DOI: https://doi.org/10.32828/mdj.v19i2.889

MDJ

Estimation of some properties of Glass Ionomer Luting Cement reinforced with Zirconium oxide Nanoparticles

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Abstract

Aim of the study: This study was designed to examine the effects of addition of Zirconium oxide nanoparticles (ZrO_2NPs) into Glass Ionomer luting cement (GIC) on the film thickness, compressive strength and Shear Bond Strength.

Materials and methods: ZrO_2NPs at (3% and 5%) concentrations were added to GIC luting cement, while the unmodified GIC cement was used as control. ISO 9917-1:2007 were used for Film thickness test, compressive strength and Shear Bond Strength. Data were analyzed via one-way ANOVA and the Tukey post hoc test, using SPSS version 23.

Results: The obtained results revealed a statistically significant difference among the tested groups for Film thickness and compressive strength ($P<0.05$). Regarding Shear Bond Strength test no significant difference was observed.

Conclusion: The incorporation of ZrO_2NPs improved compressive strength, increased film thickness concentration-dependently. Yet, didn't affect shear bond strength.

Keywords: Zirconium oxide nanoparticles, Glass Ionomer luting cement, Film thickness, compressive strength, Shear Bond Strength.

Introduction:

The term luting is frequently used in the field of dentistry refereeing to a clay-consistency or cement used to close-up joints, or to protect and secure a graft. For any used dental cement to be accepted as luting type, they should possess a film thickness not more than (0.25 µm) [1]. A wide range of dental cements supplied as luting type among them, zinc phosphate cements, Glass ionomer luting cements, and resins-based cements are the most commonly applied [2] .Luting of indirect fixed restoration when received from dental laboratory to abutment teeth is the final and a very significant face for providing and optimizing the performance of indirect type restorative prosthesis [3]. The luting GIC is supplied in a package of powder and liquid that when mixed together to formulate to a cement [2].

Among the most critical character of dental luting cements is film thickness which plays an important and significant role and important aspect of fixing the restoration. Improvement of the casting retention and maintaining of the established occlusal relationship can only be achieved if minimum film thickness utilized of dental luting cement [3]. Minimizing cement film thickness will aid in reduction of marginal leakage which ultimately minimize the possibility of dental plaque accumulation at the abutment-prosthesis margin interface, periodontal disease, and the quantity of dissolution of the used luting cement [4]. The GICs gained the highest popularity as dental luting cement because of being with superior chemical adhesion property to both dentine and enamel which in turn aid in keeping the indirect casting for a lengthier period compared to other cements [5].

The dental GICs offer several favorable criteria such as their ability to bond chemically to enamel and dentin surfaces, effective anti-caries activity, and biocompatibility. The above mentioned properties have made them widely accepted as dental luting agents, cavity liners, and restorative materials [6]. Despite their excellent characteristics, GICs do have some shortcomings, including low fracture toughness, prone to wear at a quicker rate, some of their properties such as low compressive strength and brittleness property are low rated [7].

To improve their shortcomings of GICs, a variety of modifications techniques have been employed, among these is increasing the powder/liquid ratio, utilizing different cement formula size particles, and modification with base resins [8]. Moreover, several innovative nano sized materials such as Titanium dioxide (TiO_2), hydroxyapatite (HAp), and others have been proposed additives to the GIC to enhance its properties [9].

The dental cements to which Zirconia (ZrO_2) nanoparticles have been added showed improved biocompatibility[10]. In some cases when GICs modified by addition of nanoparticles showed a higher compressive strength, this may be due to less possibility of formation of internal micro cracks and air bubbles or voids thanks to the smaller nanosized powder particles [11].

Zirconium oxide is characterized by adequate toughness property and dimensional stability; accordingly it can be utilized for the fabrication of the dental implant cores that possess high and powerful strength [12].

The current study aimed to investigate the impact of adding (3 % and 5%) by weight of ZrO_2NPs into luting GIC on the Film thickness, compressive strength and Shear Bond strength.

