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The Effect of the Incorporation of Titanium Dioxide Nanoparticles on the Mechanical and Physical Properties of Glass Ionomer Cement

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ABSTRACT

The goal of this research was to explore how incorporation of Titanium Dioxide Nanoparticles (Tio2/NPS) at two different concentrations 3% and 5% (w/w) may affect the mechanical and physical characteristics of glass ionomer cement (GIC).

Methods: Titanium Dioxide Nanoparticles (TiO2 /NPS) were incorporate at 3% and 5% (w/w) into the powder component of glass ionomer cement. As a control, unblended powder was use. A universal testing machine was use to estimate flexural strength, a Vickers micro hardness tester was used to determine surface micro hardness, and water solubility and sorption were measured according to the ISO standard. ANOVA and the Tukey test have been use to evaluate the data.

Results: GIC with 3% and 5% (w/w) TiO2 nanoparticles increased surface micro hardness, with the Tukey test revealing a significant difference in micro hardness between groups. While flexural strength showed no statistical differences (p>.0001) and no significant increase in flexural strength among the investigated groups. Water sorption and solubility exhibited statistical differences (p<.0001), with a substantial reduction of water solubility and water sorption among the investigated groups.

Conclusions: GIC containing 3% and 5% (w/w) TiO2 nanoparticles can be considered a viable restorative material with improved mechanical properties.

Key words: Glass-ionomer cement, TiO2 nanoparticles, Surface microhardness, Flexural strength, Water sorption and Water solubility

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INTRODUCTION

Glass ionomer cement (GIC) is acid-base cement is produced by mixing glass powder (inorganic component) with weak polymer acids [1]. It is a common and widely used dental cement since its introduction in 1972 [2], due to its valued properties such as adhesion to the moist tooth structure and base metals [3], good biocompatibility [4], low coefficient of thermal expansion [5], it is the modulus of elasticity is similar to that of dentin, and it has anti-cariogenic properties due to the ability to absorb and restoring fluoride [6].

Even with these advantages, glass ionomer cement has some shortcomings including low mechanical strength, humidity sensitivity, low resistance to abrasion, low fracture toughness, and high dissolution and water sorption [4,7].

Many researchers tried to improve this mechanical characteristics using various techniques or methods, such as adding specific components of materials such as metal and ceramic materials, as well as polymers [8], Furthermore, to overcome these limitations, the using of nanoparticles by researchers in dentistry has evolved into an interesting area in their researches [8].

Titanium Dioxide Nanoparticles (TiO2 /NPS) as an inorganic additive had been use in many research as they are chemically stable, non-toxic, biocompatible, and improved mechanical properties [9]. The incorporation of TNPs into GICs has been reported to improve antibacterial activity and physical properties such as micro hardness, flexural strength, and compressive strength [10], as well as increased the bond strength of the GIC to dentin when dentin was pretreated with nanoparticles after applying the conditioner [11].

Water sorption and substance solubility are two crucial physical factors that determine a restoration durability of the materials. Water sorption can cause deterioration of the matrix structure of the restoration by increasing the volume of the material [12].

For this study the null hypothesis was that adding TiO_2 nanoparticles to a GIC would have no effect on its physical properties.

MATERIALS

After approval for this research were obtain from the College of Dentistry, University of Mosul, Research Ethics Committee (UoM.Dent/D.M.6/21). The goal of the study was to see how (Tio2/NPS) integrated at a two-percentage affects the physical and mechanical charachteristics of GIC and compare them to ordinary glass ionomer cement (cavex, Germany).

METHODS

Titanium dioxide nanoparticles were incorporate into a conventional glass ionomer cement powder (cavex, Germany) at 3% and 5% (w/w) [9, 10, 13]. The Titanium dioxide nanoparticles (2935 Weslhollw Drive. Houston, Tx 77082, USA) with partial size 10-30um and nearly spherical morphology were hand-mixed with the restorative powder on a mixing paper at room temperature with a metal spatula [14].

