RESEARCH PAPER

Mechanical Property of MgO Nanoparticles Incorporated PMMA Bone Cements

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ABSTRACT

Background: PMMA with nanoparticles of MgO reduces harmful exothermic reactions of PMMA and increases its mechanical, physical and chemical properties. The combination of biomaterials with trace elements for bone cement has verified their better mechanical strength and biocompatibility response.

Aim: The purpose of the study is to evaluate the mechanical property of MgO nanoparticles incorporated with PMMA bone cement.

Materials and methods: The nanocomposites were created by combining the powder component PMMA beads with the liquid part MMA. Mechanical properties like surface roughness and micro hardness of the bone cement was assessed.

Result: The results of this study demonstrated that the PMMA-MgO material has greater Surface roughness and Microhardness than PMMA cement. According to the Independent t-test, the difference was not statistically significant (p value 0.05).

Conclusion: This study has shown that the surface roughness and microhardness of bone-PMMA interfaces were improved by the addition of MgO nanoparticles to PMMA. Although no statistically significant difference was observed, the addition of MgO nanoparticles did not adversely affect the mechanical properties of the bone cement. Further studies with larger sample sizes and evaluation of additional mechanical properties are recommended to better understand the potential benefits of MgO nanoparticle incorporation in bone cement.

Keywords: Mechanical properties, Innovation, Economic growth, Sustainability, MgO nanoparticles, PMMA bone cement, Surface Roughness

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INTRODUCTION

Recently, the concept of nanotechnology and its nanomaterials is a thriving specialty of research in a variety of fields. This field of science has the potential to breakthrough many applications such as electric and electronic devices, catalysts, optical, magnetic, and biomedical devices(1). On account of their excellent physicochemical features, high surface area to volume ratio, and distinctive nanosize structure, metal oxides nanomaterials such as SrO2, TiO, ZnO, CuO, and MaO are being increasingly applied as an alternative agent in different applications(2). Several research groups reported improvements of PMMA cement strength, osteoblast cell growth, and surface roughness properties by incorporating additives such as MgO, hydroxyapatite, and chitosan to PMMA(3). The effects of these additives to PMMA on the mechanical strength of bone-PMMA interfaces are unknown. In the last decades, many studies on the preparation of metal oxides nanocrystals with large surface area and high reactivity have been offered(4). At present, several types of metal oxides nanoparticles play a very important role in numerous areas of physics, chemistry, and materials science. The numbers of metals can form a large miscellany of metal oxides(5).

Magnesium oxide (MgO) has attracted a lot of research attention. As an adsorbent for harmful chemical compounds, MgO nanoparticles have shown overwhelming potential (6).Due to its exceptional chemical and physical properties, it has special magnetic, electrical, optical, thermal, chemical, and mechanical characteristics(7). For a number of reasons, including nontoxicity and relative ease of acquisition, it is regarded as one of the most significant among metal oxide nanoparticles(8).

Nanoparticle reinforcement has been widely explored to modify the physical and mechanical characteristics of polymer-based biomaterials(9). The incorporation of nanoparticles into PMMA bone cement can influence properties such as strength, stiffness, fracture resistance and thermal behavior by improving the interaction between the filler particles and the polymer matrix (10). Magnesium oxide nanoparticles, owing to their small particle size and large surface area, can disperse within the PMMA matrix and potentially enhance the structural integrity of the material(11). Such modifications may contribute to improving the overall performance of bone cement used in orthopedic applications (12).

Polymethyl methacrylate (PMMA), is commonly known as bone cement, and is widely used for implant fixation in various orthopedic and trauma surgery(13). In reality, “cement” is a misnomer because the word cement is used to describe a substance that bonds two things together(14). However, PMMA acts as a space-filler that creates a tight space which holds the implant against the bone and thus acts as a ‘grout’(15). Bone cements have no intrinsic adhesive properties, but they rely instead on close mechanical interlock between the irregular bone surface and the prosthesis(16). PMMA with nanoparticles of MgO reduced harmful exothermic reactions of PMMA during solidification and increased radiopacity(17). The suitability of incorporating micro and nanoparticles of MgO additives to PMMA for orthopedic applications necessitates estimating the KIC of the respective bone-cement interfaces(18). This study aims to evaluate the mechanical property of MgO nanoparticles incorporated with PMMA bone cement.

MATERIALS AND METHODS

The nanocomposites were created by combining the powder component made up of prepolymerized PMMA beads and initiator, with the liquid part, made up of PMMA and activator, in accordance with the typical procedure advised for creating bone cements. The cross-linked polymethylmethacrylate nanosphere-containing two-solution bone cements (n-TSBC), which served as controls, were created with a polymer to monomer ratio of 1:1 and a cross-linked PMMA nanospheres to linear PMMA ratio of 1.5:1. MgO nanotube samples were created utilizing Institution BS. IS05833.002's Implants for Surgery—Acrylic Res Cements standard as a reference. As per the manufacturer's instructions, manual mixing was performed in a polypropylene mixing bowl using a polypropylene spatula. To create samples with the desired dimensions, the Cements were poured into polytetrafluoroethylene (PIFE) molds that were clamped between stainless steel end plates. The samples were taken out of the molds after 30mm and dry-sanded using silicon carbide paper of a 400 grit to the proper dimensions.

