IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Biosmart Materials In Pediatric Dentistry- A Narrative Review

[1]Dr.Kavya, [2]Dr.Bala Anusha D, [3]Dr.Rangeeth Bollam Nammalwar, [4]Dr.Sruthi O.K, [5]Dr.Rishitha Nithyanandam, [6]Dr.Arjun Thomas, [7]Dr.Rajakumar Sekar.

[1]Postgraduate Scholar, [2]Assistant Professor, [3]Professor and Head, [4]Assistant Professor, [5]Assistant Professor, [6]Associate Professor, [7]Professor

[1]Department of Pediatric Dentistry,

[1]Thai Moogambigai Dental College and Hospital, Dr. M.G.R. Educational and Research Institute (Deemed to be University) Chennai, Tamil Nadu, India.

Abstract: Bio-smart materials represent an advanced category of biomimetic restorative materials designed to imitate the structure and function of natural dental tissues while responding dynamically to changes in the oral environment. In Pediatric Dentistry, these materials exhibit properties such as fluoride and calcium ion release, remineralization potential, pH responsiveness, and adaptive mechanical behavior, thereby supporting minimally invasive and preventive treatment strategies. Their integration into restorative, preventive, orthodontic, and endodontic procedures enhances biocompatibility, clinical longevity, and overall treatment outcomes in children.

Index Terms - Biomimetics, Bio-smart materials, Pediatric dentistry, Remineralization, Smart restorative materials, minimally invasive dentistry.

I. Introduction

The term ‘Biomimetics’ originates from the Greek terms bio, signifying life, and mimesis, denoting imitation.It is an interdisciplinary scientific approach that aims to understand the structure, function, and mechanisms of living organisms and apply these principles to develop artificial materials that replicate natural biological behaviour.[1]

The concept of biomimetics is based on the understanding that natural systems possess highly efficient properties such as self-repair, adaptability, strength, and functional efficiency. By studying these biological models, researchers can design engineered materials with improved performance, durability, and biocompatibility.

The goal of biomimetics in dentistry is to create materials that replicate the mechanical, biological, and physical characteristics of dentin and enamel.These biomimetic materials can interact dynamically with the oral environment, promoting remineralization, preserving tooth structure, and supporting minimally invasive and biologically based restorative treatment.

II. METHODOLOGY:

A comprehensive literature search on biosmart materials in Pediatric Dentistry was carried out utilizing internet databases such as PubMed, Scopus, and Google Scholar. Keywords such as "biomimetic materials," "smart restorative materials," and "pediatric dentistry" were used in various combinations to find relevant publications.

III. HISTORY:

The hunt for the ideal restorative material has resulted in the creation of smart materials that can adapt to environmental stimuli such as stress, temperature, humidity, and pH variations. In the 1950s, *Otto Schmitt* introduced the concept of biomimetics while studying squid nerve function. He described it as the replication of natural biological processes to develop biocompatible materials. In 1960s, these materials were manufactured. In 1990, *Takagi* described them as 'intelligent' as they adapted to environmental conditions.[2]

IV. CLASSIFICATION OF BIO SMART MATERIALS:

(1) Broad Classification of Bone Grafting Materials:

- **Osteoproductive Materials** – These materials contain osteogenic stem cells that colonize the area, leading to both intracellular and extracellular responses at the interface, promoting new bone formation.
- **Osteoconductive Materials** – These materials facilitate bone growth by providing a biocompatible scaffold that supports bone migration. They elicit only an extracellular response at the interface without directly inducing new bone formation.

(2) Smart materials primarily classified into passive and active materials.

