IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Material Science and Types of Materials Used in Provisional Restorations: A Review

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Abstract

Provisional restorations play a pivotal role in fixed prosthodontic treatments by ensuring interim function, esthetics, and protection of the oral tissues while permanent prostheses are being fabricated. The effectiveness of these restorations is intrinsically linked to the materials used and the fabrication methods employed. This review consolidates the foundational principles of material science in relation to provisional restorations and comprehensively classifies the materials employed, incorporating clinical evidence and comparative evaluations. Special focus is given to modern fabrication techniques—conventional, CAD/CAM milling, and 3D printing—and their influence on fracture strength and clinical performance.

Keywords: *Provisional Restorations, PMMA and PEMA, CAD/CAM Provisional, Acrylic Resin Temporaries,*

1.Introduction

Provisional restorations, or interim restorations, are integral components of fixed prosthodontic therapy. Their functions span from maintaining tooth position and occlusion to protecting prepared tooth structures and pulpal tissues. Additionally, they play a crucial diagnostic and esthetic role. Although temporary by design, these restorations must endure varying degrees of mechanical and environmental stresses. Material selection and the method of fabrication are critical for achieving these objectives. With recent advancements in digital dentistry, clinicians now face a broader spectrum of choices, requiring a comprehensive understanding of the science behind these materials. (1)

2. Material Science of Provisional Restorations

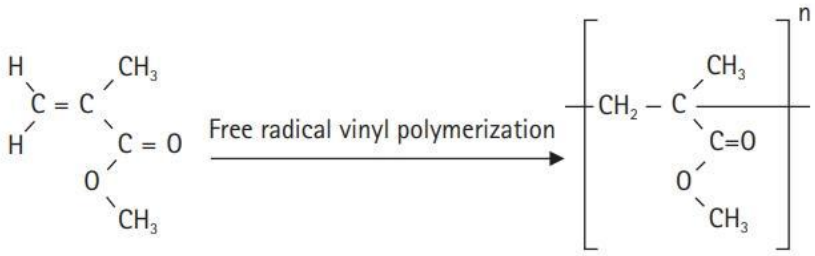
The material used for fabrication of provisional restorations typically comprises a combination of pigments, monomers, fillers, and initiators, which together produce a restorative substance that can withstand the oral environment for the interim period. Pigments are pre-incorporated by manufacturers to closely mimic the optical properties of natural tooth structure. Among all constituents, the primary monomer plays a pivotal role in defining the mechanical behavior of the provisional material. Its capacity to undergo polymerization significantly affects the material's strength, durability, and handling properties. (2)

According to Astudillo-Rubio et al. (2018), provisional restoration materials are mainly based on either monomethacrylates (e.g., PMMA, PEMA) or dimethacrylates (e.g., bis-GMA, UDMA), with polymerization achieved via free-radical mechanisms. The review concluded that dimethacrylate-based materials exhibit superior mechanical properties—particularly higher flexural strength and hardness—compared to monomethacrylate-based materials, though fracture toughness did not significantly differ. Within the monomethacrylate group, PMMA was found to have greater flexural strength than PEMA. These differences in performance are attributed to the molecular structure of the monomers: dimethacrylates tend to form cross-linked, rigid networks, while monomethacrylates result in more linear, less mechanically resilient polymers. (2)

2.1 Free-Radical Polymerization

The polymerization process invokes chemical, mechanical, dimensional, and thermal changes that affect the success of these materials in dentistry. Since monomers may be unpleasant or even harmful biologically, the chemical conversion of a monomer to a biologically inert polymer is desirable. Also, if the polymerization process is prematurely terminated or not properly initiated, the resulting restoration may not have adequate mechanical properties and will likely fail. However, because the density of the polymer is inherently and often substantially greater than that of the monomer, a dimensional contraction occurs during polymerization. The polymerization reaction is exothermic, which causes the material to become hot before it loses its fluidity. As a result, an additional contraction occurs when the restoration cools. If a direct technique is being used, the heat of reaction can cause irreversible damage to nearby pulpal tissues, which may already have been thermally insulted during cavity preparation.

(Fig:1)



Methyl methacrylate Poly(methyl methacrylate)

Initiation:

Free-radical polymerization begins with the formation of a free radical (a process called activation) and the subsequent combination of this free radical with a monomer. Free radicals are formed by the decomposition of a chemical (the initiator). The method of decomposition depends on the nature of the initiator. Possible initiators include benzoyl peroxide and camphoroquinone.

