Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Baghdad
College of Dentistry

Calcium Silicate Cements in Restorative Dentistry

A Project Submitted to
The College of Dentistry, University of Baghdad,
Department of Restorative & Aesthetic dentistry in
Partial Fulfillment for the Bachelor of Dental Surgery

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B.D.S,M.Sc.

2022

Certification of the Supervisor

I certify that this project entitled **"Calcium silicate cements in restorative dentistry"** was prepared by the fifth-year student **Fatima Ammar Jawad** under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Signature

Dr. Yasameen Hasan Motea

2022

“Dedication”

This research is lovingly dedicated to my parents and friends who have been my constant source of inspiration. They have given us the drive and discipline to tackle an task with enthusiast and determination. without their love and support this project would not have been made possible.

Fatima

“Acknowledgment”

We thank Allah for giving us the strength and patience to achieve this work, which I wish it, wilI be useful and objective.

I would like to thank Prof. Dr. Raghad Al Hashimi, Dean of the College of Dentistry, University of Baghdad.

My sincere appreciation is due to the supervisor lecturer Dr.Yasameen Hasan, for her unlimited cooperation, her guidance, advice and encouragement throughout the progress my study.

I would like to thank the whole staff in department Restorative & Esthetic dentistry, College of Dentistry, University of Baghdad for their help during this work.

Finally, I wish to express my special words of thanks to my family for their engorgement and continuous support.

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Introduction

Calcium silicate cements are gradually making their way through the various materials used in restorative dentistry. While it is true that they have long been used in endodontics, their introduction in restorative dentistry is more recent. Mineral Trioxide Aggregate (MTA) was the first of this type of materials to be developed. As a result of the favorable properties of biocompatibility and bioactivity of this first material, many manufacturers developed other MTA-like products, such as MTA Angelus and Endo CPM Sealer **(Parirokh M et al., 2010).** These materials are largely used in endodontic treatments; however, they can also be used in restorative dentistry, including direct pulp capping **(Torabinejad M et al., 2010).**

Calcium silicate cements exhibit superior characteristics in comparison to previous formulations of cements used for pulp capping, apical obturation, perforation healing, apexogenesis/apexification and other endodontic procedures. Main advantages of CS cements include their high compressive strength and longer Ca ions release. On the other hand, problematic issues so far include discoloration, poor handling properties and long setting times.

Later, in **2011**, a new material appeared in the market: Biodentine, which is indicated as a replacement for both coronal and root dentin.3 The quick hardening of this cement, in comparison with previous calcium silicates, and its improved mechanical properties made it suitable for definitive restorations in replacing dentin and as a temporary cement to restore enamel **(Watson TF et al., 2014)**. Other materials, such as TheraCal LC, have been developed more recently suggesting the use of calcium silicates mixed with composite resins, which can control hardening times since they are light-curing materials.

One of the greatest advantages of calcium silicates is their so-called bioactivity property. Bioactive materials are defined as those that “trigger a biological

response in the tissue-material interface, resulting in the formation of bonding between material and tissue **(Cao WP and Hench LL, 1996)**.

This is evident in the favorable responses observed when the material is in contact with soft tissues such as pulp and periodontal tissues, or with hard tissues such as dentin **(Kim JR et al., 2015)**.

Research shows that these cements can produce strong bonding with dentin through an area of mineral infiltration, with formation of mineral tags and diffusion of calcium and silicon to dentin **(Han L and Okiji T, 2013)**. In addition, in contact with pulp tissue, the material can stimulate dentin bridge formation **(Nowicka A et al., 2013)**. This is why the study of these materials is of particular interest to restorative dentistry, due to their potential use as restorative materials in case of deep dentin cavities, as well as in direct and indirect pulp capping therapies.

Aim of study

The aim of this project is to review the available information of calcium silicate cements, focusing on their possible applications in restorative dentistry.

CALCIUM SILICATE CEMENTS

1. Mineral Trioxide Aggregate

Mineral Trioxide Aggregate (MTA) was the first calcium silicate developed for dental use; it was developed and patented by Torabinejad and White in 1995. MTA has been used for conservative management of root fractures **(Roig M et al., 2011)**, sealing of perforations, **(Hashem AA and Hassanien EE, 2008)**, pulp capping **(Farsi N et al., 2006)**, apical plug in apexifications **(Simon S et al., 2007),** root-end filling material in apical surgeries **(Baek SH et al., 2005),** and as a coronal barrier in revascularization **(Banchs F et al., 2004)**. All of these procedures imply contact with living tissues and body fluids, an environment that favors physical modifications and chemical/biological interactions with the material. Its main component is Portland cement type I (calcium silicate), known as regular Portland cement used in construction, which is added bismuth oxide (Bi2O3) to provide it with radiopacity.

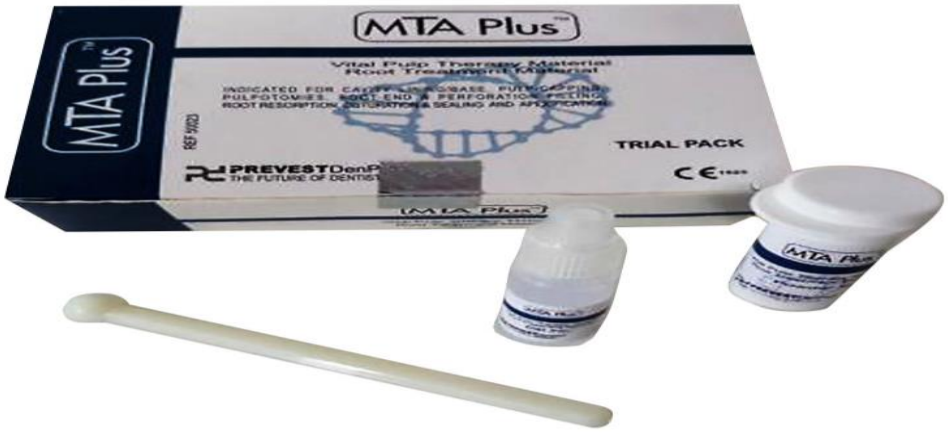

Figure (1): MTA .

