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

Bioactive Materials Used in Pediatric Dentistry

A Project Submitted to
The College of Dentistry, University of Baghdad, Department of Pedodontics and Prevention in Partial Fulfillment for the Bachelor of Dental Surgery

By

Rania Majeed Hameed

Supervised by:

Assist. Lect. Noor M. Hassan
B.D.S.,M.Sc. (Pediatric Dentistry)

2023 A.D **1444 A.H**

Certification of supervisor

I certify that this project entitled **"Bioactive Materials Used In Pediatric Dentistry"** was prepared by the fifth-year student **"Rania Majeed Hameed"**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:

Name: Assist. Lect. Noor M. Hassan
(The Supervisor)

Date: 04/05/2023

Dedication

To the center of my life, the reason for my existence, my eternal love , to **my God**.

And to the person who always believed in me and supported me,without her, I would not be standing here today. Everything I am in now is because of her efforts,I hope you will always be proud of me, **my mother(Asmaa Yaseen).**

And for my sisters &friend **(Nabaa ,Saba, Rania, Safa)** thank you for every think

For the first man in my life who supported me who made me love how I am **(Mustafa).**

Finally ,I dedicate this success to rewarding **myself** and thanking her for being patient and determined despite all the difficulties.

Acknowledgment

First of all, I thank **"Allah"** almighty for granting me the will and strength to accomplish this project, and I pray that his blessings upon me may continue throughout my life.

My sincere thanks go to **Prof. Dr. Raghad A. Al-Hashimi, Dean of College of Dentistry/University of Baghdad,** for his great support.

My deep thanks to scientific Assistant Dean **Prof. Dr. Ali Al-Bustani**,for supporting the undergraduate student.

My deep appreciation is expressed to **Assist**.**Prof. Aseel Haider M.J.Al- Haidar, Head of the Department of Pedodontics and Prevention**; for her kindness, motivation and unlimited support.

I would like to express my deepest thank to my supervisor **Assist. Lec. Noor M. Hassan** for her efforts, encouragement, and guidance. Finally, thanks to all of the teaching staff at the Department Pedodontics and Prevention; for their kind efforts.

List of content

List of Figures

List of Abbreviation

ACP	Amorphous calcium phosphate
Al^{3+}	Aluminum
Al_2O_3	Aluminum oxide /Alumina
BAG	BioActive glass
°C	celsius
Ca^{2+}	Calcium
$Ca(OH)_2$	Calcium hydroxid
CaO	calcium oxide
CS	compressive strength
CPP-ACP	casein phosphopeptide amorphous calcium phosphate
DPC	Direct pulp capping
GI	Glass ionomer
GIC	Glass inomers cement
g	gram
HA	Hydroxyapatite
L	litter
MTA	Mineral tri oxide aggregate
Mol	mole
mm	Milliliter
PAA	Polyacrylic acid
Ph	potential hydrogen
β-TCP	Beta tricalcium phosphate

SBF	stimulated body fluid
TGF- BETA	transforming growth factor–beta

Introduction

Dentistry is an ever evolving branch with continuous stipulation for advancements in dental materials. From the dawn of history, dental practitioners have been in the quest of ideal restorative dental materials. Initially these materials were thought to be biologically inert and biocompatible but in the last two decades bioactive materials seem to be alternative to these inert biocompatible materials **(Asthana and Bhargava, 2014).**

The teeth undergo a constant cycle of demineralization and remineralization, but this natural remineralization process is inadequate to prevent progression of dental caries. Hence there is a need to supplement the tooth with a biomaterial which is bioactive in nature to remineralize, repair or regenerate the tissues of tooth ,Bioactive materials, or biomaterials, have the ability to interact biologically with the tissue to which it is inserted, and to stimulate the deposition of mineralized tissue **(Raju *et al*., 2021).**

The calcium phosphate-based ceramics were the first known materials in dentistry to have bioactivity, these materials are mostly used for biomedical purposes, with different morphological characteristics. In dentistry, these materials have achieved immense importance by stimulating the deposition of osseous tissue in injured bone, and by having the ability to remineralize hard tooth tissues (enamel and dentin). Furthermore, repair materials based on aggregated trioxides mineral or on calcium hydroxide are classic biomaterials and widely used in dentistry, mainly in contact with the pulp tissue or periodontal ligament, for repair processes **,**Additionally, these materials have been shown to considerably enhance the aesthetic outcome of restorative dental procedures **(Dworkin et al., 2018; Benetti, 2019).**

In general, bioactive materials have been shown to promote the release of calcium, sodium, silicon and phosphate ions, which are metabolized by the body, having effects such as angiogenesis and antimicrobial action, which can be improved depending on the composition of the material **(Benetti, 2019**) .

This evolution of materials and compositions that display greater interactions with tooth structure is the drive for future advances **(Dworkin *et al*., 2018).**

Aim of the project

This project Represents a review of bioactive materials mostly used in pediatric dentistry in terms of classification, properties, and clinical applications.

Chapter one: Review of literature

1.1 Bioactive dentistry

The term 'Bioactivity' is defined as the ability of a material to elicit a response in a living tissue (Raju et al .,2021).

In modern dentistry, there is a great interest in the application of "bioactive" materials for restorative and reconstructive purposes. It must be noted that depending on the application, the perception of what is actually considered "bioactive" differs,As follows **(Dworkin *et al*., 2018; Benetti, 2019):-**

- In restorative dentistry, the term bioactive usually refers to the ability of a material to form hydroxyapatite crystals on its surface.
- In implantology, bioactivity concerns the potential of some materials, such as calcium phosphate ceramics and glasses, to provide a direct chemical bond between the implant and the recipient bone.
- In preventive dentistry, bioactive toothpastes have been employed with the aim to remineralize the outer enamel surface .
- In pediatric dentistry, the ease of use of these materials is particularly beneficial because of their dual-cure and bulk-fill capabilities that produce significantly less micro-leakage compared to conventional, light-cured materials. These bioactive materials are more preventative of recurrent caries, which is a leading cause of restorative replacement. This can be attributed to the fact that the bioactive materials are able to self-cure and light cure. Self-curing allows for more of the material to integrate into the tooth structure, resulting in less polymerization shrinkage and reduced stress.

1.2 Classification

Bioactive materials are classified into two major groups by Hench in 1994.

