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EVALUATIONS AND COMPARISON OF SOME MECHANICAL PROPERTIES OF THE SELF AND HOT – CURE – ACRYLIC DENTURE BASE MATERIALS UNDER DIFFERENT PRESSURES MODALITY

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Abstract :

The objectives of this study were to evaluate and compare some mechanical properties (compressive strength, tensile strength, shear strength, impact strength and transverse strength) of the self and hot–cured acrylic denture base materials under different pressures modalities. 250 samples were constructed, 200 sample were divided into four groups (50 for each, 10 for each test), subjected to different pressure forces (25psi, 50psi, 75psi, 100psi) and compared with 50 samples of hot – cured acrylic resin (10 for each test processed in water bath according to the conventional method -temperature 74C^{o}, pressure 1200psi and time was 8 hours- as a control group). The results showed that at 100psi (compressive strength, tensile strength, shears strength, and impact strength) were improved. At 75psi (transverse strength) was improved, at 50 psi (impact strength, shears strength and transverse strength) were deteriorated. While 25psi lowered the (compressive strength, tensile strength, shears strength, and transverse strength).Using 100 psi pressure improved most of self-cured acrylic resin properties compared with hot-cured acrylic while 75psi improved the transverse strength.Key words: self-cured acrylic, hot-cured acrylic, pressure modality.

الخلاصة :

من الاستعمالات الاولية للاكريلك البارد هي بناء التعويضات الاصطناعية كقواعد الطقوم. لذلك نجد لها اهمية عالية في التطبيقات (تعويضات الاسنان الاصطناعية , تقويم الأسنان , واحهة التيجان و الجسور , تعويضات الوجه والفكين , طبعة الفم , قالب السن , التيجان الأولية , الحشوات). استعمال الضغوط أثناء طبخ الاكرليك له تاثير في غالبية التفاعلات الكيمياوية للأكريلك لذلك فهو يحافظ على الأكريلك اثناء البلمرة و يؤثر في الصفات الفيزياوية و الميكانيكية في عملية الطبخ . في هذه الدراسة أجري تقييم و مقارنة لبعض الصفات الميكانيكية للأكريلك البارد المطبوخ تحت مختلف الضغوط (25psi , 50psi , 75psi, 100 psi) مع الاكريلك الحار 250 عينة للأكريلك البارد و 50 عينة للحار وقد حضرت كما يلي:

1. 50 عينة 10 لكل فحص للأكريلك الحار و عملية التحضير تجرى في جهاز الطبخ (water bath) استنادا الى الطريقة المتفق عليها (درجة الحرارة 74C^{o} , الضغط 1200 psi , الوقت 8 ساعات).
2. 200 عينة 50 لكل مجموعة للأكريلك البارد تتقسم الى 4 مجاميع و هذه موضوعة تحت ضغوطات مختلفة (25psi , 50psi , 75psi, 100 psi)

لوحظت النتائج للصفات الميكانيكية هي :

100 psi هذا الضغط تحسنت فيه (القوة الضاغطة, قوة الشد , قوة القص , قوة الصدمة) و 75psi تحسنت فيه (القوة المستعرضة).
نستطيع ان نستنتج بان عملية الطبخ للأكريلك البارد تحت الضغط 100psi هو أكثر الضغوط التي تحسنت بها الصفات الميكانيكية مقارنة مع الأكريلك الحار بينما 75psi هو الضغط الذي تحسن فيه القوة المستعرضة.

Introduction

Self- cured acrylic resin is one of the most frequently used materials in dentistry for repairs, relines, orthodontic appliances, maxillofacial prosthesis in addition to its use in crown and bridge work as a temporary coverage of prepared teeth**.** [1-4].Although self-cured acrylic has inferior