- **Passive materials** adapt to environmental changes automatically, without external intervention. They also have self-repairing properties.
- **Active materials** detect and respond to environmental changes.[3]

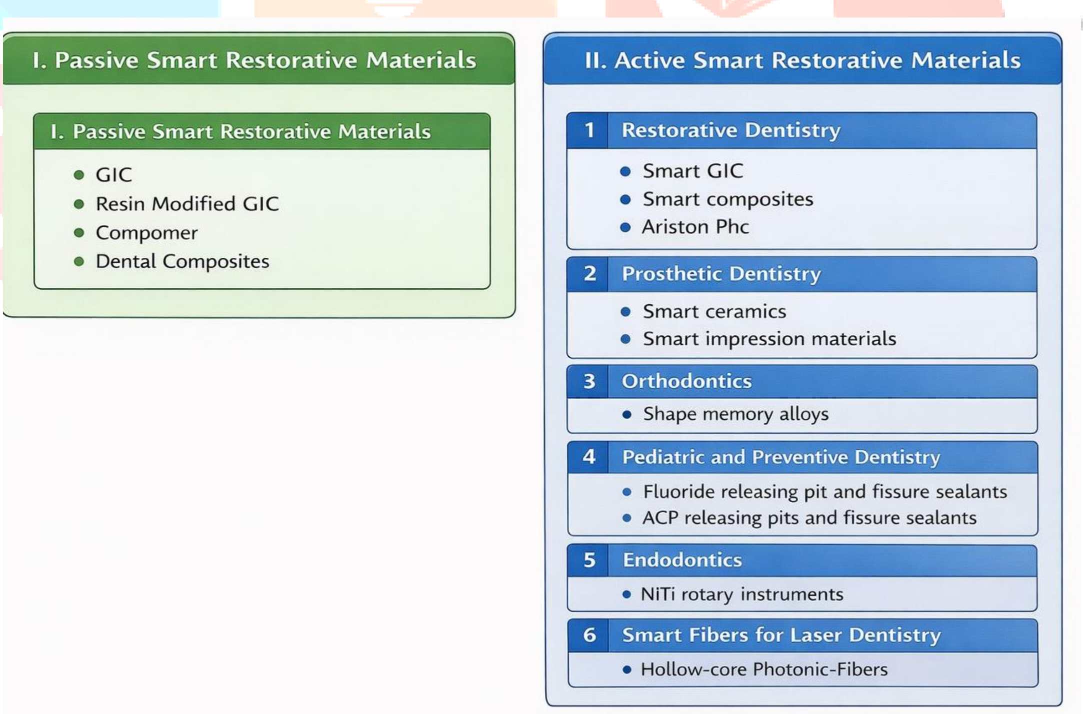


Figure 1: Classification of Smart restorative materials

V. PROPERTIES OF BIO SMART MATERIALS:

Sno.	**Property**	**Description**
1	Piezoelectric Property	Generates an electric current when subjected to mechanical stress.
2	Shape Memory Property	Recovers its original shape upon heating after deformation.
3	Thermochromic Property	Changes colour in response to temperature variations.
4	Photochromic Property	Alters colour based on lighting conditions.
5	Rheological Property	Transform from liquid to solid on exposure to magnetic field.
6	pH Sensitivity Property	Expands or contracts depending on ambient pH changes.
7	Biofilm-Responsive Property	Surface interaction with the environment is altered due to biofilm presence.

VI. USES OF BIO SMART MATERIALS IN PAEDIATRIC DENTISTRY:

- Enhances tooth remineralization
- Serves as a pulp capping material
- Used for permanent restorations
- Applied in apexification procedures
- Functions as a scaffold, promoting bone tissue regeneration

VII. FACTORS AFFECTING SMART RESTORATIONS:

Factor	Key Point
Biocompatibility	37% phosphoric acid removes smear layer → better SDF penetration. Polyacrylic acid has no significant effect.
Bond Strength	Pre-etching improves GIC & RMGIC bond strength. Etch-and-rinse > self-etch.
Conditioning vs Etching	SDF forms metallic silver → discoloration with light/heat. No effect on penetration depth.
Light Curing	Accelerates silver deposition (staining) but does not increase dentinal penetration.
Microleakage	SDF + KI + GIC shows highest resistance due to anti-MMP action and better bonding.

