Academia Journal of Medicine
Year 2026, Volume-9, Issue- 1 (January- June)

www.acspublisher.com

A Comparative Study On The Mechanical Strength Of 3D-Printed Versus Heat-Cured Denture Base Resins

Ankita Singh[1*], Arwa Hussain Chaiwala[2], Malay Debbarma[3], Sai Sagar[4], Ayushi Gupta[5] and Milind Rajan[6]

[1]Reader, Department of Prosthodontics Including Crown and Bridge, Maharishi Markandeshwar College of Dental Sciences and Research, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala, Haryana, India
[2]Assistant Professor of Family and Community Medicine, Dental Director SIU Medicine, Springfield, Illinois, USA
[3]Postgraduate Student, Department of Prosthodontics, Crown and Bridge and Oral Implantology, Maharaja Ganga Singh Dental College and Research Centre, Sriganganagar, Rajasthan, India
[4]Senior House Surgeon, Government Hospital Neyattinkara, Trivandrum, Kerala, India
[5]Lecturer, Department of Conservative Dentistry and Endodontics, Dharmsinh Desai University, Faculty of Dental Sciences, Nadiad, Gujarat, India
[6]PhD Scholar, Department of Pediatric Dentistry, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India

ARTICLE INFO

Keywords: 3D printing, denture base resin, heat-cured PMMA, flexural strength, mechanical properties

doi:10.48165/ajm.2026.9.01.35

ABSTRACT

Background: Denture base resins play a critical role in the longevity and clinical success of removable prostheses. Conventional heat-cured polymethyl methacrylate (PMMA) has long been the material of choice; however, the advent of 3D printing technology has introduced alternative materials with potential advantages in fabrication efficiency and customization. Despite these benefits, concerns remain regarding their mechanical properties.

Aim: To compare the mechanical strength of 3D-printed denture base resins with conventional heat-cured denture base resins.

Materials and Methods: This in vitro study was conducted using standardized rectangular specimens fabricated from two groups: Group I – heat-cured PMMA denture base resin and Group II – 3D-printed denture base resin. Each group consisted of equal numbers of samples prepared according to manufacturer specifications. Mechanical strength was evaluated using a three-point bending test on a universal testing machine to determine flexural strength. The obtained data were statistically analyzed using an independent t-test, with the level of significance set at $p < 0.05$.

Results: The heat-cured PMMA group demonstrated higher mean flexural strength compared to the 3D-printed resin group. The difference between the groups was found to be statistically significant ($p < 0.05$), indicating superior mechanical performance of conventional denture base material under the tested conditions.

Conclusion: Within the limitations of this study, heat-cured denture base resins exhibited greater mechanical strength than 3D-printed resins. However, 3D-printed materials offer advantages in terms of fabrication and digital workflow, suggesting the need for further advancements to enhance their mechanical properties for long-term clinical application.

Introduction

The denture base is a fundamental component of removable prostheses, serving to support artificial teeth and distribute functional forces to the underlying oral tissues.[1,2] Among the various materials available, polymethyl methacrylate

Corresponding author: Ankita Singh
Email id: singh_ankita_singh@yahoo.com

has remained the gold standard for denture base fabrication due to its favorable properties, including adequate esthetics, ease of processing, cost-effectiveness, and acceptable biocompatibility.[3] Conventional heat-cured PMMA, in particular, has been widely used owing to its superior mechanical properties compared to self-cured and light-cured alternatives. Despite these advantages, PMMA is not without limitations, as it exhibits relatively low impact and flexural strength, making it susceptible to fracture under functional and parafunctional stresses.[3-6]

In recent years, advancements in digital dentistry have revolutionized prosthodontic practice, with the introduction of computer-aided design and computer-aided manufacturing (CAD-CAM) technologies. Among these innovations, additive manufacturing, commonly known as 3D printing, has gained significant attention for the fabrication of denture bases. This technology allows for precise layer-by-layer construction of prostheses directly from digital designs, offering advantages such as reduced material wastage, enhanced reproducibility, improved fit, and streamlined laboratory workflows. Additionally, 3D printing enables rapid prototyping and customization, making it an attractive alternative to conventional techniques.

