ASSESSMENT OF THE ANTIMICROBIAL EFFICACY AND MECHANICAL PROPERTIES OF GLASS IONOMER CEMENT (GIC) INCORPORATING SILVER NANOPARTICLES IN VARYING CONCENTRATIONS FOR PEDIATRIC DENTAL APPLICATIONS

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Abstract

Background and Objectives: Although Glass Ionomer Cement (GIC) is a commonly utilized restorative material, it loses its antimicrobial effectiveness with time. To evaluate the antimicrobial property, Flexural Strength (FS) and Surface Micro Hardness (SMH) of GIC added with silver vanadate (AgVO3) nanoparticles. **Methods:** This study was performed in the Department of Pedodontics at Sri Sankara Dental College. The study was reviewed and approved by the Institutional Ethical Committee. Considering the methodology of the study conducted by Jowkar Z et al., (2019). Using SPSS (Version 24.0) software for power analysis indicated the required total of 50 samples. The number of samples to evaluate antimicrobial property was 26, and 12 samples each to test FS (Flexural Strength): and SMH (Surface Micro-Hardness). **Results:** The modified groups exhibited higher antimicrobial activity compared to the unmodified group. Group 4 exhibited the highest antimicrobial activity (27.65±1.10 mm) followed by Group 3 (24.32±0.69 mm) and Group 2 (20.30±1.21 mm). Group 1 (unmodified GIC) exhibited the least antimicrobial property with a mean zone of inhibition of 15.60±1.20 mm. One-way ANOVA showed a significant difference ($p=0.01$) between the groups. GIC added with 2.0% w/w AgVO3 nanoparticles (Group 4) exhibited higher FS with a mean of 47.62±10.10 MPa than the unmodified GIC (Group 1) **Conclusion:** Type II GIC with 2.0% w/w AgVo3 nanoparticle addition demonstrated increased FS and SMH in addition to greater antibacterial properties.

Keywords: Glass Ionomer Cement (GIC), Flexural Strength, Surface Microhardness, Silver Nanoparticles, Anti-Microbial Properties.

INTRODUCTION

The field of restorative care for children and adolescents is always changing. Silicate cement was the tooth-colored restorative material of choice in the 1950s and early 1960s. Its advantageous qualities are ascribed to the fluoride found in silicate cement powder. But with time, GIC took the place of these cements because of their high acidity, high solubility in oral fluids, poor mechanical qualities, gradual discoloration, and inadequate adhesive bond between the restoration and the tooth [1]. Because it has anticariogenic properties, leaches away fluoride ions, and forms a chemical link with hard tissues, GIC is a commonly used tooth-colored restorative material in pediatric dentistry [1,2]. Nevertheless, a few characteristics of GIC restrict its broad application as a therapeutic substance. It is demonstrated to have poor physical and mechanical qualities, such as low hardness and fracture strength, decreased wear resistance, and opaqueness. GICs have undergone numerous changes since their introduction in an effort to enhance their mechanical, physical, and chemical properties [3.4].

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Among the hardest metals, vanadium exhibits good corrosion resistance. In the medical field, implantable devices such as cardioverter defibrillators, neurotransmitters, artificial external defibrillators (AEDs), and drug infusion devices are made using vanadium added to silver since it has been shown to be biocompatible and antibacterial.

Biomedical applications can arise from the modification of vanadium oxide nanostructures using silver nanoparticles (AgNPs) [5]. AgVO3 was added to acrylic dentures to increase their antibacterial activity without changing their mechanical characteristics [6]. Without significantly altering its physico-chemical characteristics, it was shown that adding it to endodontic sealers enhanced its antibacterial activity [7].

This study was designed to add AgVO3 nanoparticles to Type II GIC in order to enhance its antibacterial property because of its positive benefits. The literature search turned up no evidence of prior attempts of this kind, nor of its impact on the cement's mechanical characteristics. Therefore, the purpose of this work was to assess the mechanical and antibacterial qualities of GIC that had been supplemented with AgVO3 nanoparticles for pediatric dental applications.

MATERIALS AND METHODS

This study was performed in the Department of Pedodontics at Sri Sankara Dental College. The study was reviewed and approved by the Institutional Ethical Committee. Considering the methodology of the study conducted by Jowkar Z et al., (2019) [8]. Using SPSS (Version 24.0) software for power analysis indicated the required total of 50 samples. The number of samples to evaluate antimicrobial property was 26, and 12 samples each to test FS (Flexural Strength): and SMH (Surface Micro-Hardness).

