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Effect of Incorporation of Poly Vinyl Pyrrolidone on Transverse Strength, Impact Strength and Surface Roughness of Autopolymerizing Acrylic Resin

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Key words
modified autopolymerizing acrylic resin, transverse strength, surface roughness.

Abstract

Autopolymerizing acrylic resin is one of the most frequently used materials in dentistry**,** but it has relatively poor mechanical properties This study investigated the effect of the addition of poly vinyl pyrrolidone on transverse strength, impact strength and surface roughness of autopolymerzing acrylic resin. A total of 60 specimens were prepared, 30 specimens of each conventional and modified autoplymerizing acrylic.20 specimens of each groups were fabricated with dimensions of (64×10×2.5) mm to conduct the transverse strength and surface roughness tests, while the remaining 10 specimens of each group were fabricated with dimensions of (80×10×4) mm to perform the impact strength test. The results of this study showed that the modified autopolytmerized acrylic had significantly higher transverse strength, and significantly lower surface roughness values while there was no significant differences in impact strength value. It can be concluded that addition of Polyvinylpyrrolidone can improve transverse strength and surface roughness of autopolymerizing acrylic resin.

Introduction

Since the mid-1940s, the majority of denture bases have been fabricated using poly (methyl methacrylate) resin such resins are resilient plastics formed by joining multiple methyl methacrylate molecules or mers[1] (Figure1). Due to its desirable properties of excellent aesthetic, colour stability, easy reproduction of details, relative lack of toxicity, ability to repair and simple processing techniques[2,3], acrylic polymers have a wide variety of applications in restorative dentistry such as denture base and artificial teeth, denture repair materials, impression trays, provisional restorations, and maxillofacial appliances for skeletal defects[4]. However, poor mechanical properties like susceptibility to fracture due to unsatisfactory transverse strength, impact strength or fatigue resistance have also been reported in acrylic resin[5].Polymethylmethacrylate denture base material usually is supplied as powder-liquid system. The liquid contains nonpolymerized methyl methacrylate. The powder contains prepolymerized polymethylmethacrylate resin in the form of small beads[1].Polymerization can be achieved through the application of heat (heat-activated or cured PMMA), chemical, such as tertiary amines (chemically activated PMMA), or by other sources of energy, such as visible light-activated, or through electromagnetic radiation such as in the case of microwave-activated resins[6]. Chemically activated resins often are referred to as cold-curing self-curing, or autopolymerizing resins[1] . The auto

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polymerized acrylic denture base materials have lower mechanical strength when compared with heat polymerized acrylic denture base resin, it has only55% to 65% of the original heat cure denture strength[7] . This is because there is a greater amount of unreacted monomer in denture bases fabricated via chemical activation which acts as a plasticizer that result in decreased transverse strength of the denture[1,8]. The reason for the higher residual monomer content in the auto polymerizing acrylic resins is due to the low degree of conversion achieved by the use of a chemical activator[1,9] .The auto polymerized acrylic resin has several uses in dentistry such as special tray and repair materials, record bases, relines, crown and bridge work as a temporary coverage of prepared teeth, orthodontic appliances, maxillofacial prosthesis[10- 12].To improve the mechanical properties of acrylic resin several attempts have been made by reinforcement with glass[13-16], carbon[17], polyethylene[18], or methyl methacrylate fibers[19,20] copolymerization and cross linking[21,22]. Graft copolymerization is one of the chemical methods used to improve polymer and produce new properties that cannot be produced by homopolymerization[23]. An effort was made by Al Fahdawi[24] to improve the physical and mechanical properties of heat cure acrylic resin by the inclusion of poly vinyl pyrrolidone polymer into polymethylmethacrylate polymer (the powder) and the results were satisfying. On the other hand many attempts have been made to improve the mechanical prosperities of autopolymerizing acrylic, Placing of auto polymerized acrylic resin in hot water during polymerization (60–80°C) Water condition may produce less residual monomer in an auto polymerizing acrylic resin, and transverse strength of the resin was twice when compared with polymerization at 23°C (open to air). This lead to an increase in the mechanical properties and long lasting performance of auto polymerized acrylic resin[25,26]. Microwave post polymerization resulted in a higher degree of conversion and higher flexural strength of an auto polymerizing acrylic resin repair material[27]. The fracture resistance was improved after post polymerization treatment for auto polymerized acrylic denture base with microwave, and the adverse effect of monomer was decreased by water bath and microwave post polymerization treatment[28]. Other attempts includes the addition of novel glass fibre, polybutene reinforcement to enhance the transverse strength of autopolymerizing acrylic resin [29]. Another important limitation of PMMA resins is their potential to support the formation of bio film so that the surface roughness and free energy of conventional denture base materials may promote microbial adherence[30]. These limitations in autopolymerizing acrylic; decrease of strength and increased surface roughness can be overcome by the addition of poly vinyl pyrrolidone polymer (pvp). PVP is a water-soluble polymer made from the monomer N-vinylpyrrolidone (Figure 2), PVP shows a high degree of compatibility, both in solution and film form, with most inorganic salt solutions and with many natural and synthetic resins, as well as with other chemicals . PVP was initially used as a blood plasma substitute and later in a wide variety of applications in medicine, pharmacy, cosmetics and industrial production. As PVP improve strength clarity ,colour receptivity of polymerization products, it is used in Polymerization of acrylic monomers, unsaturated polyesters, and substrate for graft polymerization template in acrylic polymerization [31].The aim of this study is to evaluate and compare the transvers strength, impact strength and surface roughness of autopolymerzing acrylic resin with modified autopolymerized acrylic with polyvinylpyrrolidone.

