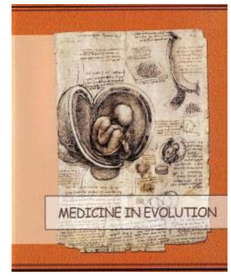
Biomaterials currently used in pulp capping treatments



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Abstract

Dental pulp capping is a treatment for deep carious lesions that affect a great part of the enamel and dentin structure, although the pulp remains vital. Failure of pulp capping leads to loss of pulp vitality and endodontic treatment. Therefore, the need for dental materials that can induce tertiary dentin formation, are biocompatible and can obtain an efficient seal, is obvious. A material that has all these properties can lead to a greater success rate for pulp capping treatments. Does it exist? What does the scientific literature say about this topic?

This article provides information about 4 modern biomaterials used for pulp capping treatments: Calcium Hydroxide, TheraCal LC, MTA and Biodentine, aiming to aid the practitioner in choosing wisely between materials.

Keywords: liners, pulp capping, biocompatibility

INTRODUCTION

A biomaterial is a natural or artificially induced material that once introduced in a living tissue acts like a medical instrument. [1] It is used to guide and control a therapeutic action into the tissue that makes contact with, alone or part of a more complex system. [2]

Materials with unique properties that can be used in direct contact with the living tissue without rejection from it, can be considered biomaterials. [1] They are used in all medical fields including dentistry, from oral surgery to paedodontics.

During dentistry's history, biomaterials have been of great focus. Some decades ago, amalgam was considered a promising biomaterial, now we can talk about materials that can induce healing of pulp inflammations.

The research community's concern regarding biomaterials has changed through time. The attention was varying between durability, aesthetics, toxicity. Nowadays one of the most asked questions is: which has a greater biocompatibility?

Biomaterials possess properties that advocate for minimally invasive dentistry by preservation of hard dental tissue and pulp. [3,4]

Calcium Hydroxide pastes, TheraCal LC, Mineral trioxide aggregate (MTA), Biodentine are among the most used biomaterials in pulp capping. The current paper will focus on these four liners, on their properties, advantages and disadvantages. According to an accepted definition, the liner is a cement or a resin covering layer, of approximately 0.5 mm, that acts as a barrier against bacteria and has also has a therapeutic effect. [5]

Calcium Hydroxide - $Ca(OH)_2$

First proposed as a liner in 1930, by Hermann, this material was used before only for root canal treatments, having antibacterial properties. Hermann noticed its potential of forming dentin bridges and advocated then the idea of using calcium hydroxide as a pulp capping material.

Since then, calcium hydroxide has been considered the golden standard in vital pulp therapies. [6,7] It has a proven antibacterial effect, stimulates tertiary dentin formation and it is biocompatible in relation to the dental pulp. Until now, it is the most frequently used liner.

Chemically speaking, this material is a strong base, obtained by heating calcium carbonate until it transforms into an oxide. Pure calcium hydroxide is a white powder with a high pH (12.6), that dissolves in water. Research has shown that a basic pH neutralizes the lactic acid from the osteoclasts, thus stopping the demineralization process of the dentin. Meanwhile, the same pH activates the alkaline phosphatases that are responsible for hard tissue formation. [8] Calcium hydroxide's effect on dentin has been proved to be the formation of mineral crystals in the dentin tubules. [9]

Calcium hydroxide properties reside in the interaction of its dissociated ions with the tissues and bacteria. Hydroxyl ions destroy the cytoplasmic membrane of the bacteria cell, stimulates protein denaturation and destroys the bacterial DNA. Its high pH is usually associated with the antimicrobial effects. [3,7,10]

Holland et al. suggested that this material acts the same way upon dentin as it acts on pulp tissue.[9] Because of its low molecular mass, $Ca(OH)_2$ can penetrate through the dentin tubules and can reach the pulp, explaining its effects even in indirect pulp capping.

The most known form of presentation is as a paste, but the powder and saline water formula is considered to be more efficient.

The newer light cured calcium hydroxide pastes are trying to overcome some of the old paste's disadvantages like reduced compressive strength, dissolution, adhesion to other materials. These pastes also contain resin so the scientific literature did not agree on its beneficial status over the conventional $Ca(OH)_2$ paste.

