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Article

Effect of the incorporation of zinc oxide nanoparticles on the flexural strength of auto- polymerized acrylic resins.

Efecto de la incorporación de nanopartículas de óxido de zinc en la resistencia a la flexión de las resinas acrílicas autopolimerizadas.

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Abstract: Background: Auto-polymerized acrylic resins are commonly used in many applications in dentistry including in maxillofacial rehabilitation such as interim prostheses, denture repair, reline, orthodontic appliances, record base, among others. These substances, however, have some negative aspects such as poor mechanical properties. Aim: The objective of the current study was to evaluate the effect of incorporating zinc oxide nanoparticles to auto-polymerized acrylic resins on their flexural strength. Materials and methods: Thirty specimens were made from auto-polymerized acrylic resins, divided into three main groups (1 control and 2 experimental). Each group had ten specimens. The two experimental groups comprised the zinc oxide powder at 1% and 2% concentrations, respectively. Acrylic specimens were fabricated with the dimension of 65mm length, 10mm width and 2.5mm thickness according to ISO 1567 specification 1999. Each specimen was subjected to the flexural strength test by a universal testing machine. The crosshead speed for the flexural strength test was 5mm/min until fracture occurred. The SPSS version 16 was utilized for the statistical analysis. The ANOVA and Tukey were used for the comparison among all groups. Results: there was a significant increase (p<0.001) in the flexural strength of the acrylic resins following the addition of zinc oxide particles (control group: 133.27 SD 1.73, ZnO 1%: 154.28 SD 2.90, ZnO 2%: 176.45 SD 0.94). Conclusions: The incorporation of zinc oxide nanoparticles has a significant effect on the flexural strength of auto-polymerized acrylic resins.

Keywords: Dental materials; acrylic resins; polymerization; flexural strength; zinc oxide.

Resumen: Antecedentes: Las resinas acrílicas autopolimerizadas se usan comúnmente en muchas aplicaciones en odontología, incluyendo la rehabilitación maxilofacial, en prótesis provisionales, reparación de prótesis, revestimientos, en aparatos de ortodoncia, bases de registro, entre otros. Estas sustancias, sin embargo, tienen algunos aspectos negativos tales como propiedades mecánicas deficientes. Objetivo: el objetivo del presente estudio fue evaluar el efecto de la incorporación de nanopartículas de óxido de zinc en la resistencia a la flexión de resinas acrílicas autopolimerizadas. Materiales y métodos: Treinta muestras de resinas acrílicas autopolimerizadas fueron hechas, divididas en tres grupos principales (un grupo control y dos experimentales), cada grupo con diez especímenes. Se incorporó polvo de óxido de zinc en los dos grupos experimentales, en concentraciones de 1% y 2%, respectivamente. Las muestras de acrílico se fabricaron con una dimensión de 65mm de longitud, 10mm de ancho y 2,5mm de espesor según la especificación ISO 1567 1999. Cada muestra se sometió a la prueba de resistencia a la flexión mediante una máquina de prueba universal. La velocidad de la cruceta para la prueba de resistencia a la flexión fue de 5mm/min hasta que se produjo la fractura. Se utilizó la versión SPSS 16 para el análisis estadístico. El ANOVA y Tukey se utilizaron para la comparación entre todos los grupos. Resultados: Se observó un aumento significativo (p<0.001) en la resistencia a la flexión de las resinas acrílicas luego de la adición de partículas de óxido de zinc (grupo de control: 133,27 SD 1,73 MPa, ZnO 1%: 154,28 SD 2,90 MPa, ZnO 2%: 176,45 SD 0,94 MPa). Conclusiones: La incorporación de nanopartículas de óxido de zinc tiene un efecto significativo en la resistencia a la flexión de las resinas acrílicas autopolimerizadas.

Palabras Clave: *Materiales dentales; resinas acrilicas; polimerización; fuerza flexible; óxido de zinc.*

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INTRODUCTION.

The use of auto-polymerized acrylic resins is very popular in removable prosthodontics, including in maxillofacial rehabilitation, these resins are utilized for many purposes such as interim prostheses, record base, denture repair, reline, and orthodontic appliance, among others.[1,2] These restorative materials are reasonably priced, chemically activated, and easily manipulated by the dental technician.[3]

The degree of polymerization of these materials, however, is not as complete as heat-polymerized resins, producing more unreacted residual monomer, leading to a lower flexural strength.[4] According to Yassin *et al.,*[5] zinc oxide, a white powder with the chemical formula ZnO, can be naturally found in the mineral zincite, but may also be synthetically manufactured.

Elemental zinc is a white-blue brittle metal in pure form. When heated, it oxidizes resulting in a low-density metal oxide. The ZnO powder has wide applications in dentistry, such as root canal sealer and in gutta-percha.

