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Review Article

The evolving landscape of dental restorative material: A mini review

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ABSTRACT:
Restorative materials play a vital role in paediatric dentistry, addressing unique challenges such as the smaller size of primary teeth, developing dentition, and the need for patient-friendly solutions. Recent advancements have revolutionized the field, with a focus on biocompatibility, improved aesthetics, and enhanced mechanical properties. Innovations include bioactive materials that release fluoride, calcium, and phosphate to promote remineralisation and prevent recurrent caries. Smart composites with colour-changing properties for better placement accuracy and resin-modified glass ionomers offering superior bonding and reduced micro leakage have gained prominence. Additionally, advancements in adhesive technology, such as self-etching adhesives, ensure efficient and durable restorations in a minimally invasive manner. This article explores the latest restorative materials, emphasizing their clinical relevance, performance, and potential to improve the quality of care in paediatric dentistry. These innovations aim to provide functional, durable, and patient-cantered solutions, fostering better outcomes for children's oral health.
Keywords: Restorative material, GIC, modern dentistry

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INTRODUCTION

Modern restorative dentistry is in a constant state of evolution, driven by advancements in materials science and a growing understanding of patient needs. This article explores the significant progress made in two key restorative materials: composite resins and glass ionomer cements (GICs), examining how recent innovations have broadened their clinical applications and optimized their performance.

Composite resins have become a mainstay in contemporary dentistry, prized for their versatility and ability to mimic natural tooth structure. Recent breakthroughs have further refined their properties, leading to improved clinical outcomes and expanding their range of applications. Nanotechnology has revolutionized composite materials. Nanofillers, with their exceptionally small particle size, have dramatically improved the strength, polishability, and wear resistance. The resulting smoother surface enhances both the aesthetics and longevity of composite restorations. Nanohybrids, combining the strength of traditional micro-hybrids with the superior polishability of nanofilled materials, offer an excellent balance of properties suitable for both anterior and posterior restorations, making them a preferred choice for a wide range of clinical situations [1,2,3,4] .The resin matrix, forming the structural framework of composite materials, has also seen significant advancements. The development of high-strength resin formulations has increased the durability of composites, making them suitable for load-bearing posterior restorations. Furthermore, significant progress in resin chemistry has addressed the persistent challenge of polymerization shrinkage. Newer materials exhibit reduced shrinkage, minimizing the risk of microleakage, secondary caries, and post-operative sensitivity, thus contributing to the long-term success of restorations.[2,4,5,6] Enhanced handling properties have significantly simplified the placement of composite restorations[2,4,7,8]. The availability of composites in a variety of viscosities, ranging from highly flowable to highly packable, allows clinicians to select the ideal material for each specific clinical scenario. Improved depth of cure enables bulk filling techniques, reducing the number of layers required and streamlining the restorative process, leading to increased efficiency and reduced chair time. The development of bioactive composites marks a paradigm shift in restorative dentistry. These innovative materials release fluoride, which plays a crucial role in preventing secondary caries and promoting remineralization. Ongoing research is exploring the incorporation of other bioactive agents, such as calcium phosphate, to further enhance their therapeutic potential and promote a more active role in maintaining oral health. The integration of composites with digital dentistry technologies has revolutionized restorative treatments. CAD/CAM technology allows for the fabrication of highly precise and predictable inlays, onlays, and crowns[9,10,11,12]. Similarly, 3D-printing resins designed specifically for dental applications enable the creation of custom restorations and appliances, opening up new possibilities for personalized patient care. Achieving natural-looking restorations is a primary concern. Composites are now available in an extensive range of shades and translucencies, allowing for excellent color matching and seamless integration with the surrounding dentition. Enhanced polishability, achieved through finer fillers and improved resin matrices, allows composites to mimic the natural luster and surface texture of teeth, creating highly aesthetic and lifelike restorations.