Class A: Osteoproductive materials

Class A bioactivity occurs when a material elicits both an intracellular and an extracellular response brought by the colonization of osteogenic stem cells at its interface resulting in both osteoproductive and osteoconductive properties. e.g.:- Bioglass **(Singh *et al*., 2021).**

Class B: Osteoconductive materials

Osteoconductive bioactivity occurs when a material elicits only an extracellular response at its interface by providing a biocompatible interface along which bone migrates,e.g.:- synthetic hydroxyapatite (HA) **(Hegde *et al*., 2016).**

1.3 Mechanisms of Bioactivity

Bioactive materials should include at least on or more than following **(singh *et al*., 2021):-**

1. Remineralizes and strengthens tooth structure through fluoride release and/or the release of other minerals.

2. Forms an apatite-like material on its surface when immersed in body fluid or simulated body fluid over time.

3. Regenerates live tissue to promote vitality in the tooth.

1.4 Bioactive Material in Practice

1.4.1 Calcium hydroxide

Calcium hydroxide is the material introduced in clinical dentistry in 1990 by Hermann. It is the gold standard material used for pulp protection in case of direct and indirect pulp capping treatment procedures. It is used as liners or sub base **(Arandi, 2017).**

Calcium hydroxide [$Ca(OH)_2$] is a white, odorless powder with a molecular weight of 74.08 g/mol.It is a strong base with a high pH (12.5–12.8) and low solubility in water (about 1.2 g/L at 25°C).The clinical indications for its use were expanded and $Ca(OH)_2$ was considered as the best medicament to induce hard tissue deposition and promote healing of vital pulpal and periapical tissues **(Mahalaxmi, 2013).**

1.4.1.1 properties

calcium hydroxide has the following properties **(Mahalaxmi, 2013):-**

- **Strength:-**

Calcium hydroxide has a low compressive and tensile strength which continues to increase with time.

- **Modulus of elasticity:-**

Calcium hydroxide has low elastic modulus , which limits its use to areas that are not critical to the support of the restoration. Hence, it is not recommended as a sole base or luting cement

- **Solubitity:-**

Calcium hydroxide is highly soluble in water when compared to other cements.

A certain extent of solubility is necessary for $Ca(OH)_2$ to produce its therapeutic effects. However, the solubility increases when it is exposed to phosphoric acid;

hence, care should be taken during acid etching and during application of varnish in the presence of this cement.

- **Thermal insulation:-**

It can be noted that $Ca(OH)_2$, when used in sufficient thickness, can provide thermal insulation. However, a thickness greater than 0.5 mm is not recommended due to its low strength. Hence, thermal protection should be provided with a separate high strength base

- **Biological reaction:-**

Calcium hydroxide stimulates the formation of reparative dentin due to its high alkalinity and antibacterial effect **(Mahalaxmi, 2013).**The hydroxyl group of $Ca(OH)_2$ provides an alkaline environment, which encourages repair and active calcification **(Raju *et al* ., 2021).**

1.4.1.2 Advantages of Calcium hydroxide

Calcium hydroxide has the following advantages **(singh *et al*., 2021):-**

- Initially bactericidal then bacteriostatic
- Promotes healing and repair
- High pH stimulates fibroblasts
- Neutralizes low pH of acids
- Stops internal resorption
- Inexpensive and easy to use

1.4.1.3 Disadvantages of Calcium hydroxide

Calcium hydroxide has the following disadvantages **(Pannu and Berwal., 2017):-**

- Does not exclusively stimulate dentinogenesis
- Does exclusively stimulate reparative dentin
- Associated with primary tooth resorption
- May dissolve after one year with cavosurface dissolution
- Does not adhere to dentin or resin restoration.

1.4.1.4 Uses of Calcium hydroxide

Calcium hydroxide can be used as follows **(Mahalaxmi, 2013):-**

1. Cavity liner

2. Direct / Indirect pulp capping

3. Pulpotomy.

4. Dressing of the root canal.

5. Long term temporary dressing.

6. Treatment of infected root canals and periapical lesions.

7. Apical closure.

8. Prevention of root resorption.

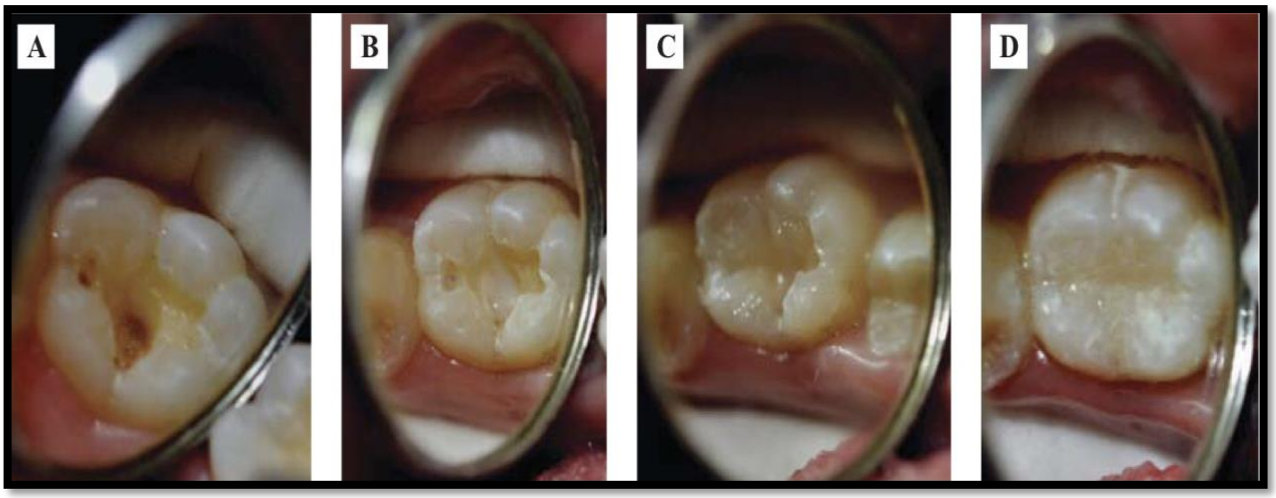
19. Repair of iatrogenic perforations.

