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Influence of Zirconia and Polymerized Microfiller on Some Properties of Polymethyl Methacrylate Denture Base

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Abstract

Polymethyl methacrylate (PMMA) is the material of choice for denture bases due to its ease of production and repairability, biocompatibility, and exceptional aesthetic appeal. However, the shortcomings of polymer materials, like inadequate mechanical and physical properties. The goal of recent study was to assess transverse strength and wettability of PMMA when mixing with zirconia and polymerized PMMA particles [ZP] as fillers with a different percentage. Sixty PMMA samples were split into three groups based on the percentage by weight of ZP filler added to each: group C: Control group, 20 samples without ZP filler (0%wt.ZP); group A: 20 samples with 2%wt. ZP; and group B: 20 samples with 4%wt. ZP. Flexural strength and wettability tests were used to evaluate all samples. ZP powder had prepared and blended by weight with PMMA powder in two distinct amounts, 2% and 4% [1.2µm and 30%ZrO, 0.69µm and 70% p-PMMA had selected according to pilot study]. To polymerize the specimens, the usual heat-curing procedure was used using a water bath, for both transvers flexural strength and wettability tests. One-way analysis of variance (ANOVA) test was used to analyse data, and the results were considered statistically significant when the P-value was less than 0.05. The results showed that adding 2% ZP powder to PMMA significantly increased transverse strength, whereas adding 4% ZP powder significantly decreased transverse strength. The wettability improved dramatically between the 2% and 4% concentrations. The mixture of zirconia and polymerized PMMA particles utilized as dental filler at 2% and 4% wt increased wettability with increasing concentration, while increasing transverse strength ranged from increased to decreased.

Keywords: *polymethylmethacrylate (PMMA), Zirconia, polymerized PMMA, transvers flexural strength, wettability*.

1. Introduction

The development of acrylic resin in 1936 was a significant step forward that has influenced contemporary dental practice. The majority of traditional removable dentures used to restore edentulous individuals are made of acrylic resin (1). Despite the extensive usage of polymethyl methacrylate (PMMA) in prosthetic dentistry, denture breakage remains a regular clinical occurrence in prosthodontic services and still an unsolved problem (2). Many research have been conducted with the purpose of increasing the characteristics of PMMA by including fillers into the composition. To enhance its physical and mechanical properties, PMMA is often mixed with fillers and particles (3,4,5). The heat-cure denture base resin or PMMA materials now available on the market are distributed as a two-part powder and liquid solution. Monomeric methyl methacrylate is the primary ingredient in the liquid component,

while prepolymerized Poly (methyl methacrylate) makes up the bulk of the powder (6).

The addition of metal powder fillers silver, copper, and aluminum particles to PMMA improved its strength (7). Zirconia's potential for incorporation into a wide range of dental materials has been investigated, and it has been discovered to be biocompatible and to increase mechanical qualities (8). Researchers have shown that zirconia is not only biocompatible, but also aesthetically superior to metal fillers. Zirconium powder, as studied by N M Ayad et al., greatly boosts the transverse strength of high impact resin, which was shown to be significantly strengthened when reinforced with 5% and 15% ZrO2(9). The addition of polymerized PMMA powder to heat-cure acrylic resin changes the chemical and physical properties (10). The impact strength and hardness of heat polymerized PMMA resin were improved after varying amounts of mixture of polymerized PMMA and zirconia fillers were added (11). The results are usually better when using a combination of reinforcement types rather than just one. Each additional reinforcement is thought to improve a different material quality (12).

The current research aimed to investigate the transversal strength and wettability after incorporating a mixture polymerized PMMA and zirconia particles into heat-cure PMMA resin.

2. Experimental Study

2.1 Materials

In current study, the mechanical and physical qualities of polymethylmethacrylate (PMMA), like transversal strength and wettability, were tested, before and after collaborating with mixture of zirconia and polymerized (PMMA).

2.1.1 Polymethylmethacrylate (PMMA)

Commonly known as "acrylic resin" or "methacrylic resin," the scientific name is "polymethyl methacrylate" (PMMA). The chemical formula for this material is (C5H8O2)n,. Most full dentures nowadays are made from acrylic resin that is heat-cured. These are available in the form of powder poly (methyl methacrylate) and liquid methyl methacrylate. The monomer and polymer mix to make a workable dough that has several applications.

