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Surface Roughness and Compressive Strength of Resin Modified Glass Ionomer Cement with the Addition of Zinc Oxide Nanoparticles

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Abstract

Introduction: Resin modified glass ionomer cement (RMGIC) is a hybrid ionomer cement by modifying glass ionomer cement (GIC) with resin. Restoration surface roughness is related to the accumulation of food debris on a restoration. The cement has a lower compressive strength than enamel and dentin. Efforts to reduce surface roughness and increase the compressive strength of RMGIC, by adding zinc oxide nanoparticles powder to RMGIC powder. Objective: This research aims to analyze RMGIC with the addition of zinc oxide nanoparticles powder as much as 1%-5% of the total mixture of RMGIC and zinc oxide nanoparticles powder on surface roughness and compressive strength. Method: This study used five treatment groups, namely groups 2, 3, 4, 5, and 6, each of which was given the addition of 1%, 2%, 3%, 4%, and 5% of the total mixture of RMGIC and zinc oxide nanoparticles powder, as well as group 1 (control) without the addition of zinc oxide nanoparticles powder. Each group consisted of 4 replications with cylindrical samples (10 mm diameter and 2 mm height) for surface roughness test and 4 replications with cylindrical samples (4 mm diameter and 6 mm height) for compressive strength test. Surface roughness was tested using surface roughness measurement and compressive strength was tested using a universal testing machine. Results: The results of statistical analysis of surface roughness and compressive strength tests showed significant differences between sample groups. Conclusion: The addition of zinc oxide nanoparticles powder on RMGIC reduces surface roughness and increases compressive strength.

Keywords: Resin Modified Glass Ionomer Cement; Zinc Oxide Nanoparticles; Surface Roughness; Compressive strength

1. Introduction

Resin modified glass ionomer cement (RMGIC) is a dental material often used for restorations. Resin modified glass ionomer cement was introduced in the late 1980s as a dental restorative material by modifying glass ionomer cement (GIC) with resin [1]. Resin modified glass ionomer cement is also referred to as hybrid ionomer cement. This cement contains fluoroaluminosilicate glass particles, water, polyacrylic acid, 2-hydroxyethyl methacrylate (HEMA), polyacrylic acid-modified methacrylate, and the catalyst is diphenyliodonium chloride (DPICI) [2]. The indication for this cement is class I cavity restoration in the lingual/palatal anterior area and pit and fissure small lesion, class III, and class V [3].

Resin modified glass ionomer cement has the advantage of releasing fluoride, so it is recommended for patients with a high risk of caries [1]. Resin modified glass ionomer cement has a higher adhesion value with dentin compared to GIC [2]. Resin modified glass ionomer cement has several disadvantages, namely that it can only be used in low pressure restorations and has mechanical properties such as flexural strength, compressive strength, compressive modulus, and diametral tensile strength lower than composite resin [1]. Resin modified glass ionomer cement has microleakage which

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is bigger than GIC because of its existence shrinkage during polymerization [4]. The use of RMGIC is limited to low-stress restorations [1].

The requirements for a restoration are to have good physical and mechanical properties. Increased surface roughness is associated with the cause of biofilm accumulation on RMGIC [1]. A smooth restoration surface is more resistant to the accumulation of food debris [2]. Smooth restoration surfaces have been shown to harbor less biofilm in vivo than rough surfaces. Surface roughness above the threshold value of 2 μm results in more biofilm accumulation on dental restorations [1].

These mechanical properties are related to the durability of the restoration during the mastication process [1]. Restoration of RMGIC class I area lingual/palatal anterior in patients with deep bite is susceptible to experiencing large chewing pressures in the palatal area of the maxillary incisors, while the compressive strength of RMGIC is known to be lower than the compressive strength of enamel and dentin. The compressive strength of this material is 202 MPa, while the compressive strength of enamel and dentin is 384 MPa and 297 MPa respectively [2].

