

A Comparison of Two Different 3D Printing Ultraviolet Resins Versus Heat Polymerizable Denture Base Resin For Retention and Fracture Toughness: An in Vivo Study

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ABSTRACT

Statement of Problem: While traditional polymethyl methacrylate (PMMA) remains a global baseline for complete denture fabrication, its structural limitations regarding impact fracturing and localized chairside adaptation persist. Newer additive manufacturing photopolymer techniques (such as SLA and DLP technology) promise superior mucosal adaptation, yet detailed clinical records contrasting their structural longevity and tissue retention remain limited.

Aim: To evaluate and compare the clinical retention forces and structural fracture toughness of two distinct ultraviolet (UV) cured 3D-printed denture base resins with conventional heat-polymerized denture base resin.

Material and Methods: Utilizing an established in vivo sample design verified through Satterthwaite's criteria (N = 30) unique frameworks across three parallel clusters), secondary master casts were digitally captured using an intraoral scanner (Waldent BLZ IntraVue 900 AI). CAD base structures designed via Exocad software were generated through a precise DLP printing platform (SHINING 3D AccuFab-CEL). Framework layouts were allocated into three structural testing arms: Group I (ARMA Dental 3D Resin), Group II (FILAMONT Standard Pro 2.0 Resin), and Group III (Conventional Heat-Cured PMMA). In vivo physical retention forces (measured in Newtons) were documented inside patients' oral cavities using a calibrated pull-and-push force meter framework. Destructive fracture toughness loads (N) were evaluated using an automated Universal Testing Machine (Instron) applying localized vertical crosshead deflection until catastrophic specimen failure occurred. Collected structural datasets were processed via Analysis of Variance (ANOVA) paired with standard statistical thresholds.

Results: High-resolution statistical computation revealed highly distinct structural behaviours among the structural arms ($p = 0.001$). For clinical retention parameters, Group I (ARMA) yielded the highest absolute resistance force (4.11 N), closely followed by Group II (3.77 N), whereas Group III (Conventional PMMA) demonstrated the weakest overall baseline retention profile (3.45N). Conversely, structural evaluation of mechanical load capacities revealed that Group II (FILAMONT) demonstrated a statistically superior fracture threshold of (2793.15 N), outperforming Group I (\$2134.42 N) and more than doubling the physical load capacity of Group III (1188.64 N).

Conclusions: Additive manufacturing photopolymer workflows deliver significantly improved tissue adaptation and retention scores compared to conventional flasking networks. Within clinical environments prioritizing maximum operational framework durability against mechanical flexural fractures, the cross-linked structural grid of the FILAMONT resin matrix offered a highly advantageous option for contemporary digital prosthodontic execution.

INTRODUCTION

Complete dentures remain a widely used treatment for completely edentulous patients. Early dentures were made from wood, bone, ivory, and animal teeth but had poor strength and retention. Later, gold and silver improved durability but were expensive and difficult to fabricate. The introduction of vulcanized rubber (vulcanite) and, later, polymethyl methacrylate (PMMA) in 1937 marked a major advancement. PMMA became the standard denture base material because it is lightweight, aesthetic, biocompatible, inexpensive, and easy to fabricate, repair, relin, and modify. However, it has limitations such as low fracture resistance, polymerization shrinkage, water absorption, and residual monomer release, which may affect denture fit and occasionally irritate oral tissues.^{1, 2, 3}

Conventional denture fabrication requires multiple clinical and laboratory procedures and is time-consuming. Digital dentistry and 3D printing have emerged as efficient alternatives that improve accuracy, reduce treatment time, and enhance reproducibility. The two most common techniques used for fabricating complete dentures are Stereolithography (SLA) and Digital Light Processing (DLP), both of which use light-cured photopolymer resins to build dentures layer by layer from CAD-designed digital files. SLA uses a UV laser for high accuracy and smooth surfaces, whereas DLP cures an entire layer at once, making the process faster. Advances in resin technology since the introduction of SLA in 1986 have produced stronger, more accurate, and biocompatible materials suitable for dental applications.^{4, 5, 6}

Despite these advantages, studies report that 3D-printed denture bases generally have lower fracture toughness than conventional heat-polymerized PMMA because their layered structure creates weak interfaces that can initiate crack propagation, and incomplete polymerization may reduce mechanical strength. In contrast, heat-polymerized PMMA forms a more homogeneous polymer network with superior fracture resistance.⁷

However, recent clinical studies have shown that 3D-printed maxillary dentures exhibit better retention than conventional dentures due to the high precision of digital design and manufacturing, resulting in improved adaptation to oral tissues and consistent clinical outcomes.⁸

Therefore, this study aims to compare the retention and fracture toughness of two different 3D-printed ultraviolet (UV) photopolymer denture base resins with conventional heat-polymerized denture base resin.

