

Effects of Al₂O₃ Nanoparticles on Compressive and Diametral Tensile Strength of Zinc Polycarboxylate Cement

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ABSTRACT

The effects of 3 wt% and 5 wt% Al₂O₃ nanoparticles on compressive and diametral tensile strength of zinc polycarboxylate cement were investigated.

Materials and Methods: 3 wt% and 5 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cements were used for this study. Specimens were divided in three groups (n=10) for compressive and diametral tensile tests. Group 1. Zinc polycarboxylate cement without nanoparticle (control group) Group 2. Zinc polycarboxylate cement with 3 wt% Al₂O₃ nanoparticles Group 3. Zinc polycarboxylate cement with 5 wt% Al₂O₃ nanoparticles. Specimens having a diameter of 4 mm and a height of 6 mm and specimens having a diameter of 4 mm and a height of 2 mm were prepared for compressive and diametral tensile tests respectively. Compressive and diametral tensile tests were performed using an universal test machine.

Results: Compressive strength decreased in 3 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cement compared to control group (p<0.05). There was no significant difference between compressive strengths of 5 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cement and control group (p>0.05). For diametral strength, there was no significant difference between 3 wt% and 5 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cement (p>0.05). Control group showed the higher diametral tensile strength than the other groups (p<0.05).

Conclusion: The lowest compressive strength occurred in 3 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cement. For diametral strength, there was no difference between 3 wt% and 5 wt% Al₂O₃ nanoparticles addition zinc polycarboxylate cement.

Keywords: Zinc polycarboxylate cement, Al₂O₃ nanoparticles, compressive strength, diametral tensile strength.

INTRODUCTION

Cements are essentially ceramic materials; in which the ceramic powders convert into solid via a chemical reaction. Inorganic or organic acids initiate setting reaction in the case of dental cements; which found a variety of applications in dentistry. The main utilizations of cements in dentistry are for cavity lining, luting applications and as more dedicated products for sealing root canals as part of a course of endodontic treatment ^[1]. Zinc polycarboxylate and glass polyalkenoate (glass ionomer) cements are two types of polyelectrolyte cements, which are widely used as adhesives in dentistry. They are the only materials currently available that are capable of chemically bonding to dentine and enamel. Due to their hydrophobicity, they can wet dentine and enamel surfaces, which is an important requirement of any adhesive or dental material ^[2]. In restorative dentistry, there has also been a growing interest in using nanoparticles to improve properties of dental restoratives ^[3].

There were several studies performed to investigate the properties of dental cements added different nanoparticles. The addition YbF₃ (ytterbium fluoride) and BaSO₄ (barium sulphate) nanoparticles (1, 2, 5, 10, 15 and 25% (w/w)) to commercial glass-ionomer cement decreased the compressive strength ^[4]. Compressive strength significantly increased in 3% (w/w) TiO₂ nanoparticles addition glass ionomer compared to control group, there was no significant difference between 5% (w/w) TiO₂ nanoparticles addition glass ionomer and control group. Compressive strength significantly decreased in 7% (w/w) TiO₂ nanoparticles addition glass ionomer ^[5]. Significant variation didn't occur in compressive strength of 1 wt% TiO₂ nanoparticles reinforced glass ionomer cement. Compressive strength increased in 3 wt% TiO₂ nanoparticles reinforced specimen and more increased in 5 wt% TiO₂ nanoparticles reinforced specimen. Low compressive strength occurred in 10 wt% nanoparticles reinforced TiO₂ specimen. Diametral tensile strength in 5 wt% TiO₂ nanoparticles reinforced specimen was higher than the other TiO₂ nanoparticles reinforced specimens ^[6].

Compressive strength of 3 wt% was the highest in 1, 2, 3 and 4 wt% forsterite nanoparticles addition glass ionomer cements. Diametral tensile strength of 1 wt% forsterite nanoparticles addition glass ionomer cement was the highest in 1, 2, 3 and 4 wt% forsterite nanoparticles addition glass ionomer cements [7]. The effects of 3 wt% and 5 wt% Al_2O_3 nanoparticles on compressive and diametral strength of zinc polycarboxylate cement were investigated in this study.

MATERIALS AND METHOD

SPECIMEN PREPARATION

Al_2O_3 nanoparticles addition zinc polycarboxylate cements were used for this study. 3 wt% and 5 wt% Al_2O_3 nanoparticles were added to zinc polycarboxylate cement. Manufacturing process were shown in Figure 1.