10. Treatment of horizontal fracture.

Calcium hydroxide as a pulp capping agent:-

Calcium hydroxide has been considered the “gold standard” of direct pulp-capping materials for several decades. Calcium hydroxide possesses antibacterial properties which can minimize or eliminate bacterial penetration and subsequent irritation of pulpal tissue,The repair mechanism may be due in part to the release of bioactive molecules from dentin matrix. Using $Ca(OH)_2$ in primary teeth was recommended only for small mechanical or traumatic exposures when condition for favorable response were optimal **(Hilton*al*, 2013**).**(Figure 1.1)**

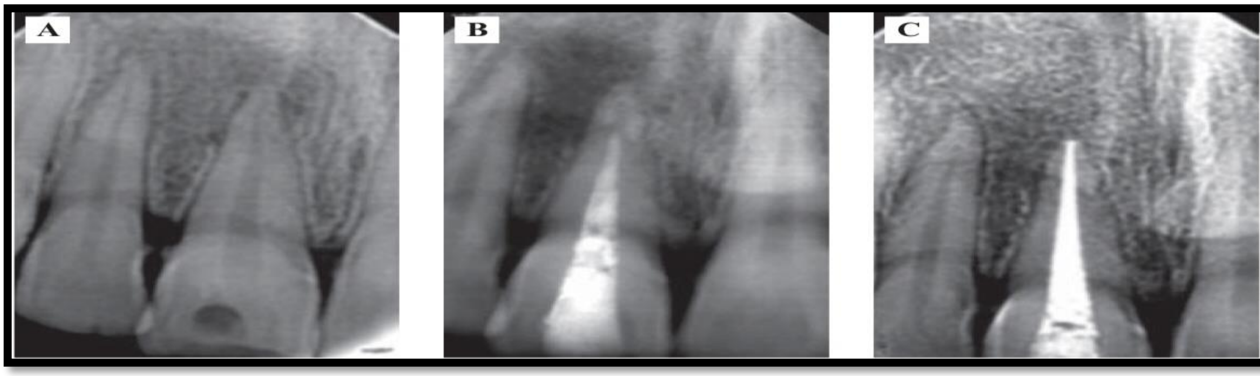
The most commonly used commercially available $Ca(OH)_2$ for pulp capping is Dycal. **(Mahalaxmi, 2013)**



Figure(1.1) Pulp capping procedure. (A) Cavity preparation (note the subpulpal floor only in the area of deep caries), (B) calcium hydroxide placement), (C) composite buildup, and (D) finished restoration **(Mahalaxmi,2013).**

Calcium hydroxide as intracanal medicatment: -

Calcium hydroxide paste used as an intracanal medicament contains the powder, a vehicle, and a radiopacifier. The material should not set, but should maintain high pH and enhance radiopacity **(Figure 1.2) (mahalaxmi, 2013).**



Figure(1.2), Calcium hydroxide as intracanal medicament.(A)Pre operative radiograph (B)radiograph after 1 month of intracanal calcium hydroxide placement showing the resorbed calcium hydroxide in the apical third of the root (c)postobturation radiograph showing periapical healing **(Mahalaxmi, 2013).**

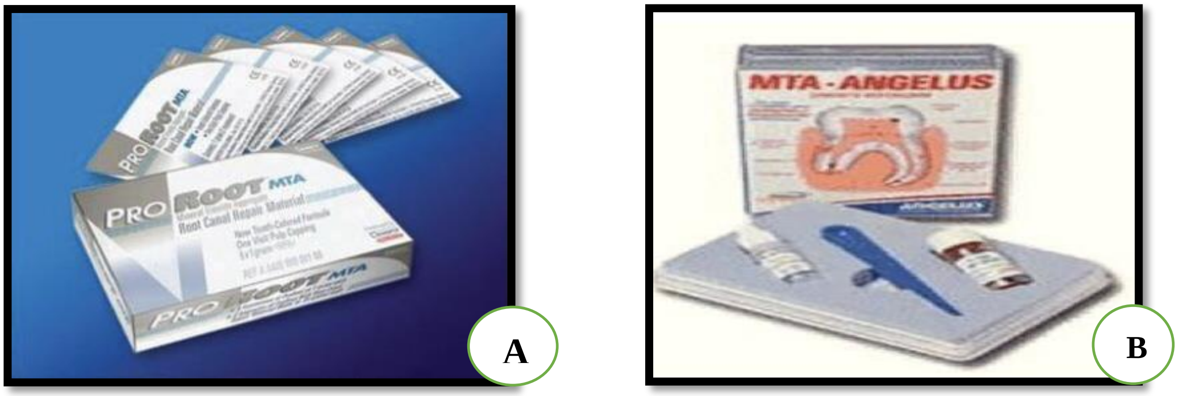
1.4.2 Mineral Trioxide Aggregate

The name Mineral Trioxide Aggregate (MTA)refers to the three oxides in Portland cement constitution: calcium oxide (CaO), silicon dioxide/silica (SiO_2) and aluminum oxide /alumina (Al_2O_3), plus the addition of the radiopaque powder known as bismuth oxide (**Benetti, 2019)**.

Mineral Trioxide Aggregate is a bioactive material that has shown promising results as a root end filling material due to its good sealing properties, biocompatibility and potential to stimulate cementogenesis (**Hegde *et al*., 2016).**

The MTA paste is obtained by mixing 3 parts of powder with 1 part of water to obtain putty like consistency. Mixing can be done on paper or on a glass slab using a plastic or metal spatula. This mix is then placed in the desired location and condensed lightly with a moistened cotton pellet**(Singh *et al*., 2017).**

There are two commercial forms of MTA have been available commerically Pro Root MTA in either the grey or white forms, and MTA-Angelus **(Varghese *et al* ., 2014).**The important barriers to the widespread use of MTA are its cost**(Figure 1.3) (Singh *et al*.,2017).**



Figure(1.3), Some of the commercially available MTA (A) A PRO ROOT MTA (B)MTA-Angelus **(Singh *et al*., 2017).**

1.4.2.1 Properties

MTA has the following properties**(Singh *et al*., 2017):-**

- **Compressive strength:-**

It takes an average of three to four hours for the MTA material to completely solidify. In comparison grey MTA exhibited greater compressive strength than white MTA.

- **Radio-opacity:-**

MTA is less radio opaque than amalgam or gutta-percha and has similar radio density as Zinc Oxide Eugenol

- **Solubility:-**

Although the set MTA shows no signs of solubility, the solubility might increase if more water is used during mixing.

- **Marginal adaptation and sealing ability:-**

This property is most vital for any restorative material especially when used for root end filling, repair of perforations, Pulp capping or pulpotomy procedures.

MTA expands during setting which may be the reason for its excellent sealing ability

- **Antibacterial and antifungal property:-**

By virtue of providing a good seal and preventing micro leakage, it can be proclaimed as an antibacterial agent especially against Enterococcus faecalis and Streptococcus sanguis in vitro.

- **Reaction with other dental materials:-**

MTA does not react or interfere with any other restorative material.

- **Tissue regeneration:-**

  MTA is capable of activation of cementoblasts and production of cementum.It consistently allows for the overgrowth of cementum and also facilitates regeneration of the periodontal ligament.

