Original Article

An *in-vitro* comparative study of wettability of four commercially available saliva substitutes and distilled water on heat-polymerized acrylic resin

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STATEMENT OF PROBLEM: Water can be used as a saliva replacement, but it is not adequately effective in moistening and lubricating the oral mucosa. Good wetting of the denture base material by the saliva substitute is critical for optimum retention of the upper complete dentures. **PURPOSE:** The purpose of the study was to compare wettability of distilled water and four saliva substitutes on DPI heat cure acrylic resin. **MATERIALS AND METHODS:** A total of 200 heat-cured acrylic samples were prepared of dimensions 2.5 × 1.5 × 2 mm. They were divided into five groups (40 samples in each group), and advancing and receding contact angles were measured using contact angle goniometer. **RESULTS:** The obtained values for advancing and receding contact angle and the resultant value of angle of hysteresis were subjected to statistical analysis. ANOVA was performed, which showed statistically significant values. **CONCLUSION:** The wettability of saliva substitute aqwet was found to be better as compared to other saliva substitutes and distilled water on heat-cured acrylic resin used in the study.

Key words: Contact angle, retention, saliva substitute, wettability

INTRODUCTION

Xerostomia is the subjective sensation of dryness of oral mucous membranes with the objective evidence of significantly decreased salivary flow.

Xerostomia could be the result of radiation treatment for oral cancer or due to the presence of systemic conditions like rheumatoid conditions, Sjogren's syndrome, diabetes mellitus, Parkinson's disease and dysfunctions of the immune system like HIV/AIDS.[1-8]

Far more often, xerostomia occurs as a side effect of drug therapy. There are more than 400 commonly used drugs that can cause oral dryness and induce salivary gland hypofunction, including analgesics, anti-histamines, anti-hypertensives, anti-depressants, diuretics and appetite suppressants.[1-9]

Decrease in the quality as well as alteration in the composition of the beneficial constituents of saliva predisposes the patient to many problems like difficulty in eating and swallowing, dry burning tongue, tender salivary glands and angular cheilitis. All the soft tissues of the oral cavity may have a thinner layer of cells than normal and, therefore, may be more susceptible to damage. Taste sensation is altered. Increased susceptibility to infections is also seen.[2-8,10,11]

Denture wearing may become difficult because dry mouth can significantly add to the problem of retaining and eating with the dentures, which invariably become loose. The salivary mucins possess rheological properties that include elasticity and adhesiveness, which aid in retention of dentures.[7,10-18]

Replacement of saliva by a fluid other than saliva has been proposed as a possible treatment in relieving subjective complaints of xerostomia for more than three decades.[1-6,19,20]

Water can be used as a saliva replacement, but it is known that water does not moisten and lubricate the oral mucosa and teeth adequately.[6] Therefore, saliva substitutes containing thickening agents for longer relief and increased moistening and lubrication of the oral surfaces have been developed. These are agents formulated as solutions, sprays or gels and have multiple contents including carboxymethylcellulose, electrolytes and flavoring. Ideally saliva substitutes should be pleasant in taste and odor, non-toxic, non-addictive, economical and must exhibit good wetting of the tissue surface of the denture.

Good wetting of the heat-polymerized acrylic resin by the saliva substitute is critical for optimum retention of the upper complete dentures.[7,21-35] For good adhesion of the denture to the supporting tissues, the saliva or saliva substitute must flow easily over the entire surface to ensure wetting of the adherent surface.

The contact angle of the saliva substitute on the denture base can be taken as an indicator of the wettability - the smaller the contact angle, the greater the wettability, or the contact angle is a useful inverse measure of wettability.[25,36,37]

Taking into consideration the importance of wetting of acrylic denture base by saliva substitutes in xerostomia patients, this study was undertaken to evaluate and compare the wettability of four commercially available saliva substitutes and distilled water on heat-polymerized acrylic resin.

MATERIALS AND METHODS

Distilled water and four saliva substitutes were used in this study [Figure 1]. They were WET MOUTH (ICPA Health Products Ltd.) AQWET (Cipla Ltd.), SALIVART (Gebauer Company) and MOUTHKOTE (Oryx Pharmaceuticals).

Two hundred samples of heat-cured acrylic resin were made by the following method:

Two sheets of modeling wax of 1.5 mm thickness were placed one over the other to get total thickness of 3 mm to compensate for the loss of acrylic during the finishing procedure and to obtain uniform thickness of 2 mm in the acrylic samples.