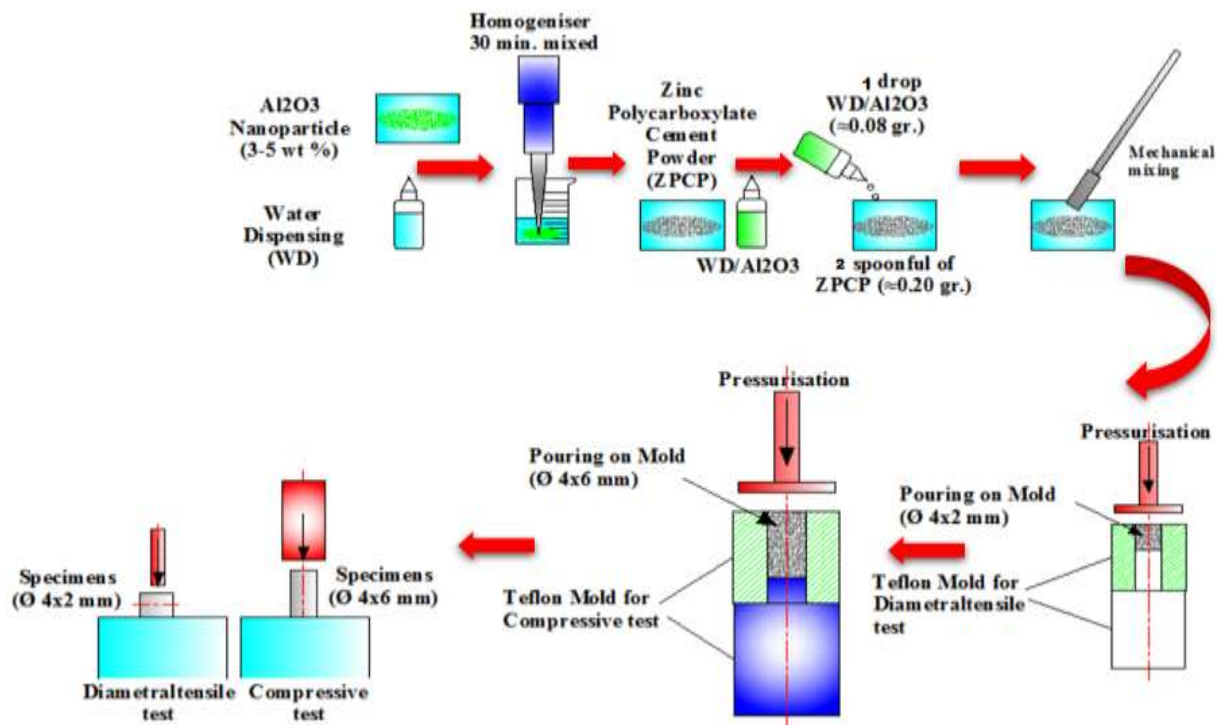


Fig. 1. Manufacturing process

Materials and manufacturers used in this study were given in Table 1.

Table (1): The materials and manufacturers

Material	Manufacturer
Zinc Polycarboxylate cement (Poly-F Plus)	GERMANY
Al_2O_3 nano powder (99.5% pure, powder size 40-50 nm)	MKNANO, Canada

Specimens were prepared in 4 mm of diameter and in 6 mm of height for compressive test using teflon mold. For diametral tensile test, specimens were prepared in 4 mm of diameter and in 2 mm of height using teflon mold. Specimens were divided in to three groups for every test. Every group consisted of ten specimens. Group 1. Zinc polycarboxylate cement without nanoparticle (control group), Group 2. Zinc polycarboxylate cement with 3 wt% Al_2O_3 nanoparticles, Group 3. Zinc polycarboxylate cement with 5 wt% Al_2O_3 nanoparticles.

COMPRESSIVE TEST

Compressive tests were performed for determine compressive strength of specimens. Tests were performed at 1 mm/min. cross head speed using by an universal test machine. Compressive load values were recorded until specimen broke. The compressive strengths of specimens were calculated using Equation 1. Where σ is compressive strength (MPa), F is compressive load at fracture (N), d is diameter of specimen (mm).

$$\sigma = \frac{4F}{\pi d^2} \quad \text{Eq. 1}$$

DIAMETRAL TENSILE TEST

Diametral tensile tests were performed at 1 mm/min. cross head speed using an universal test machine. The diametral strengths of specimens were calculated using Equation 2. Where σ is diametral tensile strength (MPa), F is diametral load at fracture (N), d is diameter (mm) and h is height of specimen (mm).

$$\sigma = \frac{2F}{\pi dh} \quad \text{Eq. 2.}$$

STATISTICAL ANALYSIS

Statistical analysis was performed with Kolmogorov-Smirnov test of normal distribution an one-way ANOVA followed by Tukey's honestly significant difference (HSD) test with a general linear model procedure in SSPS17.0 (SPSS Inc., Chicago, USA). One-way ANOVA followed by Tukey's HSD test was used with in each group to compare effectiveness of different concentrations of reinforcement. A significance level of 0.05 was used for statistical tests.

