

Glass Ionomer Cement Containing Nanoparticles Investigation

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Abstract

Glass ionomer cement (GIC) for dental restorative applications are formed by an acid-base reaction between calcium fluoro-alumino- silicate glass and polyacrylic acid. Since their introduction in 1972 to the dental field they have been widely used as restorative materials, sealant, luting cement and cavity base materials. Glass ionomers have certain exceptional properties such as chemical adhesion to dental hard tissues, anticariogenic/antibacterial properties from the release of

fluoride, good thermal compatibility with tooth structure and acceptable biocompatibility. However GICs have some disadvantages or limitations including early moisture sensitivity, brittleness and inferior mechanical strength when compared to resin- based restorative materials^[1].

Results

The statistical analysis was performed by one way ANOVA test and post-hoc Tukey HSD tests. GI-

containing 3 % and 5% (w/w) Al₂O₃ nanoparticles showed significantly higher compressive strengths compared to 3 % and 5% (w/w) SiO₂ nanoparticles and control group.

Conclusion

GI-containing 3% and 5% (w/w) Al₂O₃ nanoparticles is a promising restorative material with improved mechanical properties. This novel experimental GI may be potentially used for higher stress-bearing site restorations.

Keywords

Nanoparticle, glass ionomer cement, compressive strength.

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. Since their introduction in 1972 to the dental field they have been widely used as restorative materials, sealant, luting cement and cavity base materials. Glass ionomers have certain exceptional properties such as chemical adhesion to dental hard tissues, anticariogenic/antibacterial properties from the release of fluoride, good thermal compatibility with tooth structure and acceptable biocompatibility. However GICs have some disadvantages or limitations including early moisture sensitivity, brittleness and inferior mechanical strength when compared to resin- based restorative materials [1].

One of the major drawback is low fracture strength and increased occlusal wear rate when compared with other restorative materials. Thus special attention is needed to be looked into the mechanical properties of the GIC. Over the period they have undergone constant improvement in order to fulfil the current market trends and also to satisfy the function and aesthetic representation. They are also inexpensive when compared to resin composite restorations. Thus mechanical properties of GIC have been

investigated since their development and concerns have remained even after the development of resin modified GIC (RMGIC) [2].

Glass ionomer cements were introduced as hybrids of silicate cements and polycarboxylate cements to have characteristics of fluoride release (from silicate cements) and adhere to enamel and to some extent to dentin (from polycarboxylate cements). It is noteworthy that the physical properties of conventional glass ionomer cement can be highly variable based upon different powder/liquid ratios so mixing should be adhered to according to the manufacturers' instructions [3].

GIs although often used as restorative materials cannot generally withstand the forces generated in the posterior area of the mouth because of their low mechanical properties, especially the low fracture toughness [4-6]. Usually the performance standards for assessing restorative materials usually involve the measurements of compressive strength, diameter tensile strength, flexural strength, flexural modulus, color stability, fluoride release and adhesive bond strength [7].

Compressive tests are used in dentistry for laboratory simulation of the stress that may result from forces applied clinically to a restorative, base/liner or core build material. Most mastication forces are compressive in nature but exact critical value is unknown [8].

In this work we aim to come over the disadvantage of GIC by incorporating nano-silica and Al₂O₃ with different quantities. The objective of this research was to investigate the compressive strength of glass ionomer cement containing 3% and 5% Al₂O₃ and SiO₂ nanoparticles.

The null hypothesis of this study was that there were no differences in the compressive strengths following the addition of nanoparticles.

Material and Methods Specimen preparation

In this study conventional glass ionomer cement (MERON, Germany) were used. 3%, 5% SiO₂ and Al₂O₃ nanoparticles were added to glass ionomer powder as shown in Fig 1. The specimen of each group was prepared as shown in Fig.1. Used materials and manufacturers were given in Table 1. Specimens were divided into five groups. The specimen groups were shown in Table 2. Every group contained 10 specimens (n=10). Total of fifty specimens were prepared in dimensions of 4 mm diameter and 6 mm height.

