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Review Article

Bioactive Material in Pediatric Dentistry

Eemana Bhat*, Chaya Chhabra, Khushbu Soni, Babra Khan, Shrushti Thakre, Angha Patil

NIMS Dental College, Rajasthan , Jaipur 303121

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ABSTRACT

The evolution of restorative dentistry in pediatric practice has shifted from the use of inert restorative materials to biomimetic, biologically active agents capable of interacting with dental tissues. Bioactive materials release therapeutic ions, induce remineralization, and promote pulp healing, thus offering promising alternatives to conventional composites and amalgams. Their application in pulp therapy, restorative procedures, and preventive care makes them highly relevant in preserving primary dentition. This review outlines the classification, mechanisms of action, applications, and limitations of bioactive materials in pediatric dentistry, with emphasis on their clinical implications and future prospects.

INTRODUCTION

Pediatric dentistry requires unique restorative approaches due to the distinctive anatomy of primary teeth, including thinner enamel, larger pulp chambers, and wider dentinal tubules. Conventional materials such as amalgam and early composite resins lacked biological interaction and often led to recurrent caries or pulpal complications. Bioactive materials, defined as substances that interact with biological tissues to stimulate healing, ion exchange, or remineralization, are increasingly employed in pediatric restorative and endodontic therapies [1]. Their biomimetic potential makes them particularly suitable for minimally invasive pediatric dentistry [2].

HISTORY OF BIOACTIVE MATERIALS

The concept of bioactive materials originated in the late 1960s when Hench developed Bioglass®, a silica-based glass capable of forming a chemical bond with bone [3]. In dentistry, the first bioactive restorative materials were glass ionomer cements introduced in the 1970s, primarily valued for their fluoride release and chemical adhesion. Over the decades, materials such as calcium silicate cements, bioactive composites, and bioceramics

***Corresponding Author:** Eemana Bhat
Address: *NIMS Dental College, Rajasthan , Jaipur 303121*
Email : eemanabhat0@gmail.com

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have expanded the field, emphasizing the combination of mechanical properties and biological activity [4,5].

CLASSIFICATION OF BIOACTIVE MATERIALS

Bioactive materials in pediatric dentistry can be classified based on their composition and mechanism of action [3]:

1. **Glass Ionomer Cements (GICs) and Resin-Modified GICs** – Fluoride-releasing materials with chemical adhesion to tooth structure and anticariogenic potential [4].
2. **Bioactive Composites and Adhesives** – Resin-based restoratives enhanced with bioactive fillers such as calcium phosphate or bioactive glass [5].
3. **Calcium Silicate-Based Materials** – Mineral Trioxide Aggregate (MTA), Biodentine, and newer calcium silicate cements with excellent pulp biocompatibility [6].
4. **Silicate-Based Materials** – Including bioactive glass, which induces apatite formation and provides remineralization [7].
5. **Calcium Phosphate-Based Materials** – Hydroxyapatite and tricalcium phosphate, useful as remineralizing agents and in pulp therapy [8].
6. **Bioceramic Materials** – Sealers and putties used in vital pulp therapy and root canal obturation of primary teeth [9].
7. **Smart Dentin Replacement (SDR) Materials** – Hybrid bioactive resins designed to act as dentin substitutes with sustained ion release [10].

MECHANISMS OF BIOACTIVITY

Bioactivity involves controlled release of calcium, phosphate, fluoride, and silicate ions, which nucleate the formation of hydroxycarbonate apatite. This remineralizes enamel and dentin, seals restoration margins, and creates alkaline conditions with antibacterial action [11]. Calcium silicate materials promote dentin bridge formation by releasing calcium hydroxide [12]. Bioactive glasses dissolve in aqueous environments, releasing ions that precipitate as apatite on tooth surfaces [13]. Resin-based bioactive materials combine esthetics and strength with continuous ion release [14].

APPLICATIONS IN PULP THERAPY

Pulpotomy is one of the most common pediatric procedures, and bioactive materials have transformed its prognosis. MTA has been considered the gold standard, demonstrating superior sealing ability and pulp healing outcomes compared with formocresol [15]. Biodentine is widely adopted as a pulpotomy agent due to faster setting, reduced discoloration, and comparable success rates [16]. Bioceramic materials such as premixed sealers are also emerging as effective alternatives in vital pulp therapy of primary teeth [17].

Applications in Restorative Dentistry Glass ionomer cements remain widely used in pediatric practice because of fluoride release and ease of handling, especially in atraumatic restorative treatment (ART) [18]. Advances in resin-modified GICs and bioactive composites such as ACTIVA BioACTIVE provide enhanced esthetics, fluoride, calcium, and phosphate release while maintaining mechanical durability [19]. Clinical studies have shown ACTIVA to perform comparably to RMGIC in Class II restorations in primary molars, with improved marginal sealing [20].

APPLICATIONS IN PREVENTIVE DENTISTRY

Bioactive glass-containing toothpastes and varnishes have shown significant efficacy in remineralizing early enamel lesions and reducing hypersensitivity in molar-incisor hypomineralization (MIH) [21]. Studies demonstrate that bioactive glass improves enamel microhardness and reduces lesion progression, offering a minimally invasive approach for caries prevention [22].

BIOCERAMICS AND SMART MATERIALS

Bioceramic sealers have gained importance in pediatric endodontics for root canal obturation, offering bioactivity, resorbability, and antibacterial properties [23]. Smart dentin replacement (SDR) materials represent a new generation of bulk-fill resins with ion-releasing capability, antibacterial properties, and reduced polymerization shrinkage, making them suitable for pediatric applications [24].

LIMITATIONS AND FUTURE PERSPECTIVES

Despite their advantages, bioactive materials have certain limitations, including high cost, lower mechanical strength compared to conventional composites, and sensitivity to moisture during placement [25]. Long-term randomized controlled trials in pediatric populations are still limited. Future research should aim to develop multifunctional bioactive restoratives with improved durability, sustained ion release, and stronger antibacterial potential.

CONCLUSION

Bioactive materials have revolutionized pediatric restorative and pulp therapy by combining biological activity with restorative function. Their role in pulpotomy, restorative treatment, and preventive care demonstrates their superiority over conventional inert materials. With continued advancements, bioactive materials are expected to become integral to minimally invasive and biologically driven pediatric dentistry.

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