Glass ionomer cements (GICs) have a long and valuable history in dentistry, offering unique therapeutic advantages alongside their restorative capabilities. Recent advancements have further refined their properties and broadened their range of applications. High-viscosity GICs, characterized by a higher powder-to-liquid ratio, exhibit increased compressive and flexural strength, making them suitable for load-bearing posterior restorations[13,14,15,16]. Their condensable and packable nature simplifies handling and placement, making them a practical choice for a variety of clinical situations. The incorporation of resin components into GICs has significantly improved their physical properties, including strength, durability, and wear resistance. RMGICs also offer enhanced aesthetics compared to traditional GICs due to improved translucency and polishability. The availability of light-cured RMGICs provides clinicians with better control over setting time and allows for immediate finishing, simplifying the restorative process. GICs are well-known for their ability to release fluoride, which provides a protective effect against secondary caries and promotes remineralization[13,15,16,17]. This fluoride release mechanism makes GICs particularly valuable in patients with high caries risk. Ongoing research is exploring the incorporation of other bioactive agents, such as calcium phosphate, to further enhance their therapeutic potential. Glass carbomers represent a newer generation of GICs with improved handling characteristics and enhanced aesthetics. These materials offer a favorable balance of physical properties, fluoride release, and biocompatibility, making them a versatile option for a range of restorative needs. GICs play a vital role in minimally invasive dentistry. High-viscosity GICs are ideally suited for Atraumatic Restorative Treatment (ART), a minimally invasive approach to managing dental caries, particularly in underserved populations[18,19,20,21]. They are also well-suited for tunnel restorations, which prioritize the preservation of healthy tooth structure compared to traditional cavity preparations. The integration of GICs with CAD/CAM systems enables the fabrication of highly precise and predictable inlays, onlays, and crowns. This digital workflow enhances the accuracy and efficiency of restorative procedures, leading to improved clinical outcomes. Specialized GICs are available for a variety of applications, including luting cements for crowns, bridges, and orthodontic appliances. They are also used as base/liner materials under composite restorations, providing a fluoride-releasing layer and minimizing microleakage. These specialized formulations cater to specific clinical needs and contribute to the overall success of restorative treatments.

MATERIAL METHODOLOGY

In order to compile this review paper, a thorough and methodical investigation of recent research on developments in restorative materials was done. The following data collection, filtering, and analysis methods was employed:

1. **Literature Search:** A thorough search was carried out using electronic databases such as PubMed, ScienceDirect, Scopus, and Google Scholar.Among the search phrases were "innovations in dental composites,""bioactive restorative materials,""pediatric dentistry," and "advancements in restorative materials." The search was limited to research that was published between 1972 and 2025 in order to incorporate the most recent advancements.
2. **Inclusion and Exclusion Criteria:** Studies were chosen on the basis of how well they addressed developments in restorative materials. Clinical studies, in vitro research, systematic reviews, and meta-analyses addressing innovative materials with better characteristics, bioactivity, or improved patient outcomes were the main emphasis of the inclusion criteria. Articles discussing antiquated technology or unrelated to restorative materials were not included.
3. **Gathering Information:** Crucial information was retrieved, including the characteristics, composition, clinical performance, and advantages of the material in pediatric dentistry. Bioactive glass, bulk-fill composites, silver diamine fluoride, and high-viscosity glass ionomer cements were among the developments that received particular attention.

4. **Evaluation and Combination:** Common themes, benefits, and drawbacks of recently released materials were examined and assessed using the extracted data. Comparative analyses were conducted to demonstrate how new developments tackle issues such as method sensitivity, durability, esthetics, and remineralization.
5. **Extent and Restrictions:** This study, which is a narrative review, does not include actual experimental work and is restricted to published data. Nonetheless, the results offer a comprehensive grasp of restorative material developments that might benefit pediatric dentists and researchers.