- **Mineralization:-**

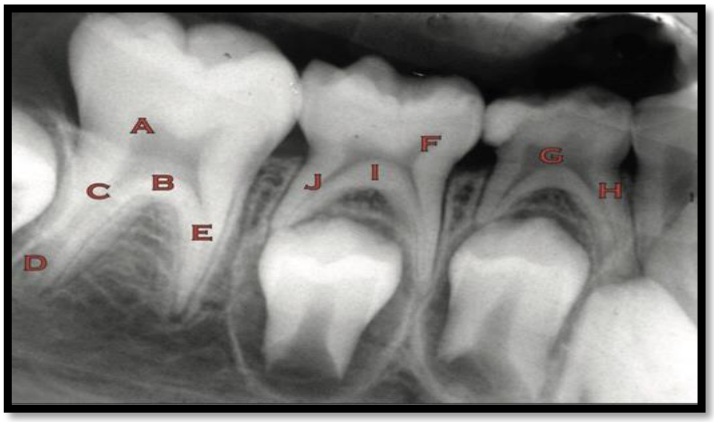
  MTA, just like calcium hydroxide, induces dentin bridge formation. Many investigators believe that the hard tissue bridge deposited next to MTA is because of the sealing property, biocompatibility, alkalinity and other properties associated with this material.

1.4.2.2 Clinical Applications

Diagrammatic representation of clinical usage of MTA is shown in **Figure (1.4) (Macwan and Deshpande, 2014):-**

1. Pulp capping
2. Pulpotomy
3. Root canal filling
4. Furcation perforation repair
5. Resorption repair

6. Repair of fracture - Horizontal and Vertical
7. Root end filling
8. Apical barrier for tooth with necrotic pulps and open apex
9. Coronal barrier for regenerative endodontics
10. Root canal sealer



Figure(1.4) ,clinical application of MTA in Primary and Permanent dentition, where, (A) Pulp capping/Partial pulpotomy, (B) Furcal repair, (C) Root canal sealer, (D) Root end filling/ Apexification, (E) Repair of root perforation/ resorption, (F) Pulp capping, (G) Pulpotomy, (H) Resorption repair, (I) Furcation perforation repair, (J) Root canal filling **(Macwan and Deshpande, 2014).**

MTA as pulp capping material:-

MTA has been proposed as a potential medicament for capping of pulps with reversible pulpitis because of its excellent tissue compatibility.It is much superior to the routinely used calcium hydroxide based on the tissue reaction and the amount and type of dentin bridge formed **(Singh *et al* ., 2017).**

MTA use in pulpotomy:-

Formacresol has been routinely used as a pulpotomy agent for deciduous teeth.

But this material has been criticized for its tissue irritating, cytotoxic and mutagenic effects. MTA was tested and found to be an ideal material with low toxic effects, increased tissue regenerating properties and good clinical results **(Figure 1.5) (Singh *et al* ., 2017).**

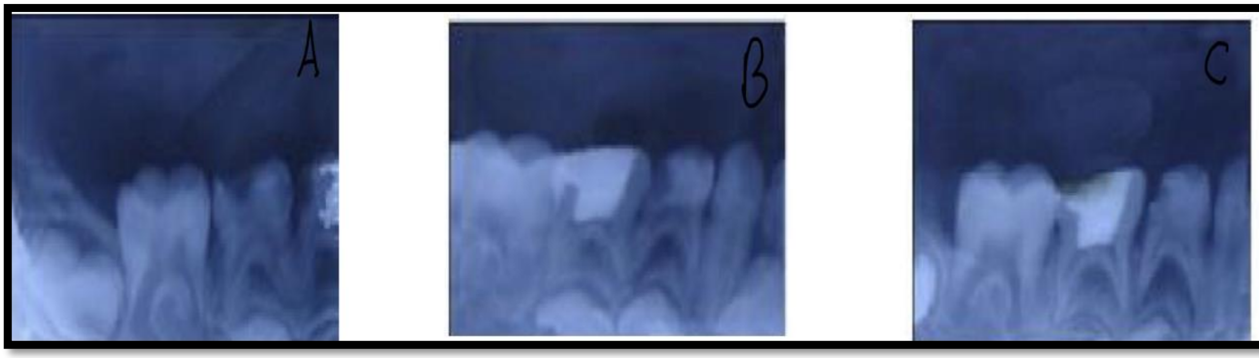


Figure (1.5), (A, B, C) Pulptomy illustrates ,(A) Diagnostic x-ray Lower left 2nd primary molar (B) Pulpotomy treatment with MTA in lower left 2nd primary molar (C) Follow up after one year period **(Al- Dahan et al., 2013).**

MTA use in apexification:-

Apexification using (MTA) provides an alternative treatment modality in immature pulpless teeth, It has become a popular material due to its superior biocompatibility, excellent marginal adaptability and good sealing ability.

Satisfactory compaction of obturating material is achievable as MTA on setting provides a sound and hard apical barrier**(Al-Dahan *et al*., 2014).**

Figure (1.6), Periapical radiographs of two teeth treated with MTA, (a) working length estimation, (b)MTA apexification for two incisors ,(c)obturation of one root canal ,(d)obturation of the other root canal, (e)follow-up at 3 month interval, (f) follow-up at 6 month interval (g)follow-up at 12 month interval **(Al-Dahan *et al*., 2014).**

1.4.3Biodentine

It is a bioactive dentin replacement material having similar properties of dentin and has a positive effect on vital pulp cells stimulating tertiary dentin formation **(Sonarkar and Purba, 2015).**

Biodentine is presented as powder and liquid. The powder is placed in a capsule while the liquid is in an ampoule. The powder is composed of tricalcium silicate, zirconium oxide, calcium carbonate and some minor additives of iron oxide added to give the colour. The liquid is made up of water with some additions of calcium chloride and a water soluble polymer.The design of Biodentine ensures optimal properties and thus enhances clinical performance **(Rini *et al*., 2021)**

To obtain Biodentine, it is necessary to insert 5 drops of the liquid in 0.7 grams of the powder that is present in the capsule. Then, the capsule is taken to the amalgamator or other compatible device for mixing the product at a speed of 4000-4200 revolutions per minute for 30 seconds **(Barreto, 2021).**

The relatively short setting time (around 12 min), can enable the use of this cement for restorative procedures; impossible with MTAs that achieve an initial setting 3-4 hours ***(*Singh *et al.*, 2021).**

1.4.3.1 Properties

Biodentine has the following properties **(Allazzam *et al.*, 2015) :-**

- It has fast setting time
- High biocompatibility
- High compressive strength
- Excellent sealing ability
- Ease of handling as well as its versatile usage in both endodontic repair and restorative procedures without causing any staining of the treated teeth.
- It has excellent antimicrobial properties due to its very high pH (pH=12).