1.1 Composition and instructions for use

Several studies have provided detailed information on the components of the main types of MTA, ProRoot MTA (Grey MTA or GMTA) and Tooth-Colored MTA (White MTA or WMTA). The main components of GMTA are described in table 1, while the components of the white version, WMTA, are tricalcium silicate and oxide bismuth. **(Camilleri J et al., 2005)**.

Table 1. Components of ProRoot MTA (Grey MTA or GMTA).

Powder	***Liquid***
Tricalcium silicate	Sterile water
Dicalcium silicate	
Bismuth oxide	

White MTA is mainly composed of dicalcium and tricalcium silicate with 20% of bismuth oxide **(Reyes-Carmona JF et al., 2009)**. Reductioin of bismuth oxide in bismith and contact with the tooth structure result in a change in the color of the material and, consequently, in the color of the adjacent tooth structure **(Marciano MA et al., 2015)**. The loss of stability of bismuth oxide molecules when in contact with a strong oxidizing agent has been pointed out as the cause for color change. Replacement of the radiopacifying agent has been suggested to prevent discoloration **(Húngaro Duarte MA et al., 2009)**. These cements are prepared by mixing MTA powder with sterile water in a 3:1 ratio. A plastic or metal spatula is used to mix the cement in a glass lab, and the mix can be applied with an instrument such as a plastic or metal amalgam carrier to bring the material to the application site **(Torabinejad M and Chivian N, 1999)**.

1.2 Curing reaction

Mixing the powder with sterile water produces a colloidal gel which soon solidifies **(Parirokh M and Torabinejad M, 2010)**. During this mixing, a hydration reaction occurs with the components, leading to the formation of calcium silicate hydrate (C-S-H) and calcium hydroxide as by-products **(Camilleri J, 2008)**.

Once the mixture starts, its pH value increases sharply, reaching to pH 12 after 20 min, which remains for three hours **(Oliveira IR, 2010)**. Camilleri has studied the chemical changes that occur when the cement hydrates. It has been observed that a high proportion of calcium ions is released quickly, due to the dissolution of calcium hydroxide to a progressive decalcification of C-S-H. This occurs more rapidly than the release of silica and bismuth. The curing time of the original version of MTA, GMTA, is 165 min (2h 45min); while WMTA takes 70 min, with a working time of 5 min **(Asgary S et al., 2008)**. This extended curing time is one of the biggest disadvantages of this type of material, and is one of the reasons why it cannot be used in single-session procedures **(Parirokh M and Torabinejad M, 2010)**. Generally, clinicians should confirm the material's curing time in a second session before moving to the next step.

1.3 Advantages of MTA

- Biocompatible with peri-radicular tissues.
- Non cytotoxic.
- Possesses antimicrobial activity.
- Non resorbable.
- Excellent Sealing properties.
- Very basic alkaline (high pH when mixed with water).
- Facilitate regeneration of periodontal ligament.

1.4 Disadvantages of MTA

- Treated area needs to be infection free when applying MTA, because an acidic environment will prevent MTA from setting.
- Requires operator expertise.
- Difficult to handle MTA as a pulp capping material due to its granular consistency, low strength and initial looseness.
- Expensive.

(Srinivasan V et al., 2009)

1.5 Applications in restorative dentistry

1.5.1 Pulp capping

MTA has been used as a potential medicament for pulp capping with reversible pulpitis as it has excellent tissue compatibility. It is much superior to commonly used calcium hydroxide-based cements on the tissue reaction and amount of dentine bridge formed. No tissue necrosis and inflammation are seen with MTA as it is observed with calcium hydroxide. With MTA, dentin bridge formation after pulp capping was seen at about 1-week that steadily increase in length and thickness within 3-months of capping. Whereas, pulp capping with calcium hydroxide, the dentin bridge was less consistent and exhibited numerous tunnel defects**. Aeinehchi et al. in 2003** reported that the formation of dentin bridge was 0.43 mm thick in 6-months with MTA, whereas it was only 0.15mm thick in 6 months when calcium hydroxide was used **(Hedge R and Battepati, 2010).**

