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The Investigation of Solubility Values, Water Sorption and Bond Strength of Auto-polymerising and Heat-polymerising Acrylic Resin Materials

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Abstract - *In this study the solubility, water sorption and the bond strength of auto-polymerising and heat-polymerising acrylic resins were investigated. Two auto-polymerising and five heat polymerising acrylic resin materials were used for this study. Thirty-five specimens were prepared (50 mm in diameter and 0.5± 0.01 in thickness) for water sorption and solubility tests. In order to examine bond strength, specimens were prepared in 2.5x10x64 mm dimensions. These specimens were repaired with QC and major repair acrylic. Some specimens were kept in distilled water for 50 hours, and others for 30 days. The strength of the bond was measured by a Pull-Compress device. As a result of the variance analysis; water sorption, solubility and the bond strength between acrylic resins were identified as statistically significant (P<0.001). The water sorption of the major acrylic resin specimens were lower than the other materials(P<0.001).*

KEY WORDS: Solubility, Water sorption, Bond strength, Auto-polymerising acrylic resin, Heat-polymerising acrylic resin.

INTRODUCTION

Acrylic resins were introduced to dentistry in 1937 [1,2]. Lack of dimensional stability may be accepted as one of the disadvantage of acrylic resin dentures. At least two recognised dimensional changes; expansion and shrinkage[3] are unavoidable in acrylic denture. Acrylic resin dentures are also known for their tendency to absorb water, which causes corresponding dimensional change[4].

Water sorption depends on polar features of resin molecules [5,6]. The expansion of the acrylic resin is produced by water absorption, thus forcing the macromolecules apart [6,7]. The water sorption of the acrylic resin can also influence the dimensional stability. However, the expansion associated with water sorption of wet heat-processed the acrylic resin dentures may compensate for the processing shrinkage [3,8]. Polymer stability is important in the finished dentures and dimensional changes that do occur may result from the leaching of traces of unreacted monomer and water-soluble additives into the oral fluids. However, these monomers sometime produce a soft tissue reaction [7].

In this study, water sorption and solubility of two auto-polymerising acrylic resins and five heat-polymerising acrylic resins were evaluated. Transversal bond strength between auto-polymerising and heat-polymerising acrylic resins were compared.

MATERIALS AND METHODS

Two auto-polymerising and five heat-polymerising acrylic resin materials were used in this study (Table 1).

Water sorption and solubility

A stainless steel mould (50 mm in diameter and 0.5± 0.01 in thickness) was used to prepare the specimens in accordance with the International Standard Organization Specification 1567 [9]. Five specimens for each acrylic resin material were polymerised in accordance with the manufacturer.

Thirty-five specimens, were placed inside an oven at 37±1°C for 23 hours, they were then left to stand at an ambient temperature for an hour. Each specimen was weighed and kept in distilled water at 37°C for 7 days. Once they were removed from the water they were dried and weighed before being placed in a desiccator. The specimens were weighed until a constant mass indicated that a state of equilibrium was reached. Mass changes were compared with the initial mass and expressed as percentage mass change by the following formula: [10]

$$\frac{m-m_i}{m_i} 100\ \%$$

m: Mass of the denture
m_i: Preface mass of the denture before water immersion
Solubility: Weight after desiccator or weight before water immersion [11]

Transverse bond strength:

A stainless steel mould in the dimensions of 2.5x10x64 mm was used to prepare the specimens (100 acrylic resin specimens in total). All materials were mixed and manipulated according to the manufacturer's instructions.

After polymerization, five specimens of each acrylic resins were ground with 320-grit silicon carbide paper, and they were stored in distilled water for 50 hours at 37 °C. 10-mm square sections were removed from the centre of each specimen, and the auto-polymerising acrylic resins were placed into these sections. 50 of the 100 specimens were repaired with QC repair acrylic and remaining specimens were repaired with major repair acrylic and flasked (Fig.1.)

Table 1. *Materials Used*

Product	*Manufacturer*
QC-20 (Heat-polymerized)	De Trey Weybridge,surrey,England
Rodex (Heat-polymerized)	Denture Material Polvere, Milano, Italy
Superacryl E (Heat-polymerized)	Spofa-Dental,Praha-Sole
Fortex (Heat-polymerized)	B.D.P Industry,İstanbul
Real acryl (Heat-polymerized)	B.D.P Industry,İstanbul
Major repair acrylic (Auto-polymerized)	Major prodotti Dentari S.P.A
QC-repair acrylic (Auto-polymerized)	De Trey,England

Table 2. *The Mean Values and Standard Deviations of Water Sorption and Solubility (n=5) (µg/ mm³).*