METHODOLOGY

Previous research incorporating AgVO3 into resins demonstrated that FS reduced as AgVO3 nanoparticle concentration increased but SMH remained same. Additionally, the maximum concentration of AgVO3 nanoparticles in the current investigation was restricted to 2% due to the fact that an increase in AgVO3 percentage causes agglomeration of nanoparticles [6]. To generate 0.5%, 1%, and 2% w/w concentration AgVO3 nanoparticles, respectively, 1.8 g of GIC (GC Type II cement, Tokyo, Japan) powder was mixed with 4 mg, 8 mg, and 16 mg of AgVO3 nanoparticles (Nano Elements sub-branch of Sigma Aldrich, Germany) [6,9].

The altered GIC was worked with in accordance with the manufacturer's instructions and put into rectangular glass molds measuring 25 x 2 x 2 mm and spherical glass molds with a diameter of 10 mm and a thickness of 2 mm. On either side, the modified GIC was covered with a thin glass slide. After four minutes of initial setting, the specimens were taken out of the mold. After that, the samples were kept for a full day at 37°C in distilled water.

The altered GIC was worked with in accordance with the manufacturer's instructions and put into rectangular glass molds measuring 25 x 2 x 2 mm and spherical glass molds with a diameter of 10 mm and a thickness of 2 mm. The antimicrobial property was evaluated using disk diffusion in a direct contact method. Unmodified GIC (Type II GIC) served as a control group and considered as

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Group 1: Twenty- six spherical disks of GIC (10 mm diameter and 2 mm thickness),

Group 2: Six samples of each concentration of AgVO3 nanoparticles were prepared and grouped as Group 2 (GIC with 0.5% w/w AgVO3),

Group 3: GIC with 1.0% w/w AgVO3 and

Group 4: GIC with 2.0% w/w AgVO3.

To eliminate moisture, the specimens were heated to 60°C in a hot air oven for one hour. The mutans strain from the grass culture was kept in PBS before being poured onto solidified agar petriplates using the pour plate technique. Digital Vernier callipers with an accuracy of 0.001 were used to measure these zones. Only the addition of 2.0% w/w AgVO3 was utilized to assess the FS and SMH because this concentration demonstrated the maximum antibacterial efficiency [7,8].

For flexural strength- A computerized universal testing machine (Instron 8801, United Kingdom) was used to measure the FS utilizing a 3-point bending test at a crosshead speed of 1 mm/minute. 14 rectangular specimens, each measuring 25 by 2 by 2 mm, were prepared: 7 samples of GIC containing 2.0% w/w AgVO3 nanoparticles (Group 4) and 7 samples of GIC that had not been altered (Group 1). After mounting the test specimen and applying load until it cracked, the FS was calculated in Megapascal (MPa) units [8].

For Surface Micro- Hardness- Vickers' micro-hardness tester (Daksh Quality Systems Pvt., Ltd., India) was used to evaluate SMH. A diamond indenter was used, and the load was set to 25 gm for 15 seconds of dwell time. To assess SMH, fourteen spherical specimens with dimensions of 10 mm in diameter and 2 mm in thickness were created, seven from unmodified GIC (Group 1) and seven from 2.0% w/w AgVO3 nanoparticles (Group 4). For every specimen, a total of five indentations were made at various locations; the mean hardness values of these five indentations were calculated as VHN [9].

Statistical Analysis

The obtained data were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) Version 24.0. Quantitative variables were compared using ANOVA as the data sets were normally distributed between the groups. An unpaired t-test was used to compare the data between the two groups for FS and SMH. A p-value of ≤0.05 was considered statistically significant.

RESULTS

Table 1: Mean values comparison among groups based on Inhibition zones (mm)

Groups	Mean±SD	p-value
1	15.60±1.20	**0.01***
2	20.30±1.21	
3	24.32±0.69	
4	27.65±1.10	

As per table 1 the mean values of inhibition zones (mm) between the groups are given in. The modified groups exhibited higher antimicrobial activity compared to the unmodified group. Group 4 exhibited the highest antimicrobial activity (27.65±1.10 mm) followed by Group 3 (24.32±0.69 mm) and Group 2 (20.30±1.21 mm). Group 1

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(unmodified GIC) exhibited the least antimicrobial property with a mean zone of inhibition of 15.60±1.20 mm. One-way ANOVA showed a significant difference (p=0.01) between the groups.

Table 2: Pair-wise comparison of zones of inhibition (mm) between the groups

Groups comparison		Mean±SD	p-value
1	2,3,4	4.5±0.54, 8.40±0.54, 11.61±0.54	**0.01***
2	3,4	4.50±0.54, 3.86±0.54	**0.01***
3	4	7.10±0.54	**0.01***

As per table 2 pair wise comparison among groups shows significant difference in the formation of inhibition zones in all groups.

