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In Vitro Assessment of the Wettability of Three Commercially Available Saliva Substitutes on Conventional, Hi-Impact and 3D Printed Acrylic Denture Base Materials

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ABSTRACT

Background: Wettability of denture base materials plays a critical role in retention, comfort, and function, particularly in xerostomic patients. Saliva substitutes are commonly used to compensate for reduced salivary flow; however, their interaction with different denture base materials requires evaluation.
Aim: To evaluate and compare the wettability of three commercially available saliva substitutes on conventional, hi-impact, and 3D printed acrylic denture base materials.
Materials and Methods: Total 180 samples were fabricated using conventional heat-cured PMMA, hi-impact PMMA, and 3D printed acrylic resin and divided into 4 groups based on different saliva substitutes. Wettability was assessed using contact angle measurement with a drop shape analyzer. Data were analyzed using one-way ANOVA and post hoc tests with significance set at $p < 0.05$.
Results: 3D printed acrylic resin exhibited the lowest contact angle, indicating superior wettability. Among salivary substitutes E-saliva exhibited better wettability. Significant differences were observed among groups.
Conclusion: 3D printed denture base materials show enhanced wettability and may be advantageous in xerostomic patients. Selection of appropriate saliva substitutes further improves clinical outcomes.
Keywords: Wettability, Saliva substitutes, PMMA, 3D printing, Denture base resin, Contact angle

INTRODUCTION

Saliva plays a vital role in maintaining oral health by providing lubrication, aiding mastication, enhancing taste, and protecting oral tissues. In edentulous patients, it contributes significantly to denture retention by forming a thin film between the denture base and mucosa, facilitating adhesion and cohesion.[1]

Xerostomia, characterized by reduced salivary flow, may result from systemic diseases, medications, or radiation therapy [2]. It leads to difficulty in denture wearing due to inadequate lubrication, reduced adhesion, and increased friction. To overcome this, saliva substitutes are commonly prescribed to mimic the lubricating and wetting properties of natural saliva [3].

Wettability is a key factor influencing denture retention and is assessed by contact angle measurement. A lower contact angle indicates better spreading of the liquid over the denture surface, thereby improving comfort and retention. The wettability of saliva substitutes depends on their composition, viscosity, and surface tension, as well as the surface properties of denture base materials.[4,5]

Conventional heat-cured polymethyl methacrylate (PMMA) remains widely used, while high-impact PMMA offers improved strength. Recently, 3D printed denture base resins have gained popularity due to their accuracy and fabrication advantages. However, their surface characteristics may influence wettability.

Hence, this study aims to evaluate and compare the wettability of selected saliva substitutes on conventional, high-impact, and 3D printed denture base materials.

MATERIALS & METHODS

Study Design:

In vitro experimental study

Materials used:

- Heat-cured PMMA (DPI)
- High-impact PMMA (Acryl-H)
- 3D printed denture base resin (ApplyLabWork DLP)
- Type III dental stone (Kalabhai Kalstone Dental Stone
- Wet mouth salivary substitute (Mouth wash)
- Biotene (Moisturizing spray)
- E-saliva (Mouth spray)

Equipment used:

- contact angle goniometer-DSA25 and software DSA4 (Fig 1)
- 3d printer (ASIGA MAX-2) (Fig 2)

Figure 1: Scanning Electron Microscope.

Figure 2: 3d printer

Sample Size and Grouping

A total of **180 specimens** were prepared and divided into four groups (n = 45) based on the test solution:

- **Group A:** Distilled water (control)
- **Group B:** Wet Mouth
- **Group C:** Biotene
- **Group D:** E-saliva

Each group was further subdivided into three subgroups (n = 15) based on denture base material:

- **Subgroup 1:** Conventional heat-cured PMMA
- **Subgroup 2:** High-impact PMMA
- **Subgroup 3:** 3D printed denture base resin

Specimen preparation:

A total of 180 rectangular specimens (21 × 16 × 2 mm) were fabricated.

