

CONTEMPORARY HYBRID ACRYLIC AND THERMOPLASTIC MATERIALS FOR REMOVABLE DENTAL PROSTHESES: A LITERATURE REVIEW

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ABSTRACT

Aim of the study. The purpose of this literature review was to evaluate contemporary hybrid acrylic materials and modern thermoplastic polymers used in removable prosthodontics, with particular emphasis on their mechanical, physical, and biological properties. The review focuses on recent approaches developed to overcome the limitations of conventional polymethyl methacrylate (PMMA) denture base materials.

Material and methods. A literature search was conducted using PubMed, Google Scholar, and NIH databases. The search strategy included the following keywords: acrylic resin, PMMA, nanoparticles, denture base reinforcement, fiber-reinforced acrylic resin, BioHPP, PEEK, acetal resin, and thermoplastic denture materials. Original research articles, review papers, and relevant scientific publications published in recent years were analyzed.

Results. The reviewed studies demonstrated that the incorporation of reinforcing agents such as zirconium dioxide (ZrO₂), titanium dioxide (TiO₂), silicon dioxide (SiO₂) nanoparticles, carbon nanotubes, and various fibers significantly improves the mechanical performance of PMMA. These modifications increase flexural strength, fracture resistance, impact resistance, and durability. Modern thermoplastic materials, including polyamide, acetal resin, PEEK, and BioHPP, offer additional advantages such as improved biocompatibility, flexibility, esthetics, and patient comfort.

Conclusions. The incorporation of fibers, fillers, nanoparticles, and hybrid reinforcement systems represents an effective strategy for enhancing the performance of conventional acrylic denture base materials. Modern thermoplastic polymers constitute promising alternatives to PMMA and contribute to the development of more durable, esthetic, and biologically compatible removable dental prostheses.

Keywords: PMMA; acrylic resin; nanoparticles; thermoplastic materials; PEEK; BioHPP; removable prosthodontics.

INTRODUCTION

Removable dental prostheses continue to represent an important treatment option for the rehabilitation of partially and completely edentulous patients. Despite the remarkable advances achieved in implant dentistry and fixed prosthodontics, conventional removable prostheses remain widely used due to their affordability, accessibility, and ability to restore oral function and esthetics. The success of removable prosthodontic

treatment depends not only on the clinical and laboratory procedures employed but also on the properties of the materials used in prosthesis fabrication.

For more than eight decades, polymethyl methacrylate (PMMA) has been considered the material of choice for denture base fabrication. Introduced into dentistry in the 1930s, PMMA rapidly gained popularity

because of its favorable esthetic appearance, ease of processing, low cost, satisfactory biocompatibility, and simple repair procedures. Furthermore, its ability to reproduce oral tissues with acceptable color stability has contributed to its widespread use in complete and removable partial dentures.

Although PMMA possesses numerous advantages, several limitations have been reported in the literature. Denture fractures remain one of the most common complications associated with acrylic prostheses. The relatively low impact strength and limited resistance to fatigue loading make PMMA susceptible to crack initiation and propagation during function or accidental dropping. In addition, polymerization shrinkage, water sorption, residual monomer release, and the formation of internal porosities may negatively affect the long-term clinical performance of acrylic dentures. These shortcomings have stimulated continuous research aimed at improving the mechanical, physical, and biological properties of conventional denture base resins.

In recent years, significant attention has been directed toward the development of reinforced and hybrid acrylic materials. Various reinforcing agents, including glass fibers, polyethylene fibers, aramid fibers, carbon nanotubes, and nanoparticles such as zirconium dioxide (ZrO_2), titanium dioxide (TiO_2), and silicon dioxide (SiO_2), have been incorporated into PMMA matrices to enhance their strength and durability. The incorporation of these materials has demonstrated promising results, including improvements in flexural strength, fracture toughness, surface hardness, wear resistance, and resistance to crack propagation.

Simultaneously, advances in biomaterials science have led to the introduction of modern thermoplastic polymers as alternatives to conventional acrylic resins. Materials such as polyamide, acetal resin,

polyether ether ketone (PEEK), and BioHPP have gained increasing attention due to their favorable mechanical properties, excellent biocompatibility, reduced allergenic potential, and enhanced patient comfort. Unlike conventional PMMA, many thermoplastic materials exhibit greater flexibility and fracture resistance, making them suitable for specific clinical situations where conventional acrylic prostheses may be less effective.

The integration of digital technologies, including CAD/CAM manufacturing systems and additive manufacturing techniques, has further expanded the possibilities for the application of both reinforced acrylic materials and thermoplastic polymers in removable prosthodontics. These technologies contribute to improved prosthesis accuracy, reduced manufacturing errors, and enhanced material performance.