	Water Sorption		*Solubility (µg/ mm³)*	
Acrylics	Mean *	SD	Mean *	SD
Superacryl	2.38[a]	0.22	0.024	0.00
Real	2.22[a]	0.13	0.022	0.05
Rodex	2.25[a]	0.43	0.021	0.02
QC-20	2.30[a]	0.16	0.023	0.06
Fortex	2.13[a]	0.13	0.021	0.01
QC-Repair	2.32[a]	0.11	0.020	0.05
Major Repair	1.20[b]	0.13	0.012	0.01

** :Means with the same letter are not significantly different*
P<0.001

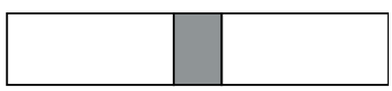

Figure 1. *Diagram of repaired specimen*

After deflasking, any remaining flash was trimmed. Half of the 50 specimens that were repaired with QC repair acrylic were stored in distilled water for 50 hours and the other 25 specimens were immersed in distilled water for 30 days. The same procedures were performed for those which were repaired with major repair acrylic resin. Bond strength between heat polymerising and auto-polymerising acrylic resins was measured with a Housefield pull-press machine at a crosshead speed of 0.05 cm/min by using a 3-point bending fixture with a span of 50 mm.

Fracture force was reported in Newtons (N), and the nature of fracture was noted as cohesive or adhesive. Examination of the specimens for adhesive or cohesive failures was made with the naked eye. Pink auto-polymerization acrylic resin layer on test surface of heat-polymerized acrylic resin was defined as cohesive failure. All examinations were made by one investigator. As water appears to act as a plasticizer for resins [12] the same process was repeated for the specimens which were stored at 37°C for 30 days.

Statistical analysis

Each test for the acrylic samples were repeated five times to ensure reproducibility, statistical analysis was performed by using the minitab program by one way analysis of variance (ANOVA).

LSD (Least square means) test was applied to the results to determine whether the significant differences existed between the means (P<0.01).

RESULTS

Water absorption (F=17.50, P<0.001) and solubility (F=4.57, P<0.01) were statistically significant. Major repair acrylic resin showed significantly lower water sorption than the other acrylic resin materials (P<0.01) (Table 2). In terms of solubility, significant differences were found between Major repair acrylic resin and other acrylic resins. No significant difference was noticed in the solubility of Super acryl E, Rodex, Real acrylic, QC-20, Fortex and QC repair acrylic.

The bond strengths between heat-polymerising and autopolymerising acrylic resins were statistically significant (F=3.73, P<0.01). The values for the acrylic resins stored in distilled water at 37 °C for 50 hours were F=144.07, P<0.001 and for 30 days were F=116.90, P<0.001. The water storage affected the transverse strength. Mean and standard deviation results of the bond strength between auto-polymerising and the heat-polymerising acrylic resins according to time interval and repair materials are shown in Table 3 and 4.

Major repair acrylic resin failures were primarily cohesive in nature across Superacrylic, Fortex and QC-20. Percentage of adhesive and cohesive failure are shown in Table 5 and 6.

DISCUSSION

The water absorption and solubility of acrylic base materials are important in clinic applications and water absorption and solubility values of a substance will affect the results of clinic studies[13]. The type of polymer and its thickness affects the amount of water absorption[6]. It is known that acrylic resins have water absorption and solubility values and when within the Standard values are accepted as unimportant with regard to clinic usage[7,14-16]. In ADA standards[17], it is stated that water sorption value in denture base resins should not be more than 0.7 mg/cm^2. Phillips[6] stated that these values should not be outside the range 0.8 mg/cm^2 and 0.04 mg/cm^2. Anderson[18] suggested that water sorption values are 0.5-0.6 mg/cm^2. Craig et al.[7] reported that water sorption values in heat-polymerising acrylic resins should be 0.6 mg/cm^2, and that solubility in water should be around 0.02 mg/cm^2, but that water absorption values in routine using acrylic resin should be in between 0.6-0.9 mg/cm^2.