Mechanical properties of bone cement

The primary target of this study was to investigate the mechanical properties of nanocomposite bone cements. In order to evaluate the long term surgical efficacy of cemented arthroplasties, two major mechanical properties of the bone cements are important, i.e. roughness and hardness. The cement layer has the main task of resisting and transferring the loads between the natural and synthetic coupled materials, while functioning as a mechanical buffer, reducing the stress concentrations and absorbing mechanical shock.

Surface Roughness Measurement

The surface roughness of the samples were measured using a stylus profilometer (Mitutoyo SJ 310®, Mitutoyo Corporation, Japan) with a 2 µm tip and a 60° angle. The stylus profilometer employs a non destructive, highly sensitive and reproducible method making it ideal for assessing how abrasion affects the surface texture of dental materials. The device was manually moved across the surface of each specimen to record baseline roughness values.

Vickers hardness tests

MgO impregnated nanotubes and control samples (6 mm diameter and 12 mm height) were prepared and the surfaces polished with a 400 grit silicon carbide paper. One sample of each cement brand was stored in air for 24 h at 23°C and one sample of each cement brand was stored in Ringer's solution for 60 days at 37 °C. The microhardness of the samples was tested according to the ISO 6507-2 standard (Institution BS. ISO 6507, 2005). Five indentations, 1 mm apart and 1 mm from the edges of the sample, were placed on both sides of each sample using a Shimadzu HMV-G31DT (Shimadzu HMV-G31DT Micro Vickers Hardness Tester) with a load of 200 g for 10s.

The statistical analysis performed (ANOVA) was carried out to establish significant differences between groups of samples using spss software the data analysis package in Excel (Microsoft). Significance between groups was defined as those with a calculated p-value of less than 0.05.

RESULT

In the current study, PMMA-MgO material has greater roughness and hardness than PMMA cement. According to the Independent t-test, the difference was not statistically significant (p value 0.05). The mean Roughness value of PMMA (mean= 0.3120) was lower than that of PMMA-MgO (mean=0.3112). The P value was 0.579 which is statistically not significant.

The mean Hardness value of PMMA (mean= 26.6840) was lower than that of PMMA-MgO (mean=28.3200). The P value was 0.218 which is statistically not significant. Due to the limited number of the control sample, no statistically significant difference exists.

Material	Sig.	Mean	Std. Deviation
Roughness PMMA	.579	.3120	.01304
NANO		.3112	.01653
Hardness	.218	26.6840	1.04593
PMMA NANO		28.3200	.60897

Table 1: Group statistics

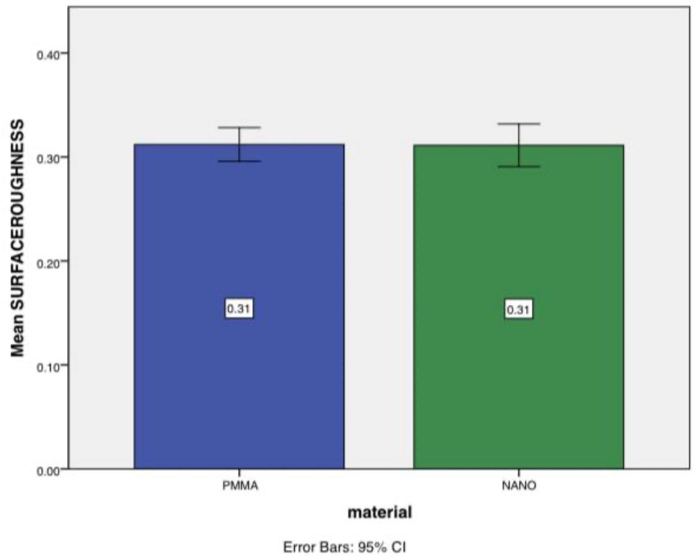

Figure 1: Bar graph represents the Mean Surface Roughness value compared with PMMA and PMMA-MgO material. 'X' axis represents Mean Surface Roughness Value and the 'Y' axis represents the PMMA and PMMA-MgO material.