VIII. ADVANTAGES AND LIMITATIONS OF BIO SMART MATERIALS:

Advantages	Limitations
Ease of use: Comparatively simple application	Unesthetic black staining – Limits widespread acceptance
Minimally invasive: Reduces the need for extensive tooth preparation	Selective stain reduction – 20% glutathione effective mainly on enamel
Non-aerosol generating: Safer in infection-control scenarios	Dentist perception vs patient acceptance – Dentists more concerned about staining than parents/patients
Cost-effective: Suitable for low-resource settings	Tooth and gingival pain (6.6%), gingival swelling (2.8%), gingival bleaching (4.7%), metallic taste, and minor white mucosal lesions (resolve in 2 days) are mild and temporary adverse effects.
Less Chairside time: Quick application	Permanent staining of surfaces & clothing – Can be managed with sodium hypochlorite
Technique-sensitivity: Less - Can be performed in non-specialist settings	Skin staining – Temporary, resolves within 14 days due to keratinocyte turnover
Improved Patient compliance: Less painful and child-friendly	Mucosal staining risk – Long-term stains if applied on intraoral wounds
Reduced tooth sensitivity – Improves brushing comfort and oral hygiene adherence	Relative contraindication – Avoid in desquamative gingivitis or mucositis

IX. RECENT ADVANCES: AND APPLICATIONS OF BIOSMART MATERIALS IN DENTISTRY:

Silver modified Atraumatic Restorations:

A topical fluoride solution called silver diamine fluoride (SDF) is frequently used at a 38% concentration, which yields around 44,800 parts per million of fluoride. Up to five tooth surfaces can be treated with each of the roughly 250 drops in a single bottle of SDF. Auto-cure GIC is favored over light-cure in SMART restorations since light might darken the SDF. [4]

Amorphous Calcium Phosphate (ACP):

In 1963, Aaron S. Posner published the first description of ACP. ACP becomes crystalline hydroxyapatite (HAP) at or below the threshold pH of 5.8, replacing the HAP lost as a result of contact to acid. In a few of seconds, the free ions quickly combine to form a gel-like structure. This structure produces calcium and phosphate ions within two minutes, which aid in pH buffering and neutralization. Formulations of ACP include Enamel Pro Varnish.[4]

Casein Phosphopeptide-Amorphous Calcium Phosphate (CPP-ACP):

Amorphous calcium phosphate (ACP) and casein phosphopeptide (CPP), a milk-derived protein, are utilized in some dentifrices under the trade name ReCaldent to remineralize early white spot lesions. Example of commercially available product is GC Tooth Mousse Plus.[4]

Smart Prep Burs:

Lasers, chemo-mechanical procedures, and mechanical rotary and non-rotary tools are different methods of caries removal. Additionally, non-invasive techniques include air abrasion, air polishing, ultrasonic, and sonic abrasion. ‘Smart Prep Burs’ are specially designed to remove only infectious dentin while retaining affected dentin, thereby increasing chance of remineralization. When these burs come into contact with normal or partially decalcified dentin, their cutting blades deflect and distort, decreasing their cutting efficiency. They are very helpful since they preserve good tooth structure, even though the caries eradication process may take a little longer.[5]

Smart Glass Ionomer Cement (Smart GIC):

Davidson was the first to recognize Glass Ionomer Cement's clever behaviour. GIC can sustain minimal dimensional changes in the presence of moisture or heat since it has a coefficient of thermal expansion comparable to that of dental hard tissues. However, water flow within its structure causes it to significantly compress when heated to 50°C in dry conditions; this behaviour is comparable to that of human dentin. According to *Mahmud GA et al* (2007), fluoride-releasing cements can lessen demineralization surrounding orthodontic brackets; this impact is independent of the amount of fluoride released. [6, 13]

Smart Composites:

Alkaline, nano-filled glass restorative materials called "smart composites" are made to react to changes in intraoral pH. They release calcium, fluoride, and hydroxyl ions when the pH falls below 5.5, which improves tooth protection and encourages remineralization. With an effective depth of up to 4 mm, these materials are appropriate for Class I and Class II cavities in both permanent and deciduous teeth.