properties than hot –cured acrylic, it is still widely used for its low cost, easy manipulation, easy fabrication and repair and natural appearance. [5] .The use of self – cured acrylic resin in prosthetic work is mainly related to its simple technique at room temperature, less time consuming and less equipment required.[6] The strength properties of the self – cured acrylic resin are less than that of the heat cured type due to lower degree of polymerization of the self – cured acrylic resin with high residual monomer which acts as a plasticizer lowering its strength properties. So pressure may affect mechanical and physical properties during curing of acrylic denture base.[7] An understanding of the physical, mechanical properties of materials used in dentistry is of tremendous importance. Because materials used to replace missing portion or teeth are exposed to attack by the oral environment and subjected to biting forces. Moreover, the restorative materials are cleaned and polished by various prophylactic procedures. As a result, their properties are the basis for the selection of materials to be used in particular dental procedures and restorations.[8] When an object is subjected to an axial compression, it is important to recognize that the failure of the body occurs as a result of the complex stress developed in the body, which includes shearing and tensile stresses.[9] In comparison with heat – activated resins, the chemically activated resins generally display lower degrees of polymerization. As a result, chemically activated resins exhibit increasing levels of residual monomer and decreasing compressive strength and stiffness values. [5] The stress is an external force which is applied to a body or specimen of material under test, an internal force, equal in magnitude but opposite in direction is set up in the body. For simple compression or tension the stress is given by the expression, stress=F/A, where F is the applied force and A the cross- sectional area. A stress resisting a compressive force is referred to as a compressive stress and that resisting a tensile force a tensile stress. [10] While the tensile strength increased as the acrylic resin polymerized under pressure at 37C^{o}.[11]A significantly higher tensile strength was noticed when the autopolymerized PMMA was processed in water at an elevated temperature. [12] On the other hand, polymerization of the materials under pressure could improve tensile strength, however, the pressure needed for the procedure is material dependent. [13] Transverse strength is a combination of tensile and compressive strength. It includes some of the elements of the proportional limit and elastic modulus. It is also described as modulus of rapture or flexural strength. [14] The decrease in the transverse strength of microwave cured materials may be related to high residual monomer values when compared with conventionally cured materials. [15] e best transverse strength of the PMMA may be attributed to the higher conversion of the monomer into the polymer. [16] Particle size could affect transverse strength of the acrylic resin and average polymer chain length undoubtedly affects the transverse strength.[17] Although transverse strength of cold-cured PMMA is approximately 80% of the heat-cured material. [18] The materials with lowest residual monomers concentration showed the greatest impact strength and the material with higher water sorption showed higher impact strength.[19] In this study different pressure degrees (25psi, 50psi, 75psi, and 100psi) were used for curing self– cure acrylic resin denture base and evaluation of some mechanical properties (compressive strength, tensile strength, shearing strength, transverse strength, and impact strength) were done in comparison with hot-cured acrylic processed in the conventional method (74ºC, pressure 1200 psi and 8 hours time).

Materials and Methods :

200 samples were prepared of self – cure acrylic resin denture base materials. They were divided into 4 groups (50 samples for each group, ten for each test); processed under different pressure forces (25psi, 50ps, 75psi, and 100psi).

The control group consists of (50 sample 10 for each test) prepared from hot – cured- acrylic denture base resin processed according to the conventional method.[11]

Samples of the 4 groups were tested for (Compressive strength, Tensile strength, Shear strength, Impact strength and Transverse strength). [8]

Metal pattern preparations

According to **ADA specification** NO.12 [20-21], and **Astem D256, (1985, 1988),** and **BS specification 2482** [22]**.** The following six metal patterns were constructed:

1. A dimension of (65mm X 10mm X 2.5mm) length, width, thickness respectively used for transverse strength test.

2. Dumbbell- shaped metal pattern of (65mm X 12.5mm X 2.5mm) length, width, thickness was constructed to be used for tensile strength test.

3. Rectangular- shaped metal pattern of (65.5mm X 12.7mm X 3.75mm) length, width, thickness was constructed to be used in impact strength test.

4. A carbon steel split cylinder of (12mm X 6mm) length, diameter was constructed to be used for compressive strength and shear strength tests.

Specimens' preparation

Using a conventional denture flasking and packing technique, all metal specimens were constructed with acrylic. The lower portion of the dental flask was filled with dental plaster mixed according to manufacturer instruction (i.e. 50 ml \ 100 gm), metal pattern was coated with the separating medium (For easy removal from the plaster) a layer of plaster mix was coated on metal pattern to avoid trapping of air when inserting the metal pattern into the plaster mix. After setting of the plaster (30 min), both the plaster and metal patterns were coated with separating medium, and another layer of plaster was poured into the upper half of the flask with vibration to get rid of the trapped air. Plaster was allowed to harden for (60 minutes) then the flask was opened and metal pattern was removed, in the same mold the cold cure acrylic specimen was constructed by placing the flask in the Ivomat machine processed by heating at ($80C^o$) for (15) minutes under different experimental pressure (25psi, 50psi, 75psi, 100psi) while hot cured acrylic was cured in a thermostatically controlled water bath (temperature at ($74C^o$) for (8) hours).