- It is much more cost effective in comparison to similar materials**.**

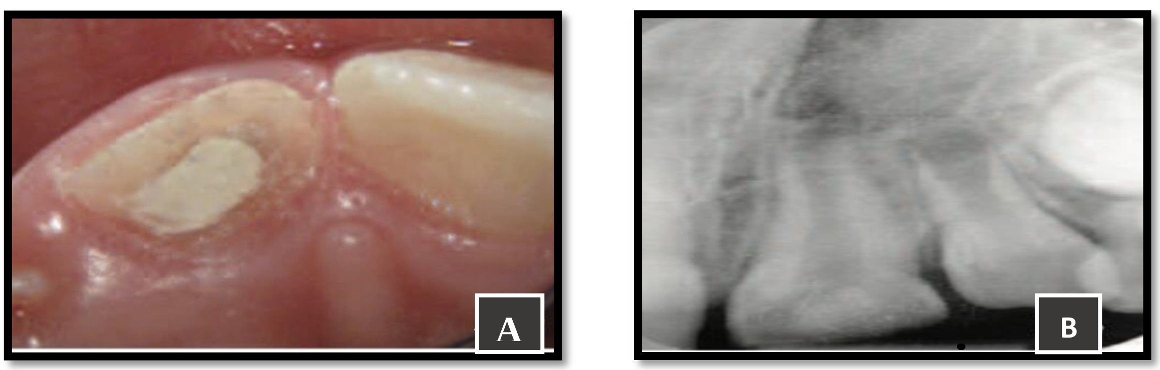
1.4.3.2 Clinical applications

It can be used in pediatric dentistry as follows **(Raju et al., 2021):-**

a. Dentine substitute under a composite restoration
b. Pulp capping
c. Pulpotomy
d. Apexification

Biodentine as a pulp capping material:-

Biodentine is recommended as an effective medicament for pulp capping procedure, as it has the unique feature in dentine bridge formation and tissue reaction **(Figure 1.7),** moreover, it has the ability to begin early mineralization from pulpal cells by releasing transforming growth factor–beta (TGF- BETA), thereby encouraging pulp healing **(Rajendraprasad., 2019).**



Figure(1.7), Biodentine as a pulp capping material , (A) biodentine used as pulp capping material,(B) postoperative radioghraph of the pulp cap with biodentine showing material with moderate radiopacity **(Ree, 2014).**

Biodentine as a pulpotomy agent:-

One of the key advantages of using biodentine in pulpotomy is that it required less time and also acts simultaneously as a filling and a dressing material. it was found that biodentine has the capacity of maintaining pulp vitality in patients opted for pulptomy treatment,as show in **(Figure 1.8) (Nasrallah *et al.*, 2018).**

Figure (1.8), Biodentine pulpotomy, Preoperative and postoperative periapical radiographs of mandibular second primary molar . (A) Preoperative radiograph; (B) postoperative radiograph taken immediately after BiodentineTM pulpotomy and restored with stainless steel crown; (C) 6-month follow-up periapical radiograph showing pulp canal obliteration of the pulpotomized mandibular second primary molar; (D) follow-up periapical radiograph with pulp canal obliteration **(Nasrallah *et al.*, 2018).**

Biodentine use in apexification:-

It was found that immature necrotic teeth after proper regenerative endodontic procedure with biodentine can still produce continued root development. It is highly recommended due to its property to induce new cementum and periodontal ligament formation **(Rajendraprasad, 2019).**

1.4.4 TheraCal LC

It is a new light-cured, resin-modified calcium silicate-filled base/ liner material designed for direct and indirect pulp capping**(Umale *et al*.,2021).**It ́s consists of tricalcium silicate particles in a hydrophilic monomer. The hydrophilic matrix provides significant calcium release that promotes dentin-pulp complex healing and regeneration **(Wassel *et al*., 2017).**

It is the easiest form of calcium silicate material to use due to its efficient syringe placement and its ability to be light cured.Hand mixing, instrument placement or trituration is not required **(Patel and Saleh, 2017).**

The application of this material in a thin layer is extremely important for shading because it is opaque and its white color can alter the desired color choice when placing the translucent composite over it**.** The manufacturer recommends placing it in 1mm layers and curing it for 20 seconds **(Dworkin *et al*., 2018)**.

1.4.4.1 Properties

Theracal has the following Properties (Umale *et al*., 2021)

1.Cytocompatibility and antibacterial properties

TheraCal LC is well tolerated by immortalized odontoblast cells. TheraCal showed a decreasing antibacterial effect on *streptococcus mutans* and very little effect on *streptococcus salivarius* and *streptococcus sanguis*.

2.PH

TheraCal LC has provided a very alkaline pH (10.66) after 3 hours, required for pulpal healing.

3. Solubility

Ideally, a liner or base material should be reasonably insoluble and have high strength.

4. Bonding

TheraCal LC is having the ability to bond to deep moist dentine, unlike Dycal which lacks adhesion. TheraCal is self-sealing, which helps in antimicrobial activity with initial bonds to dentine to resist accidental airdrying was removal.

5. Flexural strength,flexural modulus and compressive strength

TheraCal had the greatest flexural & compressive strength than MTA, Biodentine and Dycal ,in order to potentially resist fracture during immediate placement of a final restorative material.

1.4.4.2 Advantages and disadvantages

When theracal has the following advantages and disadvantages **(Anusha *et al*., 2022):-**

Advantages

- Shorter setting time facilitating immediate placement of final restoration
- Easier handling, precise placement, and higher flowability
- Acts as a scaffold for reparative dentin formation
- Ability to alkalinize surrounding pH and promote healing
- Low interfacial microleakage leading to protective seal

Disadvantages

- Lesser release of calcium ion and slower reaction rate compared with Biodentine
- Does not form calcium hydroxide following setting
- Internal root resorption
- An increase in pH due to hydroxyl ion release leads to pulpal irritation
- Cytotoxicity due to unpolymerized resin monomers
- Higher inflammatory effect and lower bioactive potential than biodentine

1.4.4.3 Clinical applications

- **TheraCal as a direct pulp capping material:-**

It should be placed directly over the exposure site, and then additional increments should be added to seal and provide a barrier for healing **(Figure 1.9) (Umale *et al*., 2021).**

TheraCal created complete dentinal bridges and mild pulpal inflammation suitable for pulp capping**(Cannon *et al.*, 2014).**

