

# A Review on Performance Comparison and Clinical Selection Strategies of Dental Restorative Materials

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## ABSTRACT

Dental restoration for tooth defects is a crucial part of oral clinical practice, and the selection of restorative materials directly affects the long-term success rate of restorations. This article systematically compares the mechanical properties, biocompatibility, aesthetic effects, and operability of currently commonly used dental restorative materials (including composite resins, glass ionomer cements, ceramic inlays, metal alloys, etc.). Based on evidence-based medical evidence, clinical selection strategies for different types of defects, tooth positions, and patient needs are proposed, providing scientific decision-making basis for oral physicians.

## KEYWORDS

Dental restoration; Biocompatibility; Ceramic inlays

## 1. INTRODUCTION

Tooth defects, which can arise due to a multitude of factors including dental caries, physical trauma, and gradual wear and tear, necessitate meticulous restoration strategies. The process of restoring these defects demands a thorough and comprehensive evaluation of both the performance characteristics of the restorative materials and the specific clinical requirements of each case. As the field of materials science has advanced significantly over the years, the spectrum of restorative materials available has broadened considerably, transitioning from the conventional amalgam fillings to the more aesthetically pleasing options such as composite resins and advanced ceramics. Despite this progress, there remain substantial variations among these materials in critical aspects like mechanical strength, resistance to wear, and the quality of marginal adaptation to the tooth structure [1] (as highlighted by Mante et al. in their 2019 study). Recognizing these disparities, the primary objective of this article is to formulate a tailored and individualized selection plan. This plan is developed through a detailed comparison of the performance parameters of the most widely used restorative materials, ensuring that the chosen material optimally meets the specific needs of each dental restoration scenario.

## 2. PERFORMANCE COMPARISON OF COMMON RESTORATIVE MATERIALS

### 2.1. Composite Resin

**Advantages:** Composite resin exhibits excellent aesthetic performance, being highly capable of matching the color of natural teeth to achieve a nearly natural restoration effect. Furthermore, it is a minimally invasive restorative material that can maximize the preservation of the original tooth structure during dental restoration, minimizing damage to the tooth. Most importantly, composite

resin possesses rapid curing properties, enabling it to complete the curing process in a short time and enhancing treatment efficiency (Ferracane, 2021).

**Disadvantages:** Composite resin undergoes a certain degree of shrinkage during polymerization, which may lead to marginal microleakage at the restoration edge, thereby affecting the Sealing property and long-term stability of the restoration. In addition, the long-term wear resistance of composite resin is relatively poor, especially in the posterior tooth region where greater masticatory pressure is exerted, making it less suitable for long-term posterior tooth restoration (Malmström et al., 2020) [2].

**Representative products:** In the market, Filtek™ Z350 XT and Tetric N-Ceram are two widely used composite resin products. Filtek™ Z350 XT is favored by dentists for its excellent aesthetic and operational performance, while Tetric N-Ceram demonstrates outstanding physical properties and durability in clinical applications. Both products hold important positions in the field of composite resins and have become commonly used materials in dental restoration.

## **2.2. Glass Ionomer Cement (GIC)**

**Advantages:** Glass ionomer cement exhibits unique therapeutic benefits in dental applications, primarily through its sustained release of fluoride ions which creates a protective environment that inhibits demineralization and promotes remineralization of adjacent tooth structures, effectively preventing secondary caries development [3]. Additionally, it forms a chemical bond with dentin through ionic exchange reactions, eliminating the need for mechanical retention that may compromise tooth integrity. This material also demonstrates excellent biocompatibility with pulp tissues, making it particularly suitable for use in deep cavities and pediatric patients.

**Disadvantages:** Despite its clinical advantages, GIC presents limitations including relatively low flexural strength (typically 40-60 MPa) and compressive strength (150-200 MPa) compared to composite resins, rendering it unsuitable for high-stress posterior restorations subjected to masticatory forces exceeding 500 N. Aesthetically, its translucent nature and tendency for water sorption-induced discoloration restrict its application in visible anterior regions, as color stability deteriorates significantly after 6-12 months of intraoral service.

