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Estimate Zinc-Oxide Particles on PMMA Mechanical Properties

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Abstract

Background: Poly-methylmethacrylate is the most used dental material for the construction of removable prosthodontic appliances. Unfortunately, it has shown to be lacking two important properties which are radio-opacity and mechanical strength. Zinc-oxide (ZnO) powder is widely used in dentistry and is considered a semiconductor material with the radio-opaque property.
Purpose**:** To determine the effect of ZnO filler powder on some mechanical properties (impact and transverse strength) of microwave-cured acrylic denture base.
Approach**:** The ZnO powder was added to the acrylic polymer powder in two percentages of 2% and 4% by weight. The prepared sample of acrylic resin was evaluated with impact and transverse strength (n=10). ANOVA and Tukey test were used at a P-value of ($P \leq 0.05$).
Results**:** Significant reduction in the transverse strength was noticed in the acrylic denture base with the incorporation of ZnO powder as a filler material in both concentrations. However, non-significant differences were observed in the impact strength with the incorporation of the ZnO filler agent.
Conclusions**:** The addition of ZnO radio-opacifier powder as a filler agent could affect the properties (impact and transverse strength) of microwave-cured acrylic resin.

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Keywords: Zinc Oxide Filler; Impact Strength; Transverse Strength; Mechanical Properties.

1. Introduction

PMMA is one of the traditionally used dental materials. It is used due to its satisfactory aesthetic, compatibility with the oral tissue, ease of technical manipulation along with low cost [1]. PMMA thermal conductivity is approximately 0.2 W/mK [2]. Compared with gold or cobalt alloy denture base materials this can present problems during denture processing. The porosity during fabrication may rise as the heat produced cannot escape. The problem may propagate with a low thermal conductivity as the denture isolates the oral soft tissues from any sensation of temperature. The patient may consume hot drinks without realizing it. This may lead to harm to the back of the throat and possibly the esophagus being scalded [3]. The PMMA seemed not ideal in every respect. Despite its popularity due to simple processing, repair, and satisfactory aesthetic, the major problem correlating with PMMA as denture material is its weak strength. It reveals poor strength and especially under stress failure inside the oral cavity, impact failure outside the oral cavity in addition to lack of radio-opacity [4, 5]. Impact strength is the energy absorbed by a substance that is measured when destroyed by a sudden blow [6]. To overcome these issues, several trials were made to adjust and enhance the mechanical, thermal, and physical properties of the PolyMMA. These include the incorporation of some fillers into the resin such as titanium dioxide, alumina, and zinc oxide [7- 9].
Zinc oxide powder (ZnO) was widely used in dentistry. It could be added to the acrylic denture base material as radio-opaque material and for its biocompatibility in temporary fillings, as well as cement base, root canal filler, and impression materials [10-13]. Zinc is a blue-white metal with an atomic number of (30) and atomic weight of (65.39). The pure form is soft. Zinc exerts only a slight influence on the strength and flow of the amalgam, while amalgam alloys without zinc are more brittle and tend to be less plastic [6, 14-16]. Crystalline ZnO forms cement-like products which are commonly used in dentistry [13-17]. It could add to substances including rubber, cement, ceramics, and plastics [18-21]. It has a high thermal conductivity. Moreover, it provides antibacterial, binding, and UV protection properties
This study was designed to evaluate the influence of two different percentages of the ZnO filler powder on the impact and transverse strength of microwave-cured PMMA.

Nomenclature			
PMMA	Polymethylmethacrylate	mm	Millimeter
UV	Ultraviolet	ADA	American Dental Association
ZnO	Zinc-oxide	P-value	Probability values
ANOVA	Analysis of Variance	C°	Centigrade
ml	Milliliter	J	Joule
Gm	Gram	N	Newton

2. Materials and Methods

60 specimens were constructed for this study (n=10). The sample was divided into two main groups for impact and transverse strength tests. The experimental groups were treated with 2% and 4% of ZnO powder, while the control group was prepared without any additives. All the tested specimens were kept at room temperature and stored in distal water to keep the dimensional stability until the specimens were tested.

2.1. Metal Pattern Preparation

According to [22], the test patterns were constructed, and a rectangular-shaped pattern of 55mm × 10.5mm × 5mm (± 0.5mm) in length, width, and thickness was fabricated for the impact strength test. While the pattern dimensions of 65mm × 10.5mm × 5mm (± 0.5mm) were prepared for transverse strength.

2.2. Mould Preparation

Microwave-flask was used in this process and the molding material was mixed following the manufacturer's instruction (50ml/100gm). The wax pattern was embedded in a layer of stone mixture, after setting; a separating medium was applied. Then a second layer was poured with vibration to avoid trapping air into the mold. Stone was allowed to sit for 60min, the flask emerged in boiling water to soften the wax pattern, then opened and cleaned from wax to leave the mold cavity clean [23-25].