- *Benzoyl peroxide* decomposes to free radicals at approximately 50°C or higher in a process called thermal activation. Excessive temperatures should be avoided during the early stages of thermal activation, because some monomers vaporize at temperatures near 100°C, with subsequent formation of porosity in the resultant polymer. Thermal activation results in greater contraction on cooling than with other activation methods and is therefore usually avoided for provisional restorations.

- Benzoyl peroxide also decomposes to free radicals when catalyzed by a tertiary amine; this process is called chemical activation. Chemical activation occurs when the activator and monomer are mixed together, so these materials are usually supplied separately—the monomer and activator are in one container, and the initiator and filler are in another. To prevent voids, proper mixing is essential. Since chemical activation requires intimate contact between the chemical activator and the initiator, it is not as efficient as thermal activation. Inefficient activation of the initiator results in more residual monomer and less color stability of the restoration, since unreacted benzoyl peroxide can cause color changes. However, since benzoyl peroxide is decomposed by both thermal and chemical activation, increased temperature can enhance its decomposition in a chemically cured system and will not increase contraction if the restoration initially undergoes chemical setting. Heating a recently set restoration in 100°C water will promote greater polymerization efficiency and remove any unconverted monomer, which might cause a sensitivity reaction in a patient susceptible to monomer irritation.

- *Camphoroquinone* decomposes to free radicals in the presence of both an aliphatic amine and blue light energy; this process is called visible-light activation. Light-activated materials have two advantages: (1) the ingredients can be mixed by the manufacturer with little porosity, and (2) working time is virtually unlimited because no setting occurs if the material is kept in a dark environment. A limitation of this method is the depth to which visible light can penetrate (less for darker materials). Whenever possible, the activation illumination should be directed toward the center of the restoration from all surfaces. For darker materials, the exposure time should be longer.

Propagation: Once initiated, the polymerization process continues by including more monomer molecules in the growing molecular chain. The material must not be disturbed, because defects can be easily incorporated if the material is jostled during this phase. During propagation:

1. The setting material undergoes an increase in density, causing contraction.
2. The exothermic heat of reaction may cause a substantial increase in temperature, with subsequent increased contraction.
3. Other physical properties (e.g., rigidity, strength, and resistance to dissolution) increase.

Termination: Due to the randomness of position of the growing chains, some of them may combine and terminate the growth process. This type of termination cannot be avoided, although it is better to have termination only after polymerization of all the monomer has occurred. Termination may also result from the reaction with eugenol, hydroquinone, or oxygen, so contact with these substances must be avoided, or at least minimized, when possible.

2.2 Properties Associated with the Monomer

The various monomers exhibit different initial and setting characteristics and result in polymers with significantly different properties such as viscosity before setting, exothermic heat of reaction, dimensional change on setting, and strength. In general, the exothermic heat of reaction during setting and the physical strength of the set mass are inversely proportional to the size of the monomer molecule.

Filler: Although the primary properties of a provisional restorative material are determined by the monomer(s) involved, enhancement in the desirable setting and mechanical properties is accomplished mainly with the filler. An increase in filler content reduces the relative amounts of exothermic heat and contraction while increasing the strength of the set material. However, too much filler can lead to insufficient handling characteristics before setting, impeding mixing and shaping and introducing porosity in the set restoration. For light-activated systems, the amount of filler is determined by the manufacturer; for other systems, incorporating as much filler as possible without interfering in the handling or manipulation characteristics of the material is preferred.

Types of Materials Used in Provisional Restorations

TYPES OF MATERIALS

1) Preformed crowns
   - Plastic
     - Acrylic
     - Cellulose Acetate
     - Polycarbonate
   - Metal
     - Aluminum
     - Stainless Steel
     - Nickel Chromium
- Self or light cure resin / Custom fabricated
  - Polymethyl meth acrylate
  - Polyethyl meth acrylate
  - BIS-GMA Composite
  - Urethane dimethacrylate
- Reinforcement material
  - Cast metal
  - Fibers
- Provisional Cements
  - Zinc-oxide and Eugenol
  - Non-Eugenol material
  - Calcium Hydroxide

Provisional restorative materials are categorized based on their form, composition, and method of fabrication. The main types include preformed crowns, self or light-cure resins, reinforcement materials, and provisional cements.