For all tests, the unmodified GIC was use as the control group.

Group I: conventional GIC (control group).

Group II: 3 percent (w/w) (TiO_2 /NPS) with GIC.

Group III: 5 percent (w/w) (TiO_2 /NPS) with GIC.

The powder–liquid ratio and mixing methods of the glass ionomer material carried according to recommended manufacturer instructions (powder liquid ratio =3.0:1 g/g).

Surface Microhardness Test (Vicker)

Specimen preparation

Ten discs shaped samples from each GIC group were prepared using a prefabricated mold (9.5 diameter x 1mm thickness) [10, 4]. The sample surface was covered with a polyester matrix matrix strip and lightly compressed with a glass slide for 1 minute. The samples were kept in the matrix for 20 minutes before being placed in a small container with distilled water and kept at 37°C for 24 hours.

Test measurement

Surface microhardness was measured for each group using Vickers's microhardness testing machine (Amsler Otto Wolpert-Werke GmbH- Ludwigshafen Germany). For each sample, indentations are made using a 10 N load, a 10 s dwell time, and a 10 indentation. The following formula was used to calculate the surface microhardness:

$HV=0.1891\ F/d^2\ (kgf/mm^2)$

Where HV is the Surface microhardness, F is the force applied to the surface, d is the average length in millimeters of the diagonal shape made by the indenter.

Water Sorption and Solubility Measurement

Specimen preparation

Ten discs shaped samples from each GIC group were prepared using a prefabricated mold (15 x 1mm) [12]. To avoid air bubbles, each sample was covered with a polyester matrix strip and pressed gently for 1 min with a glass slab.

Test measurement

The samples were weighed (m1) using digital balance (ANDG*200, Japan) and it was put in distilled water in a plastic container at 37˚c for one week.

The samples were weighted (m2), then transferred to a desiccator in an oven (LERN, Germany) at 37C°for 24 h, and weighted again (m3).

The difference between initial and wet weight gives the material's water sorption (Wsp) (m2-m1). while the solubility (Wsol) was calculated using the difference between each sample's original and final drying mass (m1-m3).

The magnitudes of water sorption (Wsp) and solubility (Wsol) ratios for each sample were measured by using these equations:

$Wsp = 100*(m2-m1)/m1$

$Wsol = 100*(m1-m3)/m1$

with V being the volume of the specimen before immersion (mm^3) [15].

Flexural Strength

Specimen preparation

A rectangular form stainless-steel split mold with dimensions (25mm length x 2mm width x 2mm height) was used to create thirty bar-shaped specimens (n=10 for each group) [16].

But conventional GIC and (TiO_2 /NPS) incorporated GIC at 3 percent and 5 percent (w/w) prepared according to the manufacturer's instructions and put in the mold, then translucent celluloid strip put on surface and covered with a glass slide and gently pressed to remove excess material.

Test measurement

The test was carried out in accordance with ISO 4049:2000. In a universal testing machine (GESTER, total testing solution, China), all samples were subjected to a three-point bending test with (0.5 mm/min) crosshead speed. The following formula was used to compute the flexural strength, FS (MPa):

($FS = 3FL/2WD^2$). When F represents the loading force applied to the specimens at the fracture site. W is the average specimens width, and D is the average specimens

Table 1: Tukey's analysis of the mean (standard deviation) of the physical parameters of GIC with added TiO2 nanoparticles.

Group	Surface microhardness (VHN)		Flexural strength (MPa)		Water sorption		water solubility	
	Mean (SD)	F, (P value)	Mean (SD)	F, (P value)	Mean (SD)	F, (P value)	Mean (SD)	F, (P value)
GIC-control	28.64(.607)a	93.85(.00)	19.65(2.82)a	.814(.454)	.373(.009)a	621.77(.00)	.225(.007)a	657.92(.00)
GIC-3% (w/w) TiO2	30.24(.383)b		17.41(4.46)a		.239(.0162)b		.124(.010)b	
GIC-5% (w/w) TiO2	31.99(.617)c		18.72(4.35)a		.160(.014)c		.083(.009)c	

Mean values with the same superscript letter in each column are not significantly different (P > 0.05), whilst the mean values with different letters are significantly different (P < 0.05).

depth. L is the distance between the supports. The mean and standard deviation was calculate, as the test was perform ten times for each group.

