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RESEARCH PAPER

Effect of Adding MgO Nanoparticles on the Hardness of Self-Cured Acrylic Resin

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ABSTRACT

This study aimed to evaluate the effect of incorporating 3% magnesium oxide (MgO) nanoparticles into conventional cold-cured acrylic resin on its surface hardness. A total of 14 circular specimens (40 mm × 2 mm) were prepared and divided into two equal groups: unmodified cold-cure acrylic resin (control) and acrylic resin reinforced with 3% MgO by weight nanoparticles. Specimens were fabricated using the conventional flasking method, finished, polished, and stored in distilled water at 23°C±2 for 48 hours. Surface hardness was measured on dry specimens using a Shore D durometer five times for each specimen and the average was calculated. Statistical analysis was performed using t-tests through SigmaPlot software version 12. The mean surface hardness of the control group was 78.6, while the group reinforced with MgO nanoparticles exhibited a higher mean hardness of 82.1. Statistical analysis showed a highly significant difference ($P \leq 0.001$) between the groups, indicating that the addition of MgO substantially improved the surface hardness of the cold-cured acrylic resin. Incorporating 3% magnesium oxide nanoparticles into cold-cured acrylic resin improves its surface hardness. This suggests the potential for MgO reinforcement to increase the longevity and clinical performance of denture base materials.

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INTRODUCTION

Acrylic resins based on polymethyl methacrylate (PMMA) are widely used in dentistry due to the following advantages: strong clinical performance, dimensional stability, affordability, simplicity of manipulation, and satisfactory cosmetic qualities [1]. This kind of material is used in orthodontic equipment, denture repairs, removable dental prosthesis, provisionals, and other dental procedures [2]. Acrylic resin permits polymerization at room temperature without the need for the traditional curing process with heat

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treatment. This kind of material offers particular clinical advantages. When compared to heat-cured acrylic resin, self-cured acrylic resin may exhibit worse mechanical qualities [3].

One important factor that directly influences acrylic resins' resistance to wear and abrasion is surface hardness [4]. Materials with insufficient surface hardness are vulnerable to abrasions in clinical settings, which can result in biofilm formation, microbial adhesion, and ultimately worse functioning and patient satisfaction [5]. Similarly, a material's mechanical strength and appearance are negatively impacted by porosity, which often arises from inadequate polymerization or improper processing [6]. Oral fluids can be absorbed due to porosity, which can result in stains, odors, and a reduction in the biocompatibility of resin [7]. Another important factor is surface roughness, which affects a material's capacity to prevent plaque buildup as well as patients' level of comfort [8]. The degree of polymerization has a direct impact on PMMA's overall performance. The degree of cytotoxicity risk is increased and the mechanical properties are weakened by the residual monomer content from incomplete polymerization [9]. Since nanoscale particles have a high surface-area-to-volume ratio and can interact with the surrounding polymer matrix more effectively than larger particles [10], its use for reinforcing has been seen as particularly significant. When properly dispersed in PMMA, the reinforcing particles can prevent polymer chains from moving, increase the material's resistance to deformation, and aid in the transmission of stress between the reinforcing agent and the polymer matrix [11]. However, before nanoparticle reinforcement is deemed effective, a few requirements must be met.

One inorganic oxide that has been explored as a potential reinforcing phase in polymer-based dental composites is magnesium oxide (MgO). It has been discovered that adding MgO to PMMA-based dental materials changes their mechanical and structural characteristics. It is feasible to think of MgO as a reinforcing phase in acrylic resins as a number of earlier research have shown that MgO nanoparticles can act on the PMMA matrix and alter its mechanical behavior [12]. By adjusting their concentrations to 1.25%, 2.5%, and 5%, Al-Taee and Al-Ali [3] investigated the impact of 50-nm MgO nanoparticles on cold-cured acrylic resin. The greatest flexural strength was discovered at 1.25% MgO concentration, whereas the minimum flexural strength was found at 5% MgO concentration, indicating that the mechanical behavior of cold-cured acrylic resin due to MgO reinforcement is substantially dependent on its concentration.

Additionally, MgO has demonstrated remarkable mechanical reinforcement and antibacterial qualities in a few experiments. Significant antifungal action against *Candida albicans* denture stomatitis was demonstrated by acrylic resins containing 2%, 4%, or 6% MgO nanoparticles [13]. Another study by Wady et al. [14], discovered that Ag nanoparticles was more effective at reducing *Candida albicans* than PMMA reinforced with MgO nanoparticles. According to a study, adding a small amount of MgO (2% or 4%) made acrylic resin harder. Nevertheless, the mechanical characteristics and color stability are negatively impacted by raising the concentration over this point [15]. In order to find out how adding 3 % magnesium oxide (MgO) nanoparticles to self-cured acrylic resin affected the material's surface hardness in comparison to unmodified self-cured acrylic resin, an in vitro experiment was carried out. It is expected that the experiment's findings will provide some insight into the viability of using MgO nanoparticles to reinforce self-cured acrylic resin.