For conventional and high-impact PMMA, wax patterns were prepared, invested in dental stone, and processed using standard compression molding technique following manufacturer's instructions. After polymerization, specimens were finished and polished, leaving the tissue surface unaltered.

For 3D printed specimens, samples were designed using CAD software and printed using a DLP 3D printer (ASIGA MAX-2) at 50 µm layer thickness. Post-processing included isopropyl alcohol cleaning and UV curing as per manufacturer's guidelines.

All specimens were cleaned, ultrasonically treated, and dried prior to testing.

Wettability Measurement

Wettability was assessed using a contact angle goniometerDSA25. A standardized droplet (8 µL) of test solution was placed on the specimen surface. Advancing and receding contact angles were recorded using digital analysis software DSA4 Lower contact angle values indicated better wettability.

Statistical Analysis

Data were analyzed using IBM SPSS software. One-way ANOVA was used to determine intergroup differences. Bonferroni post hoc test was used for pairwise comparison. A p-value < 0.05 was considered statistically significant.

RESULT

TABLE:1 CONVENTIONAL HEAT CURE DENTURE BASE MEAN ADVANCING ANGLE

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	100.2400	1.02665	98.70	101.70	<0.001
WET MOUTH	15	90.2267	.76389	89.10	91.30	<0.001
BIOTENE	15	87.2267	.76295	86.10	88.30	<0.001
E SALIVA	15	84.1667	.77337	82.90	85.20	<0.001

TABLE 2: HI IMPACT HEAT CURE DENTURE BASE MEAN ADVANCING ANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	94.2200	.93671	92.80	95.60	<0.001
WET MOUTH	15	85.0933	.86393	83.80	86.30	<0.001
BIOTENE	15	82.0867	.86178	80.80	83.30	<0.001
E SALIVA	15	78.1533	.79361	76.80	79.20	<0.001

TABLE 3: 3D PRDINTED ENTURE BASE MEAN ADVANCING ANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	86.0733	.85979	84.80	87.30	<0.001
WET MOUTH	15	78.0733	.85979	76.80	79.30	<0.001
BIOTENE	15	74.1000	.84684	72.80	75.30	<0.001
E SALIVA	15	70.0133	.84504	68.70	71.20	<0.001

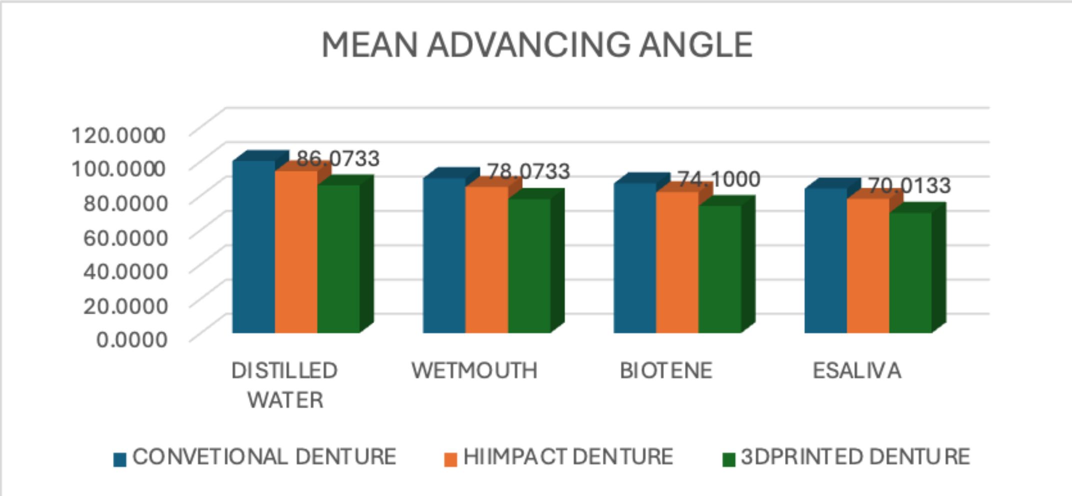


FIGURE 3: MEAN ADVANCING ANGLES

TABLE 4: CONVENTIONAL HEAT CURE DENTURE BASE MEAN RECEDING ANGLE

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	90.2400	.94249	88.80	91.60	<0.001
WET MOUTH	15	84.3933	.73140	83.30	85.40	<0.001
BIOTENE	15	82.2600	.69775	81.20	83.30	<0.001
E SALIVA	15	79.2933	.72651	78.00	80.20	<0.001