Based on the shortcomings of RMGIC, an effort is needed to improve the surface roughness and compressive strength of RMGIC. The effort is to add zinc oxide nanoparticles powder to the RMGIC powder. The addition of zinc oxide nanoparticles can influence antibacterial activity, namely by inhibiting biofilm formation [5]. Salt or oxide-based nanoparticles can react with polyacrylic acid which then forms a matrix and increases the durability of the GIC material. Nanoparticles that are smaller than GIC particles are able to fill interstitial gaps, thus strengthening the cement [6]. The addition of nanoparticles also causes the average particle size to decrease. The viscosity also decreases and produces a larger gel matrix [7].

Resin modified glass ionomer cement research with the addition of zinc oxide nanoparticles has been carried out several times. Based on Malekhoseini's research et al. (2021), additional 1% – 4% zinc oxide nanoparticles on RMGIC powder improves flexural strength and the elastic modulus of RMGIC compared with the control group over a 1 day period. Research by Fattah, Jowkar, and Rezaeian (2021) regarding the addition of 5% zinc oxide nanoparticles to RMGIC powder shows that there is an increased microshear bond strength of RMGIC. Based on several studies regarding RMGIC with the addition of zinc oxide nanoparticles from the total RMGIC powder mixture, this research uses the addition of 1%–5% zinc oxide nanoparticles powder of the total mixture of RMGIC and zinc oxide nanoparticles powder.

2. Material and methods

Surface roughness and compressive strength of RMGIC with the addition of 1%–5% zinc oxide nanoparticles of the total mixture of RMGIC and zinc oxide nanoparticles powder uses RMGIC Fuji II LC Gold Label, Japan. Batch number 002564, expires December 21, 2024 and zinc oxide nanoparticles powder ITNANO, Indonesia. This study used five treatment groups, namely groups 2, 3, 4, 5, and 6, each of which was given the addition of 1%, 2%, 3%, 4%, and 5% of the total mixture of RMGIC and zinc oxide nanoparticles powder, as well as group 1 (control) without the addition of zinc oxide nanoparticles powder. Each group consisted of 4 replications with cylindrical samples (10 mm diameter and 2 mm height) for surface roughness test and 4 replications with cylindrical samples (4 mm diameter and 6 mm height) for compressive strength test.

2.1. Sample Making

2.1.1. Surface Roughness Test Sample

The powder and liquid ratio of resin modified glass ionomer cement (RMGIC) for a cylindrical sample size with a diameter of 10 mm and a height of 2 mm based on factory regulations is 2 measuring spoons: 4 drops of liquid. Two measuring spoons of RMGIC powder weigh 0.64 g, while 4 drops of RMGIC liquid weigh 0.2 g. The ratio of ingredients in each sample group can be seen in Table 1.

Details of the ratio of ingredients for each sample in Table 1 for 1 repetition per group. RMGIC and zinc oxide nanoparticles powder in group 2 which has been weighed, is poured onto a centrifuge tube, and then mixed with a vortex mixer for 5 minutes. The preparation of powder mixtures in groups 3, 4, 5, and 6 was carried out in the same way as group 2.

RMGIC powder or a mixture of RMGIC-zinc oxide nanoparticles powder and RMGIC liquid is mixed and then put into a sample mold with a diameter of 10 mm and a height of 2 mm made of Teflon on top of a glass slab. The dough is put into the mold using a plastic filling instrument, then the dough is pressed using a cement stopper until solid. The top of the sample was given a celluloid strip and thin glass measuring 6 cm x 6 cm x 0.5 cm and weighed 1 kg for 30 seconds (to remove excess dough and level the surface). After 30 seconds the weights and thin glass were removed and then exposed to light LED curing unit with the tip positioned perpendicular and attached to the surface celluloid strip for 20 seconds. The sample is removed from the mold, then the excess side is reduced using a fine finishing diamond bur.

Table 1 Details of the ratio of research materials for each group of cylindrical samples with a diameter of 10 mm and a height of 2 mm.