Finishing and polishing

All the acrylic resin specimens were finished by sand paper sheet and continuous water- cooling (to avoid over heating).While polishing was accomplished by using bristle brush and pumice with dental lathe polishing machine using law speed (1500rpm). The final glossy surface was obtained with wool brush and polishing soap on dental lathe, the specimens were continuously cooled with water to avoid over heating during finishing and polishing to prevent distortion of the specimens according by the **ADA specification** NO. 12 **(1975)**

Mechanical test:-

5.Compressive strength

The compressive strength was measured by using instron machine especially equipped with grips suitable for holding the test specimen. Set at cross- sectional area head speed of 2mm/min with a chart speed 20mm/min.the load was measured by a compressive load with a maximum capacity (2500 kg) the force at failure was measured (kg) which converted into (N).

The values of compressive strength were calculated by the following:

C.S. = $F / \pi d h$

C.S. =Compressive strength (N/mm^2).

H = Height of the specimen (mm).

F = Force at failure (N).

d =Diameter of the specimen (mm).

2. Tensile strength

The tensile strength was measured by using instron testing machine equipped with grips suitable for holding the test specimen. Set at cross head speed of 0.5mm/min with a chart speed 20 mm/min. The loads were measured by a tensile load cell with a maximum capacity (100kg). The recorded

force at failure was measured (kg) which were converted into (N). The values of tensile strength were calculated by the following

T.S. = F/A

Where:-

T.S. = Tensile strength (N/mm^2).

F = Force at failure (N).

A = Area of cross section at failure (mm).

3. Shear strength

A computerized testing machine was used for this purpose. The chisel shaped rod was a hand made one in order to fit at the interface for the specimen. Each sample was held by a specially made split mold and placed in the lower member (jaw) of the testing machine so that the chisel shaped rod was always positioned at 90^o to the acrylic resin Junction. The specimen were loaded to failure at 250 kg load cell by the (instron machine) and speed 1mm/min with achart speed 20mm/min. Failure the machine was zeroed and calibrated The load to failure representing the force of bond failure was recorded in (Newton's) by digitizing the test over graph supplied by the machine computer. The force was then divided by the surface area ($50.28mm^2$) of each specimen to obtain the shear bond strength in (mpa). According to the following formula S.S= F/ SA = mpa

Where:-

S.S =shear strength (mpa). F = Force (N).

SA = Surface area of the bonded site (mm^2)

Which was calculated as follows:-

$SA=R^2 \times 22/7=mm^2$ where: (R^2 = Square radius)

SA= 16 X 22/7=50

4. Transverse strength

The transverse strength of acrylic resin specimens was measured in three points bending on an instron testing machine. The values of transverse strength were calculated by the following equation:

$$S. = 3PI/ 2bd^2$$

S. = Transverse strength (N/mm^2)

P = Maximum force exerted on specimen (N).

I = Distance between the supports (mm).

b = Width of a specimen (mm).

d = Depth of a specimen (mm).

5. Impact strength

Evaluation of impact strength was done according to the procedure given by the **ASTM, D256, (1985)** with charpy type impact machine which was supplied with a pendulum. In this procedure, weights differ according to the material to be tested.The specimens were held horizontally and struck by the pendulum of (2j) capacity at the center of the tested specimen in the notch area. The scale reading gives the impact energy in (j) The value of charpy impact strength was computed by the following formula **According to ISO180, (2000)** for determination of impact strength.

Impact strength (KJ/M^2) = $E / t\ w$

Where *E* is the absorbed energy in (KJ), while *t* is the thickness of the specimen and *w* is the remaining width at the notch base in (m^2).

Results

Descriptive statistics which include tables of (mean, SD, SE) and graphical presentation (Bar chart) was used along with inferential statistics in order to accept or reject the statistical hypothesis which include ANOVA table with the result of multiple comparison test (LSD).

1. Compressive Strength Test Result:

Compressive strength values showed that, there were a highest mean (27.479 ± 1.1223) in 50psi group, while the smallest one was 25psi (18.410± 1.0329).as shown in table(1) and figure(1) From **ANOVA** with **LSD** as shown in table (2) observed a highly significant difference (P< 0.01) in most comparison between pressure group with control group and a pressure groups itself, with exception only in 100psi compared with control group which give a non- significant difference (P>0.05).