TABLE 5: HI IMPACT HEAT CURE DENTURE BASE MEAN RECEDING ANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	74.0733	.85979	72.80	75.30	<0.001
WET MOUTH	15	72.0733	.85979	70.80	73.30	<0.001
BIOTENE	15	68.9000	.83495	67.60	70.10	<0.001
E SALIVA	15	65.9000	.83495	64.60	67.10	<0.001

TABLE 6: 3D PRINTED DENTURE BASE MEAN RECEDING ANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	82.0800	.87276	80.70	83.30	<0.001
Wet mouth	15	78.1000	.84261	76.90	79.30	<0.001
BIOTENE	15	76.1000	.83666	74.90	77.30	<0.001
E SALIVA	15	73.2467	.78637	71.90	74.30	<0.001

FIGURE 4: MEAN RECEDING ANGLE

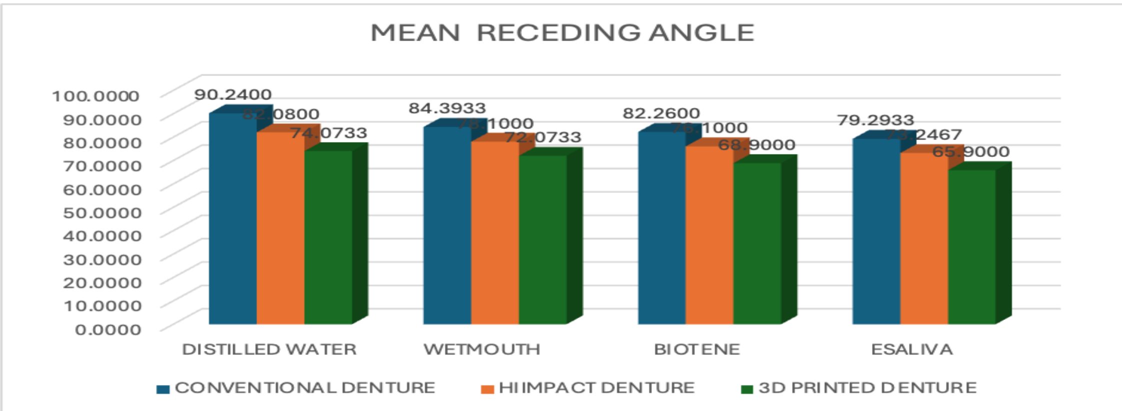


TABLE 7: CONVENTIONAL HEAT CURE DENTURE BASE MEAN HYSTERESISANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
Distilled water	15	12.1400	.09856	12.00	12.30	<0.001
Wet mouth	15	6.9867	.14075	6.80	7.20	<0.001
BIOTENE	15	5.9667	.14475	5.70	6.20	<0.001
E SALIVA	15	4.9067	.11629	4.70	5.10	<0.001

