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Review Article

A Review on Dental Material with Regard to Biocompatibility Properties

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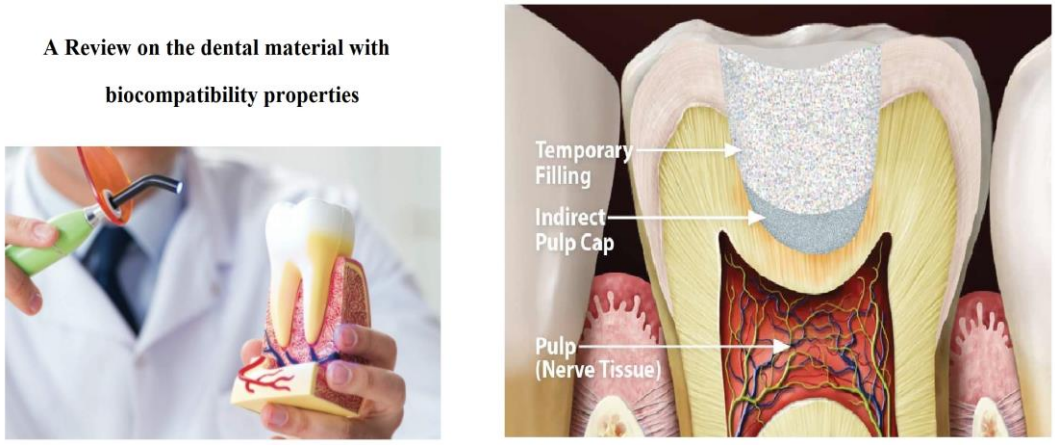
ABSTRACT

The use of dental materials in the human mouth is not possible except by relying on physiological, biological, pathological studies and the study of physical, mechanical, and chemical properties. Pulp capping is a treatment to deal with cases of reversible pulpitis that initiates the formation of reparative dentin so that vitality and tissue function can be maintained. The use of mineral trioxide aggregate (MTA) as a pulp capping material has shown promising results in clinical trials. The success of pulp capping treatment can be seen from reparative dentin formation through histological examination. The aim is to determine the potential use of MTA as a pulp capping material against reparative dentin formation. Secondary data from several search engines such as ProQuest, Taylor and Francis, PubMed, and Wiley appropriate with keywords were obtained through 334 journals. Journals were filtered and identified by title, abstract, and keywords with a total of 28 journals; then, they were re-filtered by considering the complete contents yielding five journals. All the research journals reviewed in this literature revealed that pulp capping with MTA on permanent human teeth could form reparative dentin. One research journal only investigated the absence of reparative dentin; two other research journals used the location of the formation of reparative dentin against medicament.
In contrast, the other two journals utilized the thickness of reparative dentin as the assessment criteria. MTA as pulp capping material for reversible pulpitis treatment can form reparative dentin that could be seen from the histological examination. The quality of reparative dentin can be evaluated based on the thickness of the reparative dentin and the location of the reparative dentin formation against pulp capping material.

GRAPHICAL ABSTRACT



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Introduction

People often visit dentists when they are suffering from an illness [1, 2]. Indonesia Health Data Profile 2010 revealed that pulp and periapical diseases are found in the 7th of the ten most common diseases of outpatients in Indonesian Hospitals [3-6]. According to the Health Profile of Surakarta in 2014, the prevalence of pulp abnormalities and periapical tissue was 16,186 cases (2,56%) from the data of outpatient disease patterns in Surakarta Community Health Centre [4-9]. However, the distribution data of pulp disease remain obscure.

Ingle's pulp disease classification comprises reversible pulpitis, irreversible pulpitis, and pulp necrosis. The pulp in reversible pulpitis undergoes mild to moderate inflammation, which if it is given proper treatment, the pulp could be saved. Clinically, reversible pulpitis is characterized by the absence of spontaneous pain that will disappear if the stimulus is eliminated [10–13]. The etiology of reversible pulpitis is caries, trauma, and iatrogenic in dental procedures that cause pulp exposure [14].

Pulp capping is a treatment for reversible pulpitis to keep the pulp vital and maintain its function. That treatment could form reparative dentin from odontoblast-like cells that differentiate from pulp stem cells. Calcium hydroxide is a golden standard material for pulp capping, but calcium hydroxide has some flaws [15]. Mineral Trioxide Aggregate (MTA) is a pulp capping material deemed correct for the deficiency of calcium hydroxide. The success rate of MTA as pulp capping material is very satisfying, which may reach 90% [16]. MTA has osteoinduction ability, which can induce stem cells from the pulp to be able to differentiate [17, 18]. Compared to calcium hydroxide, reparative dentine formation in MTA is faster, and the occurrence of inflammation is lower [19, 20]. Reparative dentin formation is a success indicator of the pulp capping treatment [21].

