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Original Article

Dentistry Section

Comparative Evaluation of Compressive and Impact Strength of Cold-polymerised and Heat-polymerised Acrylic Resins Reinforced with Different Additives: An In-vitro Study

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ABSTRACT

Introduction: Polymethyl Methacrylate (PMMA) is widely used for denture base fabrication; however, its limited mechanical properties may predispose it to fracture. Fibre reinforcement has been proposed to improve its strength and durability. Despite this, there is limited comparative evidence evaluating the effect of different fibre reinforcement on both self-cure and heat-cure acrylic resins.

Aim: To assess and compare the compressive and impact strength of self-cure and heat-cure acrylic resins reinforced with glass and polypropylene fibres.

Materials and Methods: The present in-vitro study was conducted at the Department of Prosthodontics, CKS Theja Institute of Dental Sciences and Research, India from August to November 2024. A total of 120 specimens were divided into six groups (n=20) (Group I-Group VI) based on resin type (self-cure, heat-cure) and reinforcement (control, glass fibre, polypropylene fibre). The inclusion criteria comprised standardised acrylic resin specimens fabricated according to the specified dimensions and specimens free from visible defects such as porosity, cracks, or surface irregularities. Standardised specimens were prepared for compressive and impact strength testing. Fibres (2 wt%) were incorporated during the dough stage. Compressive and impact strength were evaluated using a universal testing machine and Charpy impact tester, respectively. Data were analysed using one-way Analysis of Variance (ANOVA) and Tukey's post-hoc test ($p<0.05$).

Results: All reinforced groups showed significantly higher compressive and impact strength than controls ($p<0.001$). Glass fibre-reinforced heat-cure resin demonstrated the highest compressive strength (219.22±7.47 MPa) and impact strength (14.23±2.73 kJ/m^2), followed by polypropylene-reinforced heat-cure resin. Among self-cure groups, glass fibre reinforcement showed superior compressive (126.35±3.79 MPa) and impact strength (6.05±0.67 kJ/m^2) compared to polypropylene fibres. One-way ANOVA revealed significant intergroup differences for compressive strength ($F(5,114)=977.33$, $p<0.001$) and impact strength ($F(5,114)=194.68$, $p<0.001$). Tukey's post-hoc test confirmed significantly greater mechanical performance in glass fibre -reinforced and heat-cure groups compared to other groups ($p<0.001$).

Conclusion: According to the findings of the present study glass fibre reinforcement, particularly in heat-cure PMMA, significantly enhances mechanical properties and may improve denture durability.

Keywords: Denture base materials, Mechanical properties, Polymers, Prosthodontics, Reinforcement materials

INTRODUCTION

Oral health is integral to overall health, and the condition of the dentition significantly influences nutrition, speech, and quality of life. Contrary to common belief, tooth loss is not an inevitable consequence of aging; rather, it results from factors such as poor oral hygiene, dental caries, periodontal disease, and trauma. With adequate preventive care, teeth can often be retained into advanced age. When all teeth are lost, the condition is termed edentulism, an irreversible state that may be partial or complete and has been described as the "final marker of disease burden for oral health." Edentulism remains prevalent worldwide due to limited awareness, socioeconomic constraints, and inadequate access to care and it adversely affects functional ability and psychosocial well-being [1].

Prosthetic rehabilitation, including removable and fixed options, is essential for restoring function and esthetics. Among these, complete dentures fabricated from PMMA remain widely used because of their affordability, acceptable mechanical properties, and ease of processing. Acrylic resins particularly heat-cured and cold-cured variants are extensively utilised in prosthodontics. Mechanical properties such as compressive and impact strength are critical for clinical longevity, as they determine resistance to fracture under masticatory forces [2].

Heat-cured resins generally demonstrate superior strength and dimensional stability owing to more complete polymerisation and lower residual monomer content [3]. In contrast, cold-cured resins, although convenient for chairside use, often exhibit inferior mechanical properties due to chemical polymerisation at room temperature [4]. To enhance performance, reinforcing agents such as glass fibres, polyethylene fibres, and nanoparticles have been incorporated into the resin matrix. Studies report improved strength with glass fibre reinforcement and increased compressive strength with TiO_2 nanoparticles [5,6]. However, outcomes depend on the type, concentration, and dispersion of reinforcements, as well as interfacial bonding [7,8].