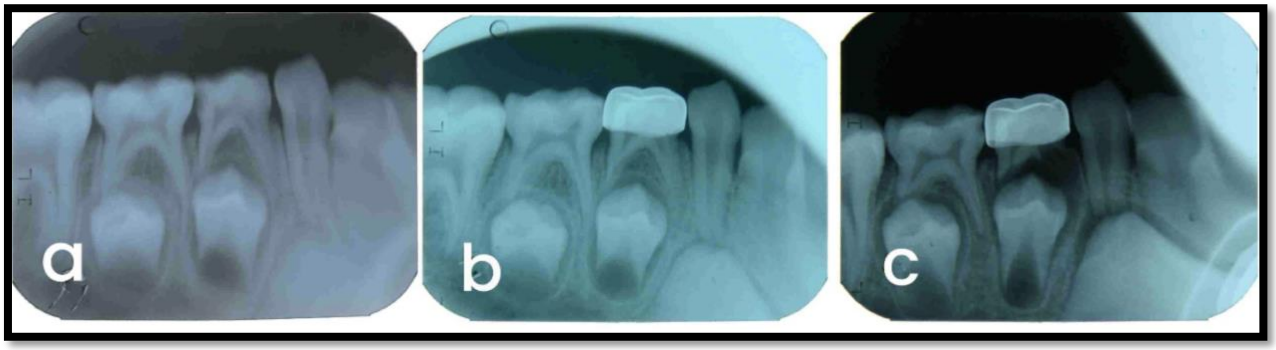


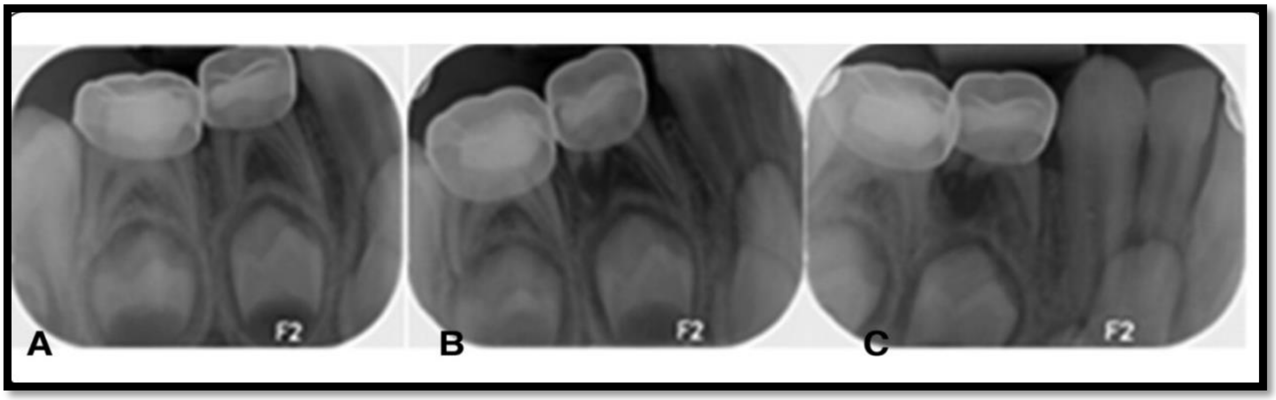
Figure (1.9), DPC in a mandibular first primary molar. (a) preoperative, (b) postoperative, (c) 6 months (**Wassel *et al.*, 2023).**

- **TheraCal 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 **(Umale *et al.*, 2021).**

TheraCal as a pulpotomy agent:-

In primary teeth using TheraCal LC exhibited decreased cell proliferation, viability, and migration with limited cell attachment. No evidence of tooth discoloration was observed **(Figure 1.10)**. Histologically, infiltration of chronic inflammatory cells, hard tissue, and osteodentin formation were observed **(Anusha *et al* ., 2022)**



Figure(1.10),TheraCal Pulpotomy in lower right first primary molar; (a) postoperative radiograph, (b) at 3 months showing internal root resorption, (c) at 6 months showing internal root resorption **(Wassel *et al.*, 2017).**

1.4.5 Bio-Ionomers

Glass Ionomer Cement (GIC) is essentially an aluminosilicate glass particulates that reacted with a polymeric acid**.**It is dental restorative material used in dentistry as a filling material and luting cement**(Pargaonkar *et al.*, 2018*;* Al-Tae'e *et al*., 2020).**

Glass-ionomer cements are widely used in oral healthcare, especially due to their ability to adhere to the tooth structure and fluoride-releasing capacity. Since GIC exhibit an inherent ability to adhere to tooth tissue, they have been the subject of modifications to enhance bioactivity, biomineralisation, and their physical properties. Chemically activated GICs, commonly referred to as conventional GICs, typically consist of ion leachable glasses based on calcium or strontium alumino fluorosilicate and weak polymeric water soluble acids of polyacrylic acid (PAA) They set by an acid base reaction, and the setting reaction is initiated by mixing glass powder and polymeric acids. which leaches out ions, commonly Ca^{2+} and Al^{3+} ions, into the aqueous medium **(Makanjuola and Deb, 2023).**

1.4.5.1 Properties

Bio-Ionomers has the followings properties (**Fierascu, 2022; Makanjuola and Deb, 2023):-**

- The mineralization potential of GIC is a desirable property, which has prompted researchers to explore different ways to enhance the bioactivity of GIC by the modification of the GIC-matrix by incorporating bioactive glasses (BAG), beta-tricalcium phosphate (β-TCP)such as the following:-
    - **a)** Add of wollasonite or MTA (The inclusion of either wollasonite or MTA (20% or below) into glass-ionomer powders resulted in a mineralised surface layer following storage of specimen in Simulated body fluid (SBF) without compromising Compressive strength (CS) or setting properties. The MTA additives increased the CS as the modified GIC matured compared to the control.
    - **b)** bioactive glass or casein phosphopeptide amorphous calcium phosphate (CPP-ACP) or chitosan were incorporated in glass ionomer (GI) powder(The addition of BAG, CPP-ACP or chitosan significantly improved the CS and Flexural strength (FS),The BAG-GIC showed a significantly higher fluoride release compared to the other groups,all the modified GIC groups showed significantly less bacterial adhesion than the conventional GIC.
    - **c)** The additional of 15% nano-β-TCP into GIC enhanced protection against acid demineralisation and promoted remineralisation of enamel surface.
- It has a good adhesion properties in moist environments
- It has a lower cytotoxicity when compared with other types of dental restoration materials

- The hydrophilicity allows them to bond to the teeth in the presence of residual fluids

1.4.5.2 Clinical application

Bio ionomers has the following application **(Sikka and Brizuela, 2023):-**

Restorative Material

Glass ionomer cement is popularly used in pediatric restorations thanks to its easy placement and better marginal adaptation. It is also indicated for restoring permanent teeth in low stress-bearing areas like class III and class V lesions. It is the material of choice in high-caries-risk patients due to the fluoride release.

