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PMMA – EGGSHELL COMPOSITE PREPARATION AND STUDYING MECHANICAL PROPERTIES AS A DENTAL MATERIAL

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Abstract: In recent years, many researchers used polymethyl methacrylate in dental applications due to good mechanical and physical properties. In this research, the eggshell powder had mixed with polymethyl methacrylate resin for the preparations of new composite materials have good mechanical properties and low cost compared with industrially processed powders. The hand lay-up technique was adopted for the preparation specimens composite materials that made from a polymethyl methacrylate as a matrix with (1%, 3%, 5% and 7%) weight fraction eggshell powder (before and after burning) a reinforcement material. The mechanical properties were analyzed by utilizing (SPSS) according to (One-Way ANOVA). The results showed that the addition of the eggshell (before and after burning) powder at a ratio of (7% weight fraction) improves the values of tensile properties and fracture toughness, while this ratio leads to a decrease in values of elongation percentage at break and impact strength compared with other specimens. Also, the results showed that the Sig value was lower in all mechanical properties of specimens reinforced with eggshell powder after burning than specimens reinforced with eggshell powder before burning with a polymethyl methacrylate resin, where the percentage of improvement was in ultimate tensile strength 64 %, modulus of elasticity 13 %, elongation percentage 6 %, impact strength 75% and 81% fracture toughness.

Keywords: *Poly methyl methacrylate, Eggshell particle, tensile properties, Impact strength, Fracture toughness, One Way ANOVA*

تحضير ودراسة تأثير مسحوق قشورالبيض على بعض الخواص الميكانيكية لراتنجات البولي مثيل ميثا اكريليت المستخدمة في تطبيقات الأسنان

الخلاصة: في السنوات الأخيرة ، العديد من الباحثين استخدموا البولي مثيل ميثا اكريليت في تطبيقات طب الأسنان بسبب خصائصه الميكانيكية والفيزيائية الجيدة . في هذا البحث تم خلط مسحوق قشور البيض مع راتنجات ميثيل ميثاكريليت البولي لإعداد مواد متراكبة جديدة لها خواص ميكانيكية جيدة وذات تكلفة منخفضة مقارنة مع المساحيق المجهزة صناعية . تقنية الصب اليدوي هي الطريقة المعتمدة لتحضير عينات المواد المتراكبة من البولي مثيل ميثا اكريليت كمادة اساس مع (1٪ ، 3 ٪،5 ٪ و 7٪) كسور وزنية من مسحوق قشور البيض (قبل وبعد الحرق) كمواد تقوية . الخواص الميكانيكية تم تحليلها باستخدام (SPSS) بالاعتماد على (تحليل التباين الاحادي) . اظهرت النتائج ان اضافة مسحوق قشور البيض (قبل وبعد الحرق) بنسبة (7% كسر وزني) يحسن من قيم خواص الشد ومتانة الصدمة ، في حين هذة النسبة تؤدي الى انخفاض في قيم نسبة الاستطالة ومقاومة الصدمة بالمقارنة مع العينات الاخرى . ايضا اظهرت نتائج أن قيمة Sig كانت أقل في كل الخواص الميكانيكية للعينات المدعمة مع مسحوق قشور البيض بعد الحرق من العينات المدعمة بمسحوق قشور البيض قبل الحرق مع راتنج بولي ميثيل ميثاكريليت ، حيث كانت نسبة التحسن في قوة الشد القصوى 64٪ ، معامل يونك 13٪ ، نسبة الاستطالة 6٪ ، مقاومة الصدمة 75٪ و متانة الكسر 81٪ .

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1. Introduction

Bio-composite material composed of matrix resin reinforced with natural fibers or particle and usually derived from plants, or cellulose particles or membrane waste [1]. Many materials have been developed to restore or replace bone structures damaged or lost due to illness or accidents. Among these, materials have been the study and use of biologically active ceramics to a large extent, because of its bone characteristic and the ability to reinforce the formation of bone and ceramic continuous interface, thus allowing the implantation mechanism [2].

Polymethyl methacrylate resin is widely used in synthetic dental applications because it has many properties such as ease of treatment, low cost, ability to match colors and lightweight. Despite these advantages, but polymethyl methacrylate resin possesses a weak resistance to impact strength and fatigue resistance [3-4]. Even Skinner noted in 1959 that the important thing that plays a major role in dental applications is an aesthetic quality because most people want their teeth to look at nature to a great extent [5]. At present, the expression of aesthetic quality is one of the main factors to restore teeth in their natural form.

The eggshell particle is a biological material distinct, which commonly considered waste. Nevertheless, it has wonderful properties which can be used in several fields and consequently its possible applications are widely studied in these days [6]. *Ahmed O. Alhareb et.al.* have studied the effect of adding weight fraction (5%, 7.5% and 10%) nitride butadiene rubber (NBR), reinforced with 5% weight fraction from Al_2O_3, YSZ, and SiO_2 on density, impact strength and fracture toughness for specimens fabricated from polymethyl methacrylate resin matrix. Results show the fracture toughness and impact strength of the specimens reinforced with Al_2O_3 better when compared to YSZ and SiO_2 particles. It has been established that the combination of 10% weight fraction nitride rubber with 5% weight fraction Al_2O_3 gives the optimum impact strength, fracture toughness and density [7]. *Sihama I. Salih ,et.al.* have studied the effect of different volume fractions 1%, 2%, and 3% nano- HA and micro-ZrO_2 reinforced with 5% volume fractions glass/Kevlar woven fiber on tensile properties of poly methyl methacrylate resin. From results can be observed the values of tensile strength and modulus of elasticity are improved with 3% volume fraction (nano -Hn and micro ZrO_2), on the other hand the values of elongation at break decreased with 3% volume fraction (nano -Hn and micro ZrO) [8].