Due to the lack of sufficient comparative evidence regarding the influence of various reinforcement techniques on both cold-cure and heat-cure resins, the present study was designed to evaluate and compare the compressive and impact strength of reinforced acrylic resins under standardised in-vitro conditions.

The aim of this study was to evaluate and compare the compressive and impact strength of self-cure and heat-cure acrylic resins reinforced with glass and polypropylene fibres. The study assessed the compressive and impact strength of reinforced and non-

reinforced acrylic resins and compared the influence of different reinforcement materials on their mechanical properties. The null hypothesis (H_0) stated that there would be no significant difference in compressive and impact strength among acrylic resins with and without reinforcement, whereas the alternative hypothesis (H_1) proposed that significant differences would exist among the groups.

MATERIALS AND METHODS

The present in-vitro experimental study was conducted in the Department of Prosthodontics, CK.S. Theja Institute of Dental Sciences and Research, India, from August to November 2024. Ethical approval was obtained from the Institutional Ethics Committee (Approval No.: CKS/PROSTHO/22-23/03).

Sample size calculation: The sample size for the present in-vitro study was determined based on previously published studies evaluating mechanical properties of PMMA resins [2]. The calculation was performed using G*Power software (Version 3.1, Heinrich Heine University, Düsseldorf, Germany). Considering a large effect size (f=0.40) derived from prior literature, an alpha error (α) of 0.05, a statistical power (1-β) of 80%, and six study groups, with one-way Analysis of Variance (ANOVA) as the planned statistical test, the minimum required sample size was calculated to be 10 specimens per group. Accordingly, a total of 120 specimens were prepared and divided equally for compressive strength and impact strength testing, with separate specimens fabricated for each test to avoid structural compromise during evaluation. For each test, 60 specimens were allocated into six groups (n=10 per group). Thus, the study comprised 60 specimens for compressive strength testing and 60 specimens for impact strength testing.

Inclusion and Exclusion criteria: The inclusion criteria comprised standardised acrylic resin specimens fabricated according to the specified dimensions and specimens free from visible defects. Specimens exhibiting porosity, cracks, or other processing defects were excluded from the study.

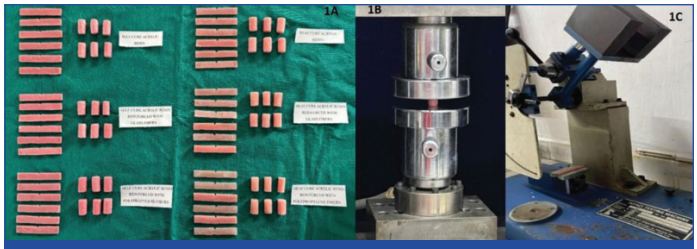
Materials used: Auto-polymerised PMMA and heat-polymerised PMMA (DPI, Mumbai, India) were used for specimen fabrication. Reinforcing materials included glass fibres and polypropylene fibres (KDM fibres Ltd.,). Modelling wax (Maarc, India), sodium alginate separating medium (DPI, Mumbai, India), dental plaster (White Gold), and petroleum jelly were used during specimen preparation.

Study Procedure

Specimen preparation: Custom stainless-steel moulds were fabricated to standardise specimen dimensions: cylindrical moulds (22×12 mm) for compressive strength testing and rectangular moulds (70×10×3 mm) for impact strength testing. The specimen dimensions were selected in accordance with ISO 1567 specifications for denture base polymers to ensure standardisation, reproducibility, and reliable comparison of mechanical properties among the study groups [9].

Wax patterns were prepared using modelling wax and invested in dental plaster using conventional flasking procedures. Dewaxing was carried out at 100°C for 10 minutes, followed by application of sodium alginate separating medium.

The acrylic resin was prepared as per the manufacturer's guidelines, maintaining a monomer-to-polymer ratio of 1:2 [Table/Fig-1]. A concentration of 2 wt% glass and polypropylene fibres was incorporated into the resin matrix. The fibres were immersed in monomer for 10 minutes prior to mixing and subsequently added during the dough stage. Manual mixing was performed to achieve uniform distribution, resulting in random orientation of fibres within the matrix. The material was then packed into moulds and bench-cured for 30 minutes. Specimen preparation and mechanical testing procedures were performed according to ISO 1567 specifications for denture base polymers [9].