2.3. Dough Mixture Preparation

The preparation of the heat acrylic mixture was mixed (3:1) by volume according to the manufacturer's instruction (OVA 238, Czech Republic). The control group was prepared without any additives while that of the experimental groups was added with 2% and 4% of ZnO. A 2% of ZnO was added to 98% of acrylic powder while a 4% of ZnO was added to 96% of acrylic powder and the mixtures were mixed homogeneously in a jar container [26]. The heat-cured monomer liquid then was added to the powdered mixture then stirred and kept in a container at room temperature (23◦C±5◦C) to create dough.

2.4. Curing Cycle and Polishing Procedures

Curing was done in a microwave oven (TDS M1877N, Korea) at heating up to 500◦C and let for 4 minutes [22].
After curing, the specimen was finished using sandpaper of 600 and 1200 grit size. Then polished using a dental lathe polishing machine with bristle brush and pumice at a speed of 1500rpm, and finally with wool brush and polishing soap [27, 28].

2.5. Testing Procedures

2.5.1. Impact Strength

According to the ASTM D-6110 and ISO-179, the Charpy- impact strength test was achieved [29-33] using an impact-tester machine (TMI 43-1, USA), Fig. 1. The impact pendulum of 5 Joule capacities was used to strike the specimens at the center when held horizontally, and the impact energy scale reading was in (J).
The value of impact strength was calculated by the following formula:

$$\text{Impact strength } (J/mm^2) = A / t\,w * 10^3 \quad (1)$$

A =absorbed energy in (J), t = thickness of the specimen, and w = width in (mm^2) at the specimen's center.

Fig 1. Charpy impact tester machine

2.5.2. Transverse Strength

A 3-Point universal tester machine (Instron (1122), Taiwan) was used to accomplish the transverse strength test, Fig. 2. In this procedure, the device was applied with two supports of polished cylindrical surface placed 50mm apart, and a central loading plunger of 6mm diameter. The supports were parallel to each other and perpendicular to the longitudinal centerline.
To carry out this test, a constant crosshead speed of 5mm/min was applied; the load was measured by a compression load cell of the maximum capacity of 10KN.
The loading plunger was midway between the supports that clench at each end of the two supports; the specimens were deflected to fracture. The transverse strength was computed according to the formula [34]:

Transverse Strength: $(N/mm^2) = 3PI / 2bd_2$ (2)

Where P = maximum force (N), I = distance between the two supports (mm), b = width of specimens (mm) and d = depth of specimens (mm).

Fig 2. Three-point transverse taster machine

3. Results

The results of the impact strength test revealed that the highest mean value was in the control group (4.0640 J/ mm^2) while the lowest mean value was in the experimental (4 % ZnO) group (3.7160 J/mm^2) as in Table 1 and Fig. 3.

Table 1 Descriptive statistics of Impact Strength

Groups	Mean	Std. Deviation	N
Control	4.0640	.43648	10
2% ZnO2	3.8270	.53660	10
4% ZnO2	3.7160	.41661	10
Total	3.8690	.47343	30

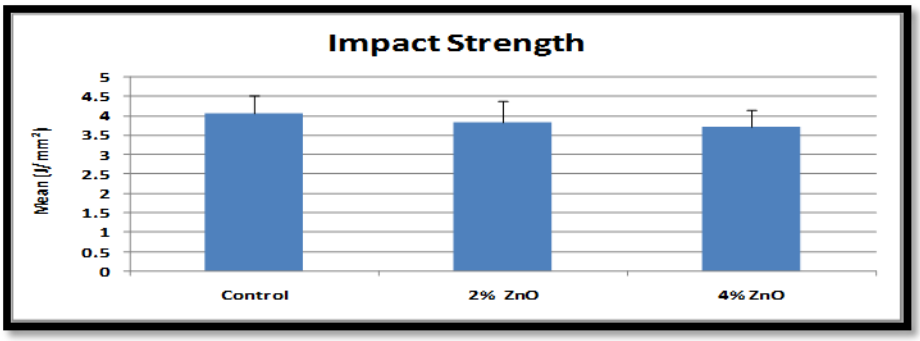

Fig 3. Mean distribution of the impact strength after incorporation of the ZnO powder

NOVA test revealed the non-significant difference between control and experimental groups as in Table 2.