RESULTS AND DISCUSSIONS

In this study the comparison of compressive and diametral tensile strength was done between the control group and the specimens containing different concentrations of Al_2O_3 nanoparticles. The compressive and diametral tensile strengths of three group specimens calculated and deviation values were determined with statistic analysis. These values were shown in Table 2 and Table 3.

Table 2. Mean compressive strengths and standard deviations of groups

Groups	Mean compressive strength (MPa)	Standard deviation
Group 1 (without nanoparticle)	34.06	11.64
Group 2 (3 wt% Al_2O_3 nanoparticle)	17.61	2.58
Group 3 (5 wt% Al_2O_3 nanoparticle)	27.51	6.49

Table 3. Mean diametral tensile strengths and standard deviations of groups

Groups	Mean diametral tensile strength (MPa)	Standard deviation
Group 1 (without nanoparticle)	6.78	0.72
Group 2 (3 wt% Al_2O_3 nanoparticle)	4.71	0.97
Group 3 (5 wt% Al_2O_3 nanoparticle)	5.13	1.14

One-way analysis of variance showed a significant difference between mean values of compressive strength ($P=0.000$). Statistical analysis using the posthoc Tukey HSD significant differences test revealed that although compressive strength decreased in 3 wt% Al_2O_3 nanoparticles addition cement (Group 2) ($p<0.05$), there were no significant difference between control group (Group 1) and 5 wt% Al_2O_3 nanoparticles addition cement (Group 3) ($p>0.05$). Highest mean compressive strength was observed in Group 1 and Group 3, while the lowest was seen in Group 2 (Fig 2).

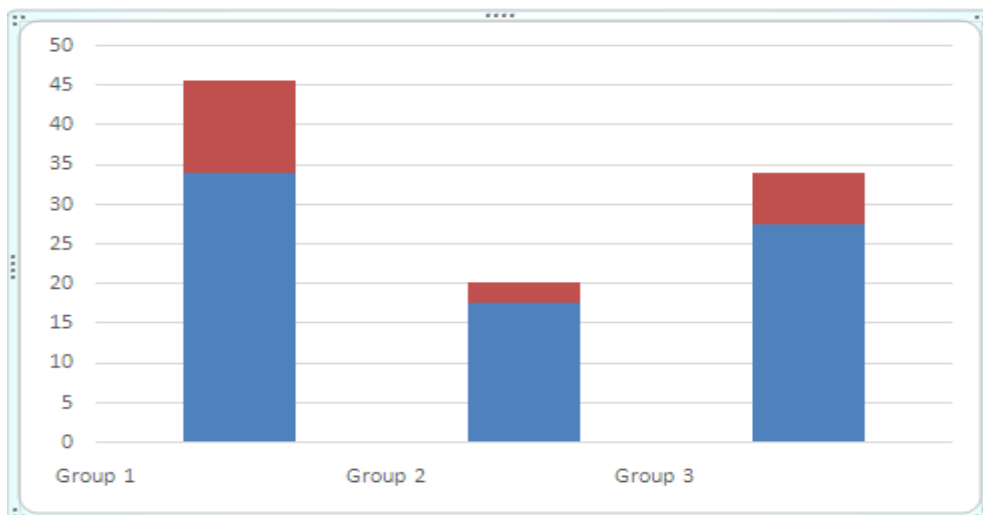


Fig 2. The graphics of mean compressive strengths of groups

For diametral strength, there was no significant difference between 3 wt% (Group2) and 5 wt% (Group3) Al_2O_3 nanoparticles addition zinc polycarboxylate cement ($p>0.05$). Control group (Group1) showed the higher diametral strength than the other groups ($p<0.05$) (Fig3).

