

Restorative options for primary teeth in pediatric dentistry

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Abstract

Restoration of primary teeth is a fundamental component of pediatric dental care, as primary dentition plays a critical role in mastication, speech development, esthetics, and the maintenance of arch integrity for the eruption of permanent teeth. Dental caries remains one of the most prevalent chronic diseases in children worldwide, making the selection of appropriate restorative materials essential for achieving durable and biologically acceptable outcomes. This narrative review aims to evaluate the restorative options available for primary teeth in pediatric dentistry, with emphasis on their clinical performance, advantages, and limitations. Due to the anatomical and histological differences between primary and permanent teeth—such as thinner enamel and dentin, larger pulp chambers, and shorter functional lifespan—restorative material selection in primary teeth requires specific considerations. Traditional materials, including dental amalgam, have demonstrated long-term durability and moisture tolerance; however, their use has declined due to esthetic demands and concerns regarding mercury exposure. Glass ionomer cements and their modified forms offer chemical adhesion to tooth structure, fluoride release, and cariostatic properties, making them particularly suitable for children at high caries risk, despite their relatively lower mechanical strength. Resin-based materials, such as composite resins, compomers, giomers, and ormocer-based systems, provide superior esthetics and acceptable mechanical properties, but their clinical success is highly dependent on proper isolation and technique sensitivity. Full-coverage restorations, including stainless steel crowns, veneered crowns, prefabricated zirconia crowns, and newly developed polymer-based crowns, are recommended for extensively damaged primary teeth, especially following pulp therapy. Stainless steel crowns remain the gold standard for posterior primary teeth due to their durability and cost-effectiveness, whereas zirconia and aesthetic crowns offer improved esthetic outcomes with certain limitations related to tooth preparation and retention. Recent advancements in restorative materials and digital technologies, such as CAD-CAM-fabricated crowns, have expanded treatment options in pediatric dentistry. In conclusion, no single restorative material fulfills all clinical requirements. The selection of restorative options for primary teeth should be individualized based on the child's age, caries risk, tooth location, functional demands, esthetic expectations, and level of cooperation. Appropriate material selection contributes significantly to the long-term oral health and overall well-being of pediatric patients.

Keywords: Primary teeth, restorative materials, pediatric dentistry, glass ionomer cements, composite resins, zirconia crowns

1. Introduction

Dental caries is a highly prevalent disease, affecting more than 621 million children worldwide, and is thus recognized as a significant public health concern (1). Dental caries are a preventable and treatable disease (2). Both invasive and non-invasive treatments are available for the management of carious lesions. The goal of restorative treatments is to restore function and ideal aesthetics through accurate diagnosis and treatment (3). Restorative procedures aim to preserve the sound tooth structure, prevent trauma to the pulp and surrounding soft tissues, and consequently achieve more successful and long-lasting restorations (4).

The selection of appropriate restorative treatment materials is crucial for treatment success. An ideal restorative material should be similar to tooth tissue and possess physical and chemical properties that allow it to remain undeformed in the oral cavity for a long time. Additionally, it should have biocompatibility, adequate adhesive properties, aesthetics, sufficient mechanical strength, and ease and speed of application (5). New materials are continuously being developed to enhance the properties of restorative materials used in dental practice, such as sealing, aesthetics, anticariogenicity, and durability.

The anatomical and histological characteristics of primary teeth differ from those of permanent teeth, leading to differences in the considerations required for selecting restorative materials. Thin enamel and dentin thickness, small tubercle-to-tubercle and occlusal distances, flat proximal contacts, occlusally orient cervical enamel rods and sudden constriction of the crown in the cervical region significantly influence the success of restorations in primary teeth (6). Moreover, factors such as the shorter retention time of primary teeth in the mouth compared to permanent teeth, limited working time in pediatric patients, and patient compliance during treatment also affect the selection of restorative materials (7).

This study aims to provide information about the restorative materials used in primary teeth.