RESULTS

Surface Microhardness and Flexural Strength

Surface microhardness data showed normality. As shown in table (1), one way analysis of variance test displayed that there were statistical differences between groups at p-value <.0001 and also the Tukey test was displayed that there is a significant increase in microhardness between groups.

While flexural strength data also displayed normality but ANOVA test displayed that there were no statistically significant differences between groups as the p-value >.0001. The Tukey test was showed no significant increase in flexural strength among the investigated groups.

Water sorption and solubility

Water sorption and solubility data showed normality, the one way analysis of variance test displayed that there were statistical differences between groups at p-value <.0001, and the Tukey test was showed a significant decrease in water sorption and water solubility between all investigated groups (Table 1).

DISCUSSION

According to the findings of this study, the influence of (TiO2/NPS) at two concentrations on the physical and mechanical characteristics of GIC was estimate to be:

Vicker Microhardness Test

There is a significant increase in the Vicker micro harness test in GIC with TiO2 /NPS) nanoparticles incorporation This finding agrees with the previous study of Contreras et al. and Elsaka et al. as reported that the surface microhardness of GIC can be improved by adding 3% (w/w) TiO2/NPS [10,13]. The increase in surface microhardness was attributed to fewer amounts of glass particles that present on the surface of GIC, resulting in a higher quantity of acid interacting with the nanoparticles [13]. Furthermore, the nanoparticles are too tiny in size, which increases particle packing inside the cement matrix after setting, causing the high density of nanoparticles to resist the diamond indenter.

Flexural Strength

The dental material is subjected to repeated flexing, twisting, and bending forces under the clinical situation and it should withstand these forces, so flexural strength measurement is important for simulating these forces.

The incorporation of (TiO2 /NPS) has no effect on the flexural strength and this result agrees with Contreras et al. that found there was a decrease in flexural strength in both, core shade and base cement after 3% and 5% (w/w) TiO2 NPs addition10 also Jowkar et al., found no significant increase in Flexural strength4. While Alaska et al. found there is improvement in Flexural strength [13].

This finding may be due to the fact that when TiO2 nanoparticles are compared with the glass particles of conventional GIC, their particles size is much smaller which lead to obtain larger surface area, SO there will be insufficient amount of polyacrylic ionomer that available to make enough bonding to this increased surface area of powder. As a result, to this decrease in crosslinking between ionomer and powder particles, the bonding at the particle -ionomer interface become weak [13].

Water Sorption and Solubility

Water sorption and solubility, which determines a material's resistance to dissolution or disintegration is considered one of the most essential properties that influence dental materials half-life. The mechanical properties of dental materials are affected by their water sorption and solubility, which directly affect how long dental restorations last. Water sorption has two impacts on the material's mechanical properties: deterioration and lamination.

The water solubility of the dental material has an unfavorable effect on its mechanical characteristics, resulting in a loss of material mass and a failure of the interfacial integrity between tooth and restoration, which raises the chance of microleakage at the margins of restoration and ultimately its failure [17].

Both water sorption and solubility of GIC with (TiO2/ NPS) incorporation are significantly reduced in this research, which might be attributed to a reduction in the quantity of air voids, which, if present, will seem shallower than those found in the unmodified cement. In addition, in comparison to the cracks in the original cement, the lengths and widths of the cracks in the modified cement's matrices lessen [18].

CONCLUSION

The combination of GIC and anoparticles of TiO2 is a potential restorative material with enhanced physical characteristics. Surface microhardness increased significantly, and water sorption and solubility decreased significantly.

