Review Article

DENTAL PULP RESPONSE TO MTA, CEM AND BIODENTINE AS PULP CAP MATERIALS (REVIEW OF EVIDENCE)

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Abstract

Aim: dental pulp therapy is one of the therapeutic options for preserving the pulp after the exposure by trauma or caries. The pulp capping methods mainly relies on the ability of the pulp tissue to heal. A wide range of materials are used to cover the pulp. The purpose of this review is to evaluate the response of dental pulp to direct pulp cap treatment with MTA, CEM and Biodentine as the material.

Methods: This study was a review study to evaluate the response of dental pulp to direct pulp cap treatment with MTA, CEM and Biodentine. The search was conducted on Google, Google Scholar, and Pubmed. The criteria for entering the articles were: laboratory study, clinical practice, review articles and etc. in English. No time limit applied.

Conclusion: It is imperative that a dentist be aware of the characteristics of an ideal pulp cap treatment material, and uses the appropriate pulp material while treating pulp with pulp cap techniques. Evidence has shown that Biodentine and CEM have similar efficacy to MTA for direct pulp coverage.

Key words: *Pulp cap treatment, MTA, CEM and Biodentine.*

Introduction

One of the goals of dental treatments is to maintain the pulp vitality with covering the healthy pulp.[1] Direct pulp capping of the pulp involves placing a biocompatible materials on the pulp tissue that is exposed to traumatic or iatrogenic lesions.[2,3] The purpose of the treatment is to maintain healthy pulp by sealing the pulp tissue against bacterial infiltration and forming a dentine bridge at the exposed site.[2] The purpose of direct pulp capping treatment is to seal the pulp and prevent bacteria and stimulate leakage, blockage of the exposed area by the stimulating to form a dentine bridge and maintain the survival of the pulp.[4]

Direct pulp capping was first introduced in 1756 by Phillip Pfaff; he used a piece of gold foil as a pulp capping material on an exposed pulp.[5,6] In 1923 Davis suggested use of a mixture of zinc sulphate and calcium sulphate with zinc oxide as a pulp capping material.[4]

Decision to perform direct pulp cap treatment should be decided only after careful examination of the patient's symptoms, performing diagnostic tests, considering patient's age and the size of the exposed area. To examine the pulp condition, the dentist should look at the physical appearance of the exposed pulp, radiographic evaluation, and lack of symptoms indicating of irreversible pulpitis. In case that the microleakage of the bacteria is prevented, the exposed pulp has the ability to heal and respond positively. The material used in direct pulp capping should be biocompatible, have high sealing and preventing bacterial infiltration ability and do not dissolve over time. According to Cox *et al*., The recovery of pulp does not depend on the type of coating material, but the ability of the material to seal and the prevention of bacterial penetration. In presence of microleakage, the inflammation will continue to persist and recovery will not be observed.[4]

Long-term clinical studies show that direct pulp cap treatment can provide a success rate of 80% to 90%. These figures are comparable to the success rate of root canal treatment, which is expected to be 85% to 90%.[2]

Various materials have been used for pulp cap treatment such as calcium hydroxide, collagen, bonding material, calcium phosphate, hydroxyapatite, lasers (CO2), glass ionomer, resin modified glass ionomer, Mineral trioxide aggregate(MTA), MTYA1-Ca, growth factors (BMP, Insulin Like Growth Factors- I, etc.), Bone sialoprotein, pseudo-enzymes, stem cells, , Calcium enriched mixture (CEM), Enamel Matrix Derivative, proteins associated with Amelobasts, Castor Oil Bean cement, Portland cement and Biodentine.[7,8]

Mineral trioxide aggregate (MTA) is calcium silicate hydrophilic cement. Biocompatibility and bioactivity have been reported in In-vivo and in-vitro studies. For this reason, it is used as a common biomaterial for various endodontic treatments, such as: pulp cap treatment, regeneration, root perforation repair, apexification and root filling material (9).
Subsequently, Calcium enriched mixture (CEM) was introduced; a cement containing various calcium compounds, including calcium silicate and calcium phosphate, with a clinical application similar to MTA. It has been shown that CEM liberates calcium hydroxide and calcium silicate on hydration, in a manner similar to that seen in MTA, indicating bioactivity and odontogenic differentiation potential of this substance.[9]

Biodentine has been introduced as a dental restorative agent and only recently has been used for direct pulp capping. Biodentine is a calcium silicate-based restorative cement with dentin-like mechanical properties. This material increases the formation of restorative dentin in areas with direct contact to the pulp tissues.[2,10]

The purpose of this review was to evaluate the response of dental pulp tissue to direct pulp cap treatment with MTA, CEM and BIODENTIN.