Table 3. *Transverse Fracture Means of Repaired Acrylic Resins at each time interval (N)*

Materials	*50 hours*		*30-day*	
	Mean	*SD*	*Mean*	*SD*
Superacryl	74	3.6	49	3.9
Real	81	3.1	48	4.0
Rodex	66	4.0	39	4.1
QC-20	74	3.6	49	3.6
Fortex	71	3.1	57	3.8

SD: X+ Sx

Table 4. *Transverse Fracture Means and SD of Repaired Acrylic resins by the repair materials*

Materials	*QC-Tamir*		*Major Tamir*	
	X	*Sd*	*X*	*Sd*
Superacrylic	45.00	3.58	78.00	3.58
Fortex	46.00	3.58	82.79	3.79
Rodex	53.00	3.58	52.00	3.58
QC-20	33.00	3.58	90.00	3.58
Real	59.00	3.58	70.00	3.58

Table 5. *Percentage of Failure for QC-Repair Material (%)(n=5)*

Materials	*Mode of Bond Failure*			
	Adhesive		*Cohesive*	
	50 h	*30 days*	*50 h*	*30 days*
Superacryl	80	80	20	20
Real	40	80	60	20
Rodex	80	80	20	20
QC-20	40	40	60	60
Fortex	100	80	0	20

Table 6. *Percentage of Failure for Major Repair Material (%)(n=5)*

Materials	*Mode of Bond Failure*			
	Cohesive		*Adhesive*	
	50 h	*30 days*	*50 h*	*30 days*
Superacryl	100	100	0	0
Real	40	40	60	60
Rodex	20	60	80	40
QC-20	100	100	0	0
Fortex	100	100	0	0

In the present study, the mean values of water sorption for heat polymerising acrylic resins were 2.25 µg/mm^3 for Rodex, 2.38 µg/mm^3 for Superacryl, 2.22 µg/mm^3 for Real,and 2.30 µg/mm^3 for QC-20. These values are in accordance with ADA standards.

Water sorption and solubility values have been evaluated for percentage weights, and the authors determined that water absorption of heat polymerising acrylic resin was 2.9 %, and that solubility was 2.8 %. In auto-polymerising acrylic resin, water absorption was 2.5% and solubility was 3.87%[19].

Yavuzyılmaz et al.[13] determined that the mean of water absorption for heat polymerising acrylic resin was 1.05 mg/cm^2, and the mean of solubility was 0.05 mg/cm^2; the mean of water sorption for auto-polymerising acrylic resin was 0.81 mg/cm^2 and the mean of solubility was 0.66 mg/cm^2. In this study, Major repair acrylic resin showed lower water sorption than that of the other acrylic resin materials. The low water sorption could be related to its higher residual monomer content [20].

The solubility of acrylic resins represents the amount of water soluble ingredients, unreacted monomers, plasticizers, and initiators that leached out during the 7 days the specimen was immersed in water [20]. Fletcher et al [21] found that auto-polymerising acrylic resins exhibited higher residual monomer levels than that of heat-polymerising acrylic resins. These higher residual monomer contents could be related to the higher solubility levels of auto-polymerising acrylic resins reported by Walter et al [11].

The excessive amount of remaining monomer in auto-polymerising acrylic resin may lead to weakening of the bond strength between the auto-polymerising and heat polymerising acrylic resins[21].

Cucci et al.[20] reported that auto-polymerising acrylic resin had exhibited shrinkage after 60 days of storage in water. Dixon et al.[22] determined that the resistance of acrylic resin materials reduced when they were stored in water. The water which is absorbed by the material acts as a plasticizer and decreases the mechanical properties such as transverse strength, hardness and fatigue limit [22,23,30].

The present study showed that there were no significant differences in mean solubility between the heat polymerising acrylic resin and QC-repair auto-polymerising acrylic resin. One of the problems with auto-polymerising acrylic resins is the failure of adhesion between the auto-polymerising acrylic resin and the denture base resin. Failure at the bond site can be either adhesive or cohesive. If the failure is adhesive, the interface between the heat-polymerising acrylic resin and the auto-polymerising acrylic resin lacks strength, whereas cohesive failure indicates that bonding to the denture base surface was adequate [20, 24].

Arena[24] stated that a weak bond between acrylic base material and repair material could create a potential surface for bacterial growth and promote staining. The investigators reported that monomer process on intersurface of auto-polymerising and heat-polymerising acrylic resins was increased the bond strength [25-27].

In the repair process by conventional heat-polymerising acrylic resin, the fracture strength was higher than the auto-polymerising acrylic resins which was due to a good connection of two the subjects [28-30].

Dinçkal and Aladağ[30] suggested that the bond strength between heat and auto-polymerising acrylic resin specimens were reduced after water storage. In this study, the transverse strength of acrylic resins obtained a significant reduction after water storage.

CONCLUSION

- Major repair acrylic resin exhibited lower water absorption than the other materials.
- No difference was noted in the solubility of materials.
- Transverse fracture mean of Rodex was lower than the other acrylic resins.
- The failure on the surface between auto-polymerising and heat polymerising acrylic resins are frequency cohesive.

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