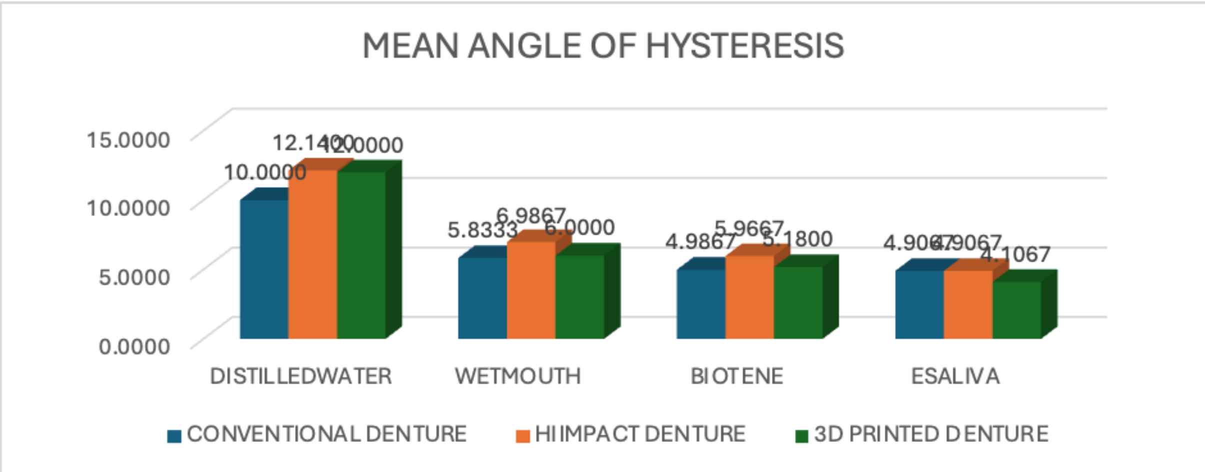
TABLE 8: HI IMPACT HEAT CURE DENTURE BASE MEANHYSTERESIANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	12.0000	.19272	11.60	12.40	<0.001
WET MOUTH	15	6.0000	.23604	5.70	6.30	<0.001
BIOTENE	15	5.1800	.08619	5.00	5.30	<0.001
E SALIVA	15	4.1067	.10328	3.90	4.30	<0.001

TABLE: 9 3D PRINTED DENTURE BASE MEAN HYSTERESIS ANGLES

GROUPS	N	MEAN	SD	MINIMUM	MAXIMUM	P VALUE
DISTILLED WATER	15	10.0000	.11952	9.80	10.20	<0.001
WET MOUTH	15	5.8333	.04880	5.80	5.90	<0.001
BIOTENE	15	4.9867	.12459	4.80	5.20	<0.001
E SALIVA	15	4.9067	.11629	4.70	5.10	<0.001

FIGURE 5:MEAN ANGLE OF HYSTERESIS



Bonferroni post-hoc analysis revealed statistically significant differences among all three denture base materials for both advancing and receding contact angles in distilled water, wet mouth, Biotene, and E-saliva ($p < 0.05$)**.** 3D printed denture base resin demonstrated significantly lower contact angles indicating higher wettability**,** followed by high-impact denture base resin**,** while conventional heat-cure denture base resin showed the least wettability**.**

Wettability Interpretation:

The mean advancing angle in all groups is Conventional heat cure > Hi-impact heat cure> 3D printed. The wettability of 3Dprinted > Hi-impact > Conventional heat cure denture material as shown in (Fig 3)

The mean receding angle in all groups is Conventional heat cure > Hi-impact heat cure> 3D printed. The wettability of 3Dprinted > Hi-impact > conventional heat cure denture material as shown in (Fig 4)

The mean angle of hysteresis of Hi-impact > of 3Dprinted > conventional heat cure denture material as shown in (Fig 5)

DISCUSSION

Saliva plays a vital role in maintaining oral health and denture function by providing lubrication, adhesion, buffering action, and antimicrobial protection.[6] It significantly contributes to denture retention through interfacial surface tension, viscosity, and adhesion between the denture base and oral mucosa.[7] In conditions such as xerostomia, where salivary flow is reduced or altered, denture retention and patient comfort are severely compromised, necessitating the use of artificial salivary substitutes.[6]

Wettability is a critical factor influencing denture retention and is commonly assessed by measuring the contact angle formed between a liquid and a solid surface. A lower contact angle indicates better wettability and enhanced spreading ability of the fluid over the denture base.[8] As described by O'Brien (2013), materials with higher surface energy and hydrophilic characteristics exhibit improved wettability, thereby enhancing denture retention. Dynamic contact angle analysis, including advancing and receding angles, provides a more clinically relevant assessment of wetting behavior under functional conditions.

