Evaluation of Impact and Transverse Strength of Denture Bases Repaired with Nano Reinforced Resin

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ABSTRACT

Background: Failure of resin bases were a major disadvantage recorded in the constructed dentures. Reinforcements of the repair joint with nano fillers represent an attempt to enhance the strength and durability. The purpose of the research was to estimate the influence of nano fillers reinforcement with (ZrO_2 and Al_2O_3) on impact and transverse strength of denture bases repaired with either cold or hot processing acrylic resin.

Materials and methods: A hundred and forty (140) samples were processed with hot cured resin and organized in subgroups depending on the repair materials and condition (without repair (control), repair with hot cure, cold cure, hot and cold cure reinforced with either (5% Zr_2O or 0.5% Al_2O_3). The samples in these subgroups were processed depending on the test applied (impact and transverse strength). The samples were immersed in distalled water for about four weeks at 37°C before testing, after that, the samples prepared for each test were subdivided depending on the selected subgroups of the study. Repairing the samples with cold cure resin was done with the aid of Ivomet; after that the samples incubated for 48 hours in 37°C distilled water. Transverse strength test was done by using INSTRON universal testing machine while the impact test was done by using CHARPY impact testing machine.

Results: The reinforcement of the repair joint with nano-fillers improves both impact and transverse strengths.

Conclusion: Repair strength is directly proportional to the mode of resin processing, reinforcement with nano-fillers improve the strength of the repaired joint significantly.

Key words: Nano-fillers, reinforcement, repair joint. **(J Bagh Coll Dentistry 2016; 28(4):9-15)**

INTRODUCTION

The primarily aims of any denture repair were to recreate the pre-fracture strength of the denture and to preserve the durability of that denture for long time and with low cost. [1] The dentures were susceptible to fracture either by sudden impact outside the patient mouth [2], or by continuous bending inside the patient mouth during masticatory function and in this case the fracture site is expected to be near the midline. [3] Cold cured resin provide a fast and simple method for repairing fractured dentures, although the durability of the repaired denture is reduced rendering it clinically with inferior performance.[4] Also heat cured and now a day's light cured resin represent the most successful materials used in the repair of fractured dentures with better performance.[1]

The incorporation of the nano-fillers to the polymer matrix provides an opportunity for the enhancement of the mechanical properties of the resulted resin composite. This would be influenced by the ratio, adhesion between the polymer matrix and the fillers, configuration and structure and finally the chemical constituent of those fillers. [5] For example ZrO_2 and Al_2O_3 addition to the resin significantly enhance the impact and transverse strength of the denture base by consuming the amount of energy applied and arresting plastic deformation. [6]

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Also these fillers will not influence the esthetic qualities of the acrylic resin because of its white color. [7]

The aims of this study were to estimate the influence of nano-fillers incorporation (5%ZrO_2 and 0.5% Al_2O_3) on impact and transverse strength of denture bases repaired with either hot or cold cured resin and comparing the results with none repaired samples.

MATERIALS AND METHODS

A. The preparation of plastic mold:

Depending on the type on strength test intended, two plastic patterns were selected and made:

1. A rectangular pattern with dimensions of (65mm x 10mm x 2.5mm) was used for transverse strength test.
2. A bar pattern with dimensions of (80mm x 10mm x 4mm) was used for impact strength test.

B. The preparation of the stone mold:

A universal metallic flask was used for construction of the stone mold as illustrated in figure 1.

Figure 1: Metal flask used and stone mold construction.