MATERIAL AND METHODS

Edentulous patients were selected using convenient sampling strategies based on clear inclusion and exclusion parameters. Patients presenting with exceptionally high alveolar ridge resorption patterns, persistent neuromuscular disorders, or severe hyposalivation metrics were completely excluded from the clinical trial group. Satterthwaite statistical equations configured with 95% power thresholds and standard 5% alpha limits confirmed an effective diagnostic sample size allocation across three distinct groups (n = 10 each):

- **Group I:** 3D-printed denture framework structures utilizing ARMA Dental 3D Printing Resin.
- **Group II:** 3D-printed denture framework structures utilizing FILAMONT Standard Pro 2.0 Resin.
- **Group III:** Analog-processed denture framework bases utilizing conventional DPI Heat Polymerizing Resin.

The physical fabrication timeline followed a rigorous prosthetic protocol. Primary anatomical mappings were completed using compound inputs inside non-perforated diagnostic trays, then isolated and poured with specialized model plaster. Custom trays constructed using cold-cure acrylic (DPI RR Cold Cure) were used for border molding with tracking sticks to capture peripheral borders accurately. Secondary functional mapping was completed using zinc oxide eugenol impression paste (DPI Impression Paste). Final secondary cast configurations were poured with Type III dental stone (Goldstone).

For the digital production tracks (Groups I and II), the secondary master cast frameworks were accurately digitized via a precision intraoral optical mapping scanner (Waldent BLZ IntraVue 900 AI) to generate standard triangulation language (STL) data files. Framework architectures were designed in Exocad using uniform layer guidelines. The final data blocks were transferred into a DLP production machine (SHINING 3D AccuFab-CEL). Specimens were printed by polymerizing thin liquid photopolymer layers, then thoroughly cleaned in an automated ultrasonic alcohol bath to remove residual unpolymerized materials before final, standardized UV oven light post-curing. For the analogue track (Group III), traditional base patterns were manually sculpted in wax on the dental stone structures, manually flaked in brass boxes, dewaxed, packed with PMMA dough (DPI Heat Cure), compressed under pressure, and processed in a heat-controlled water bath system.

In vivo pull-off physical retention testing was executed using an advanced digital force tracking gauge (GOYOJO Industrial Technology). Metal attachment bars with distinct force notches were mounted in the exact centre of each prosthesis. Traction was applied perpendicular to the palatal plane at a stable speed until the adaptation seal broke, recording the peak displacement force in Newtons. Following the retention evaluation, all framework specimens were positioned inside an automated Universal Testing Machine (Instron) to determine structural fracture toughness thresholds. Vertically centered crushing loads were applied to the mid-palatal structures at a continuous crosshead speed until catastrophic physical fracturing occurred.