Method

This research is a review study to evaluate the response of dental pulp tissue to direct pulp cap treatment with MTA, CEM and Biodentine. Data base used for this research was Google site, Google scholar, and Pubmed by using the keywords of pulp capping materials, direct pulp capping, sealed dental caries, Mineral Trioxide Aggregate (MTA), Calcium enriched mixture (CEM), Biodentine and pulpotomy. Articles related to the subject reviewed then selected and the necessary information were collected, categorized and presented. The criteria for entering the articles were: experimental studies, clinical trials, review articles and etc. in English. No time limit applied.

Results

An ideal material for a pulp cap treatment should have the following characteristics.

- Stimulating the formation of restorative dentine
- Maintain pulp vitality
- Fluoride release to prevent secondary caries
- Bactericidal or bacteriostatic
- Bond to dentin
- Bond to restorative materials
- Resist forces during restoration.
- Be sterile
- Radiopaque
- Have a bacterial seal [5,8]

Advantages and disadvantages of MTA, CEM and Biodentine as direct pulp materials are presented in table 1.

Pulp Capping Agent	Advantages	Disadvantages
Biodentine	• Biocompatible • Good antimicrobial activity. • Stimulate tertiary dentin formation • Stronger mechanically, • Less soluble and produces tighter seals compared to Ca(OH)2 • Less setting time, good handling characteristics than MTA	• More long-term • clinical studies are needed for a definitive evaluation of Biodentine
MTA	• Good biocompatibility • Less pulpal inflammation • More predictable hard tissue barrier formation in comparison to calcium hydroxide • Antibacterial property • Radiopacity • Releases bioactive dentin matrix proteins	• More expensive • Poor handling characterstics • Long setting time • Grey MTA causes tooth discoloration • Two step procedure • High solubility
CEM	• Economical • Shorter setting time • Good handling characteristics • Better flow • Less film thickness and • Ability to form hydroxyapatite • Cementogenesis	Not mentioned

Table 1: Advantages and disadvantages of MTA, CEM and Biodentine as direct pulp materials.[5,11]

Mineral Trioxide aggregate

MTA was discovered by Torabinejad in 1993 at the University of Loma Linda in the United States. MTA is widely used in dentistry and especially in endodontic treatments. MTA is used as a pulp-capping material, a root filling material, and a perforation restorer.[12,13] This cement consists of *dicalcium silicate, tricalcium silicate, tricalcium aluminate and tetracalcium aluminophosphate*. Two types of white and grey MTA have been introduced, that are similar to white and grey Portland cements beside presence of bismuth oxide in MTA, which is a radiopaque substance. The main difference between two types of MTA is the amount of some compounds, especially iron oxide. The cement consists of a hydrophilic powder that hardens in the presence of moisture. When this cement is mixed with water, the colloidal gel created has a setting time within 4 hours after which a hard and resistant substance will be formed. The initial pH of the mixture is 10.2, which increases to 12.5 after 3 hours of mixing. Calcium hydroxide is the most important compound that releases from MTA in water. The formation of calcium hydroxide, in addition to coagulation necrosis and dystrophic calcification, which is induced after subcutaneous placement of MTA, also justifies by its high pH. MTA is a bioactive substance on bone marrow cells and stimulates the production of interleukin due to its alkaline pH and the release of calcium ion.[14]

The original MTA was originally introduced in grey, which caused a change in color of the tooth after its application and created concerns about the esthetic results of treatment using this material. This material was then presented with a tooth-colored formulation also known as white MTA. The crystalline structure as well as the chemical properties and mechanism of the effect have not changed much between two types of MTA, although higher concentrations of aluminum oxide, magnesium oxide and iron oxide in grey MTA leads to significant coloring of the teeth.[13,14]

Experimental studies have shown that MTA not only does not induce apoptosis in pulp cells but induces proliferation of pulpal cells.[15]

Animal studies have shown that when MTA is used as a direct cap material, it maintains pulp vitality and integrity and hard tissue formation compared to calcium hydroxide and other coating materials.[16]