2.1.2 Zirconia (ZrO2)

Zirconia, which is also called zirconium dioxide (ZrO2), is one of the most common ceramic materials used today. Mechanical engineering has made use of them. They are well-suited for numerous components, such as engine parts, cutting tools, and dentures, due to their very high strength, hardness, fracture toughness, and wear resistance. Adding zirconia (ZrO2) fillers to PMMA has been shown to greatly improve the material's flexural strength, impact strength, fracture toughness, and hardness.

2.1.3 Polymerized PMMA

It is an additive substance used to test the physical and chemical characteristics of heat-cured acrylic resin; another name for it is recycled polymethylmethacrylate. Chemical and physical properties of thermal acrylic resins are altered when polymerized polymethylmethacrylate is added, one such alteration is decrease the release of residual monomer.

2.1.4 Preparation the mixture of polymerized PMMA and zirconia

Heat cure PMMA resin balls (Spofa Dental, Markova, Czech Republic) were made according to the manufacturer's instructions. The mechanical grinding-milling equipment (Silver Crest, Zhejiang, China) ground the resulting PMMA balls and sieved using the sieving machine (FRITSCH, GmbH, Germany) to create a powder with an average particle size of 0.69µm. To create a mixture of polymerized PMMA and zirconia powder (ZrO2) filler, 70% (w/w) polymerized PMMA powder (0.70µm) was mixed with 30% (w/w) (ZrO2) (1.2µm) (FIXANAL, Sigma Aldrich, Germany).

2.2 Fabrication of samples

Totaling 60 were split into two groups of 30 (one for each test) and then further separated into three groups of 10 (one for each % of ZP filler) for analysis. The subdivided group tested for transvers strength and wettability.

The recommended PMMA/ZP research composite material was constructed using the

following measurements (To create a PMMA/ ZP composite, we used electronic balance to add ZP at 2% wt. to a PMMA resin basis at 98% wt., and at 4% wt. to a PMMA resin base at 96% wt.) The selection of the ratio of the addition of ZP to PMMA resin was designated according to the pilot study. To ensure that the ZP would be conventional compression method. Following the manufacturer's guidelines, the PMMA powder and liquid were mixed together (Spofa Dental, at 74 degrees Celsius, followed by 1/2 hour at 100 degrees Celsius). After taking the flask out of the water bath, it was allowed to cool at room Czech Republic). Following the manufacturer's instructions, a short-cycle heatpolymerization processing procedure was carried out (1.5 hours evenly distributed throughout the acrylic resin powder and that the color would be constant, the mixes were blended at 400 rpm for 30 minutes. Plastic sheets were prepared for transvers strength and wettability checks. By use of a water-bath curing apparatus, PMMA and PMMA/ZP composites were cured in the conventional compression method. Following the manufacturer's guidelines, the PMMA powder and liquid were mixed together (Spofa Dental, Czech Republic). Following the manufacturer's instructions, a short-cycle heatpolymerization processing procedure was carried out (1.5 hours at 74 degrees Celsius, followed by 1/2 hour at 100 degrees Celsius). After taking the flask out of the water bath, it was allowed to cool at room temperature. After being completed and polished using a standardized procedue, all of the PMMA samples were kept in distilled water for 2 days before to testing.

2.2.1 Transverse Strength Test

The specimens' (30 specimens) dimensions (65mm length, 10mm width, and 2.5mm thickness) employed in this study are depicted in Fig. 1

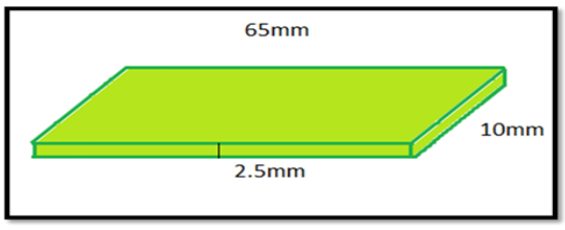

Fig. 1. Transverse Strength testing specimen dimensions.