Smart Ceramics:

Smart ceramics offer outstanding aesthetics without sacrificing durability or dependability. These materials are perfect for dental restorations since they are biocompatible and free of metals. Because zirconium oxide is used, the Cercon system has many benefits, such as high strength, toughness, dependability, and biocompatibility. Maximum durability and a natural appearance are guaranteed by this incredibly thin monolithic material. Example: Cercon Zirconium Smart Ceramic System[11]

***Shape Memory Alloys (SMA*):**

When exposed to thermo-mechanical loads, metals known as Shape Memory Alloys can revert to their original length or shape. They display important characteristics such strong resistance to wear and fatigue, shape memory effect, superelasticity, and superior biocompatibility. For instance, nickel-titanium (NiTi) is a popular SMA in dentistry because of its remarkable durability and flexibility.[7]

Nickel Titanium Alloy:

Buehler et al. at the Naval Ordnance Laboratory (NOL) created the nickel-titanium (NiTi) alloy, commonly referred to as Nitinol, which has great fatigue resistance, shape memory, and super elasticity. It exists in two phases: the austenitic (high-temperature) phase with a hexagonal lattice that can vary in response to stress or temperature variations, and the martensitic (low-temperature) phase with a body-cantered cubic lattice. Introduced by Walia et al. (1988), 55NiTiNOL (55 wt.% Ni, 45 wt.% Ti) rotary devices improve access to curved root canals in endodontics, enabling focused preparations with minimal canal transportation and procedural mistakes. NiTi archwires are superior to stainless steel in orthodontics because of their superelasticity and shape memory, which allow for constant, mild stresses for effective tooth movement.[8]

Smart Fibres For Laser Dentistry:

Laser stands for "Light Amplification by Stimulated Emission of Radiation." One kind of electromagnetic wave generator is a laser.

Three distinctive characteristics of the emitted laser are as follows:

- Waves that are monochromatic have the same energy and frequency.
- Coherent waves have a specific phase and are related to one another in terms of time and speed.
- Collimated: the beam divergence is very small and the emitted waves are almost parallel.

Hollow-core Photonic Fibers have been designed to emit high-fluency laser light that can ablate tooth enamel. These photonic fibres are referred to as "smart fibres." Photonic Crystal Fibre can be utilized for optical diagnosis and detection by transmitting plasma emission, in addition to carrying a high-power laser pulse to a tooth surface. When employing these fibres, caution should be exercised because laser light may leak out and damage healthy tissue.[9]

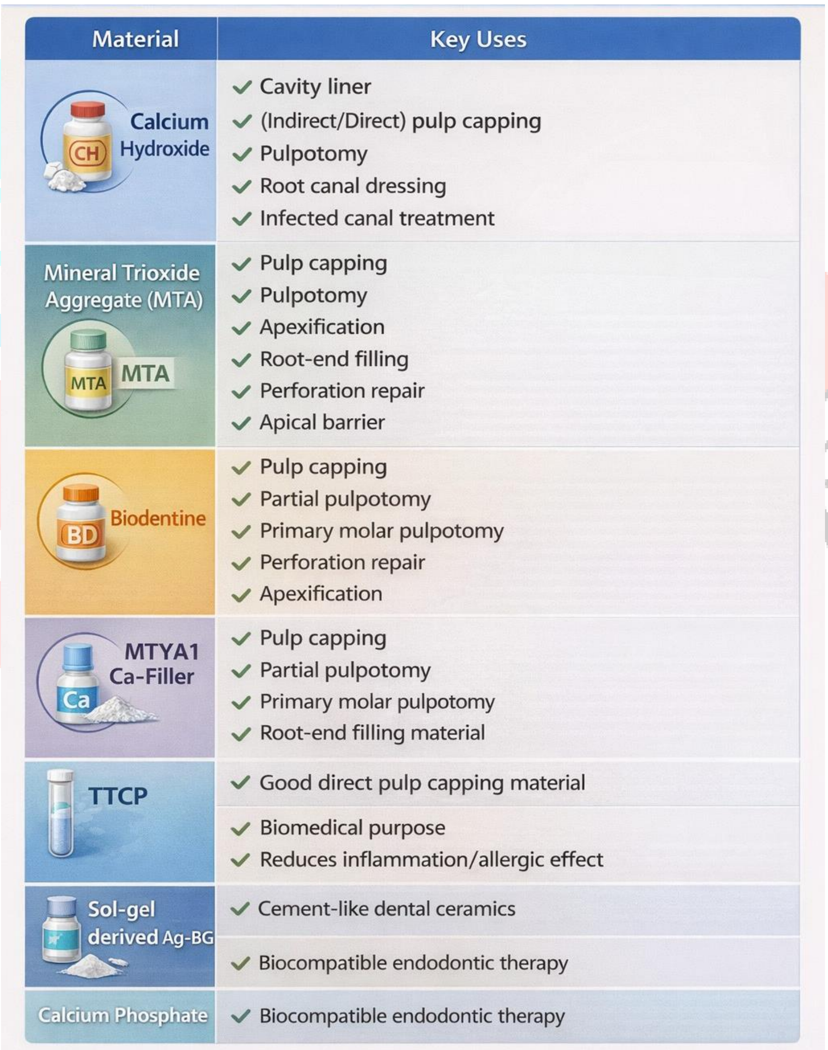
Smart Sutures:

Thermoplastic polymer-based sutures with shape memory and biodegradability are known as "smart sutures." These sutures can identify infections since they are composed of silk or plastic threads that have micro-heaters and temperature sensors inserted in them. They are knotted loosely at first, but they shrink and tighten for better wound closure when the temperature rises above their thermal transition threshold.

Smart Antimicrobial Peptides

Streptococcus mutans which is the main cause of dental caries, is the target of Smart Antimicrobial Peptides, which are pheromone-guided peptides. These peptides, which are essential for tissue regeneration technologies, have a variety of peptide sequences and post translational modifications; the majority are amphipathic, consisting of cationically charged α-helical and β-sheet structures. They work by attaching themselves to negatively charged microbial membranes, such as lipopolysaccharides, which causes membrane breakdown or intracellular translocation for deadly consequences. To efficiently suppress cariogenic bacteria and improve oral health, Smart Targeted Antimicrobial Peptides (STAMPs) can be added to dental floss, toothpaste, and mouthwash.[4]

X. APPLICATIONS OF BIO SMART MATERIALS IN PEDIATRIC DENTISTRY:



Material	Key Uses
Calcium Hydroxide	✓ Cavity liner ✓ (Indirect/Direct) pulp capping ✓ Pulpotomy ✓ Root canal dressing ✓ Infected canal treatment
Mineral Trioxide Aggregate (MTA)	✓ Pulp capping ✓ Pulpotomy ✓ Apexification ✓ Root-end filling ✓ Perforation repair ✓ Apical barrier
Biodentine	✓ Pulp capping ✓ Partial pulpotomy ✓ Primary molar pulpotomy ✓ Perforation repair ✓ Apexification
MTYA1 Ca-Filler	✓ Pulp capping ✓ Partial pulpotomy ✓ Primary molar pulpotomy ✓ Root-end filling material
TTCP	✓ Good direct pulp capping material ✓ Biomedical purpose ✓ Reduces inflammation/allergic effect
Sol-gel derived Ag-BG	✓ Cement-like dental ceramics ✓ Biocompatible endodontic therapy
Calcium Phosphate	✓ Biocompatible endodontic therapy

Figure 2: Most commonly used biomimetic materials in Pediatric Dentistry

ACP-Releasing Pit and Fissure Sealants:

First identified by Aaron S. Posner in 1963, amorphous calcium phosphate (ACP) is essential to the biological synthesis of hydroxyapatite (HAP). ACP is frequently utilized in dental cements, adhesives, pit and fissure sealants, and composites due to its preventive and restorative qualities.[3]

Mechanism of Action:

In the oral environment, ACP is stable at both neutral and high pH. However, ACP transforms into crystalline HAP when pH falls to 5.8 or lower (critical pH), replacing lost HAP crystals as a result of demineralization. In under two minutes, the released calcium and phosphate ions quickly form a gel-like structure that neutralizes acids and buffers pH before turning into amorphous crystals.