MATERIALS AND METHODS

Mould preparation

According to Alwaeli and Alsegar [16], Circle-shape plastic pattern was made by cutting nylon sheet using CNC (CNC Router, Italy) into desired shape and dimensions (40mm diameter x2mm thickness) regarding to ADA specification No.12/ 2002.

During preparation of the mold, the lower portion of the flask was partly filled with dental stone blue colour (Zhermack, Germany) (Fig. 1) which was mixed according to the manufacturer's instructions. After the stone was set, the remaining space of the lower half was filled with heavy body silicone yellow colour (Zhermack, Zetaplus, Germany) which were mixed according to the manufacturer instructions. Before silicone setting, the 3 plastic patterns were inserted carefully. Then, separating medium were applied on to the silicone in the lower half and allowed to dry. The upper portion of the flask was, then, reassembled onto the lower portion and filled with mixed stone, with

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vibration by a dental vibrator. After the complete setting of the stone, the flask was opened and the plastic patterns were removed to get a mold ready for making the specimens (Fig. 1) [17].

Specimen grouping

14 specimens were prepared, and divided into two equal groups. The control group (A) is cold -cured acrylic resin without addition and the test group is cold -cured acrylic resin with 3% MgO by weight (ChangshaSantech Materials Co., China) (B). MgO was mixed with acrylic powder by shaking using the electronic balance for weighing [4].

Cold-cured acrylic resin specimen's preparation

Cold-cured acrylic resin (Angel Dent., China) was mixed at a ratio of 1/3 according to the manufacturer instructions and packed into the mould at the proper stage. Then, the flask portions were reassembled after application of separating medium on the upper half and pressed in the hydrolic press at 50 psi for 1 hour. Then the flasks were opened, and the specimens were removed. Conventional finishing and polishing procedure have been followed (Fig. 2). The specimens were stored in distilled water at 23°C±2 for 48 hours before the testing (ADA specification No. 12) [18].

Hardness Test

Hardness values were obtained for all specimens using a durometer hardness tester/ type Shore D (TH 210, Time Group Inc., Italy) (Fig. 3). The instrument consists of a blunt-pointed indenter 0.8 mm in diameter that tapers to a cylinder 1.6 mm.



Fig. 1. Stone and silicone mold and plastic pattern.

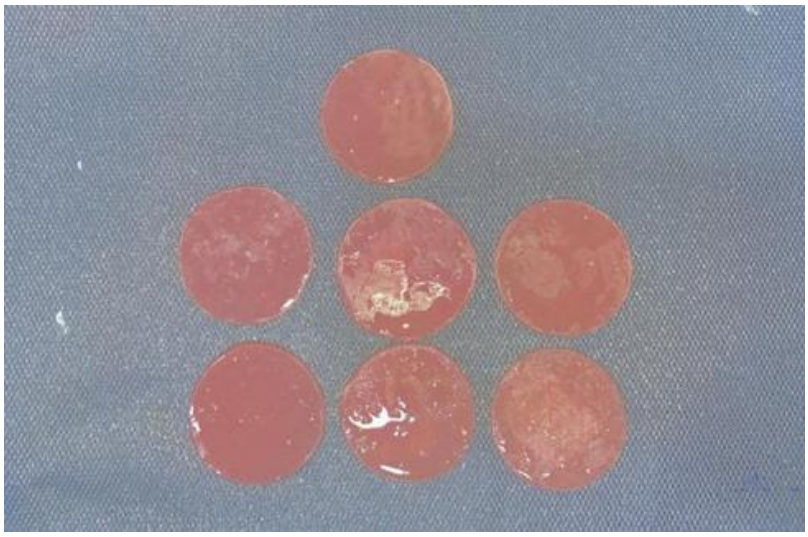


Fig. 2. Cold-cured acrylic specimens after finishing.

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The indenter is attached to a digital scale that is graduated from 0 to 100 units. The measurements were taken directly from the digital scale reading. Each specimen was subjected to five indentations and the means were calculated.

Statistical Analysis

SigmaPlot software version 12 was used to analyze the data. The results were displayed in tabular form and as bar graphs with means ± standard deviation (SD). $P \leq 0.05$ was considered significant, $P \leq 0.01$ was considered strong significance, and $P > 0.05$ was considered non-significant.

RESULTS AND DISCUSSION

T-test was used to compare the means of the various experimental groups because the data were normally distributed. According to Table 1, surface hardness mean value of group A is 78.6 ± 0.9, whereas group B has a higher mean value of 82.1 ± 0.9. Fig. 4 box plot showed that group B is significantly higher than group A ($P \leq 0.001$).

The increase in surface hardness with the addition of MgO suggests that the inorganic particles added to the polymeric matrix have a reinforcing impact. This outcome is also in line with prior research on the mechanical impact of adding MgO nanoparticles to dental materials. In particular, Naguib et al. [19] discovered that adding MgO nanoparticles to resin composites had a significant impact on the material's mechanical properties, including microhardness, demonstrating the viability of using MgO nanoparticles as reinforcing material in dental polymers.

The results presented in this research are in line with the visually represented pattern. The reinforcement of the matrix polymer with inorganic particles (MgO), which makes the material more difficult to deform under load, may be the cause of the higher hardness values for the material



Fig. 3. Hardness tester (Shore D).