However, the transition from conventional to digital fabrication methods raises important concerns regarding the mechanical properties of 3D-printed denture base resins. Unlike heat-cured PMMA, which undergoes polymerization under controlled temperature and pressure conditions, 3D-printed resins are typically fabricated through photopolymerization processes. This difference in polymerization mechanisms may influence the material's internal structure, degree of conversion, and ultimately its mechanical performance. Factors such as layer orientation, printing parameters, and post-processing protocols can further affect the strength and durability of 3D-printed prostheses.[8,9]

Mechanical strength, particularly flexural strength, is a critical parameter in evaluating denture base materials, as dentures are subjected to complex masticatory forces during function. Insufficient strength can lead to midline fractures, patient discomfort, and frequent prosthesis failure, thereby compromising treatment outcomes.[10,11] Therefore, it is essential to assess whether 3D-printed denture base resins can withstand functional loads comparable to those of conventional heat-cured PMMA.

Although several studies have explored the properties of 3D-printed dental materials, there remains a need for direct comparative analysis focusing on their mechanical strength in relation to traditional denture base resins. Such evidence is crucial for guiding clinicians in material selection and for determining the clinical viability of emerging digital fabrication techniques.

Hence, the present in vitro study was undertaken to compare the mechanical strength of 3D-printed denture base resins with that of conventional heat-cured denture base resins, thereby contributing to the growing body of evidence in digital prosthodontics.

Materials and Methods

This in vitro comparative study was conducted to evaluate and compare the mechanical strength of 3D-printed denture base resins with conventional heat-cured denture base resins. A total of 40 standardized specimens were fabricated and divided into two groups, with 20 specimens in each group. Group I comprised heat-polymerized polymethyl methacrylate (PMMA) resin specimens fabricated using DPI Heat Cure Denture Base Resin (Dental Products of India, Mumbai, India), while Group II consisted of 3D-printed specimens fabricated using NextDent Denture 3D+ resin (NextDent B.V., Soesterberg, Netherlands).

All specimens were prepared in accordance with ISO 20795-1:2013 standards for denture base polymers, with dimensions standardized at 65 mm × 10 mm × 3 mm. For Group I, wax patterns were first fabricated using a stainless steel mold of the desired dimensions. These patterns were subjected to conventional flasking and dewaxing procedures. The heat-cured PMMA resin was mixed according to the manufacturer's instructions, packed into the mold, and polymerized using a long curing cycle at 74°C for 8 hours. Following polymerization, the specimens were allowed to bench cool, retrieved, and finished and polished using standard laboratory techniques.

For Group II, specimens were digitally designed using CAD software and fabricated using a 3D printer (NextDent 5100, 3D Systems, USA) with a layer thickness of 50 µm. After printing, the specimens were cleaned in isopropyl alcohol to remove any uncured resin and subsequently subjected to post-polymerization in a UV curing unit (LC-3DPrint Box, NextDent) as per the manufacturer's recommendations. The specimens were then finished and polished to ensure uniform surface characteristics.

The mechanical strength of all specimens was evaluated by measuring flexural strength using a three-point bending test in a universal testing machine (Instron, Norwood, MA, USA). Each specimen was placed on two supports with a span length of 50 mm, and load was applied at the center at a crosshead speed of 5 mm/min until fracture occurred. The maximum load at fracture was recorded, and flexural strength was calculated using the standard formula.

The obtained data were tabulated and statistically analyzed using SPSS software (Version 25.0; IBM Corp., Armonk, NY, USA). Mean and standard deviation values were calculated for each group, and an independent t-test was applied to compare the mean flexural strength between the two groups.

The level of statistical significance was set at $p < 0.05$. As this was an in vitro study, ethical approval was not required.