DISCUSSION

The field of dental restorative materials has experienced a remarkable renaissance, with both composite resins and glass ionomer cements (GICs) undergoing transformative advancements. These innovations have significantly elevated the aesthetic outcomes of restorations while simultaneously enhancing their durability, improving handling characteristics, and even introducing therapeutic benefits. This progress has broadened the scope of clinical applications for these materials, solidifying their essential role in modern dental practice. Glass ionomer cements (GICs), while traditionally valued for their fluoride release and chemical bonding to tooth structure, have also undergone significantadvancements[13,15,16,22,23]. Anhydrous GICs simplify handling and extend shelf life by eliminating the liquid component, making them easier to use and store. Resin-modified glass ionomers (RMGICs) represent a significant step forward, bridging the gap between GICs and composites. These materials combine the beneficial properties of both, offering improved strength, enhanced durability, and better aesthetics through a dual-cure mechanism. Nano-ionomers, utilizing nanoparticles, enhance the aesthetics, wear resistance, and polishability of GICs while retaining their desirable fluoride release properties[24,25,26]. Compomers, a hybrid of composites and GICs, primarily rely on light activation for setting and offer a limited dual-cure mechanism compared to RMGICs[13,27]. Ceramic-reinforced GICs, incorporating ceramic particles, boost the strength of these materials, making them suitable for posterior applications where greater load-bearing capacity is required. Condensable or self-hardening GICs are particularly well-suited for Atraumatic Restorative Treatment (ART) and pediatric dentistry due to their ease of placement and reduced moisture sensitivity[13,28,29]. Low-viscosity or flowable GICs are often designed for fluoride recharge, providing sustained therapeutic benefits without compromising the material's strength. Giomers represent a novel category in dental restorative materials, fusing the advantages of GICs and composites[2,29,30,31,32]. These materials offer fluoride release and recharge, excellent aesthetics and polishability, and enhanced biocompatibility. These collective advancements in both composite and GIC materials have significantly expanded the possibilities available in restorative dentistry, empowering clinicians to provide more durable, aesthetically pleasing, and even therapeutic restorations tailored to the unique needs of each patient.

Composite resins, once relegated to the realm of simple fillings, have now evolved into highly sophisticated systems boasting a diverse array of properties. This evolution is largely driven by key innovations, most notably in filler technology. Nanofillers, with their exceptionally fine particle size of less than 100 nanometers, have revolutionized composite materials[4,33,34]. These ultra-fine particles enhance the material's strength, polishability, and wear resistance, resulting in restorations with smoother surfaces, improved aesthetics, and increased longevity. Nanohybrids, which cleverly combine the inherent strength of micro-hybrids with the superior polishability characteristic of nanofillers, offer a well-balanced approach suitable for a wide range of applications, from anterior restorations where aesthetics are paramount to posterior restorations where strength and durability are critical[35,36,37,38]. Ceromers, classified as indirect composite materials, achieve a harmonious blend of aesthetics, durability, and abrasion resistance by combining ceramic particles with a polymer matrix[18,39,40]. This unique composition makes them ideally suited for inlays, onlays, and veneers, where precise fit and lifelike appearance are essential. Ormocers, or organically modified ceramics, distinguish themselves through their interpenetrating organic and inorganic networks[18,40,41]. This unique structure contributes to reduced polymerization shrinkage and improved marginal seal, expanding their applications beyond traditional dentistry and into areas like adhesives and sealants. Fiber-reinforced composites, which incorporate reinforcing fibers such as glass, polyethylene, or carbon within a resin matrix, achieve enhanced strength and flexural properties[42,43,44,45]. These materials are particularly valuable for specialized applications like dental prostheses and splints, where structural integrity is paramount. Nanocomposites, incorporating nanoparticles or nanoclusters, exhibit a suite of improved properties, including enhanced mechanical performance, increased thermal stability, improved corrosion resistance, greater translucency, and enhanced handling characteristics, making them a versatile option for a broad range of restorative needs[46,47].

The resin matrix, an equally critical component of composite materials, has also undergone significant improvements. High-strength resins have been developed, expanding the use of composites into load-bearing posterior restorations, where they were previously considered less suitable. Reduced shrinkage resins address the long-standing concern of polymerization shrinkage, a phenomenon that can lead to microleakage and an increased risk of secondary caries. By minimizing shrinkage, these advanced resins contribute to more predictable and long-lasting restorations. Handling characteristics, crucial for clinical success, have been optimized through the development of viscosity variations. Clinicians now have access to a spectrum of composite viscosities, ranging from highly flowable materials ideal for liners and sealants to highly packable (condensable) composites designed to simulate the placement of amalgam, the latter achieving this packability through a specifically engineered filler network. Improved depth of cure allows for deeper light penetration, which in turn facilitates bulk filling techniques. This advancement significantly reduces the number of layers required for a restoration, streamlining the clinical procedure and saving valuable chair time. Beyond their traditional role as passive fillers, composites are now demonstrating bioactivity. Certain composites are formulated to release fluoride, which aids in the prevention of secondary caries and promotes remineralization of the surrounding tooth structure. Ongoing research is exploring the incorporation of other bioactive agents, such as calcium phosphate, to further enhance the therapeutic potential of these materials.