Group	RMGIC Powder	Zinc Oxide Nanoparticles Powder	RMGIC Fluid
Group 1 (control)	0.6400 g	0 g	0.2 g
Group 2	0.6336 g	0.0064 g	0.2 g
Group 3	0.6272 g	0.0128 g	0.2 g
Group 4	0.6208 g	0.0192 g	0.2 g
Group 5	0.6144 g	0.0256 g	0.2 g
Group 6	0.6080 g	0.0320 g	0.2 g

2.1.2. Compressive Strength Test Sample

The powder and liquid ratio of resin modified glass ionomer cement (RMGIC) for a cylindrical sample size with a diameter of 4 mm and a height of 6 mm based on factory regulations is 0.32 g RMGIC powder:0.1 g RMGIC liquid. Details of the ingredient ratios for each sample group are in Table 2.

Table 2 Ratio of research materials for each group of cylindrical samples with a diameter of 4 mm and a height of 6 mm

Group	RMGIC Powder	Zinc Oxide Nanoparticles Powder	RMGIC Fluid
Group 1 (control)	0.3200 g	0 g	0.1 g
Group 2	0.3168 g	0.0032 g	0.1 g
Group 3	0.3136 g	0.0064 g	0.1 g
Group 4	0.3104 g	0.0096 g	0.1 g
Group 5	0.3072 g	0.0128 g	0.1 g
Group 6	0.3040 g	0.0160 g	0.1 g

Details of the ratio of ingredients for each sample in Table 2 for 1 repetition per group. RMGIC and zinc oxide nanoparticles powder in group 2 which has been weighed, is poured onto a centrifuge tube, and then mixed with a vortex mixer for 5 minutes. The preparation of powder mixtures in groups 3, 4, 5, and 6 was carried out in the same way as group 2.

RMGIC powder or a mixture of RMGIC-zinc oxide nanoparticles powder and RMGIC liquid is mixed and then put into a sample mold with a diameter of 4 mm and a height of 6 mm made of teflon. The RMGIC dough is put into a mold on top of a 2 mm high glass slab pressed using a cement stopper until solid then irradiated with LED curing unit for 20 seconds. The second layer is filled the same as the first layer. The third layer is put into the mold using a plastic filling instrument 2 mm thick, then press the dough using cement stopper until solid. The top of the sample was given a celluloid strip and thin glass measuring 6 cm x 6 cm x 0.5 cm and weighed 1 kg for 30 seconds (to remove excess dough and level the surface). After 30 seconds the weights and thin glass were removed and then exposed to a light LED curing unit with the tip positioned perpendicular and attached to the surface celluloid strip for 20 seconds. The sample is removed from the mold, then the excess side is reduced using a fine finishing diamond bur.

2.2. Sample Storage

Samples were stored in glass cup containers containing distilled water, put it in an incubator to maintain the temperature for 24 hours. The sample was removed from the container containing the distilled water, then dried and put back into the glass container. The glass container containing the sample was placed in a desiccator to maintain humidity before being tested for surface roughness and compressive strength.

2.3. Sample Testing

2.3.1. Surface Roughness Test

The samples were tested for surface roughness using surface roughness measurement (Mitutoyo SJ-210, Japan) with a speed of 0.25 mm/sec and a pressure of 4 mN. The samples were tested 3 times in different positions and then averaged (Ra) to obtain the surface roughness value for each sample. Surface roughness value in micrometers (μm).

2.3.2. Compressive Strength Test

The samples were tested for compressive strength using a universal testing machine (Shimadzu AG-X, Japan) with a load of 5 kN at a speed of 1 mm/min. The compressive strength value is in Megapascals (MPa).

3. Results and discussion

3.1. Surface Roughness Test Research Results

In the research data from the sample surface roughness test, it was found that a greater mean surface roughness value indicates a rougher sample surface. A smaller mean surface roughness value indicates a smoother sample surface in micrometers (μm). Data from the surface roughness test research for each sample group can be seen in Table 3 and displayed using a line diagram in Figure 1.