Result

The flexural strength values of both groups were recorded and analyzed. The mean flexural strength of the heat-cured PMMA group (Group I) was found to be higher than that of the 3D-printed resin group (Group II). The difference between the two groups was statistically significant, indicating superior mechanical strength of the conventional heat-cured denture base resin under the conditions of this study. **(Table 1)**

Table 1: Comparison of Flexural Strength Between Group

Group	Material	Mean Flexural Strength (MPa) ± Standard Deviation	p-value
Group I	Heat-cured PMMA	92.45 ± 5.12	< 0.001
Group II	3D-Printed Resin	68.30 ± 4.87	

Discussion

The present in vitro study compared the mechanical strength, specifically flexural strength, of 3D-printed denture base resins with conventional heat-cured polymethyl methacrylate (PMMA). The results demonstrated that the heat-cured PMMA specimens exhibited significantly higher flexural strength than the 3D-printed denture base resins, indicating superior resistance to fracture under bending forces.

Flexural strength is a critical property for denture base materials, as dentures are routinely subjected to complex masticatory and parafunctional forces in the oral environment.[12,13] Fracture of dentures, particularly along the midline, is a common clinical complication and is often attributed to inadequate material strength. The higher flexural strength observed in heat-cured PMMA in this study can be attributed to its well-established polymerization process, which occurs under controlled heat and pressure conditions.[14] This results in a more homogeneous polymer matrix, reduced residual monomer content, and improved intermolecular bonding, all of which contribute to enhanced mechanical properties.

In contrast, 3D-printed denture base resins are fabricated using additive manufacturing techniques based on photopolymerization. This process involves layer-by-layer deposition and curing of resin, which can introduce anisotropy and weak interlayer bonding. The presence of layer lines and potential voids between layers may act as spots of stress concentration, thereby reducing the overall strength of the material. Additionally, the degree of polymer conversion in 3D-printed resins may be lower compared to heat-cured PMMA, especially if post-curing protocols are not optimized, further affecting mechanical performance.[15,16]

Another important factor influencing the strength of 3D-printed resins is the printing orientation. Studies have shown that specimens printed at different angles exhibit varying mechanical properties, with certain orientations leading to reduced resistance to fracture due to the alignment of layers relative to applied forces. In the present study, although standardized printing parameters were maintained, inherent limitations of the additive manufacturing process may have contributed to the lower flexural strength observed in the 3D-printed group.

The findings of this study are consistent with several previous investigations that reported superior mechanical properties of conventional heat-cured denture base resins compared to 3D-printed materials. However, it is important to note that despite their lower strength, 3D-printed resins offer several advantages, including reduced fabrication time, improved reproducibility, digital storage of designs, and enhanced customization. These benefits make them a promising alternative, particularly in cases where rapid denture fabrication is required.

From a clinical perspective, the lower flexural strength of 3D-printed denture base resins suggests that they may be more suitable for interim or provisional prostheses rather than long-term definitive dentures, especially in patients with high occlusal loads or parafunctional habits. However, ongoing advancements in material science and printing technologies are expected to improve the mechanical properties of these materials, potentially bridging the gap between digital and conventional fabrication methods.

The present study has certain limitations. Being an in vitro study, it does not fully replicate the complex oral environment, where factors such as thermal cycling, water sorption, fatigue loading, and microbial activity can influence material properties. Additionally, only one brand of 3D-printed resin and one type of conventional heat-cured PMMA were evaluated, which may limit the generalizability of the findings. Future studies should include a wider range of materials, evaluate additional mechanical properties such as impact strength and fatigue resistance, and incorporate simulated oral conditions to provide more comprehensive insights.

Within the limitations of this study, it can be concluded that conventional heat-cured PMMA denture base resins continue to demonstrate superior mechanical strength compared to currently available 3D-printed alternatives. Nevertheless, the advantages offered by digital fabrication highlight the need for continued research and development in this evolving field of prosthodontics.

Conclusion

Within the limitations of this in vitro study, it can be concluded that conventional heat-cured polymethyl methacrylate (PMMA) denture base resin demonstrated significantly higher flexural strength compared to 3D-printed denture base resin. This indicates that heat-cured PMMA possesses superior resistance to fracture and remains more reliable for long-term clinical use in denture fabrication.

Although 3D-printed denture base resins exhibited lower mechanical strength, they offer notable advantages such as ease of fabrication, reduced processing time, and enhanced digital workflow. Therefore, these materials may be considered suitable for interim or provisional prostheses, with potential for broader clinical application as material properties continue to improve.

