THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Effects of DLP printing orientation and postprocessing regimes on the properties of 3D printed denture bases

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ABSTRACT

Statement of problem. The variety of recommended postprocessing techniques and printing parameters makes it challenging to determine the best approach to 3-dimensionally (3D) printed dentures.

Purpose. The purpose of this in vitro study was to assess the effect of printing orientations (0, 45, and 90 degrees) and postprocessing treatments (ultraviolet [UV], heat, or combination) on the mechanical and surface properties of 3D printed denture base resin.

Material and methods. Three-dimensionally printed denture base resin specimens were fabricated at 0-, 45-, and 90-degree printing orientations, followed by 4 postprocessing techniques (UV, Heat, UV+Heat, and control). Microhardness was assessed using a Vickers microhardness tester. Additionally, the flexural strength (FS) and modulus of elasticity (MoE) were analyzed using a 3-point bend test. Wettability was measured according to the sessile drop test. The fractured surfaces were observed under scanning electron microscopy (SEM).

Results. FS was significantly greater ($P<.001$) at a print orientation of 90 degrees (73.7 MPa) compared with 0 and 45 degrees (55.2 and 61.8 MPa). No significant difference in FS was found among postprocessing treatments (all complied with the International Organization for Standardization [ISO] requirements). The UV group had the highest MoE (up to 2061 MPa), followed by the heat-treated groups (up to 1412 MPa). The 45-degree print orientation showed the highest contact angle (CA) in almost all groups (CA=117.6 ±11.7), and UV led to higher hydrophilicity (CA=33.9 ±12.0). The effect of build orientation on the microhardness depended on the postprocessing technique with the highest value (23.4 ±1.3) achieved by UV postprocessing in combination with the 90-degree orientation.

Conclusions. The optimal FS of 3D printed denture base resin is achieved when it is printed in a vertical orientation (90 degrees relative to the platform base). Thermal annealing as a postprocessing technique combined with UV can effectively enhance FS, induce favorable wettability, and reduce stiffness. (J Prosthet Dent 2025;134:239.e1-e9)

Computer-aided design and computer-aided manufacturing (CAD-CAM) technology has shown promising results in various dental fields,[1] with a rising popularity in denture fabrication.[2–4] Dentures can be manufactured either subtractively (SM) or additively (AM).[5] SM uses milling to create custom shapes by subtracting materials, whereas AM refers to 3-dimensionally (3D) printing shapes layer-by-layer.[6] AM techniques include stereolithography (SLA), digital light processing (DLP), fused deposition modeling (FDM), and selective laser melting (SLM),[7] all of which involve CAD, transformation to a standard tessellation language (STL) file, slicing, printing, and postprocessing.[8]

Three-dimensional printing techniques possess clear

Supported by the Lloyd Carr-Harris Fellowship (recipient: N.E-A.), Faculty of Dental Medicine and Oral Health Sciences, McGill University; and by the Vanier Canada Graduate Scholarship (recipient: D. J.), Canadian Institutes of Health Research (CIHR), Canada.
No conflict of interest.
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Clinical Implications

This research sought to enhance the qualities of the 3D printed denture base materials by examining printing settings and postprinting processing methods. The research findings allow clinicians to tailor the postprocessing approaches of the 3D printed dentures to meet the requirements of each patient. Thermal treatment may prove beneficial for processing bulkier denture bases, particularly when concerns arise regarding the penetration of UV light.

advantages over SM, including cost effectiveness, because of the reduced time needed for prosthesis fabrication, less material waste, and reduced wear of rotary instruments.[9] AM is straightforward and enables the concurrent fabrication of multiple restorations with good strength and fit.[10,11] However reduced flexural strength, fracture toughness, color stability, and denture base adaptation have been reported for printed dentures in comparison with milled dentures.[12]

The outcome of 3D printing is directly influenced by the printing parameters (including the printing orientation and print layer thickness) and the choice of material, AM technology, and postprocessing technique.[13,14] As a result, the selection of appropriate parameters for 3D printing is key to achieving optimal outcomes.[15]

Printing orientation is the primary parameter affecting the mechanical and surface properties of 3D printed dentures,[16] defining surface geometry and the layer-by-layer configuration of a 3D printed material.[17,18] How print orientation impacts mechanical properties is unclear. Some researchers have reported that printing in a horizontal orientation relative to the build platform augments flexural strength when compared with vertical orientation.[19,20] Conversely, other studies[21–23] have reported that a vertical layer orientation yields the greatest flexural strength compared with a horizontal orientation, attributing this to the intralayer strength.

