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Effect of Addition Strontium Carbonate on Some Mechanical Properties of Heat Cured Acrylic Denture Base Material

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Abstract: ***Background: The polymethyl methacrylate is most commonly material used for fabricating removable partial and complete denture. The aim of this study was to evaluate the effect of addition of different concentration of strontium to acrylic denture base on mechanical properties (transverse strength, impact strength and hardness) some properties of heat cured acrylic denture base material. Materials and Methods: For this study, 150 specimens were prepared. The specimens were divided into three groups according to test (transverse strength test, impact strength test and hardness test), then each group subdivided into 5 group according to concentration of strontium added to polymethyl methacrylate (0wt%, 1wt%, 3wt%, 5wt%, 7wt%).The results were analysed by one way ANOVA test. Results: the results showed the transverse strength and hardness of all groups with strontium is higher significantly than control group (polymethyl methacrylate without strontium).while the best concentration of strontium added to acrylic to improve mechanical properties is 5wt%. Conclusion: The acrylic resin denture base material with addition strontium carbonate will improve transverse strength, impact strength and hardness. The best concentration for improve these mechanical properties was 5wt% of strontium***

Keywords: strontium, polymethyl methacrylate, transverse, impact strength

1. Introduction

One of the most commonly used materials for the construction of removable dentures is poly methyl methacrylate.[1]Regardless of its fame, this material satisfies the aesthetic demands but mechanically it is far from perfect. [2]

Appropriate aesthetics and desirable characteristics of polymethyl methacrylate resin make this material a good pick out for prosthodontic applications because of excellent aesthetic properties, adequate strength, low water sorption, low solubility and low thermal conductivity, reproduce surface details accurately, can be easily repaired and is free from toxicity.[3] Also it has limitations including a high thermal expansion coefficient, low thermal conductivity, a low elasticity coefficient, low impact strength, and low resistance to fatigue . [4, 5] common problem in prosthodontic practice that troubles both patients and prosthodontistsis denture fracture which result from inordinate masticatory forces or denture deformation during use and cause bending forces that contribute to fatigue of the material and subsequent fracture. [6]

Improving mechanical properties of acrylic have been used various methods to reinforce acrylic base composite by materials like fibers and particles.[7-9] Several researchers of PMMA have been shown good fatigue behavior and impact strength when it is reinforced bycarbon fibers [10-13], glass fiber [14, 15], nylon fibers[16], aramid fiber[17, 18], also polyethylene and sapphire fibers seem to enhance the physical properties of acrylic resin.[19-22]

Rapidly development in nanotechnology was increased in restoration dentistry by adding nanoparticles to an acrylic base to improve some physical and mechanical properties of PMMA[23], like add nanosilver particles to improve thermal conductivity and compressive strength of PMMA[24] and add 1wt% Tio_2 nanoparticle show increase tensile strength.[25] . In 1790 in area close to Scottish village Strontium was discovered which was alkaline earth metals and not isolated until 1808 because it not found in its free form in nature due to high oxidises, forming strontium oxide.[26]

Strontium, calcium and magnesium are divalent cations belongs to group 2 of the periodic table which have ability to bonds with blood proteins at different degrees in biological liquids.[27]

The aim of this study was to evaluate the effect of addition of different concentration of strontium to acrylic denture base on mechanical properties (transverse strength, impact strength and hardness)

2. Materials and Methods

The best concentration of strontium chloride to incorporate to heat cure acrylic denture base material, the pilot study was done.

The specimens were formed in collage of dentistry, University of Baghdad prosthetic department lab. For each test, 3specimens for each concentration (1wt%, 3wt%, 5wt%, and 7wt% of strontium chloride) were constructed. According to the manufacturing instructions Plastic dies were prepared for each test:

(80mm ×10 mm× 4mm±0.2mm) dimension for Impact strength test[28]

(65 mm × 10 mm × 3 mm) dimension for hardness and transverse test[29] plastic dies coated with thin layer cold mold seal (separating medium) then invested in the lower half of the denture flask.

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Usually one half of plastic mold thickness was embedded in the stone to make easily remove from mold after setting, then thin layer of separating medium was applied on the surface, second pour was made then compressed the flask by press for 5 min. after complete set open the flask and carefully remove plastic mold from stone. According to manufacturer's instructions, conventional complete denture processing procedure follow to packed acrylic at dough stage in the mold .The sample Finishing and polishing before testing.