Antimicrobial composites, incorporating agents like silver or antibiotics, provide an added layer of protection by inhibiting bacterial growth and enhancing biocompatibility. Digital integration is revolutionizing the field of restorative dentistry. CAD/CAM composites enable the precise fabrication of inlays, onlays, and crowns, while specialized composite resins designed for 3D printing allow for the creation of highly customized restorations and appliances, ushering in an era of personalized dentistry. Aesthetics remain a paramount consideration in restorative dentistry. Improved color matching, achieved through a wide array of shades and translucencies, combined with enhanced polishability resulting from finer fillers and improved resin matrices, allows for the creation of natural-looking restorations that seamlessly mimic the luster and appearance of natural teeth[48,49,50,51]. Specialized composite formulations cater to specific clinical needs. Flowable composites are ideal for small Class I restorations and as pit and fissure sealants, while stimuli-responsive composites, which change their properties in response to external stimuli like temperature or pH, hold promise for targeted treatment approaches[52,53]. Self-healing composites, capable of repairing minor damage through the release of resin from microcapsules, offer the potential for extended restoration longevity[54,55,56].Recent advances have concentrated on the evolution of simplified systems that involve single-step delivery[57]. The trend started with the introduction of fifth and sixth generation bonding agents. Fifth generation dentinal adhesives comprised of two bottle systems containing etchant in one and primer and bonding agent in another.[58] Similarly, the seventh generation also has two bottles or one bottle package that needs to be mixed before application.[59] All-in-one and self-etch are the most recent revolution in the dental adhesive system. Even though separate etching and rinsing are not required, they are capable of conditioning the tooth surface and preparing it for adhesion, thereby reducing the chair side time. The reduced technique sensitivity and clinical operation time make this material more favorable in pediatric dentistry.[58]

One such product launched recently as Constic (DMG, Germany) is available as a single syringe tube. It is indicated for small/shallow class I cavities and allows for polymerization to a depth of ≤2 mm. Such a material can be considered of true advantage in children as it allows for single-step application, less technique sensitivity, and reduced chair time.[60,61]

CONCLUSION

The landscape of dental restorative materials is continually evolving, with composite resins and glass ionomer cements (GICs) at the forefront of this progress. Both materials have witnessed significant advancements that have not only broadened their clinical applications but also dramatically enhanced their performance. Composite resins, propelled by nanotechnology, improved resin matrices, and enhanced handling properties, have become incredibly versatile, offering a compelling combination of strength, durability, and esthetics. The development of bioactive composites, with their ability to release fluoride and other therapeutic agents, represents a significant step forward, moving beyond simply filling defects to actively promoting oral health. Furthermore, the integration of composites with digital dentistry technologies has opened up new avenues for personalized and precise restorative treatments. GICs, with their long-standing reputation for therapeutic benefits, have also experienced a renaissance. High-viscosity and resin-modified GICs offer improved strength and handling, while the inherent fluoride release of GICs continues to be a valuable asset in caries prevention. The development of glass carbomers and specialized GIC formulations further expands their utility in a variety of clinical situations. The ongoing research into incorporating other bioactive agents promises to further enhance the therapeutic potential of GICs. Ultimately, these advancements in composite resins and GICs provide clinicians with a wider array of options to meet the diverse needs of their patients. By understanding the unique properties and evolving capabilities of these materials, dentists can deliver more effective, long-lasting, and aesthetically pleasing restorations, contributing to improved oral health outcomes and patient satisfaction. The future of restorative dentistry looks bright, with continued innovation in these materials promising even greater advancements in the years to come.

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