2. Amalgam

Periodontology is concerned with diseases affecting the gu Amalgam is a restorative material composed of a mixture of metals such as silver, copper, tin, and mercury (8). Owing to its lower technical sensitivity and moisture control requirements compared to resin-based materials, amalgam may be preferred for the restoration of primary teeth (9). It can be used in Class I and II cavities of primary and permanent teeth in situations where durability and strength are required, and aesthetics are not a concern (10). While the seven-year success rate of amalgam restorations in primary Class I cavities has been reported to range between 85-96%, the annual failure rate has been reported to be 32% (11). The

decreased preference for amalgam in recent years has been influenced by discussions regarding the potential negative effects of mercury on general health, environmental concerns, and the increased availability of aesthetic alternatives (10). Some disadvantages of dental amalgam include its lack of chemical adhesion to tooth tissue, inability to allow for minimally invasive cavity preparation, low fracture resistance, and high thermal conductivity. Additionally, amalgam restorations require more aggressive retentive preparations than resin-containing restorations do. The need to extend the preparation into decay-prone fissures also increases the size of the preparation (12).

The Food and Drug Administration (FDA) recommends avoiding the use of dental amalgam and evaluating alternative restorative materials in certain high-risk populations, such as pregnant women, nursing women, children under six years of age, individuals with kidney dysfunction, and those with pre-existing neurological conditions. However, the American Dental Association (ADA) has stated that amalgam is a durable, safe, and effective restorative option and that no new scientific evidence was included in the FDA's recommendations. ADA encourages dentists to review all restoration options with their patients, including the risks and benefits of amalgam (13).

3. CONVENTIONAL GLASS IONOMER CEMENT

Conventional glass ionomer cements (CGIC) consist of filler particles reinforced with glass that are surrounded by ion-crosslinked polymer matrices. CGICs are obtained by combining the fluoride release and translucency properties of silicate cements with the chemical adhesion and biological compatibility of polycarboxylate cements with tooth tissues (14). The hardening reaction of CGICs is an acid-base reaction. During the hardening reaction, the glass particles reacted with polyalkenoic acid, resulting in a high fluoride release effect within the first 24 hours. The initially high fluoride release rapidly decreases after 24-72 hours, approaches a stable level within 10-20 days, and the fluoride content is rapidly depleted within a few months. Studies comparing different restorative materials have found that CGICs exhibit the highest fluoride release (15, 16). CGICs have the ability to uptake fluoride from the environment depending on the concentration gradient (17). The anticariogenic potential due to fluoride release, biocompatibility, and chemical adaptation to tooth tissues makes CGICs a special group of materials. However, their poor mechanical properties, such as low fracture resistance, hardness, and wear resistance, limit their use as restorative materials in areas exposed to high stress in the posterior regions (18). During application, the early contamination of the material with water and saliva reduces its hardness and increases its solubility. CGICs are highly sensitive to excessive dryness, leading to cracks, fissures, discoloration, and

marginal leakage (19). CGICs, when applied with atraumatic restorative treatments in areas with limited access to treatment, have shown acceptable clinical performance and survival rates (20).

4. Resin-modified glass ionomer cement

To improve the moisture sensitivity and mechanical strength of CGICs, a hybrid restorative material consisting of 80% glass ionomer cement and 20% resin-based material was introduced in the late 1980s (21). This material was developed to address the existing issues with CGICs while preserving the fluoride release, rechargeability, and chemical adhesion properties of CGICs. The physical and mechanical properties of resin-modified glass ionomer cements (RMGIC) are between those of CGICs and composite resins (18). The addition of a resin component to the CGIC composition introduced a secondary polymerization reaction during hardening. A matrix is formed as a result of light polymerization, and this matrix continues the acid-base reaction, allowing better hardening and higher resistance of the material (22). RMGIC, like CGIC, has the ability to chemically bond to tooth tissues, release fluoride, and, due to its resin content, offers easy preparation and application and longer and controlled working time, making it an alternative to amalgam and composite resins in primary teeth (23).

The addition of the resin matrix allows these resin-based cements to bond to composite restorations and can be used as base or liner materials in primary and permanent tooth cavities (24). Studies in the literature have indicated that RMGIC is as clinically successful as amalgam in Class II restorations of primary teeth, and less recurrent caries are observed at the margins of teeth restored with RMGIC than with amalgam (25).