Table (1) Descriptive statistics for compressive strength according to the studied groups.

studied groups	N	Mean	Std. Deviation	Std. Error	Mini.	Maxi.	ANOVA (f-test) P-value
Control	10	24.606	1.0501	0.3321	23.17	26.00	0.00 Highly Sig. (P<0.01)
25psi	10	18.410	1.0329	0.3266	17.07	19.51	
50psi	10	27.479	1.1223	0.3549	26.42	29.27	
75psi	10	22.794	1.0271	0.3248	21.54	24.39	
100psi	10	24.769	0.9697	0.3066	23.57	26.00	
Total	50						

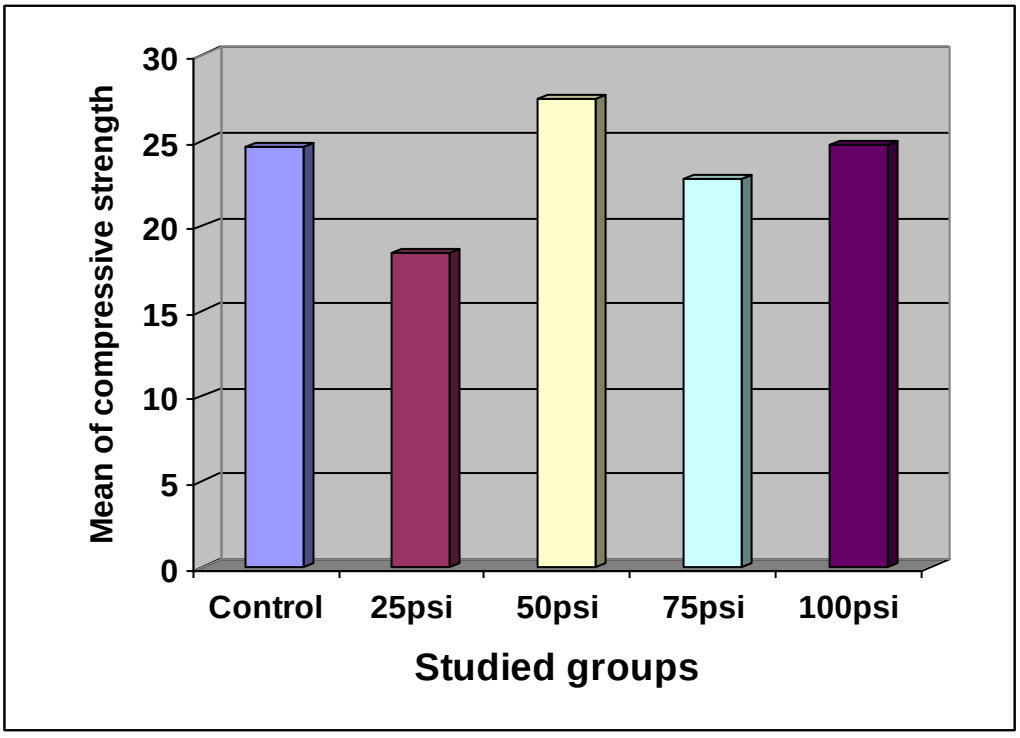

Figure (1) Descriptive statistics for compressive strength according to the studied groups.

Table (2) the result of multiple comparison test (LSD) of compressive strength between tested materials groups.

LSD (F-test)	Control	25psi	50psi	75psi	100psi
Control	-	HS	HS	HS	NS
25psi	-	-	HS	HS	HS
50psi	-	-	-	HS	HS
75psi	-	-	-	-	HS
100psi	-	-	-	-	-

2.Tensile Strength Test Result

Tensile strength values in **Table (3) and Figure (2)** was the highest mean in 50psi (63.372 ± 1.8057) and the smallest mean is 25psi (42.770 ± 1.0564). One way **ANOVA** with **LSD** observed a highly significant difference (P< 0.01)between 25psi and 50psi with control group with non-significant difference (P> 0.05) 75psi and 100psi with control group. The comparison between pressure group item itself, there were a highly significant difference (P< 0.01) in most situation while a significant difference (P<0.05) in comparison between 75psi and 50psi, and non- significant difference (P> 0.05) when compared between 100psi and 75psi. Shown as table (4)

Table (3) Descriptive statistics for tensile strength according to the Studied groups.

