral trioxide aggregate; PSC: preformed steel crown; RMGI: resin-modified glass ionomer; TheraCal: resin-modified calcium silicate; PC: Portland cement.

According to the material used

The articles included used different materials that were compared with MTA: bioactive materials (NeoPUTTY® (8), BiodentineTM (10, 13, 14)), bioceramic materials (BCputty (9), Bio-C Pulpo (12, 15), TheraCal (11), 3Mixtatin (7), BC RRMTM (6), Portland Cement® (17)) and bioactive materials derived from MTA (NeoMTA® (8), BIOfactor MTA (16), ProRoot MTA (16), MTA Angelus (15)), to evaluate their success rate in pulp treatment.

According to clinical and radiographic follow-up

All of the articles included underwent a control review to evaluate the final outcome of pulp treatment. Eleven studies (6-13, 15-17) were considered at one year, and only one (14) at two years; however, they all coincided in the 3-month interval.

According to success rate

In the included studies, the performance of the materials applied during different periods was evaluated clinically and radiographically. Three studies found a success rate of up to 3 months (6, 10, 15); four reported at 6 months (7, 8, 11, 14); two at 12 months (9, 17); and one at 1 month (16); however, two studies indicated that no success rate was evident in the months of follow-up (12, 13).

According to final restoration

Among the included studies, there were two types of final restoration: resin-modified glass ionomer (10) and stainless steel crown (9, 12, 16, 17). Additionally, only three studies used both (6, 7, 11) and four (8, 13-15) did not include final restoration in the pulpotomy procedure.

DISCUSSION

Currently, new materials have emerged for use in pulp therapies, such as bioactive materials, which, in addition to replacing lost tissue and regenerating it, are also biocompatible with human tissues, so that there are no toxicity or rejection phenomena (5). The studies collected explore in greater detail the comparison of this material with others, demonstrating its efficacy, similarity, and clinical and radiographic success rate (6-17).

MTA emerged as a low-solubility biocompatible material used for pulp therapies; however, due to its long setting time, discoloration, and poor handling characteristics, the need arose to seek new alternatives. This is the case with Biodentine, which is easier to handle, has a shorter setting time, and causes less discoloration compared to MTA (18). In this regard, two studies verified discoloration at one year and two years of clinical and radiographic follow-up (13, 14).

Another new material is calcium silicate cement (CSC). These are characterized by their low toxicity, high biocompatibility, and high sealing capacity without tooth discoloration (19), which sets this material apart from MTA and Biodentine (10). The studies reviewed evaluated various CSC materials in comparison with MTA and found that they can be alternatives to the latter (6, 9, 11, 12, 15-17). However, one study (8) evaluated NeoPutty® as a pulpotomy medication in comparison with NeoMTA, finding that the group treated with the latter material demonstrated greater clinical and radiographic success.

On the other hand, the use of 3Mixtatin has been reported. This material not only serves as a medication but also as a filling material. Its potent antibacterial properties and anti-inflammatory capabilities play a crucial role in improving clinical outcomes in pulp treatments. Despite these benefits, some analyses do not categorize it as a bioactive material (7).

In addition, other reviewed studies show variability regarding final restoration options after pulpotomy (6-13, 15-17). Both resin-modified glass ionomer and stainless-steel crowns stand out as options used in each procedure. This focus on the appropriate choice of final restorations is crucial to ensuring optimal clinical and radiographic results, significantly impacting the long-term outcomes of pulp treatment.

Finally, the main limitation was that only scientific articles in English were considered, so it is suggested that, in a future update, articles in other languages be included to enrich the information obtained.

CONCLUSIONS

The bioactive materials evaluated are effective for pulpotomies of primary teeth, as they demonstrate similar success rates with clinical and radiographic evaluations, although the choice of material will depend on factors such as cost, clinical management, and operator preference. The development of bioactive materials, such as Biodentine and calcium silicate cements, represents a significant advancement in modern dentistry. These materials outperform MTA in several aspects, such as easy handling, faster setting times, and less propensity for discoloration. There are also other innovations, such as 3Mixtatin, known for its dual capacity as a medicating agent and filling material.

In evaluating the success rate of materials, it has been found that the incorporation of an adequate final restoration after each treatment not only improves long-term effectiveness but also ensures optimal clinical results and a consistent improvement in patients' quality of life. Continued research and refinement of these advances are essential to continually raise the standards of dental care and ensure exceptional outcomes in clinical practice.

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NMGP: conceptualization and design, literature review, research and data collection, data analysis and interpretation.
MECF: conceptualization and design, literature review, methodology, validation, formal analysis, data analysis and interpretation, supervision, writing – original draft, writing – review & editing.
RJRE: conceptualization and design, literature review, methodology, validation, supervision, writing – original draft, writing – review & editing.
ACMRA: supervision, writing – original draft, writing – review & editing.

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