Materials and Methods

GIC luting cement (TOKUSO IONOMER-Tokuyama- Japan) mixed with ZrO_2NPs 98% Purity and particle size of 50 nm supplied from US-Nano Inc., digital electronic balance with precise accuracy (0.001) was used to weight the powders. A Tube Roller Mixer machine was used to ensure homogenous powders mixing of ZrO_2NPs with GIC powder at 60 rpm for two hours [13, 14]. The predetermined GIC liquid /powder ratio was then mixed manually according to standard ratio recommended by the manufacturer using a metallic cement spatula.

For each testing procedure, 30 samples were fabricated that was divided into three groups (N=10), One control unmodified group (GIC cement only) which was tested against two group to which 3% and 5% by weight of ZrO_2NPs were added to the cement respectively.

Film thickness test: ISO 9917-1:2007 [15] for GIC was utilized to perform film thickness test. Two equal size rectangular glass plates having uniform thickness hold against each other were measured five times to the nearest 0.1 µm (Reading A) with aid of a digital high precision micrometer. The GIC for each testing group was prepared based on the manufacturer's recommendations, then 0.1 ml of the mixed luting cement was sandwiched in the middle of the previously mentioned two glass plates. Finally, a universal testing machine (DRK 101 digital electronic computerized Shandong China) was used to load 150 N on the upper glass plate. After seven minutes, total thickness of the used glass plates with the sandwiched cement was considered as (Reading B). The subtraction of reading A from reading B (B−A) was considered as the combined final

film thickness for the GIC specimen being tested [16].

Compressive strength (CS) test: For sample preparation and testing procedure 1SO 9917 [15] were employed, Ten cylindrical shaped samples were prepared for each group according to the following parameter dimension (height = 6 mm, diameter = 4 mm) using prefabricated Teflon molds. Prepared samples were left at room temperature for one hour, and then placed in glass container filled with distilled water at 37C inside the incubation for 7 days [17]. Testing procedure was done immediately after removal from the incubator by placing the wet samples vertically in the machine grasping head with force directed on the sample long axis, then the sample was loaded with a digitally controlled crosshead compression speed of (1 mm/ min) in the testing machine until fracture of the sample. The calculation of compressive strength test was done by using this formula

P/r2, (P) refer to the load value at sample fracture, (r) representing the radius of the used sample, and = 3.14.

Finally, the CS values which is obtained in (kgf/mm^2) will be converted to Mega Pascal (MPa) using the formula [18] CS [MPa] = CS [Kgf/mm^2] × 0.09807.

Shear Bond Strength: Thirty extracted molar teeth were selected for this test and stored in a box containing NaCl solution. The selected teeth were embedded vertically in a cylindrical acrylic resin blocks. Silicon-carbide abrasive sandpaper was used to remove the occlusal enamel surface for preparing and obtaining a flat-smooth dentin surfaces[19]. ISO 9917-1:2017 [15] was employed to perform shear bond strength test by a Teflon split mold with the following parameters (diameter = four mm, height= 3 mm). The GIC mixed according to the manufacturer recommendations then packed, condensed to fill the mold cavity and left to set at room temperature. After one hour later, the mold was cut off, thus exposing the sample bonded to the surface of dentine. The package (teeth-GIC bonded specimens) was immersed in a glass dish containing distilled water at 37C for 24 hours. Finally, each specific sample undergoes the process of dislodgement testing process using a knife like (sharp) mandrel attached to the upper head of digitally controlled universal testing machine set crosshead speed at (0.5 mm/min). The value of the dislodging force was recorded and the below equation was employed to calculate the shear bond strength of GIC-Dentine surface

Shear bond strength (MPa) = force / area [20].

Results:

Significant statistical difference ($p < 0.001$) among study groups were found regarding film thickness and compressive strength. Yet, no significant statistical difference was seen when the groups compared for shear bond strength ($p=0.66$). On the other hand, all pairwise comparisons regarding film thickness and compressive strength exhibited a statistically significant difference ($p < 0.05$) when Post hoc test used [Figure 1].