Table 3 Mean value and standard deviation of surface roughness for each sample group.

Group	n	Average (μm)	Standard Deviation
Group 1 (control)	4	0.1718	0.0140941
Group 2	4	0.1954	0.0528368
Group 3	4	0.1097	0.0199654
Group 4	4	0.1166	0.0167543
Group 5	4	0.1123	0.0128907
Group 6	4	0.1134	0.0228848

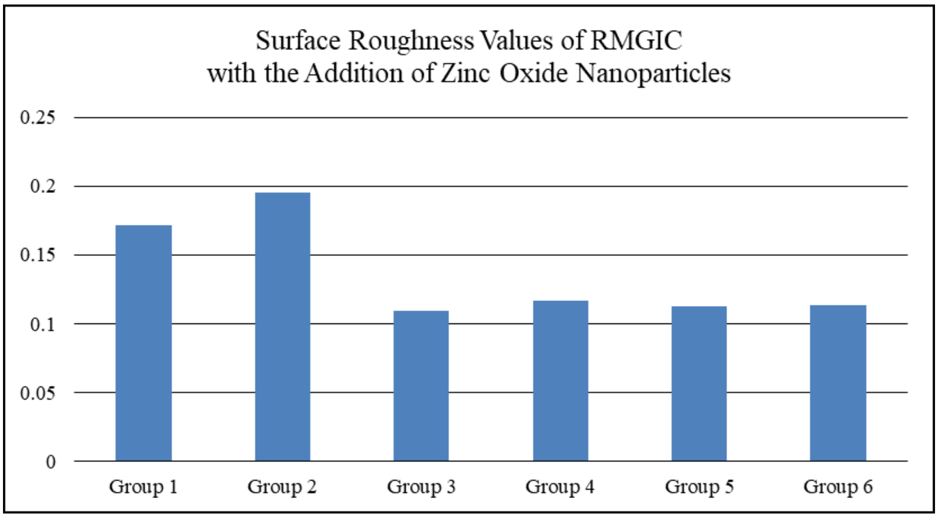

Figure 1 Bar diagram of the average surface roughness value of the sample

3.1.1. Analysis of Surface Roughness Test Data

The results of data analysis of RMGIC surface roughness research with the addition of zinc oxide nanoparticles powder were not normally distributed and not homogeneous so it was continued with statistical data analysis of the Kruskal-Wallis test and after this Mann-Whitney test. The results of the statistical data analysis of the Kruskal-Wallis test showed that p=0.008, so that the results of the statistical analysis of the Kruskal-Wallis test showed a significant difference. This can be interpreted that RMGIC with the addition of zinc oxide nanoparticles powder shows a significant difference in surface roughness values in all sample groups. The results of statistical data analysis of the Mann-Whitney test can be seen in Table 4.

Table 4 Results of statistical data analysis of the Mann-Whitney test.

Group	1	2	3	4	5	6
1	-	1.000	0.021*	0.021*	0.021*	0.021*
2	-	-	0.021*	0.021*	0.021*	0.021*
3	-	-	-	0.386	0.885	0.773
4	-	-	-	-	0.468	0.885
5	-	-	-	-	-	0.885
6	-	-	-	-	-	-

Information:*: indicates significant differences

Based on Table 4, there are significant differences between group 1 and group 3, group 4, group 5, and group 6. In group 1 and group 2 there are no significant differences. There were significant differences between group 2 and group 3, group 4, group 5, and group 6 respectively. In group 3, group 4, group 5, and group 6, respectively, there were no significant differences.

3.2. Compressive Strength Test Research Results

In the research data from the sample surface roughness test, it was found that a higher compressive strength value indicates an increase in the compressive strength of a dental material. Data on compressive strength test results for each sample group can be seen in Table 5 and displayed using a line diagram in Figure 2.