Saeed S. and Elnaz M. have studied the effect of adding (0.5%, 1% and 2% weight fraction) nano TiO_2 particles on tensile strength with PMMA resin matrix. The results show, according to SEM images that the specimen (PMMA+TiO_2) has good distribution compared to other specimen. The (one-way analysis) showed significant variation between the contents of TiO_2 particles in acrylic resin matrix because the P value was less than 0.001 [9].

The objective of the current work is:

1. Attempting to obtain the new composite materials prepared from eggshell waste with poly methyl methacrylate resin which is used in the denture application.

2. Study the effect of adding eggshell powder (before and after burning) on tensile properties and impact properties of polymethyl methacrylate resin matrix.

2. Materials and Methods

2.1 Materials

Polymethyl methacrylate (DURACRYL PLUS SELF-CURING) resin matrix used in this research has high flexural strength, smooth surface, long plastic phase, easy finishing, high color stability and polishing (provided by Spofa Dental Company). The eggshell powder (before and after burning) was used as the strengthened materials with (1%, 3%, 5% and 7%) weight fraction. Electric furnace with a temperature of 1000 C^{o} was used to burn eggshells at 700 C^{o} and to stabilize for 2 hours. Figure (1) indicates steps for preparing eggshell powder and Table (1) shown the chemical composition of eggshell powder was examined by using X-Ray Fluorescence spectrometer. Figures (2) and (3) indicate the distribution and particle size of eggshell powder before and after burning, where the average particle size for eggshell before burning was (15µm) and after burning was (10. µm). The X-ray diffraction of eggshell powders indicated is shown in Figure (4).

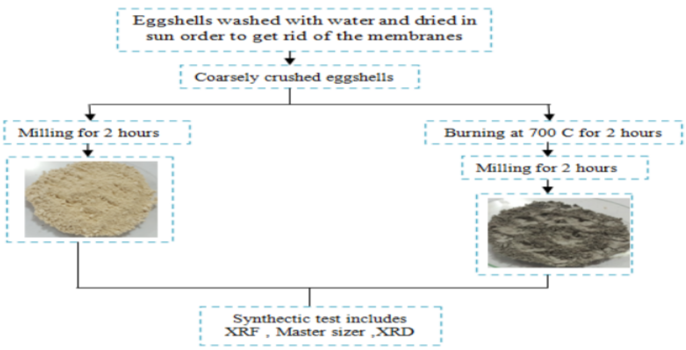


Figure (1) The steps for preparing eggshell powder and synthetic tests

Table (1) Chemical composition of eggshell

Chemical Composition	Ratio, % (Before burning)	Ratio% (After burning)
CaO	50.30	89
SiO_2	0.015	0.036
Al_2O_3	0.020	0.030
MgO	0.050	0.066
Fe_2O_3	0.05	0.10
Na_2O	0.50	0.75
P_2O_5	0.30	0.37
SrO	0.19	0.26
NiO	0.013	0.020
SO_3	0.60	0.75
Cl	0.022	0.031
K_2O	0.09	0.014
MnO	0.029	0.032
CuO	0.006	0.008
TiO_2	0.025	0.033
ZnO	0.0027	0.0030

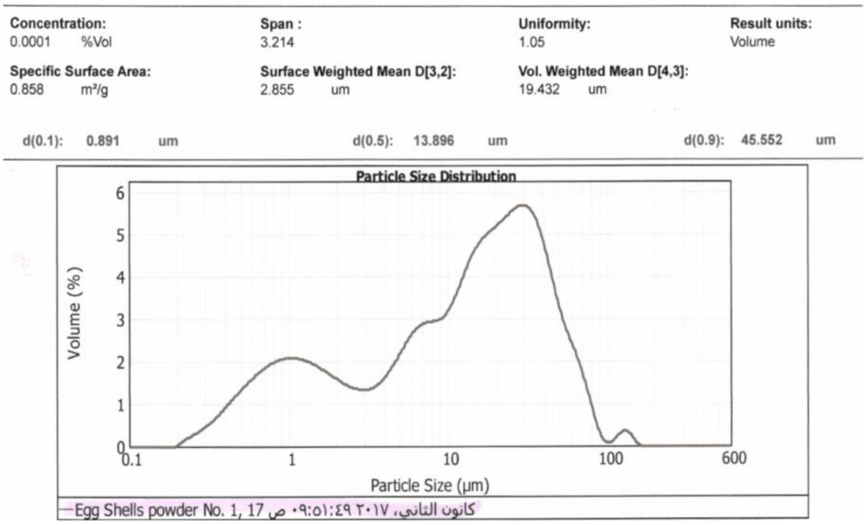


Figure (2) Particle size and distribution of eggshell particle before burning.