Then after the removal of the plastic patterns the stone mold were ready for acrylic resin packing. The acrylic resin (spofa Dental, Europe) were mixed and packed in the stone mold following the recommendation of the manufacturer, after that the water bath processing was accomplished by using short cycle. Followed by bench cooling and deflasking, then samples retrieving with finishing and polishing. The samples were stored in 37°C distilled water for about four weeks. [8]

Samples repair for impact and transverse strength test:

1. Hot cured repaired samples:

The finished samples for transverse strength were attached to plastic orientation device made especially for this study had central groove with dimensions of (31mm × 10mm × 2.5mm). While for the impact strength the dimensions were (38.5mm ×10mm×4mm) for length, width and depth respectively.[9] These devices permit the samples to fracture with a bevel angle of 45° and provide a space of 3mm between the two halves of the sample. Then the space between them were filled with the repair resin material after painting the two halves with hot cured monomer by using zero degree fine brush for duration of 3 minutes. [10] Resin was manipulated according to manufacturer recommendations and processed in short curing cycles in a water bath curing machine for 1.5 hour at 74°C then 30 minutes at 100°C. Then the samples were allowed for bench cooling then deflasking was done and samples were retrieved, finished and polished before they were incubated at 37°C for 48 hours, and as shown in figure 2.

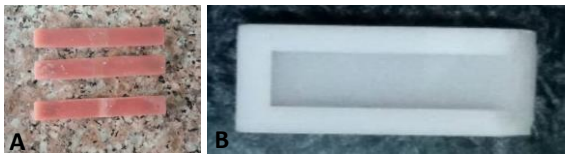

Figure 2: (A): Repaired samples ready for testing; (B): Plastic orientation device for sample holding.

2. Cold cured repaired samples:

The same procedure was done but cold cured monomer was used and the samples were cured by using an (Ivomet) machine (Palmat universal/ Kulzer) at 30 IB/Inch^2 with temperature of 37°C for 15 minutes. (11) The incorporation of either ZrO_2 or Al_2O_3 nano fillers were done to the repair materials which were either cold cured or hot cured acrylic resin.

Nano fillers incorporation to repair resin:

The silanated nano fillers were added to the monomer of the repair material weather it was hot or cold cured in order to provide chemical union between the nano-fillers and the resin matrix and by selection of the most appropriate concentration which were 5% for ZrO_2 and 0.5% for Al_2O_3 and the addition were accomplished with the aid of sonicated mixing device for a duration of 180 seconds in order to provide maximum desperation of the fillers to the monomer. [12, 13]

The strength testing of the samples:

1. For impact strength test:

A seventy samples were processed and became ready for testing, these samples include control without repair (10), 30 samples repaired with hot cured resin (10 without fillers, 10 with 5% ZrO_2 and 10 with 0.5% Al_2O_3) and another 30 samples repaired with cold cured resin (10 without fillers, 10 with 5% ZrO_2 and 10 with 0.5% Al_2O_3). The impact strength was measured by using Charpy type impact testing machine (Impact tester, N.43-1, INC.USA), the impact strength were estimated by the following equation; $I= E/bd \times 10^{3;}$ where I is Impact strength in (KJ/M2) and E is impact energy applied on samples in (J), b is width of the sample in (mm), d is thickness of the sample in (mm). The energy was applied at a scale of 2 (Joules).

2. For transverse strength test:

Another seventy samples includes: control without repair (10), 30 samples repaired with hot cured resin (10 without fillers, 10 with 5% ZrO_2 and 10 with 0.5% Al_2O_3) and another 30 samples repaired with cold cured resin (10 without fillers, 10 with 5% ZrO_2 and 10 with 0.5% Al_2O_3). The transverse strength was measured by using Instron universal testing machine, the transverse strength was estimated by the following equation S= 3PI/2bd2; where S is Transverse strength in (N/mm2) and P is peak load applied on samples in (N) and I is the space separating supporting holders in (mm), b is width of the sample in (mm), d is depth of the sample in (mm) the load was applied at a scale of 500 (N) with cross head speed of (1mm/min) and as shown in Figure 3 and 4.

Figure 3: Instron universal testing machine during sample testing.

Figure 4: Repaired samples after finishing the transverse strength testing.

Statistical analysis of the data of the study was done by using three ways analysis of variance (ANOVA) table to organize the data according to the addition of nano-fillers and their type in addition to the curing method and the confidence level were set at 95%. Also T-test was applied during making comparison between the means to detect the level of significant differences.