**Modified type:** Resin-modified glass ionomer cements (RMGICs) represent a hybrid material class that integrates the benefits of conventional GIC with resin components, exemplified by products like Fuji II LC. These modified formulations incorporate 20-30% resin monomers (e.g., HEMA, Bis-GMA) which polymerize via light activation, resulting in improved mechanical properties (flexural strength up to 80 MPa) [4] and reduced setting time while maintaining fluoride-releasing capabilities.

## **2.3. Ceramic Materials**

**Advantages:** Ceramic materials exhibit exceptional aesthetic properties, capable of replicating the natural optical characteristics of dental tissues with high translucency and chromatic stability, thus achieving lifelike restorative results that meet patients' cosmetic expectations. Furthermore, they demonstrate superior wear resistance comparable to natural enamel (approximately 15-25 µm/year in wear rate), ensuring long-term dimensional stability even under continuous masticatory forces. Importantly, ceramics possess excellent biological inertness, showing no degradation or ion release in the oral environment, which minimizes the risk of allergic reactions or tissue irritation (Guess et al., 2022).

**Disadvantages:** Despite their advantages, ceramics have inherent brittleness with flexural strength ranging from 80-500 MPa depending on the type, necessitating sufficient tooth structure support or reinforcement for posterior applications. The manufacturing process involves sophisticated techniques such as CAD/CAM milling or heat pressing, leading to higher material costs (3-5 times that of composite resins) and longer production cycles (typically 5-7 days for laboratory fabrication).

Additionally, their low fracture toughness (2-5 MPa·m<sup>1/2</sup>) increases susceptibility to catastrophic failure under excessive occlusal loading without proper occlusal adjustment.

Classification:

Feldspathic ceramics (e.g., VITA Mark II): Characterized by a glassy matrix with feldspar crystals (65-75% by volume), these ceramics offer superior aesthetic blending for anterior veneers through layered staining techniques. Their modulus of elasticity (60-70 GPa) allows for optimal marginal adaptation but limits their use to low-stress areas due to moderate flexural strength (80-120 MPa).

Lithium disilicate glass ceramics (e.g., IPS e.max): Reinforced with needle-like lithium disilicate crystals (45-55% volume fraction), this material combines high aesthetic performance with enhanced mechanical properties (flexural strength 360 MPa, fracture toughness 3.3 MPa·m<sup>1/2</sup>). It is particularly suitable for anterior and premolar inlays/onlays requiring both translucency and structural integrity, with chemical bonding capabilities to resin cements.

Zirconia ceramics (e.g., LAVA™): Yttria-stabilized tetragonal zirconia polycrystals (3Y-TZP) exhibit exceptional mechanical strength (flexural strength 900-1200 MPa, fracture toughness 8-10 MPa·m<sup>1/2</sup>), making them ideal for posterior crowns and fixed dental prostheses. The material undergoes phase transformation toughening under stress, though it requires opaque coping design (translucency 15-20%) that may compromise aesthetic results in anterior regions without layered porcelain application.

## 2.4. Metal Alloys

Advantages: Metal alloys exhibit an exceptionally high level of mechanical strength, (making them particularly well-suited for the repair of large defects where robust structural support is crucial. Additionally, they demonstrate good marginal adaptation, (ensuring a precise and secure fit at the edges of the restoration, as highlighted by Donovan et al. [5] This combination of strength and adaptability makes them a reliable choice in various dental and orthopedic applications.

Disadvantages: Despite their mechanical advantages, metal alloys suffer from several significant drawbacks. Firstly, they tend to have poor aesthetic qualities, which can be a major concern in visible applications such as dental crowns or bridges. Secondly, there is a potential for allergic reactions, particularly with alloys containing nickel and chromium, which can cause discomfort or adverse reactions in some patients. Furthermore, metal alloys possess high conductivity, both in terms of electrical and thermal properties, which can lead to sensitivity issues and discomfort for patients.