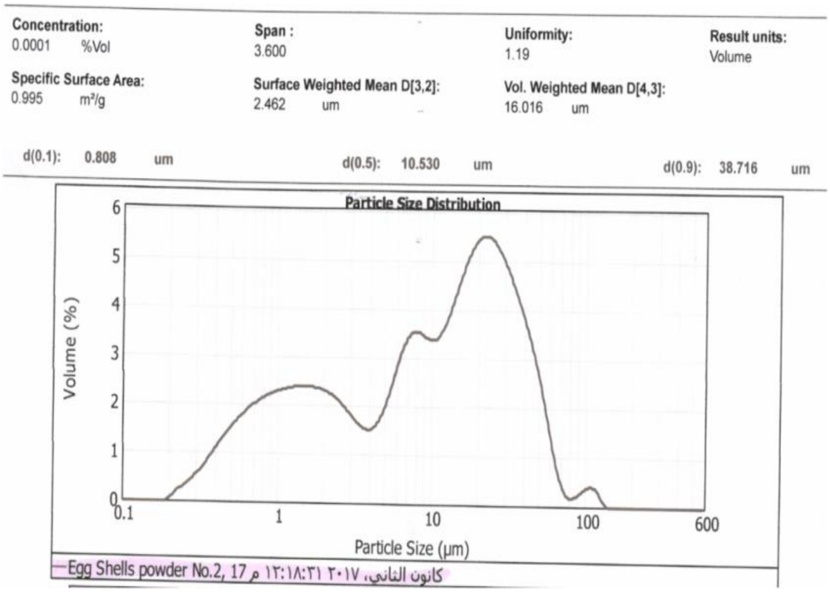


Figure (3) Particle size and distribution of eggshell particle after burning

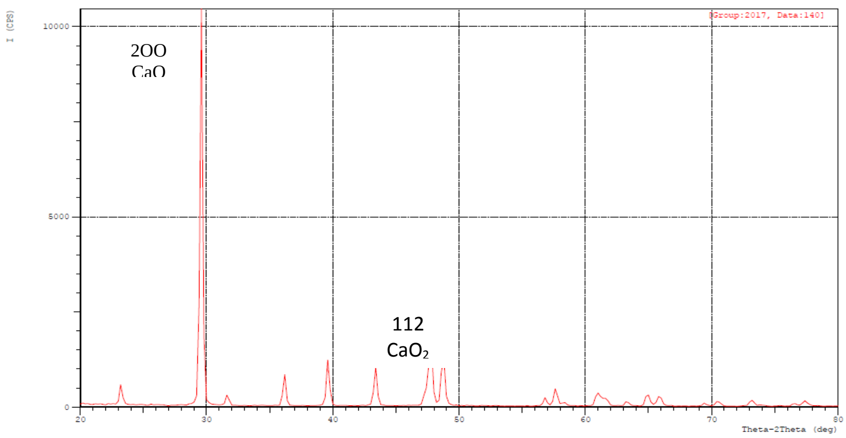


Figure (4) X-Ray Diffraction of eggshell powder

2.2 Methods and Preparation of Composite Test Specimens:

The mould used in this research is made from glass mould with dimensions (17cm ×17cm ×0.5 cm) covered with a glass plate to obtain a smooth surface of the prepared specimens by used the hand lay-up method [10&11]. Weighing the amount from eggshell powder and poly methyl methacrylate resin by using an electronic balance (with precision 0.0001 digits) for filling the mold cavities. The weight fractions of the matrix and strengthened materials by using theory of the rule of mixtures as shown in the relation were embellished below [12&13]. The eggshell powder should be mixed together with (liquid monomer MMA) at room temperature continuously and homogenized in order to produce composite material specimens. The specimens were processed by heat treatment at 55 ° C for three hours in order to less level of residual monomer and remaining stresses after removal of these specimens from the mold [14]. The specimens were cut according to ASTM (D 638-03 and ISO -180) for tensile and impact test. Table (2) shows the mixing ratio of the composite specimens described

Table (2) Mixing ratio of the composite specimens described.

Specimens	Composition (W.F)
	Before burning
A	100% PMMA
B1	99% PMMA +1% Eggshell
B2	97% PMMA+ 3% Eggshell
B3	95% PMMA + 5% Eggshell
B4	93% PMMA + 7% Eggshell
	After burning
C1	99% PMMA +1% Eggshell
C2	97% PMMA+ 3% Eggshell
C3	95% PMMA + 5% Eggshell
C4	93% PMMA + 7% Eggshell

$$Wp = \frac{wp}{wc}.100\% \quad (1)$$

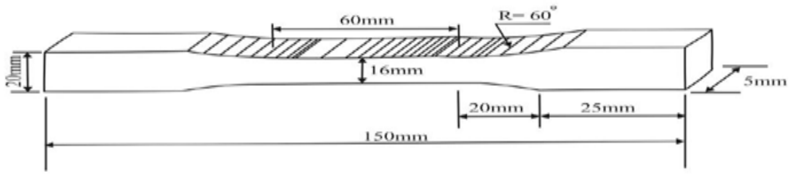
$$Wm = \frac{wm}{wc}.100\% \quad (2)$$

Where:
wp , wc, wm : weight of the particles, composite and matrix
Wp , Wm : weight fraction of the particles and matrix x

3. Mechanical Properties:

3.1 Tensile Properties:

Conduct a tensile test utilizing (UNIVERSAL TESTING MACHINE LARYEE) with a load of (50 KN) and strain rate (0.5 mm/min). Figure (5) shows the dimensions of the tensile specimen according to ASTM D 638-03 [15].



