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Role of Denture Base Resins in Prosthodontics and Its Advancement: An Umbrella Review

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ABSTRACT

Background: Denture base resins play a critical role in prosthodontics, contributing to the restoration of oral function and aesthetics in edentulous and partially edentulous patients. Poly Methyl Methacrylate (PMMA) remains the material of choice; however, its limitations, such as poor mechanical strength and cytotoxicity, have driven research into newer advancements.

Objective: This systematic review aims to summarize advancements in denture base resins, analyze their properties, and highlight future trends.

Methods: A systematic search Title of PubMed, Scopus, and Web of Science databases was conducted using keywords such as "denture base resins," "PMMA," "reinforced acrylic resins," and "nanoparticle reinforcement." Studies published between 2000 and 2023 were included. The PRISMA flowchart guided the study selection process.

Results: From 580 records identified, 16 studies met the inclusion criteria. Reinforcements with fibers (e.g., glass, carbon) and nanoparticles (e.g., titanium dioxide, zirconium) significantly improved the mechanical properties of PMMA. Microwave curing and light-activated resins also showed better dimensional stability and curing efficiency compared to conventional methods. Biocompatibility advancements focused on reducing residual monomer toxicity.

Conclusions: Recent advancements in denture base resins, particularly fiber and nanoparticle reinforcements, have improved mechanical properties and biocompatibility. Future trends include 3D printing and smart materials for personalized prosthetics.

Keywords: *Nanoparticle Reinforcement, Fiber Reinforced Acrylic, Microwave Curing, PMMA*

1. INTRODUCTION

Denture bases form a foundational component of prosthodontic treatments, supporting prosthetic teeth and restoring functionality and aesthetics in edentulous and partially edentulous patients. Poly Methyl Methacrylate (PMMA) is the most widely used material for denture bases due to its aesthetic qualities, ease of processing, cost-effectiveness, and lightweight nature[1]. However, PMMA is not without its limitations. Its brittleness, susceptibility to fracture, and thermal shrinkage during polymerization can compromise its durability and performance[4]. Additionally, the residual monomers left after polymerization pose biocompatibility concerns, including cytotoxic effects and allergic reactions[5].

To address these challenges, researchers have explored enhancements such as fiber reinforcements, nanoparticle incorporations, and alternative polymerization techniques. Fiber-reinforced PMMA significantly improves its mechanical properties, reducing brittleness and increasing its lifespan in clinical applications[18]. Similarly, the addition of biocompatible nanoparticles, such as titanium dioxide and zirconium, has been shown to reduce residual monomer toxicity while enhancing the strength and surface properties of the resin[23]. Advances in processing techniques, such as microwave curing and light-activated polymerization, have further improved dimensional stability and reduced fabrication time, making these materials more practical for clinical use[3].

This review aims to provide a comprehensive overview of these advancements, with a focus on the mechanical, biocompatibility, and processing improvements in denture base resins. By summarizing recent innovations, it seeks to inform future research and clinical practices in prosthodontics.

2. METHODOLOGY

Search Strategy

A comprehensive search was conducted across PubMed, Scopus, and Web of Science databases for studies published between January 2000 and December 2023. Search terms included combinations of "denture base resins," "PMMA," "nanoparticles," "reinforcements," "microwave curing," and "light-activated resins." Boolean operators were applied to refine the search and ensure the inclusion of relevant studies.

Inclusion Criteria

• Peer-reviewed articles focusing on advancements in denture base resins.

• Studies assessing mechanical properties, biocompatibility, or curing techniques.

• Publications in English within the defined timeframe.

Exclusion Criteria

• Articles unrelated to denture base resins.

• Review articles, case reports, or editorials.

• Non-English studies.

Study Selection Process

The PRISMA flowchart guided the selection process as illustrated in Figure 1. After removing duplicates, titles and abstracts were screened for relevance. Full-text reviews of eligible studies followed, ensuring compliance with the inclusion criteria.