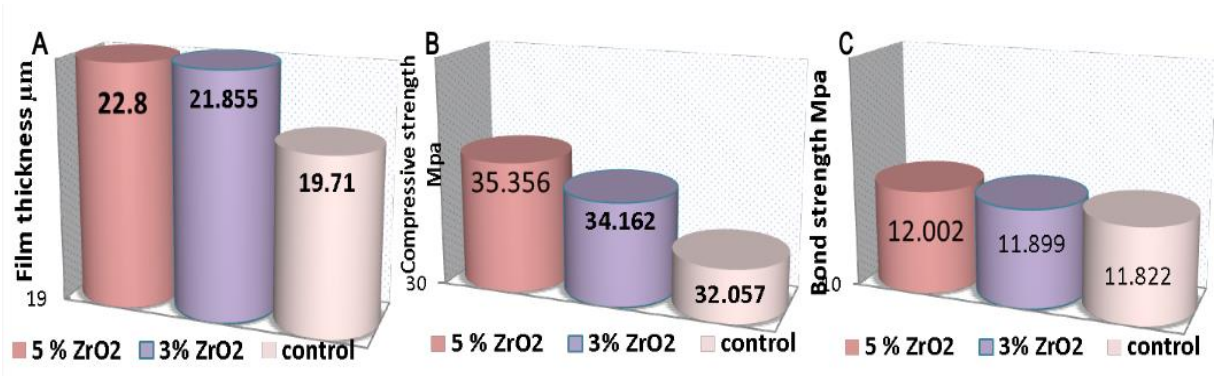

Figure 1: Bar chart summarizes the mean difference related to Film thickness (µm) (A), Compressive strength (Mpa) (B), and Shear bond strength (Mpa) (C).

The results of compressive strength and film thickness showed that the mean values was directly related to the percentage of the added nanoparticle, as a result the 5% ZrO_2NPs group showed the highest mean value followed by 3% group while the control group was with the least value, the obtained result indicated that these value was statistically significant according to ANOVA and Post Hoc test as shown in table.1 and 2 for film thickness, and table.3 and 4 for compressive strength respectively.

Table.1 ANOVA- film thickness test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	50.140	2	25.070	166.418	.000
Within Groups	4.067	27	.151		
Total	54.208	29			

Table.2 Post hoc tests- film thickness test

LSD

(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	3%	-2.14500*	.17358	.000	-2.5012	-1.7888
	5%	-3.09000*	.17358	.000	-3.4462	-2.7338
3%	control	2.14500*	.17358	.000	1.7888	2.5012
	5%	-.94500*	.17358	.000	-1.3012	-.5888
5%	control	3.09000*	.17358	.000	2.7338	3.4462
	3%	.94500*	.17358	.000	.5888	1.3012

* Mean difference is statistically significant at P.Value 0.05.

Table.3 ANOVA- compressive strength

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	55.800	2	27.900	192.660	.000
Within Groups	3.910	27	.145		
Total	59.710	29			

Table.4 Multiple Comparisons- compressive strength

LSD

(I) sample	(J) sample	Mean Difference (I - J)	Standard error	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
control	3%	-2.10500*	.17019	.000	-2.4542	-1.7558
	5%	-3.29900*	.17019	.000	-3.6482	-2.9498
3%	control	2.10500*	.17019	.000	1.7558	2.4542
	5%	-1.19400*	.17019	.000	-1.5432	-.8448
5%	control	3.29900*	.17019	.000	2.9498	3.6482
	3%	1.19400*	.17019	.000	.8448	1.5432

* Mean difference is statistically significant at P.Value 0.05.

Regarding shear bond strength, the same pattern was observed in which the increase in the added ZrO2NPs caused increase in the shear bond strength group versus the control group, and the 5% added group present the highest shear bond value followed by 3% group and finally the control group exhibited least value, but again in reverse to the film thickness and compressive strength test, the difference in the shear bond strength was statistically non-significant as shown in table 5 and 6 respectively.