Postprocessing, which involves the removal of the support structures, postrinsing, and postpolymerization, also affects the properties of the 3D printed material.[8,24] At the end of the printing process, the photosensitive resins have not been fully polymerized.[24] Various ultraviolet (UV) postpolymerizing methods have been implemented to completely polymerize the remaining resin and thus increase strength.[8,20,21,24–26] However, UV postpolymerization can only harden the outer surface of the material and might not enhance the properties of the interior 3D printed parts (candy-shell effect).[8]

Fine surface characteristics are required to minimize the microbial adhesion to and staining of a denture base.[27] Surface wettability represents how easily liquids can spread across a surface, indicating how much the prosthesis is prone to the adherence of saliva and other fluids.[28] Hydrophilicity also affects microbial adhesion in different ways. For instance, hydrophobic surfaces foster the attachment of *Candida albicans*,[19,29] whereas high hydrophilicity might promote staining, bacterial growth, and plaque accumulation.[30] A study on the wettability of conventionally versus digitally produced dentures has shown lower hydrophilicity for 3D printed denture base material compared with the heat-polymerized polymethyl methacrylate (PMMA).[31]

During clinical use, the denture base is subjected to a combination of compressive, tensile, and shear forces, which may result in prosthesis fracture.[32] Therefore, ensuring that the denture base conforms to standards regarding flexural strength and modulus is crucial to resisting fracture and deformation under mastication forces. The International Organization for Standardization (ISO) requirements for flexural strength of denture base polymers is 65 MPa.[33]

The authors are unaware of a previous study assessing the effects of thermal annealing on the mechanical and surface properties of a photopolymerized denture base resin printed in various orientations. Therefore, the aim of this in vitro study was to assess the effect of printing orientations (0, 45, and 90 degrees) and postprocessing treatments (UV, heat, or combination) on the mechanical and surface properties of 3D printed denture base resin in terms of flexural strength (FS), modulus of elasticity (MoE), microhardness (VHN), and wettability. The null hypotheses were that the print direction and the postprocessing technique would not affect the mechanical and surface properties of the 3D printed denture base material.

MATERIAL AND METHODS

A total of 120 bar-shaped specimens were printed after design in a CAD software program (FlashDLPrint; Flashforge Corp). To measure FS and MoE, specimens were designed with a 64×10×3.3-mm dimension according to the ISO 20795–1:2013 standard.[33] Thereafter, the specimens were saved as STL files and exported to a 3D printer (Hunter; Flashforge Corp).

A commercially available 3D printed denture base resin (FREEPRINT denture; DETAX GmbH) was used for specimen fabrication (Table 1). The resin bottle was homogenized using a roller mixer (LC-3D Mixer, NextDent, 3D systems; Vertex Dental B.V.) before dispensing into the vat. The specimens were 3D printed in 3 printing orientations (0, 45, and 90 degrees) (n=40), with a layer thickness of 100 µm (Fig. 1). For the 0- and 45-degree specimens, the widest side (64×10 mm) was

Table 1. Manufacturer information for investigated photopolymerized denture base resin material*

Name/ Manufacturer	Color/Lot No.	Indication	Composition	ISO 20795-1 Standard	
				Flexural Strength	Flexural Modulus
FREEPRINT denture (DETAX GmbH)	Pink-transparent #260302	Light polymerizing, biocompatible resin for 3D printing of removable denture bases.	MMA-, THF-, MA- and TPO-free. (tasteless) isopropylidenediphenol peg–2 dimethacrylate, 7,7,9(or 7,9,9)-tri-methyl–4,13-dioxo–3,14-dioxa–5,12-diazahexadecane–1,16-diyl bismethacrylate, 2-hydroxyethyl methacrylate, diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide, Hydroxy propyl methacrylate, phenyl bis(2,4,6-trimethyl-benzoyl)-phosphine oxide.	>65 MPa	>2000 MPa

*https://www.detax.de/en/shop/produkte/Freeprint-denture.php

*https://www.detax.de/de-wAssets/docs/en/pressecenter-3D/Fachinformationen/DETAX-Freeprint-3D-Katalog_EN.pdf