Two rectangular glass plates measuring 2.6 × 1.6 mm

Figure 1: Four salivary substitutes

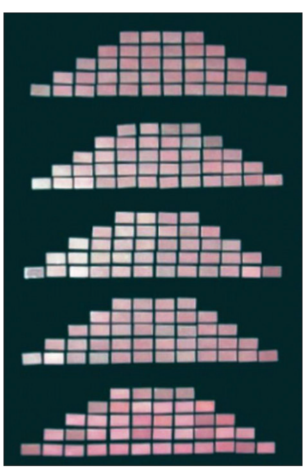

Figure 2: 200 samples of heat activated conventional acrylic denture base resin material

Figure 3: Contact angle goniometer and software Windrop++

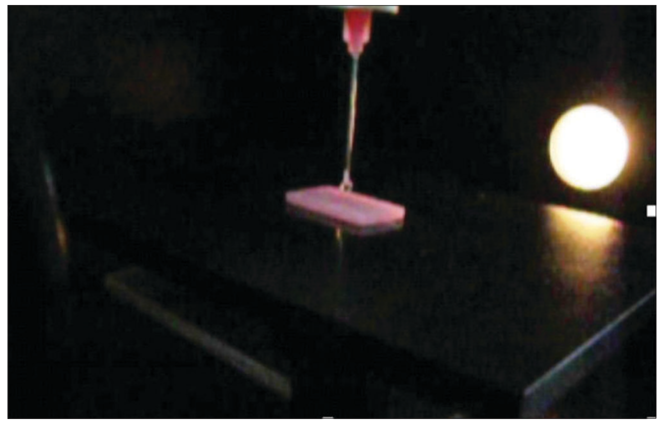

Figure 4: Samples evaluated by Windrop++

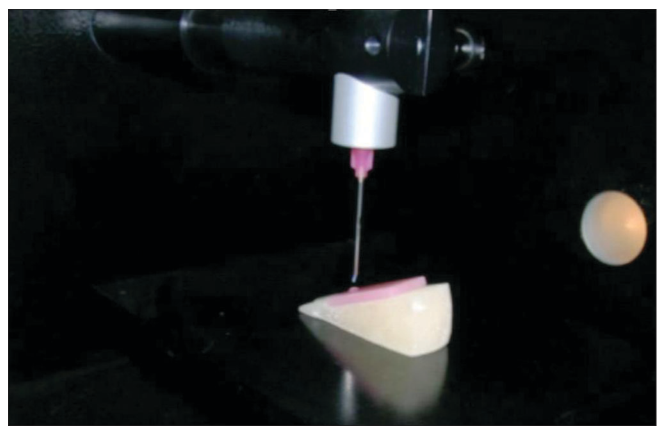

Figure 5: Samples evaluated by Windrop++

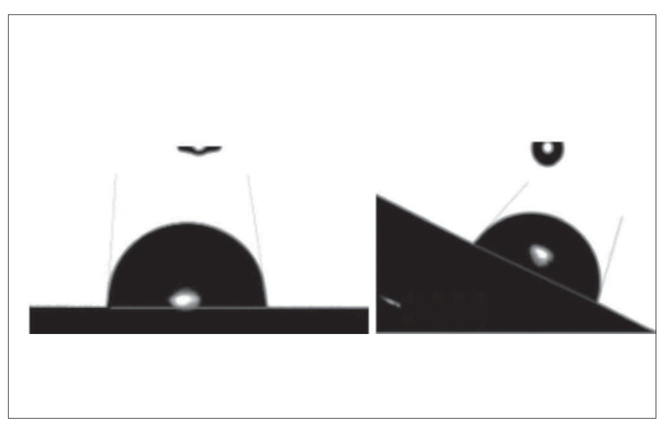

Figure 6: Measurement recorded

were stabilized on either side of the wax strips and the wax was cut along all the sides using a sharp carver. The resultant wax sample was checked for required thickness and uniformity using wax gauge. The samples were stored in air-tight containers.

Fabrication of heat-cured acrylic resin samples

The wax samples were invested using dental plaster in varsity flasks. A heat-activated conventional acrylic denture base resin material (Dental Products of India) was used.

Flasking and processing was done according to the manufacturer's instructions. Two hundred samples were made by the above method [Figure 2]. The samples were stored in water for 24 h.

The samples were finished to get an even thickness of 2 mm using flat cherry stones and sandpaper as in clinical practice. No finishing was done for surface to be tested (tissue surface) to simulate clinical practice. To get a flat surface, the samples were finished on the other side (polished surface) manually using sandpaper on a flat surface.

The samples were first cleaned for 5 min with soft cotton immersed in water saturated with household soap and then rinsed well with running water. They were cleaned with spirit to remove any soap residues.

This was followed by immersion in sonic denture cleaner for 15 min. The samples were dried prior to viewing under an electron microscope.

The samples were then viewed under scanning electron microscopy to verify the effectiveness of finishing and cleaning procedures. The magnification used was at 2000×.

Preparation of the samples

After the cleaning procedure, the samples were placed in a glass petridish and placed in the oven. Then, the samples were dried in the oven at 44°C for 30 min and then cooled to a temperature of 22°C. The temperature of the room was controlled by air conditioners.