Initial human studies were in the form of a case reports and limited to intact teeth with healthy pulp, which were candidate to extract for other treatments. The histological evaluation in these studies showed that MTA induced less inflammation, hyperemia and necrosis, better formation of odontoblastic layer and create a thicker dentin bridge, compared to calcium hydroxide.[17]

In a clinical trial performed by Eghbal *et al*., 14 permanent molar teeth with caries exposure of the pulp, self-sustained and delayed pain and with diagnosis irreversible inflammation of the pulp, were selected. Patients were in the range of 16 to 28 years old. A pulpotomy was

performed, a pulp cap material was placed and after two months the teeth were prepared for a histological examination. The results showed that none of the patients experienced post-treatment pain. Histological examination showed formation of dentin and presence of healthy and non-inflammatory pulp in all patients.[18]

Daniele *et al*. performed a clinical study on 77 patients between the ages of 14 and 68 (80 teeth) that required direct pulp cap treatment. Teeth were treated by MTA and after 10 years of follow-up. The results showed that dentin formation was observed by radiography in 27.5% of cases, and the normal thickness of the periodontal ligament (PDL) was observed in all the teeth. Some of the teeth were showed a change in color related to treatment with grey MTA. No sign of pulp calcification, root canal resorption and endodontic lesions was seen. Also all the teeth were vital.[19]

Yasini *et al*. evaluated the clinical success of direct pulp capping treatment with calcium hydroxide and MTA on 18 posterior teeth. After follow-up of 3 and 12 months results showed that MTA is a biocompatible material, stimulates dentine formation and provides a good Seal as an alternative to calcium hydroxide and it is recommended for direct pulp capping.[4]

Calcium Enriched Mixture (CEM)

CEM was introduced in 2006 by Asgari.[11,14] As the name implies, this cement is made up of various compounds such as CaO, SO3, P2O5 and SiO2 with small amounts of Al2O3, Na2O3, MgO and Cl.[20]

The antimicrobial effect of CEM cement was compared with calcium hydroxide which is considered to be one of the best materials to be used in infectious root canals, as well as with MTA as one of the best materials used in professional dental treatments and Portland cement. The results have shown that CEM has an antimicrobial activity against bacteria such as Pseudomonas aeruginosa, Enterococcus faecalis, Escherichia coli and Staphylococcus aureus, and has an antimicrobial activity similar to calcium hydroxide and better than MTA and Portland cement. Also, the antifungal effects of MTA and CEM on Candida Albicans have been compared and it has been shown that both of these substances eliminate any fungal contamination after 24 hours.[21]

A study of CEM microleakage and its comparison with IRM and three types of American, Brazilian and Iranian MTA as root-end filling materials in various environments has been done. Research results have shown that the highest sealing ability was seen in CEM, then MTA and the least seal was in IRM. Sealing ability by CEM and MTA was significantly higher than IRM.[21]

The cytotoxicity of CEM with MTA has been compared on L929 fibroblast cells using MTT technique and on the human gingival fibroblasts using electron microscope. The results of these studies have shown that the cytotoxicity of CEM and MTA is similar, but both materials are significantly better than IRM.[21]

Comparison of CEM, MTA and calcium hydroxide as a pulp cap material indicate that CEM and MTA induced dentin formation with higher velocity and better structural integrity, but calcium hydroxide did not form a complete dental bridge.[21]

CEM has the ability to produce hydroxyapatite crystals on its surface in a normal saline environment. The crystalline structure of this hydroxyapatite is similar to that of standard hydroxyapatite crystals. This characteristic does not exist in the MTA. Therefore, it can be concluded that the CEM ingredients contains of chemical elements required to form hydroxyapatite crystals in contrast to MTA. In addition, CEM, produces more amounts of hydroxyapatite in a medium similar to Interstitial fluid.[21]

A study regarding physical properties of CEM in comparison with MTA shown that the operating time and dimensional changes of CEM and MTA were similar. Setting time in CEM was shorter, the flow rate was higher, and the film thickness was less than MTA.[21]

Asgary *et al*. used MTA, CEM, and calcium hydroxide as a direct pulp cap material in dog teeth, and they reported the formation of complete dentin in all samples covered with CEM. They reported that CEM have biological properties similar to MTA.[22]