Development trend: In response to these disadvantages, the industry has been trending towards the use of high noble alloys and titanium alloys. These materials are chosen for their reduced likelihood of causing adverse reactions, thereby enhancing patient comfort and safety. High noble alloys, which contain a higher proportion of precious metals, offer improved biocompatibility and reduced allergenic potential. Titanium alloys, on the other hand, are renowned for their excellent biocompatibility and corrosion resistance, making them a preferred choice in both dental and medical applications. This shift towards more biocompatible materials represents a significant advancement in the field, aiming to mitigate the drawbacks associated with traditional metal alloys while maintaining their structural benefits.

## 3. CLINICAL SELECTION STRATEGIES

### 3.1. Selection Based on Defect Type

Class I cavity (occlusal fossa): For posterior teeth, it is advisable to opt for high-filler composite resins, such as Filtek Bulk Fill, which provide excellent mechanical properties and durability. Alternatively, ceramic inlays can be a suitable choice due to their superior strength and aesthetics. In

contrast, for anterior teeth, nanocomposite resins are preferred, as they offer excellent polishability and color matching, ensuring a natural appearance [6].

**Class II cavity (mesio-occlusal-distal):** In cases of large defects, CAD/CAM ceramic onlays are recommended due to their precision fit, high strength, and long-term durability. These onlays are fabricated using advanced computer-aided design and manufacturing techniques, ensuring optimal restoration outcomes. For small to moderate defects, layered resin restorations can be effectively utilized. This approach involves the incremental placement of resin composite materials, which allows for better adaptation to the cavity walls and improved aesthetic results.

**Class IV cavity (incisal defect):** For incisal defects, fiber-reinforced resin materials, such as everX Flow, are a viable option. These materials incorporate glass fibers within the resin matrix, enhancing the mechanical properties and fracture resistance of the restoration. Additionally, a combined restoration approach using ceramic veneers can be employed. This method involves the placement of thin ceramic shells over the incisal surface, providing excellent aesthetics and structural support (Guess et al., 2022).

### **3.2. Selection Based on Tooth Position**

**Anterior Tooth Area:** In the anterior tooth region, the primary focus is on achieving optimal aesthetics. This is because the front teeth are highly visible and significantly impact a person's smile and overall facial appearance. Consequently, materials that offer superior aesthetic properties, such as layered resin or all-ceramic restorations, are preferred. These materials can closely mimic the natural color, translucency, and texture of teeth, ensuring a seamless and visually appealing result.

**Posterior Tooth Area:** For the posterior tooth region, the emphasis shifts to durability and functionality. The back teeth are subjected to substantial chewing forces and mechanical stress, making wear resistance and fracture resistance critical factors. To address these requirements, high-strength ceramics or resin-modified glass ionomer cement (GIC) are recommended choices (Ferracane, 2021). These materials are designed to withstand the rigors of mastication while providing reliable long-term performance, thereby ensuring both the structural integrity and functional longevity of the restoration.

### **3.3. Selection Based on Patient Factors**

**Pediatric patients:** For young patients, the selection of restorative materials should prioritize both efficacy and safety. GIC (Glass Ionomer Cement), known for its fluoride-releasing properties that aid in caries prevention, is a preferred choice. Alternatively, prefabricated crowns, which offer a quick and effective solution for restoring primary teeth, are also recommended (Donovan et al., 2020). These options ensure that the dental needs of pediatric patients are met while promoting long-term oral health.

**Patients with high caries risk:** Individuals who are at an elevated risk of developing dental caries require materials that provide additional protective measures. Fluoride/antimicrobial resins, such as Beautifil Flow Plus, are highly effective due to their ability to release fluoride and inhibit bacterial growth. Another suitable option is RMGIC (Resin-Modified Glass Ionomer Cement), which combines the benefits of both resin and glass ionomer materials, offering enhanced durability and caries prevention.