Numerous studies have been carried out using nanoparticles with the aim of enhancing the mechanical properties of acrylic resins. Metal fillers such as silver nitrate, zinc oxide and zirconium dioxide have significantly improved the mechanical properties of auto-polymerized acrylic resins.[6-9]

Andreotti *et al.,*[10] concluded that the use of zinc oxide nanoparticles slightly reduced the flexural strength of auto-polymerized acrylic resins used for ocular prostheses. Furthermore, Al-Shammari[11] reported that zinc oxide enhanced the flexural strength of heat-polymerized acrylic resins.

On the other hand, Kamonkhantikul *et al.,*[12] concluded that the zinc oxide filler did not result in any improvement in the flexural strength of the acrylic resins.

However, there are few published articles about the influence of zinc oxide on auto-polymerized acrylic resins. Therefore, the present study was carried out to assess the influence of incorporating zinc oxide in different concentrations into auto-polymerized acrylic resins on flexural strength. The null hypothesis was that there were no significant differences among all groups.

MATERIALS AND METHODS.

The flexural strength of auto-polymerized acrylic resin (Spofadental, Jicin, Czech Republic) was assessed following the addition of zinc oxide powder (Golchadent, Iran). Tin foil (Zinnfoile, Dentaurum Pforzheim, Starke, Germany) and petroleum jelly (Hebei, China) were used as the separating medium. Thirty specimens were made from auto-polymerized acrylic resin, divided into three major groups, each with ten specimens.

According to ISO 1567 specification, each specimen was prepared with a dimension of 65mmx10mmx3 m in length, width, and thickness, respectively.[13]

All specimens were made by using plastic patterns that were invested into stone moulds (Zhermack, Rovigo, Italy). (Figure 1 and Figure 2)

According to the manufacturers' instructions, the control group (free of ZnO) was prepared by adding 22g of the acrylic powder to 10ml of the acrylic monomer. A dry and clean ceramic jar was used for the mixing, and the mix was incubated at 23°C for 6min until reaching the dough stage. The acrylic dough was rolled and then placed into the stone mould, and the two parts of the container were joined and placed under the hydraulic press (up to 20 bar) for five minutes. Next, the upper and lower parts were carefully opened and incubated at room temperature for twenty minutes. Following complete curing, each specimen was carefully removed from the flask. Then all acrylic specimens were finished and polished by the conventional method. Acrylic specimens were kept in distilled water for 7 days at 23°C.[14]

The above process was repeated for experimental groups with modifications that the experimental group ZnO 1 was made from auto-polymerized acrylic resin and zinc oxide (0.22g ZnO, 21.78g acrylic powder, 10ml monomer) while the experimental group ZnO 2 was formed by adding 0.44g of zinc oxide powder to 21.56g acrylic powder and 10ml monomer.

Flexural strength test

The flexural strength test was carried out on all acrylic specimens using a universal testing machine. (Figure 3)

Each specimen was marked with two lines at the borders regarding the holding with the test table. The space between lines was 10mm.

Another line was marked at the middle of each

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specimen where the striker is attached via the testing machine. The crosshead speed for the flexural test was five millimetres per minute.

The load was applied to each specimen until fracture happened. The values of flexural strength (MPa) were calculated using the following equation[15]: $S=3PI/2BD^2$

Where:

The letter S represents flexural strength (N/mm^2).

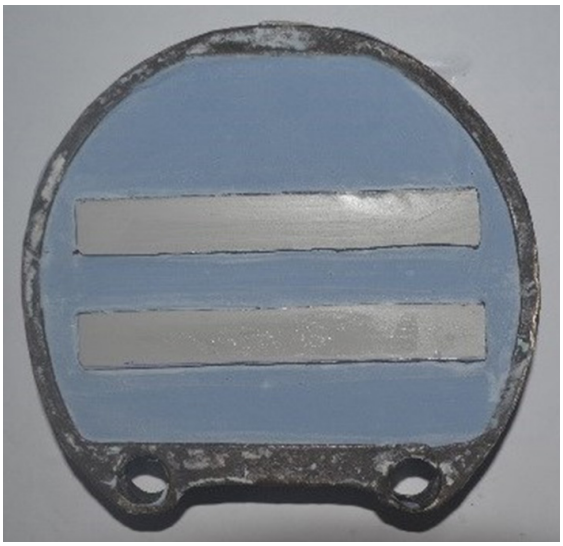
The letter P represents the maximum force applied to the specimen (N).

The letter I represents the distance between the supports (mm).

The letter B represents the width of a specimen (mm).

The letter D represents the depth of a specimen (mm).

Figure 1. Plastic patterns located onto stone mould.



RESULTS.

Statistical analyses (SPSS version 16 software; IBM, New York, USA) indicate the incorporation of zinc oxide filler has significantly improved the flexural strength of acrylic resins. Mean and standard deviation (SD) values are listed in Table 1.

The second experimental group had the greatest mean value of flexural strength. On the other hand, the control group (without filler) had the lowest mean value of flexural strength. Furthermore, there are significant differences between all groups ($p<0.001$) as illustrated in Table 2.(Tukey HSD multiple comparison tests).