RESULTS

The findings of the impact and transverse strength tests were presented in tables 1&2 and figures (5) and (6).

Table 1: The data of means in (KJ/M^2) with standard deviations and standard error for impact strength test.

Groups	Mean	S.D.	S.E.	Min.	Max..
Control	8.70	0.57	0.26	7.77	9.2
Cold alone	3.73	0.17	0.08	3.52	3.99
Cold& ZrO_2	4.46	0.54	0.24	3.54	4.87
Cold& Al_3O_2	3.44	1.07	0.48	2.08	4.65
Hot alone	6.14	0.46	0.21	5.35	6.46
Hot & ZrO_2	7.01	0.84	0.37	6.02	8.07
Hot & Al_3O_2	6.58	0.39	0.18	6.06	7.16

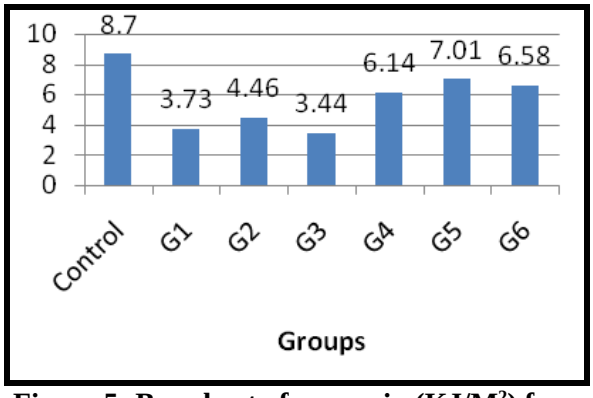

Figure 5: Bar chart of means in (KJ/M^2) for impact strength test.

Table 2: The data of means in (N/mm^2) with standard deviations and standard error for transverse strength test.

Groups	Mean	S.D.	S.E.	Min.	Max.
Control	99.08	6.71	3.00	90	106.8
Cold alone	62.66	2.08	0.93	61.2	66
Cold& ZrO_2	67.80	4.28	1.92	63.6	73.2
Cold& Al_3O_2	55.68	1.96	0.88	54	58.8
Hot alone	65.22	2.45	1.10	61.2	67.2
Hot & ZrO_2	77.64	5.24	2.34	72.4	85.2
Hot & Al_3O_2	83	3.46	1.55	79.6	87.6

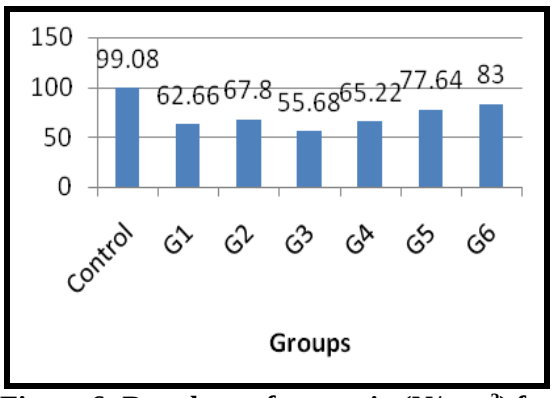

Figure 6: Bar chart of means in (N/mm^2) for transverse strength test.

For the F test and ANOVA table for the detection of differences between groups and within groups, the data revealed high significant difference for both impact and transverse strength tests and these findings were shown in table 3 and 4.

Table 3: F-test and ANOVA table for comparison of the groups and between groups for impact strength test.

Groups	Sum of square	d.f	M.S.	F-test	P-value
Between groups	111.13	6	18.52	45.4	0.000 HS
Within groups	11.41	28	0.41		
Total	122.55	34			

Table 4: F-test and ANOVA table for comparison of the groups and between groups for transverse strength test.

ANOVA	Sum of squares	d.f	M.S.	F-test	P-value
Between groups	6480.81	6	1080.14	64.68	0.000 HS
Within groups	467.57	28	16.70		
Total	6948.38	34			

For the comparison between the control and various experimental groups, the results revealed that for impact strength test, all the experimental groups showed high significant reduction in the impact strength and as illustrated in table 5.