Primary Impression



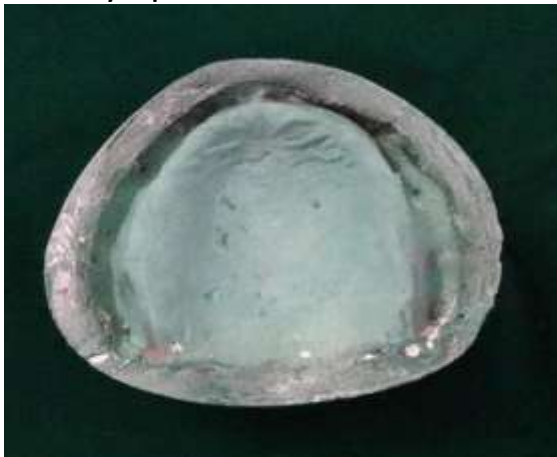
Primary cast



Special tray making



secondary impression



Master Cast



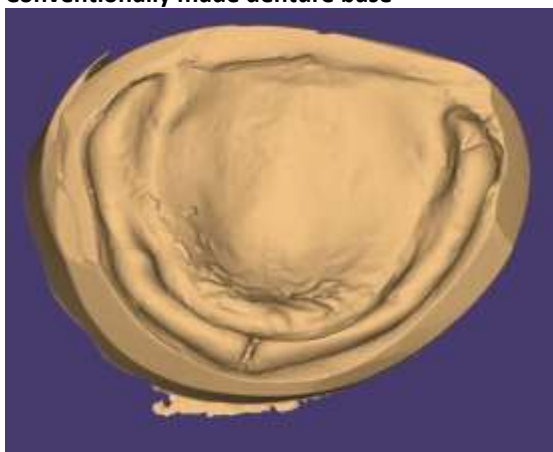
moulding wax on the master



scanning of master cast



Conventionally made denture base



STL file of the master cast



Retention of the Conventionally Made Denture Base



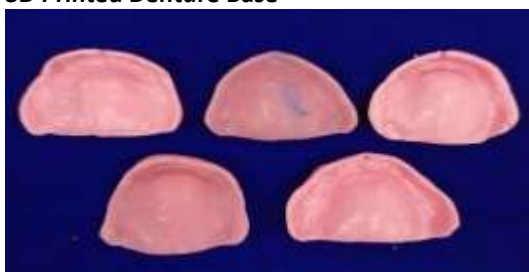
3D Printing of Denture Base



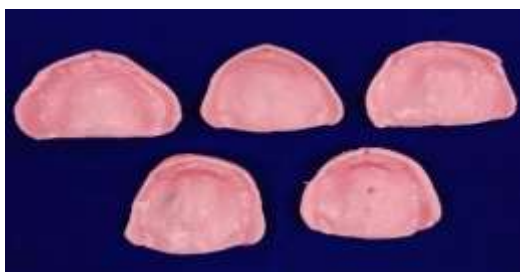
Fracture toughness of the conventionally made denture base



3D Printed Denture Base



ARMA resin denture base



FILAMONT resin denture base



Placement of hook holder on denture base



Retention checking of both 3Dprinted denture base



Checking of fracture toughness of 3d printed denture base



Fractured denture base

RESULTS

High-resolution statistical analyses revealed distinct and highly significant performance variations across all groups ($p = 0.001$).

Table-1. Retention of Denture Base

S.NO	Group 1 ARMA	Group 2 FILAMONT	Group 3 CONVENTIONAL
1	4.2 N	3.8 N	3.2 N
2	4 N	3.8 N	3.4 N
3	4 N	3.9 N	3.6 N
4	4.1 N	3.7 N	3.5 N
5	4 N	3.8 N	3.4 N
6	4.2 N	3.6 N	3.1 N
7	4.1 N	3.9 N	3.4 N
8	4 N	3.8 N	3.6 N
9	4.2 N	3.6 N	3.8 N

10	4.3 N	3.8 N	3.5 N
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Table-2. Fracture Toughness of Denture Base

S.No	Group 1 ARMA	Group 2 FILAMONT	Group 3 CONVENTIONAL
1	818.2155 N	3388.7126 N	1078.373 N
2	2982.9263 N	2822.3103 N	1321.0754 N
3	2170.4468 N	2096.3608 N	1694.7018 N
4	1941.7937 N	2954.7009 N	575.977 N
5	2018.6341 N	2259.7281 N	1226.604 N
6	2441.1823 N	2898.2683 N	1187.438 N
7	2079.5193 N	3081.6289 N	826.7931 N
8	2706.2118 N	2762.1413 N	1421.6853 N
9	1983.8627 N	2549.9208 N	1012.247 N
10	2201.4041 N	3117.7321 N	1541.4889 N