Fallahinejad Ghajari *et al*. performed a clinical trial using MTA and CEM as a direct pulp cap material in the preliminary teeth. After 6 months, the clinical success rate was 94.8% in the CEM group and 100% in the MTA group. The formation of dentin bridge was not observed in any of the two groups.[23]

Biodentine

Biodentine was introduced by the Septodont's Research Group.[8,24] and was commercially available in 2009. It was specifically designed as a replacement for dentine. Biodentine has a wide range of applications such as endodontic treatments (perforated root, apexification, restorative and retrograde restorative material in endodontic surgery) and pulp capping material and can be used as a replacement dentin in restorative dentistry. This material has been formulated as a MTA-based cement but improved some of the properties of MTA, such as physical properties and handling.[25]

Biodentine contains tricalcium silicate, dicalcium silicate, calcium carbonate, iron filler, ferrus oxide and zirconium oxide. Tricalcium silicate and dicalcium silicate are respectively the main and second material, while zirconium oxide acts as a radiopaque ingredient. On the other hand, the liquid contains calcium chloride as an accelerator and a hydrosoluble polymer acting as a water reducing agent. It is also mentioned that it has a fast setting time and increased particle size. The setting time of this material is 9-12 minutes. This shorter setting time is an improvement compared to other calcium silicate materials. It is

characterized by release of calcium in solutions. Tetracalcium silicate materials are also defined as hydroxyapatite sources.[25]

Tran *et al* treated exposed pulp by Biodentine and calcium hydroxide and then assessed the dentin bridge formation in each material. They noted that the structure induced by calcium hydroxide contains several cells called inclusion, formerly known as tunnel defects reported by Cox *et al*. (1996). These defective areas, as undesirable areas, facilitate the migration of microorganisms to the pulp and lead to endodontic infections. On the contrary, the formation of a dentine bridge formed by Biodentine showed a well-localized pattern in the affected area, unlike calcium hydroxide. The dentine quality was also better compared to calcium hydroxide. Odontoblast organization was also better in Biodentine and dentine tubules were clearly visualized.[26]

Nowicka *et al*. evaluated the response of the pulp-dentin complex to direct pulp capping with MTA and Biodentine on human molars in a clinical study. The results showed that after 6 weeks, the majority of the samples formed a complete dentin bridges and no inflammatory response of the pulp was seen. The layers of Odontoblast and Odontoblast-like cells formed in the form of dentin tubes under osteodentin. There was no significant difference between the Biodentine and MTA groups during the period. Therefore, Biodentine has the same efficacy of MTA in the clinical treatments and can be used as a substitute for direct pulp cap methods. The formation of a complete dentin bridge and no inflammatory response were the main findings of this study.[10]

Nowicka *et al*. in another study evaluated the pulp response to MTA and Biodentine in direct pulp cap treatment. Their results showed that Biodentine was better than MTA in terms of dentin formation. They concluded that forming a dentine bridge in pulp after direct pulp cap treatment depends on the type of capping material.[27]

Shayegan *et al*. conducted a study that evaluated the response of pulp of pigs to Biodentine when treated after pulpotomy in 7, 28 and 90 days follow-up. Their results indicate that Biodentine has bioactive characteristics, it repairs hard tissues and does not induce any moderate to severe pulp inflammation. They also pointed out that this material had the ability to maintain a marginal integrity due to the formation of hydroxyapatite crystals that could increase sealing ability. Due to its excellent sealing ability, there is no risk of microleakage that causes the pulp to be infected or necrosis and does not endanger the success of vital pulp therapy.[28]

Zanini *et al*. Evaluated the biological effect of Biodentine on mouse pulp cells by analysing the expression of several biomolecule markers after the culture of OD-21 cells with or without Biodentine. Their results, in accordance with other studies, were in favour of Biodentine, due to its ability to increase the proliferation of OD-21 and biomineralization.[29]

Jalan *et al*., In a clinical study on 45 human premolar teeth, showed that after 45 days of direct pulp cap with Biodentine and calcium hydroxide, dentin bridge in the teeth coated with Biodentine were consistently thicker and more continuous and had less dentinal inflammation was see in Comparison with calcium hydroxide.[2]

Conclusion

Direct pulp cap should only be done when the pulp does not show irreversible pulpitis symptoms. MTA, CEM and Biodentine have mainly shown similar effects as a direct pulp cap material and can replace each other in treatments.

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