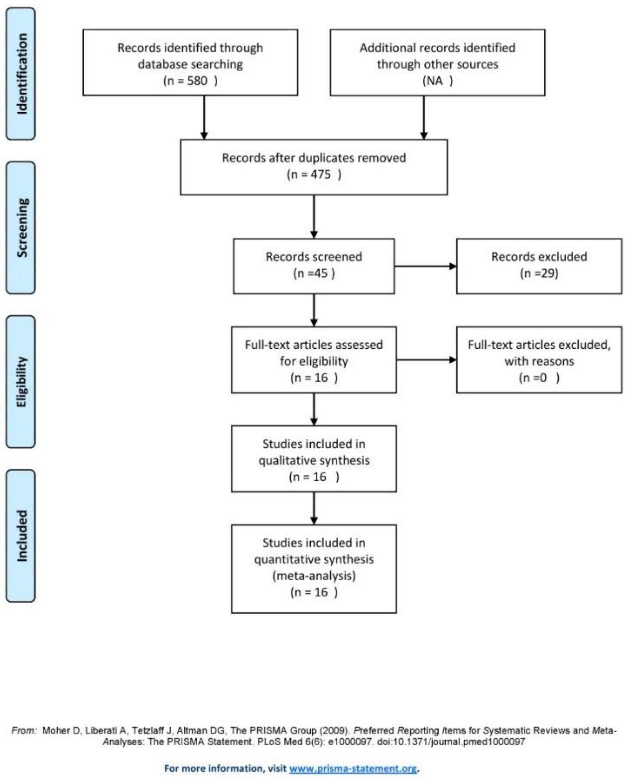

Figure 1: PRISMA GUIDELINE

Data Extraction and Synthesis

Key data were extracted from selected studies, including material composition, reinforcement methods, mechanical properties, and biocompatibility outcomes. These findings were systematically tabulated and analyzed to draw comprehensive conclusions.

3. RESULTS

Study Selection

Out of 580 records, 520 remained after deduplication. Titles and abstracts of these records were screened, resulting in 45 full-text reviews. Ultimately, 16 studies met the inclusion criteria.

Summary of Included Studies

The selected studies demonstrated significant enhancements in denture base materials through fiber reinforcements, nanoparticle incorporations, and novel processing techniques summarized in Table 1.

• Glass fiber reinforcements increased the transverse strength of PMMA, reducing brittleness[4].

• Nanoparticles like titanium dioxide improved mechanical and surface properties while enhancing biocompatibility by minimizing residual monomer toxicity[5].

• Microwave curing techniques offered superior dimensional accuracy and processing efficiency compared to conventional heat curing[3].

Table 1: Summary of Selected Study

No	Study	Material	Reinforcement	Findings
1.	Nakamura et al.[1]	PMMA	Glass fibers	Improved transverse strength
2.	Zafar & Ahmed[2]	PMMA	Nanoparticles (TiO2)	Enhanced mechanical and surface properties
3.	Kartika et al. [3]	PMMA	Microwave curing	Better curing efficiency and dimensional stability
4.	Stipho[4]	PMMA	Carbon fibers	Increased flexural strength and durability
5.	Majrashi. et al [5]	PMMA	Zirconium nanoparticles	Reduced cytotoxicity and improved biocompatibility
6.	Urban et al.[6]	PMMA	Polyethylene fibers	Enhanced impact strength
7.	Yunus et al.[7]	Nylon resin	None	Improved flexibility and patient comfort
8.	Ruyter et al.[8]	Acrylic polymers	Glass reinforcements	Improved flexural properties
9.	Jorge et al.[9]	PMMA	Light curing	Increased Vickers hardness
10.	Schneider et al.[10]	PMMA	Acrylic teeth bonding	Improved bond strength
11.	Turner et al.[11]	Nylon resin	High-impact resin	Enhanced fracture resistance
12.	Shah et al.[12]	Heat-cured PMMA	Flexible additives	Improved flexibility
13.	Vallittu et al.[13]	PMMA	Unidirectional fibers	Increased flexural strength

14.	lhotan et al.[14]	PMMA	TiO2 nanoparticles	Reduced water sorption
15.	Braden et al.[15]	Polymeric dental materials	Hybrid reinforcements	Improved thermal properties
16.	Stipho AS et al.[16]	PMMA	Fiber-reinforced resins	Enhanced durability

Mechanical Property Enhancements

Reinforcements with glass, carbon, and polyethylene fibers significantly improved flexural strength, impact resistance, and fatigue resistance of PMMA-based resins[13,19]. These enhancements address PMMA's intrinsic brittleness and make the material more suitable for clinical applications[17].