**Patients with bruxism:** For those who suffer from bruxism, a condition characterized by excessive grinding or clenching of teeth, the choice of restorative materials must withstand significant mechanical stress. Zirconia full crowns are an excellent choice due to their exceptional strength and resistance to wear. Alternatively, metal occlusal designs, which incorporate robust metal components on the occlusal surface, provide added durability and protection against the destructive forces of

bruxism. These materials help ensure the longevity and functionality of the dental restorations in patients with bruxism.

#### **4. FUTURE DEVELOPMENT DIRECTIONS**

**Smart responsive materials:** These include innovative substances like pH-sensitive fluoride-releasing resins, which have been extensively studied and documented in the research conducted by Mante et al. in 2019. These materials are designed to intelligently respond to changes in the surrounding pH levels, thereby releasing fluoride in a controlled manner to enhance various applications, particularly in dental and medical fields. The responsiveness and adaptability of these resins make them a significant advancement in the development of smart materials, as highlighted in the aforementioned study.

**Biomimetic restorative materials:** These innovative materials are designed to closely mimic the natural properties of dental tissues, specifically bio-ceramics that simulate the elasticity of dentin. One prominent example includes ZrO<sub>2</sub>-SiC composites, which are engineered to replicate the mechanical characteristics and flexibility of dentin, thereby enhancing the structural integrity and functional performance of dental restorations. By emulating the inherent elasticity of dentin, these bio-ceramics aim to provide a more biocompatible and durable solution for dental repairs, ensuring better integration with the surrounding natural tooth structure and improving the overall longevity of the restoration.

**3D Printing Technology: Chairside Rapid Fabrication of Personalized Ceramic Restorations** (Guess et al., 2022). This innovative technology enables on-site manufacturing of customized ceramic restorations through advanced additive manufacturing systems, utilizing digital intraoral scanning (accuracy  $\pm 10 \mu\text{m}$ ) and layer-by-layer material deposition processes. By integrating computer-aided design (CAD) with selective laser sintering (SLS) or stereolithography (SLA) techniques, dental practitioners can complete restoration fabrication within a single clinical visit (typically 90-120 minutes), eliminating traditional laboratory workflows that require 5-7 days. The technology supports personalized restoration designs with precise marginal adaptation ( $< 50 \mu\text{m}$  gap) and anatomical conformity, while offering material flexibility including zirconia (ZrO<sub>2</sub>) and lithium disilicate compositions. Clinical studies demonstrate that 3D-printed ceramic restorations achieve 95% survival rates at 2-year follow-ups, comparable to conventional CAD/CAM fabricated restorations, with significant improvements in patient satisfaction regarding treatment time and aesthetic outcomes (Guess et al., 2022).

#### **5. CONCLUSION**

The restoration of tooth defects necessitates a delicate balance between various critical factors, including the mechanical properties of the materials used, the aesthetic demands of the patients, and the biological characteristics of the teeth and surrounding tissues. Composite resins, known for their versatility and ease of application, are particularly suitable for addressing moderate to small tooth defects, providing a reliable solution that meets both functional and aesthetic needs. On the other hand, ceramic materials stand out as ideal choices for areas that demand high aesthetic standards or are subject to significant load-bearing requirements, owing to their superior durability and natural appearance. Additionally, Glass Ionomer Cement (GIC) possesses unique advantages, especially in pediatric patients and individuals with a high risk of caries, due to its fluoride-releasing properties and biocompatibility.

When making clinical decisions regarding tooth restoration, it is imperative to integrate a comprehensive assessment of the defect characteristics, such as size, location, and severity, with the specific functional requirements of the tooth in question. Furthermore, individual patient differences,

including age, overall health status, and personal preferences, must be meticulously considered to ensure the most appropriate and effective treatment plan. Looking ahead, the advent of intelligent materials and advanced digital technologies holds great promise for further enhancing the outcomes of restorative dental procedures. These innovations are expected to offer more precise, efficient, and personalized solutions, ultimately improving the overall quality of dental care and patient satisfaction.

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