studied groups	N	Mean	Std. Deviation	Std. Error	Mini.	Maxi.	ANOVA (f-test) P-value
Control	10	61.947	0.9254	0.2926	60.82	63.27	0.00 Highly Sig. (P<0.01)
25psi	10	42.770	1.0564	0.3341	41.20	44.15	
50psi	10	63.372	1.8057	0.5710	60.82	65.73	
75psi	10	62.194	1.0568	0.3342	60.82	63.77	
100psi	10	61.706	0.8637	0.2731	60.82	62.82	
Total	50						

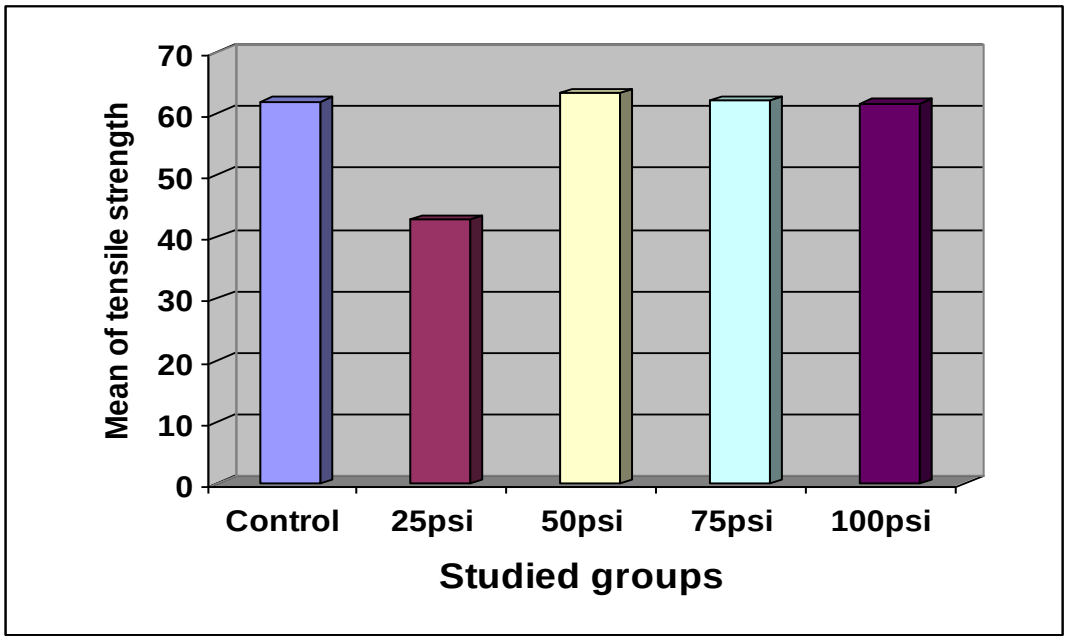

Figure (2) Descriptive statistics for tensile strength according to the studied groups.

Table (4) the result of multiple comparison test (LSD) of tensile strength between tested materials groups.

LSD (F-test)	Control	25psi	50psi	75psi	100psi
Control	-	HS	HS	NS	NS
25psi	-	-	HS	HS	HS
50psi	-	-	-	S	HS
75psi	-	-	-	-	NS
100psi	-	-	-	-	-

3.Shear Strength Test Result

The highest mean values of shear strength were obtained in specimens 100psi(31.646 ± 1.2408) while the lowest mean in the pressure group 25psi (15.137 ± 1.2508). Table (5), Fig (3) One way **ANOVA** was highly significant difference (P< 0.01) and **LSD** test showed that, There were a highly significant difference (P< 0.01) between most of the tests groups with control group and the pressures groups itself, only 100psi when compared with control group gives a significant difference (P< 0.05).shown as table (6)

Table (5) Descriptive statistics for shear strength according to the studied groups.

studied groups	N	Mean	Std. Deviation	Std. Error	Mini.	Maxi.	ANOVA (f-test) P-value
Control	10	32.764	1.0265	0.3246	30.83	33.75	0.00 Highly Sig. (P<0.01)
25psi	10	15.137	1.2508	0.3955	13.07	16.58	
50psi	10	24.700	1.3922	0.4402	23.02	26.34	
75psi	10	28.329	1.2662	0.4004	26.34	29.85	
100psi	10	31.646	1.2408	0.3924	30.24	33.56	
Total	50						