5. High-viscosity glass ionomer cement

High-viscosity glass ionomer cements (HVGCs) were introduced to reduce the moisture sensitivity of CGICs, increase wear resistance under occlusal forces, and expand their indications beyond Class I and Class V restorations (26). They were also intended to replace composite resin and amalgam as permanent restorative materials (18). HVGCs were obtained by increasing the powder/liquid ratio of the CGICs, adding polyacrylic acid to the powder, and modifying the particle size (27). These cements, which share the exact hardening mechanisms as CGICs, exhibit improved wear resistance, surface hardness, flexural strength, compressive strength, and reduced solubility. Their hardening is quick, and their moisture sensitivity is significantly reduced, with very low solubility in oral fluids. Owing to

their rapid hardening reactions, early exposure to water does not negatively affect their physical properties (22). Their fluoride release and biocompatibility were similar to those of CGICs (28). In a study comparing fluoride release, HVGC exhibited the highest fluoride release, followed by nano-ionomers, compomers, and ionomers (29). In another study comparing the one-year fluoride release of Fuji IX GP Extra, Glass Ionomer FX-II, Ketac Molar Easymix, and Riva Self Cure materials, the highest fluoride release was reported for Fuji IX GP Extra (30). Factors such as changes in the powder and liquid contents, powder/liquid ratio, and mixing methods affect the mechanical properties of the material (31). Owing to the difficulty in determining the correct powder/liquid ratios for clinical use and the challenges of manual mixing, capsule forms have been developed for clinicians. Molina et al. found that capsule forms of HVGCs had significantly higher tensile strength, flexural strength, and compressive resistance compared than manually mixed forms (28).

6. Polyacid-modified composite resin (COMPOMER)

This restorative material contains dimethacrylate monomers with two carboxyl groups and ion-releasing glass-like fillers, which are found in CGICs. It consists of 20-30% CGIC and 70-80% composite resin (21). The hardening reaction of compomers is an addition polymerization reaction similar to that of conventional composites. Following light polymerization, cross-linking occurs between the monomers, leading to an initial hardening reaction of the material. Water absorption begins after the hardened material comes into contact with the oral environment. This triggers an acid-base reaction between the reactive glass fillers and acid groups of the functional monomer, resulting in fluoride release from the glass filler (32). Compomers contain 13% fluoride, and their fluoride release rate is lower than that of CGICs (18). Fluoride release can act as an acid buffer and prevent caries development on proximal surfaces in contact with the restoration (33). Studies have shown that the amount of fluoride released from compomers is lower than that released from CGICs and RMGICs. This difference is attributed to the binding of fluoride to the filler particles in compomers after irradiation and before exposure to water (33, 34). Compomers offer positive properties, such as aesthetics, suitable adhesion to the tooth structure, and similar wear resistance to primary teeth (35). Additionally, compared with CGICs, compomers have higher flexural strength values and significantly lower wear rates. Compomers can be used with one-step bonding adhesive systems, reducing the number of steps required for application, which is advantageous, particularly during the treatment of pediatric patients. They also offer high clinical success rates and are considered a good option for treating both the anterior and posterior primary

teeth. These properties have contributed to the compomers being the most commonly used materials in pediatric dentistry in many countries (36).

7. Giomer

Giomers are light-curing restorative materials that contain pre-reacted glass ionomer (PRG) particles and have been introduced to the market as fluoride-releasing materials. PRG particles are formed by an acid-base reaction that occurs between fluoroaluminosilicate glass particles and polyalkenoic acid in an aqueous environment (37). Giomers possess both the fluoride release and recharge properties of glass ionomer cement and the aesthetic, biocompatibility, and polishability characteristics of composite resins (38). In an *in vitro* study conducted on primary teeth, the marginal leakage of the compomer, ormocer, giomer, and RMGIC was statistically similar (39). In a clinical study involving 146 primary teeth with Class II cavities restored with hybrid composite resin, RMGIC, compomer, and giomer, the 24-month follow-up report indicated that RMGIC was the most successful material in terms of biological evaluation criteria, whereas giomer resin had the highest survival rate (40).

