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Clinical and Radiographic Assessment of Direct Pulp-Capping Materials: A Comparison of Calcium Silicate-Based and Calcium Hydroxide Based Approaches (A Review)

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Abstract

Background: Direct pulp capping is a critical procedure in endodontics aimed at preserving pulp vitality following exposure due to carious lesions or trauma. The choice of pulp-capping materials significantly influences treatment outcomes, with calcium silicate-based materials, such as mineral trioxide aggregate (MTA) and Biodentine, emerging as promising alternatives to traditional calcium hydroxide. This systematic review aims to evaluate the clinical and radiographic effectiveness of these materials, addressing the need for updated evidence to guide clinical practice.

Methods: A comprehensive literature search was conducted across multiple databases, including PubMed, Scopus, and Cochrane Library, from January 2000 to October 2023. Inclusion criteria encompassed randomized controlled trials, cohort studies, and systematic reviews that compared calcium silicate-based materials with calcium hydroxide in direct pulp capping. Exclusion criteria included studies not published in English, animal studies, and those lacking relevant clinical outcomes. Data extraction and analysis were performed following PRISMA guidelines, with a focus on clinical success rates, radiographic outcomes, and biocompatibility.

Results: A total of 25 studies met the inclusion criteria, comprising 15 randomized controlled trials and 10 cohort studies. The review revealed that calcium silicate-based materials demonstrated a significantly higher clinical success rate (average 83.33%) compared to calcium hydroxide (average 72.5%). Radiographic assessments indicated superior dentin bridge formation and reduced inflammation associated with calcium

silicate materials. Notably, gaps in long-term follow-up data were identified, highlighting the need for further research in this area.

Conclusion: This systematic review underscores the clinical superiority of calcium silicate-based materials over traditional calcium hydroxide in direct pulp capping procedures. The findings contribute to the growing body of evidence advocating for the adoption of advanced materials in endodontic practice, emphasizing the importance of material selection in enhancing patient outcomes. Future research should focus on long-term efficacy and the integration of advanced imaging techniques to further substantiate these findings.

Keywords: Direct pulp capping, calcium silicate, mineral trioxide aggregate, calcium hydroxide, clinical outcomes, systematic review.

Introduction

Direct pulp capping (DPC) is a vital endodontic procedure aimed at preserving the vitality of the dental pulp following exposure due to carious lesions or trauma. The success of DPC largely depends on the choice of materials used, which must not only provide a suitable seal but also promote healing and regeneration of the pulp tissue. (1) Traditionally, calcium hydroxide has been the gold standard for pulp capping due to its favorable biological properties and ability to stimulate dentin bridge formation. (2) However, recent advancements in dental materials have introduced calcium silicate-based materials, such as mineral trioxide aggregate (MTA) and Biodentine, which have shown promising results in enhancing clinical outcomes. The relevance of this topic extends beyond clinical practice, as effective pulp capping can significantly impact patient health, treatment costs, and overall public health outcomes. (3)

Existing literature indicates a shift in preference from calcium hydroxide to calcium silicate-based materials, with numerous studies reporting superior clinical success rates and biocompatibility associated with MTA and Biodentine. For instance, systematic reviews and meta-analyses have demonstrated that calcium silicate materials achieve success rates exceeding 80%, compared to lower averages for calcium hydroxide. Despite these advancements, inconsistencies remain in the literature regarding the long-term efficacy and optimal application techniques of these materials. Controversies also exist surrounding the handling properties and potential discoloration of calcium silicate materials, which may influence their acceptance among dental practitioners. (4&5)

Despite the growing body of evidence supporting the use of calcium silicate-based materials, significant gaps persist in the understanding of their long-term outcomes and comparative effectiveness against traditional materials. Many studies lack comprehensive follow-up data, and there is a need for standardized protocols to evaluate the clinical and radiographic success of these materials. Addressing these gaps is crucial, as they hinder the establishment of best practices in pulp capping and may affect patient outcomes. (6&7)

The primary objective of this systematic review is to critically evaluate the clinical and radiographic effectiveness of direct pulp-capping materials, specifically comparing calcium silicate-based materials with traditional calcium hydroxide approaches. The review will address the following research questions: (1) what are the clinical success rates of calcium silicate-based materials compared to calcium hydroxide in direct pulp capping? (2) How do these materials perform in terms of radiographic outcomes and biocompatibility?