Table 3: Comparison of Mean Flexural Strength among groups

Groups	Mean±SD	p-value
1	26.88±8.62	**0.01***
4	47.62±10.10	

As per table 3 GIC added with 2.0% w/w AgVO3 nanoparticles (Group 4) exhibited higher FS with a mean of 47.62±10.10 MPa than the unmodified GIC (Group 1). A statistically significant difference (p=0.01) in mean FS was observed between the two groups.

Table 4: Comparison of Surface Micro hardness among groups

Groups	Mean±SD	p-value
1	49.46±0.76	**0.01***
4	61.28±2.54	

As per table 4 GIC added with 2.0% w/w AgVO3 nanoparticles (Group 4) exhibited higher SMH with a mean of 61.26±2.54 VHN than the unmodified GIC (Group 1), and showed a statistically significant difference (p=0.01) in SMH between the two groups.

DISCUSSION

In the current work, it was found that, in comparison to standard GIC, GIC combined with AgVO3 nanoparticles displayed improved mechanical and antibacterial capabilities. However, because of their subpar physical characteristics, secondary caries have been documented to occur. Additionally, the fluoride release characteristic is not long-lasting and is not strong enough to inhibit bacteria [1]. The antibacterial activities of GICs were found to be enhanced by the addition of theobromine [10], polymers (2-methacryloxytroponones, Epigallocatechin-3-gallate (EGCG), sodium fusiadate, triclosan, furanone, poly quaternary ammonium salts) [3,11], metals (Zinc, strontium, bioglass) [12].

It has been demonstrated that adding TiO2, ZnO, and hydroxyapatite nanoparticles to the GIC enhances both its mechanical and anticariogenic qualities. Stainless steel nanopowder added to GIC demonstrated enhanced mechanical characteristics [13]. Agglomeration of silver nanoparticles was a prevalent issue, despite the fact that adding AgNPs to GIC increased its antibacterial capabilities. Silver vanadate (AgVO3) nanoparticles were created as a solution to this problem. AgVO3 serves as an AgNP carrier and lessens AgNP loss due to leaching [6].

This study made it clear that the quantity of AgVO3 nanoparticles introduced directly correlated with antibacterial activity. The antibacterial activity of GIC with 2.0% w/w

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AgVO3 nanoparticles was highest, followed by 1.0% w/w AgVO3 and 0.5%. It is appropriate to note that both fluoride release and silver must have contributed to antimicrobial activity since the modified GIC samples with AgVO3 shown the higher antibacterial property [14]. Fluoride ion release suppresses microbial growth, metabolism, and plaque formation [15]. Other theories include the replication of bacterial DNA by active silver ions, the structural damage caused by oxygen free radicals generated by silver, and other chemicals containing phosphorus [16].

The mechanical characteristics of the cement may be affected by the size, density, and enclosed voids of the GIC powder particles. Higher mechanical characteristics are produced by filler particles of smaller sizes because they occupy more of the vacant areas between glass ionomer particles [17]. However, the addition of a larger concentration of nanoparticles resulted in a decrease in the cement's mechanical qualities. A high powder/liquid ratio that results in a dry mix, insufficient wetting of the matrix and filler bond, and overcrowding of filler particles could all be to blame [18]. In the current study, samples with higher concentrations of AgVO3 showed higher FS and SMH in addition to higher levels of antibacterial activity.

The SMH measures a material's resistance to piercing or indentation. AgVO3 nanoparticles were added to resins at different doses (0.5, 1, 2.5, 5, and 10) but there was no change in SMH of the resins. Nevertheless, FS dropped when more than 1% AgVO3 was added. Although it may not be optimal for promoting antibacterial activity, the lower concentration of AgVO3 in acrylic resins may be perfect for obtaining the mechanical qualities. It has been demonstrated that adding more AgVO3 at higher concentrations improves antibacterial action while keeping SMH values constant [18].

CONCLUSION

When AgVO3 nanoparticles were introduced to Type II GIC, it showed better mechanical and antibacterial qualities than the original. FS and SMH were higher in samples containing 2.0% w/w AgVO3 than in samples containing the other amounts under investigation. In the field of pediatric restorative dentistry, GIC with prolonged antibacterial activity and enhanced mechanical and physical qualities is preferred. The characteristics of GIC were enhanced by the inclusion of AgVO3 nanoparticles. However, such a change should be validated in vitro for biocompatibility as well as other mechanical and physical qualities before to being used clinically.

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Conflict of Interest: None declared

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