Table 5: t test for the comparison between the control and the experimental groups for impact strength test.

Groups	t-test	d.f.	p-value	Sig.
Control &Cold Alone	18.523	8	0.000	HS
Control &Cold ZrO_2	12.081	8	0.000	HS
Control &Cold Al_2O_3	9.699	8	0.000	HS
Control &Hot Alone	7.777	8	0.000	HS
Control & Hot ZrO_2	3.721	8	0.006	HS
Control & Hot Al_2O_3	6.832	8	0.000	HS

And for the transverse strength test, also the data showed that all the experimental groups showed high significant reduction in the transverse strength, and as revealed in table 6.

Table 6: t test for the comparison between the control and the experimental groups for transverse strength test.

Groups	t-test	d.f.	p-value	Sig.
Control &Cold Alone	11.597	8	0.000	HS
Control &Cold ZrO_2	8.788	8	0.000	HS
Control &Cold Al_2O_3	13.886	8	0.000	HS
Control &Hot Alone	10.603	8	0.000	HS
Control & Hot ZrO_2	5.634	8	0.000	HS
Control & Hot Al_2O_3	4.764	8	0.001	HS

Effect of Nano addition:

For the effect of nano fillers reinforcement to the repair media when compared with repair without reinforcement, the data revealed non-significant improvements for all repair medias reinforced with nano-fillers except for repair with cold cure with ZrO_2 which revealed significant improvements in the impact strength (table 7).

Table 7: t test for comparison between groups reinforced with nano-fillers with the non reinforced one, for impact strength test.

Groups	t-test	d.f.	p-value	Sig
Cold Alone & Cold ZrO_2	-2.901	8	0.020	S.
Cold Alone & Cold Al_2O_3	0.607	8	0.561	NS
Hot Alone & Hot ZrO_2	-2.035	8	0.076	NS
Hot Alone & Hot Al_2O_3	-1.601	8	0.148	NS

While for transverse strength test, the data revealed significant improvements for all repair medias reinforced with nano-fillers except for repair with cold cure with Al_2O_3 which revealed high significant reduction in the transverse strength and as shown in table 8.

Table 8: t test for comparison between groups reinforced with nano-fillers with the non reinforced one, for the transverse strength test.

Groups	t-test	d.f.	p-value	Sig
Cold Alone & Cold ZrO_2	-2.413	8	0.042	S
Cold Alone & Cold Al_2O_3	5.460	8	0.001	HS
Hot Alone & Hot ZrO_2	-4.805	8	0.001	HS
Hot Alone & Hot Al_2O_3	-9.381	8	0.000	HS

Effect of polymerization methods:

For the effect of polymerization methods the data revealed high significant improvements for all repair with hot cure resin when compared with cold cure one for all groups in the impact strength (table 9).

Table 9: t test for comparison between groups repaired with cold cure resin with groups repaired with hot cured one, for the impact strength test.

Groups	t-test	d.f.	p-value	Sig
Cold Alone & Hot Alone	-11	8	0.000	HS
Cold ZrO_2& Hot ZrO_2	-5.747	8	0.000	HS
Cold Al_2O_3& Hot Al_2O_3	-6.165	8	0.000	HS

While for transverse strength test, the data revealed significant improvements for all repair with hot cured resin compared with cold cured one except for repair with cold cure alone compared with hot cured alone which revealed non significant improvement in the transverse strength (table 10).

Table 10: t test for comparison between groups repaired with cold cure resin with groups repaired with hot cured one for the transverse strength test.

Groups	t-test	d.f.	p-value	Sig
Cold Alone & Hot Alone	**-1.782**	**8**	**0.113**	**NS**
Cold ZrO_2& Hot ZrO_2	**-3.252**	**8**	**0.012**	**S**
Cold Al_2O_3& Hot Al_2O_3	**-15.363**	**8**	**0.000**	**HS**

Effect of nano-fillers type:

For the effect of nano fillers type the data revealed non-significant reduction for all repair groups reinforced with Al_2O_3 nano-fillers compared with groups repaired with ZrO_2 for the impact strength (table 11).