Reparative dentin is represented by a dentin bridge that can be assessed through histological examination [22]. The histological examination provides information on inflammatory cell response, tissue necrosis, and hard tissue formation [23]. Histology examination results can be analyzed to observe and evaluate the quality of reparative dentin [24]. Dentin quality can be seen from the place of the reparative dentin formation against the material, the thickness of the reparative dentin, and the reparative dentin formation as per criteria previously set [24, 25].

This literature review aims to understand the potential use of mineral trioxide aggregate (MTA) as pulp capping material against the formation of reparative dentin reviewed from the histological aspect.

Literature Review

Pulp

Pulp is a connective tissue encompassing nerves, blood vessels, essential substances, interstitial fluids, odontoblasts, and fibroblasts [26]. Based on [19], histologically, the pulp has four zones from the periphery to the core, *odontoblast layer, cell-free zone of Weil, cell-rich zone,* and pulp core. Pulp serves several functions such as induction function, formation, nutrition, self-defense, and nutrition [27].

Reversible Pulpitis

Reversible pulpitis is a mild to moderate inflammatory condition in the pulp caused by a condition that can damage tissue. In reversible pulpitis, the pulp may return to normal condition after stimulation is removed [26].

Based on [19]**,** Reversible pulpitis etiology is the irritation of the pulp to external stimulus related to dentin permeability. Normally, enamel and cementum act as barriers that cover the permeable tubules of dentine. However, when caries and iatrogenic errors damage the natural barrier, the tubules in dentin will become permeable. External fluid may enter the open tubules and cause pulp pain and irritation. Agents that can prompt pulp injury are trauma due to accident or occlusion trauma, thermal injury (overheating in preparing teeth and smoothing restoration), and chemical stimulus of sweetness or acidic food.

Signs and symptoms of reversible pulpitis include sharp pain that is not spontaneous. Pain occurs if there is stimulation, deliberate, and does not continue after the stimulation is eliminated. Pain stimuli are often originated from food, cold water, and cold air [121].

Pulp Capping

Pulp capping is a treatment to deal with reversible pulpitis cases. The purpose of pulp capping is to initiate reparative dentin formation so that vitality and tissue function can be maintained [15]. In the pulp capping treatment, hard tissues and soft tissues infected with bacteria must be removed and covered with restoration material so that the bacteria cannot permeate deeper tissue [28, 29].

Indications of pulp capping are exposure by the pulp in less than 24 hours, trauma, or iatrogenic factor. The pulp capping is performed on permanent teeth requiring simple restoration, no bleeding, or minimal bleeding on the exposed pulp area. Contraindications of pulp capping treatment are widely exposed pulp, spontaneous pain, pulp bleeding, and radiography results indicating the presence of pathology in the apex area [119].

One of the criteria to characterize the success of pulp capping is asymptomatic, and the tooth gives a good response in sensibility tests such as the electric pulp test (EPT). Pulp capping is considered successful when the condition of lamina dura is good, there is no periodontal space widening, and there is no visible radiolucent area in the periapex on radiography examination [30]. On histology examination, an odontoblast-like cell will be seen covering the exposure site on pulp that differentiate to reparative dentin [31].

Pulp Capping Material

The material must be biocompatible, bioactive, antibacterial, and can form apatite [32]. The material must stimulate hard tissue repair, as shown by the formation of reparative dentin and the ability to cover the pulp chamber to prevent the entry of bacteria from the oral cavity, so the vitality of the pulp could be maintained [19, 33].

Mineral Trioxide Aggregate (MTA)

Mineral trioxide aggregate (MTA) is a mixture of tricalcium silicate, calcium silicate, tricalcium aluminate, and calcium oxide with bismuth oxide in ratio 4: 1 [30]. MTA is available in 2 colors, white MTA and gray MTA. *Mineral Trioxide Aggregate* (MTA) shows a good result in clinical trials as a pulp capping treatment [34]. MTA has good biocompatibility, and attachment between MTA and dentin is adequate. MTA may stimulate the proliferation of hDPCs (human dental pulp cells) and differentiate odontoblast-like cells. MTA stimulates fewer inflammatory reactions and induces thicker dentine bridges [35].