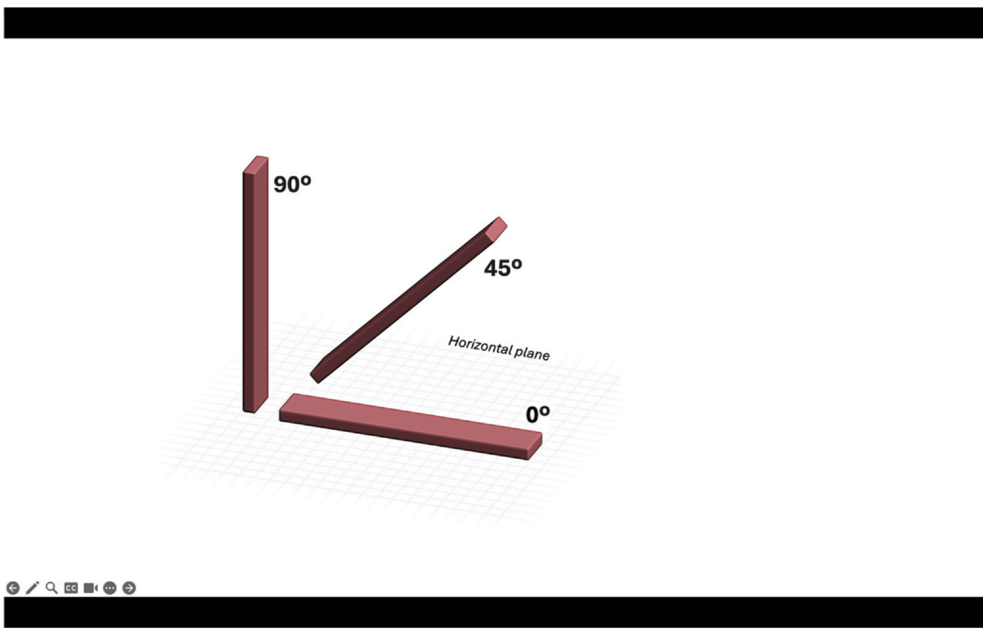

Figure 1. Three-dimensionally printed specimens in three printing orientations relative to printer platform (0, 45, and 90 degrees).

turned down and directly faced the printing platform. After printing, the specimens were scraped from the platform, and the support structures were removed by using low-speed rotary instruments (Brasseler USA). Residual nonpolymerized resin on the printed specimens was rinsed with isopropyl alcohol (FormWash; Formlabs). The surface of specimens was ground using 200-, 400-, and 800-grit SiC paper (McMaster-Carr), and rinsed with water.

Forty specimens were manufactured for each printing orientation and randomly divided (by lottery) into 4 subgroups based on postprocessing methods (n=10). For the first group, the inferior and upper surfaces of 10 specimens were each postprocessed for 30 minutes (total: 60 minutes) using a light polymerization unit (FormCure; FormLabs) with a wavelength of 405 nm that generated a temperature up to 80 °C. A polymerization time of 30 minutes per surface was used based on the best results from previous studies.[20,21] Another 10 specimens received thermal postpolymerization in a 105 ±5 °C oven (Shel Lab; Sheldon Manufacturing Inc.) under vacuum for 1 hour.[8] The third group received 60 minutes of UV followed by 1 hour of thermal postpolymerization. For the Control group (n=10), no postprocessing procedure was applied. The specimens were stored in 37 °C distilled water for 48 hours before testing.[34] All tests were performed at room temperature.

FS was measured with a 3-point bend test using a universal testing machine (AGS-X; Shimadzu) operated by a software program (Trapezium X; Shimadzu). Prior to the testing, the dimensions of each specimen (width and height) were measured at 3 different points, and the average was calculated using digital calipers (Euro-Cal IV; Fowler) with a measuring accuracy of ±0.1 mm. Following the ISO 20795–1 standard for denture base polymers, the specimens were centered on a fixture with a span width of 50 mm (Fig. 2). The loading wedge applied force with a crosshead speed of 5 mm/minute, and the specimens were loaded until fracture. The peak load was recorded as the fracture load, and the FS (σ) was measured using the formula $\sigma = \frac{3FL}{2bh^2}$ where,

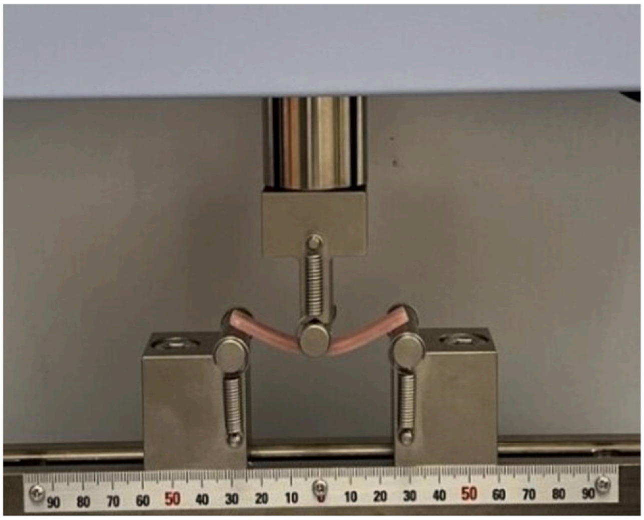

Figure 2. Loaded specimen in universal testing machine until fracture.

σ= FS (MPa), F is the maximum load at fracture (N), L is the span length (50 mm), b is the width of the specimen, and h is the height of the specimen. In addition, the MoE (in MPa), which defines the resistance to elastic deformation in bending, was calculated using the formula MoE= $\frac{F.L^3}{d.4bh^3}$, where, F/d is the gradient of load versus deflection curve at the linear section, L is the span length (50 mm), b is the width of the specimen, and h is the height of the specimen.