(a)

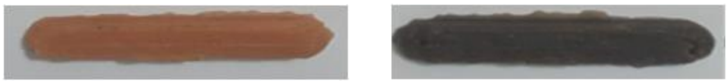
(b)

Figure (5) tensile test (a) standard, (b) specimen empirical.

3.2 Impact Properties:

Figure (6) shows the dimensions of the impact specimen according to standard (ISO-180) at the room temperature [16].

(a)



(b)

Figure (6) Impact test (a) standard, (b) specimen empirical.

4. Discussion of Results

4.1 Ultimate Tensile Strength

Standard deviation and mean values ultimate tensile strength of all specimens are illustrated in Table 3. From Table 3 the highest mean value of ultimate tensile strength was exhibited by C4 (72±2.646) followed by B4 (67.33±1.528), while the lower mean value of ultimate tensile strength was exhibited by C1 (59±2) followed by B1 (56±2). Table 4 indicates (one way ANOVA) statistical test done to study the effect weight fraction and process burning of eggshell on the values of ultimate tensile strength. There is a significant difference between all specimens, but the specimens (after burning) were highly significantly more than specimens (before burning) because two reasons: firstly the (Sig= .001) for specimens (after burning) was less than (Sig = .002) for the specimens (before burning), secondly; the values ultimate tensile strength rises with decreasing particle size of filler, where smaller particles of filler have a higher total surface area this leads to creating amply interfaces between the matrix resin and filler and increase in the ability of stress transport from the resin polymethyl methacrylate to the filler composite this agree with [8 & 17]**.** From Figure 7 can observe the specimen pure polymethyl methacrylate is weaker than other specimens reinforced with eggshell fillers because the matrix resin alone is unable to resist the tensile force applied to. The mechanical properties of polymer composite material, reinforced with different fillers are based on many factors such as good bonding strength, particle size, particle loading and active load transfer between the matrix resin and reinforced [18].

Table 3 (A-B) Standard deviation and mean values of ultimate tensile strength

(A) Specimens before eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
B1	3	56.00	2.000	1.155	51.03	60.97
B2	3	58.00	1.732	1.000	53.70	62.30
B3	3	60.33	2.517	1.453	54.08	66.58
B4	3	67.33	1.528	.882	63.54	71.13

(B) Specimens after eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	3	59.00	2.000	1.155	54.03	63.97
C2	3	60.67	2.517	1.453	54.42	66.92
C3	3	63.67	2.082	1.202	58.50	68.84
C4	3	72.00	2.646	1.528	65.43	78.57

Table 4 (A-B) ANOVA (One -Way) statistics analysis of ultimate tensile strength

(A) Specimens before eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	219.583	3	73.194	18.688	.002
Within Groups	31.333	8	3.917		
Total	250.917	11			

(B) Specimens After eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	300.333	3	100.111	18.482	.001
Within Groups	43.333	8	5.417		
Total	343.667	11			

