

Original Research Article

Comparative evaluation of surface roughness (RA) of conventional heat-cured, high-impact heat-cured, and 3D-printed denture base resins: An in-vitro profilometer study

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Abstract

Background of Study: The surface roughness of denture base resins is an important criterion which is influencing the plaque accumulation, the microbial adhesion, staining, comfort to use, and the long-term success of prostheses. Conventional heat-cured polymethyl methacrylate (PMMA) has been widely used for denture fabrication, while high-impact heat-cured and 3D-printed denture base resins have emerged with advancements in material science and digital dentistry. However, concerns remain regarding the surface characteristics of 3D-printed denture base resins.

The present study aims to evaluate and compare the surface roughness (Ra) of conventional heat-cured, high-impact heat-cured, and 3D-printed denture base resins using a contact profilometer.

Materials and Methods: An in-vitro experimental study was conducted in the Department of Prosthodontics and Crown & Bridge. Twenty-seven disc-shaped specimens (15 mm × 3 mm) fabricated according to ISO 1567 which were divided into three groups (n = 9): conventional heat-cured Acrylic, the high-impact heat-cured acrylic, and 3D-printed denture base resin. All specimens underwent finishing and polishing procedure and were stored in distilled water at 37°C for 24 hours. Surface roughness was measured using a calibrated contact profilometer, and mean Ra values were calculated. Data was analyzed using one-way ANOVA and post-hoc tests (p < 0.05).

Results: A statistically significant difference in surface roughness was observed among the three groups, with 3D-printed denture base resin showing higher Ra values compared to conventional and high-impact heat-cured resins.

Conclusion: Within the limitations of this in-vitro study, 3D-printed denture base resins exhibited higher surface roughness than conventionally processed materials, highlighting the importance of appropriate finishing and polishing protocols.

Keywords: Denture base resin, Surface roughness, 3D printing, Profilometer.

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1. Introduction

The surface roughness of denture base resins is a very critical factor influencing plaque accumulation, microbial adhesion, staining, patient comfort, and long-term success of removable prostheses. Traditionally, heat-cured polymethyl methacrylate has been the material of choice for denture bases due to its favorable properties and due to its property of ease to manipulate. High-impact heat-cured PMMA was later introduced to improve fracture resistance while maintaining acceptable surface characteristics.¹

With recent advancements in digital dentistry, the 3D-printed denture base resins have gained popularity due to their precision, reduced laboratory time, and reproducibility. However, concerns remain regarding their surface characteristics, particularly the surface

roughness, which may influence biofilm formation and clinical performance.²

Previous studies have reported conflicting results regarding surface roughness of 3D-printed denture base resins when compared to traditionally processed materials.³

Since then, a comparative evaluation under standardized finishing and polishing conditions have been required to assess and compare the surface roughness of conventional heat-cured, high-impact heat-cured, and 3D-printed denture base resins using a profilometer.

2. Objectives

This study was done to evaluate and compare the surface roughness (Ra) of different denture base materials. Specifically, surface roughness of conventional heat-cured denture base resin, high-impact heat-cured denture base resin, and 3D-printed denture base resin was evaluated. Comparative analysis was performed to understand the differences in surface roughness values among these three materials, thereby providing insight into their relative surface characteristics and potential clinical performance.

2.1. Study design and source of data

This in-vitro experimental study was conducted in the Department of Prosthodontics and Crown and Bridge. Present study measure the surface roughness (Ra) of denture base resin specimens fabricated and tested under standardized conditions.