Further research incorporating larger sample sizes, multiple material systems, and simulation of intraoral conditions is recommended to validate and expand upon these findings.

References

Jacobson TE, Krol AJ. A contemporary review of the factors involved in complete denture retention, stability, and support. Part I: Retention. The Journal of Prosthetic Dentistry 1983;49(1):5-15. doi:10.1016/0022-3913(83)90245-2.

Jacobson TE, Krol AJ. A contemporary review of the factors involved in complete dentures. Part III: Support. The Journal of Prosthetic Dentistry 1983;49(3):306-313. doi:10.1016/0022-3913(83)90213-0.

Zafar MS. Prosthodontic applications of polymethyl methacrylate (PMMA): An update. Polymers 2020;12(10):2299. doi:10.3390/polym12102299.

Xu X, He L, Zhu B, Li J, Li J. Advances in polymeric materials for dental applications. Polymer Chemistry 2017;8(5):807-823. doi:10.1039/C6PY01957A.

Imazato S, Ma S, Chen J, Xu HHK. Therapeutic polymers for dental adhesives: Loading resins with bio-active components. Dental Materials 2014;30(2):97-104. doi:10.1016/j.dental.2013.06.003.

Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. Journal of Prosthodontic Research 2016;60(1):12-19. doi:10.1016/j.jpor.2015.10.001.

Abdulkarim LI, Alharamlah FSS, Abubshait RM, Alotaibi DA, Abouonq AO. Impact of digital workflow integration on fixed prosthodontics: A review of advances and clinical outcomes. Cureus 2024;16(10):e72286. doi:10.7759/cureus.72286.

Blatz MB, Conejo J. The current state of chairside digital dentistry and materials. Dental Clinics of North America 2019;63(2):175-197. doi:10.1016/j.cden.2018.11.002.

Abdelnabi MH, Swelem AA. 3D-printed complete dentures: A review of clinical and patient-based outcomes. Cureus 2024;16(9):e69698. doi:10.7759/cureus.69698.

Patankar RC, More V, Jadhav R, Sabane A, Kadam P, Gachake A. Comparative evaluation of flexural strength of denture base resin materials processed using compression molding technique, injection molding technique, and computer-aided design CAM technique: An in vitro study. Dental Research Journal 2022;19:100. doi:10.4103/1735-3327.364682.

Machado AL, Puckett AD, Breeding LC, Wady AF, Vergani CE. Effect of thermocycling on the flexural and impact strength of urethane-based and high-impact denture base resins. Gerodontology 2012;29(2):e318-e323. doi:10.1111/j.1741-2358.2011.00474.x.

Abhay PN, Karishma S. Comparative evaluation of impact and flexural strength of four commercially available flexible denture base materials: An in vitro study. The Journal of Indian Prosthodontic Society 2013;13(4):499-508. doi:10.1007/s13191-012-0203-0.

Silva FA, Silva TB, Rached RN, Del Bel Cury AA. Effect of intrinsic pigmentation on the flexural strength of a microwave-cured acrylic resin. Brazilian Dental Journal 2002;13(3):205-207. doi:10.1590/S0103-64402002000300013.

Mithran A, Rakhra J, Jain SK, Chikkanna M, Gowrish S, Pillai SG, Babu JS, Swarnalatha C, Nayyar AS. Comparative evaluation of impact strength of mechanically modified heat polymerized polymethyl methacrylate (PMMA) resin with addition of 0.5, 1, 2 wt% of silver nanoparticles (AgNPs): An in-vitro study. Journal of Orthodontic Science 2023;12:64. doi:10.4103/jos.jos_43_23.

Perea-Lowery L, Gibreel M, Vallittu PK, Lassila LV. 3D-printed vs. heat-polymerizing and autopolymerizing denture base acrylic resins. Materials 2021;14(19):5781. doi:10.3390/ma14195781.

Berli C, Thieringer FM, Sharma N, Müller JA, Dedem P, Fischer J, Rohr N. Comparing the mechanical properties of pressed, milled, and 3D-printed resins for occlusal devices. The Journal of Prosthetic Dentistry 2020;124(6):780-786. doi:10.1016/j.prosdent.2019.10.024.