Materials and Methods

A- Specimens grouping:

A total of 60 specimens were prepared to be used in this study. They were divided into three main groups according to the type of the test, each group consists of 20 specimens, each main group was farther

subdivided into two sub groups according to the material used as(control and experimental), where each sub group consist of 10 specimens (figure3).

B- Specimens preparation

1-metal pattern preparation: two different metal patterns were constructed according to the required test

1.Transvers strength and surface roughness test; the metal patterns were prepared with dimensions of (65±0.3×10±0.03×2.5±0.03mm length, width, thickness respectively) according to ADA[32] No.12, 1999..

2. Impact strength test: the patterns were prepared with dimensions of 80×10×4 mm (length, width, and thickness respectively) according to International Standard Organisation[33] 1567.

2- Mould preparation

For the preparation of the stone mould the prepared metal patterns (for transverse strength, surface roughness and impact strength) were coated with separating medium after that, invested in metal flask which was filled with dental stone type3 (Elite model IVORY,Zhermack, ITALY) that mixed in 30 gm/100 ml (powder/ water)ratio. After final setting of stone material, the metal patterns were removed carefully.

3-Specimens fabrication

Control group specimens were prepared from pink cold cure acrylic resin (Triplex, CE 0123 Ivoclar Vivadent, Liechtenstein) with 13gm/10ml (powder/liquid) ratio. While the experiment group specimens were prepared from the same pink cold cure resin with incorporation of white powder of poly vinyl pyrrolidone (p.v.p-30, Mumbi,India,2013) with concentration of 20% by weight according to previous study it has closest testing value in comparison with control group[24] in the powder. Thorough mixing of PVP powder with the polymer, then the mixture was passed through a sieve to produce more homogenous mix. The experimental group prepared from poly methyl methacrylate 80% +PVP 20% +Methacrylate.

4-Cold cure acrylic manipulation

Sprinkle on technique, in which the polymer is saturated by its monomer, the polymer and the monomers were applied alternately until the mould was filled. left to be set in the room temperature(23+ 2°C) for 20 minutes (open to air), after curing, each specimen was retrieved from its respective mould and the excess was trimmed gently with an acrylic bur. . The accuracy of the dimensions was verified with a digital vernier calliper, at three locations of each dimension to within 0.2 mm tolerance.

5- Finishing and polishing

All the specimens were finished and polished (except the specimens for surface roughness test) with a lathe-polishing machine with speed of 400 rpm. To avoid excessive heat, which may lead to distortion of the specimens, pumice (Nekmuice pumice powder fine grained 45µm used in polishing with a large amount of water. Polishing was accomplished using bristle brush and rage well until glossy surface was obtained.

All specimens were conditioned in water at 37 ° C for 48 hours before being tested according to ADA specification No. 12.1999.

C-Testing

Transverse strength test: The resulted twenty samples of auto polymerized acrylic resin(control and experimental specimens) that prepared for TS test was collected and stored in distilled water for 48 hours at37+2°C. After conditioning period, the samples were tested by three points bending test by flexural testing machine. The test consisted of gradually applying a force to each specimen by using a universal test machine (Hydraulic press,LeyboldHarris Co.,British)) at a crosshead speed of 5 mm/min until fracture occurred. The machine has three shafts in which the two inferior ones serves to hold the sample and the superior one serve to apply force to the centre of the sample. The three shafts have the same ray of 2.5 mm in order to avoid differences in the results. The centre of the

specimen was determined by using a millimetre ruler and the resulting central point was marked with an OHP marker pen. .the load was applied perpendicular to the centre of the specimen. The fracture force was registered in Newton. All measurements were obtained on the same day. Transverse strength was calculated according to the following equation:

$TS = 3WL/2bd^2$.

