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Comparative evaluation of compressive strength of conventional glass ionomer cement and glass ionomer cement modified with nano-particles

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Abstract
Glass ionomer cement (GIC) possesses certain properties of adhesive, biocompatibility, and fluoride releasing but its certain disadvantages led to its various modifications.
Aim: To evaluate and compare the effect of various additives on the flexural strength of glass ionomer cement.
Materials and Method: 30 samples for evaluation of compressive strength were equally divided into 3 groups: Group 1- Control (Conventional GIC- Non modified), Group 2: GIC Powder modified with 3% TiO2 and Group 3: GIC Powder modified with 10% Nano Hydroxyapatite.
Result: The mean compressive strength value of Group 5 showed statistically significant higher flexural strength among all the groups (177.14 ± 0.81).
Conclusion: The results of the study revealed that glass ionomer cement powder can be modified with nano-hydroxyapatite and nanotitanium to improve its compressive strength.

Keywords: Compressive strength, glass ionomer cement, 3% titanium dioxide nano-powder, 10% nano-hydroxyapatite

Introduction
Glass ionomer cement (GIC) for dental restorative applications are formed by an acid-base reaction between calcium fluoro-alumino-silicate glass and polyacrylic acid [1]. Their favourable adhesive and fluoride releasing properties have led to their widespread use as luting materials, cavity liners and bases, and restorative materials.[2] However, the major disadvantages are fracture toughness, low wear-resistance and in the past high dissolution.[3] These insufficient mechanical properties of GIC led to limitation of its applications in the non-stress bearing regions [4]. Improvement of the mechanical properties of polymeric materials by nanoparticles incorporation was studied.
The incorporation of nano-hydroxyapatite into GICs may not only improve the biocompatibility of GICs, but also have the potential of enhancing the mechanical properties. In addition, it has the ability to increase the bond strength to tooth structure due to its similar composition and structure to enamel and dentin [5].
It has recently been reported that the incorporation of TiO_2 NPs to GIC at 3% and 5% (w/w) significantly enhanced the fracture toughness, compressive strength, flexural strength and hardness [3]. This might be due to the fine size of the nanoparticles incorporated along with the powder of the GIC [6].
Hence the aim of this *in vitro* study was to compare and evaluate the compressive strength of conventional GIC and GIC modified with titanium dioxide nano-powder and nano-hydroxyapatite

Materials and Method
Conventional GIC (Type IX)
3% Titanium dioxide nano-particles (w/w)
10% nano-hydroxyapatite (w/w)

Modification of Glass Ionomer with Nano-titanium
9mg of glass ionomer cement was mixed with 0.3mg of titanium dioxide powder in order to modify glass ionomer with 3% titanium dioxide nano powder.

Modification of Glass Ionomer with Nano-hydroxyapatite
9mg of glass ionomer was mixed with 1 mg of nanohydroxyapatite in order to modify glass ionomer with 10% titanium dioxide nano powder.

Compressive strength measurement
Specimen preparation
Ten cylindrical samples each from conventional GIC and from GIC modified with Titanium Dioxide nanopowder and from Gic modified with nanohydroxyapatite (6 mm in height and 4 mm in diameter) were made using pre-fabricated Teflon moulds and tested for compressive strength ccording to 1SO 9917. The specimens were stored at 37°Cfor an hour and then immersed in a small container for incubation in water at 37°C for 7 days

Test method
Compressive strength (CS) was assessed at 7 days after mixing. Wet specimens were placed in a vertical position with force incident on their long axis, and loaded in compression at acrosshead speed of 1.0 mm/min in a universal testing machine, until fracture occurred. The CS was calculated by the following formula: $P/3.14*r^2$, where P is the load at fracture, r is the radius of the specimen, and pi = 3.14. The CS values [kgf/mm^2] were converted into Mega Pascal (MPa) as follows CS [MPa] = CS [Kgf/mm^2] × 0.09807.