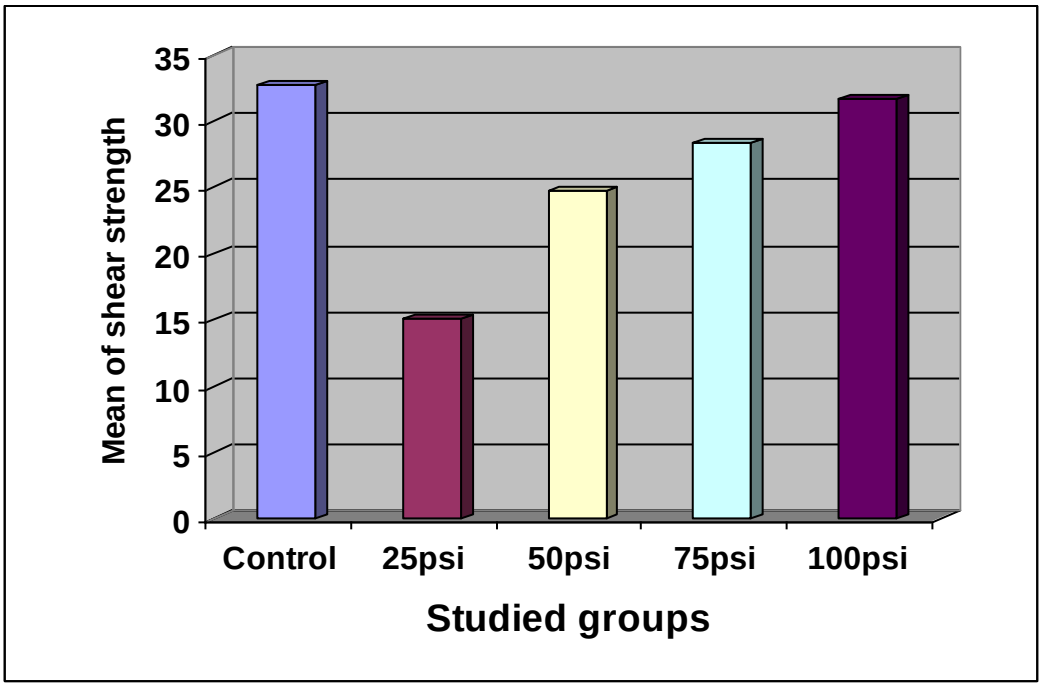

Figure (3) Descriptive statistics for shear strength according to the studied groups.

Table (6) the result of multiple comparison test (LSD) of shear strength between tested materials groups.

LSD (F-test)	Control	25psi	50psi	75psi	100psi
Control	-	HS	HS	HS	S
25psi	-	-	HS	HS	HS
50psi	-	-	-	HS	HS
75psi	-	-	-	-	HS
100psi	-	-	-	-	-

4. Transverse Strength Test Result

Transverse strength values varied with the difference pressure. The highest mean values of transverse strength were obtained in specimen 75psi (115.955 ± 1.5932) while the smallest mean values of transverse strength were obtained in specimens 25psi (71.456 ± 0.9715 table (7) and figure (4). One way **ANOVA** was a highly significant difference (P< 0.01) and **LSD** test showed that, there were a highly significant difference (P< 0.01) between 25psi and 50psi when compared with control group while a non- significant difference (P>0.05) between 75psi and 100psi with control group. The comparison between pressures groups itself, Showed there were a highly significant difference (P< 0.01) in most cases, only the 100psi With 75psi which gives non-significant difference (P>0.05) table (8).

Table (7) Descriptive statistics for transverse strength according to the studied groups.

studied groups	N	Mean	Std. Deviation	Std. Error	Mini.	Maxi.	ANOVA (f-test) P-value
Control	10	115.718	1.8454	0.5836	113.01	117.72	0.00 Highly Sig. (P<0.01)
25psi	10	71.456	0.9715	0.3072	70.63	72.99	
50psi	10	74.832	1.3413	0.4242	72.98	76.52	
75psi	10	115.955	1.5932	0.5038	113.01	117.72	
100psi	10	115.150	1.5280	0.4832	113.01	117.72	
Total	50						

