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The effect of polyamide microparticles addition on some mechanical properties of light-cured acrylic resin

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ABSTRACT

The general upgrading of polymer denture base material and research continuously looking for ideal restorative dental material with better properties, adequate esthetic properties, less expensive and easier to handle material to develop photo polymerization dental materials. This study was conducted to evaluate the effect of addition polyamide on mechanical microparticle properties light cure denture base material. One hindered sixty specimens from light-cured acrylic resin (Aurora). The divided mainly into four groups according to test used (Transverse strength test, impact strength test, hardness test and tensile strength test) with 40 specimens for each group. The results show an increase in Transverse strength, impact strength, hardness and tensile strength in all experimental group when compared to control group the highest mean values for all tests included in the study appeared in group B 1% polyamide. The addition of polyamide microparticle improves transverse, tensile, impact strength and hardness properties of denture base material.

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INTRODUCTION

Polymethylmethacrylate PMMA is the material used since 1930 for dental prosthesis removable complete and partial denture and temporary fixed partial denture, also use for implant supported overdenture (Straioto FG, Alves R. 2010; Akin H *et al.,* 2011).

The general upgrading of polymer denture base material and research continuously looking for ideal restorative dental material with better properties, adequate esthetic properties, less expensive and easier to handle material to develop photo polymerization dental materials (Assery MK, Al-Shamrani SM. 1995; Fellman S. 1989; Rueggeberg FA. 2002) removable prosthodontic and in 1984 developed continuity, triad type of light cure resin was introduced to the market which suitable for fixed, removable and maxillofacial prosthesis (Barateri L. 1998; Andreopoulos A, *et al.,* 1991).

The use of photopolymerization resin material has several advantages. (Bural C, *et al.,* 2011; Jorge JH, *et al.,* 2003) the biocompatibility of material due to less residual mono methylmethacrylate which dissolve in human saliva and cause erythema burning sensation and hypersensitivity on mucosa and tongue as reported by Tanoue et al. (Hugger A, Stüttgen U. 2005; Pfeiffer P, *et al.,* 2008; Tanoue N, *et al.,* 2005).

Many research demonstrated the various type of fiber reinforcement photo polymerization resin material improvement in mechanical properties such as Kevlar fiber (Berrong JM, *et al.,* 1990), carbon fiber (DeBoer J, *et al.,* 1984; Fatihallah AA. *et al.,* 2016), polyethylene fiber (Dixon DL & Breeding LC 1992; Natarajan P & Thulasingam C 2013), glass fiber (Stipho H. 1998; Vallittu PK. 1997) and metallic fiber (Vallittu P, Lassila V 1992).

Polyamide (nylon 6) is thermoplastic polymers, considered as one of the most used types of aliphatic polyamide produced by condensation a diamine with dibasic acid (Ucar Y, *et al.,* 2012). The polyamide use as polymer denture base in 1950 (Phoenix RD, *et al.,* 2004) but because of its properties (high water absorption and discoloration tendency) stop use as primary denture base material and only use for reinforcing denture as fibers, powder and films. The polyamide reinforces denture because of its ability to increase resistance to fracture due to sudden or repeating stress and providing high modulus to the material of denture above the glass transition temperature (Tg) (Vlasveld D, *et al.,* 2005).

The goal of the study was to evaluate some mechanical properties of light-activated PMMA by reinforcement with polyamide micro powder.

MATERIALS AND METHODS

One hindered sixty specimens was prepared from light cure acrylic resin (aurora). They divided mainly into four groups according to test used (Transverse strength test, impact strength test, hardness test and tensile strength test) with 40 specimens for each group.

Each group consist of 4 subgroups;

A = with 0 % polyamide (10 specimens) as control
B = with 0.5 % polyamide (10 specimens)
C = with 1 % polyamide (10 specimens)
D = with 1.5 % polyamide (10 specimens)

The plastic pattern for each test was prepared by laser cutting machine according to standardization;

Transverse and hardness test ADA specification no 57, 12 (1999) (Fatihallah AA, *et al.,* 2018)
Impact test ISO 180 (2000) (Dilara P, Briassoulis D. 1998)
Tensile test ISO 527:1993(Yu S-H, *et al.,* 2013)

The polyamide powder weighting by use electron digital balance into 0.5%, 1%, 1.5% by weight then added to liquid of light cure after that powder was added and mixing by auto mixer for 5 min. and applied into plastic mold over glass palate which prepared previously with standard dimension after lubricated with separated media (cold mold seal) after applied polymerized material was pressed into the mold. Superior lubricated glass slab was placed onto the superior surface of the mold to ensure that a fiat parallel surface was formed. The glass slab was removed, and the mold was placed in the Triad unit and was polymerized for 5 minutes. The specimen was removed from the mold, placed in the unit again with the uncoated side facing down, and polymerized for 5 minutes. After complete polymerization, all specimen inspect for any defect before tested.