Results
The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0. Data were expressed as Mean ± SD. Analysis of variance (ANOVA) was employed for inter group analysis of data and for multiple comparisons. Welsh two sample t test was applied. A P-value of less than 0.05 was considered statistically significant. (Table 2) The mean flexural strength value of Group 2 showed statistically significant higher compressive strength among all the groups (177.14 ± 0.81). Statistically significant difference in compressive strength was found amongst all the groups that is Group 2 > Group 3 > Group 1.

Table 1: Descriptive statistics of compressive strength (MPa) among various groups

Group	N	Mean	SD	95% Confidence interval of the difference		Min	Max
				Lower Bound	Upper Bound		
Conventional GIC	10	132.09	0.79	131.52	132.65	131.3	133.6
GIC modified with 3%TiO2	10	177.14	0.81	176.56	177.71	175.9	178.3
GIC modified with 10% nHAP	10	148.80	0.83	148.20	149.38	147.3	149.8

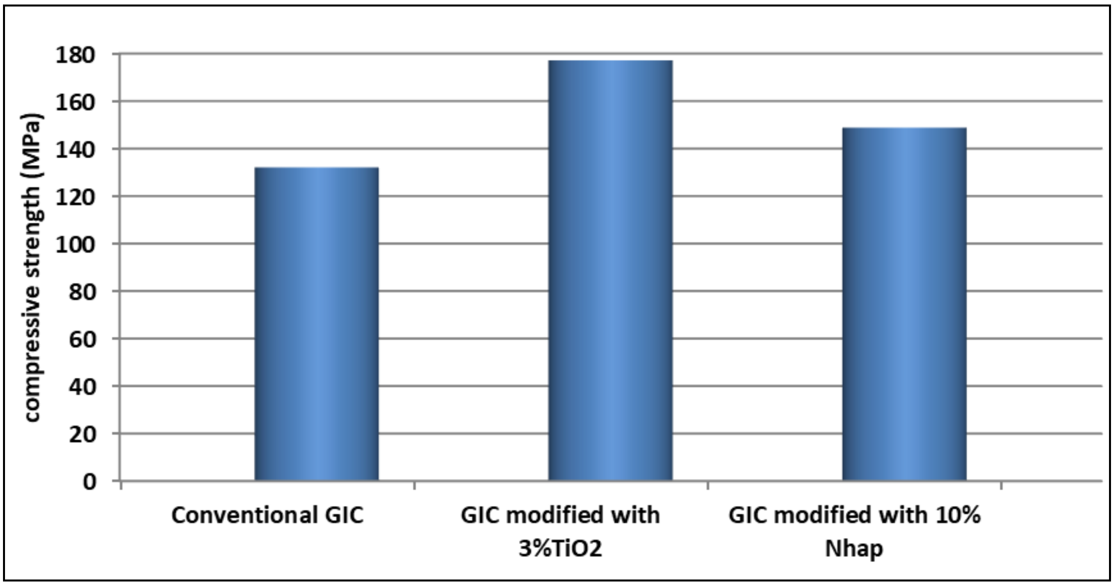

Fig 1: Comparison of mean compressive strength values of all groups

Table 2: Statistically significant difference found among the three groups

Groups	T Statistic	df	P-value
Conventional GIC	-126.21	17.989	<0.0001
GIC modified with 3% TiO2	77.576	17.991	
GIC modified with 10% nHAP	-46.262	17.961	

Welch two sample t-test

Discussion
Nanotechnology involves the use of systems, modifications or materials which have the size in the range of 1–100 nm. Key applications of nanotechnology in dentistry include implant surface modifications, production of reinforced polymeric composites by incorporation of nano-sized particles, and caries prevention. Recent studies have suggested that incorporation of nano-sized particles or "nanoclusters" can improve the mechanical properties of dental restorative material such as resin composites. Similar approaches have been attempted to improve the physical and mechanical characteristics of GIC using nanotechnology [7].
The improved properties of nanohydroxyapatite are thought to be because of:

1. The matrix of HAp-added GIC was strengthened compared to conventional GIC by increased metal ions

participating in the cement hardening reaction. The metal ions (Ca^{2+}) are supplied by the dissolution of HAp particles.
2. The HAp particles in GIC was reinforced first by the adsorption of GIC matrix and then by the formation of an "intermediate layer" between the surface of the primary HAp crystals and the absorbed matrix.
3. HAp-added GIC was reinforced by adhesion of the improved matrix and the improved HAp particles [8].