3.1 Preformed Crowns

Also known as proprietary shells, a variety of preformed crowns are available commercially. These include tooth-shaped shells made of plastic (acrylic, polycarbonate), cellulose acetates, and metal (aluminum, stainless steel, nickel-chromium). Preformed crowns are typically used for single-unit restorations where rapid chairside temporization is required. (4)

These crowns are available in a variety of sizes and shapes and can be selected based on the anatomical configuration of the tooth. Although convenient and time-saving, most preformed crowns require significant modification including internal relief, axial contouring, and occlusal adjustment. They often must be relined with autopolymerizing resins to ensure proper fit and retention. (4)

- **Polycarbonate Crowns**: Considered the most esthetic of preformed options, these crowns offer natural tooth-like appearance and are highly color stable. They are commonly used in anterior regions and combine micro-glass fibers with polycarbonate plastic for added strength. Easy to trim and polish, polycarbonate crowns are suitable for short- to moderate-term use. (4)

- **Cellulose Acetate Crowns**: Transparent and thin (0.2–0.3 mm), these are used as matrices filled with auto-polymerizing resin. Since they do not bond chemically or mechanically to the lining resin, they are peeled off after setting. Particularly useful when polycarbonate crowns are difficult to adapt due to limited occlusal clearance or rotated teeth. (5)

- **Aluminum and Tin-Silver Crowns**: Primarily used for posterior teeth. Anatomically shaped aluminum crowns are easier to adapt, while cylindrical forms require significant modifications. Tin-silver crowns, with reinforced occlusal tables, are more resistant to wear. These are adapted via swaging blocks to match cervical contours without risking margin fractures. (4)

- **Nickel–Chromium Crowns**: These are extremely durable and are mainly used for extensively damaged primary teeth. They are trimmed, contoured, and luted without the need for relining. Their hardness makes them suitable for longer-term temporization, especially in pediatric dentistry. (7)

3.2 Custom-Fabricated Materials

Custom-fabricated provisional restorations are considered the gold standard for long-term temporization. They allow intimate adaptation to the prepared tooth, and esthetics, contours, and occlusion can be tailored precisely. Based on the activation method and composition, the materials include:

- **Polymethyl Methacrylate (PMMA)**: Known for its clarity, strength, and durability. First introduced in the 1940s, PMMA is still widely used. It is supplied as a powder-liquid system. Advantages include excellent esthetics, polishability, and longevity. However, it exhibits high polymerization shrinkage, significant heat generation, and a pungent odor.(6)

- **Polyethyl Methacrylate (PEMA)**: Developed in the 1960s, PEMA is less exothermic and demonstrates lower shrinkage compared to PMMA. It is easier to handle and less irritating to the pulp, making it more suitable for short-term provisionals. It has poor wear resistance and limited color stability. (2)

- **Composite Resins (Bis-Acryl)**: These materials consist of bis-GMA or urethane dimethacrylate with inorganic fillers. They polymerize through auto-, light-, or dual-cure systems. Their low shrinkage and heat generation yield excellent marginal adaptation. Most are dispensed via automix cartridges. However, they are brittle in thin sections, difficult to repair, and limited in shade options.

- **Visible Light-Cured Resins (VLC)**: These urethane dimethacrylate-based resins are cured using blue light and contain camphoroquinone as a photoinitiator. VLC materials reduce residual monomer content, enhancing biocompatibility. They offer better working control, lower shrinkage, and are suitable for use when esthetics and marginal adaptation are critical. (2)

(Fig:2)

(Fig:3)

(Fig:4)

3.3 Reinforcement Materials

To improve the structural performance of provisional restorations, especially in long-span prostheses, reinforcement is essential.

- **Metal Frameworks**: Provide high rigidity and allow minimal bulk design. These frameworks prevent micro-movement at the prosthesis-tooth interface, minimizing mechanical failure and enhancing marginal seal. However, metal frameworks are time-consuming, expensive, and require laboratory fabrication. [8]

- **Fiber Reinforcement**: Reinforces polymers with materials like glass, polyethylene, carbon, and aramid fibers. These fibers increase tensile and flexural strength but not compressive strength. For optimal results, the fibers must be thoroughly wetted and properly positioned. Pre-impregnated fiber strips offer improved strength and simplify handling. [9]

3.4 Provisional Luting Materials

Temporary cements serve a dual purpose: retention of the provisional restoration and protection of the pulp from bacterial invasion and chemical insult. They must also allow easy retrieval when needed. [10]

- **Zinc-Oxide Eugenol (ZOE)**: Possesses soothing effects on the pulp and has antibacterial properties. However, it may interfere with the polymerization of resin-based materials. ZOE-based cements can show increased leakage over time but are effective for short-term cementation.