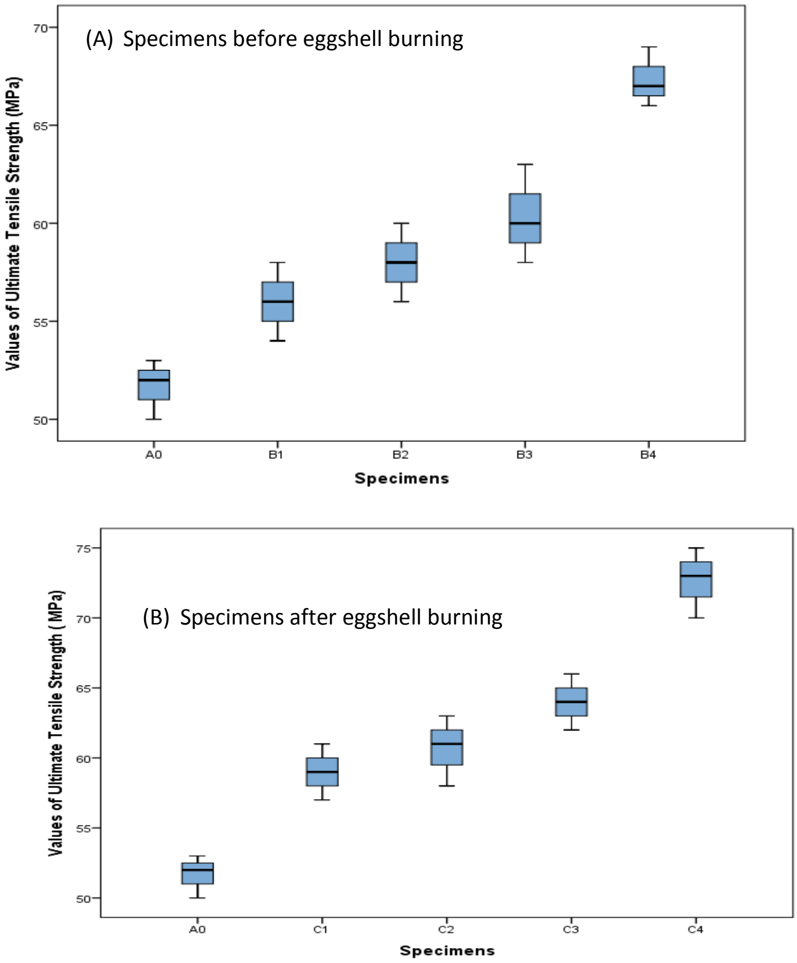


Figure 7 (A-B) Ultimate tensile strength of all specimens

4.2 Modulus of Elasticity

The result values of standard deviation, mean and (One-Way) ANOVA statistics analysis, and modulus of elasticity (with a different weight fraction of eggshell particles before and after burning), in polymethyl methacrylate matrix composite material is shown in Tables 5 & 6 and Figure 8. From Tables 5 it can be noted that the modulus of elasticity improved for the better with an increasing weight fraction of filler content in the polymethyl methacrylate resin matrix, the mean value modulus of elasticity was (3.267±3055 MPa) in (B4), (4.267±3055) in (C4) according to these results the weight fraction (7 wt. % eggshell particles after burned) has the greatest value mean when compared with other weight fractions (1%, 3% &5% eggshell particles). The reason increasing modulus of elasticity values may be related to good interface adherence strength between the matrix resin and filler content, where the addition eggshell particles with polymethyl methacrylate resin give young modulus higher than alone PMMA resin that leads to improving the stiffness of the composite. Table 6 shows the ANOVA statistical analysis test for specimens before and after eggshell burning with polymethyl methacrylate resin matrix composite material, the specimens reinforced with eggshell after burning to have more significant statistical differences (Sig < .001) than specimen reinforced with eggshell before burning (Sig < .004), as the smallest value (Sig ≤ 0.05) significant statistical differences great, this results agree with [19]. Figure 8 is shown the modulus of elasticity for specimens reinforced with eggshell particles after burning was superior to specimens eggshell reinforced with eggshell particles before burning. This is due to the mean particle size of eggshell after burning smaller than before burning, also the distributed regular and randomly of eggshell particles inside the polymethyl methacrylate resin and easiness the penetration of polymer matrix material, this leads to creating good interfaces between the matrix material and reinforcing material [20].

Table 5 (A-B) Standard deviation and mean values modulus of elasticity

(A) Specimens before eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
B1	3	2.233	.2517	.1453	1.608	2.858
B2	3	2.600	.2000	.1155	2.103	3.097
B3	3	2.733	.1528	.0882	2.354	3.113
B4	3	3.267	.3055	.1764	2.508	4.026

(B) Specimens after eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	3	2.833	.2517	.1453	2.208	3.458
C2	3	3.300	.2000	.1155	2.803	3.797
C3	3	3.700	.2000	.1155	3.203	4.197
C4	3	4.267	.3055	.1764	3.508	5.026

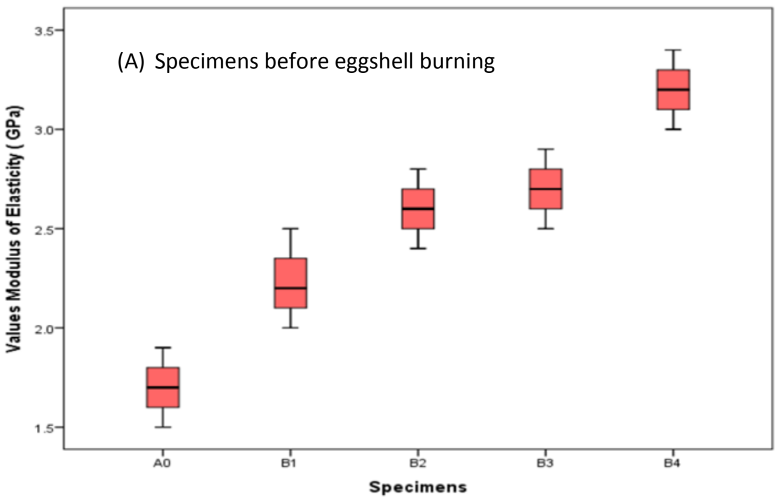
Table 6 (A-B) ANOVA (One- Way) statistics analysis modulus of elasticity

(A) Specimens before eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.649	3	.550	9.995	.004
Within Groups	.440	8	.055		
Total	2.089	11			

(B) Specimens after eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.329	3	1.110	18.756	.001
Within Groups	.473	8	.059		
Total	3.802	11			