Hydroxyapatite has an effect on both the setting reaction mechanism and the degree of polysalt bridge formation of the glass ionomer, which improves the mechanical properties of the final set cement. Hydroxyapatite is soluble in acidic solutions; as a result, calcium ions can be extracted from the surface of HA after mixing the powder with a polyacid [5].

Titanium dioxide (TiO_2) nanoparticles have been proposed for use as reinforcing fillers to dental resin composites and epoxy. TiO_2 as an inorganic additive has many promising properties as it is chemically stable, biocompatible and non-toxic [2].

In the present study, the control group showed the least compressive strength among all the experimental groups that is 132.09±0.79 MPa. Glass ionomer restoratives (GIR), frequently composed of calcium aluminosilicate, fluoride and polyacrylic acid, are interesting materials because of their good adhesion to the calcified tissues, their ability to release fluoride and relatively low cost. However, they are brittle materials with relatively poor mechanical performance. Actually, the poor mechanical performance presented by GIR materials is not only due to their brittle characteristic. GIR are multicomponent materials. If the adhesion between each component is weak, or in other words, if the interfacial tension between each component is high, the mechanical properties are poor. Therefore, an additive able to reduce the interfacial tension or to increase the adhesion among the components might lead to a better mechanical performance.

Hamoy *et al.* evaluated the effect of adding micro and nano particles of hydroxyapatite (HA) to glass ionomer cement. These additions enhanced the mechanical properties which include compressive strength, microhardness and biaxial flexural strength [9].

Kim *et al.* studied three experimental GICs and conventional GIC that differed in the additive incorporated into a commercial GIC liquid. Mechanical properties like compressive strength, diametral tensile strength, flexural strength and modulus of elasticity were measured according to the incubation time. Bioactive glass-incorporated GIC showed enhanced mechanical properties such as compressive, diametral tensile and flexural strength [10].

The compressive of Group 2 that is glass ionomer cement powder modified with 3% titanium dioxide nanopowder 177.14 ± 0.81 MPa.

Contreras *et al.* investigated the physical, antibacterial activity and bond strength properties of conventional base, core build and restorative of glass ionomer cement (GIC) compared to GIC supplemented with titanium dioxide (TiO_2) nanopowder at 3% and 5% (w/w). The supplementation of TiO_2 NPs to restorative GIC significantly improved Vickers microhardness, flexural and compressive strength. These studies are in accordance with the results of our study [3].

The compressive strength of Group 3 that is glass ionomer cement powder modified with 10% nano-hydroxyapatite and liquid is unmodified, has lower values that is 148.80± 0.83 MPa. Moshaverinia *et al.* incorporated nanohydroxy into commercial glass ionomer powder. Compressive, diametral tensile and biaxial flexural strengths of the modified glass ionomer cements were evaluated. Results showed that after 1 and 7 days of setting, the nanohydroxyapatite/fluoroapatite added cements exhibited higher compressive strength higher diametral tensile strength and higher biaxial flexural strength as compared with the control group [5].

Conclusion

Within the limitations of this study, the following conclusions were drawn:
1. Statistically significant difference was found in compressive strength amongst all the groups that is
2. Group 2 > Group 3 > Group 1.
3. Group 2 that is glass ionomer cement powder modified with 3% TiO_2 nanopowder showed highest flexural strength.
4. The results of this study showed that glass ionomer cement powder can be modified with nano-hydroxyapatite and nanotitanium to improve its flexural strength

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