Table 11: t test for comparison between groups repaired with Al_2O_3 with groups repaired with ZrO_2 for the impact strength test.

Groups	t-test	d.f.	p-value	Sig
Cold ZrO_2& Cold Al_2O_3	1.915	8	0.092	NS
Hot ZrO_2& Hot Al_2O_3	1.055	8	0.322	NS

While for transverse strength test, the data revealed high significant reduction of cold cured repaired with Al_2O_3 compared with groups repaired with ZrO_2. While for the hot cured repair; it revealed non-significant improvement in the transverse strength when the Al_2O_3 fillers were used compared with ZrO_2 (table 12).

Table 12: t test for comparison between groups repaired with $Al_2O_3$with groups repaired with ZrO_2 for the transverse strength test.

Groups	t-test	d.f.	p-value	Sig
Cold ZrO_2& Cold Al_2O_3	5.750	8	0.000	HS
Hot ZrO_2& Hot Al_2O_3	-1.910	8	0.093	NS

DISCUSSION

Numerous techniques were existed to restore the fractured resin dentures to their original strength the preparation of the surfaces and sites to be joined are of paramount significance of ensuring prolonged service life of the prosthesis. Mechanical or Chemical treatment were introduce to change the joint surface morphology or by improving the acrylic resin surface chemistry of better adhesion promotion. [28]

The addition of fillers in the form of nano particles had a various shapes and sizes into a resin polymer that serve as a composite matrix which improve the mechanical behavior of the resulted composite material. [30]

The results of the present study were explained according to the influence of each variable involve in the study and its relevant effect on both the impact and transverse strength and as follows:

A. Effect of nano-fillers incorporation:

The impact strength was improve after the incorporation of nano-fillers and the maximum improvement were noticed when the repair were done with cold cured acrylic reinforced with Zr_2O nano-fillers as shown in table (7). The explanation were that the spaces formed around the nano-fillers leads to improvement in the impact strength by altering the pathway of growing cracks as a result of the perfect bond strength between the nano-fillers and polymer matrix. Also the growing cracks were arrested due to the nano-fillers being protected by formation of internal cross linking shear bonds between the fillers and the polymer matrix leading to increase the molecular bonding weight. [14, 23]

The transverse strength, were improved by the addition of both types of nano-fillers, table (8). This is due to that these fillers were perfectly spread inside the polymer matrix and when the polymerization temperature where applied during curing, these fillers will attains the alpha phase which is the requested phase characterized by high stable hexagonal configuration, so when the mechanical stress builds up during testing, and growing cracks start to develop, this hexagonal configuration initiated and consume the mechanical energy necessary for cracks union and fracture developments. [15, 25, 26]

On the other hand, the reduction in the transverse strength of the samples repaired with cold cure reinforced with Al_2O_3 had many explanatory reasons which may be due to; the concentration of too many stresses by high concentration of fillers which in turn changing the modulus of elasticity of the resin to be more stiff and void formation and air entrapment which will behave as weakening points for the continuity of the matrix resulting in facilitating the spread of the cracks inside the vicinity of the matrix with reduction in the total area of force distribution. Also, spaces creation in the polymer matrix with insufficient unity between the fillers and polymers may also play role for such finding. [16, 24]

B. Effect of polymerization methods:

All tested groups repaired with hot cured resin leads to high significant improvements in both impact and transverse strength (table 9, 10). This attributed the higher curing temperature and pressure applied during heat polymerization leading to more softening effects on the repaired joints and better spreading of the repair medium with stronger repair joint [17], in addition the nano-fillers added to the resin will reduce the amount of coefficient of thermal expansion due to the great interfacial interaction between the resin matrix and nano-fillers which result in limitation of polymer mobility [27], while the cold curing repair resin is cured with lower amount of pressure applied leading to the formation of porosities from the internal type and also the higher amount of residual monomer contributed to the formation of many voids inside the repair medium, these spaces will act a stress concentration area facilitating the micro cracks creation and propagation of cracks to total failure when load is applied. [17, 5]