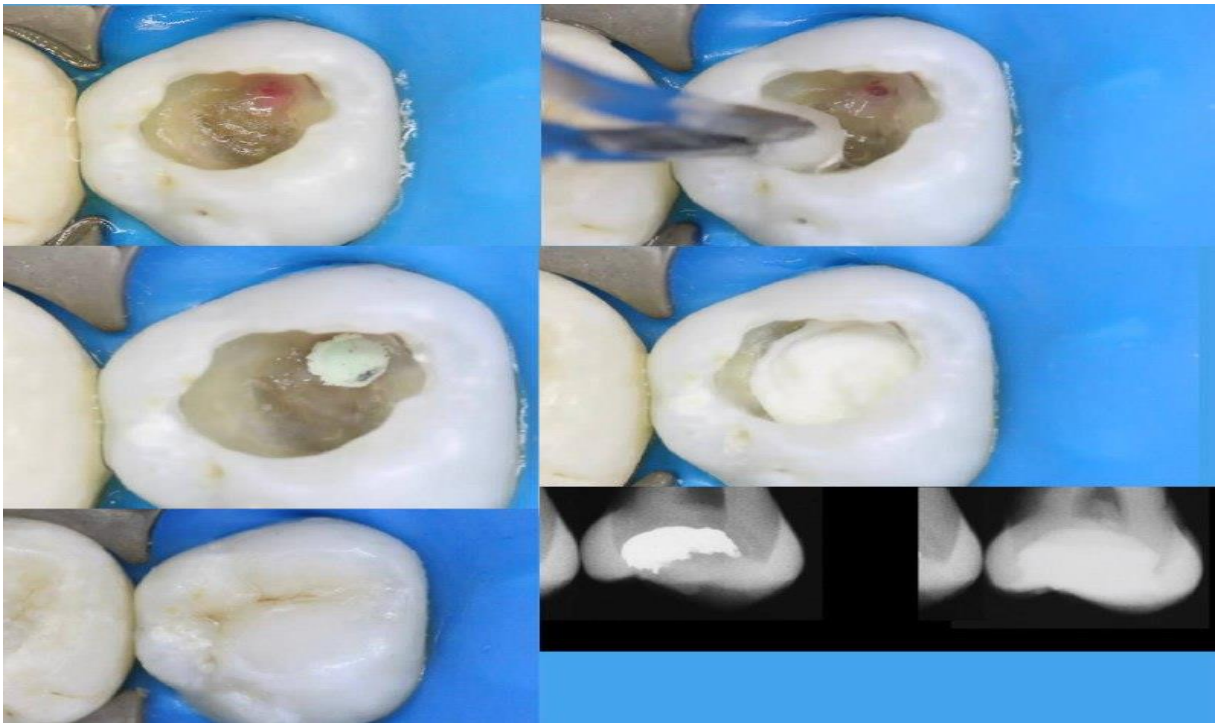

Figure (2): Pulp capping with MTA

1.5.2 Non-vital pulpotomy

MTA was tested and found to be an ideal material with low toxic effects, increased tissue regenerating properties and excellent clinical results. The presence of blood has little impact on the setting when 2mm thick layer of MTA was placed over pulp during pulpotomy. Discolouration of teeth was observed in 60% of the deciduous molars treated with MTA. However, this discoloration of the tooth was not a problem as it would be restored with a stainless ssteel crown **(Hedge R and Battepati, 2010).**

1.5.3 Vital pulpotomy (apexogenesis)

It is defined as amputation of coronal pulp completely without inserting anything into the root canal system. This procedure was done mostly for vital teeth with immature roots.

Method for placement of a pulp capping, a pulpotomy is as follows **(Hedge R and Battepati, 2010)** ;

- First, bleeding is controlled with cotton moistened with sodium hypochlorite (NaOCl).
- MTA is placed over the exposed pulp using a large amalgam carrier, and the moist cotton pellet is placed over it.
- Then, the material is allowed to set, and the rest of the cavity is filled with a temporary filling material.
- In the next appointment that is after 1-week, the temporary filling is removed along with the cotton pellet and restored with a permanent restoration.

1.5.4 Root-end filling

Endodontic surgery followed by root-end filling is necessary where routine endodontic treatment is not possible. This procedure involves surgical exposure of the root apex, root resection, and plugging the apical foramen with a suitable material that provides a complete apical seal which is non-toxic, nonresorbable, dimensionally stable and radio-opaque. Numerous materials have been used as root-end filling agents, but they fail to prevent leakage. Amalgam most commonly used proved to be much inferior when tested with MTA. MTA treated teeth show less inflammation, more cementum formation and regeneration of periradicular tissues.

The procedure includes the following steps **(Hedge R and Battepati, 2010)**;

- The flap is raised under local anaesthesia, followed by ostectomy, root-end resection and hemorrhage control.
- MTA is placed into the root end cavity with a small carrier and packed into place with a plugger.
- The moist environment can be created by inducing mild bleeding from the adjacent tissues and bringing the blood over MTA as placement of wet cotton is not possible.
- The area should not be rinsed after placement of MTA.

- The flap is then sutured back into place.

1.5.5 Obturation of the canal

MTA can be used to obturate the root canal of a retained primary tooth where the erupting permanent tooth is absent. This material is not recommended for the obturation of primary teeth that are expected to exfoliate since it is anticipated that MTA will be absorbed slowly, if at all used **(Hedge R and Battepati, 2010)**.

1.5.6 Repair of perforation

For repairing, the clinicians need a material that should be biocompatible, should withstand moisture without dissolving and should have the excellent sealing ability. MTA can also be used for the treatment of perforation that may be caused by an iatrogenic cause or complication of internal resorption **(Simon S et al., 2007).**