Importance:
•When necessary, it strengthens the tooth's natural defence system.
• It has a lengthy lifespan. Patient compliance is not necessary for its efficacy.
For instance, Bosworth's Aegis Pit and Fissure Sealant.

2.Fluoride-Releasing Pit and Fissure Sealants:

Although occlusal surfaces make up only 12% of the tooth surface, they are eight times more susceptible to caries than smooth surfaces. Therefore, preventing occlusal caries is crucial for preserving tooth structure.

Fluoride Incorporation Methods:

1. Anion Exchange System – Organic fluoride compounds chemically bound to the resin.
2. Fluoride Salt Addition – Fluoride salts added to the unpolymerized resin.

Mechanism of Fluoride Release: The exact mechanism remains speculative, but fluoride release may occur due to:

- Porosity within the sealant material.
- Weak binding of fluoride ions or fluoride glass to the polymerized resin molecules.

Examples: Fluoroshield and Delton Plus

XI. CONCLUSION:

Bio-smart materials represent a significant advancement in pediatric dentistry by combining biomimetic principles with intelligent material behavior. Their ability to respond to environmental changes, release therapeutic ions, and support remineralization makes them highly suitable for minimally invasive and preventive treatment approaches in children. By closely mimicking natural tooth structure and function, these materials enhance clinical longevity, improve patient outcomes, and contribute to biologically driven, conservative dental care.

REFERENCES

1. Dhull KS, Dutta B, Verma T. Biosmart materials in dentistry: An update. Int J Oral Care Res. 2017;5(2):143-8.
2. Padmawar N, Pawar N, Joshi S, Mopagar V, Pendyala G, Vadvadgi V. Biosmart dental materials: A new era in dentistry. Int J Oral health med res. 2016;3(1):171-6.
3. Hassan SA, Bhateja S. Smart materials in pediatric dentistry-a review. IP J Paediatr Nurs Sci. 2020;3:31-.
4. Natarajan D. Silver modified atraumatic restorative technique: a way towards “SMART” pediatric dentistry during the COVID-19 pandemic. Frontiers in Dentistry. 2022 Mar 12;19:12.
5. Lăcătușu R, Daniela-Maria P, Marcel NR, Borislav-Dusan C, Ionut OA, Nadina I, Ramona D, Roxana O. Mechanical Evaluations of Devitalized Teeth Reconstructed Using Direct and Indirect Techniques. Medicine in Evolution. 2025 Jun 15;31(2):153-65.
6. Jain P, Kaul R, Saha S, Sarkar S. Smart materials-making pediatric dentistry bio-smart. Int J Pedod Rehabil. 2017 Jul 1;2(2):55.
7. Joshi SR, Thacker S, Mopagar VP, Padmawar NS, Patil CK, Pendyala GS. Smart Materials in Pediatric Dentistry. Journal of the International Clinical Dental Research Organization. 2024 Jul 1;16(2):115-9.
8. Bhatnagar A, Wagh S, Singh B, Agarwal RR, Khan F. Smart materials-a review. Ann. Dent. Spec. 2016 Jan 1;4(1):10-2.

9. Shanthi M, Sekhar ES, Ankireddy S, Shah SG, Bhaskar V, Chawla S, Trivedi K. Smart materials in dentistry: Think smart. Journal of Pediatric Dentistry/Jan-Apr. 2014;2(1):33.
10. Bhatnagar A, Wagh S, Singh B, Agarwal RR, Khan F. Smart materials-a review. Ann. Dent. Spec. 2016 Jan 1;4(1):10-2.
11. Little DA. A smart ceramics system for expanded indications. Inside Dent. 2012;8(12):1-4.
12. Kamila S. Introduction, classification and applications of smart materials: an overview. American Journal of Applied Sciences. 2013 Aug 1;10(8):876.
13. Itota T, Carrick TE, Yoshiyama M, McCabe JF. Fluoride release and recharge in giomer, compomer and resin composite. Dental Materials. 2004 Nov 1;20(9):789-95.