RESEARCH PAPER

Influence of Sro2 Nanoparticles in an Acrylic Bone Cements on Its Mechanical and Physical Properties

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ABSTRACT

Background: Acrylic bone cements are often used in orthopedics for a variety of purposes, including bone defect filling, antibiotic release, and joint fixation. PMMA is the most common form of cement used to bind and transmit load between the implant and the bone. A new generation Nanostructured SrO-reinforced acrylic bone cements with adequate radiopacity and biocompatibility would have superimposed particle morphology and display improved static and dynamic mechanical characteristics.

Aim: The aim of the study is to determine the influence of SrO2 nanoparticles on the mechanical and physical properties of acrylic bone cements.

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. The statistical analysis (ANOVA) was performed to determine significant differences between groups of samples using the SPSS software, the data analysis tool in Excel (Microsoft).

Result: The present study, results show that the mean hardness and contact angle value of PMMA are 26.68 and 74.598 respectively whereas the mean hardness and contact angle value of PMMA incorporated with Sro2 nanoparticles are 28.984 and 67.080 respectively. However, the experimental results suggest that SrO_2 nanoparticle reinforcement enhances the physicomechanical properties of acrylic bone cement, supporting its potential use as a performance-improving additive.

Conclusion: This research has shown that adding SrO2 nanoparticles to PMMA improved the hardness of the bone-PMMA interactions. Overall, the incorporation of SrO_2 nanoparticles resulted in a trend toward increased hardness and decreased contact angle compared to conventional PMMA, but these differences did not reach statistical significance within the parameters of the present study. The ideal concentration of Sro2 particles in PMMA to improve mechanical and physical properties should be investigated.

Keywords: PMMA, SrO2, Good health and well being, Hardness, contact angle, Innovation, quality education

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INTRODUCTION :

Acrylic bone cements are often used in orthopedics for a variety of purposes, including bone defect filling, antibiotic release, and joint fixation(1). The majority of commercial Acrylic bone cements on the market today are made up of two components: a solid made primarily of poly(methyl methacrylate) (PMMA) and a liquid made primarily of methyl methacrylate (MMA), which are combined and then transformed into a hardened cement paste through the polymerization reaction of the monomer(2).

PMMA is the most common form of cement used to bind and transmit load between the implant and the bone . The two main advantages of using it are the best primary fixation that can be obtained between the implant and bone and the patient's quicker recovery(3). PMMA, on the other hand, is a fragile material with a short fatigue life and low fracture resistance. Therefore , Denture repair resins, artificial teeth, orthodontic retainers, partial dentures, and an all-acrylic dental restorative were made predominantly with PMMA cements(3).Bone cements are often used to anchor a variety of implant designs, according to Havelin et al. (1993), Malchau et al. (2002), and Malchau et al. (2005) the load-bearing and weight-bearing properties of the cured cements, which are materials, play a crucial role in implant performance(4).

A new generation Nanostructured SrO-reinforced acrylic bone cements with adequate radiopacity and biocompatibility would have superimposed particle morphology and display improved static and dynamic mechanical characteristics. An alkaline earth metal called strontium, strontium oxide (SrO) is a very basic oxide(5). With a size that exhibits outstanding high thermal stability and excellent optical qualities.The concept that useful structures may be created by individually manipulating atoms and molecules is the basis of nanotechnology(6). It is expected that this technology will lead to significant advancements in the fields of materials science, biotechnology, nanotechnology, and the health sciences in general. Advances in dentistry and novel diagnostic and treatment approaches for oral health are also expected.The initial queries about nanotechnology in dentistry concern its applicability and the length of time needed to put research findings into(7) . The aim of the study is to determine the influence of SrO2 nanoparticles on the mechanical and physical properties of acrylic bone cements.

MATERIALS AND METHODS :

Synthesis of strontium nanoparticles

50ml solution of 0.1M solution of strontium nitrate and 50 ml solution of 0.02M citric acid were prepared using doubly distilled water and were collectively taken in a beaker. 50ml solution of 0.5M sodium hydroxide was taken in a burette and added drop by drop into the solution taken in the beaker and was stirred well using a magnetic stirrer arrangement. The precipitate so formed was allowed to settle down under the effect of gravity. The precipitate was then centrifuged and washed several times using distilled water to remove all the remaining impurities. The washed precipitate was dried under sunlight and powdered using an agate mortar. The dried precipitate then annealed at a temperature of 800°C for two hours to obtain strontium oxide nanoparticles from their corresponding hydroxide.

Bone cement protocol

The nanocomposites were created by combining the powder component, made up of prepolymerized PMMA beads and initiator, with the liquid part, made up of MMA and activator, in accordance with the typical procedure advised for creating bone cements. The cross-linked polymethy)methacrylate 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. Sro2 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 250 grit to the proper dimensions.

