Original article

Evaluation of Water Sorption of Various Heat-Curing Acrylic Resins and the Effect of Aqueous Environment on its Fracture Toughness

Hanan Moussa[1], Mardeia Hamad[1], Amel Lefsaay[1]
[1] Assistant lecturer, Prosthodontics Department, Faculty of Dentistry, University of Benghazi.

ABSTRACT
Background: Water sorption is one of the concern regarding acrylic resin denture base materials since it might affect the dimensional stability of the prosthesis, furthermore the absorbed water may dramatically compromise the physical and mechanical properties. **Methods:** Three different commercial denture base materials (heat-curing acrylic resin) available in local markets were used (Vertex, Ivoclarw and Luxacryl) to evaluate water sorption and the effect of dry and wet environment on the fracture toughness of these materials. Water sorption test was carried out according to international organization for standardization (ISO) Specification 1567-2000. The fracture toughness was determined using single edge notch bending test (SEN-B) according to ISO 13586:2000. **Results:** Water sorption in term of percentage was highest for Ivoclar (0.78% of its weight) and lowest for Luxacryl (0.68% of its weight). Statistical analysis with two-way Analysis of Variance (ANOVA) test showed a significant difference between different acrylic material groups, and between different water immersion times ($p<0.0001$). For fracture toughness, it has been found that the Ivoclar samples displayed the highest fracture toughness after 28 days of immersion in distilled water at room temperature. Statistical analysis with two-way ANOVA test showed a significant difference for fracture toughness between different acrylic material groups ($P<0.04$).
Conclusion: in general, fracture toughness of denture base materials was highly-changed after immersion in water.
Key-words: Acrylic Resin Denture-Base Materials, Water Sorption, Fracture Toughness.

Corresponding author: Mardeia Hamad. Prosthodontics Department, Faculty of Dentistry, University of Benghazi,-Libya.
E mail: mardiaali@yahoo.com.

INTRODUCTION

Replacing missing teeth is representing a great concern to a majority of people and their artificial replacement with a partial or a complete denture is the treatment option that maintains the normal oral function. A widely accepted denture base material is a heat–curing acrylic resin poly methyl methacrylate (PMMA).[1] Acrylic polymers had been used as an exterior facings for fixed prosthesis to enhance the esthetic property of the prosthesis.[2-4] Although acrylic resin has satisfied properties for instance; ease of manipulation, chemical stability, moderate cost, light weight and good color matching to the oral tissue,[5] it falls to achieve ultimate mechanical requirements of dental prosthesis.[6-8] There are many factors affecting on the mechanical properties of acrylic resin materials and make prediction of the service life of these materials difficult. Water sorption is representing one of the concerns regarding the acrylic resin materials.

The meaning of sorption of material represents the amount of water adsorbed on the surface and then absorbed inside the material whiles the restoration is in service. Since both adsorption and absorption are representing the same term sorption is usually used to include the total phenomena.[9] When the denture in use, it will be in contact with saliva and when it is not in use may be soaked in water. Plasticizers and other soluble components such as unreacted monomer may evaporate-out over extended periods, while water or saliva is absorbed. Even though water sorption and solubility occur at the same time there is no correlation between them.[10]

Water sorption may be highly-acceptable from the clinical perspective since it could facilitate the adaptability of denture adaptation to oral tissue.[11,12] Instead water particles diffuse between the macromolecules of the acrylic denture base material, forcing them apart which may change dimensional status of the denture.[13] It was found that water absorption may produce the internal stresses into the denture material that may result in crack beginning and propagation and may eventually end with the denture fracture.[14-16]

The fracture toughness of a material reflects the resistance of material to fracture and represent the energy required to propagate a crack through the material to complete fracture. Recent attempts have been made to reinforce dental acrylic materials by impregnating them with different fillers. However, these fillers may act as stress-concentration points and increase the possibility of material fracture because of their irregular shapes and directions throughout the matrix.[1,17,18] Generally, intrinsic physical aging and /or storage in wet environment can decrease fracture toughness of acrylic materials.[2, 19]

On the other hand, it was confirmed by Hill *et al*, when he studied three types of denture base acrylic materials that for most notched specimens fracture toughness dramatically increased on testing in wet compared with testing in dry environment.[20] Fracture toughness has been used as initial parameters to determine the clinical potential and limitations of dental materials. [21]Higher fracture toughness equals higher resistance to crack growth, which can be equated to higher clinical performance.[22] In the present research, the water sorption as well the fracture toughness of three types of heat-curing acrylic resin denture base materials was checked out in humid and wet conditions.