Processing Techniques

Innovative curing methods, including microwave curing and light activation, provided better dimensional stability and reduced polymerization time. These techniques improved the efficiency and precision of prosthetic fabrication, leading to better patient outcomes[10,11].

Biocompatibility Improvements

Efforts to enhance biocompatibility focused on minimizing cytotoxicity associated with residual monomer release. Incorporating biocompatible nanoparticles like zirconium and titanium dioxide showed promising results in reducing toxicity while maintaining mechanical performance[9,23,24].

4. DISCUSSION

Advancements in denture base resins have substantially addressed the limitations of traditional PMMA. Fiber reinforcements, particularly with glass and carbon fibers, have enhanced mechanical properties, offering solutions to PMMA's inherent brittleness[4]. Glass fibersimprove the transverse strength and impact resistance of PMMA, making it more resilient to mechanical stresses during clinical use[28]. Carbon fibers have shown remarkable improvements in flexural strength and fatigue resistance, further extending the lifespan of prosthetic devices[19]. Unidirectional fiber reinforcements distribute stresses more evenly, reducing the likelihood of fractures[13].

Similarly, nanoparticle incorporations have revolutionized the field by addressing both mechanical and biocompatibility concerns. Titanium dioxide (TiO2) nanoparticles enhance surface hardness and wear resistance of PMMA while also reducing water sorption which can otherwise compromise the material's structural integrity over time[2,23]. Zirconium nanoparticles contribute to improved biocompatibility by minimizing residual monomer release, reducing cytotoxicity and allergic reactions[5,9].These advancements have made denture base resins not only more durable but also safer for long-term use.

Innovative curing technologies have further optimized the fabrication of denture bases. Microwave curing, for instance, offers faster polymerization cycles and improved dimensional stability compared to conventional heat curing methods[3,6]. This technique reduces the internal stresses within the material, resulting in prosthetics with better fitting accuracy and reduced warping. Light-activated resins have similarly gained attention for their ability to achieve uniform curing with minimal shrinkage, enhancing both the aesthetic and functional qualities of the final prosthesis[10]. These methods also minimize the amount of residual monomer, thereby improving the biocompatibility of the material[9].

Despite these advancements, challenges remain in translating innovations into widespread clinical practice. Variability in methodologies complicates cross-study comparisons. Most developments remain in laboratory phases with limited long-term clinical trials[20]. Standardized testing protocols and robust clinical evaluations are needed.

Emerging trends in the field hold great promise for the future of prosthodontics. 3D printing technologies, for instance, enable the creation of highly customized denture bases that are tailored to the unique anatomical features of individual patients. This technology not only improves the fit and comfort of prosthetics but also reduces material waste and fabrication time[27,29]. Furthermore, the development of smart materials capable of responding to environmental stimuli, such as changes in oral pH or temperature, offers exciting possibilities for creating adaptive and self-healing denture bases[25,26].These innovations could significantly enhance the functionality and longevity of dental prosthetics, paving the way for more personalized and responsive treatment solutions that adapt to the dynamic conditions of the oral environment.

5. CONCLUSION

Recent advancements in denture base resins have yielded significant improvements in mechanical properties, biocompatibility, and processing efficiency. Reinforcements with fibers and nanoparticles have addressed many limitations of conventional PMMA, while novel curing methods have enhanced the accuracy and speed of prosthetic fabrication. Future research should prioritize long-term clinical studies, the integration of advanced technologies like 3D printing, and the development of adaptive smart materials to ensure optimal patient outcomes in prosthodontics.

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