Mechanical properties of Bone

Investigating the mechanical characteristics of nanocomposite bone cements was the main goal of this research. The stiffness and hardness of the bone cements are two key mechanical characteristics that must be taken into consideration when assessing the long-term surgical efficacy of cemented conservative treatment. In addition to acting as a mechanical buffer, lowering stress concentrations, and absorbing mechanical shock, the cement layer's primary duty is to resist and transfer loads between connected natural and synthetic materials. Compressive testing was carried out in accordance with ISO 5833:2002, with cylindrical shaped samples (diameter and height are 6 mm and 12 mm, respectively)

The machine used had a crosshead speed of 20 mm per minute and was a Shimadzu HMV-G31DT with software. Compressive after three months of sample ageing at 37 °C in PBS, a strength test was conducted.

Contact angle measurements.

The evaluation of surface wettability in the studied samples was conducted using the Telescopic Goniometer (Kernco Model No: G II, Kerno Instrument Co, Texas, United States of America). This instrument is equipped with a specialized photo micrographic camera attachment, facilitating the recording of observed data. To measure the wettability of denture base materials, the appropriately prepared and cleaned sample was positioned on the mechanical stage of the contact angle goniometer. A small droplet of carboxymethyl cellulose (CMC)- based artificial saliva substitute (Aqwet; Cipla, Mumbai, Maharashtra, India) was carefully deposited onto the sample surface using a microburette, and the resulting contact angle was measured. This comprehensive approach allows for a precise assessment of the wetting behavior of the surfaces under investigation

Vickers hardness tests

Sro2 impregnated nanotubes and control samples (6 mm diameter and 12 mm height) were manufactured, and the surfaces were polished with 400 grit silicon carbide paper. One sample of each brand of cement was kept in Ringer's solution for 60 days at 37 °C and one sample of each brand was kept in the air for 24 hours at 23 °C. The samples' microhardness was evaluated in accordance with ISO6507-2 standard (Institution BS. ISO6507, 2005).Using a Shimadzu HMV-G31DT (Shimadzu HMV-G31DT Micro Vickers Hardness Tester) with a load of 200 g for 10s, five indentations were made on both sides of each sample, spaced 1 mm apart and 1 mm from the sample's edges.

Statistical analysis

The statistical analysis (ANOVA) was performed to determine significant differences between groups of samples using the SPSS software, the data analysis tool in Excel (Microsoft). Significance between groups was determined as those with a calculated p-value of less than 0.05.

RESULT:

The present study evaluated the effect of incorporating SrO_2 nanoparticles into polymethyl methacrylate (PMMA) bone cement by comparing its hardness and surface wettability with that of conventional PMMA.

The mean Vickers hardness value of conventional PMMA was 26.68 ± 1.04, whereas the PMMA incorporated with SrO_2 nanoparticles showed a higher mean hardness value of 28.98 ± 0.71. Although the experimental group demonstrated an increase in hardness compared to the control group, statistical analysis using ANOVA revealed that the difference was not statistically significant ($p = 0.352$).

Surface wettability was assessed using contact angle measurements. The mean contact angle value of conventional PMMA was 74.59° ± 0.75, while the PMMA–SrO_2 nanocomposite exhibited a lower mean contact angle of 67.08° ± 1.29. This reduction in contact angle indicates improved wettability in the nanoparticle-incorporated group. However, similar to the hardness results, the difference between the two groups was not statistically significant ($p = 0.198$).

MATERIAL	Sig.	Mean	Std. Deviation

Hardness	PMMA	.352	26.6840	1.04593
	NANO		28.9840	.71367
Contact angle	PMMA	.198	74.5980	.75038
	NANO		67.0800	1.29112

Table1: Group statistics

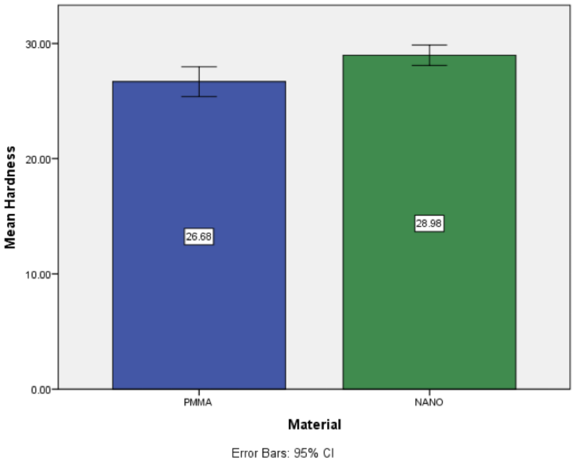

FIGURE 1 : Bar graph represents the Mean Hardness value compared with PMMA and PMMA-Sro2 material. 'X' axis represents Mean Hardness Value and the 'Y' axis represents the PMMA and PMMA-Sro2 material.