The test was conducted using an Instron universal testing equipment (WDW-20, Laryee Technology Co., Ltd., China) , and the specimens were placed on bending fixtures made of two parallel (50 mm) supports, and the force was applied using a rod centered between the supports creating deflections till a fracture occurred. The transverse strength was calculated using the equation below:

T = 3PL/ 2Pd2 (ADA specification No.12, 1999)

T= Transverse strength (N/ mm2)

P= Maximum force that exerted on samples (N)

L= Distance between the supports (mm)

b= the samples width (mm) d= depth of the samples (mm)

2.2.2 Wettability test

Specimens (30) with dimensions of 20mm in length, 15mm in width, and 2mm in thickness were created (Ramanna, 2018), as seen in Fig. 2.

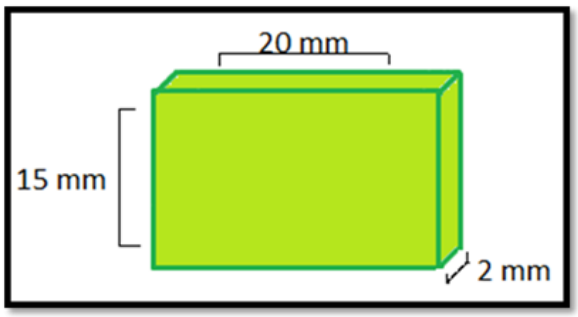

Fig. 2. dimensions of wettability specimen test.

As contamination of the investigated surfaces is likely to introduce an error, the test specimens in this investigation were manufactured on a regular basis.

Measurements in this study were taken using a contact angle goniometer (Nanoscience instruments, USA), a direct optical method distinguished by its simplicity. The wettability of samples was determined by applying a single drop of distilled water at room temperature.

3. Statistical Analysis

Data description, analysis and presentation were performed using Statistical Package for social Science (SPSS version -22, Chicago, Illionis,

USA), Minimum, Maximum, mean, Standard Deviation (SD) and standard error (SE), simple chart bar and One way Analysis of Variance (ANOVA) test.

4. Results and Discussion

Figures (3) and (4) show the results of microscopic tests performed on control and experimental specimens ZP 2% wt. using a field emission scanning electron microscope (FE-SEM) at 1.00KX magnification. As can be seen in Fig. 4, the ZP fillers are evenly dispersed throughout the polymer matrix.

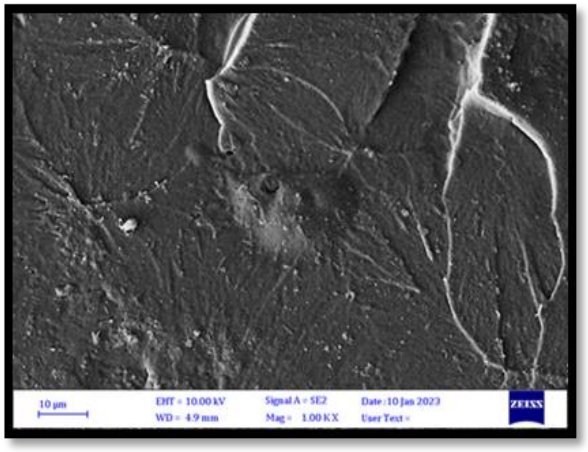

Fig. 3. FE-SEM of the fractured surface of control sample at magnification 1.00KX

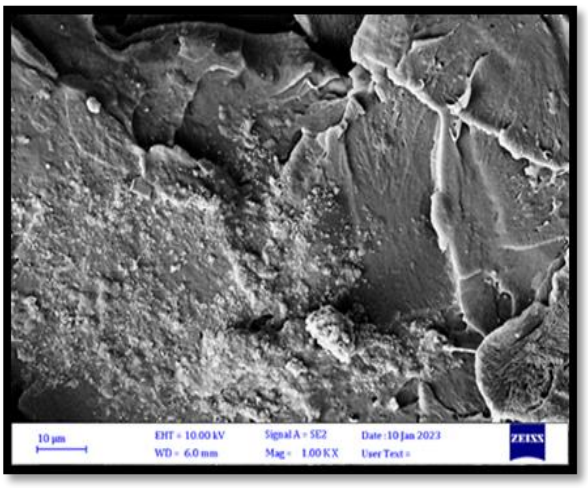

Fig. 4. FE-SEM of the fractured surface of reinforced specimen with 2%ZP at magnification 1.00KX

Descriptive statistical analyses of transverse strength for all groups evaluated were available, the highest mean value of transverse strength is related to A group (106.30 Nmm2), while the lowest mean value was related to B group (86.74 Nmm2) followed by group (97.16 Nmm2) as shown in Table1.