Measurement of contact angles

The advancing and receding contact angles were measured using contact angle goniometer and software Windrop++ [Figure 3].

The 200 samples were divided into five groups with 40 samples in each group. Distilled water was used in group 1; WET MOUTH in group 2; AQWET in group 3; SALIVART in group 4; and MOUTHKOTE in group 5.

A pre-cleaned, oven-dried glass syringe was filled with distilled water up to 5 ml. The syringe was carefully fitted into the metal housing and loaded on the syringe holder.

The metal housing had a knob on its superior aspect which could be turned clockwise in order to expel liquid through the needle. It was graduated in microlitres; therefore, the liquid used for each drop could be standardized.

The acrylic sample was held with tweezers only on the sides, taking care not to touch the surface of the sample. The sample was placed at the centre of the table just below the needle of the syringe.

The software program Windrop++ was used to measure the advancing and receding contact angles. After measuring the advancing contact angles, the drop was wiped away and a new area on the sample was selected for measurement of receding contact angles. The samples were placed at 24° inclined to the horizontal plane [Figures 4 and 5].

After the values were obtained, the sample was removed and a new sample was placed. The procedure was repeated for 40 samples in the first group.

Later, the above procedure was followed for all the samples in the five groups, and measurements were made and recorded [Figure 6].

RESULTS

Means of contact angle values were as follows [Table 1]. The angle of hysteresis was calculated as the difference between the advancing and receding contact angle values.

ANOVA was carried out to test the significance in difference of contact angle values in the five groups.

The ANOVA table revealed [Table 2] that there was a significant difference between the contact angle values of distilled water and the four saliva substitutes.

A multiple comparison test using Bonferroni's test

Table 1: Advancing contact angles, receding contact angles and angles of hysteresis

	N	Mean	SD	Minimum	Maximum
Mean of advancing contact angle value					
Distilled water	40	86.26	2.34	82.7	90.6
WET MOUTH	40	86.21	2.38	82.7	90.6
AQWET	40	71.25	1.44	68.8	73.8
SALIVART	40	86.71	3.07	80.7	93.7
MOUTHKOTE	40	81.72	2.77	75.1	86.5
Mean of receding contact angle value					
Distilled water	40	69.625	1.14	68.4	71.5
WET MOUTH	40	65.095	2.73	60.1	69.4
AQWET	40	42.86	1.28	40	44.5
SALIVART	40	66.39	2.48	63	70.6
MOUTHKOTE	40	60.3725	1.41	58.8	63.4
Mean of angle of hysteresis value					
Distilled water	40	19.51052632	2.97	14	28.8
WET MOUTH	40	21.16125	2.73	14.65	25.8
AQWET	40	28.39875	1.82	24.5	32
SALIVART	40	20.315	2.99	16	27.5
MOUTHKOTE	40	21.34625	3.15	14	25.9

Table 2: ANOVA results

Source of variation	Sum of squares	d.f.	Mean squares	F
ANOVA results for advancing angle				
Between	1.2233E+04	4	3058	345.3
Error	1727	195	8.857	
Total	1.3961E+04	199		
ANOVA results for receding angle				
Between	1.2490E+04	4	3123	1030
Error	591.1	195	3.031	
Total	1.3081E+04	199		
ANOVA results for angle of hysteresis				
Between	2044	4	511.1	62.70
Error	1589	195	8.151	
Total	34	199		

was carried out to verify the significance of difference between the contact angles in a pair of groups.

The test revealed that values for distilled water, WET MOUTH and SALIVART were not significantly different from each other. However, group 3 (AQWET) and group 5 (MOUTHKOTE) showed statistically significant difference as compared to other groups. Moreover, when compared within them, the test showed statistically significant difference.

DISCUSSION

Xerostomic patients have difficulty with chewing, swallowing and speech. Dryness of the oral mucosa renders it more susceptible to irritation and epithelial atrophy, leading to possible inflammation, fissuring and ulceration. The wearing of dental prosthesis may cause discomfort. A lack of salivary buffering action also leads to increased risk of caries. Qualitative and quantitative deficiency of the saliva causes an unhealthy and painful environment.[1-7]

In addition, saliva plays an important role in the retention of complete dentures and protecting oral health.

Artificial saliva products are useful agents for the palliative treatment of xerostomia at present. Saliva substitutes are divided into two groups: carboxymethyl cellulose and mucin-based saliva substitutes. Mucin-based saliva substitutes have been proved to show better wettability than carboxymethylcellulose-based saliva substitutes, but they are derived from porcine derivatives, mainly the gastric mucin, and therefore are likely to be objectionable to the Indian population. Therefore, saliva substitutes used in the study contained carboxymethyl cellulose, which imparts lubrication and viscosity.[1,6,7,9,38-40]

The results of the study showed that group 3 (AQWET) showed good wettability and a high value of hysteresis angle in comparison to other saliva substitutes.