Transverse strength test

The specimens fabricated were with dimensions of (65mmx10mmx2.5mm), length, width and thickness respectively. After conditioning in the water at 37°C for 48 hrs the samples were subjected to a 3 point bending test using an Intron machine (Laree CO., Ltd. China). The stress was recorded, and determination of the transverse strength follows this formula (Fatihallah AA, *et al.,* 2018).

Transverse strength= 3PI/2bd2 (25) where;

P: is the peak load
I: is the span length
B: is the sample width
D: is the sample thickness

Impact strength

Specimens were kept in distilled water for 48 hrs. At 37°C before being tested. Rectangular samples of dimension (80mmx10mmx4mm) were fabricated. The test was performed using Izadi impact testing machine (Time testing machine, China) (25). The energy absorbed by the un-notched specimens was calculated using this equation:

Impact strength= (E/bud) x103, where;

E: is the impact energy absorbed in joules
B: is the width of the sample
D: is the thickness of the sample

The tensile strength

The samples were prepared with dimension according to ISO 527:1993 (Fatihallah AA. *et al.,* 2016). The test specimens grip suitable for holding of Intron testing machine. Each specimen was set at a crosshead speed of 0.5 mm/min chart speed. For each Specimen loaded was recorded when its fracture, and a load of fracture from the Instron graph reader in kilograms (kg) which were converted into Newton (N).

The values of tensile strength were calculated.

For each sample according to the following;

Formula TS = F/A Where;
TS = Tensile strength (N/m^2)
(Then converted to MPa)
F = force at failure (N)
A= Area of the cross section at failure (m^2)

Surface hardness

The samples were prepared with a dimension of (65mmx10mmx2.5mm) and stored in distilled water for 48hrs. At 37°C (Fatihallah AA. *et al.,* 2016; Fatihallah AA, *et al.,* 2018). Shore D hardness tester (Glucometer, Germany) with a calibrated scale

Table 1: Transverse strength, impact strength, hardness and tensile strength mean and standard deviation for the control group and experimental groups

groups	Control A		B		C		D	
test	mean	S.D.	mean	S.D.	mean	S.D.	mean	S.D.
Transverse strength	46.96	1.83	56.08	1.81	72.04	4.35	53.18	1.36
Impact strength	0.32	5.44	6.01	0.19	5.58	0.33	6.07	0.4
hardness	101.8	1.22	105.6	7.82	104.4	2.07	84.62	3.42
Tensile strength	24.70	2.62	25.08	2.40	25.80	1.71	17.06	4.10

Table 2: Transverse strength, impact strength, hardness and tensile strength ANOVA test between the control group and experimental groups

test	Sum of Squares		df	Mean Square	F test	P value	Sig.
Transverse strength	Between Groups	1713.245	3	571.082	83126	.000	HS
	Within Groups	109.921					
impact strength	Between Groups	1.463	3	.488	4.685	.016	HS
	Within Groups	1.665					
hardness	Between Groups	1436.501	3	478.834	24.309	.000	HS
	Within Groups	315.168					
Tensile strength	Between Groups	251.188	3	83.729	19.371	.000	HS
	Within Groups	69.160					

Table 3: Transverse strength, impact strength, hardness and tensile strength LSD multiple comparison test between the control group and experimental groups

LSD		Transverse strength		impact strength		hardness		Tensile strength	
		Sig.		P value	Sig.	P value	Sig.	P Value	Sig.
control A	B	.000	HS	.029	S	.000	HS	.776	NS
	C	.000	HS	.772	NS	.000	HS	.415	NS
	D	.002	HS	.007	S	.000	HS	.000	HS
B	C	.000	HS	.051	5	.675	NS	.592	NS
	D	.099	NS	.502	NS	.368	NS	.000	HS
C	D	.000	HS	.013	HS	.195	NS	000	HS

NS: Not significant at P> 0.05; S: Significant at P< 0.05; HS: Significant at P< 0.01

from (0-100 units) was used. The final value of this test was obtained by calculating the average value of 5 readings performed for each sample. All measurements were done by one person.