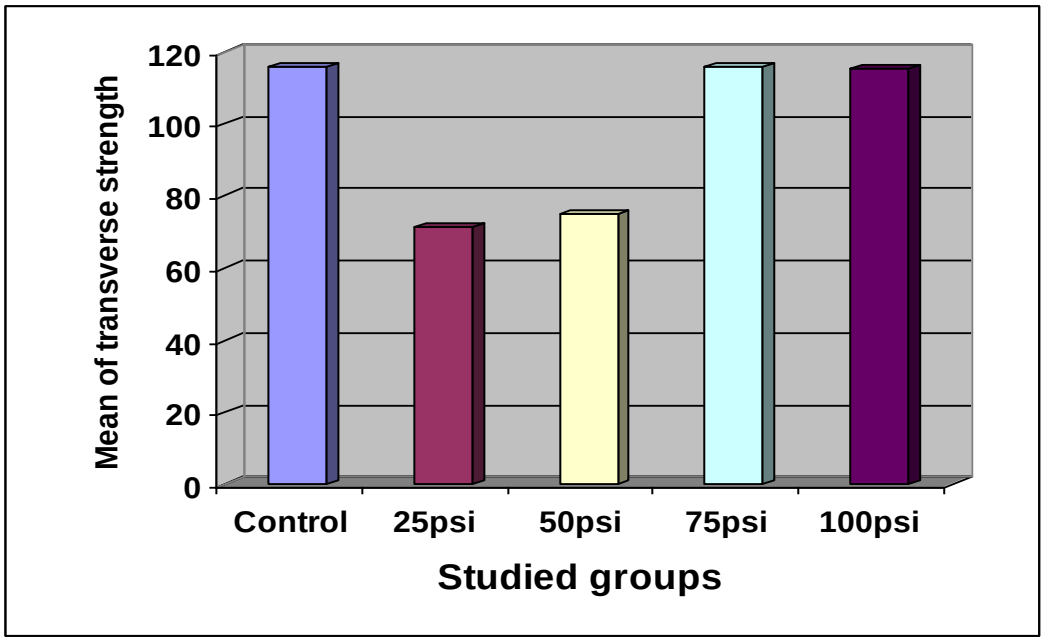

Figure (4) Descriptive statistics for transverse strength according to the studied groups.

Table (8) the result of multiple comparison test (LSD) of transverse strength between tested materials groups.

LSD (F-test)	Control	25psi	50psi	75psi	100psi
Control	-	HS	HS	NS	NS
25psi	-	-	HS	HS	HS
50psi	-	-	-	HS	HS
75psi	-	-	-	-	NS
100psi	-	-	-	-	-

5. Impact Strength Test Result

The increased mean in 100psi was (7.360 ± 0.8579) while the decreased mean in 50psi (6.12 ± 0.7146) for impact strength values obtained from the different pressure specimens. Shown in table (9) and figure (5). One way **ANOVA** with highly difference (P< 0.01) and **LSD** test showed that, there were a significant difference (P< 0.05) between 100psi and control group while the most other pressure group when compared with control group gives a highly significant difference (P< 0.01), but a non – significant difference (P> 0.05) between the most pressures groups itself, while a highly significant difference (P< 0.01) between 100psi with 25psi and 50psi, all of these details obtained from the table (10).

Table (9) Descriptive statistics for impact strength according to the studied groups.

studied groups	N	Mean	Std. Deviation	Std. Error	Mini.	Maxi.	ANOVA (f-test) P-value
Control	10	8.110	1.1180	0.3535	6.50	9.50	0.00 Highly Sig. (P<0.01)
25psi	10	6.420	0.5884	0.1861	5.70	7.40	
50psi	10	6.120	0.7146	0.2260	5.20	7.40	
75psi	10	6.660	0.5038	0.1593	6.30	7.40	
100psi	10	7.360	0.8579	0.2713	6.30	8.40	
Total	50						