8. Glass carbomer

Glass carbomers are glass ionomer-based cements containing carbonized nanoparticles that have recently been introduced into the market. They differ from conventional CGICs because of their inclusion of nano-sized powder particles and fluorapatite. The addition of nanoparticles to the material is intended to reduce solubility, increase compressive and flexural strength, and improve the mechanical properties of the material, with the aim of creating an enamel-like structure (41). The hardening reaction of the glass carbomer is similar to that of CGIC, with calcium fluorapatite nanocrystals responsible for the remineralization process, initiating the formation of fluorapatite. Compared with CGIC and RMGIC, glass carbomers have longer working times, better aesthetics and translucency, and better wear and fracture resistance. Similar to CGICs, glass carbomers exhibit fluoride release and recharge properties (14). Glass carbomers can be used as restorative materials in Class I and Class II cavities of primary and permanent teeth, as repair materials for crown and bridge restorations, as fissure sealants, cervical fillings, and Class V cavities; and as crown/bridge cement (42). Chen et al. found that after two years, glass carbomer-based fissure sealants exhibited the lowest retention compared to glass ionomer-based and resin-based fissure sealants in a study evaluating their caries-preventive effects (43). In a study comparing the microleakage of CGIC, glass carbomer, and compomer, Cehreli et al. found that glass

carbomer cement exhibited the highest microleakage (44).

9. Zirconomer

Zirconomers are restorative materials developed by adding nano-zirconium fillers to glass components. The addition of Zr to the glass component enhances the structural stability of the material and increases its compressive strength and durability, thereby improving its mechanical properties for use in posterior regions (45). In a study comparing the fluoride release and antibacterial properties of RMGIC, giomer, and Cention N with zirconomer, the highest fluoride release was observed with the zirconomer on the 14th day, while the lowest fluoride release was observed with the giomer. After 48 h of hardening, the zirconomer exhibited the highest antibacterial effect, whereas the giomer showed the lowest antibacterial effect (46).

10. Composite resins

Composite resins are aesthetic materials used in pediatric dentistry for preventive resin restorations, anterior tooth restorations, and Class I and II restorations, as they bond adhesively to tooth structures and have controlled hardening properties (47). Composite resins consist of an organic matrix, inorganic fillers, a coupling agent that binds these two components together, polymerization activators, and color pigments. Composite resins are classified based on the size of the filler they contain. The size of the filler particles affects the aesthetics, polishability, polymerization depth, polymerization shrinkage, and physical properties of the material. Smaller filler particles provide better polishability and aesthetic properties, whereas larger filler particles enhance the durability of the material (48). The disadvantages of composite restorations include the technical sensitivity required for application, longer application time compared to amalgam and other restorative materials, and decreased biocompatibility due to the Bisphenol A content. Polymerization shrinkage, which leads to marginal gaps and compromised adhesion, is another disadvantage of composites that can result in postoperative sensitivity, discoloration, secondary caries, and pulpal pathology. To minimize these adverse effects and achieve successful restorations, technical precision, and careful case selection are essential (49).

Flowable hybrid composites are obtained by increasing the particle size and reducing the filler content. According to a previous study, flowable composites are among the most commonly used restorative materials for Preventive Resin Restoration (PRR), and over 30% of pediatric dentists use either flowable composites or a combination of flowable and condensable composites (50). In a study conducted by

Jean et al., flowable composites were found to be the preferred material for pit and fissure sealants (51). Another study comparing the retention of flowable composites with conventional resin-based sealants found that flowable composites showed better retention when used as pit and fissure sealants (52).

11. Ormoser

Ormoser is a restorative material developed to eliminate the problems caused by the polymerization shrinkage of composite resins. This material was produced by modifying the matrix of composite resins. Unlike conventional composites, ormosers are composed of silanized filler particles and inorganic-organic copolymers. This material, formulated as a new three-dimensional inorganic-organic polymer, has a coefficient of thermal expansion similar to that of a natural tooth structure (48). Despite having a lower filler content, ormosers have been shown to exhibit lower wear rates and shrinkage levels similar to those of hybrid composites. However, due to difficulties in scaling and manipulating the prototypes, the matrix of the initial commercial products was modified by adding methacrylate, which reduced the initial promising advantages (53).