RESULTS

The (SEM) examination of the fractured impact portion are shown in Figure structural image of specimens from all groups shown in the figure can be seen polyamide in denture base material.

Phase analysis was studied using 3121 powders X-ray Diffractometer using Cu K radiation. The 2Θ angles were swept from 20-80° instep of one degree. The XRD (fig 4) shown powder of polyamide A and polyamide powder with light cure acrylic B. it could see polyamide peak at 20.83 which disappear when mixed with light cure acrylic.

The result in table 1 shown transverse strength in all experimental group is higher than the control group, and highest result obtains with group c (1% polyamide) as mean value (72.04) while control group mean value (46.96) which was statistically significant as shown in table 2.

The impact strength was statistical highly significant as shown in table 2, and higher impact strength was obtained by adding 1% polyamide powder. The hardness and tensile strength was increased by increase ratio of polyamide to light cure acrylic until 1% as mean value for addition 0.5% of polyamide (hardness 105.6, tensile 25.08) and for 1% polyamide (hardness 104.4, tensile 25.8) then drop to (hardness 84.6, tensile 17.06) by adding 1.5% polyamide.

When applying ANOVA Table with multiple comparison least significant difference test to compare the mean values within for each test there were highly significant differences between and within groups for surface hardness, transverse strength and impact strength test (P values < 0.01), while no significant differences found between and among groups compared in surface roughness test. (Table 2 and 3).

DISCUSSION

The photopolymerization resin material is one of developed polymeric denture base material due to its advantage (short polymerization process and elimination flashing procedure and process free of monomer), but in compared to heat cure acrylic is less transverse strength, impact strength and ten-

sile strength, so to improve these properties to fitful ideal properties required from denture base the polyamide was added.

Flexure or transverse strength present by force or resistance to breaking denture base due to masticatory force inside of the patient mouth which may be present as continual stress.

In this study, show a slight improvement in flexural strength in group reinforcement with polyamide in compared with the control group and higher result show in light cure acrylic with 1% polyamide.