MATERIAL AND METHODS

Three commercially denture base materials (heat-curing acrylic resin) available in local markets were evaluated in this study.

1. Vertex-Dental bv J, V. Oldenbameveltln 62, 3705HJ Zeist The Netherlands Rapid Simplified Heat- Curing Acrylic.
2. Triplex-Hot,Ivoclar Vivadent AG, FL-9494 Schaan /Liechtenstein ,conformto /entsprich : ISO 1567 , ADA 12 , Type 1, Class 1
3. Luxacryl , Conform A La Norme :ISO 1567 ,19, rue Henri-Dunant -SEYSSINS 38180 Grenoble (France).

Specimen preparation for water sorption:

Water absorption test was done according to (ISO) Specification 1567-2000. The specimens were cut to 0.5-0.6g using band saw, thereafter, polished with sand paper grade p280 and p1200 to improve the surface finish and to remove cutting marks. Five specimens were prepared for each material. The specimens were dried in vacuum oven at 37±1°C for 24hs and kept in desiccator containing silica gel for 24hs prior to immersion in distilled water.

Water sorption testing

The specimens were weighed using analytical balance of reading 0.0001g then immersed in distilled water at room temperature and weighed after 0, 7, 14, 21 and 28 days of water immersion.
The change in weight percentage was calculated via:

$$\text{Change in weight} = \frac{W_1 - W_0}{W_0} \times 100\%$$

W_0 and W_1 are the weight of sample before and after immersion, respectively.

Specimen preparation for fracture toughness testing

The fracture toughness was calculated using single-edge notch bending test (SEN-B) according to ISO 13586:2000. The test specimens were prepared using molded plate as in Figure (1). [Thickness (B) = 4 mm, width (W) = 20 mm, span length (L) = 64 mm, overall length = 80 mm, notch length (a) = 4. mm]. A natural crack was done by tapping on a new razor blade placed in the notch.

Fracture toughness test

The SEN-B specimens were tested at a crosshead speed of 1.00 mm/min. The values for fracture toughness (K_C) were calculated using the following equation:

$$K_c = \frac{P_c \frac{S}{4}}{B \frac{W^2}{6}} \left[1.93 - 3.07\left(\frac{a}{W}\right) + 14.53\left(\frac{a}{W}\right)^2 - 25.1\left(\frac{a}{W}\right)^3 + 25.8\left(\frac{a}{W}\right)^4 \right]$$

Where: P_c = Load at peak (N), B = specimen thickness (mm), W = specimen width (mm), a = notch length (mm), S = span length, mm

They were tested at intervals of 1, 7, 14, 21 and 28 days. The specimens were then manually dried using soft tissue paper. The Fracture Toughness Test was then applied according to the procedures described in previous section.

The data entry and analyses were performed using two-way ANOVA at the 95% confidence level for both water sorption and fracture toughness. The level of significant was set at P value < 0.05. The samples were submerged in distilled water at room temperature.