Where {TS = transverse strength (MPa). W=maximum load at midpoint of the sample (Kg).L = distance between the supports (50 mm). b = width of the sample (10mm).d = thickness of the sample(2.5mm)}.

Impact strength test: The resulted twenty samples of auto polymerized acrylic resin (control and experimental specimens) that prepared for impact strength test after being conditioned in distilled water at 37±2°c for 48 hours. The impact strength test was conducted following the procedure by the ISO 179 with impact testing device (Amity ville L.IN.Y New York USA). The specimen was supported horizontally and struck by free, swinging pendulum of 5 jouls, the scale reading give the impact energy in joules. The charpy impacted strength of un notched specimens was calculated in kilo jouls per square meter. It is given by the formula:

$Impact\ strength = A/YX10^3$

Where A=the impact energy in jouls X=the width in millimetres of test specimen Y=the depth in millimetres of test specimen.

Surface roughness test (Ra): All the specimens were immersed in distilled water at 37±2°c for 48 hours before being tested according to ADA No 12,1999. Surface roughness of the specimens was measured using a contact stylus profilometer (Surface roughness tester/ Talysurf ,TalyorHobson,UK,England). This device is supplied with sharp stylus surface analyzer from diamond to trace the profile of surface irregularities. When recording of all the peaks and recesses which characterized the surface by its scale the acrylic specimens were placed on its stable stage and the location of the test area was selected the analyzer was traversed towards the right direction along the specimen surface. Three measurements were made for each specimen and the mean R_a values were used for the statistical analysis.

Statistical analysis: statistical analysis was performed with the SPSS software for Windows (v. 19.0). Means and standard deviations were obtained for each group. The obtained data was tabulated and statistically analyzed using students paired t test, significance level equal to 0.05.

Results

The transverse strength mean value of experimental group is 72.40 N/mm^2 which is higher than that of control group which is 53.40 N/mm^2 that means there is an increase in the transverse strength about 35% and the difference is highly significant ($p<0.05$) as shown in Table 1, while Table 2 shows that the Impact strength mean value of the experimental group is 8.10 KJ/m^2 which is higher than that of the control group 7.55 KJ/m2 which means that the increase in the impact strength is only 8%, the difference is statistically not significant ($p>0.05$).On the other hand Table 3 indicates that the mean value of surface roughness of experimental group is .0696 µm which is significantly lower than that of control group .7040 µm as p value is less than 0.05.

Discussion

Autopolymerizing acrylic resin is one of the most frequently used materials in dentistry. However, it has several disadvantages as poor mechanical properties. Attempts have been made to strengthen acrylic resin materials with either chemical modification with grafted co-polymers and stronger cross linkage or by the use of various reinforcing materials as inclusion of metals, glass, carbon[34]. This study have attempt to modify autopolymerizing acrylic by incorporation of PVP ,which has wide range of applications in many felids such as Pharmaceuticals, Cosmetics, Food, adhesives, Polymers and textiles [31], and

study its effect on transverse strength, impact strength and surface roughness.

Transverse strength, the force needed to deform the material to fracture or irreversible yield[1,4]. It is a combination of compressive, tensile and shear strengths, all of which directly reflect the stiffness and resistance of a material to fracture [35,36]. Flexural failure of denture base resins is considered the primary mode of clinical failure [37]. The flexural three-point bending test is useful in comparing denture base materials as it simulates the type of stress that is applied to the denture during mastication [38]. The present study indicates that the transverse strength of modified autopolymerizing acrylic is significantly higher than the conventional one. This may be due to the experimental group prepared by graft copolymerization method which increases the rigidity of experimental material[1]. In alkane molecules(-cH3) the carbons atoms which attaches to each other by single bonds, the rotation of it about the centre become relatively free, the freedom makes the material more elastic[39].Impact strength; the ability of a material to resist a sudden high level force or shock[1,4], This study shows that the value of impact strength of modified autopolymerized acrylic is comparable to that of control group that means fractures of dentures still occur, but are usually associated with carelessness or unreasonable use by the patient. Considering functional stresses, the oral environment, and expected service life, denture base materials perform remarkably well[4].The surface properties of any denture base material is of particular concern as studies of denture base materials have shown a direct link between surface roughness, the accumulation of plaque and the adherence of Candida albicans. Increased presence of Candida species are reported in denture related stomatitis [40,41].Surface roughness is an important feature associated with biofilm formation. Ra values were near to 0.2 μm, which can be considered as minimally susceptible to microorganism colonization[42].In this study, surface roughness was tested to observe if the modification of autopilymerizing acrylic resin by Polyvinylpyrrolidone could affect this property. PVP indeed influenced the Ra; as the value of Ra of modified autopolymerized acrylic is significantly lower than that of the conventional autopolymerized acrylic one. The addition of PVP produced surfaces which is below the accepted threshold (Ra = 0.2 μm).It can be explained that decrease surface roughness is due to hydrogen bond, the strongest and especially important kind of intrermolecular attraction is hydrogen bond.This attraction occurs between a hydrogen atom covalently bond to a highly electronegative atom such as Oxygen, Nitrogen or florine and an electronegative atom on an adjacent molecule reducing the distance between the atoms which lead to smooth surface[43].