12. Strip crowns

Strip crowns have been used since the late 1970s to restore the form, function, and aesthetics of the anterior and posterior primary teeth with the development of bonding agents and composite resins (31). The availability of multiple color and crown form options, ease of placement in areas with space constraints, and high patient and parent satisfaction are some of the reasons for the frequent preference for strip crowns (54). However, difficulties in retention may be encountered with strip crowns in cases where isolation cannot be achieved due to moisture and bleeding or when there is insufficient enamel and dentin tissue. Additionally, the application of strip crowns may be challenging in very young children because of cooperation problems (55). In a retrospective study investigating the clinical success of strip crowns, Manmontri et al. reported an 80% survival rate at the end of 24 months, noting that the failure rate of strip crowns increased in cases of high caries risk and extensive caries involving multiple surfaces (56). Strip crowns are less resistant to wear and fracture than other anterior crowns. According to the results of a study by Kupietzky et al. evaluating the clinical and radiographic performance of strip crowns, no crown loss was observed in any of the 112 teeth, but small fractures were detected in approximately 12% of the crowns (57). Another study found that over 80% of strip crowns were successful after two years of follow-up (58).

13. Stainless steel crowns

Crowns are preferred in cases of extensive carious destruction of primary teeth, as they reduce the long-term failure rates associated with other restorative materials (59). In the early 1950s, Dr. Humphrey introduced stainless steel crowns (SSCs) for the first time as space maintainers and crown restorations (60). SSCs contain 12-30% chromium, 8% Ni, and 1-20% carbon (61). SSCs for primary teeth are produced in various sizes and are commonly used in the restoration of teeth with extensive caries, pulp treatment, or developmental defects. They are also frequently preferred for full-crown restorations in children with early childhood caries (59). In one study, the annual failure rates of primary molar restorations exposed to occlusal stress were 0-14% for SSCs, 0-35,3% for amalgam restorations, 0-25,8% for CGIC restorations, 0-15% for compomer restorations, and 0-11% for composite restorations. The primary causes of failure are secondary caries, marginal defects, fractures, and wear (11). A survey study reported that resin-based materials were most preferred for Class I and II restorations, while SSCs were the most preferred material for three or more surface cavities (62).

Open-faced SSCs were obtained by removing the front face of the SSCs used on the posterior teeth and placing the resin. This material exhibits similar stability, gingival adaptation, and durability to SSCs, and is more aesthetic than metal SSCs. However, the long treatment time, possibility of fracture due to occlusal forces, and inability to fully meet aesthetic expectations are among its disadvantages (63).

Veneered SSCs are esthetic full-coverage restorations used in the anterior region of primary teeth. The crowns had a resin veneer on the front surface of the SSC. Unlike open-faced SSCs, they can be cemented without any preparation in the patient's mouth. The production of aesthetic parts by the manufacturer and their mechanical properties, similar to those of SSCs, are among the advantages of these crowns. However, their disadvantages include their inability to be applied in children with space constraints, limited color options, the risk of veneer loss, and the need for more preparation compared to SSCs (61). A retrospective study reported that these restorations provided ideal retention but had a high risk of veneer loss (64).

14. Prefabricated zirconia crowns

In recent years, the concept of esthetic dentistry has become important in pediatric dentistry as well. It has been reported that SSCs are the most durable and structure-preserving restorations for primary molars and are considered the gold standard (59). To address the shortcomings of existing restorations and to meet the esthetic needs of children and parents, various

restorative materials have been used in the restoration of primary teeth. Although these different restorative materials are more esthetic than SSCs, they have disadvantages, such as poor gingival health, inferior mechanical properties, and the exposure of restoration margins (65). Due to these disadvantages, prefabricated zirconia crowns (PZCs) were introduced in 2008 as an alternative treatment for the restoration of decayed primary teeth (66). PZCs are similar to SSCs in terms of clinical parameters, except for retention and gingival health. SSCs have better retention, whereas PZCs offer better gingival health. PZCs possess strong esthetic, biocompatibility, and low thermal conductivity properties (67). Furthermore, PZCs are reported to be three times stronger than metal-supported porcelain crowns, as they are milled from a sintered dense single-crystalline block (68). In a study evaluating parental satisfaction regarding esthetic expectations, PZCs were found to be more successful than strip crowns and veneered crowns (69). However, despite these advantages, PZCs, unlike SSCs, cannot be shaped, bent, or adjusted to achieve good marginal adaptation and mechanical retention, thereby creating challenges in the fit between the tooth and crown (59). Additionally, the tooth preparation required for PZCs is much more extensive and aggressive than that required for materials such as like SSCs. This weakens the tooth structure, leading to desiccation and failure of the crown under masticatory loads (70).