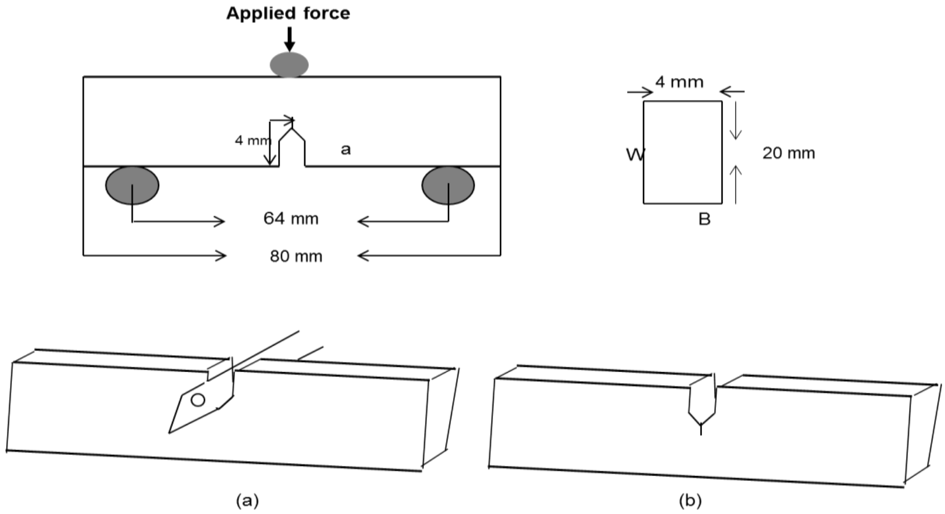

Figure 1: Fracture sample dimensions

RESULTS

Water sorption

The means and standard deviation of means of water sorption values are shown in Table 1 and Figure (2). Five samples of each material were used to measure the water sorption. The result in terms of percentage increase in the first day of storage in water at room temperature then became increasing gradually, reaching the constant value (0.74% of its weight) at 21-28 days for Vertex and continue in weight gain until 28 day for Luxacryl and Ivoclar water sorption with 28 days immersion time was highest for Ivoclar (0.78% of its weight) and lowest for Luxacryl (0.68% of its weight). Statistical analysis with two-way ANOVA test showed a significant difference between different acrylic material groups, and between different water immersion times (P<0.0001).

Table 1: The Means and Standard Deviation of Means of Water Sorption.

Material Type	1 Day (%)	7 Days (%)	14 Day (%)	21 Day (%)	28 Day (%)
Luxacryl	0.17 ±0.029	0.45 ±0.007	0.57 ±0.02)	0.63 ±0.01	0.67 ±0.023
Vertex	0.17 ±0.01	0.48 ±0.020	0.64 ±0.012	0.74 ±0.043	0.74 ±0.023
Ivoclar	0.22 ±0.038	0.53 ±0.018	0.67 ±0.01	0.75 ±0.008	0.78 ±0.000

Fracture toughness

The means and standard deviation of means of fracture toughness values are shown in Table 2 and Figure 2. Four samples of each material were used to measure the fracture toughness. It can be seen that the Vertex samples displayed the highest fracture toughness before submerged in distilled water, but it show decrease in its fracture toughness after 24 hours of immersion by 5.4% of dry fracture toughness, increasing after 14 days but it still less than the original dry fracture toughness then increase after 28 days reaching constant value at 21-28 days

For both Luxacryl and Vertex the maximum value of fracture toughness were reached after 14 days of immersion in distilled water, while for Ivoclar was reached after 21 days of immersion, It can be seen that the Ivoclar samples displayed the highest fracture toughness after 28 days of immersion in distilled water at room temperature. The fracture toughness of Ivoclar was higher by 17% than that of luxacry and higher by 12.24% than that of vertex. Statistical analysis with Two Way ANOVA test showed a significant difference between different acrylic material groups (P<0.04).

Table 2: The Means and Standard Deviation of Means of the Fracture Toughness.

Material Type	1 Day (N/m²)	7 Days (N/m²)	14 Day (N/m²)	21 Day (N/m²)	28 Day (N/m²)
Luxacryl	1.20± 0.06	1.35 ±0.198	1.47 ±0.049	1.35 ±0.08	1.37 ±0.07
Vertex	1.56 ±0.11	1.48 ±0.078	1.47 ±0.087	1.44 ±0.15	1.42 ±0.11
Ivoclar	1.44 ±0.065	1.72 ±0.023	1.78 ±0.21	1.86 ±0.10	1.86±0.10