After determining the FS, 3 fractured specimens from each group were tested for wettability and Vickers microhardness. The specimens were cut 10 mm away from the fracture line under water cooling.[35] The intact surfaces of the fractured specimens were evaluated for microhardness. Each surface was subjected to 3 indentations (n=9) by applying a load of 2.9 N for 15 seconds using a digital hardness tester (CM-100AT; Sun-Tec). The average number was recorded as the Vickers microhardness number (VHN).

For the wettability test, the angle created by a distilled water droplet on the surface of the specimens was determined using the sessile drop technique.[36] A syringe dispensed a 20-µL drop of distilled water onto the specimen's surface while positioned horizontally on a bench that had been previously verified for levelness. The water droplet spread was photographed using a camera on a goniometer (Dataphysics Instruments GmbH) (Fig. 3). The captured image was analyzed with a software program (SCA20_U V. 4.3.9; Dataphysics Instruments GmbH). The contact angle (θ) was measured on both the right and left sides of the water drop's tangent line to the specimen's solid edge, with the mean value reported.[37] Three different locations were assessed for each of the 3 specimens (n=9).

The texture and morphology of the fractured specimens were characterized with a scanning electron microscope (SEM). The specimens (n=8/printing orientation) were coated with a 4-nm-thick platinum layer in a sputter coater (EM ACE600; Leica Microsystems). After that, the fractured surfaces were observed by SEM (FlexSEM 1000; Hitachi Ltd) under high vacuum and using an accelerating voltage of 10.0 kV at ×100 magnification. The fields characterized by smooth and compact surfaces represented brittle fracture patterns, while those with a rough and uneven texture exhibited a range of fracture behaviors from brittle to ductile.[38]

Statistical analyses were performed by using a statistical software program (IBM SPSS Statistics, v24; IBM Corp) (α=.05 for all tests). The Kolmogorov–Smirnov test was applied to assess normality. All data were described as mean ±standard deviation. Two-way ANOVA with the post hoc Tukey HSD test was used to further analyze the FS, MoE, microhardness, and wettability in each group and to evaluate interactions between variables (printing orientations and postprocessing method).

RESULTS

After confirming data normality (Kolmogorov–Smirnov, *P*>.05) and homogeneity of variances (*P*=.700), the 2-way ANOVA was performed. For the FS, the interaction effect of postprocessing treatment and printing orientation was not significant (F=2.168, df=6, *P*=.052). The main effects, however, were significant (*P*<.001) (Table 2). Regarding printing orientation, the 90-degree groups showed significantly higher FS compared with the 45-degree (*P*<.001) and 0-degree (*P*<.001) groups. The specimens printed at 45 degrees showed significantly higher FS compared with 0-degree (*P*=.019) specimens (Fig. 4).

For the effect of postprocessing technique on FS, the unprocessed groups had significantly lower FS when compared with the others (*P*<.001) (Fig. 4). The difference between the heat-treated groups (Heat+UV or Heat alone) and the UV postprocessing groups was not significant (*P*>.05).

The 2-way ANOVA also showed a significant interaction between the effects of postprocessing treatment

Figure 3. A, Representative photograph of water droplet spread. B, Goniometer.

Table 2. FS (MPa, mean ±standard deviation) values according to postprocessing treatment and printing orientation

FS#,*					
Postprocessing Treatment	**Printing Orientation (Degree)**			**Total**	***P***
	0	**45**	**90**		
UV	53.8 ±6.9	65.9 ±14.1	79.8 ±10.3	66.5 ±15.0^{A}	-
Heat	67.3 ±14.1	64.8 ±6.0	72.6 ±5.9	68.2 ±9.7^{A}	-
UV+Heat	59.8 ±13.6	71.3 ±13.0	84.9 ±6.3	72 ±15.2^{A}	-
Unprocessed	39.9 ±13.6	45 ±11.1	57.6 ±5.5	47.5 ±12.7^{B}	-
Total	55.2 ±15.7^{c}	61.8 ±15.0^{b}	73.7 ±12.5^{a}	63.6 ±16.3	<.001
P	-	-	-	<.001	-

ANOVA showed significant differences between #printing orientation (*P*<.001) and *postprocessing treatment (*P*<.001).

Different uppercase letters demonstrate post hoc Tukey results showing significance in difference between postprocessing treatments (*P*<.05).

Different lowercase letters demonstrate post hoc Tukey results showing significance in difference between printing orientations (*P*<.05).