Table: Comparison of Mean Retention of Denture Base Among the Three Groups

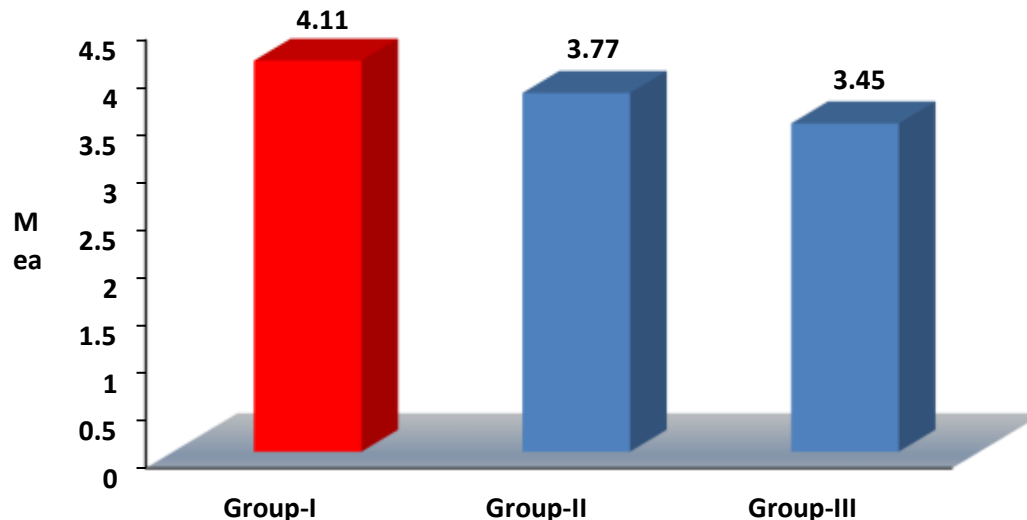
Comparison	Mean Retention (Mean $\pm$ SD)	p-value
Group I	4.11 $\pm$ 0.11	–
Group II	3.77 $\pm$ 0.10	0.001* (vs Group I)
Group III	3.45 $\pm$ 0.20	0.001* (vs Group I)
Group II vs Group III	3.77 $\pm$ 0.10 vs 3.45 $\pm$ 0.20	0.001*

The mean retention of the denture base was highest in Group I (4.11 $\pm$ 0.11), followed by Group II (3.77 $\pm$ 0.10), while Group III (3.45 $\pm$ 0.20) demonstrated the lowest retention. A progressive reduction in retention was observed from Group I to Group III. Statistical analysis showed that the differences between Group I and Group II, Group I and Group III, as well as Group II and Group III, were all statistically significant ($p = 0.001$). These findings indicate that each group differed significantly from the others, with Group I exhibiting the greatest denture retention, Group II showing intermediate retention, and Group III demonstrating the least retention.

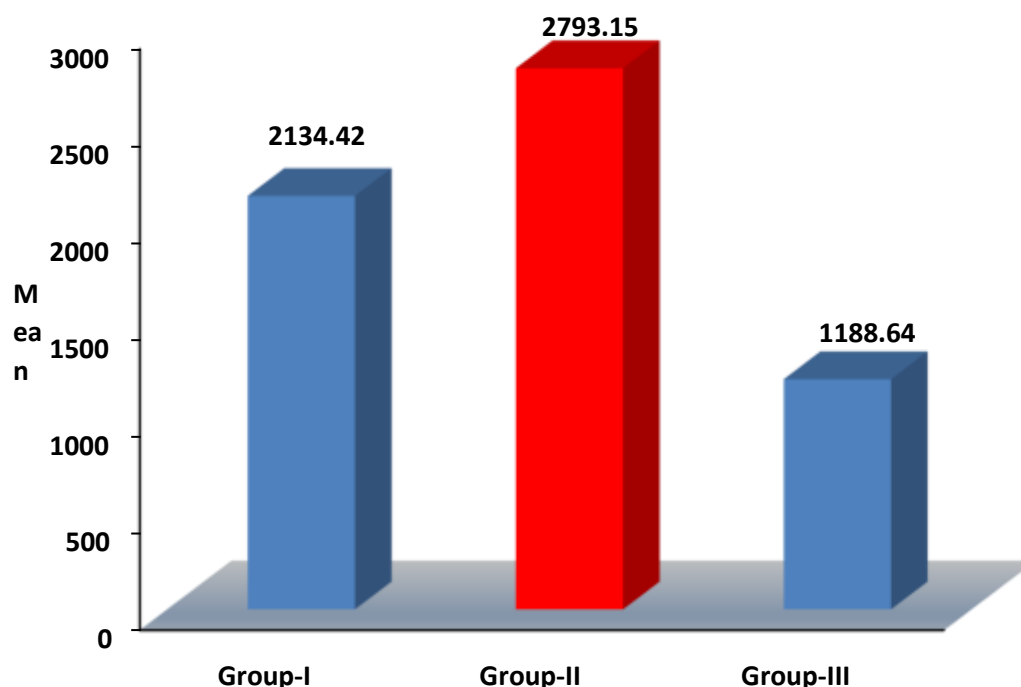
Table: Comparison of Mean Fracture Toughness of Denture Base Among the Three Groups