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containing MgO. The conclusion, which states that filler addition and characteristics have a significant impact on the mechanical and tribological behavior of resinous materials, is in line with the scientific literature on dental materials [20]. The characteristics of fillers and their interactions with the matrix they are included in have a significant impact on the mechanical properties of resin composites [21].

The results of the LSD test provide more evidence that the difference between the groups containing MgO and the control group was not the result of pure chance. The direction of the difference is comparable to the descriptive results shown in Table 1, where the addition of 3% MgO caused the mean hardness value in the control group to change from 78.6 to 82. This outcome is consistent with how inorganic fillers affect the stiffness of dental materials made of resin. The composition, concentration, size, and distribution of fillers are important parameters influencing the mechanical properties, such as hardness and stiffness, according to several reviews of dental composites [22,20]. The research conducted by Naguib et al. [18,22] confirms the observed result and demonstrates that the addition of MgO nanoparticles can improve the mechanical properties of resin composites, including hardness. Therefore, MgO's contribution to the rise in surface hardness is confirmed by the relevance of the LSD result.

The positive shift in the earlier results of the description is statistically confirmed by the results of Table 4. The enhanced ability to withstand localized surface deformation brought about by the addition of MgO can account for the 3.5%

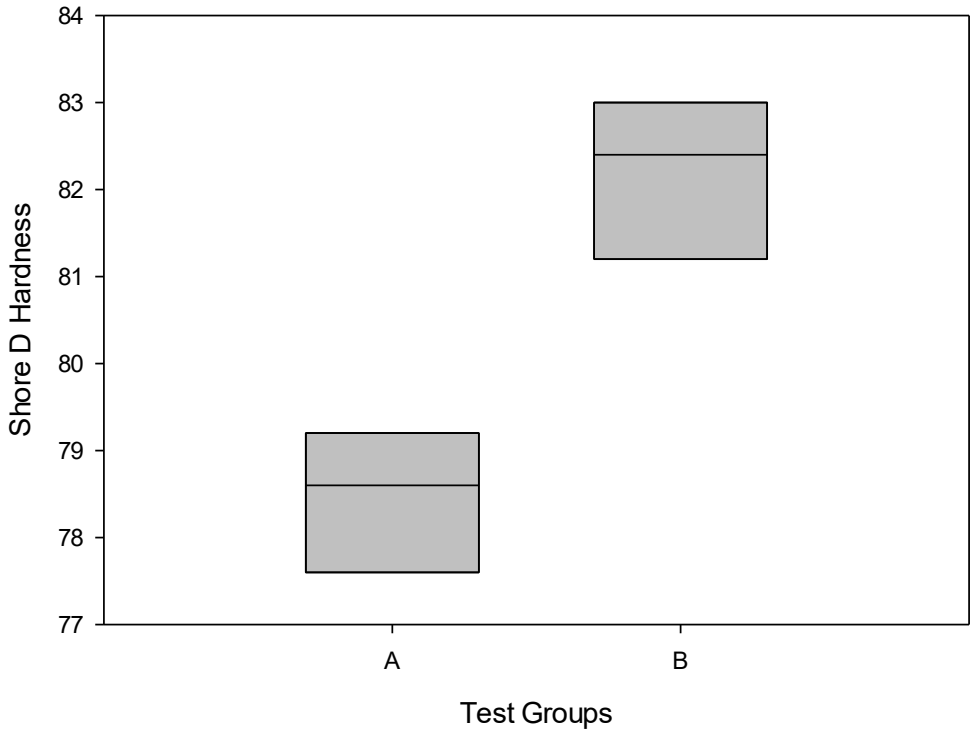


Fig. 4. Box plot of Shore D hardness values of test groups.

Table 1. Descriptive Statistics of Mean and standard deviation of all groups.

Group studied	No.	Mean	standard deviation	Min	Max
A	7	78.6	0.9	77	80
B	7	82.1	0.9	80	84

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increase in the average hardness level. It might be explained by the enhanced contact between the filler and polymer matrix as well as the higher hardness level of the inorganic phase of MgO. According to research, one of the most important factors affecting the mechanical performance of dental resin materials is the reinforcement impact of fillers [20]. However, the degree of augmentation should be taken into account in relation to the MgO content, particle size, surface treatment, distribution within the polymer matrix, and interaction with it. The mechanical response of the resin could not rise proportionately to the increasing concentration of nanoparticles, according to recent studies of MgO modified PMMA. From a scientific perspective, this result could be because MgO particles reinforce the polymer matrix, increasing its stiffness and resilience to localized deformations. The scientific literature on reinforced dental plastics supports these claims.

CONCLUSION

This study showed that adding MgO nanoparticles to cold-cured acrylic resin significantly increased its surface hardness. MgO is useful reinforcing filler that improves the resin's durability and mechanical resistance without sacrificing production efficiency. These results demonstrate the potential of MgO as a useful additive in dental prosthesis and emphasize the need for ongoing innovation to enhance the durability and functionality of denture base materials.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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