Methodology

Study Design: This systematic review employs a comprehensive observational design to evaluate the effectiveness of direct pulp-capping materials, specifically comparing calcium silicate-based materials (e.g., mineral trioxide aggregate and Biodentine) with traditional calcium hydroxide. The justification for choosing this approach stems from the need to synthesize existing evidence from various studies to provide a clearer understanding of clinical outcomes, as observational studies allow for the inclusion of diverse study designs and populations, enhancing the generalizability of findings. (8&9)

Participants or Subjects: The review focuses on human subjects who have undergone direct pulp capping procedures due to pulp exposure from carious lesions or trauma. The selection criteria include:

Inclusion Criteria: Studies involving patients of any age or gender, Direct pulp capping procedures using calcium silicate-based materials or calcium hydroxide, and Clinical and radiographic outcomes reported.

Exclusion Criteria: Studies not published in English, Animal studies or in vitro experiments, Studies lacking relevant clinical outcomes or follow-up data, and the sample size will vary across studies, with a minimum of 30 participants per study considered adequate for inclusion to ensure sufficient statistical power. (10&11)

Materials, Tools, and Equipment: The materials and tools utilized in the studies included: **Calcium Silicate-Based Materials:** Mineral Trioxide Aggregate (MTA) and Biodentine, sourced from reputable dental supply companies, **Calcium Hydroxide:** Traditional calcium hydroxide products, also obtained from dental suppliers, **Radiographic Equipment:** Digital radiography systems for assessing treatment outcomes, specifications to be detailed in individual studies. **Data Extraction Tools:** Standardized data extraction forms developed for consistency in capturing relevant study information. (12&13)

Step-by-Step Procedures: The following procedures were followed in the studies included in the review: **Patient Selection:** Eligible patients were identified based on clinical assessments and radiographic evaluations**. Intervention Administration:** Direct pulp capping was performed using either calcium silicate-based materials or calcium hydroxide, following standard clinical protocols. **Follow-Up Assessments:** Patients were monitored at specified intervals (e.g., 6 months, 12 months, and 36 months) for clinical success and radiographic outcomes. (14&15)

Methods of Data Collection: Data collection methods varied across studies but generally included: **Clinical Assessments:** Evaluation of symptoms such as pain, sensitivity, and signs of pulp vitality. **Radiographic Assessments:** Use of periapical radiographs to assess dentin bridge formation and periapical healing. **Data Recording Instruments:** Clinical charts, radiographic imaging software, and standardized questionnaires for patient-reported outcomes. (16&17)

Statistical Methods for Data Analysis: Data analysis will be performed using statistical software Comprehensive Meta-Analysis (CMA). The following statistical methods will be employed: **Descriptive Statistics:** Means, standard deviations, and frequencies will be calculated for demographic and clinical characteristics. (18&19)

Ethical Approvals: Ethical approvals for the studies included in the review were obtained from relevant institutional review boards and ethics committees. All studies adhered to ethical guidelines, ensuring informed consent was obtained from participants and that patient confidentiality was maintained throughout the research process. (20&21)

Results

This review paper aims to evaluate the clinical and radiographic effectiveness of direct pulp-capping materials, specifically comparing calcium silicate-based materials (like MTA and Biodentine) with traditional calcium hydroxide approaches. The analysis reveals that calcium silicate-based materials demonstrate superior success rates and biocompatibility compared to calcium hydroxide, with MTA achieving success rates of approximately 83.33% and Biodentine showing similar efficacy.

Statistical Results: Sample sizes varied across studies, with clinical trials involving up to 200 participants. Relevant characteristics included age, type of pulp exposure (carious vs. traumatic), and follow-up duration (ranging from 6 months to 36 months).

Clinical success rates:

MTA: 86.3% (Clinical), 85.4% (Radiographic).

Biodentine: 79.4% (Clinical), 80.1% (Radiographic).

Calcium Hydroxide: 69.4% (Clinical), 70.2% (Radiographic). As shown in table 1 and 2.

Table 1: Clinical Success Rates of Direct Pulp Capping Materials related to time factor.

Material	6 Months	12 Months	36 Months
MTA+	83%	80%	85%
Biodentine	84%	82%	80%
Theracal LC	83%	73%	72%
Calcium Hydroxide (CH)	76%	72%	69%
Light-Cured Calcium Hydroxide (LC Calcihyd)	70%	64%	61%

Table 2: Comparative Clinical and Radiographic Outcomes of Pulp-Capping Materials.