Conclusions

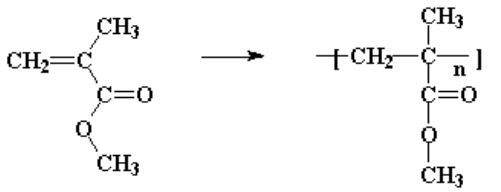
Within the limitations of this in vitro study the following conclusions can be drown:

1-The addition of polyvinyl pyrrolidone to autopolymerized acrylic resin enhance the transverse strength of the material .

2-Impact strength of autopolymerizing acrylic was not significantly influenced by the addition of poly vinyl pyrrolidone.

3-Surface roughness of autopolymerized acrylic was significantly improved by the addition of poly vinyl pyrrolidone.

Further work is clearly needed to investigate the effect of addition of PVP on other physical and mechanical properties of autopolymerizing acrylic.



Methylmethacrylate **Polymethylmethacrylate**

Fig.(1):- Polymerization of Methyl methacrylate to get Poly (methyl methacrylate).

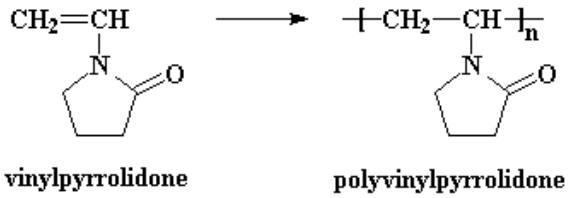


Fig.(2):- Polymerisation of Vinylpyrrolidone.

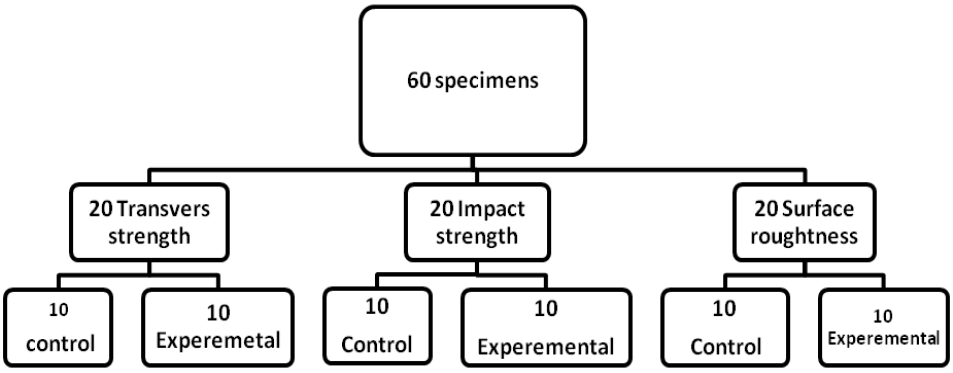


Fig.(3):- specimens groups.

Table(1):- mean of Transverse strength (N/mm^2) of study groups.

Study groups	Mean	Slandered deviation	t-value	p-value	Significance
Control	53.40	1.90	4.538	.001*	Highly significant
Experimental	72.40	1.81			

*P<0.05

Table(2):- mean of impact strength (KJ/m^2) of study groups.

Study groups	Mean	Standard deviation	t-value	p-value	Significance
Control	7.500	1.86	.476	.646*	Non significant
Experimental	8.10	2.08			

*p>0.05

Table(3):- mean of surface roughness (µm) of study groups.

Study groups	Mean	Standard deviation	t-value	p-value	Significance
Control	.7040	.0085	2.315	0.046*	Significant
Experimental	.0696	.00797			

*p<0.05

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