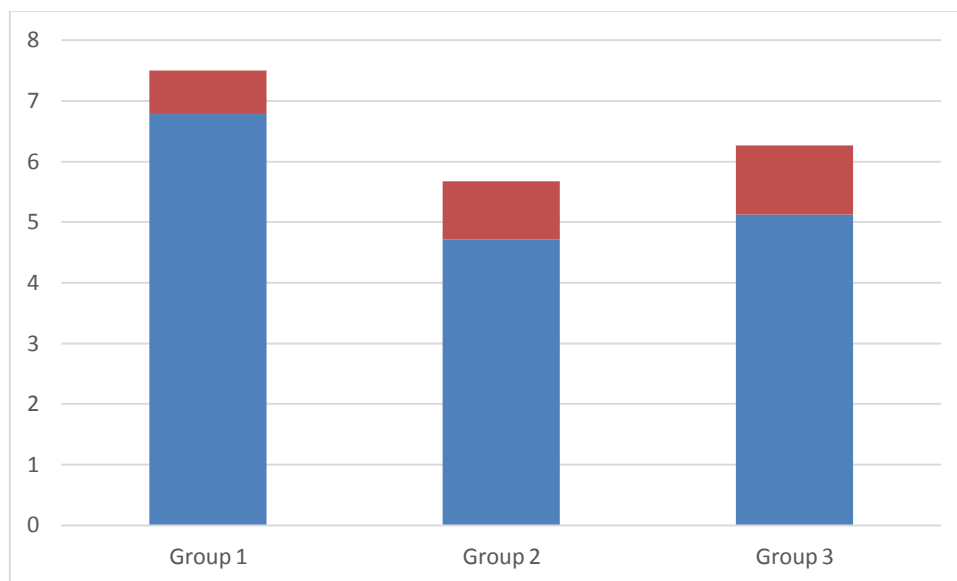


Fig 3. The graphics of mean diametral strengths of groups

Prentice et al. 2006 added YbF_3 (ytterbium fluoride) and BaSO_4 (barium sulphate) nanoparticles (1, 2, 5, 10, 15 and 25% (w/w)) to commercial glass-ionomer cement. The effects of ytterbium fluoride and barium sulphate nanoparticles on strength and reactivity of commercial glass-ionomer cement were investigated. Working time, initial setting time, compressive strength and surface hardness were examined. To add YbF_3 and BaSO_4 nanoparticles to glass-ionomer cement decreased the compressive strength. Elsaka et al. 2011 added 3%, 5% and 7% (w/w) TiO_2 nanoparticles to conventional glass-ionomer. Fracture toughness, compressive strength, microtensile bond strength, flexural strength, surface microhardness, antibacterial activity, fluoride release and setting time were investigated. Compressive strength significantly increased in 3% (w/w) TiO_2 nanoparticles addition glass ionomer compared to control group, there was no significant difference between 5% (w/w) TiO_2 nanoparticles addition glass ionomer and control group. Compressive strength significantly decreased in 7% (w/w) TiO_2 nanoparticles addition glass ionomer.

Khademolhosseini et al. 2012 investigated the mechanical properties of TiO_2 and Al_2O_3 nanoparticles reinforced glass ionomer cements. Compressive strength, diametral tensile strength and microhardness were determined. Significant variation didn't occur in compressive strength of 1 wt% TiO_2 nanoparticles reinforced glass ionomer cement. Compressive strength increased in 3 wt% TiO_2 nanoparticles reinforced specimen and more increased in 5 wt% TiO_2 nanoparticles reinforced specimen. Low compressive strength occurred in 10 wt% TiO_2 nanoparticles reinforced specimen. Diametral tensile strength in 5 wt% TiO_2 nanoparticles reinforced specimen was higher than the other TiO_2 nanoparticles reinforced specimens. Sayyedani et al. 2014 investigated the effects of 1 wt, 2 wt, 3 wt and 4 wt% forsterite nanoparticles on mechanical properties of glass ionomer cements. Forsterite nanoparticles were produced by a sol-gel process. Three-point flexural strength, diametral tensile strength, and compressive strength were determined. Compressive strength was the highest in 3 wt% forsterite nanoparticles addition glass ionomer cement. Diametral strength was the highest in 1 wt% forsterite nanoparticles addition glass ionomer. Vanajassun et al. 2014 added 3% w/w ZnO nanoparticles to conventional glass-ionomer cement. Antibacterial and mechanical properties of nanoparticles addition glass-ionomer cements were determined. Agar diffusion, compressive strength and shear bond strength tests were performed. Significant difference didn't occur between mean compressive strengths of control group (84.096 MPa) and 3% w/w ZnO nanoparticles addition group (84.462 MPa).

CONCLUSIONS

The effects of Al_2O_3 nanoparticles on compressive and diametral tensile strength of zinc polycarboxylate cement were investigated. According to test results the following conclusions found:

1. Compressive strength decreased in 3 wt% Al_2O_3 nanoparticle addition cement compared to control group.
2. There was no significant difference between compressive strengths of 5 wt% Al_2O_3 nanoparticles addition cement and control group.
3. There was no significant difference between diametral tensile strengths of 3 wt% and 5 wt% Al_2O_3 nanoparticles addition cement.

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