Moreover, significant differences among all groups ($p<0.001$) are shown in Table 3.

Figure 3. Specimen under test on an universal testing machine.

Figure 2. Stone mould.

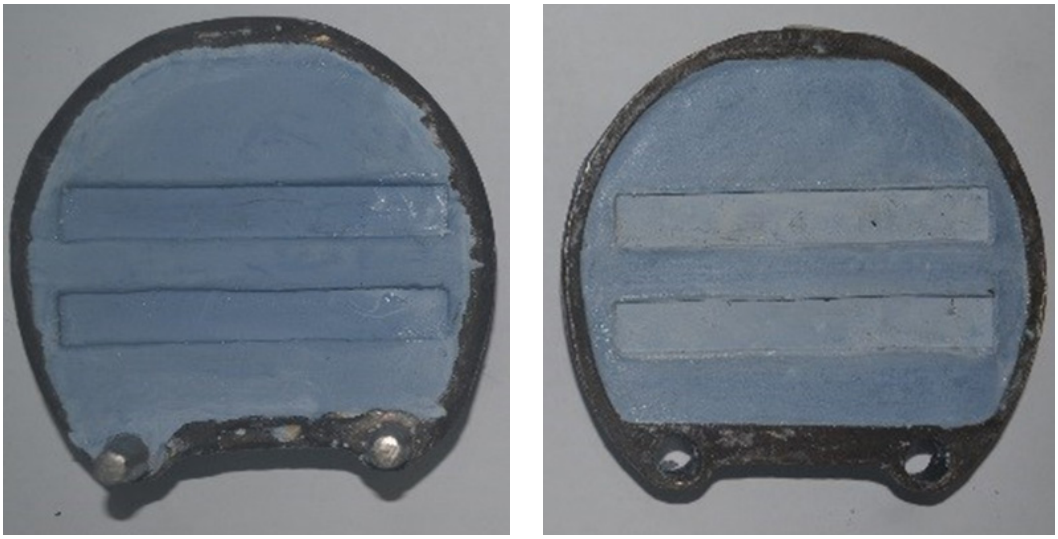


Table 1. Mean and standard deviation of flexural strength.

Groups	Mean	Standard deviation
Control	133.27	1.73
Experimental group (ZnO 1)	154.28	2.90
Experimental group (ZnO 2)	176.45	0.94

Table 2. Tukey HSD multiple comparisons test for flexural strength.

Groups	N	Subset for alpha = 0.05		
		1	2	3
Control	10	133.27		
ZnO 1	10		154.28	
ZnO 2	10			176.45
Significance		1.000	1.000	1.000

Table 3. Results of the ANOVA test.

ANOVA					
Flexural Strength	Sum of Squares	Degrees of freedom	Mean Square	F	Significance
Between Groups	9322.21	2	4661.10	$1.13x10^3$	0.000
Within Groups	111.21	27	4.12		
Total	**9433.41**	**29**			

DISCUSSION.

The current research was carried out in order to evaluate the effect on the flexural strength of adding ZnO to auto-polymerized acrylic resins. The literature on the effect of ZnO filler on the mechanical properties of auto-polymerized acrylic resins is scant. The current study showed that the addition of zinc oxide powder significantly enhanced the flexural strength compared to the control group. (Table 1 and Table 2)

The increase in the mean values of flexural strength following the addition of zinc oxide powder is believed to be due to the greater bond between ZnO particles and the polymer matrix. These results are in agreement with Li *et al.,*[16] who found that the greatest flexural strength was observed in micro-composite dentures following the incorporation of zinc oxide fillers.

In addition, the current results were similar to those reported by Alhavaz *et al.,*[6] who found that the flexural strength of auto acrylic resins was significantly increased after the addition of zinc oxide particles.

Likewise, these results are in accordance with a study conducted by Al-Shammari[11] who found that zinc oxide fillers increased the flexural strength of the acrylic resins.

Nonetheless, the present results differ from the study by Andreotti *et al.,*[8] who reported that the use of zinc oxide slightly reduced the flexural strength of auto-polymerized acrylic resins used for the construction of ocular prostheses.

The current results also disagree with a study carried out by Kamonkhantikul *et al.,*[12] who reported that the zinc oxide filler did not result in any improvement in the flexural strength of acrylic resins because of their shape (spherical), which evenly directed the stress throughout the resin matrix.

The null hypothesis was rejected as there were significant differences among all the studied groups. The current research concluded that the addition of zinc oxide powder significantly improved the flexural strength of auto-polymerized acrylic resins. Further research to assess the impact strength and surface hardness of the acrylic resins with the addition of ZnO fillers at different concentrations is required.

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Clinical significance: Auto-polymerized acrylic resins are widely used in many applications in dentistry (including in maxillofacial rehabilitation) such as in interim obturators, record base, repair, and reline.

These materials must have adequate mechanical properties to resist deformation. The addition of zinc oxide powder has significantly enhanced the flexural strength of auto-polymerized acrylic resins.

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Authors' contributions: The author contributed to the work

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