[Table/Fig-1]: a) Specimens after processing; b) Test specimens placed between the jaws of universal testing machine; and c) Charpy impact testing machine.

The prepared specimens were categorised based on two mechanical tests: compressive strength and impact strength. For each test, specimens were further divided into six subgroups according to the type of acrylic resin and reinforcement used (n=10 per subgroup). Group I comprised self-cure PMMA without reinforcement and served as the control, while Group II and Group III included self-cure PMMA reinforced with glass fibres and polypropylene fibres, respectively. Similarly, Group IV consisted of heat-cure PMMA as the control group, whereas Group V and Group VI included heat-cure PMMA reinforced with glass fibres and polypropylene fibres, respectively.

- **Processing and finishing:**

Self-cure acrylic resin processing: Self-cure acrylic resin was mixed in the manufacturer-recommended polymer-to-monomer ratio (3:1 by volume) and allowed to reach the dough stage before packing into moulds. Polymerisation was carried out at room temperature (approximately 23-25°C) under bench curing conditions for the recommended duration.

Heat-cure Acrylic Resin Processing: Polymerisation of heat-cured samples was carried out at 74°C for two hours, followed by a final boiling stage lasting one hour. The specimens were then allowed to cool at room temperature, retrieved, finished with tungsten carbide burs, and polished using progressively finer abrasive papers and pumice. All samples were conditioned in distilled water at 37°C for 48 hours before evaluation [10].

- **Mechanical testing:**

Compressive strength testing: Compressive strength was evaluated using a universal testing machine (Model: H50KS, Manufacturer: Tinius Olsen) [Table/Fig-1b]. Prior to testing, all specimens were stored in distilled water at 37°C for 48 hours to simulate oral conditions. Each cylindrical specimen (22 mm height×12 mm diameter) was positioned vertically between the compression plates of the testing machine. A uniaxial compressive force was delivered at a constant crosshead speed of 1 mm/min until fracture, with the peak load at failure documented in Newtons (N) [11].

$\sigma = F/A$,

Where, F is the maximum load at fracture and A is the cross-sectional area [12].

Impact strength testing: Impact strength was evaluated using a Charpy impact testing machine (Model: I-14, Impact Analysis Instruments Pvt. Ltd., India) [Table/Fig1c]. Rectangular specimens (70 mm×10 mm×3 mm) were positioned horizontally on the support anvils with the unnotched surface facing away from the pendulum. Unnotched specimens were used to simulate clinical conditions and assess inherent material strength without stress concentration. Each specimen was subjected to a single pendulum blow in accordance with standard impact testing procedures. The equipment was calibrated prior to testing to ensure accuracy and reliability of measurements.

The specimen was impacted by a pendulum of known energy, and the absorbed fracture energy was measured from the calibrated scale of the device; impact strength was subsequently determined using the formula [13]:

Impact strength=Energy absorbed / (width×thickness).

STATISTICAL ANALYSIS

Data analysis was performed using Statistical Package for Social Sciences (SPSS) software (version 27.0; IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test, which confirmed that all variables followed a normal distribution (p>0.05). Accordingly, parametric tests were applied. Differences among the six groups were analysed using one-way ANOVA. When significant differences were detected, Tukey's post-hoc test was used for multiple pairwise comparisons between groups. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 120 specimens were equally distributed among six groups (n=20 per group), ensuring uniform sample allocation for both self-cure and heat-cure acrylic resins with and without reinforcement. This standardised grouping facilitated reliable comparison across all experimental conditions.

The mean compressive strength values demonstrated a significant increase in all reinforced groups compared to their respective controls. Among self-cure groups, glass fibre reinforcement showed the highest mean compressive strength (126.35±3.79 MPa), followed by polypropylene reinforcement (110.16±4.40 MPa). Similarly, in heat-cure groups, glass fibre-reinforced specimens exhibited the highest compressive strength (219.22±7.47 MPa), followed by polypropylene reinforcement (175.13±10.62 MPa). Overall, heat-cure resins demonstrated higher compressive strength than self-cure resins across all groups. The difference among groups was statistically significant {F(5,114)=977.33, p<0.001} [Table/Fig-2].