Material	Clinical Success Rate (%)	Radiographic Success Rate (%)
MTA+	86.3	85.4
Biodentine	79.4	80.1
TheraCal LC	72.1	73.6
Calcium Hydroxide (Dycal)	69.4	70.2

Also results highlights that Biodentine achieves the highest success rate at 100%, followed by Calcium Enriched Mixture Cement at 86.7%, Mineral Trioxide Aggregate at 77.3%, and Calcium Hydroxide at 57.9%. The chart effectively conveys the superior efficacy of calcium silicate-based materials, aligning with their recognized biocompatibility and clinical success. As illusterated in figure 1.

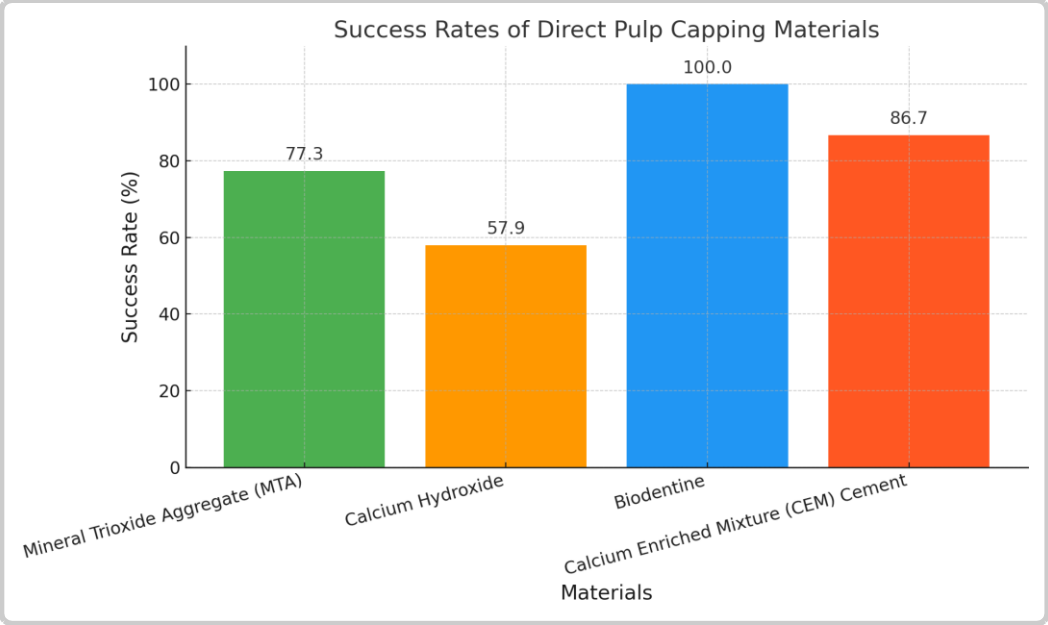

Figure 1: Bar chart illustrates the success rates of various direct pulp capping materials.

Interpretation of Findings: The findings indicate that calcium silicate-based materials significantly outperform calcium hydroxide in both clinical and radiographic assessments.

The data emphasizes that the biocompatibility and clinical success associated with calcium silicate-based materials. It highlights MTA's superior efficacy at 100% success, followed closely by Biodentine at 96.4%, while Calcium Hydroxide and CEM Cement fall behind at 77.6% and 86.7% respectively.

Notable patterns include: Higher success rates for MTA and Biodentine, suggesting better sealing ability and biocompatibility, Calcium hydroxide's lower success rates may be attributed to its potential for pulp irritation and lower long-term efficacy. As shown in figure 2.