Table 1,
Descriptive statistics of transverse strength (N\mm2) among groups.

Groups	N	Mean	±SD	±SE	Minimum	Maximum
C	10	97.156	3.024	0.956	93.000	103.330
A	10	106.303	5.600	1.771	99.650	118.730
B	10	86.741	1.633	0.516	84.900	90.600

N: Number; SD: standard deviation; SE: standard error.

The mean values of transverse strength results represent in Fig. 3. The one-way ANOVA test for comparing mean values of control and experimental groups reveals a significant ($p<0.05$) difference between groups, as shown in Table 2.

Fig. 3. Bar chart of mean values of transverse strength test among studied groups.

Table 2,
One-way ANOVA test of Transverse strength (N\mm2) among groups.

	Sum of Squares	df	Mean Square	F	P value
Between Groups	1916.03	2	958.02	66.58	0.000
Within Groups	388.51	27	14.39		
Total	2304.55	29			

A material's transverse is a measure of its stiffness and resistance to fracture. Because of its potential significance to a denture base's loading properties, transverse strength tests were conducted (13). The means value of transverse strength and the one-way ANOVA test in tables (1, 2) and figure (1), showed that adding ZP (group A and group B) to PMMA was significantly increased and decreased respectively comparison with the control PMMA, This increase in transverse strength may be related back to the interruption in the crack propagation that occurred during the interstitial filling of the acrylic resin matrix with ZP (14). When 4% ZP was added, the transverse strength decreased as compared to 2% ZP, an increase in filler usage may be responsible for this drop. It's possible that after a saturation threshold is achieved, the effect of greater filler content on strength disappears, no additional filler particles may be incorporated into the resin. When filler particles are added to a matrix that has already attained saturation, the resin matrix continuity is broken, and the strength of the reinforced specimens decreases (15). Previous research indicated that adding 0.125% and 0.25% weight silicon carbide nanoparticles to acrylic denture base material had no significant effect on the material's transverse strength, impact strength, and surface roughness (16). Transverse strength values were found to be highest for (PMMA) reinforced with glass fibres, then for (PMMA) reinforced with butadiene styrene, and lowest for conventional denture base resins (Jaikumar et al., 2015). Glass fibers have a substantial impact on individuals who have a thick occlusal load or when the denture base resin fractures (17).

Descriptive data for the wettability test were shown in Table 3. For both the control and experimental groups,), the highest mean value of contact angles was related to C group (71.32°) and followed by A group (67.61°), while the lowest mean value was established with the B group (62.69°).

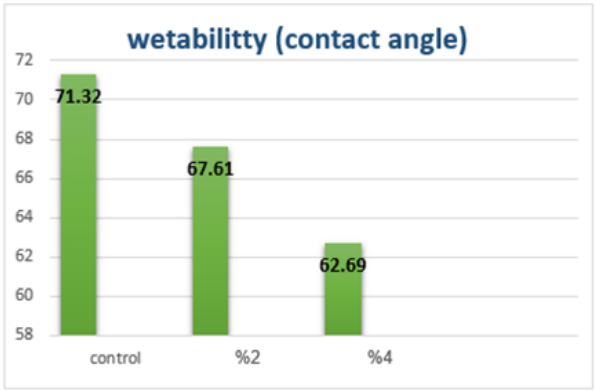

Fig. 4. Comparison of mean wettability (contact angle) test scores between groups

Table 3,
Descriptive statistics of wettability(contact angle°) among groups

Groups	N	Mean	±SD	±SE	Mini.	Maxi.
C	10	71.324	2.866	0.906	66.500	75.010
A	10	67.610	2.430	0.768	63.300	70.500
B	10	62.694	3.942	1.246	57.620	67.820

N: Number; SD: standard deviation; SE: standard error.

As can be seen in Table 4, there is a statistically significant ($p<0.05$) difference between the control and experimental groups when comparing their mean values

Table 4,
One-way ANOVA of wettability test (°) among groups.