C. Effect of nano-fillers type:

For the impact strength testing and for all curing methods, table 11 revealed that repairing with ZrO_2 nano-fillers leads to non-significant improvement when compared with Al_2O_3 nano-filles and that's because of the conversion of both ceramic fillers leads to higher molecular volume exerting pressure on the supporting resin matrix leading to inhibition in crack propagation [18], and the metal oxide with saline coupling agent will reduce the amount of water absorbing by polymer by decreasing the voids between the resin matrix

and nano-fillers leading to less water sorption and overall improvement in mechanical properties. (29)

The transverse strength was reduced when repairing was done with cold cured acrylic reinforced with Al_2O_3 nano-fillers and this was attributed to the harmful effect of the weak bond strength between the nano-fillers and the polymer matrix compared with the ZrO_2. (19)

The result revealed that during repair with hot cured resin reinforced with Al_2O_3 nano-fillers the transverse strength were non significantly improved and this explained by the fact that the crystals configuration of that fillers tends to be converted to the highly fixative alpha hexagonal structure during application of increasing temperature as for example, hot curing. So, when loads are applied during the transverse strength testing, the conversion will be started simultaneously with the cracks developments and propagation, also this configuration will consume the fracture energy and arrest the fracture. (20) While for the repair with hot cure resin reinforced with ZrO_2, the transverse strength were reduced due to that the higher processing temperature will resulted in higher range of conversion from tetragonal to monoclonic crystal configuration accompanied by plastic deformation which will negatively affect its strength and shelf life.(21,22)