2.2. Materials used

Three different types of denture base resins were evaluated in this study (**Figure 1**):

1. Conventional heat-cured polymethyl methacrylate denture base resin
2. High-impact heat-cured denture base resin
3. 3D-printed denture base resin

2.3. Specimen fabrication

A stainless-steel split mold measuring 10 mm in diameter and 2.5 mm (ISO 1567)⁴ in thickness was used to fabricate standardized resin specimens. For the conventional and high-impact heat-cured denture base resins, modeling wax patterns were prepared using wax sheets and invested in dental flasks.³ Flasking and dewaxing (**Figure 2**) were carried out following standard laboratory procedures. The resins were packed and polymerized using a water bath curing unit according to the manufacturers' instructions.³

2.4. Finishing and polishing

All specimens were finished and polished using a standardized protocol (**Figure 4**) to minimize operator variability. Finishing was performed using silicon carbide abrasive papers of progressively finer grit sizes (400, 600, 800, and 1200 grit) under running water.² Polishing was then done using polishing cake and polishing lathe with felt wheels and buffs. After polishing, specimens were cleaned in an ultrasonic cleaner containing distilled water to remove residual debris.



Figure 1: A): Conventional heat-cured denture base resins and **B):** High-impact heat-cured denture base resins and; **C):** Prevest denpro 3D printed denture base resin

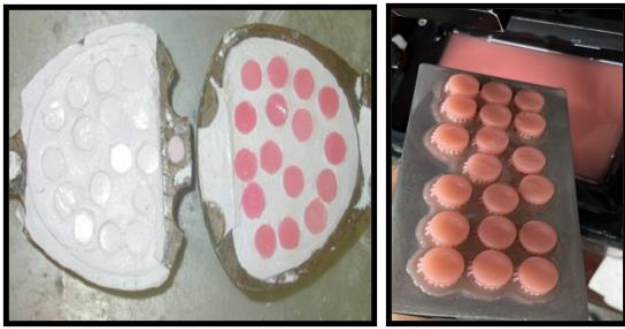


Figure 2: Fabricated sample 1 conventional heat-cured and 3 -3D printed denture base resin

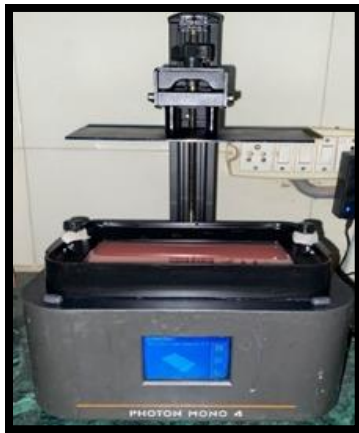


Figure 3: 3D Printer photon mono 4



Figure 4: Finishing and polishing set up

2.5. Surface roughness evaluation

Surface roughness measurements recorded using a contact profilometer (**Figure 5**). Each specimen was measured on multiple points on the polished surface, and the mean surface roughness (Ra) value was calculated. All the measurements were done under standardized conditions, and the recorded Ra values was obtained from lab for accuracy and reliability.



Figure 5: Surface roughness evaluation set up

2.6. Statistical analysis

Recorded surface roughness values were tabulated and subjected to statistical analysis. Descriptive statistics used to determine mean and standard deviation values for each group. Inferential statistical tests applied to compare surface roughness among the different denture base resin groups. A p-value of less than 0.05 was considered statistically significant.

3. Result

Surface roughness measurements recorded for all denture base resin specimens using a contact profilometer. Both arithmetical mean surface roughness (Ra) and maximum the height of the profile (Rzmax) was evaluated on the top and the back surfaces, and average values was calculated for each material.

The PYRAX ACRYL-HI (high-impact denture base resin) specimens demonstrated variation in surface roughness between two evaluated surfaces. The top surface exhibited a higher Ra value (1.488 μm) compared to back surface (0.709 μm). Mean Ra value was 0.732 μm , while average Rzmax was 7.374 μm . These findings indicate moderate surface irregularities with significantly more different between surfaces, suggesting a non-uniform surface texture. This variability may be attributed to differences in processing conditions, including polymerization technique and finishing procedures.