Group	Description	Mean±SD (MPa)	F-value	df	p-value
Group I	Self-cure Control (SC-C)	86.23±4.65	977.33	(5,114)	<0.001
Group II	Self-cure Glass Fibre (SC-GF)	126.35±3.79			
Group III	Self-cure Polypropylene Fibre (SC-PP)	110.16±4.40			
Group IV	Heat-cure Control (HC-C)	139.90±7.53			
Group V	Heat-cure Glass Fibre (HC-GF)	219.22±7.47			
Group VI	Heat-cure Polypropylene fibre (HC-PP)	175.13±10.62			

[Table/Fig-2]: Comparison of compressive strength among study groups.
Data are presented as mean±standard deviation (SD). Statistical analysis was performed using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test for multiple comparisons. A p-value <0.05 was considered statistically significant. PMMA: Polymethyl methacrylate

Impact strength values were significantly higher in reinforced groups compared to unreinforced controls. Glass fibre reinforcement resulted in the greatest improvement in impact strength in both self-cure and heat-cure resins. Among self-cure groups, glass fibre reinforcement showed the highest impact strength (6.05±0.67 kJ/m^2), followed by polypropylene fibres (4.58±0.45 kJ/m^2), while the control group showed the lowest values (3.35±0.47 kJ/m^2). Among heat-cure groups, glass fibre reinforcement demonstrated the highest impact strength (14.23±2.73 kJ/m^2), followed by polypropylene fibres (12.02±1.38 kJ/m^2) and control group (9.09±1.10 kJ/m^2). Heat-cure resin groups consistently showed higher impact strength values compared to self-cure groups. The intergroup differences were statistically significant {F(5,114)=194.68, p<0.001} [Table/Fig-3].

One-way ANOVA revealed a statistically significant difference in both compressive strength and impact strength among the six groups (p<0.001). This indicates that the type of resin and the incorporation of reinforcing materials had a significant effect on the mechanical properties evaluated in this study.

Group	Mean±SD (kJ/m^2)	F-value	df	p-value
Self-cure control	3.35±0.47	194.68	(5,114)	<0.001
Self-cure glass	6.05±0.67			
Self-cure polypropylene	4.58±0.45			
Heat cure control	9.09±1.10			
Heat cure glass	14.23±2.73			
Heat cure polypropylene	12.02±1.38			

[Table/Fig-3]: Comparison of impact strength among study groups.
Data are presented as mean±standard deviation (SD). Intergroup comparison was carried out using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test. A p-value <0.05 was considered statistically significant. Values are expressed in kilojoules per square meter (kJ/m^2)

Post-hoc analysis demonstrated significant pairwise differences between control and reinforced groups. Glass fibre reinforcement showed a significantly higher increase in compressive strength compared to polypropylene fibres in both self-cure and heat-cure resins (p<0.001). Additionally, heat-cure groups exhibited significantly greater compressive strength than corresponding self-cure groups, indicating superior mechanical performance [Table/Fig-4].

Comparison	Mean difference	p-value
Group I (Self-cure control) vs Group II (Self-cure glass fibre)	40.12	<0.001
Group I (Self-cure control) vs Group III (Self-cure polypropylene fibre)	23.93	<0.001
Group II (Self-cure glass fibre) vs Group III (Self-cure polypropylene fibre)	16.19	<0.001
Group IV (Heat-cure control) vs Group V (Heat-cure glass fibre)	79.31	<0.001
Group IV (Heat-cure control) vs Group VI (Heat-cure polypropylene fibre)	35.22	<0.001
Group V (Heat-cure glass fibre) vs Group VI (Heat-cure polypropylene fibre)	44.09	<0.001
Group II (Self-cure glass fibre) vs Group V (Heat-cure glass fibre)	92.87	<0.001
Group III (Self-cure polypropylene fibre) vs Group VI (Heat-cure polypropylene fibre)	64.96	<0.001
Group I (Self-cure control) vs Group IV (Heat-cure control)	53.67	<0.001

[Table/Fig-4]: Tukey's Post-hoc analysis for compressive strength.
Pairwise comparisons were performed using Tukey's post-hoc test following one-way ANOVA. Mean difference represents the difference between group means. A p-value <0.05 was considered statistically significant

Tukey's post-hoc test revealed statistically significant differences between most group comparisons. Glass fibre-reinforced groups showed significantly higher impact strength compared to both control and polypropylene-reinforced groups (p<0.001). Heat-cure resins demonstrated significantly greater impact strength than self-cure resins. Cross-comparisons between corresponding groups (self-cure vs heat-cure) were also found to be statistically significant, confirming that both reinforcement type and curing method significantly influence impact resistance [Table/Fig-5].