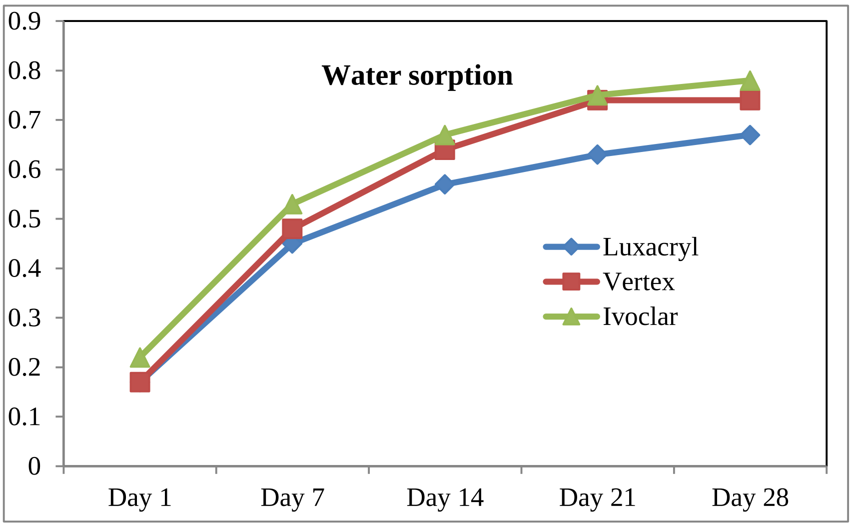

Figure 2: Water Sorption of Heat Curing-Acrylic Resin.

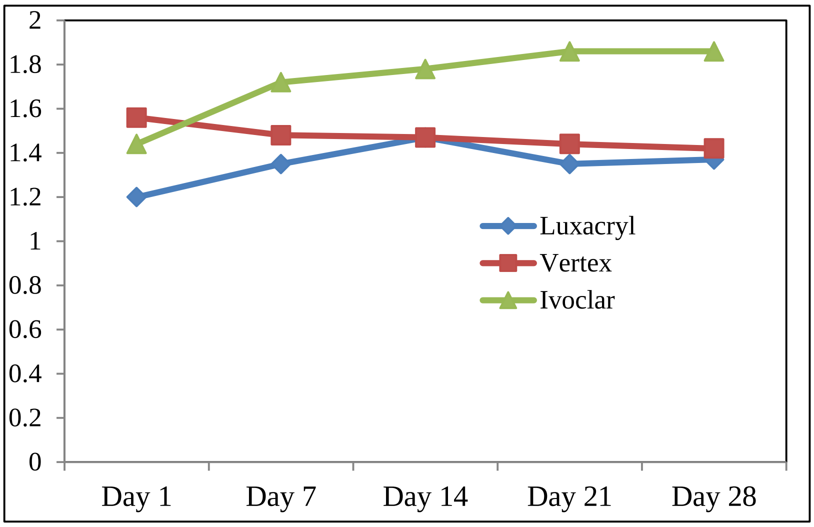

Figure 3: Fracture toughness of heat curing-acrylic resins.

DISCUSSION

In present study, the experimental manner that is recommended by ISO Specification 1567-2000 for measuring the total of water sorption was used. The gradual increase in water sorption in our study was in agreement with the study done by Dixon *et al.*[23] There is parallel relation between the quantum of remaining monomer and the percentage of water absorption.[24] The superficial remaining monomer of the resin probably diffuses into water, causing decrease in the weight of the samples. The reason for no weight lost for some samples having higher percentage of remaining monomer content may be due to the nature of remaining monomer in the polymer matrix which is located deep not superficial. If the remaining monomer is not near to the surface of the specimen, entrapped in the inner layers of resin late, it cannot diffuse out into water in short time. Even though it will leached out in final stage, the amount of water absorption into polymer will be high enough to compensate for the weight lost caused by the remaining monomer diffusion from resin to the water. As a result, a weight increase instead of weight decrease was observed.[22]

After submerging in the water, the fracture toughness was elevated due to entering of water into the polymer which acting as an internal plasticizer that is responsible for increasing the plasticity as reported by Deb *et al.*[24] These results were also in an agreement with the study done by Hill *et al.*[20] The Ivoclar sample increased by 19.16% after 28 days immersion in distilled water compared to its dry fracture toughness and vertex samples increase by 16.4%, while fracture toughness of vertex samples dropped by 4.0% of its dry fracture toughness. This may be attributed to the high content of remaining monomer in the polymer matrix and leaching rate of remaining monomer was not coincided with diffusion rate of the water into the polymer matrix.

Conclusion

A significant variation between acrylic material groups, and between different immersion times in their water sorption. Overall behaviour of analyzed tested materials displayed that the samples of Ivoclar and Luxacryl showed higher reading of fracture toughness after immersion in water. In general, fracture toughness of tested denture base materials was increased after saturated in water.

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