DPI heat-cured denture base resin specimens showed relatively uniform surface roughness values between top (0.822 μm) and back (0.963 μm) surfaces. Mean Ra value was 0.893 μm , and average Rzmax was 8.230 μm . Results indicate a comparatively smoother and more consistent surface finish across both surfaces. Among the tested materials, DPI heat-cured resin demonstrated better surface homogeneity, which may be advantageous in minimizing bacterial adhesion and improving clinical performance.

Table 1: Surface roughness measurements were recorded

S. No.	Sample ID/ Brand Name	Location	Roughness Value (Ra) μm	Average Roughness Value (Ra) μm	Roughness Value (Rzmax) μm	Average Roughness Value (Rzmax) μm
1	PYRAX ACRYL-HI	Top Side	1.488	0.732	9.776	7.374
		Back Side	0.709		4.971	
2	DPI Heat Cure	Top Side	0.822	0.893	10.194	8.230
		Back Side	0.963		6.265	
3	Prevest DenPro (3D printed denture base resin)	Top Side	1.486	1.230	12.019	8.786
		Back Side	0.973		5.553	

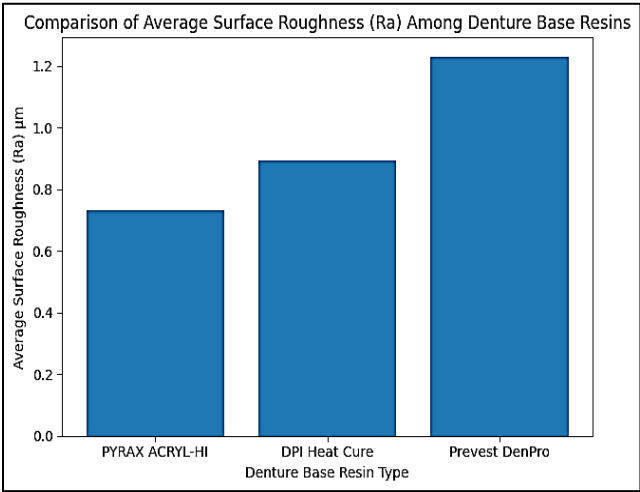


Figure 6: Comparison of average surface roughness (RA) values of the PYRAX ACRYL-HI, DPI heat-cured, and prevest denpro denture base resins

The Prevest DenPro (3D-printed denture base resin) specimens exhibited the highest surface roughness values among all groups. Top surface showed an Ra value of 1.486 μm , while back surface had a lower Ra value of 0.973 μm . Mean Ra value was 1.230 μm , and average Rzmax was 8.786 μm , which was the highest among all groups. These findings indicate a comparatively rougher surface profile with deeper surface irregularities, which may create favorable conditions for microbial retention.(Table 1)

High-impact heat-cured denture base resin (PYRAX ACRYL-HI) demonstrated lowest mean surface roughness (Ra) followed by conventional heat cure and Prevest 3D printed denture base resin with highest surface roughness (Figure 6).

4. Discussion

Surface roughness of denture base resins is a critical determinant of plaque accumulation, microbial adhesion, staining, and long-term clinical performance. In present in-vitro study, differences in surface roughness were

observed among conventional heat-cured, high-impact heat-cured, and 3D-printed denture base resins, even though all specimens were subjected to standardized finishing and polishing protocols.

In present study, high-impact heat-cured denture base resin demonstrated lowest surface roughness values among the tested materials. This finding suggests that incorporation of impact-modifying agents does not adversely affect surface smoothness when appropriate finishing and polishing procedures are applied. Although John et al.⁵ reported that impact modifiers may increase surface irregularities compared to conventional denture base resin, present findings indicate’s such differences can be minimized with standardized post-processing techniques.

Conventional heat-cured denture base resin exhibited moderate surface roughness values with relatively uniform characteristics between surfaces. Which indicates that conventional PMMA can achieve consistent surface smoothness when processed and polished adequately, supporting its continued clinical reliability.

The highest surface roughness values in the present study were observed in the 3D-printed denture base resin group. These results are in agreement with Al-Dulaijan et al.,⁶ who reported significantly higher Ra values for 3D-printed resins due to the inherent layer-by-layer fabrication process, which produces a stepped surface morphology which persist even after polishing.