Table.5 ANOVA- shear bond strength

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.163	2	.082	.412	.667
Within Groups	5.348	27	.198		
Total	5.511	29			

Table.6 Multiple Comparisons- shear bond strength

LSD

(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	3%	-.07700	.19903	.702	-.4854	.3314
	5%	-.18000	.19903	.374	-.5884	.2284
3%	control	.07700	.19903	.702	-.3314	.4854
	5%	-.10300	.19903	.609	-.5114	.3054
5%	control	.18000	.19903	.374	-.2284	.5884
	3%	.10300	.19903	.609	-.3054	.5114

Discussion

In the modern dentistry, the most widely cement type used for cementation of fixed prostheses is GICs [21]. Luting cements film thickness of is a very critical property that greatly affects the selection of a long lasting luting agent. Some manipulation variables such as powder–liquid ratio significantly affect the film thickness. Additionally, it is documented that luting cements consistency have a direct relation on film thickness and the accurate tooth surface-restoration interface adaptation [22, 23].

In the present study, the obtained results for film thickness showed that all the tested groups present with film thickness less than 25 µm and thus meets the requirements of ISO 9917-1 standard [15]. The finding of the current research revealed that value of film thickness increased when the amount of added ZrO_2NPs to the GIC cement increased and this increase in film thickness value was ZrO_2NPs concentration dependent , this finding is similar to other studies [24, 25, 26] who found the same results and this may be due to a slight increase of the viscosity of the modified luting cement when compared to control group, which ultimately contribute to an increase of the film thickness [27, 28], also this increase in film thickness can be explained based on fact that small sized particles with less than 50 nm may results in increasing surface area of contact [28] or increase in the viscosity of the cement after addition of the nanoparticle [25].

Regarding compressive strength, the obtained results of the current study showed an improvement of the quality of compressive strength of the GICs following incorporation of ZrO_2NPs when compared to the unmodified group. The finding of the current study agree with many previous studies [24, 29, 30, 31, 32] who concluded that increased proportion of smaller tiny sized additive led to increased compressive strengths, the most logical explanation for this effect may be due to influence of nanoparticles on the reinforcement or enhancement of the standard matrix of the luting GIC cement that have been formed [26] and proving the cement matrix with more compression capability without deformity or deterioration in addition to enhancing the level of formation of the GIC polysalt bridge. [13]. In contrast, the finding of the current study disagree with a previously done study by Gupta et al [26] who found that addition of conventional body ceramic additive and Ethanol at less than 10% did not induced any significant statistical change in the value of compressive strength value while comparing with the control groups and this difference could be due to difference of the type, form and particle size additionally the use of different concentrations of the additive that induced weakening of the GIC matrix and consequently compromising the compressive strength property used in that study compared to the current study.

Evaluation of the shear bond strength is significant specially when dealing with considerably brittle materials like GICs [33] .In the present study, the obtained results showed a slight but statistically insignificant increase in the value of shear bond strength

with increasing concentration of ZrO_2NPs and this agree with previous study done by Rezvani [33] and Garcia -contreras et al [34], who explained that addition of nanoparticles to GIC cement basic powder, does not influence the shear bond strength, this could be explained by the presence of low attraction ionic force between additive particles and luting cement base powder, And this could be due to the fact that the nanoparticles may act as an inert particle forming obstacles that enhance crack formation, Nanosized particles can occupy and fill the empty gaps and spaces between the larger sized glassionomer powder particles [35] and provide extra site for bonding with the polymer matrix [36] or the added nano-size particle allows their dispersion without any significant geometric matrix change between and around polymer chains of the cement.

Conclusion

The incorporation of ZrO_2NPs significantly improved compressive strength and increased film thickness and this effect is concentration-dependent. Yet, the added nanoparticles didn't affect shear bond strength.

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