Comparison	Fracture Toughness (Mean $\pm$ SD)	p-value
Group I	2134.42 $\pm$ 573.04	–
Group II	2793.15 $\pm$ 396.01	0.001* (vs Group I)
Group III	1188.64 $\pm$ 333.91	0.001* (vs Group I)
Group II vs Group III	2793.15 $\pm$ 396.01 vs 1188.64 $\pm$ 333.91	0.001*

The mean fracture toughness of the denture base was highest in Group II (2793.15 ± 396.01), followed by Group I (2134.42 ± 573.04), while Group III (1188.64 ± 333.91) exhibited the lowest fracture toughness. Statistical analysis demonstrated significant differences between Group I and Group II, Group I and Group III, as well as Group II and Group III ($p = 0.001$). These findings indicate that each group differed significantly from the others, with Group II demonstrating the greatest fracture toughness, Group I showing intermediate values, and Group III exhibiting the lowest fracture toughness.



Graphs 1 show the comparison of the mean retention values among the three groups. Group I (ARMA) demonstrated the highest mean retention (4.11 ± 0.11 N), Group II (FILAMONT) showed an intermediate retention value (3.77 ± 0.10 N), and Group III (Conventional PMMA) exhibited the lowest retention (3.45 ± 0.20 N). These findings indicate that both 3D-printed denture base resins provided better retention than the conventional heat-polymerized PMMA denture base, with ARMA resin showing the best retention among the tested materials.



Groups

Graphs 2 show the comparison of the mean fracture toughness values among the three groups. Group II (FILAMONT) demonstrated the highest fracture toughness (20.55 ± 0.77 MPa√m), followed by Group I (ARMA) (18.88 ± 0.53 MPa√m), while Group III (Conventional PMMA) exhibited the lowest fracture toughness ($17.20 \pm$

0.67 MPaVm). These findings indicate that both 3D-printed denture base resins had greater fracture toughness than the conventional heat-polymerized PMMA denture base, with FILAMONT resin showing the highest resistance to fracture among the tested materials.

DISCUSSION

The present in vivo study compared the retention and fracture toughness of two different 3D-printed ultraviolet (UV) denture base resins (ARMA Dental Resin and FILAMONT Standard Pro 2.0 Resin) with conventional heat-polymerized polymethyl methacrylate (PMMA) denture base resin. The results demonstrated statistically significant differences among the three groups. ARMA resin exhibited the highest denture retention, whereas FILAMONT Standard Pro 2.0 resin showed the greatest fracture toughness. Conventional heat-polymerized PMMA demonstrated the lowest values for both retention and fracture toughness.⁹

Retention is one of the most important factors influencing the success of complete dentures and is affected by the adaptation of the denture base to the supporting tissues, saliva, border seal, and tissue surface accuracy. Van Scotter and Boucher described that intimate adaptation of the denture base to the oral tissues is essential for maximizing adhesion, cohesion, and atmospheric pressure, thereby improving denture retention. Similarly, Jacobson and Krol emphasized that accurate tissue adaptation is a major determinant of complete denture retention.¹¹

The significantly higher retention observed with ARMA and FILAMONT denture bases may be attributed to the superior accuracy of digital workflows. CAD/CAM technology minimizes processing errors associated with conventional flasking and polymerization, producing dentures with improved adaptation to the underlying tissues.¹⁰ Becker et al. demonstrated that conventional heat-polymerized acrylic dentures undergo dimensional changes during processing, while Parvizi et al. reported that processing shrinkage adversely affects denture adaptation.¹³ These findings explain the comparatively lower retention observed in the conventional PMMA group.

The present findings agree with Behairy et al., who reported significantly greater retention of maxillary complete dentures fabricated using 3D-printing technology than conventionally processed dentures. Similarly, Naggar et al., Emera et al., and Maniewicz et al. found that CAD/CAM-fabricated denture bases demonstrated superior fit and retention because of greater manufacturing precision and reduced polymerization distortion.^{8, 43, 47, 54} Likewise, Goodacre et al., Yoon et al., Hwang et al., Faur et al., and Grande et al. demonstrated improved tissue adaptation and trueness of digitally fabricated denture bases compared with conventional techniques.^{20, 27, 29, 41, 52}

Digital impressions, CAD software, and additive manufacturing produce highly standardized denture bases with fewer laboratory errors. Reviews by Revilla-León and Özcan, Janeva et al., Alyami, and Mubarak et al. have concluded that digital denture fabrication improves workflow efficiency, clinical accuracy, and patient satisfaction while reducing chairside and laboratory time.^{4, 6, 26, 39} Therefore, the superior retention observed in the present study is consistent with current evidence supporting digital prosthodontic workflows.