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REFERENCES

1. Park EY, Kang S. Current aspects and prospects of glass ionomer cements for clinical dentistry. Yeungnam Univ J Med 2020; 37:169.
2. Allam G, El-Geleel A. Evaluating the mechanical properties, and calcium and fluoride release of glass-ionomer cement modified with chicken eggshell powder. Dent J 2018; 6:40.
3. Lyapina MG, Tzekova M, Dencheva M, et al. Nano-glass-ionomer cements in modern restorative dentistry. J IMAB Annu Proc 2016; 22:1160-5.
4. Jowkar Z, Jowkar M, Shafiei F. Mechanical and dentin bond strength properties of the nanosilver enriched glass ionomer cement. J ClinExp Dent 2019; 11:e275.
5. Al-Taee L, Deb S, Banerjee A. An in vitro assessment of the physical properties of manually-mixed and encapsulated glass-ionomer cements. BDJ open 2020;6:1-7.
6. Bezerra IM, Brito AC, De Sousa SA, et al. Glass ionomer cements compared with composite resin in restoration of noncarious cervical lesions: a systematic review and meta-analysis. Heliyon 2020; 6:e03969.
7. Khaghani M, Doostmohammadi A, Alizadeh S. Investigation of the Compressive Strength of Glass Ionomer Cement Containing Hydroxyapatite Nano and Micro Particles. Austin J Biotechnol Bioeng 2016; 3:1068.
8. Alobiedy A, Alhille A, Al-Hamaoy A. Mechanical Properties Enhancement of Conventional Glass Ionomer Cement by Adding Zirconium Oxide Micro and Nanoparticles. J Eng 2019: 72-81.
9. Cibim DD, Saito MT, Giovani PA, et al. Novel nanotechnology of TiO2 improves physical-chemical and biological properties of glass ionomer cement. Int J Biomater 2017.
10. Garcia-Contreras R, Scougall-Vilchis RJ, Contreras-Bulnes R, et al. Mechanical, antibacterial and bond strength properties of nano-titanium-enriched glass ionomer cement. J Appl Oral Sci 2015; 23:321-8.
11. Jowkar Z, Fattah Z, Ghanbarian S, et al. The Effects of Silver, Zinc Oxide, and Titanium Dioxide Nanoparticles Used as Dentin Pretreatments on the Microshear Bond Strength of a Conventional Glass Ionomer Cement to Dentin. Int J Nanomed 2020; 15:4755-4762.
12. Elbahrawy EM, Rahim RA. Effect of addition of chitosan on water sorption, solubility and microhardness of glass ionomer cement. Tanta Dent J 2017; 14:164.
13. Elsaka SE, Hamouda IM, Swain MV. Titanium dioxide nanoparticles addition to a conventional glass-ionomer restorative: influence on physical and antibacterial properties. J Dent 2011; 39:589-98.
14. Alatawi RA, Elsayed NH, Mohamed WS. Influence of hydroxyapatite nanoparticles on the properties of glass ionomer cement. J Mater Res Technol 2019; 8:344-9.
15. Yilmaz MN, Gul P, Kiziltunc A. Water sorption and solubility of a high-viscous glass-ionomer cement after the application of different surface-coating agents. European J Gen Dent 2020; 9:118-21.
16. Guimaraes IR, Gomez FM, De Goes MF. Effect of activation mode on flexural strength and elasticity modulus of dual cure resin cements. Odovtos Int J Dent Sc 2016; 18:61-71.
17. Lima R, De Farias J, Andrade A, et al. Water sorption and solubility of glass ionomer cement indicated atraumatic restorative treatment considering the time and the ph of the storage. Rev Gaúch Odontol 2018; 66:29-34
18. Gjorgievska E, Van Tendeloo G, Nicholson JW, et al. The incorporation of nanoparticles into conventional glass-ionomer dental restorative cements. Microsc Microanal 2015; 21:392-406.