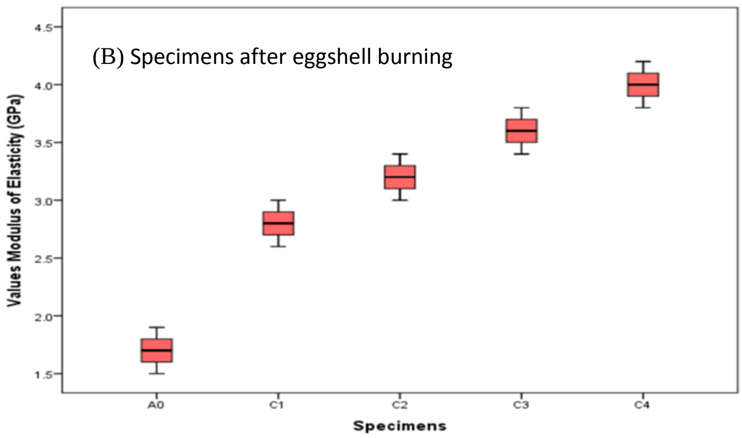


Figure 8 (A-B) Values modulus of elasticity

4.3 Elongation Percentage at Break

The elongation at break is a measurement of the ductility of polymer composite material. Tables (7&8) and Figure 9 are shown the value elongation percentage at break for poly methyl methacrylate resin strengthened with different weight fraction from the eggshell particle (before and after burning). Table 7 indicates the result mean values and standard deviation of elongation percentage at break of all specimens. The values percentage elongation at break (%) of specimens decrease with increasing weight fraction of the eggshell before and after burning ,where the mean value elongation percentage at break was (2.867±2517) in specimen (B1), (2.167±2082) in specimen (B4), (3.267±1525) in specimen (C1), (2.300±2646) in specimen (C4) from these values turns out the specimens strengthened with the eggshell particle after burning have elongation percentage at break better than specimens strengthened with the eggshell particle before burning, but decreases with increasing weight fraction. This is because the filler which larger sized particles offering more resistance to movement and thus the decreases the elongation percentage, also the elongation ratio values depends on the interface between filler and matrix [21]. There was statistically significant difference (Sig <0.05) in the elongation at break between all specimens in acrylic resin as shown in the Table 8, where value (Sig = .001) for specimens reinforced with eggshell after burning less than value (Sig = .014) value for specimens reinforced with eggshell before burning this indicates the specimens which give value (Sig ≤ 0.05) have better elongation properties. Figure 9 shows the specimen pure acrylic resin has a value elongation percentage at break higher when compared with other specimen composite materials. From tensile test can be observed the ultimate tensile strength and modulus elasticity improved the better with addition eggshell particles in polymethyl methacrylate resin due to the increased bonding area between polymer resin matrix and reinforced materials this agree with [22]. The decreased elongation percentage at break with increasing weight fraction eggshell particles may be due to the appearance of particles allows the stiffening influence within the matrix and so requires a mechanical limitation on the composites [8].

Table 7 (A-B) Standard deviation and mean value elongation percentage at break for

(A) Specimens before eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
B1	3	2.867	.2517	.1453	2.242	3.492
B2	3	2.600	.2000	.1155	2.103	3.097
B3	3	2.333	.1528	.0882	1.954	2.713
B4	3	2.167	.2082	.1202	1.650	2.684

(B) Specimens after eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	3	3.267	.1525	.0882	2.887	3.646
C2	3	3.000	.1000	.0577	2.752	3.248
C3	3	2.700	.2000	.1155	2.203	3.197
C4	3	2.300	.2646	.1528	1.643	2.957

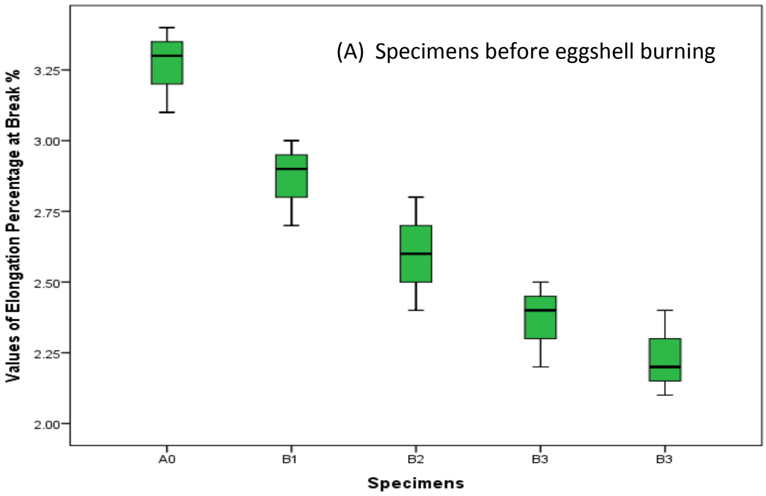
Table 8 (A-B) ANOVA (One- Way) statistics analysis of elongation percentage at break

(A) Specimens before eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.849	3	.283	6.660	.014
Within Groups	.340	8	.042		
Total	1.189	11			

(B) Specimens after eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.550	3	.517	14.419	.001
Within Groups	.287	8	.036		
Total	1.837	11			