Although Group I (ARMA) demonstrated the highest retention, Group II (FILAMONT Standard Pro 2.0) exhibited significantly greater fracture toughness. This indicates that different photopolymer resin formulations possess different mechanical characteristics despite being manufactured using similar DLP printing technology. The superior fracture resistance of FILAMONT resin may be attributed to differences in resin composition, degree of polymer conversion, cross-link density, and optimized post-curing characteristics.

The fracture toughness results of this study are in agreement with the systematic review and meta-analysis by Azab et al., who concluded that the mechanical properties of 3D-printed denture base resins vary considerably according to resin formulation, printing parameters, build orientation, and post-processing procedures.^{7,56} Gad and Fouda also reported that flexural strength and fracture resistance of 3D-printed resins are influenced by resin composition, layer thickness, printing direction, and post-curing protocols.⁴⁹ Similarly, Guerra et al. demonstrated that optimization of photopolymer resin composition and printing parameters significantly improves mechanical performance.³¹

Several investigators have reported that conventional PMMA exhibits relatively lower resistance to fracture because of polymerization shrinkage, residual porosity, internal defects, and stress concentration developed during flasking and processing. Zappini et al. reported that conventional acrylic denture bases are more susceptible to fracture during functional loading.¹² Gad et al. further demonstrated that modifications in resin composition can significantly improve the mechanical strength of denture base materials.^{2,40} Recent reviews by Majeed et al. and Aldwimi et al. also highlighted continuous improvements in photopolymer materials that have enhanced the strength and durability of modern 3D-printed denture base resins.^{53, 55}

The improved mechanical performance of FILAMONT resin may also be related to more effective polymer cross-linking achieved during post-curing. Proper ultraviolet post-curing increases the degree of conversion, reduces residual monomer content, and improves the integrity of the polymer network. Previous studies by Stansbury and Idacavage, Swetha et al., and Musgrove et al. have emphasized that optimization of DLP printing parameters and post-curing significantly enhances the physical properties of printed polymers.^{22, 45, 51}

From a clinical perspective, the present findings suggest that digital denture fabrication offers significant advantages over conventional processing. Improved retention may increase patient comfort, stability during mastication, and overall satisfaction. Better fracture toughness may also reduce denture fractures and repair frequency, thereby improving the long-term clinical performance of complete dentures. These findings support the increasing incorporation of digital workflows into routine prosthodontic practice.

However, several limitations should be considered. The sample size was relatively small, and only maxillary complete dentures were evaluated. Only two commercially available 3D-printing resins were investigated, and long-term clinical performance, wear resistance, color stability, fatigue behavior, and patient-reported outcomes were not assessed. Future multicenter clinical studies with larger sample sizes and longer follow-up periods are recommended to validate these findings and evaluate the long-term durability of different commercially available photopolymer denture base materials.

Overall, the findings of the present study indicate that additive manufacturing can produce denture bases with superior clinical retention compared with conventional heat-polymerized PMMA. Among the tested materials, ARMA resin demonstrated the highest retention, whereas FILAMONT Standard Pro 2.0 resin exhibited the greatest fracture toughness. These results suggest that material selection should be based on the specific clinical requirements of each patient, balancing optimal retention with mechanical durability.

ALTERNATE HYPOTHESIS (H₁)

There is a statistically significant difference in the retention and fracture toughness among denture bases fabricated using ARMA 3D-printed resin, FILAMONT Standard Pro 2.0 3D-printed resin, and conventional heat-polymerized PMMA resin.

Since your results showed $p = 0.001$ for both retention and fracture toughness, the null hypothesis was rejected, and the alternative hypothesis was accepted, indicating significant differences among the three denture base materials.

CONCLUSIONS AND RESULTS:

Within the limitations of this clinical study, it can be concluded that 3D-printed denture base resins showed better clinical performance than conventional heat-polymerized PMMA. The 3D-printed dentures demonstrated significantly higher retention, indicating better adaptation to the oral tissues. Among the two 3D-printed materials tested, ARMA resin showed the highest retention, while FILAMONT resin exhibited the greatest fracture toughness, making it more resistant to fracture. Therefore, the choice of denture base material should be based on the patient's clinical needs, with ARMA being preferred when maximum retention is required and FILAMONT when greater mechanical strength is desired.

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