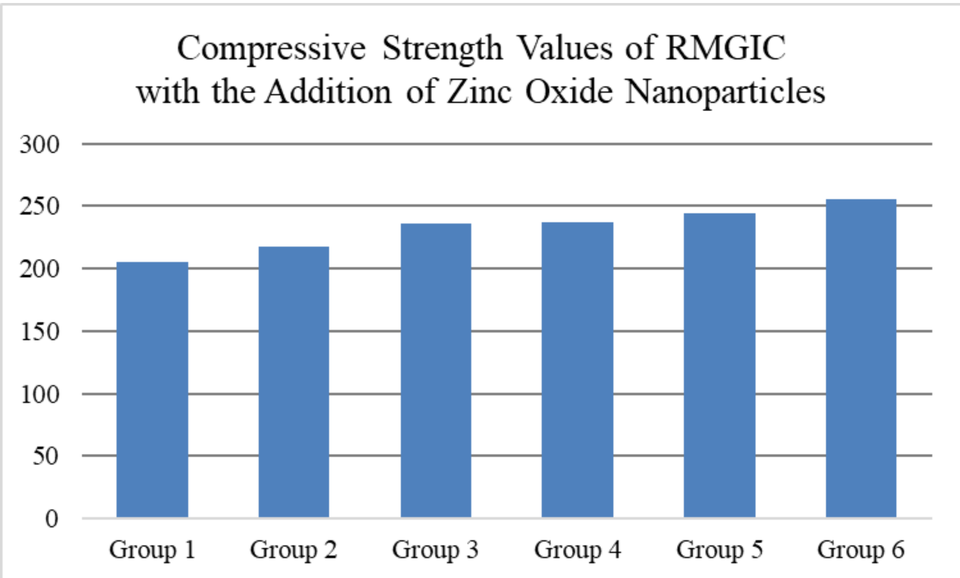

Figure 2 Bar diagram of the average compressive strength value of the sample

Table 5 Mean value and standard deviation of compressive strength for each sample group

Group	n	Rates	Standard Deviation
Group 1 (control)	4	205.257 MPa	15.945
Group 2	4	217.776 MPa	13.457
Group 3	4	235.969 MPa	12.835
Group 4	4	236.754 MPa	16.362
Group 5	4	244.187 MPa	4.074
Group 6	4	255.692 MPa	4.697

3.2.1. Analysis of Compressive Strength Test Data

The results of data analysis of RMGIC compressive strength research with the addition of zinc oxide nanoparticles powder had a normal and inhomogeneous distribution so it was continued with statistical data analysis of the one-way ANOVA test and after that Games-Howell test. The one-way ANOVA test result obtained was a p value of 0.000. This can be interpreted that the compressive strength of RMGIC with the addition of zinc oxide nanoparticles shows significant differences in all sample groups. The results of the statistical data analysis of the Games-Howell test can be seen in Table 6.

Table 6 Results of statistical data analysis of the Games-Howell test.

Group	1	2	3	4	5	6
1	-	0.823	0.151	0.192	0.067	0.029*
2	-	-	0.453	0.532	0.120	0.039*
3	-	-	-	1.000	0.811	0.223
4	-	-	-	-	0.931	0.399
5	-	-	-	-	-	0.069
6	-	-	-	-	-	-

Information:*: There is a significant difference

Based on the Table 6, there are significant differences between group 1 and group 2 compared to group 6. The results of research data analysis show that there are no significant differences between group 1 compared to group 2, group 3, group 4, and group 5 respectively.

4. Conclusion

Based on the research results, it can be concluded that the addition of zinc oxide nanoparticles powder as much as 2%, 3%, 4%, and 5% of the total mixture of RMGIC and zinc oxide nanoparticles powder can reduce the surface roughness of RMGIC, and the addition of zinc oxide nanoparticles powder as much as 5% of the total mixture of RMGIC and zinc oxide nanoparticles powder increases the compressive strength of RMGIC.

Compliance with ethical standards

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Disclosure of conflict of interest

The author has no conflicts of interest to declare.

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