$Ca(OH)_2$ main disadvantages are [3,4,7,8,11,12]:

- Reduced compressive strength
- Low elastic modulus
- Thermal conductivity when set in a thin layer as in capping
- Needs a second material as a base to cover it up, besides the final restorative material
- Water and acid high solubility
- Its properties disappear in time
- Dissolution in time
- Does not adhere to most of the other dental materials it takes contact with, or dentin
- When used in primary teeth, it may produce a faster root resorption
- Does not inhibit the formation of bacterial biofilm
- Some of the formed dentine bridges are discontinued or have defects, tunnels fail to provide a hermetic seal leading eventually to pulp inflammation.

TheraCal LC

TheraCal LC (Bisco, USA) is a light cured resin modified silicate, being considered a formula between $Ca(OH)_2$/MTA/resin light cured $Ca(OH)_2$. Though most practitioners associate it with $Ca(OH)_2$ pastes, its composition is more similar to that of MTA.[13]

It is composed of the primary mineralogical phases of Portland Cement type III, thickening agents, resin, bismuth oxide, barium sulphate. It is considered a 4th generation calcium silicate and according to ISO 9917-2017 part 2, clause 4.1 – a class II cement. [12]

It is commercialized in syringes as a single paste, and it does not require mixing. This format allows for easy handling and it does not have a short working time, being a light-cured material.

Because of its unique composition, a combination of calcium hydroxide and Portland Cement to which resin is added, the material can not fit in any of these categories. However, there are many debates on this product. One of the most significant debates is about the resin component that can produce a harmful amount of heat, that makes it unwise to be used near or in contact with the living pulp tissue. The manufacturer conversely insists that the heat generated by the resin is in a small amount and is not dangerous to the pulp if it is placed in layers of 1 mm, light cured for 20 seconds each. Those that endorse the use of TheraCal LC claim that the newest composition of the material does not contain Bis-GMA monomer, the monomer that is actually harmful to the pulp. [12]

TheraCal LC has a remineralizing potential. This property makes it useful in the partial caries removal techniques used in minimally invasive dentistry nowadays. The potential to form crystals similar to hydroxyapatite advocates also for a chemical bond between the material and dentin that can secure a safer seal of the dentinal tubules. [14] It protects against demineralizing agents reaching the pulp tissue or remaining dentin layer underneath. [15] The dentin bridges are considered to be better organized than in calcium hydroxide pastes cases.[16]

According to Voicu et al., once TheraCal LC sets, it shows a smooth surface, most likely due to its resin component.[17] This aspect makes it convenient for the upper layer while also securing a better bond to the final restauration material, such as composite resin. Meraji and Camilleri endorse the idea that the bond between TheraCal LC and resin composites is better than between glassionomers and composites. [18] It is radiopaque and can be easily traced on X-Rays underneath other materials, showing the liner’s durability in time.[12]

The liner has an antibacterial potential that is similar to that of calcium hydroxide on *Streptococcus mutans*, but less efficient on *S. Salivarius* or *S. sanguinis*.[19] It releases an increased amount of calcium ions, a property associated with antibacterial effects. This release is shown to be greater than of calcium hydroxide pastes, but less than of tricalcium silicate-based materials. The alkaline pH also promotes its bactericide effect, keeping its high level for a long time. [12]

It has unique hydrophilic properties that make it a more stable and durable composition, being far less soluble than calcium hydroxide paste. The producers advise for the material to be placed on a rather humid dentin in order to maintain all its properties.

Among the disadvantages of TheraCal LC are [15,19,20, 21, 22]:

- Insufficient humidity of the dentin may cause the material not to reach its full potential
- The harmful potential of the resin contained in the liner
- The heat generated by the lamp may produce irreversible changes in the pulp
- Low cytocompatibility

Mineral trioxide aggregate (MTA)

MTA is a cement that derives from Portland Cement, and the main constituent phases are tricalcium and dicalcium silicate, and tricalcium aluminate. This formula can also contain other components, depending on the commercial product, that are meant to enhance its properties.

There are two main categories of MTA on the market: grey and white, with the difference being the presence of iron in the composition of the first one.