3. Transverse Strength Test

The transverse strength test was done by Instron testing machine for acrylic specimens after immersed in distilled water at 37°C for 2 days before the test.[30]

The transverse strength was calculated by divided maximum force exerted on specimens to cause fracture on depth and width of acrylic specimens using the following formula:

$$S = \frac{3PI}{2bd^2}$$

S= Transverse strength (N/ mm2)
P= maximum force exerted on specimens (N)
l=the supporting width in mm=50
b= width of the samples (mm)
d= depth of the samples (mm)

Impact strength test

The impact strength test was done according to methodology suggested by ISO 179 by putting specimens in distilled water at 37°C for 2 days before the test .[30]

Calculate the charpy type impact strength of unnotched acrylic specimens in kilo Joules per square meter by using the following equation:

Impact strength = $\frac{A}{X*Y}$ x 10^3 (Kj/M2)

A: The impact energy absorbed in Joules
X: Is the width of the specimens in millimeters
Y: Is the depth of the specimens in Millimeters.

Surface Hardness test

The specimens were stored in distilled water for two days before measurement of Shore D surface hardness.[30] with the Durometer hardness tester. Measurements were commenced on five different areas for each specimen and an average was calculated for each one.[30]

Storage specimens for 2 days in distilled water then measurement the surface hardness by using durometer hardness tester (shore D hardness) according to American National Standard/ American Dental Association. Five measurements were done on different areas of each specimen (the same selected area of each specimen and the average of the five readings was calculated.[30]

4. Results/Discussion

The statistical analysis was done by use spss version 23 and the results shown that for transverse strength test higher mean value for group modified with 5wt% strontium(76.83 MPa) than control (group with 0wt% strontium)(68.14 MPa), and for one way ANOVA test indicate highly significant results.

For impact strength test the results shown higher mean value for group modified with 5wt% strontium (8.943 Kj/m^2) than control (group with 0wt% strontium) (6.728 Kj/m^2), and for one way ANOVA test indicate non significant results.

For surface hardness test the group modified with 5wt% strontium was (85.61gm/mm), while for control group (82.06 gm/mm) which was highly significant as shown in (table 1), (table 2) and (table 3)

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

test	*Transverse strength*		*hardness*		*Impact strength*	
groups	mean	S.D.	mean	S.D.	mean	S.D.
control	68.14	8.87	82.06	0.88	6.72	1.42
1%	68	3.05	85.32	1.02	5.38	0.55
3%	71.85	6.20	80.96	2.10	7.47	2.64
5%	76.83	13.43	85.61	0.69	8.94	0.10
7%	59.83	7.19	85.15	2.24	5.38	2.03

Table 2: Transverse strength, hardness and impact strength one way ANOVA between control group and experimental groups

Test	*df*	*Mean Square*	*F test*	*Sig.*	
Transverse strength	4	18.516	9.301	0.001	HS
hardness	4	271.715	4.242	0.008	HS
Impact strength	4	4.529	1.678	0.290	NS

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

Hardness		*Impact Strength*		*Transverse Strength*		LSD	
	Sig.		Sig.		Sig.		
NS	0.974	NS	0.45	HS	0.005	1wt%	control
NS	0.392	NS	0.669	NS	0.288	3wt%	
S	0.051	NS	0.235	HS	0.003	5wt%	
S	0.061	NS	0.451	HS	0.007	7wt%	
NS	0.374	NS	0.259	HS	0.001	3wt%	1wt%
S	0.048	NS	0.082	NS	0.773	5wt%	
NS	0.066	NS	1	NS	0.869	7wt%	
NS	0.254	NS	0.412	HS	0	5wt%	3wt%
HS	0.009	NS	0.26	HS	0.001	7wt%	
HS	0	NS	0.083	NS	0.651	7wt%	5wt%

different concentration of strontium (0wt%, 1wt%, 3wt%, 5wt%, 7wt%) to polymethyl methacrylate acrylic denture base on mechanical properties (transverse strength, impact strength and hardness).

The transverse strength

The addition of strontium improves the transverse strength of PMMA denture base when compared with control group. This may due to improve in fracture resistance which increase by increase strength of rigidity of the resin due to segmental motions of macromolecules of resin are restricted by strontium particle.[31] increase in the transverse strength may be due to rigid and stiffness of strontium filler particle

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cause transfer stress to rigid stiffer filler from flexible polymer.[32]

The impact strength

As shown in table 1, the impact strength in all groups was higher than unmodified group . Adding strontium particle the crack propagation may be decrease due to good bonding between matrix of PMMA and strontium particle. Also impact strength increase can explain by high interfacial shear strength between filler and matrix.[33]

Also increase impact strength may be due to reduce the segment motion which result from form efficient network of filler and PMMA . [34]

The hardness

The hardness measurement showed direct increase with concentration up to 5wt% which record the higher value of hardness than other concentration. The increase in hardness may be explained by cross linking density(network density) and increase with increase concentration of strontium may be due to randomly distributed rigid filler particles into matrix of acrylic .(35)

5. Conclusion

The acrylic resin denture base material with the addition of strontium carbonate improved transverse strength, impact strength and hardness. The best concentration for improvement of these mechanical properties was 5wt% of strontium

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