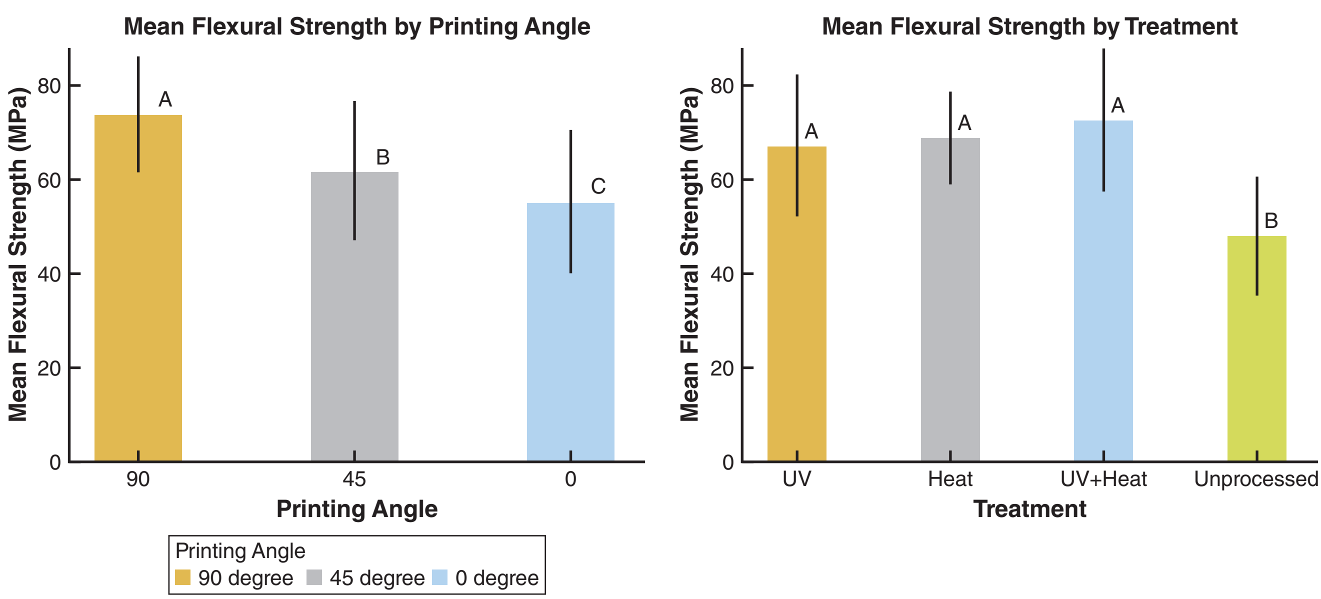

Figure 4. Mean flexural strength (MPa) of tested groups by printing orientation and postprocessing treatment. Different letters represent significant difference within each group according to post hoc Tukey test (*P*<.05).

Table 3. MoE (MPa, mean ±standard deviation) values according to postprocessing treatment and printing orientation

	Modulus *,$		
Postprocessing Treatment	**Printing Orientation (Degree)**		
	0	**45**	**90**
UV	2039 ±74^{A,a}	2024 ±100^{A,a}	2061 ±46^{A,a}
Heat	1412 ±214^{C,a}	1284 ±163^{C,b}	1271 ±149^{C,b}
UV+Heat	1837 ±110^{B,a}	1790 ±69^{B,a}	1737 ±84^{B,a}
Unprocessed	820 ±109^{D,a}	880 ±101^{D,a}	1064 ±71^{D,b}

ANOVA showed significant differences between *postprocessing treatment (*P*<.001) and $interaction (*P*<.001).

Different uppercase letters demonstrate post hoc Tukey results showing significance in difference (*P*<.05) between postprocessing treatments in each printing orientation in column.

Different lowercase letters demonstrate post hoc Tukey results showing significance in difference (*P*<.05) between printing orientations in each postprocessing treatment in row.

and printing orientation on the MoE (F=5.709, df=6, *P*<.001). The UV treatment led to the highest MoE in comparison with other postprocessing treatments (*P*<.05), followed by the combination of UV and heat, heat treatment alone, and unprocessed groups (Table 3). The effect of printing orientation on MoE depended on the postprocessing treatment (Fig. 5).

Regarding wettability, a significant interaction was found between the effects of postprocessing treatment and printing orientation (F=7.912, df=6, *P*<.001). The interaction disclosed that the effect of printing orientation on the wettability depended on the postprocessing treatment (Table 4). The 45-degree printing orientation had significantly higher contact angle values when

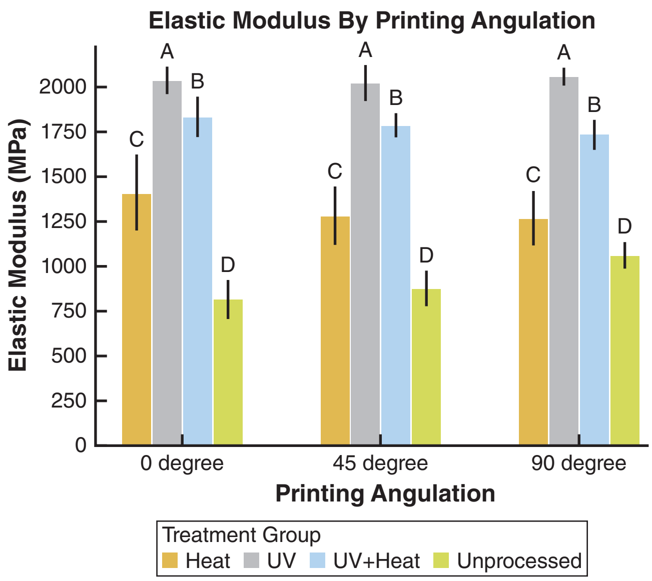

Figure 5. Elastic modulus of tested groups based on printing orientation and postprocessing treatment. Different letters show significant difference within each group according to post hoc Tukey test (*P*<.05).