Ryu et al. further demonstrated fabrication technique and printing orientation influence surface roughness, with 0-degree orientation showing lower roughness compared to 45 and 90 degrees.⁷ Printing orientation was standardized in present study, increased roughness can be attributed primarily to the additive manufacturing process.

Singh et al. noted although surface roughness values of 3D-printed resins sometimes be comparable to conventional materials, their surface characteristics differ due to differences in resin composition and processing techniques.⁸ Which suggests that surface roughness alone may not fully represent clinical behavior, although higher Ra values indicate a need for improved surface optimization.

Present study demonstrated that 3D-printed denture base resins have higher surface roughness than conventional and high-impact, likely due to the additive manufacturing process and associated irregularities. Factors such as build orientation, as reported by Alharbi et al. may also influence material properties. Increased roughness can promote plaque accumulation and microbial adhesion, emphasizing need for optimized printing and finishing protocols.⁹

In contrast, CAD/CAM materials exhibited greater homogeneity and improved properties, as reported by Stawarczyk et al., while higher roughness of 3D-printed resins highlights importance of adequate finishing and polishing.¹⁰

However, it has been reported that 3D-printed resins may sometimes show smoother surfaces but inferior mechanical properties, with printing orientation and post-curing influencing surface characteristics. Such variations may be due to differences in materials and processing techniques.¹¹

Clinically, higher surface roughness observed in 3D-printed resins is significant. Bollen et al.¹² established a threshold Ra value of 0.2 μm , beyond which plaque accumulation increases, while Radford et al. demonstrated increased adhesion of *Candida albicans* on rough surfaces, raising risk of denture stomatitis.¹³ Aati et al. also emphasized his concerns regarding physical and microbial behavior of these materials.¹⁴

Al-Dulaijan et al. reported 3D-printed denture base resins exhibit surface roughness values comparable to conventional heat-polymerized resins, although certain printing orientations, particularly 45°, can significantly increase surface irregularities.¹⁵

Findings of this present study supports existing literature, indicating that while conventional and high-impact heat-cured resins can achieve acceptable smoothness with proper polishing, 3D-printed denture base resins exhibit higher surface roughness due to inherent manufacturing characteristics. This highlights the need for improved post-processing and optimization of printing parameters to enhance clinical performance.

5. Conclusion

High-impact heat-cured denture base resin (PYRAX ACRYL-HI) demonstrated lowest mean surface roughness (Ra) values among materials tested, indicating a comparatively smoother surface. Conventional heat-cured denture base resin (DPI) exhibited moderate surface roughness with more uniform values between surfaces. In contrast, 3D-printed denture base resin (Prevest DenPro) showed the highest Ra and Rzmax values, indicating greater surface irregularities. These findings suggest that high-impact heat-cured resin provides superior surface smoothness, while 3D-printed resins may require improved finishing and processing techniques to achieve comparable surface quality.

Abbreviations

Ra: Arithmetic Mean Surface Roughness

Rzmax: Maximum Height of Surface Profile

PMMA: Polymethyl Methacrylate

ISO: International Organization for Standardization

CAD/CAM: Computer-Aided Design/Computer-Aided Manufacturing

Author Contributions

Aditi Vashisht: Conceptualization, specimen fabrication, data collection, analysis, manuscript preparation, and literature review.

Varun Kumar: Study design, supervision, guidance, and manuscript review.

Geeta Arya: Data interpretation, methodology guidance, and critical revision of the manuscript.

Jyotsna Seth: Statistical guidance, manuscript editing, and final approval of the manuscript.

Ethical Approval

Ethical approval was not required as this was an in-vitro study with no human or animal involvement.

Declaration of Patient Consent

Patient consent was not required as this study did not involve human participants or patient data.

Financial Support and Sponsorship

None.

Conflict of Interest

None.

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