Pulp protection

It used as liner or bases beneath metallic and composite restoration.

Luting agent

GIC can be used for luting of indirect restorations (metal and metal-ceramic) post and core and orthodontic bands and brackets.

1.4.6 Bioactive composite

It is a new bioactive restorative material called ActivaTM BioActive Restorative (Pulpdent Corp., USA) has been developed and introduced in the market.This material aims to combine the strength and esthetics of composites with all the benefits of glass ionomers, mimicking the physical and chemical properties of natural teeth **(Figure 1.11) (Lardani *et al.*, 2022).**

The components of ActivaTM are a patented bioactive ionic resin, a patented rubberized resin, and a bioactive ionomer glass **,**It ionic resin matrix allows the diffusion of calcium, phosphate and fluoride ions **(Kandil and Sherief, 2021).**

The rubberized resin is tough and durable, and contains reactive glass ionomer fillers that, in addition to a high fluoride release rate, mimic physical and chemical properties of natural teeth.

1.4.6.1 Properties

- **Polymerization**

It has a low polymerization shrinkage (1.7%) and high depth of light cure (4 mm), which allow for bigger increments and less time to complete the restoration **(Lardani *et a*l., 2022).**

- **Remineralization**

It stimulates the remineralization process by forming mineral apatite crystals **(Nanavati *et al* ., 2021).**

- **Bonding**

The bond thus formed is responsible for reducing marginal gaps and protecting the teeth against recurrent caries and failure of the restoration, Therefore the improved properties of activa restorative material may contribute to the higher bond strength values **(Nanavati *et al* ., 2021).**

Figure (1.11), clinical case in which use of Activa BioActive (A) pre operatory graph, (B) pre operatory radiography, (C) post operatory **(Lardani *et a*l., 2022).**

Because of these properties, this material has many indications for class I and class II caries in primary molars and it is also indicated in cases where the isolation is compromised or impossible and in patients with high caries index due to it fluoride-releasing properties **(Lardani *et a*l., 2022).**

1.4.7 Bioaggregate

Bio aggregate,it is a new generation of bio ceramic material is developed as a result of utilizing the advanced science of nanotechnology to produce ceramic particles that, upon reaction with water produce biocompatible and aluminum free ceramic biomaterials **(Raju *et al* ., 2021).**

The major components of BioAggregate is tricalcium silicate, dicalcium silicate, tantalum pentoxide, and calcium phosphate monobasic, To provide radiopacity, tantalum pentoxide is used in BioAggregate rather than the bismuth oxide in MTA **(Madfa *et al* ., 2014)**

The working time of BioAggregate is around 5 minutes. Upon mixing a thick paste-like mixture is formed. If additional working time is required, simply cover the mixture with a moist gauze sponge (**Raju *et al* ., 2021).**

1.4.7.1 Properties

Bioaggregate has the following properties **(Madfa *et al* ., 2014):-**

- It has excellent handling characteristics after mixing with water
- It is more biocompatible than any other root end filling and repair materials
- It has high sealing ability
- It assessed the long-term fracture resistance of human immature permanent teeth
- It has high pH and released calcium ions are required for a material to stimulate mineralization in the process of hard tissue healing.

1.4.7.2 Clinical application

It is indicated for repair of root perforation, repair of root resorption, root end filling, apexification, pulpotomy, and pulp capping (Figure1.12) (**Raju *et al* ., 2021).**

Figure (1.12) , pulpotomy using of bioaggregate, in 8-year-old boy (a) Intraoral appearance,(b)Radiographic appearance,(c)Intraoral appearance after 24 months,(D) Radiographic appearance after 24 months **(Tuloglu and Bayrak, 2016).**

Chapter two : Conclusion

With advances in technology, a ceaseless quest for bio mimetic materials which protects and maintains the health of hard and soft tissue persists.

Bioactive materials offer better alternative to the conventional dental materials, providing a potential benefit over non-bioactive materials .

They Possess a remineralizing and reinforcement effect on hard dental tissue. They also Protecting tooth structure from the harmful effects of all types of acids due to the increased pH level which provided by mineral saturation.

They have the ability to Chemically bond to hard dental tissues which in turn help to decrease sensitivity originated by bonding technique defects.

Furthermore, They are capable of releasing calcium and phosphorus ions from their composition, forming a mineral comparable to that of natural hydroxyapatite.

Thus, the benefits of bioactive materials appear to be of significant value in producing long durable restoration and help to repair damaged hard dental structure while decreasing the chance for recurrent decay occurs around existing restorations.

REFERENCES

(A)

- Al-Dahan, Z.A., Khalaf, M.S. and Al-Assadi, A.H., 2014. Apexification and periapical healing of immature teeth using Mineral Trioxide Aggregate. *Journal of baghdad college of dentistry*, 26(3), 108-112.
- Al-Dahan, Z.A., Zwain, A.M. and Al-Assadi, A.H.M., 2013. Clinical and radiographical evaluation of pulpotomy in primary molars treated with Pulpotec (PD), Formocresol and Mineral Trioxide Aggregate (MTA). Dentistry, 25(4), 164-170.
- Allazzam, S.M., Alamoudi, N.M. and El Meligy, O.A.E.S., 2015. Clinical applications of biodentine in pediatric dentistry: a review of literature. *Journal of Oral Hygiene & Health,* 1-6.
- Al-Tae'e, S.S., Almitwalli, O.M. and Farid, S.B., 2020. Preparation of glass ionomer cement from recycled low alumina glass. *Karbala Int J Mod Sci*, 6.
- Anusha, D.B., Prathima, G.S., Sanguida, A., Nandakumar, S. and Kavitha, M., 2022. Role of TheraCal LC in pediatric dentistry: A narrative review. *Journal of International Oral Health*, 14(2), p.111.
- Arandi, N.Z., 2017. Calcium hydroxide liners: a literature review. *Clinical, Cosmetic and Investigational Dentistry*, 67-72.
- Asthana, G. and Bhargava, S., 2014. Bioactive materials: a comprehensive review. *Sch. J. App. Med. Sci*, 2(6E), 3231-3237.

(B)

- Barreto, A., Zimmer, R., Reston, E.G. and Klein-Junior, C.A., 2021. The use of Biodentine as a pulp capping material. Brazilian *Journal of Development*, 7(11), .104527-104534.
- Benetti, F. (2019). *Bioactive Materials in Dentistry Remineralization and biomimetalization.* Nova Science Publishers.

(C)

- Calcium Hydroxide in Dentistry, (2016). *Chettinad Health City Medical Journal*, 5(1): 30-33.