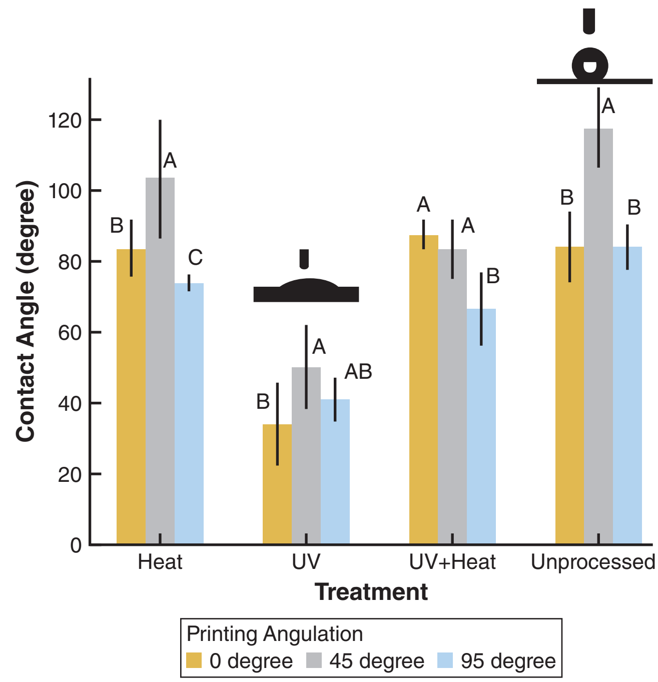

Figure 6. Contact angle values by treatment group and printing orientation. Different letters show significant difference within each group according to post hoc Tukey test(*P*<.05).

Table 4. Contact angle (degrees, mean ±standard deviation) values according to postprocessing treatment and printing orientation

Contact Angle$^{\#,*,\$}$

Postprocessing Treatment	Printing Orientation (Degree)		
	0	45	90
UV	33.9 ±12.0^{B,b}	50.2 ±11.7^{D,a}	41.1 ±6.3^{C,ab}
Heat	83.6 ±8.6^{A,b}	103.6 ±17.6^{B,a}	73.8 ±2.4^{B,c}
UV+Heat	87.6 ±4.1^{A,a}	83.4 ±8.4^{C,a}	66.7 ±10.2^{B,b}
Unprocessed	84.1 ±10.4^{A,b}	117.6 ±11.7^{A,a}	84.4 ±6.2^{A,b}

ANOVA showed significant differences between $^{\#}$printing orientation (*P*<.001), *postprocessing treatment (*P*<.001), and $^{\$}$interaction (*P*<.001).

Different uppercase letters demonstrate post hoc Tukey results showing significance in difference (*P*<.05) between postprocessing treatments in each printing orientation in column.

Different lowercase letters demonstrate post hoc Tukey results showing significance in difference (*P*<.05) between printing orientations in each postprocessing treatment in row.

compared with the 90-degree orientation in all groups, except for the UV group. Moreover, the 45-degree printing orientation had significantly higher contact angle values compared with the 0-degree orientation in all groups (*P*<.05), except for the UV+heat group (Fig. 6). UV treatment resulted in significantly lower contact angle values compared with the other postprocessing conditions (*P*<.05).

The main effect analysis showed that UV polymerization led to significantly lower contact angles and higher wettability compared with all other postprocessing treatments (*P*<.05). Adding heat to the UV treatment, however, greatly increased hydrophilicity (*P*<.05). Unprocessed specimens showed the highest contact angle, and the lowest wettability compared with the processed specimens in both the 45- and 90-degree orientations (*P*<.05).

The microhardness analysis showed a significant interaction between the postprocessing treatment and printing orientation (F=4.526, *P*<.001). UV treatment resulted in significantly higher microhardness when compared with the unprocessed specimens (*P*<.05) (Table 5). In UV-treated groups, no difference in microhardness was found among print orientations (*P*>.05). However, the 90-degree orientation showed higher microhardness compared with other orientations in the heat-treated and unprocessed groups (Fig. 7).