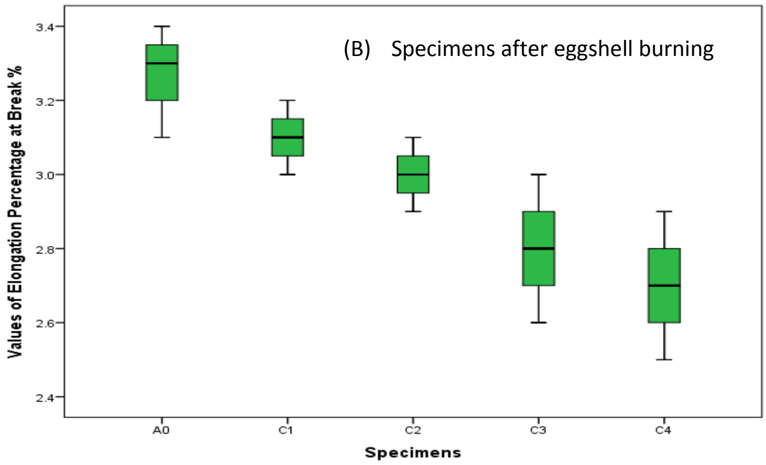


Figure 9 (A-B) Values elongation percentage at break

4.4 Impact Strength:

Tables 9 & 10 and Figure 10 shows the results of impact strength for all specimens. Table 9 illustrates the mean and standard deviation of impact strength for specimens (before and after burning). From this Table can be noted the mean and standard deviation value impact strength decreases with 7% weight fraction of filler content, where the mean and standard deviation value of specimens B3 and C3 (8.367±1528), (9.300±2000) respectively higher than specimens (B1, B2, B4, C1, C2, C4), also the mean and standard deviation value of specimens reinforced with eggshell after burning was higher than specimens reinforced with eggshell before burning. ANOVA statistic analyses between all specimens are shown in Table 10. From this Table can be shown the specimens reinforced with eggshell after burning has more significant statistical differences than specimens reinforced with eggshell before burning because the (Sig value) (.001) was less in specimens reinforced with eggshell after burning than (Sig value) (.002) in specimens reinforced with eggshell before burning, this result agree with [7].

Furthermore, the Figure 10 shows the addition 7% weight fraction of eggshell particles leads decrease in the impact strength values less than (1%, 3% and 5%) weight fraction of eggshell particles. This is due the high weight fraction of the filler content lead increase the stress concentration in the composite material and thus such tresses are enough to break the interactions at the interface and reducing the energy dissipation during the test this results agree with [23, 24].

Table 9 (A-B) Standard deviation and mean value of impact strength

(A) Specimens before eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
B1	3	7.400	.2000	.1155	6.903	7.897
B2	3	7.600	.1000	.0577	7.352	7.848
B3	3	8.367	.1528	.0882	7.987	8.746
B4	3	7.933	.2082	.1202	7.416	8.450

(B) Specimens after eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	3	7.833	.3055	.1764	7.074	8.592
C2	3	8.400	.3606	.2082	7.504	9.296
C3	3	9.300	.2000	.1155	8.803	9.797
C4	3	8.533	.2517	.1453	7.908	9.158

Table 10 (A-B) ANOVA (One- Way) statistics analysis values of impact strength

(A) Specimens before eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.609	3	.536	18.390	.002
Within Groups	.233	8	.029		
Total	1.842	11			

(B) Specimens after eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.283	3	1.094	13.401	.001
Within Groups	.653	8	.082		
Total	3.937	11			

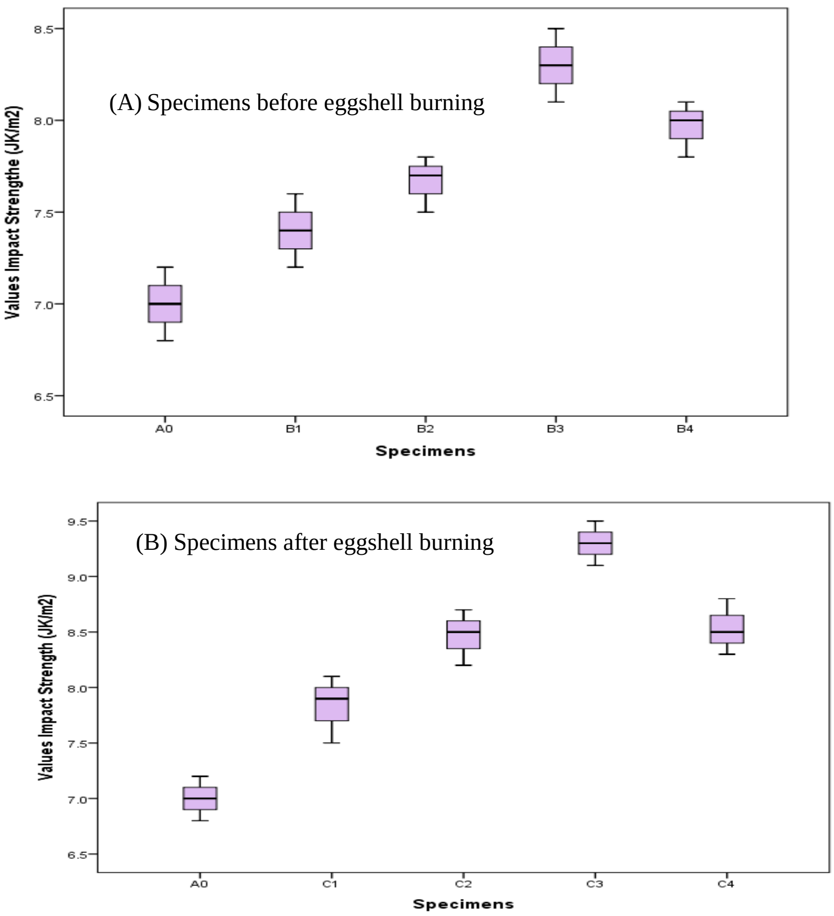


Figure 10 (A-B) Values of impact strength.