Mineral trioxide aggregate (MTA) placed over the pulp exposure area may initiate a healing response and maintain pulp vitality. Manipulation is conducted by mixing MTA powder with sterile water to a putty-like consistency. The MTA is placed over the exposure site after the teeth are disinfected using sodium hypochlorite. The area is patted using cotton pellets and sealed [19].

Reparative Dentin

Reparative dentin is formed due to the regeneration and repair of hard tissue in the pulp dentin complex in response to the natural healing of teeth when primary odontoblasts death [36]. Reparative dentin serves as a biological seal to protect the pulp tissue underneath and maintain the vitality of the pulp [16]. Reparative dentin is formed by calcifying odontoblast-like cells that differentiate from stem cells after primary odontoblast cells die. Most of the reparative dentin has tubules, irregular and localized in the injury area [19, 27, 37]. Dentinal bridges are formed near the columnar cells of the pulp tissue, with a polarized nucleus that indicates the formation of odontoblasts cells [23]. Histological analysis is employed to assess the quality of reparative dentin and inflammatory cells reaction [24]. Histological examination results are evaluated based on the type and degree of pulp inflammation, formation of reparative dentin, and the incidence of necrosis [34].

Result and Discussion

The entire research journal in this literature review showed that pulp capping with trioxide aggregate mineral (MTA) performed on permanent human teeth could form reparative dentin. Based on the journal by [32, 38], reparative dentin formed 14 days after treatment.

Research journals reviewed in this literature review used several criteria in evaluating reparative dentin. The research journal [39] only probed the presence or absence of reparative dentin in the research journals conducted by [31, 38]. They used the location of the formation of reparative dentin against medicament. Pulp capping with MTA could induce reparative dentin on surfaces that are in direct contact so that the reparative dentin formed near the medicament material is assumed more proper. The exposed pulp can be covered by reparative dentin more quickly and more completely. This condition is shown in Figure 1. This finding is in accordance with the research journal by [22], which used MTA as a pulp capping material, dentinal bridge form near the capping material in all specimens that were evaluated after three months.

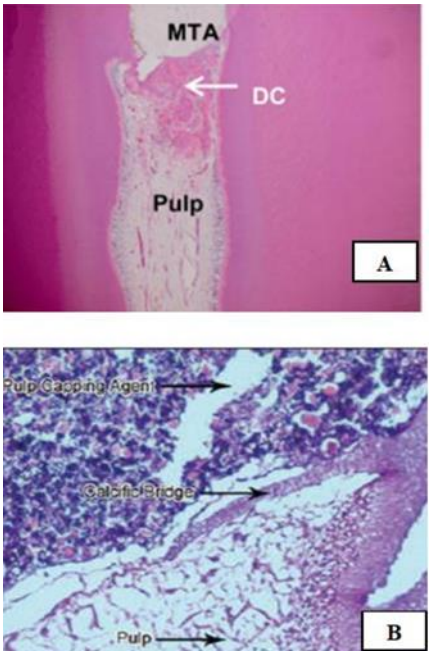

Figure 1: The dentinal bridge is formed directly adjacent to the capping material (MTA) in Figure A (top) [27], while in Figure B (bottom), it can be seen that there is a gap or distance between the dentinal bridge and the capping material [31]

In research by [32, 34], the reparative dentin evaluation was administered by measuring its thickness. The thicker reparative dentin formed, the higher the success rate of the treatment would be. The thickness of reparative dentin will increase over time. These findings correspond to the journal by [32], reparative dentin at 8th week was thicker than at 2nd week. This research [31] also mentioned that reparative dentin on the 45th-day evaluation was thicker than the 15th day.

Both materials used in journals reviewed in the literature review could form reparative dentin. However, MTA has several advantages over other materials. In the study's results examined by [34], the MTA group showed an incidence of inflammation lower than another experimental group. Also, MTA could form reparative dentin, which was thicker and faster than calcium hydroxide, so that in clinical evaluation, teeth treated with MTA could heal faster. This finding is shown in Figure 2.