Under SEM, the 0-degree groups showed smooth and compact surfaces, indicating a brittle fracture mode, while the 45- and 90-degree groups underwent a more intermediate/ductile form of fracture (rough appearance with crack lines). When the layers were more aligned with the direction of the load (45- and 90-degree orientations), the interface between the layers fell directly in line with the load path. This alignment can cause the layers to delaminate because of the tensile stress generated during bending after load application (Fig. 8).

DISCUSSION

The different postprocessing methods and printing parameters suggested by the manufacturers make it

Table 5. Microhardness (VHN, mean ±standard deviation) values according to postprocessing treatment and printing orientation

Microhardness$^{\#,*,\$}$				
Postprocessing Treatment	Printing Orientation (Degree)			Total
	0	45	90	
UV	22.8 ±0.4^{A,a}	22.8 ±0.4^{A,a}	23.4 ±1.3^{A,a}	23.0 ±0.9
Heat	21.2 ±0.7^{B,b}	21.4 ±1.5^{B,ab}	22.4 ±0.5^{AB,a}	21.7 ±1.1
UV+Heat	23.3 ±1.6^{A,a}	22.7 ±1.4^{A,a}	22.4 ±1.0^{AB,a}	22.8 ±1.4
Unprocessed	20.1 ±1.3^{C,b}	18.2 ±0.7^{C,c}	21.4 ±1.8^{B,a}	19.9 ±1.8

ANOVA showed significant differences between #printing orientation (P<.001), *postprocessing treatment (P<.001), and $interaction ($P$<.001).

Different uppercase letters demonstrate post hoc Tukey results showing significance in difference (P<.05) between postprocessing treatments in each printing orientation in column.

Different lowercase letters demonstrate post hoc Tukey results showing significance in difference (P<.05) between printing orientations in each postprocessing treatment in row.

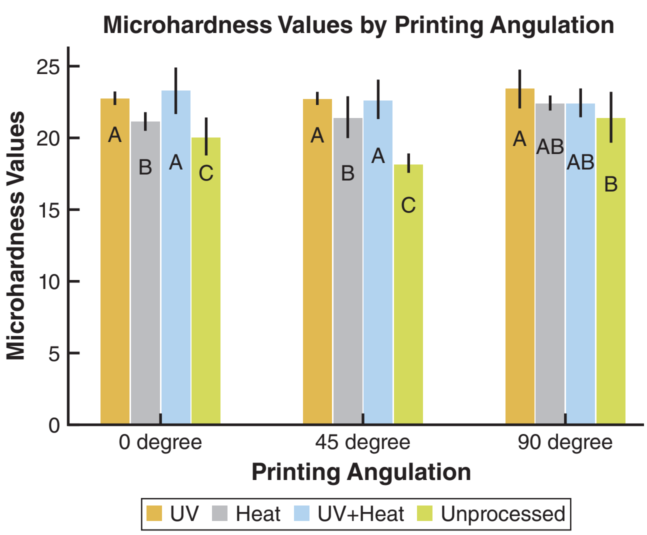

Figure 7. Microhardness values based on printing orientation and postprocessing treatment. Different letters show significant difference within each group according to post hoc Tukey test (P<.05).

challenging for clinicians to find the optimal printing technique. The authors are unaware of a previous study investigating the effects of thermal postpolymerization on the mechanical and surface characteristics of denture base photopolymers printed in various orientations. Although this study evaluated a single 3D printed resin by using independently created specimens – not sampled from a denture base – the null hypothesis that the print direction and the postprocessing technique would not affect the mechanical and surface properties of the 3D printed denture base material was rejected, as both printing orientation and postprocessing treatments significantly affected the mechanical and surface properties of DLP-printed denture base resin.

The build orientation was found to significantly affect the FS of the 3D printed denture base resin. Specimens built in a direction parallel to the load application demonstrated better mechanical properties, consistent with previous studies.[21–23] Variations in fusion quality between adjoining layers,[18] as well as diverse monomer exposure to varying light orientations are mechanisms through which build orientation affects the mechanical properties.[19]

The findings of this study substantiate that the adhesion between the successive layers was stronger than the intralayer strength. Contrary to some previous studies reporting higher FS with 0-degree print orientation,[19,20] the results of this study showed that only the 90-degree orientation with an average FS of 73 MPa met the ISO 20795–1 requirements for FS (65 MPa).[33] The different results reported previously could be because of the different resin (NextDent Denture 3D+; Vertex Dental B.V.) tested, which might have different anisotropic properties and interlayer adhesion compared with the resin used in the current study.