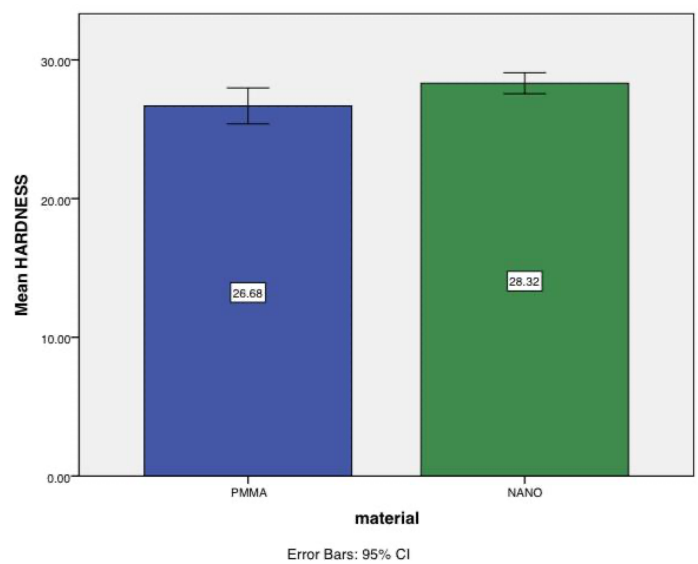

Figure 1: Bar graph represents the Mean Hardness value compared with PMMA and PMMA-MgO material. 'X' axis represents Mean Hardness value and the 'Y' axis represents the PMMA and PMMA-MgO material.

DISCUSSION:

In the present investigation, the result is due to the differences in surface roughness, microhardness at the interfaces of bone-cement with MgO in cement compared to that without MgO. Our present study results show that the mean roughness and hardness value of PMMA are 0.3120 and 26.6840 respectively whereas the mean roughness and hardness value of PMMA incorporated with MgO nanoparticles are 0.3112 and 28.3200 respectively. Increased surface roughness resulted in less micro movement of cracks at the bone-cement interface, which increased the load and elongation at the fracture. Increased surface roughness and microhardness helped strengthen the interfacial mechanical properties of bone-cement or implant-cement joints.

Magnesium oxide is a ceramic that has seldom been used in the orthopedic industry due to its poor mechanical properties(19). MgO containing PMMA cement samples significantly reduced temperature increases during the solidification of MMA(20). Importantly, when nanoparticles were included instead of regular (or micron-sized) particles, the temperature decreases were noticeably higher(21).

When compared to the other PMMA-AP cements, PMMA-MgO samples had the lowest flexural strength. When compared to PMMA and PMMA-BaSO4 samples, PMMA-MgO samples showed no appreciable difference in fracture toughness values (22).The granules, the main solid component of the cement, are largely responsible for the mechanical qualities of PMMA bone cement (23). The other mechanical properties, such as the dynamic properties, need to be examined because the cement is subject to cyclic loads (24). Cements with micro or nano MgO particles exhibited lower elastic modulus and higher exothermic temperatures while curing compared to those without MgO(25). According to Liu-Synder et al. (26), PMMA additives (such as antibiotics and radiopacifiers) have been shown in the past to adversely affect osseointegration. Whenever a new material is added into PMMA, the resulting PMMA cements should be tested for cytocompatibility properties.

When comparing the results of this study to other studies, which have used additives to improve the mechanical properties of acrylic based bone cement, the results are encouraging in terms of improvements in mechanical properties and merits further investigation. Bone cement research focuses on enhancing mechanical quality, cure speed, and biocompatibility.

Although the differences observed in surface roughness and microhardness between conventional PMMA and MgO nanoparticle-incorporated PMMA in this study were not statistically significant, the results indicate that the incorporation of MgO nanoparticles does not adversely affect the mechanical properties of the bone cement. The comparable mechanical performance suggests that MgO nanoparticles can be incorporated into PMMA without compromising its structural integrity. Further investigations with larger sample sizes and evaluation of additional mechanical parameters may provide more comprehensive insights and help establish the potential benefits of MgO nanoparticle incorporation in PMMA bone cement.

CONCLUSION:

This study has shown that the surface roughness and microhardness of bone-PMMA interfaces were improved by the addition of MgO nanoparticles to PMMA. This finding suggests that adding MgO particles to PMMA should be further investigated with respect to applications.The findings of this study's mechanical properties can be applied to orthopedic applications. Investigations are currently being conducted to determine the ideal MgO particle concentration for PMMA to improve mechanical capabilities.

Within the limitations of this study, the incorporation of magnesium oxide (MgO) nanoparticles into polymethyl methacrylate (PMMA) bone cement showed comparable surface roughness and microhardness values to conventional PMMA. Although no statistically significant difference was observed, the addition of MgO nanoparticles did not adversely affect the mechanical properties of the bone cement. Therefore, MgO nanoparticles may be incorporated into PMMA without compromising its structural integrity. Further studies with larger sample sizes and evaluation of additional mechanical properties are recommended to better understand the potential benefits of MgO nanoparticle incorporation in bone cement.

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CONFLICT OF INTEREST:

All the authors declare that there was no conflict of interest in the present study.

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