- **Non-Eugenol Cements**: These are preferred when using resin-based provisional or permanent restorations due to their compatibility and lack of plasticizing effects. TempBond NE is a commonly used non-eugenol cement.

- **Calcium Hydroxide Cements**: Offer excellent biological compatibility and pulp protection. These cements exhibit lower microleakage and are well-suited for longer-term temporization. [10]

- **RMGIC**: Resin-Modified Glass Ionomer Cement (RMGIC) combines the fluoride release and chemical bonding of conventional GIC with the added strength and hydrophobicity of resin. It cures through both light-activated polymerization and a traditional acid–base reaction. RMGIC offers improved bond strength and fracture toughness compared to conventional GIC, though it remains mechanically weaker than resin cements. It retains similar fluoride release patterns, supporting its anticariogenic effect. However, the inclusion of resin components like HEMA increases cytotoxicity, making RMGIC less biocompatible than conventional GIC. [10]

- **Hybrid CaAl**: Hybrid CaAl/GIC is a water-based, self-adhesive permanent cement composed of calcium aluminate and glass ionomer, mixed with distilled water. It sets via acid–base and glass ionomer reactions without requiring surface pre-treatment. CaAl/GIC offers good working and setting times, high retentive strength, and easy cleanup. Notably, it is bioactive—releasing calcium and phosphate ions, promoting remineralization, and exhibiting strong antibacterial properties. Its sealing ability and resistance to microleakage are comparable to self-adhesive resin cements, helping prevent recurrent caries. While it shows favorable clinical performance in areas such as retention and color stability, long-term studies and further evaluations of its mechanical and chemical properties are still

needed. It is suitable for cementing crowns, bridges, inlays, onlays, and posts made from metal or high-strength ceramics. [10]

- **Self adhesive resin cement**: Self-adhesive resin cement is a simplified, all-in-one resin cement that bonds to tooth structures without separate etching or adhesive steps. It contains acidic monomers (e.g., MDP), dimethacrylate monomers (e.g., Bis-GMA), fillers, and initiators, allowing it to etch and infiltrate the tooth surface initially, then gradually shift to a more hydrophobic state as the pH increases. Clinically, it offers ease of use and reduced postoperative sensitivity compared to GIC and RMGIC. However, its bond strength to enamel and dentine is lower than that of conventional multi-step resin cements due to limited etching capability and its reliance on the smear layer. While effective for many indirect restorations, it is not recommended for cases with poor retention or esthetic demands, such as veneers or resin-bonded bridges, due to its weaker adhesion and potential for marginal discoloration.[10]

Luting Material	ZOE/ZONE	Zinc Phosphate	Zinc Poly-Carboxylate	GIC	RMGIC
Metal	✓		✓	✓	✓
Bis-acryl	✓		✓		
PEMA	✓		✓		
PMMA	✓		✓		

(Table 1)

4.Conclusion and Future perspective

Despite their essential role in fixed prosthodontics, provisional restorations have inherent limitations, including lower mechanical strength, marginal integrity, and esthetic stability compared to permanent restorations. They are susceptible to wear, discoloration, polymerization shrinkage, and pulpal irritation due to residual monomer release and heat generation during fabrication. Additionally, the performance of newer materials such as fiber-reinforced resins, CAD/CAM blocks, and 3D-printed provisionals remains inadequately validated through long-term clinical studies. Looking forward, there is significant scope for the development of advanced biocompatible materials with improved strength, color stability, and ease of manipulation, as well as for the integration of digital workflows to enhance accuracy and efficiency. Future research should focus on clinical trials evaluating long-term outcomes of modern materials and fabrication techniques. In conclusion, while provisional restorations are indispensable for functional, esthetic, and protective roles in prosthodontics, careful material selection and ongoing research are critical to optimizing their clinical performance and reliability.

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