15. Bioflx crown

BioFlx crowns were introduced in 2021 by Kids-e-Dental LLP (Andheri, Mumbai, India) as flexible, durable, and aesthetically pleasing prefabricated crowns for primary molar teeth. These crowns are made of a high-strength resin polymer used in the medical device industry and are single-colored, metal-free, and tooth-colored. BioFlx crowns are autoclavable and, according to the manufacturer, are similar to stainless steel crowns in tooth preparation. These crowns have a radiopacity equivalent to 1 mm, comparable to enamel, which allows for the easy evaluation of crown margins and vital pulp treatment cases on radiographs. They possess a mechanically strong structure but are also easy to place due to their flexibility. The sandblasted inner surface of the restoration enhances retention, while the occlusal-adaptive structure leads to pit formation in high occlusal areas instead of wear.

Additionally, these crowns are designed to show no visible color change in the mouth for up to one year. However, it is not recommended to bend or fold BioFlx crowns at the gingival margins. While the crowns are flexible, limited contouring is possible due to the material's elastic memory of the material. Moreover, the lack of trial crowns, as seen with zirconia crowns, and the need for thorough cleaning of contamination such as blood and saliva before cementation are considered

disadvantages of BioFlx crowns. BioFlx crowns are not recommended for use with the Hall technique or for patients with bruxism (71).

16. Crowns manufactured using cad-cam

Various restorative materials have been used to restore primary teeth with excessive material loss. However, these materials do not fully meet all expectations regarding durability and aesthetics. The disadvantages of existing crowns, along with technological advancements, have created the need for more practical and aesthetically superior crowns that can be prepared and applied more easily. Crowns designed and manufactured using computer-assisted design and manufacturing (CAD-CAM) systems have become increasingly common. This system involves collecting data on a computer, creating a three-dimensional model, designing based on these data, and then producing the restoration. CAD-CAM restorations, when considered together with the concept of restorative and conservative tooth preparation, prevent unnecessary removal of tooth structure, resulting in restorations that are much more compatible and well-processed, obtained in a single session, and specific to the tooth being restored (72). The use of CAD-CAM restorations in pediatric dentistry clinical practice is not widespread (73). The infrequent use of CAD-CAM restorations is attributed to the high cost of production, the need for experienced personnel to operate the equipment, and the difficulty in transferring teeth with deep subgingival margins to a computer environment (74). In a study comparing crowns prepared using the CAD-CAM method on primary molars under in vitro conditions, it was reported that polymeric CAD-CAM resin blocks could be preferred for full coronal restorations in primary molars with extensive coronal destruction because of their esthetic properties, low preparation cost, and ability to be prepared chairside in a single session (73).

17. Conclusion

In pediatric dentistry, the restoration of primary teeth is of great importance not only for aesthetic concerns but also for maintaining the child's overall oral health and chewing function. Primary teeth play a critical role in preserving the space for permanent teeth, fulfilling chewing functions, and contributing to proper speech development. Therefore, the selection of materials to restore these teeth is crucial. Each restorative material has its own advantages and application areas. When selecting, factors such as the child's age, extent of caries, function of the tooth, and aesthetic considerations should be considered. Additionally, the child's ability to cooperate with the dentist is a determining factor in material selection. The applied

restorative treatment should not only address the current condition of the tooth but also contribute to its healthy development.

In conclusion, the materials used in the restoration of primary teeth should be chosen not only to provide temporary solutions but also to support the child's overall dental health and establish a solid foundation for future oral health. The correct choice of material should meet both short-term aesthetic and functional needs and serve the purpose of maintaining long-term oral health.

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