- Cannon, M., Gerodias, N., Vieira, A., Percinoto, C. and Jurado, R., 2014. Primate pulpal healing after exposure and TheraCal application. *Journal of Clinical Pediatric Dentistry,* 38(4), 333-337.
- Chen, S., Cai, Y., Engqvist, H. and Xia, W., 2016. Enhanced bioactivity of glass ionomer cement by incorporating calcium silicates. Biomatter, 6(1)

(D)

- Dworkin, O., Kugel, G. and Cheen Loo, B.D.S., 2018. What is bioactive dentistry? A review. Dentistry Today, 37(1), 44-46.

(F)

- Fierascu, R.C., 2022. Incorporation of Nanomaterials in Glass Ionomer Cements—Recent Developments and Future Perspectives: *A Narrative Review*. Nanomaterials, 12(21), p.3827.

(H)

- Hamdy, T.M., 2018. Bioactivity: a new buzz in dental materials. EC Dental Science, 17(8), .1-6.
- Hegde, S., Shetty, D. and Hegde, S., 2016. The advent of bioactive materials in dentistry: a review. *Research Journal of Pharmaceutical*, Biological and Chemical Sciences, 7(5), 2701-2705.
- Hilton, T.J., Ferracane, J.L., Mancl, L. and Northwest Practice-based Research Collaborative in Evidence-based Dentistry (NWP), 2013. Comparison of CaOH with MTA for direct pulp capping: a PBRN randomized clinical trial. *Journal of dental research*, 92(7_suppl), S16-S22.

(K)

- Kandil, M. and Sherief, D., 2021. Marginal adaptation, compressive strength, water sorption, solubility and ion release of a claimed Bioactive restorative material. *Egyptian Dental Journal*, 67(1-January (Fixed Prosthodontics, Removable Prosthodontics and Dental Materials)),547-561.

(L)

- Lardani, L., Derchi, G., Marchio, V. and Carli, E., 2022. One-year clinical performance of Activa™ bioactive-restorative composite in primary molars. Children, 9(3), p.433.

(**M)**

- Macwan, C. and Deshpande, A., 2014. Mineral trioxide aggregate (MTA) in dentistry: A review of literature. *Journal of Oral Research and Review*, 6(2), p.71.
- Mahalaxmi, S. (2020). *Materials Used in Dentistry*, 2nd ed. India: Wolters Kluwer India Pvt. 694-702.

- Makanjuola, J. and Deb, S., 2023. Chemically Activated Glass-Ionomer Cements as Bioactive Materials in Dentistry: A Review. Prosthesis, 5(1), 327-345.
- Madfa, A.A., Al-Sanabani, F.A. and Al-Kudami, N.H.A.Q., 2014. Endodontic repair filling materials: A review article. *British Journal of Medicine and Medical Research*, 4(16), p.3059.

(N)

- Nasrallah, H., El Noueiri, B., Pilipili, C. and Ayoub, F., 2018. Clinical and radiographic evaluations of Biodentine™ pulpotomies in mature primary molars (Stage 2). *International journal of clinical pediatric dentistry*, 11(6), p.496.
- Nanavati, K., Katge, F., Chimata, V.K., Pradhan, D., Kamble, A. and Patil, D., 2021. Comparative evaluation of shear bond strength of bioactive restorative material, zirconia reinforced glass ionomer cement and conventional glass ionomer cement to the dentinal surface of primary molars: an in vitro study. *Journal of Dentistry*, 22(4), p.260.

(P)

- Patel A.Z.and Abdul Rahman M Saleh, 2017. "TheraCal lc: an extensive literature review", *International Journal of Current Research*, 9, (07), 54531-54535.
- Pannu, R. and Berwal, V., 2017. Calcium hydroxide in dentistry: *a review. J Appl Dent Med Sci*, 3(3), 24-31.
- Pargaonkar, S., Padubidri, M., Gunjal, S., Patil, P., Musmade, D. and Sankhe, C., 2018. Glass Ionomer Cement: Brief Review in Pediatric

Dentistry. *International J. of Healthcare and Biomedical Research*, 6(03), 13-17.

(R)

- Rajendraprasad, D., 2019. Review on biodentine: A boon to pediatric dentistry. *Int J Oral Health Dent*, 5(2), 55-8.
- Raju, S.S., Srujana, M.P., Kiranmayi, M., Reddy, E.R. and Sai, S., 2021. Bio active materials in pediatric dentistry: *A review*. *Int J Appl Dent Sci*, 7(1), 345-51.
- Rini, S.J., Dr. Rini SJ, Dr. Shinu Lal, Dr. Swathy Sukumaran, Dr. Rajesh Pillai and Dr. Afzal A.,2021. An insight into biodentine: A review. *International Journal of Applied Dental Sciences*; 7(3): 89-92.
- Ree, M., 2014. Vital pulp therapy with Biodentine™ in two immature, traumatized teeth. Septodont Case Studies Collection, 8, 25-30.

(S)

- Singh S, Mandlik J, Kanyal K, Danle R, Jadhav A.(2017) Mineral Trioxide Aggregate-A Review. *Indian Journal of Conservative and Endodontics*, 2(1):16-21.
- Singh, D.A.P.S., 2021. Bioactive material in pediatric dentistry. *University Journal of Dental Sciences*, 7(2),345-348.
- Sonarkar, S. and Purba, R., 2015. Bioactive materials in conservative dentistry. *Int J Contemp Dent Med Rev*, 2015, 1-4.
- Sikka, N. and Brizuela, M., 2023. Glass ionomer cement. StatPearls.

(T)

- Tuloglu, N. and Bayrak, S., 2016. Partial pulpotomy with BioAggregate in complicated crown fractures: three case reports. *Journal of Clinical Pediatric Dentistry*, 40(1), 31-35.

(U)

- Umale K., Gade V., Asani R., & Kosare P., Gaware S. and Gawande R. 2021. Theracal lc: A boon to dentistry. Archives of Dental Research. 11, 112-117.

(V)

- Varghese, L., Hegde, M.N., Shetty, A. and Shetty, C., RESEARCH AND REVIEWS: *JOURNAL OF DENTAL SCIENCES*.

(W)

- Wassel, M., Hamdy, D. and Elghazawy, R., 2023. Evaluation of four vital pulp therapies for primary molars using a dual-cured tricalcium silicate (TheraCal PT): one-year results of a non-randomized clinical trial. *J Clin Pediatr Dent*, 1, p.13.
- Wassel, M.O., Amin, D.H. and Badran, A.S., 2017. Clinical, Radiographic, and Histological Evaluation of TheraCal Pulpotomy in Human Primary Teeth. *Egyptian Dental Journal*, 63(3-July (Orthodontics, Pediatric & Preventive Dentistry)), 2175-2185.