In the present study, all salivary substitutes demonstrated significantly lower advancing and receding contact angles compared to distilled water across all denture base materials. This indicates superior wettability of artificial saliva, which can be attributed to their composition, including lubricants, viscosity-enhancing agents, and film-forming components. These findings are consistent with studies by Jaiswal et al[9]. and Singh et al.,[10] who reported improved wettability of salivary substitutes compared to water on denture base materials.

Among the tested salivary substitutes, E-saliva exhibited the lowest contact angle values, followed by Biotene and Wet Mouth, indicating the highest wettability. This may be due to its favorable rheological properties and enhanced ability to form a continuous lubricating film over the denture surface. Similar observations were reported by Mohsin et al.,[11] who found that E-saliva demonstrated superior spreading ability and wettability on acrylic denture bases. Biotene showed intermediate wettability, which aligns with findings by Pawan Kumar et al[7]., while Wet Mouth, although better than distilled water, exhibited comparatively higher contact angles. Studies by Ramana et al. [12] and Srivastava et al[13]. also support the improved wetting behavior of Wet Mouth compared to water, attributed to the presence of carboxymethylcellulose.

Distilled water, used as the control medium, exhibited the highest advancing and receding contact angles across all materials, indicating poor wettability. This is due to its lack of viscoelastic and lubricating properties necessary for effective film formation. Similar findings were reported by Sasi AK et al[14]., who concluded that distilled water shows inferior wettability compared to salivary substitutes.

Among the denture base materials, 3D-printed resin demonstrated the lowest contact angle values, indicating superior wettability, followed by high-impact heat-cure resin and conventional heat-cure resin. The enhanced wettability of 3D-printed resin may be attributed to differences in surface characteristics, polymerization techniques, and surface energy associated with additive manufacturing. Poker et al[15]. reported that 3D-printed resins exhibit lower contact angles and improved hydrophilicity compared to conventional acrylic resins. Similarly, Artopoulou et al[16]. emphasized the need for further evaluation of 3D-printed materials due to their distinct surface properties.

High-impact heat-cure polymethyl methacrylate demonstrated better wettability than conventional heat-cure resin, which may be attributed to the incorporation of elastomeric components that modify surface characteristics and improve interaction with fluids. Ramana et al.[12] reported similar findings, indicating lower contact angles and improved wettability of high-impact PMMA compared to conventional PMMA.

Conventional heat-cure PMMA, although widely used, exhibited comparatively higher contact angles, indicating lower wettability. This may be influenced by factors such as surface roughness, residual monomer content, and processing techniques, as reported by Anusavice et al.[17]

Contact angle hysteresis, which represents the difference between advancing and receding angles, was also evaluated in this study. Lower hysteresis values observed with salivary substitutes, particularly E-saliva, indicate better wetting stability and resistance to liquid displacement, which may positively influence denture retention under functional conditions.

Overall, the findings of this study highlight the significant influence of both denture base material and salivary substitute on wettability. The superior performance of 3D-printed denture base resin in combination with E-saliva suggests a promising approach for improving denture retention and comfort in patients with xerostomia.

CONCLUSION

Within the limitations of this in-vitro study, the following conclusions were drawn:

- Salivary substitutes significantly improved the wettability of denture base materials compared to distilled water.
- Among the salivary substitutes tested, E-saliva demonstrated the highest wettability, followed by Biotene and Wet Mouth.
- 3D-printed denture base resin exhibited the highest wettability, followed by high-impact heat cure denture base resin, while conventional heat cure denture base resin showed the least wettability.
- Advancing and receding contact angles were lowest with E-saliva across all denture base materials, indicating superior spreading ability.
- Contact angle hysteresis values were lowest in E-saliva groups, suggesting improved liquid stability and surface interaction.
- The results indicate that 3D-printed denture base materials combined with suitable salivary substitutes may enhance denture retention and comfort, especially in patients suffering from xerostomia.

Declaration by Authors

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Conflict of Interest: No conflicts of interest declared.

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