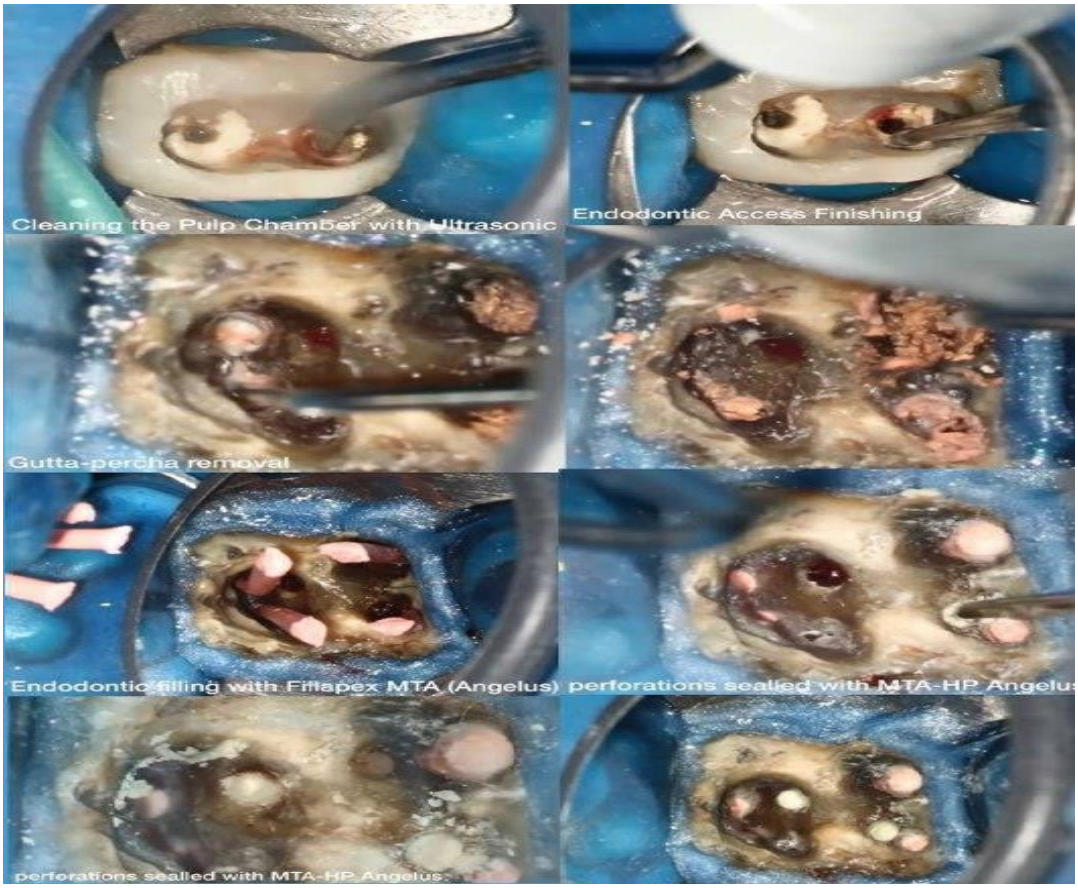

Figure (3): Repair of perforation with MTA

1.5.7 Repair of fracture

- Horizontal root fracture

The success rate of the fracture treatment depends on the location (cervical, middle, apical) where it occurs. The root fracture located in the cervical and middle thirds causes difficulty for dental immobilization, leading to injury or even preventing the consolidation of the fragments. For these cases, it is possible to strengthen the tooth with an intra-canal pin cemented with MTA. The canal is instrumented, and then an apical plug with MTA is performed. A metal pin is selected in order to remain adjusted in the canal that is filled with MTA, and the pin is seated inside. Thus, there is reinforcement for the root, preventing mobility of the coronary segment **(Roig M et al., 2011).**

- Vertical root fracture

To repair the vertical fracture, remove the root canal filling material from the treated roots and bond the pieces internally with composite bonded resin. After raising the flap, groove the entire vertical fracture to the composite with a small bur under constant water spray. Place MTA in the groove, cover it with a resorbable membrane, and suture the soft tissue flap. To improve the prognosis of these cases, the patient should be instructed to follow meticulous oral hygiene and the treated tooth should not be probed for at least 12 weeks **(Kim S and Kratchman S, 2006).**

1.6 Scientific evidence supporting its applications in restorative dentistry

1.6.1 Direct coating

In **2010**, **Parirokh and Torabinejad** conducted a review suggesting that MTA is a promising material to preserve pulp vitality when used in direct pulp capping. The authors state that this seems to be the material of choice for direct capping therapies, compared with other available materials for the treatment of permanent teeth.

In **2011**, **Aguilar and Linsuwanont** published a systematic review on pulp therapy in permanent teeth with pulp exposure due to caries and treated with MTA and calcium hydroxide. They found out that both materials can provide satisfactory results in pulp therapies, such as direct pulp capping and total or partial pulpotomy. Success rates after 3 year were high:

- **72.9%** for direct pulp capping (in patients aged 6 to 10 years)
- **99.4%** for partial pulpotomy (in patients aged 6 to 27 years)
- **99.3%** for total pulpotomy (in patients aged 6 to 70 years)

These revisions were followed by four publications of trials comparing MTA and calcium hydroxide (a material generally used in vital pulp therapies in permanent teeth), most of which found better results for MTA **(Chailertvanitkul P et al., 2014)**.

Mente et al., **2010** assessed patients who were treated with direct capping following pulp exposure, using calcium hydroxide and MTA. They observed a higher rate of success with MTA **(78%)** compared with calcium hydroxide **(60%)**, concluding that MTA seems to be more effective in maintaining pulp vitality after direct capping.

Similar results were obtained by **Hilton et al** in **2013** in their randomized clinical study, finding out a lower probability of failure in teeth treated with MTA **(19.7%)** compared with calcium hydroxide **(31.5%)**.

On the other hand, **Chailertvanitkul et al** in **2014** found no difference in terms of success rate when performing direct capping following pulp exposure with MTA and calcium hydroxide, but they did find a tendency to a higher probability of failure in pulp exposure greater than 5 mm2, with a 2-year follow-up.

Leye et al in **2012** found no significant differences in survival rates with MTA and calcium hydroxide at 6 months, but they did find differences at 3 months, with more favorable results for MTA.

A clinical study has also been published evaluating the preservation of the vitality of teeth treated with MTA in direct capping. The success rate (conservation of vitality) after 3.6 years was 91.3% **(Marques MS et al., 2015)**.