	Sum of Squares	df	Mean Square	F	P value
Between Groups	374.79	2	187.396	18.96	0.000007
Within Groups	266.89	27	9.885		
Total	641.68	29			

Wettability is the amount of wetness that occurs when solid and liquid phases contact (18). Its determine how moist or dry something is (whether it's hydrophilic or hydrophobic), by testing its surface wettability with a liquid (19). Contact angle is a crucial factor in determining how wettable bases for dentures are. Each substance has its own characteristic angle, which is related to the surface energy of solids and the surface tensions of liquids. (20). According to the result in the current study, table (3 and 4), Figure (4) the wettability value was increased with increase ZP particles integrated material (decreased contact angle). This might be due to the zirconia particles which, if utilized, would decrease the absorbent polymer's bulk because they are insoluble in water (21). Possible explanations for the second element include the mixture of zirconia and polymerized PMMA particles that increase the surface roughness of modified specimens (11), this findings can also be explained by the direct relationship between wettability and surface roughness, so the addition of ZP increase surface roughness, it increase wettability (decrease contact angle) (22,23). Previous research indicated that adding 1wt.% and 1.5wt.% of silanized microcrystalline cellulose powder had a highly significant increase in contact angle values of wettability test (decrease wettability) between control group and both experimental groups (24) Ismaeel IJ et al. (2015) showed that the incorporation of Silanated polypropylene fibers resulted in a considerable increase in wettability (25).

5. Conclusion

The addition of 2% ZP fillers to heat-polymerized PMMA resin resulted in improved transverse strength, while wettability was enhanced at different percentages of ZP fillers. These findings imply that altering heat-polymerized PMMA resins with suitable fillers can improve the fracture resistance and survival rate of denture bases. However, it is critical to examine the correct concentration of fillers in order to produce the necessary mechanical characteristics and wettability for certain therapeutic applications. More research and long-term experimental studies are needed to confirm these findings and evaluate the effectiveness of these modified PMMA resins in practical dental applications.

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تأثير الزركونيا والحشو الدقيق المبلمر على بعض خصائص قاعدة طقم الأسنان بولي ميثيل ميثاكريلات

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الخلاصة

يأتي الاستخدام العالمي لبولي ميثيل ميثاكريلات (PMMA) كمادة أساسية لأطقم الأسنان من سهولة المعالجة والإصلاح والتوافق الحيوي والمظهر الجمالي الممتاز. ومع ذلك، فإن أوجه القصور في مواد البوليمر، مثل الخواص الميكانيكية والفيزيائية غير كافية. كان الغرض من هذه الدراسة هو تقييم القوة المستعرضة وقابلية البلل PMMA بعد الاختلاط مع جزيئات الزركونيا **و** PMMA المبلمرة **[**ZP] كمواد مالئة بنسبة مختلفة. تم تقسيم ستين عينة PMMA إلى ثلاث مجموعات بناء على النسبة المئوية بالوزن لحشو ZP المضاف إلى كل منها: المجموعة **C**: المجموعة الضابطة، 20 عينة بدون حشو ZP (0٪ بالوزن.)؛ المجموعة أ: 20 عينة بوزن 2٪ ZP ؛ والمجموعة ب: 20 عينة بوزن 4٪. تم استخدام اختبارات قوة الانحناء وقابلية البلل لتقييم جميع العينات. تم تحضير مسحوق ZP وخلطه مع مسحوق PMMA بالوزن بنسبتين مختلفتين 2٪ و 4٪]1.2 ميكرومتر و 30٪ ZrOو 0.69 ميكرومتر و 70٪ **p-** PMMA. لبلمرة العينات، تم استخدام إجراء المعالجة الحرارية المعتادة باستخدام حمام مائي، لكل من اختبارات قوة المرونة وقابلية البلل. تم تحليل البيانات من الدراسة باستخدام تحليل التباين أحادي الاتجاه ANOVA**)** مع اختبارات Tukey's HSD و T3 **'s**Dunnett اللاحقة **(**مع قيمة **P** معنوية تبلغ **p (**0.05>**)**وكانت النتائج زيادة معنوية في قوة المرونة المستعرضة لوحظت مع إضافة مسحوق ZP **إلى** PMMA بنسبة 2٪. بينما حدث انخفاض كبير بنسبة 4٪. لوحظت زيادة كبيرة في قابلية البلل بنسبة 2٪ و 4٪. مزيج من زركونيا وجزيئات PMMA المبلمرة المستخدمة كحشو الأسنان في 2 ٪ و 4 ٪ بالوزن. تعزيز وتقليل القوة المستعرضة على التوالي، في حين عززت قابلية البلل مع زيادة التركيز.