Comparison	Mean difference	p-value
Self-control vs Glass	2.70	<0.001
Self-control vs Polypropylene	1.23	<0.001
Self-glass vs Polypropylene	1.47	<0.001
Heat control vs Glass	5.14	<0.001
Heat control vs Polypropylene	2.93	<0.001
Heat glass vs polypropylene	2.21	<0.001
Self-glass vs heat glass	8.18	<0.001
Self-polypropylene vs heat polypropylene	7.44	<0.001
Self-control vs heat control	5.74	<0.001

[Table/Fig-5]: Tukey's post-hoc analysis for impact strength.
Pairwise intergroup comparisons were carried out using Tukey's post-hoc test. Mean difference indicates the difference between compared groups. A p-value < 0.05 was considered statistically significant. Values are expressed in kJ/m^2

DISCUSSION

Despite its widespread use, PMMA exhibits low impact and compressive strength, making it vulnerable to fracture. To address these limitations, reinforcement strategies have been extensively explored, as they enhance mechanical properties without altering clinical handling. It has been reported that the incorporation of nanoparticles, including zirconia (ZrO_2) and titanium dioxide (TiO_2) improve strength by reducing porosity and enhancing matrix bonding [14,15]. Fibre reinforcement, particularly with glass fibres, has been reported to improve the mechanical properties and fracture resistance of PMMA denture base materials [16].

Natural fillers and alternative polymerisation techniques have also demonstrated improvements in material performance. Based on these findings, the present study utilised glass and polypropylene fibres as reinforcing agents for both self-cure and heat-cure PMMA resins [17].

Glass fibres were selected due to their high strength, thermal stability, and ability to distribute stresses effectively within the resin matrix, especially when adequate interfacial bonding is achieved [18]. Polypropylene fibres, being lightweight, hydrophobic, and biocompatible, offer good resilience and cost-effectiveness, making them a suitable alternative [19].

The results of the present study demonstrated that reinforcement significantly enhanced both compressive and impact strength of acrylic resins. Among the materials tested, glass fibre reinforcement showed the highest improvement in both properties, followed by polypropylene fibres. These findings are consistent with previous studies, where glass fibres have been shown to provide superior reinforcement due to better stress transfer and resistance to crack propagation [4].

Heat-cure resins exhibited significantly greater mechanical strength than self-cure resins in both reinforced and unreinforced groups. This may be attributed to a higher degree of polymerisation and lower residual monomer content, resulting in improved structural integrity [4]. In contrast, self-cure resins, polymerised at room temperature, tend to have inferior mechanical properties due to incomplete polymerisation. Although polypropylene fibre reinforcement improved the mechanical performance compared to control groups, its effect was comparatively lower than that of glass fibres, possibly due to differences in fibre-matrix adhesion and intrinsic material properties. Overall, the findings indicate that both the curing method and type of reinforcement significantly influence the mechanical performance of PMMA resins. Heat-cured PMMA reinforced with glass fibres demonstrated the most favourable results, suggesting its potential for enhanced durability and clinical performance in denture fabrication [18].

Several studies in the literature support the findings of the present study regarding the effectiveness of reinforcement in improving the mechanical properties of acrylic resins. Moslehifard E et al., reported that incorporation of TiO_2 nanoparticles into heat-cure acrylic resins enhanced surface characteristics, reduced porosity, and improved overall mechanical properties, indicating that structural modifications can significantly strengthen polymer matrices [14]. Similarly, Felemban NH and Ebrahim MI demonstrated that modified zirconi-titanium dioxide nanoparticles improved tensile strength and surface hardness, reinforcing the concept that material reinforcement enhances the performance of polymer-based dental materials [15].

Studies by Gad MM et al., demonstrated that fibre reinforcement, particularly with glass fibres, significantly enhances fracture toughness, flexural strength, and impact resistance, highlighting their superiority over other reinforcing materials [20].