2. BIODENTINE

Biodentine is a cement-based calcium silicate that has been advertised as "the first all-in-one material" to be used whenever dentin has been damaged. This material has been developed in an effort to produce a calcium silicate with better mechanical properties **(Grech L at al., 2013)** and hardening times **(Septodont, 2014)**. Biodentine has a wide range of applications including endodontic repair (root perforations, apexification, resorptive lesions, and retrograde filling material in endodontic surgery) and pulp capping and can be used as a dentine replacement material in restorative dentistry.

Figure (4): Biodentine.

In a study, **Kayahan et al** in **2013** evaluated the effect of acid etching on the compressive strength of Biodentine. Acid etching is an important step in the placement of composite restorations. The authors concluded that acid etching did not significantly affect the compressive strength of Biodentine. Therefore, the author suggested that Biodentine could serve as a lining material under light cured resin materials in an esthetically sensitive area **(Kayahan MB et al., 2013)**.

2.1 Composition and instructions for use

Biodentine comes as a capsule containing powder and a liquid contained in a vial. According to the mixing instructions, the contents of the vial should be squeezed into the capsule and then mixed in an amalgamator for 30s. Depending

on preference, the contents of the capsule is applied with a porta amalgam, a spatula, or a device such as the Root Canal Messing Gun. Table 2 shows the components as stated by the manufacturer.

Table 2. Components of Biodentine, (Septodont, France) according to manufacturer's specification

Powder		Liquid	
Tricalcium silicate (3CaO.SiO2)	Main component and regulate the setting reaction	Calcium chloride (CaCl2 2H2O)	Accelerator
Dicalcium silicate (2CaO.SiO2)	Second main component	water	Hydration
Calcium Carbonate (CaCO3)	Filler	Superplasticizer (Water reducing agent)	Improves handling
Zirconium dioxide (ZrO2)	Radio Pacifier		

According to the manufacturer, the Active Biosilicate Technology used to produce Biodentine ensures the purity of calcium silicate, as opposed to other calcium silicate cements based on Portland cement which contain non-purified mixtures with low concentrations of metal impurities. However, recent studies have found remains of arsenic, lead, and chromium in Biodentine. Moreover, the found levels of arsenic are higher than those allowed by ISO 9917. Nevertheless, the same components have been reported for MTA, but since the release in the physiological solution is minimal, they have been considered safe **(Camilleri J et al., 2012)**.

The manufacturer has suggested that this material's reduced curing time (12 min) compared to traditional calcium silicates such as MTA (70 min) is due to the smaller size of the powder particles, thus allowing a greater reaction area. In

addition, the calcium chloride added to the liquid has proven to be a powerful accelerator of reaction in these materials **(Wiltbank KB et al., 2007).**

The manufacturer also states that the material's best mechanical properties are due to the lack of impurities, along with the addition of calcium carbonate powder and the optimal density of the powder obtained in the mix. The water-soluble polymer probably plays an important role in achieving better powder density, since an easy-to-handle mix is obtained with a smaller amount of water **(Septodon, 2014).**

Finally, it has been supposed that zirconium dioxide is added in order to provide it with radiopacity, since it is has been used in other materials for the same purpose **(Tanomaru-Filho M et al., 2007)**.

This is another important difference with MTA, where radiopacity is provided by means of oxide bismuth **{**a compound that according to some authors has an unwanted effect on the material**} (Montesin FE et al., 2004)**.

2.2 Curing reaction

The curing reaction of Biodentine is similar to that of MTA, with production of hydrated calcium silicates and calcium hydroxide as by-products **(Grech L et al., 2013)**. but the speed of reaction is greater in Biodentine **(Camilleri J, 2013)**

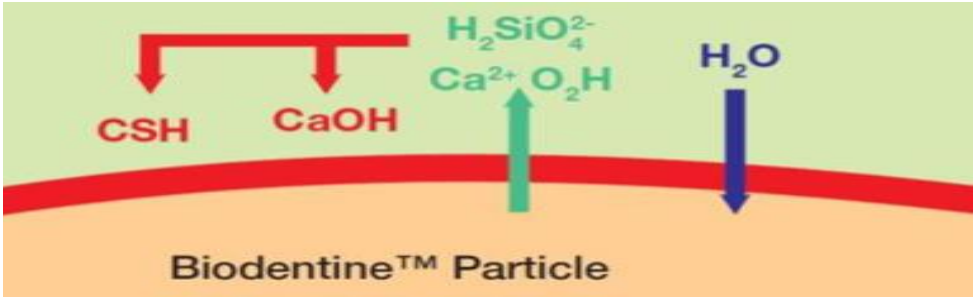

Figure (5): Precipitates of hydrated gel on particles surface.

$$2(3CaO.SiO2) + 6H2\ O \rightarrow 3CaO.2SiO2\ .3H2\ O + 3Ca\ (OH)\ 2$$

As seen in the equation above, Water interacts with tricalcium silicate and results in the formation of calcium silicate gel (C-S-H) and a calcium hydroxide. The hydrated gel precipitates on the surfaces of the remaining silicate particles (Figure 2) and in the spaces between the particles, gradually filling spaces between the unreacted tricalcium silicate **(Singh H et al., 2014)**.

The initial curing reaction takes about 12 min. However, impedance spectroscopy has shown that the reaction continues for up to 14 days **(Villat C et al., 2010).** The study of **Villat et al in 2010** suggests that the complete hydration reaction of this silicate is much slower than that observed in the acid-base reaction of glass ionomer cements, concluding that this reaction could continue for months, extending ion exchange, decreasing porosity, and increasing the material's mechanical properties.

2.3 Applications in restorative dentistry

Biodentine is indicated as a substitute for dentin in both the coronal and the root portions.