4.5 Fracture Toughness:

The result of the mean and standard deviation with ANOVA statistics of fracture toughness for all specimens within poly methyl methacrylate resin are illustrated in Tables 11&12 and Figure 11. From Table 11 can be observed the maximum mean values of fracture toughness was (6.1667±.18148) for specimen (B4), followed (6.6767±.25325) for specimen (C4). This indicates the fracture toughness increased with an increased weight fraction of the filler because of the strong effect positively in the impact strength and raises the impact energy required to break the specimens [25]. From Table12 ANOVA statistics analysis turns out that the values (Sig = .005, .003) less than 0.05 this means that the eggshell particle before and after burning have an effect on the fracture toughness compared with specimen neat acrylic resin. Figure 11 indicates the (KC) for neat acrylic resin are lower than other specimens reinforced with eggshell powder (before and after burning), because when added these fillers in the acrylic resin composite lead to hindering and obstacle the crack propagation in the materials and also these fillers improve bonding within the resin matrix with reinforced material these results agree with [17,26].

Table 11 (A-B) Standard deviation and mean value fracture toughness

(A) Specimen before eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
B1	3	4.4033	.22502	.12991	3.8444	4.9623
B2	3	5.1233	.22121	.12771	4.5738	5.6728
B3	3	5.7807	.19417	.11210	5.2983	6.2630
B4	3	6.1667	.18148	.10477	5.7159	6.6175

(B) Specimen after eggshell burning

Specimens	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	3	5.2267	.19218	.11096	4.7493	5.7041
C2	3	5.9233	.28290	.16333	5.2206	6.6261
C3	3	6.5373	.21601	.12471	6.0007	7.0739
C4	3	6.6767	.25325	.14621	6.0476	7.3058

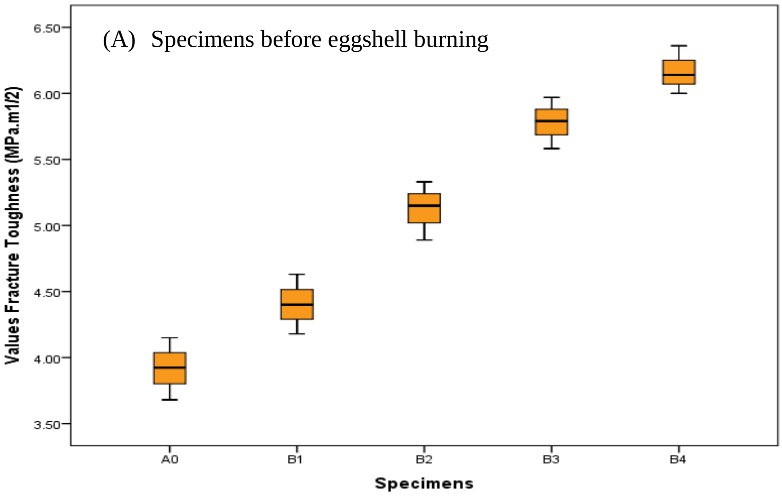
Table 12 (A-B) ANOVA (One- Way) statistics analysis of fracture toughness

(A) Specimen before eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.396	3	1.799	42.270	.005
Within Groups	.340	8	.043		
Total	5.736	11			

(B) Specimen after eggshell burning

Specimens	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.952	3	1.317	23.137	.003
Within Groups	.456	8	.057		
Total	4.408	11			



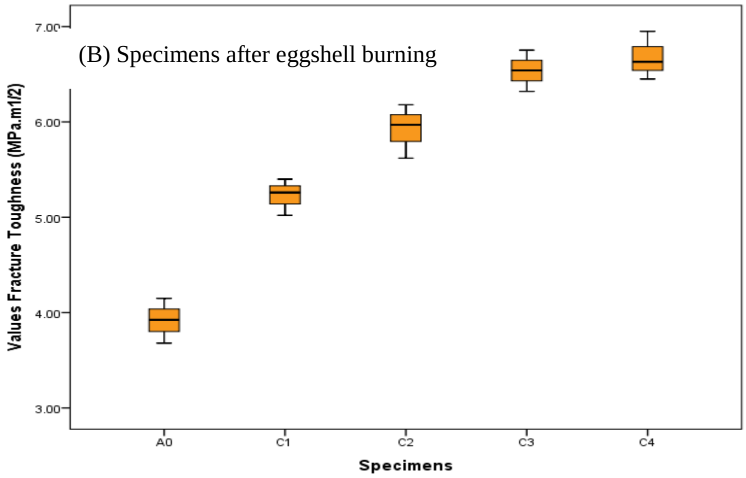


Figure 11 (A-B) Values of fracture toughness

3. Conclusions:

The results appeared in this research is incorporated the eggshell powder (before and after burning) into the acrylic resin improved the tensile strength, modulus of elasticity, impact strength and fracture toughness, also the largest mean values of tensile strength, modulus of elasticity and fracture toughness are found in specimens reinforced with (7%) weight fraction eggshell powder (before and after) burning. The specimens reinforced with (1%) weight fraction eggshell powder (before and after) burning have largest mean values of the elongation percentage at break, while the specimens reinforced with (5%) weight fraction eggshell powder (before and after) burning have largest mean values of impact strength. ANOVA (One – Way Analysis) it can be observed that specimens with values (Sig) less than 0.05 have the best mechanical properties.

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