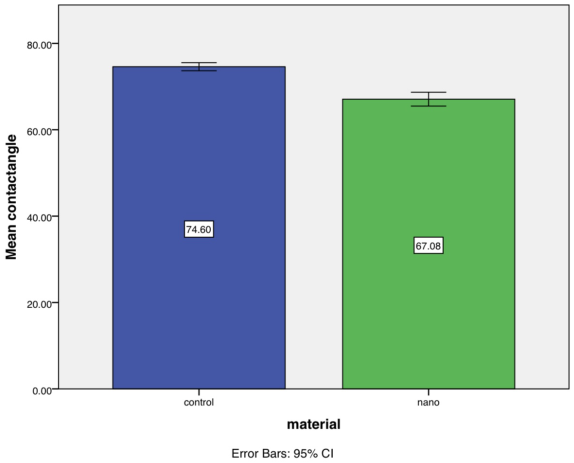

FIGURE 2 : Bar graph represents the Mean Contact angle value compared with PMMA and PMMA-Sro2 material. 'X' axis represents Mean Contact angle value and the 'Y' axis represents the PMMA and PMMA-Sro2 material.

DISCUSSION:

The present study was carried out to evaluate the influence of SrO_2 nanoparticles on the mechanical and physical properties of polymethyl methacrylate (PMMA) bone cement, particularly focusing on microhardness and surface wettability(8). PMMA has long been used as a standard bone cement in orthopedic and dental applications due to its ease of handling and good fixation properties; however, its relatively low fracture resistance and limited surface bioactivity have prompted researchers to explore nanoparticle reinforcement as a potential strategy for material improvement(9).

In this study, the incorporation of SrO_2 nanoparticles resulted in a slight increase in the mean microhardness values of the experimental group compared to conventional PMMA(10). Although the difference was not statistically significant, the observed trend suggests that the presence of nanoparticles may contribute to minor reinforcement within the polymer matrix(11). This could be attributed to the ability of nanoparticles to occupy microvoids within the cement and restrict polymer chain mobility, thereby improving resistance to indentation. Similar trends have been reported in previous studies where metal oxide nanoparticles were incorporated into acrylic-based materials to enhance their mechanical behavior(12).

The contact angle measurements in the present study showed a reduction in the wettability angle in the SrO_2-incorporated samples, indicating improved surface hydrophilicity(13). A lower contact angle generally reflects better surface wettability, which may enhance protein adsorption and cell adhesion when used in biological environments. Even though the reduction was not statistically significant, the findings suggest that SrO_2 nanoparticles may modify the surface characteristics of PMMA in a manner that could be beneficial for biological integration. Surface wettability plays an important role in determining the interaction between bone cement and surrounding tissues, and improvements in this parameter may contribute to better clinical outcomes(14).

Strontium-based compounds have previously been reported to promote osteogenic activity and improve bone regeneration(15). The addition of strontium-containing nanoparticles into bone cement is therefore of particular interest because it may provide both mechanical reinforcement and biological advantages. In the present study, although significant mechanical enhancement was not observed, the incorporation of SrO_2 did not negatively affect the structural integrity or surface properties of the cement, which is an important consideration when modifying established biomaterials(16).

One possible explanation for the lack of statistical significance in the results may be the relatively low concentration of nanoparticles used or the limited sample size(17). Nanoparticles tend to agglomerate within polymer matrices if not adequately dispersed, which may reduce their reinforcing potential. Improved dispersion techniques, such as ultrasonic mixing or surface functionalization of nanoparticles, could potentially enhance their distribution within the PMMA matrix and lead to more pronounced changes in mechanical properties(18).

Another limitation of this study is that only two properties—microhardness and contact angle—were evaluated. Bone cement performance in clinical applications is influenced by multiple factors including compressive strength, fatigue resistance, fracture toughness, and long-term stability in physiological conditions(19). Future studies should therefore include a broader range of mechanical and biological tests to fully assess the potential benefits of SrO_2 nanoparticle incorporation(20).

Despite these limitations, the present study contributes to the growing body of research exploring nanoparticle-reinforced bone cements. The findings indicate that the addition of SrO_2 nanoparticles is feasible and does not adversely affect the material's basic properties. With further optimization in terms of nanoparticle concentration, dispersion techniques, and long-term testing, SrO_2-reinforced PMMA may emerge as a promising modification for improving the performance of acrylic bone cements in orthopedic and dental applications.

CONCLUSION:

Within the limitations of this in vitro study, the incorporation of SrO_2 nanoparticles into polymethyl methacrylate (PMMA) bone cement demonstrated a marginal increase in hardness and a reduction in contact angle compared to conventional PMMA. However, these differences were not statistically significant ($p > 0.05$). This indicates that the addition of SrO_2 nanoparticles did not adversely affect the mechanical or surface properties of the bone cement, while maintaining comparable performance to the control material. Although the observed trends suggest a potential positive influence of SrO_2 nanoparticles on the physicomechanical characteristics of acrylic bone cement, further investigations with larger sample sizes, varying nanoparticle concentrations, and long-term aging studies are required to establish their clinical relevance and optimize their incorporation for orthopedic and dental applications

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