Indications for restorative dentistry include:

- Temporary restoration of enamel
- Final restoration of dentin
- Restoration of lesions of large and/or deep cavities (sandwich technique)
- Restoration of deep cervical or root lesions
- Direct and indirect pulp capping

The manufacturer indicates that applying the product does not require any prior treatment and that, once hardened, the cement should be treated as if it were healthy dentin. In the case of a sandwich technique using this material, it has been

recommended to fully restore the cavity in the first session, remove the outer part after one week to six months and cover it with composite resin **(Septodon, 2014)**.

2.4 Scientific evidence supporting its applications in restorative dentistry

2.4.1 Direct pulp capping

Only one clinical study assessing Biodentine as a restorative material in direct pulp capping has been published to date. The study by **Nowicka et al in 2013** involved drilling pulp premolars extracted for orthodontic purposes capping with Biodentine (n = 11) and MTA (n = 11). After 6 weeks, most premolars showed formation of full dentin bridge, with absence of pulp inflammatory response; no significant differences were found between Biodentine and MTA during the observation period **(Nowicka A et al., 2013).** Other articles have evaluated this material in animal models and in extracted molars.

Tran XV et al in **2012** conducted a study in rats also showing the consistent formation of dentin bridge in pulp cappings made with Biodentine and MTA **(Tran XV et al, 2012)**. In these cases, the formed bridge is located in the affected area, with an ortodentine type of organization, in contrast to what was observed in treatments performed with calcium hydroxide, which showed cell inclusions similar to osteodentine.

In their study, **Laurent et al** in **2012** used healthy premolars recently extracted, which were kept in a culture and subjected to direct capping procedures with Biodentine. In all the evaluated premolars (n = 15), they noted the formation of mineralization foci, which increased in size until day 28 {date of the last observation}. They also noticed the expression of markers of mineralization, suggesting that the material is capable of inducing the differentiation of

odontoblast cells, involved in the formation of dentin tissue **(Laurent P et al., 2012).**

However, the level of evidence in studies in animals or in exvivo models is smaller than that achieved in clinical trials. Therefore, it is necessary to conduct additional clinical trials to provide more evidence on the use of this material in direct pulp capping.

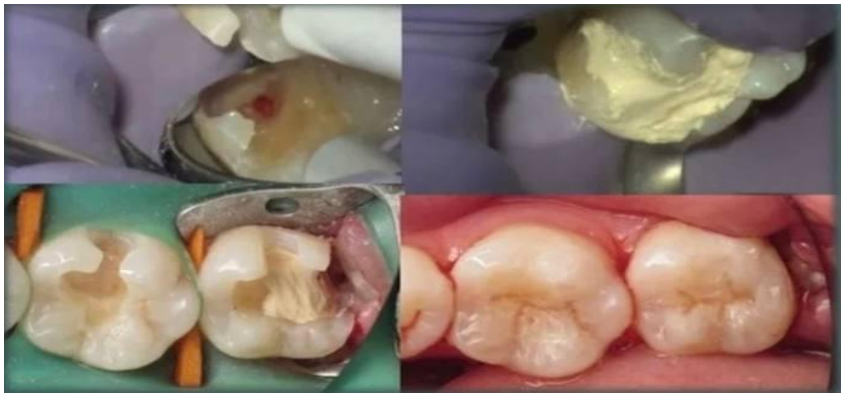

Figure (6): Direct pulp capping with Biodentine.

2.4.2 Indirect pulp capping

A randomized clinical study recently evaluated the use of Biodentine in indirect pulp capping. The study analyzed 72 restorations (36 made with BiodentineTM and 36 with glass ionomer), with a follow-up of up to one year, finding out no differences between the materials when measuring the clinical efficacy of pulp vitality conservation **(Hashem D et al., 2015)**.

However, the authors noted that most teeth with apical radiotransparency (which was not detected at baseline with periapical x-rays but later with computed tomography) that decreased in size or were eliminated were treated with Biodentine, while most recent lesions or their progression were found in teeth treated with glass ionomer.

These results were attributed to the bioactive characteristics of Biodentine, which have been reported from in vitro studies **(Kim JR et al., 2015)**.

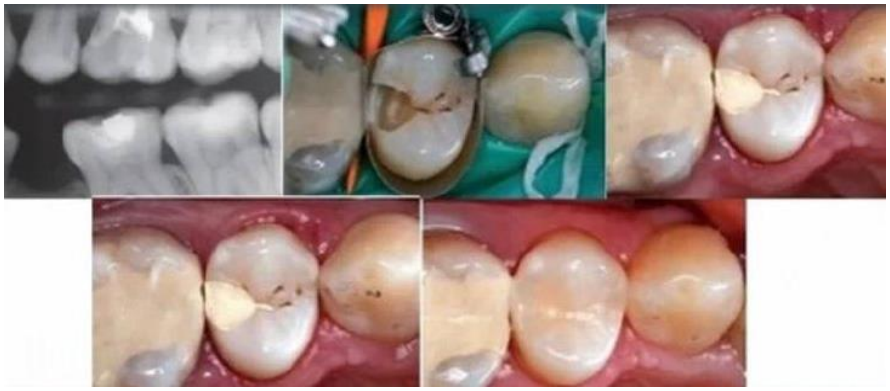

Figure (7): Indirect pulp capping with Biodentine.

2.5 Permanent restoration of dentin and temporary restoration of enamel

Only one clinical study using Biodentine as a restorative material (of enamel and dentine) has been published to date. This clinical, multicentered, randomized study with a three-year follow-up has only published the results obtained during the first year. Class I and Class II restorations (n = 397) were performed with Biodentine and composite resin. The initial assessment of the product shows very satisfactory results in terms of anatomical shape, marginal adaptation, and proximal contacts; however, the composite resin restorations showed better clinical behavior in these parameters after six months.