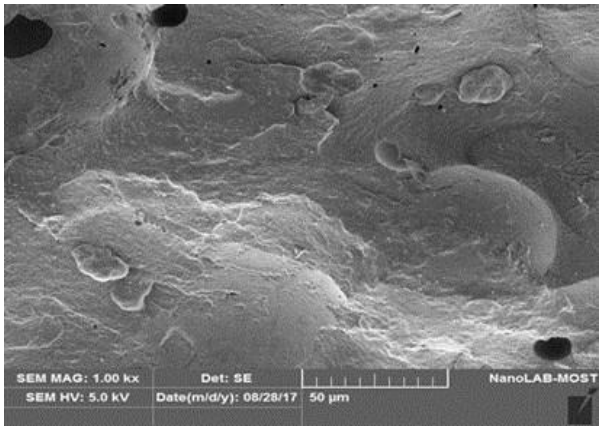

Figure 1: SEM of polyamide fiber in the matrix at 100X

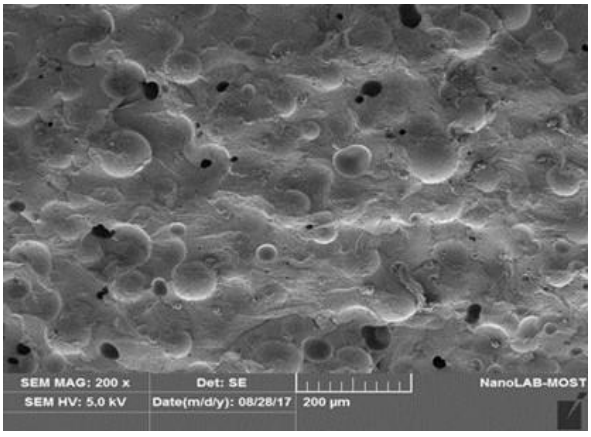

Figure 2: SEM of polyamide fiber in the matrix at 200X

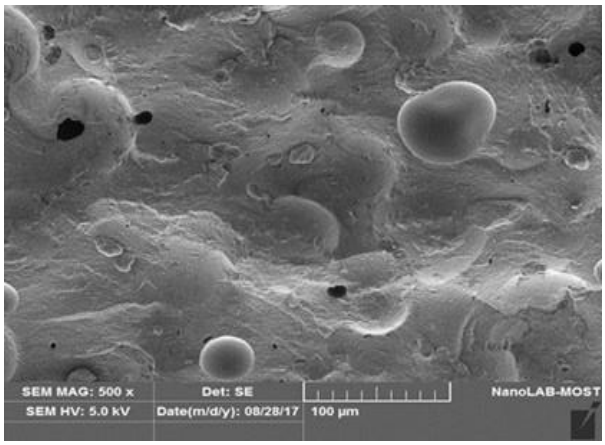

Figure 3: SEM of polyamide fiber in the matrix at 500X

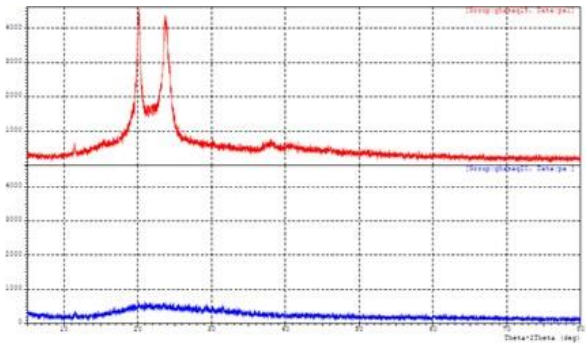

Figure 4: X-ray diffraction patterns of polyamide powder alone (A) and combination polyamide in the matrix (B)

This can be explaining as; the mechanical properties are mostly depended on interfacial bonding (include physical, mechanical and chemical bonding) between polyamide and polymer matrix, the chemical bonding is used in this research. the chemical bonding means, there is a chemical bond between polyamide and polymer (chemical bond here hydrogen group) due to chemical structure light cure which is urethane di methacrylate, microfine silica and high molecular weight acrylic resin and chemical structure polyamide include the nylons and the aramid. Both types are formed from polymers of long-chain polyamides. This could be seen in figure 4 by phase analysis using X-ray diffractometer as polyamide peak at 20.83 which disappear when mixed with light cure acrylic due to a chemical reaction between two polymer change the structure.

This may be due to limit segment motion of molecular chain as a result of even distribution of polyamide in matrix This agree with Yu SH et al. in 2013 (Yu S-H, *et al.,* 2013) who research Comparison of denture base resin reinforced with polyaromatic polyamide fibers of different orientations. and found addition polyamide increased flexural strength and flexural modulus. And also agree with Soygun *et al.,* in 2013. Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials and found Nylon increased the fracture resistance of PMMA, as it has high resistance to continual stress. Therefore, incorporating nylon fiber in PMMA increased its structural elasticity.

The results revealed that hardness of light cure resin reinforced with polyamide particle is significantly higher than the control group which may be due to Polyamide is nylon base polymer have amide bond c (o) N-H in the main chain, by reacting with photo polymerization resin material to form hydrogen bonds between oxygen and nitrogen atoms of various amide groups. This gives a matrix more hardness and stiffness. So can see the group

with addition polyamide powder more hardness than without polyamide powder.

The difference in modulus of elasticity between particle and matrix as a light cure is less flexible than polyamide may increase the strength of the material as seen increase in impact strength as a concentration of fiber increase. Also maybe increase impact strength as increase adhesion of powder to light cure matrix, this agreement with the result as impact strength for all groups reinforced with polyamide particle is higher than light cure resin without polyamide microparticles.

Tensile strength in all experimental group is higher than the control group, and the highest result obtains with group c (1% polyamide). This may be due to the cross-linking density of polymer increase by addition polyamide powder made denture base stiffer and stronger as seen in SEM as polyamide have intimate contact with matrix without any gap which could be explained by chemical bonding between polymer.

CONCLUSION

The addition of microparticle polyamide improves transverse strength, impact strength, tensile strength and shore A hardness properties of denture base material.

Conflicts of interest: none

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