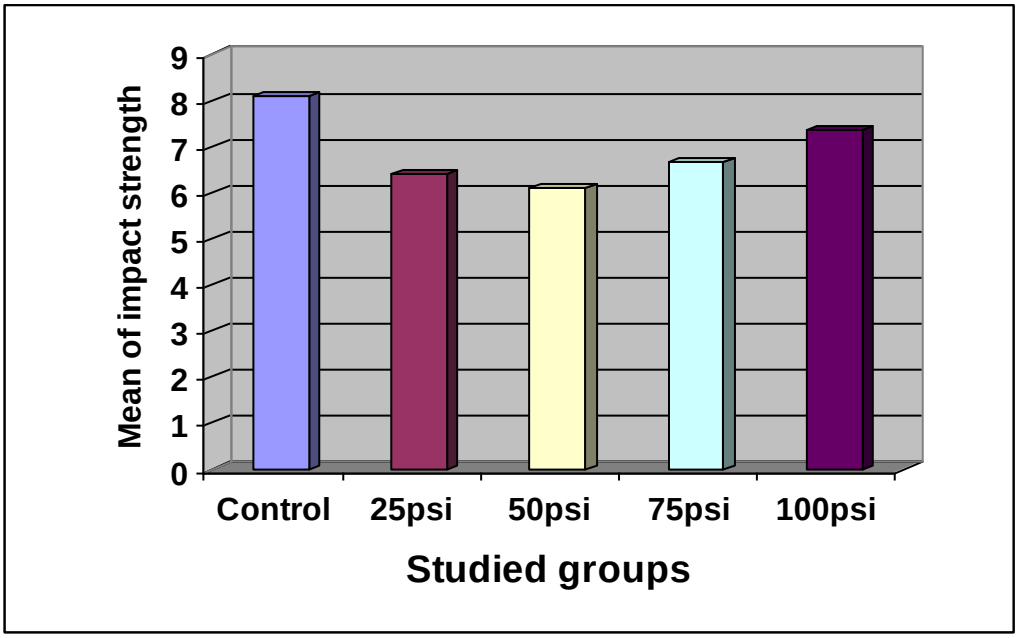

Figure (5) Descriptive statistics for impact strength according to the studied groups.

Table (10) the result of multiple comparison test (LSD) of impact strength between tested materials groups.

LSD (F-test)	Control	25psi	50psi	75psi	100psi
Control	-	HS	HS	HS	S
25psi	-	-	NS	NS	HS
50psi	-	-	-	NS	HS
75psi	-	-	-	-	NS
100psi	-	-	-	-	-

Discussion

1. Compressive strength

The high value of compressive strength in specimens under pressure 100psi compared with the hot –cured acrylic could be related to the decreased stretching of acrylic resin and stable molecular weight. [15, 6] In case of 50psi and 75psi, the lower value of compressive strength could be due to increased levels of residual monomer of the acrylic resin which lead to decrease in the compressive strength. [9] While the porosity and internal faults may adversely affect the compressive strength of the material. [18]

2. Tensile strength

Increasing tensile strength at 100psi when compared with other rest groups, (25psi, 50psi, 75psi), and a highly significant difference compared with hot – cured acrylic**.** [12, 5] The high values of tensile strength in specimens at 100psi as compared with the hot- cured acrylic might be related to higher pressure with elevated temperature with concentration of reinforcement of acrylic resins causes increase tensile strength, and prevention of the porosity and water sorption which lead to increase tensile strength.[5] In 25psi and 50psi, the lower value of tensile strength compared with the hot – cured acrylic resin could be related to insufficient pressure leading to increased porosity and water sorption due to decrease tensile strength. [12, 6]

3. Shear strength

The Shear strength at 100psi specimens in the self – cured acrylic resin was highly significant in comparison with hot – cured acrylic resin and other groups. [5, 10] The high values of shear strength in specimens in pressure 100psi compared with the hot- cured acrylic could be related to absence of the porosity leading to increase shear strength, lower molecular weight of acrylic resin due to increase shear strength, the most important which increase of the shear strength is the degree of the polymerization exhibited by the material. [10]

Lower values of the shear strength at 25psi and 50 psi and 75psi compared with hot- cured acrylic might be due to the presence of high molecular weight lead to decrease shear strength. [9]

4. Transverse Strength

Highly significant transverse strength at 75psi compared with the hot-cured acrylic which could be due to the higher conversion of the monomer into the polymer.[15] The high values of transverse strength at 75psi compared with hot – cured acrylic resin Might be related to increase the molecular weight and long polymer chain length resulted from more complete polymerization at this pressure that could increase the transverse strength.[18] The significant reductions of transverse strength at 25psi and 50psi compared with hot-cured acrylic resin could be due to insufficient pressure lead to increase the distance between molecular chains lead to decrease the transverse strength. [17]

5. Impact strength

The high values of impact strength at 100psi compared with hot –cured acrylic resin. This might be related to the lowest residual monomer concentration which increases impact strength. While a significant reduction of impact strength at 25psi, 50psi and 75psi could be due to insufficient pressure with elevated temperature leading to water sorption or porosity and high level of residual monomer. [18, 19]

Conclusions

It can be concluded that the processing of self-cured acrylic resin under 100psi pressure improved most of its properties compared with hot – cure acrylic resin. While 75psi improved the transverse strength.

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