This is why this study recommends that after 6 months it is necessary to remove the outermost layer of Biodentine and to restore with composite resin, leaving it only as permanent replacement of dentin and temporary replacement of enamel **(Koubi G et al., 2013)**.

3. THERACAL LC

TheraCal LC is a new light-cured, resin-modified calcium silicate-filled base/ liner material designed for direct and indirect pulp capping **(Gandolfi MG et al., 2012)**. After more than five years of extensive research and development, TheraCal LCwas made available to clinicians in November 2011 by Bisco Inc, Schamburg, IL, USA. **(Paul L, 2011)**

Figure(8): TheraCal LC

In vitro studies have examined its physical and chemical properties **(Camilleri J, 2014)**.

Camilleri in 2014 noted that, just as Biodentine, TheraCal LC allows calcium phosphates to deposit on its surface when in contact with a saline solution; however, the release of calcium ions is significantly lower that than of Biodentine.

Gandolfi et al in 2012 has demonstrated that TheraCal LC solubility is less than that of MTA and calcium hydroxide; in addition, it has a weak radiopacity (less than required by standard ISO 6976) and can be light-cured in thickness of 1.7 mm. Since this material has been recently released, there are no clinical studies evaluating its behavior, and so far there is only one published study in animals.

Cannon et al in 2014 conducted a study in primates performing direct pulp capping with TheraCal LC. The authors noted that teeth treated with this material had way more frequent dentin bridge formation, compared with calcium hydroxide and glass ionomer **(Cannon M et al., 2014)**.

3.1 Composition of TheraCal LC

TheraCal LC is a hybrid material, consists of a single paste containing CaO, calcium silicate particles (type III Portland cement), Sr glass, fumed silica, barium sulphate, barium zircon ate & resin containing Bis-GMA & polydimethacrylate. **(Kunert M and Szymanska ML, 2020)**. The original patent sheet of TheraCal LC stated that, it consists of Portland type III cement (45%), fumed silica as a thickening agent (7%), resin (43%), bismuth oxide (3%), and barium sulfate (3%) as radiopaquers **(Arandi NZ and Rabi T, 2018)**.

3.2 Uses of TheraCal LC

3.2.1 TheraCal LC is used as a direct pulp capping material

A direct-composite restoration performed by clinician for a patient presenting with an asymptomatic direct carious exposure. Light bleeding should be controlled with sterile saline compression. TheraCal LC should be placed directly over the exposure site, and then additional increments should be added to seal and provide a barrier for healing. TheraCal has been tested clinically as a direct pulp capping agent in primates by Cannon et al. The experiment concluded that TheraCal LC created complete dentinal bridges and mild pulpal inflammation suitable for pulp capping **(Kunert M and Szymanska, 2020).**

3.2.2 TheraCal LC is used as an indirect pulp capping agent

Infected soft dentine is removed, leaving affected dentine. If radiographic examination shows a close approximation of an asymptomatic pulp, then TheraCal LC should be placed onto moist dentine. A base should be placed over the TheraCal LC and the restoration completed. Since TheraCal LC has low

temperature changes during light curing, it is preferable to use in deep cavities as an indirect pulp capping agent **(Kunert M and Szymanska, 2020).**

3.2.3 TheraCalTM LC is used as a cavity liner

TheraCal LC is promoted by the manufacturer for use as a protective liner with restorative materials, cement, or other base materials. TheraCal LC has been approved as "apatite stimulating" by the US Food and Drug Administration and secures a protective physical lining despite contact with dentinal or pulpal fluids. Studies showed that TheraCal may be considered as the material of choice as a liner in deep Class II cavities requiring pulp capping procedure as compared to RMGIC **(Kunert M and Szymanska, 2020).**

3.2.4 TheraCalTM LC is used to seal root Canal orifices

TheraCal LC also protects endodontically treated teeth. In a particular case, endodontic retreatment was completed. The chemically softened, disinfected furcation floor required sealing of root orifices and softened dentine at the furcation floor. TheraCal LC should be added in 1mm increments to provide a visually discernible orifice and furcation floor seal **(Patel AZ et al., 2017)**.

3.3 Application method

TheraCal LC is available in syringe form. Because of this, accurate placement of the flowable material is easy and is an advantage noted by clinicians, along with the light cured ability. According to the manufacturer, TheraCal is placed in the increments of 1mm and light cured for 20 seconds **(Kunert M and Szymanska ML, 2020)**.

3.3.1 Application method in indirect pulp capping

In Vitro Study by **Gowda VB et al in 2015** :

1. **Step 1:** Isolate the tooth. Remove infected carious tooth structure. Leave preparation visibly moist.

2. **Step 2:** TheraCal LC directly applied to preparation in 1mm incremental layers.
3. **Step 3**: Each increment is light-cured for 20 seconds.
4. **Step 4:** Surrounding enamel is etched.
5. **Step 5:** Bonding agent is applied and light cured.
6. **Step 6:** Final restoration. (After core buildup)