Given the continuous evolution of denture base materials and the growing demand for durable, esthetic, and biologically compatible prosthetic solutions, a comprehensive evaluation of contemporary hybrid acrylic materials and modern thermoplastic polymers is necessary. Therefore, the aim of this literature review is to analyze the current evidence regarding the composition, properties, advantages, limitations, and clinical applications of these materials in removable dental prostheses.

MATERIAL AND METHODS

This study was conducted as a narrative literature review focusing on contemporary hybrid acrylic materials and modern thermoplastic polymers used in removable prosthodontics. The review aimed to evaluate recent advances in denture base materials and their influence on the mechanical, physical, and biological performance of removable dental prostheses.

A comprehensive search of the scientific literature was performed using the electronic databases PubMed, Google Scholar, and the National Institutes of Health (NIH). The search was limited primarily to articles published between 2017 and 2025 in peer-reviewed scientific journals.

The search strategy included combinations of the following keywords: *acrylic resin, polymethyl methacrylate (PMMA), denture base resin, nanoparticles, zirconium dioxide nanoparticles, titanium dioxide nanoparticles, silicon dioxide nanoparticles, carbon nanotubes, fiber reinforcement, glass fibers, polyamide, acetal resin, PEEK, BioHPP, thermoplastic denture materials, and removable dental prostheses.*

Original research articles, systematic reviews, narrative reviews, and relevant scientific publications addressing the modification and reinforcement of PMMA, as well as the clinical application of thermoplastic materials in prosthodontics, were included. Studies focusing exclusively on fixed prosthodontics, implant components, or materials unrelated to removable dental prostheses were excluded.

The selected publications were analyzed with respect to material composition, mechanical properties, flexural strength, fracture resistance, impact resistance, surface hardness, biocompatibility, esthetic characteristics, and clinical performance. Particular attention was given to studies investigating the incorporation of fibers, fillers, nanoparticles, and hybrid reinforcement systems into acrylic resins, as well as those evaluating the use of modern thermoplastic polymers as alternatives to conventional PMMA denture base materials.

The collected data were organized and synthesized to provide a comprehensive overview of the current state of knowledge regarding contemporary denture base

materials and their potential clinical applications in removable prosthodontics. Results and DISCUSSIONS

Polymethyl methacrylate (PMMA) remains the most widely used denture base material due to its favorable esthetic properties, ease of processing, acceptable biocompatibility, and relatively low manufacturing costs. Since its introduction into dentistry, PMMA has become the gold standard for the fabrication of complete and removable partial dentures.

Despite these advantages, PMMA exhibits several inherent limitations. Denture fractures are among the most frequently reported complications associated with acrylic prostheses. The material demonstrates relatively low impact strength and limited resistance to cyclic fatigue, making it susceptible to crack initiation and propagation during mastication or accidental dropping. Furthermore, polymerization shrinkage, residual monomer release, water sorption, and porosity formation may adversely affect its long-term clinical performance.

These limitations have stimulated considerable research efforts aimed at improving the physical and mechanical properties of conventional acrylic resins through the incorporation of reinforcing agents and advanced biomaterials.

Nanoparticle-Reinforced Acrylic Resins

Nanotechnology has emerged as one of the most promising approaches for improving denture base materials. Due to their extremely small particle size and large surface-area-to-volume ratio, nanoparticles can significantly modify the mechanical behavior of acrylic resins.

Among the investigated nanofillers, zirconium dioxide (ZrO_2), titanium dioxide (TiO_2), and silicon dioxide (SiO_2)

nanoparticles have shown particularly encouraging results. Studies have demonstrated that the addition of silanized zirconia nanoparticles increases flexural strength, fracture toughness, and surface hardness while improving resistance to crack propagation.

Titanium dioxide nanoparticles have also been associated with enhanced mechanical performance and antimicrobial properties. Their incorporation may reduce microbial adhesion and contribute to improved oral hygiene in denture wearers. Silicon dioxide

nanoparticles have been shown to increase stiffness and dimensional stability while maintaining satisfactory esthetic characteristics.

Carbon nanotubes represent another innovative reinforcing material. Owing to their exceptional mechanical properties, they can substantially increase impact resistance and fracture strength. However, challenges related to uniform dispersion and possible color alterations remain important limitations for their routine clinical application.

Table 1. Main nanoparticles used for PMMA reinforcement

Nanoparticle	Main effects on PMMA
Zirconium dioxide (ZrO ₂)	Increased flexural strength, fracture toughness, hardness
Titanium dioxide (TiO ₂)	Improved hardness, antimicrobial activity, impact resistance
Silicon dioxide (SiO ₂)	Increased stiffness and dimensional stability
Carbon nanotubes	Enhanced fracture resistance and toughness

Fiber reinforcement represents another effective strategy for strengthening denture base materials. Different types of fibers have been incorporated into acrylic resins to improve their resistance to functional and accidental loading.