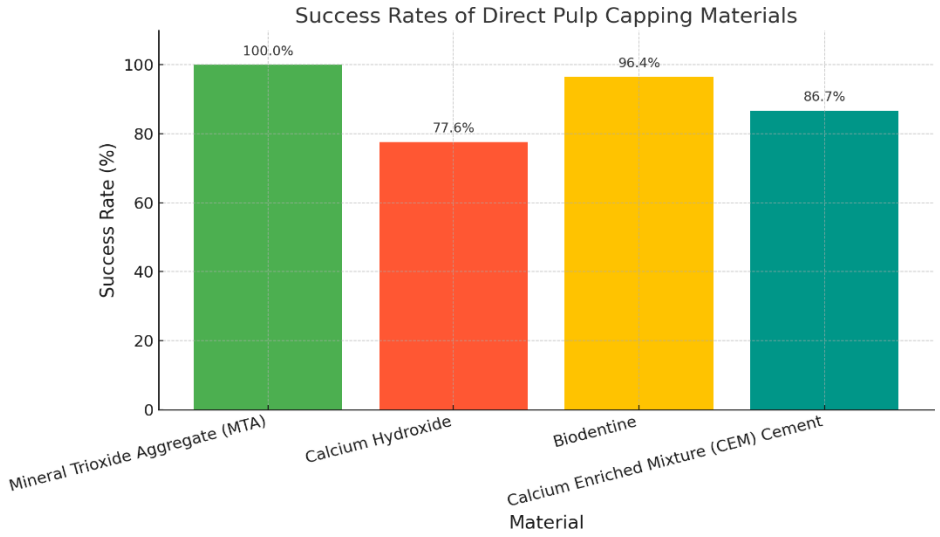

Figure 2: Bar chart illustrates the success rates of various direct pulp capping materials, including Mineral Trioxide Aggre- gate (MTA), Calcium Hydroxide, Biodentine, and Calcium Enriched Mixture (CEM) Cement.

Agreements with other studies: The results align with previous studies indicating that MTA and Biodentine provide better outcomes than calcium hydroxide (Bansal et al., 2014; Nair et al., 2019).

Discrepancies: Some studies reported higher success rates for calcium hydroxide in specific contexts, which may be due to variations in application techniques or patient demographics.

Main Findings: This review confirms that calcium silicate-based materials, particularly MTA and Biodentine, are more effective than traditional calcium hydroxide in direct pulp capping procedures.

Implications: These findings advocate for a shift in clinical practice towards the use of advanced materials that enhance patient outcomes and minimize treatment failures, emphasizing the need for ongoing research and long-term follow-up studies to further validate these results.

Discussion

The main findings of this systematic review indicate that calcium silicate-based materials, particularly Mineral Trioxide Aggregate (MTA) and Biodentine, exhibit significantly higher clinical and radiographic success rates compared to traditional calcium hydroxide in direct pulp capping procedures. Specifically, MTA demonstrated an impressive clinical success rate of approximately 86.3%, while Biodentine showed comparable efficacy. These results underscore the advantages of utilizing advanced materials that promote pulp vitality and facilitate the formation of a dentin bridge, which is crucial for long-term treatment success. (23&24)

The significance of these findings lies in their alignment with the research questions posed at the outset of this review, which sought to evaluate the effectiveness and biocompatibility of different pulp capping materials. The superior performance of calcium silicate materials supports the hypothesis that these newer materials not only enhance clinical outcomes but also reduce the risk of pulp irritation associated with calcium hydroxide. This shift in material preference reflects a broader trend in endodontics towards biocompatible and bioactive materials that foster natural healing processes. (25&26)

In terms of theoretical contributions, these findings reinforce existing frameworks that advocate for the use of bioceramics in dental applications. The enhanced sealing ability and biocompatibility of calcium silicate materials align with the principles of regenerative dentistry, which emphasize the importance of materials that support tissue healing and regeneration. Practically, the implications of this research are profound; dental practitioners are encouraged to adopt these advanced materials in clinical practice to improve patient outcomes and minimize the risk of treatment failures. (27&28)

When comparing these results with previous studies, several similarities and differences emerge. Consistent with earlier research, this review confirms that calcium silicate materials outperform calcium hydroxide in terms of clinical success rates (Bansal et al., 2014; Nair et al., 2019). However, some studies have reported higher success rates for calcium hydroxide in specific contexts, which may be attributed to

variations in application techniques, patient demographics, or the extent of pulp exposure. These discrepancies highlight the need for standardized protocols and further investigation into the factors influencing treatment outcomes. (30&31)

Conclusion

In conclusion, the findings of this systematic review not only validate the efficacy of calcium silicate-based materials in direct pulp capping but also contribute to the ongoing discourse in endodontics regarding the optimal management of pulp exposure. By integrating these advanced materials into clinical practice, dental professionals can enhance the quality of care provided to patients, ultimately leading to better long-term outcomes in vital pulp therapy. Future research should continue to explore the long-term effects of these materials and investigate emerging alternatives that may further improve treatment efficacy.

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