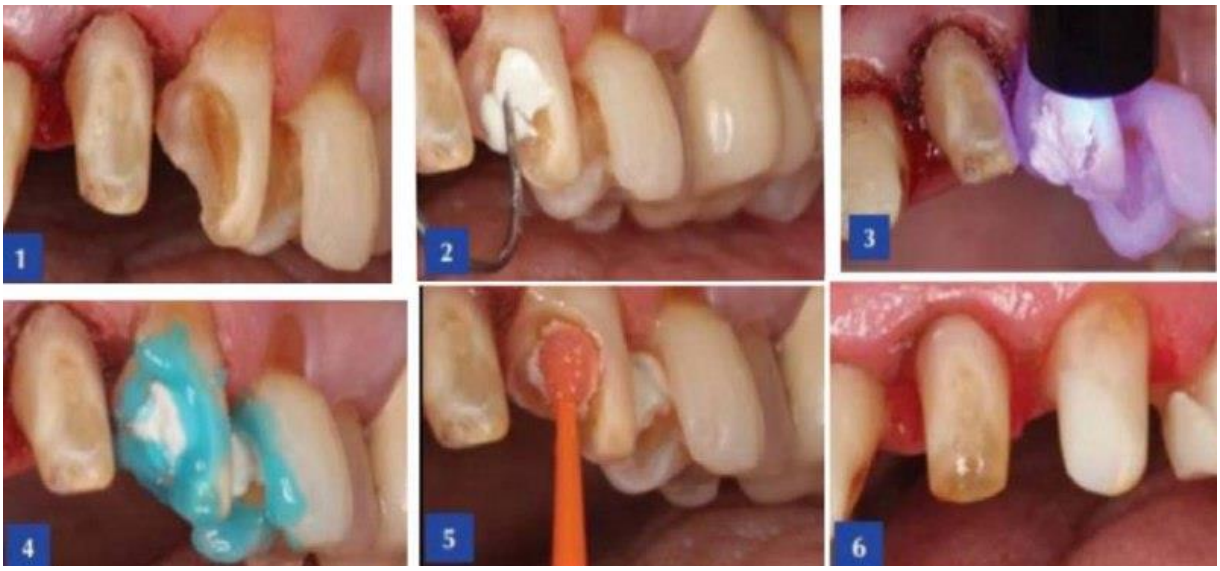

Figure (9): Application methon of TheraCal LC for Indirect pulp capping.

3.3.2 Application method in direct pulp capping

In Vitro Study **(Gowda VB et al, 2015)** in cairo :

1. **Step 1:** Isolate tooth.
2. **Step 2:** Remove infected carious tooth structure. Achieve hemostasis. Leave preparation visibly moist.
3. **Step 3:** Apply TheraCal LC directly to exposed pulp. Layer is not to exceed 1 mm in depth. Cover all the exposed areas and extend TheraCal LC at least 1 mm onto sound dentin surrounding the exposure. Lightcure for 20 seconds.

4. **Step 4:** Apply adhesives.
5. **Step 5:** Continue tooth restoration.

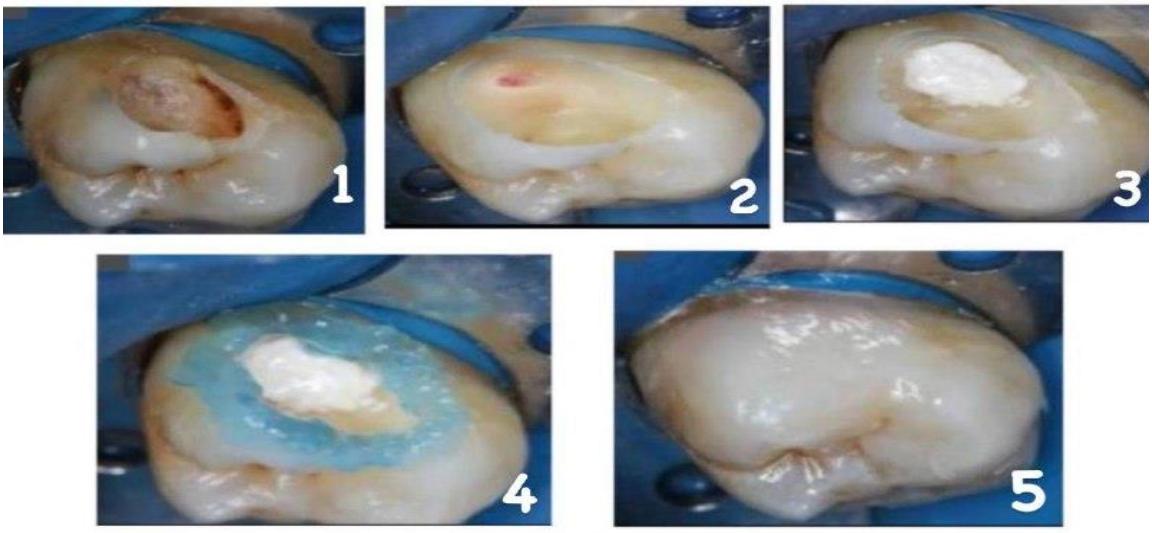

Figure (10): Application method of TheraCal LC for Direct pulp capping.

3.4 Setting reaction

TheraCal LC is a hydraulic silicate material that sets by hydration. Hydration is the chemical reaction that contributes to the setting of a hydrophilic cement. Setting starts when the material comes in contact with water. TheraCal LC does not include water for hydration of material. It depends upon the water taken up from the environment and its diffusion within the material. Hence, the manufacturer's instructions implement placing the TheraCal had a greater early strength to potentially resist fracture during immediate placement of a final restorative material **(Paul L, 2011)**.

CONCLUSIONS

Calcium silicates are alternative dental materials that can be used in direct and indirect capping, cavitary liner, dentin replacement in class I, II and V cavities, and as semi-permanent restorations of enamel.

Indications for direct and indirect capping are supported by clinical studies, especially in the case of MTA for direct capping. New applications proposed for these materials, such as replacement of dentin in class I, II and V cavities have still insufficient clinical evidence; However, in vitro studies show promising results.

The biocompatibility and bioactivity properties make of calcium silicates one of the restorative materials that offer a more favorable response by pulp tissue.

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