Glass fibers are among the most commonly used reinforcing materials due to their favorable esthetics, chemical stability, and high tensile strength. Their incorporation into PMMA has been associated with significant improvements in flexural strength and resistance to fracture.

Polyethylene fibers have demonstrated excellent toughness and impact resistance, while aramid fibers provide high strength and fatigue resistance. Polypropylene and polyamide fibers have also been investigated, with studies reporting

improvements in durability and crack resistance.

Recent research suggests that hybrid reinforcement systems combining fibers and

nanoparticles may provide superior mechanical performance compared with the use of a single reinforcing material. Such combinations may create synergistic effects that further enhance the structural integrity of denture bases. The search for alternatives to conventional acrylic resins has led to the development of several thermoplastic materials used in removable prosthodontics.

Polyamide materials, commonly known as nylon-based resins, are characterized by flexibility, high fracture resistance, and excellent esthetics. They are particularly useful for patients with allergies to residual methyl methacrylate monomer. Flexible

removable partial dentures fabricated from polyamide provide improved comfort and adaptation to oral tissues. However, these materials may present challenges related to polishing, color stability, and repair procedures.

Acetal resin is a highly crystalline thermoplastic polymer with excellent fatigue resistance and flexibility. It is frequently used for esthetic clasp fabrication in removable partial dentures. The tooth-colored appearance of acetal clasps improves esthetics compared with conventional metal clasps while maintaining satisfactory retention and durability.

Polyether ether ketone (PEEK) is considered one of the most promising high-performance polymers in modern prosthodontics. The material exhibits excellent biocompatibility, low plaque accumulation, chemical stability, and favorable mechanical properties. In addition, its elastic modulus is closer to that of cortical bone than metallic alloys, potentially contributing to more favorable stress distribution.

PEEK has been successfully used for removable partial denture frameworks, implant-supported restorations, and fixed prosthetic constructions. Its lightweight structure and high resistance to wear make it particularly attractive for long-term clinical applications.

BioHPP is a ceramic-reinforced PEEK material specifically developed for dental applications. The addition of ceramic fillers improves stiffness while preserving shock-absorbing properties. BioHPP demonstrates excellent biocompatibility, low weight, favorable esthetics, and high patient acceptance.

Table 2. Characteristics of modern thermoplastic materials used in removable prosthodontics

Material	Main advantages	Main limitations
Polyamide	Flexibility, fracture resistance, esthetics	Difficult polishing and repair
Acetal resin	Esthetic clasps, flexibility, low water absorption	Limited rigidity
PEEK	Biocompatibility, strength, low weight	Higher cost
BioHPP	Shock absorption, esthetics, excellent biocompatibility	Higher manufacturing costs

Digital Technologies and Future Perspectives

The introduction of CAD/CAM systems and digital manufacturing technologies has significantly influenced the development of modern denture base materials. Milled PMMA discs and digitally fabricated prostheses generally demonstrate improved mechanical properties, reduced porosity, and superior dimensional accuracy compared with conventionally processed acrylic resins.

The combination of digital workflows with advanced hybrid acrylic and thermoplastic materials represents one of the most promising directions in contemporary prosthodontics. Future research is expected to focus on the development of multifunctional materials capable of combining superior mechanical performance, antimicrobial activity, improved esthetics, and long-term biological stability.

Overall, the available evidence suggests that both reinforced acrylic materials and modern thermoplastic polymers provide significant improvements over conventional PMMA and may contribute to enhanced clinical outcomes and patient satisfaction.

CONCLUSIONS

The incorporation of modern reinforcing agents into polymethyl methacrylate (PMMA) denture base resins has emerged as an effective strategy for overcoming some of the material's inherent limitations. Numerous studies have demonstrated that the addition of nanoparticles, fibers, and bioactive fillers can significantly improve mechanical properties such as flexural strength, impact resistance, fracture toughness, and wear resistance. Furthermore, certain additives provide antimicrobial activity and enhanced biocompatibility, contributing to improved oral health and patient comfort.

Despite these promising results, the effectiveness of reinforcement depends largely on the type, concentration, size, and distribution of the incorporated materials, as

well as on the manufacturing process employed. Excessive filler loading or inadequate dispersion may adversely affect esthetics, surface quality, and mechanical performance. Consequently, the optimization of filler characteristics and processing techniques remains essential for achieving predictable clinical outcomes.

Current evidence suggests that reinforced PMMA materials have considerable potential to increase the longevity and functionality of removable dental prostheses. However, many available studies are laboratory-based, and long-term clinical investigations are still limited. Future research should focus on standardized testing protocols and clinical validation to determine the most effective reinforcement strategies for routine prosthodontic practice.

Overall, the development of reinforced acrylic resins represents an important advancement in prosthetic dentistry, offering opportunities to enhance the durability, performance, and biological properties of denture base materials while maintaining their affordability and ease of fabrication.

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