MTA cements are bioactive materials that increase the healing potential of the tissues they interact with, being considered a veritable biomaterial. In contact with the tissues they release calcium ions, stimulating the cellular proliferation and adhesion and having an antibacterial effect. [6,7,] The release of calcium ions is considered greater than that of calcium hydroxide or TheraCal LC. [23,29]

MTA ensures an alkaline pH that stimulates the production of cytokine, inducing cell formation. By stimulating dentin bridges formation, the cement can be used successfully in root perforations, apexification, and direct pulp capping. Several studies pointed out that the dentin bridges formed by MTA are superior to those obtained by calcium hydroxide liners. [11,24,25]

The cytotoxic potential of MTA is very low.[7] It is highly biocompatible. That is why it is indicated in vital pulp therapies for both temporary and permanent teeth. It does not stimulate root resorption. Several researchers stated more than 10 years ago that the cement was considered promising for vital pulp therapies. [26-28] Since then, the scientific literature attested this fact by numerous clinical trials with long follow-ups, the success rate being close to or even 100% in most of the studies. [4,7,9,13,14]

It is a radiopaque cement. It can be easily traced on x-Rays.

Its level of solubility is low (if mixing with a greater amount of water than specified), ensuring a tight and durable seal of the tissue that it covers.

It can be covered by almost any restoration material, while also being compatible with the tooth structures.

MTA's main disadvantages are [7,11,25,27,28]:

- Time consuming technique, a big disadvantage when considering a child patient
- The long setting time of the material implies two treatment sessions on the tooth
- Difficult handling, requires sometimes special instruments for a good manipulation
- High costs for both the material and the instruments needed.

Biodentine

One of the newest biocompatible material on the market, it is promoted by its manufacturer as the most suitable dentin replacement. Reportedly it has the same or similar properties with dentin. According to the liner's definition, Biodentine doesn't really fit in this category, but Kaur et al. claims the material as being the first to accomplish the roles of a liner, a base and a temporary filling/interim restauration altogether. [25]

Biodentine appears to overcome MTA's and calcium hydroxide's disadvantages.[29]

From a chemical point of view, it is a mixture of powder and liquid, together in a capsule. The powder is formed of tricalcium silicate (80%), dicalcium silicate, calcium carbonate, zirconium oxide and iron oxide. The liquid is calcium chloride - setting accelerator, hydrosoluble polymer and water. The company that developed Biodentine did not state the specifics of the composition, that is why when related to it, the literature shows slightly different opinions.[25] The reaction between the powder and the liquid leads to the formation of high pH cement, with calcium, hydroxyl and silicate ions. The pH and the ions release stimulate mineralization, dentin bridge formation and a high-quality seal for the dentine tubules or for the pulp tissue. Caron et al. found out in their study that the mineral part and the sealing are superior to MTA cements.[30]

According to some of the articles reviewed in the current paper, this material has higher compressive strength and is more elastic then MTA and calcium hydroxide. [25,31] As for the biocompatibility, the balance inclines also for Biodentine. [32]

Regarding dentin bridge formation potential, it seems to be similar to MTA.[33]

Catala et al. observed that Biodentine is a material with an adequate cytocompatibility on stem cells and that it stimulates cell proliferation on a higher level than the other cements that were included in their study – MTA Repair HP and NeoMTA Plus. [34]

Having properties so similar to that of dentine, Biodentine seems at least in theory the most suitable material to be used in both direct and indirect pulp capping. It can also be used as an interim material, suitable for two-step approaches in capping.

It is a rather easy to manipulate material, it is not time consuming and with costs lower than those for MTA but higher than those for calcium hydroxide. The setting of the material takes about 7 minutes

Biodentine's known disadvantages are [35]:

- Weak restorative material in its early setting phase – makes it preferable to delay the final restoration for 2 weeks in order to allow the material to reach optimal properties
- Relatively high costs.

CONCLUSIONS

Calcium hydroxide paste, despite its disadvantages, is still the most used liner worldwide by practitioners. The use of TheraCal LC in capping techniques is still debatable, studies reporting different results with respect to pulp vitality preservation. While in indirect capping or as a base liner the indications seems to be pertinent, the literature mostly agrees for no use of the material in contact with the pulp. MTA is considered by some the new golden standard, taking calcium hydroxide's place, but the aforementioned issues of cost and setting makes it less used in everyday practice. Longer clinical trials are needed to assess Biodentine's supremacy over other biomaterials in pulp capping, though some may have already stated it.

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