The present study found that thermal annealing was comparable with UV postprocessing in terms of FS. Regardless of the polymerization technique, the FS of all postprocessed specimens were above the minimum acceptable FS recommended by ISO. Therefore, the present study suggested that thermal polymerization can promote the cross-linking of the remaining monomers, thus improving the mechanical properties of the 3D printed photopolymers.[26,39,40] A recent study on 3D printed interim crown material also showed that postprinting heat-polymerization for 15 minutes can enhance the degree of conversion and decrease the release of residual monomer.[41]

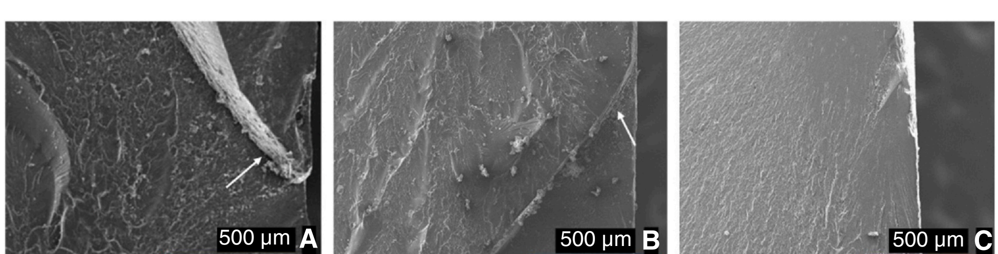

Figure 8. Scanning electron microscope images (original magnification ×100) showing fracture morphology of specimens. A, Printed at 90 degrees. B, Printed at 45 degrees. C, Printed at 0 degrees. Delamination can be seen in 90- and 45-degree groups.

MoE is an essential property which dictates the extent to which the denture base can resist plastic deformation under repetitive masticatory forces.[42] The effect of build orientation on the MoE depended on the postprocessing technique. However, in most of the groups, the 90-degree orientation showed favorable MoE. Regardless of the print orientation, the UV group had the highest MoE, followed by the heat-treated groups. Heat treatment may reduce stiffness by relaxing stress and increasing polymer chain mobility, enabling them to reorganize in a way that can absorb and recover from deformation more effectively. UV polymerization may increase stiffness because of increased cross-linking density. The high FS values combined with lower MoE achieved in annealed dentures may result in a rehabilitation option for patients with mandibular or palatal tori or severe undercuts, for whom less stiffness is desirable. These dentures might also be used as a promising substitute treatment plan for rehabilitating anomalies such as ectodermal dysplasia.[43] Therefore, the use of thermally treated 3D printed resins can create an opportunity to choose a postprocessing method adjusted to patient needs.

Similar to previous research,[19] this study showed that the 45-degree printing orientation led to greater contact angles (88.69 degree), indicating the lowest hydrophilicity. The results showed a mean 66.52-degree contact angle for the 90-degree orientation, which is similar to the reports in the literature of a contact angle for heat-polymerized PMMA (65.06 degree) after thermocycling.[31] Regarding the postprocessing technique, as expected, the UV group showed the lowest contact angle and the highest hydrophilicity, as UV has been reported to excite surface radicals, resulting in increased surface activity.[44] Adding heat to the UV treatment may reverse this polarization of the surface, resulting in a less hydrophilic surface compared with only UV.

Surface hardness has been described as the capacity of a material to withstand permanent penetration or indentation.[37] In agreement with an earlier study,[21] the present study showed an increasing trend in microhardness when print orientation changed from 0 to 90 degrees. Moreover, the UV treatment resulted in higher microhardness when compared with the unprocessed groups, consistent with a previous study[41] that reported a direct correlation between hardness and degree of conversion achieved by UV postpolymerization in a 3D printed resin. In the present study, all microhardness values of the 3D printed specimens that underwent postprocessing exceeded 20 VHN. A previous study comparing CAD-CAM and conventional PMMA reported a microhardness of 18.09 VHN for conventional PMMA,[37] suggesting that the 3D printed resin used in this study had comparable clinical acceptability in terms of hardness.

In this study, a 100-µm layer thickness was used since it was reported that the highest FS for 3D printed resins occurs at 100 µm.[41] The findings from this study can have implications for improved efficiency in dental laboratories. Adopting printing orientations that are more vertical enables the concurrent production of multiple dentures with support structures avoiding critical intaglio surfaces. This leads to improved accuracy and savings in terms of both time and cost.

Limitations of this study included the use of rectangular specimens rather than denture base shapes that replicate a real patient, the evaluation of a single material, and the absence of aging simulation. Further studies should examine the effects of printing layer thickness and build orientation on flexural properties. Consideration must be given to how extreme bending during FS tests may impact calculations of modulus and strength. Research on different resin brands and postprocessing methods, as well as the analysis of monomer conversion and thermomechanical behavior after heat treatment, could yield valuable insights.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The printing orientation affected the mechanical properties of 3D printed denture base material, with the 90-degree orientation showing the highest FS with a favorable MoE and microhardness.
2. Postprocessing 3D printed dentures with UV resulted in acceptable FS and the highest MoE, hydrophilicity, and microhardness among the tested techniques.
3. Thermal annealing, especially when combined with UV, offers high FS values, promising wettability and microhardness, and reduced stiffness.

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https://doi.org/10.1016/j.prosdent.2025.02.035