The findings of the present study are also in agreement with several investigations emphasising the advantages of glass fibre reinforcement. Stipho HD reported that incorporation of glass fibres into PMMA reduced deformation and improved fracture resistance [21]. Similarly, Fonseca RB et al., demonstrated that appropriate surface treatment of glass fibres further enhances bonding and mechanical performance [22], while Kim SH and Watts DC and Bashi T and Al-Nema L reported significant improvements in impact strength with fibre reinforcement [23,24]. Abdulmajeed AA et al., additionally showed that increasing fibre content enhances flexural and impact strength, further supporting the role of fibre reinforcement in improving material performance [25].

However, some studies have reported contrasting findings. Stipho HD noted that although glass fibre reinforcement improved certain mechanical properties, it could increase brittleness under high-impact conditions, potentially affecting resilience [21].

Although fibre reinforcement improves mechanical properties, certain limitations have been reported. Özdemir AK et al., observed histopathological changes associated with fibre-reinforced acrylic resins, suggesting that exposed or poorly finished fibres may cause tissue irritation. Increased surface roughness has also been linked to greater bacterial adhesion and plaque accumulation. These concerns can be minimised through proper finishing and polishing of the prosthesis [26].

The effectiveness of reinforcement is influenced by multiple factors, including fibre type, orientation, adhesion to the resin matrix, polymerisation technique, and processing conditions. Inadequate bonding or improper fibre distribution may compromise mechanical performance and clinical durability. Therefore, optimising these parameters is essential to achieve consistent and predictable outcomes [22].

The present study provides a comparative evaluation of self-cure and heat-cure acrylic resins reinforced with glass and polypropylene fibres, offering clinically relevant insights into material selection. Standardised specimen preparation and controlled in-vitro conditions ensured methodological consistency and reproducibility. The use of both compressive and impact strength testing allowed a comprehensive assessment of mechanical behaviour under different loading conditions. Statistical analysis confirmed that the observed improvements were significant, supporting the reliability of the findings. Furthermore, the results were consistent with most previous studies, while also acknowledging conflicting evidence, thereby providing a balanced interpretation. Clinically, the findings suggest that appropriate reinforcement, particularly with glass fibres, can enhance denture strength, reduce fracture risk, and improve longevity, ultimately benefiting patient outcomes. The null hypothesis stating that reinforcement would not influence the compressive and impact strength of self-cure and heat-cure acrylic resins was rejected, as significant differences were observed among the reinforced and unreinforced groups. Glass fibre reinforcement, particularly in heat-cure PMMA, demonstrated the highest improvement in mechanical properties.

Future research should focus on in-vivo studies to better simulate clinical conditions and validate these findings. Exploration of advanced reinforcement materials such as graphene, carbon nanotubes, and hybrid composites may provide further improvements in mechanical performance. Long-term aging studies are required to evaluate durability over time. Comparative analysis using alternative processing techniques, including Computer-Aided Design / Computer-Aided Manufacturing (CAD/CAM) and injection moulding, may offer additional insights. Multicentre studies with larger sample sizes are also recommended to enhance generalisability.

Limitation(s)

The present study has certain limitations. Being an in-vitro investigation, it does not fully replicate intraoral conditions such as temperature fluctuations, salivary effects, microbial activity, and complex masticatory forces. Only two types of reinforcing materials were evaluated, limiting comparison with other advanced materials. Long-term aging and durability of reinforced resins were

not assessed. Although the sample size was statistically adequate, it may not represent all clinical variations. Additionally, potential confounding factors such as variability in fibre distribution, manual mixing technique, and processing conditions were not specifically controlled or analysed, which may have influenced the mechanical properties.

CONCLUSION(S)

Considering the limitations inherent to this in-vitro study, it can be inferred that reinforcement significantly improves the mechanical properties of acrylic resins. Glass fibre reinforcement demonstrated superior enhancement in both compressive and impact strength compared to polypropylene fibres and control groups. Heat-cure acrylic resins showed higher mechanical strength than self-cure resins in both reinforced and unreinforced conditions. Among all groups, glass fibre-reinforced heat-cure acrylic resin exhibited the best overall performance. These findings suggest that glass fibre reinforcement, particularly in heat-cure PMMA, can improve the durability and clinical performance of denture base materials.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Apr 04, 2026
- Manual Googling: Jun 04, 2026
- iThenticate Software: Jun 06, 2026 (7%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

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