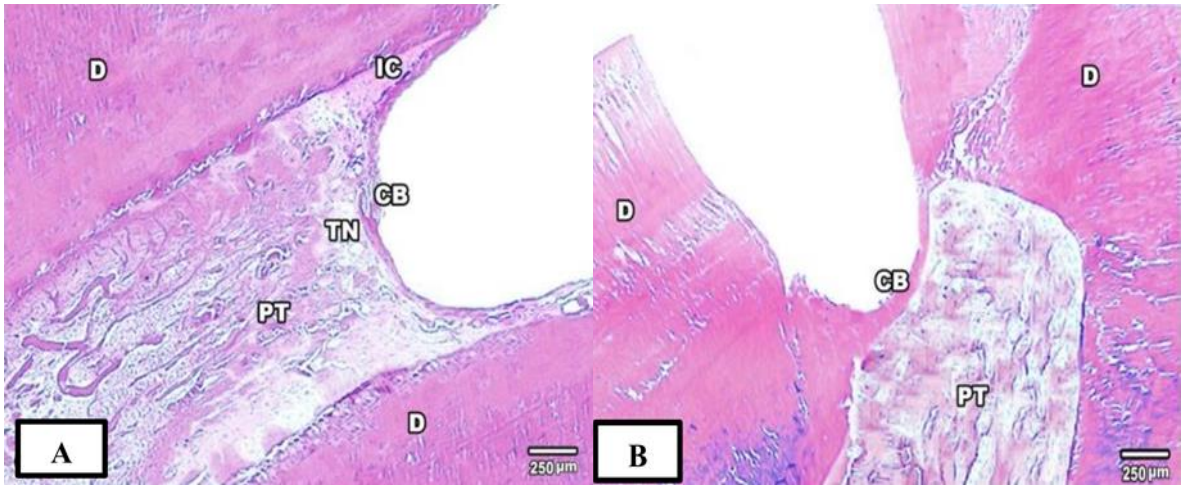

Figure 2: Comparison of reparative dentin thickness during three months evaluation after pulp capping treatment between calcium hydroxide material (top) and MTA (bottom). D is dentin, PT is pulp tissue, CB is the calcific bridge, IC is inflammatory cells, and TN is tissue necrosis [23]

Figure 2 shows that the reparative dentin in the MTA group was thicker than the calcium hydroxide group. In the calcium hydroxide group, necrotic tissue and inflammatory cells were seen, whereas, in the MTA group, there was no necrotic tissue seen.

Pulp capping with MTA can induce fibrodentin and reparative dentin on surfaces in direct contact with MTA [34]. Calcium oxide in MTA reacts with tissue fluid to form calcium hydroxide [40]. Calcium ions released by calcium hydroxide from MTA can stimulate fibronectin synthesis, initiating stem cell differentiation [41]. Calcium hydroxide from MTA also reacts when it encounters carbon dioxide from the pulp tissue and produces calcium crystals. Fibronectin and fibrin contact calcium crystals can accelerate cell migration, proliferation, and adhesion in synthesizing fibrodentin matrix [42].

The formation of reparative dentin begins with the formation of a fibrodentin matrix, which is tubular and irregular [37]. The fibrodentin matrix is a fibronectin-rich matrix that serves as a reservoir growth factor-like TGF-β and inductive molecules in odontoblast-like cells differentiation [42]. Odontoblast-like polarized and elongated cells will secrete a tubular dentin-like matrix that mineralizes into reparative dentin [43]. The newly formed reparative dentin is of uneven thickness with a normal-looking pulp, minimal inflammation [44]. On histological examination, reparative dentin is irregular, tubular, and localized at the exposure site. There are fewer tubules in reparative dentin than tubules in primary or secondary dentin [37, 43]. The tubules of reparative dentin can be seen in Figure 3.

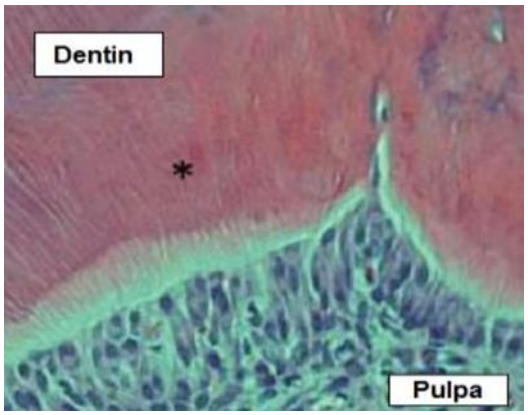

Figure 3: Dentin tubules on reparative dentin are shown by an asterisk symbol [45]

Conclusions

Mineral trioxide aggregate (MTA) as pulp capping material for reversible pulpitis treatment can form reparative dentin that could be observed from the histological examination. The quality of reparative dentin can be evaluated based on the thickness of the reparative dentin and the location of the reparative dentin formation against pulp capping material. The results of this study indicated that the pulp capping with MTA can induce fibrodentin and reparative dentin on surfaces in direct contact with MTA.

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Authors' contributions

All authors contributed toward data analysis, drafting and revising the paper and agreed to responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

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