REFERENCES

1. Stipho HD, Stipho AS. Effectiveness and durability of repaired acrylic resin joint. J Prosthet Dent 1987; 58: 249-53.
2. Stipho HD. Repair of acrylic resin denture base reinforce with glass fiber. J Prosthet Dent 1998; 80: 546 -50.
3. Beyli MS, von Fraunhofer JA. An analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent 1981; 46(3): 238-41.
4. Nitkin DA, Sponzo MT. Simplified denture repair technique. J Prosthet Dent 1979; 41: 355-7.
5. Jordan J, Jacob KL, Shart MA. Experimental trends in polymer. Nano-composites – A review. Mater Sci Eng 2005; 393:1-11.
6. Asar NV, Hamdi A, Turan K, Ilser T. Influence of various metal oxides on mechanical and physical properties of heat-cured polymethyl methacrylate denture base resins. J Adv Prosthodont 2013; 5: 241-7.
7. Ichikawa Y, Akagawa Y, Nikai H, Tsuru H. Tissue compatibility and stability of a new zirconia ceramic in vivo. J Prosthet Dent 1992; 68(2): 322-6.
8. Polyzois GL, Tarantili PA, Frangou MI, et al. Fracture force, deflection at fracture, and toughness of repaired denture resin subjected to microwave polymerization or reinforced with wire or glass fiber. J Prosthet Dent 2001; 86: 613-9.
9. Al-Nadawi LM. The effect of different surface treatment and joints surface shapes on some mechanical properties of the repaired acrylic denture base resin cured by two different techniques. A master thesis, College of Technology, University of Technology 2005.
10. Hasan RH. Denture teeth bond strength to heat water bath and microwave cured acrylic denture base material. Comparative study. A master thesis, College of Dentistry, Mosul University, 2002.
11. Al-Mudarris BA. Effect of metal inserts on the transverse strength and deflection of repaired acrylic specimens. A master thesis, College of Dentistry, University of Baghdad, 1999.
12. Safi IN. Evaluation of the effect of modified nanofillers addition on some properties of heat cure acrylic resin denture base material. A master thesis, Department of Prosthetic Dentistry, College of Dentistry, University of Baghdad, 2011.
13. Muklif OR. Studying the effect of addition a composite of silanized Nano-Al_2O_3 and plasma treated polypropylene fibers on some physical and mechanical properties of heat cured PMMA denture base material. A master thesis, College of Dentistry, University of Baghdad, 2015.
14. Sun L, Gibson RF, Gordaninejad F, Suhr J. Energy absorption capability of nanocomposites: a review. Composites Sci Technol 2009; 69(14): 2392-409.
15. Ayad NM, Badawi MF, Fatah AA. Effect of reinforcement of high-impact acrylic resin with zirconia on some physical and mechanical properties. Rev clín pesq odontol (Impr.) 2008; 4(3): 145-51.
16. Grant AA, Greener EH. Whisker reinforcement of polymethyl methacrylate denture base resins. Australian Dent J 1967; 12(1): 29-33.
17. Dhiman RK, Chowdhury SK. Midline fracture in single maxillary complete acrylic vs. flexible denture. M Jafi J 2009; 65:141-5.
18. Stevens R. An introduction to zirconia; zirconia and zirconia ceramics. 2nd ed. Twickenham; Magnesium elekrtum; 1986.
19. Chaijareenont P, Takahashi H, Nishiyama N, Arcsornnukit M. Effect of different amounts of 3-methacryloxypropyltrimethoxysilane on the flexural properties and wear resistance of alumina reinforced PMMA. Dent Mater J 2012; 31(4): 623–8.
20. Ellakwa AE, Morsy MA, EI-sheikh AM. Effect of Aluminum oxide addition on the Flexural strength and thermal diffusivity of heat-polymerized acrylic resin. J Prosthodont 2008; 17: 439-44.
21. Chevalier J, Olagnon C, Fantozzi G. Subcritical crack propagation in 3Y-TZP ceramics: static and cyclic fatigue. J Am Ceram Soc 1999; 82: 3129-38.
22. Studart AR, Filser F, Kocher P, Gauckler LJ. *In vitro* lifetime of dental ceramics under cyclic loading in water. Biomaterials 2007; 28: 2695-705.
23. Ahmed MA, Ebrahim MI. Effect of zirconium oxide nano-fillers addition on the flexural strength, fracture toughness and hardness of heat polymerized acrylic resin. World journal of nano science and engineering 2014; 4: 50-7.
24. Arora P, Singh SP, Arora V. Effect of alumina addition on properties of poly-methyl methacylate-a comprehensive review Int J Biotech trends stech, IJBTT 2015; (9): 1-7.
25. Jasim BS, Ismail IJ. The effect of silanized alumina Nano-filling addition on some physical and mechanical properties of heat cured polymethyl methaglate denture base material. J Bagh Coll Dentistry 2014; 26(2): 18-23.
26. Satarabadi M, Kharcari NM, Rezai A. An experimental investigation of HA/AL_2O_3 Nanoporticles on mechanical properties of restoration

materials. Engineering Solid Mechanics 2014; 173-182.
27. Safi IN. Evaluation of the effect of Nano-fillers (TiO_2, AL_2O_3, SiO_2) addition on glass transition temperature, E-Medulas and Coefficient of thermal expansion of acrylic denture base material. J Bagh Coll Dentistry 2014; 26(1): 37-41.
28. Memarian M, Shayestenmj JM. The effect chemical and mechanical treatment of the denture base resin surface on the shear bond strength of the denture repairs. Rev Clin Odontol Curitiba 2009; 5(1): 11-17.
29. Asar NV, Albayrak H, Korkmaz T, Turkyilmaz I. Influence of varies metal oxides on mechanical and physical properties of heat-cured J Adv Prosthodont 2013; 5: 241-7.
30. Hasan SAB, Dimitrijevic MM., Kojovic A, Stojanovic DB, Dwicic KO, Heinemann KMJ, Aleksic R. The effect of the size and shape of alumina nanofillers on the mechanical behavior of the PMMA Matrix campsite. J Serb Chem Soc 2014; 79(10): 1295-307.