Table 2 (ANOVA) between tested groups in (J/mm^2)

Groups		N	(P-Value)	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	2% ZnO	10	.500	NS	-.2799-	.7539
	4% ZnO	10	.235	NS	-.1689-	.8649
2% ZnO	4% ZnO	10	.856	NS	-.4059-	.6279

($P \leq 0.05$) NS: Non-significant

The transverse strength test revealed the highest mean value in the control group (72.3270) while the lowest mean values in the experimental (4 % ZnO) group (53.2530) as in Table 3 and Fig. 4.

Table 3 Descriptive statistic of Transverse Strength

Groups	Mean	Std. Deviation	N
Control	72.3270	6.39614	10
2% ZnO2	60.0100	6.36324	10
4% ZnO2	53.2530	4.11635	10
Total	61.8633	9.74807	30

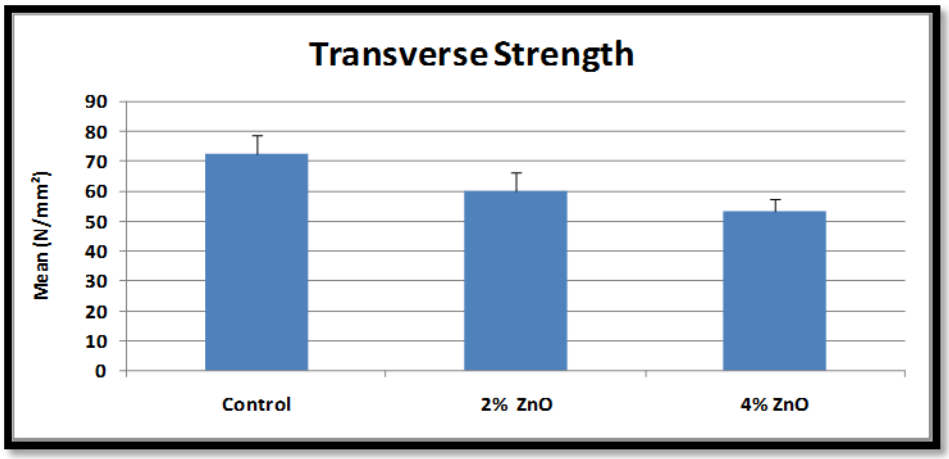

Fig 4. The mean distribution of the Transverse strength after adding the ZnO powder

NOVA test revealed a significant difference between control and experimental groups as in Table 4.

Table 4 ANOVA-test showing the transverse strength in (N/ mm^2)

Groups		N.	(P-Value)	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	2% ZnO	10	.000	S	5.9683	18.6657
	4% ZnO	10	.000	S	12.7253	25.4227
2% ZnO	4% ZnO	10	.035	S	.4083	13.1057

(P≤ 0.05) S: Significant difference

4. Discussion

4.1. Impact Strength

In the present study, the transverse and impact strength of microwave-cured acrylic are evaluated after the addition of 2% and 4% zinc oxide powder.

The present data results showed that impact strength may affect highly by the measurements of ZnO filler incorporated into the acrylic resin. The additions of 2% and 4% of ZnO powder to the microwave-cured resin have shown the same impact strength as that of non-additives. The final resin polymerization is probably affected by the incorporation of ZnO powder filler material. It may rely on the relationship between the impact strength and the adding of ZnO with various measurements of weight to the resin structure. This may result in less energy absorption due to stress concentration around the zinc oxide particles and consequently create crack propagation. The increase in the ZnO percentages could affect the boundary regions. This might lower the energy dissipation per unit volume which in turn lowers the impact strength, or it could be related to less force absorption by the ZnO particles before fracture. This result disagrees with the [8] which concluded that the increase in the impact-strength of the microwave acrylic may be due to the increase of the ZnO content which improves and increase the energy absorption during the impact test.

4.2. Transverse Strength

The 3-Point bend test was originally selected to simulate the flexural loading that an upper denture receives during mastication since it reflects the stress arrangement in the clinical condition [33].

The addition of ZnO powder lowered significantly the transverse strength of microwave-cured acrylic compared to a non-additive denture base.

This decrease in the transverse strength may be related to the existence of ZnO fillers with an acrylic matrix which in turn acts as inclusion bodies. Each particle caused a microfracture that weakened the resulting denture base [26].

This result probably could be agreed with the result of [5] which found that the addition of inorganic fillers like Zirconia, Titanium oxide, ZnO, and magnesium oxide to PMMA to be used for implant purposes could lower the denture base mechanical properties.

5. Conclusion

The present study concluded that the addition of 2% and 4% of ZnO as a filler agent to the microwave-cured acrylic produce a non-improvement effect on the impact and transverse strength values than that of the non-additive denture base. It showed that the addition of ZnO as a filler may impair the properties (impact and transverse strength) of the denture material.

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