The static contact angles of both saliva substitutes and distilled water at the left and right boundaries of the drop of fluid were not significantly different for a specific group. The results indicated that the test surfaces for each denture base material were homogeneous. The standardized method suggested by Patton *et al.* for cleaning the test surfaces effectively removed contaminants from the test surfaces.[27]

The advancing contact angles of both saliva substitutes and distilled water were significantly greater than the receding contact angle.

The fundamental requirement suggested for denture retention has been contact angle hysteresis, namely the difference between the advancing liquid-solid contact angle and the receding angle. Advancing contact angle is defined as the angle that a liquid drop forms on a dry solid surface. Receding angle is formed when the liquid recedes on the previously wet solid surface.[33]

The significant differences in the contact angle values must be analyzed in terms of the advancing-receding contact angle hysteresis induced by these surfaces. Contact angle hysteresis is influenced by surface heterogeneity, surface roughness, surface deformation and chemical contamination of water. In addition, contact angle hysteresis of polymer surfaces can be induced by the mobility and reorientation of surface polymeric chains. The presence of liquid in contact with a solid may provoke the reorientation of polymer surface groups, leading to contact angle hysteresis.

Equilibrium contact angle has been regarded as related to denture comfort, and denture retention is more related to contact angle hysteresis.

Theoretical considerations and experimental results clearly demonstrate that, with the exception of some specific cases such as perfectly wettable solids ($\partial = 0°$), the contact angle of the advancing liquid front on a dry solid surface (advancing contact angle ∂A) is different than the receding contact angle (∂R).[34]

When the liquid front recedes on a solid surface, the dewetting mechanism produces at first a contact angle variation and then a displacement of the liquid-solid contact line.

When, instead of pure liquids, solutions containing different surface-active agents (such as surfactant or proteins) are used in contact angle measurements, adsorption of these molecules at the liquid-solid interface induces an important hysteresis.

Force required to dislodge the denture vertically denoted as F max

$$F_{max} = mg \frac{\text{Cos } \partial R}{\text{Cos } \partial A}$$

where mg is the weight of the denture, ∂R is the receding angle and ∂A is the advancing angle.

From this equation, it is clear that force required to separate the two surfaces increases with increase in hysteresis angle.

The capillary force, which helps restrain any dislodging force on the denture, is increased by complete wetting of the surface, high surface tension of the saliva and large tissue contact area of the denture.

The capillary force *F*, responsible for retention of a denture, can be expressed by the following equation:

$$F = \frac{\tilde{\gamma}A(\cos\ \partial 1 + \cos\ \partial 2)}{dg}$$

where $\tilde{\gamma}$ is the surface tension of saliva, A is the area of tissue surface of the denture, $\partial 1$ is the advancing contact angle, $\partial 2$ is the receding contact angle, d is the film thickness, and g is the gravitational force.

Thus, contact angle hysteresis and denture geometry at the meniscus contact line are the determinant factors of denture retention.

A large number of important conditions influencing denture retention in mouth may be taken into account while choosing denture base materials and denture shape. For example, retention might be improved in cases of denture base surfaces with high values of advancing angles and low values of receding angles.

A factor that would affect the magnitude of contact angle of a fluid on a solid surface is the roughness of the adherent surface, which differs with respect to the solid.[27]

Surface roughness, even in test specimens of the same group of denture base material, was an uncontrollable variable. The variability in surface roughness of denture base materials must be considered when contact angle data are evaluated.

Contamination of the studied surfaces may produce a change in the water surface tension that, in turn, would induce an error in the measured contact angle values. The origin of this contamination may be of chemical nature (migration of the residual monomer from the polymer bulk to the surface) or of microbial nature (formation of metabolites). However, in the application of angle measuring techniques, the liquid drop was left in contact with the polymer surface for less than 2 min. Moreover, the extremely careful rinsing procedure made it highly improbable that either chemical or microbial contamination occurred.

Surface heterogeneity may play its role in increasing contact angle hysteresis. In this case, the advancing contact angle would depend on the fraction of the surface occupied by a low surface-energy phase; the receding angle would be influenced by a high surface-energy phase.

Good wetting of the acrylic denture base resin by saliva substitutes is of clinical importance. The quality of life for xerostomia patients may be improved by the use of a suitable saliva substitute.

CONCLUSION

Despite several limitations of this study, the following conclusions can be drawn: Group 3 (AQWET) has the lowest advancing and receding contact angle values and the highest angle of hysteresis on heat-cured acrylic resin (DPI heat-cured denture material).

Based on contact angle values, group 3 (AQWET) has the best wetting ability on heat-cured resin acrylic dentures fabricated with DPI heat-cured denture material.

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