Compressive strength test

Compressive tests were performed in an universal test machine with 1 mm/min. cross head speed. Compressive loading were applied until specimen is get to be broken and compressive load values were recorded. Compressive strength values were calculated by Equation 1. Where σ (MPa) is compressive strength, F (N) is compressive load at fracture and d (mm) is specimen diameter.

Results

Mean and standard deviations of compressive strength for groups were given in Fig.2. Data showed a significant increase in compressive strength for the GI cement containing 5% (w/w) Al₂O₃ NPs compared to the control group and 3% and 5% (w/w) SiO₂ group. There was significant difference between GI cement containing 3% (w/w) Al₂O₃ control group and 3% SiO₂ group. There was no significant difference between control and 3% and 5% (w/w) SiO₂ group. The ratio quantity (3% and 5%) had no significant effect on compressive strength for both Al₂O₃ and SiO₂ groups. The compressive strength values of 3% SiO₂ were significantly smaller than 3% and 5% (w/w) Al₂O₃ group. On the other hand there was no significant difference between 3% Al₂O₃ and 5% SiO₂ group.

Discussion

In recent decades, glass ionomer cements (GICs) have been widely used as a luting agent, a cavity liner and for bases and restorative material. Some important characteristics of GICs include fluoride ion release, a low thermal coefficient of expansion almost near the tooth, the bonding ability to the tooth and metallic surfaces and biocompatibility [27]. However, its use is associated with problems like high technique sensitivity and lower esthetics compared to composite resins. Furthermore due to its low compressive strength and mechanical properties it can not be applied as a restorative material at areas under occlusal stress [28]. Low resistance to fracture of glass-ionomers is commonly attributed to the presence of porosity in the cement matrix. These are formed by the inclusion of air during mixing [29]. Once the material sets, these voids become trapped in the cement where they act as stress concentrations and thus points of mechanical weakness [30] between both of the tested materials, or between the different types of nanoparticles. Elizabeta Gjorgievska et al. [31] found that although the nanoparticles were of different sizes, there were no noticeable differences in their behavior and all appeared to blend readily into the cement and to reduce the porosity when set as we concluded in our study.

The present study involves two different types of nanoparticles, namely Al₂O₃ and SiO₂. They were selected because they exhibit relatively low toxicity when present in other dental restorative formulations [32,33,34]. In addition, compressive strength investigation were carried out on 3 and 5 wt % additions of the different nanoparticles; hereby presented are the results of the samples with 5wt% addition of Al₂O₃ nanoparticle, which showed the best performance (Table 3). SiO₂, Al₂O₃, or TiO₂ particles are tougher than the sintered filler particles

in GIC. Therefore, under an indentation loading, these particles would undergo elastic rather than plastic deformation, as compared to GIC [25].

Khademolhosseini et al., 2012 [35] used the nanoparticles' ratio as we preferred in our study from 1 to 3 wt.% has led to a moderate increment of compressive strength, the specimens containing 5 wt.% TiO₂ have demonstrated more highlighted enhancement in the value of compressive strength as well as a higher diametrical tensile strength and microhardness values compared to the others [35]. In the light of this study, future investigations can be done with TiO₂ nanoparticle.

The compressive and diametral tensile strengths of Al₂O₃/TiO₂-GICs was, however, significantly greater than another GICs due to the better particle size distribution and interfacial bonding between the particles and the matrix in Khademolhosseini et al's study [35] as it was in our study.

The mechanical strength is found to be dependent upon the particle size and particle size distribution of restorative materials [36]. As a result, the composition of glass particles with a larger particle size and Al₂O₃/TiO₂ particles with nano size particles has led to a wide distribution of the particle size. This would allow a high packing density of the mixed particles within the glass ionomer matrix [36]. On the other hand, the wide distribution of nano sized particles within the larger glass particles can generate a high packing density of glass ionomer cement with an enhanced mechanical strength as we similarly found higher compressive strengths for 5% Al₂O₃ nanoparticles. However, lower amount of voids as well as good distribution of nano powders in Al₂O₃/TiO₂-GIC can result in the highest amount of mechanical properties [35].

In addition to particle size and particle size distribution, the cross-linking formation during setting plays an important role on the final mechanical properties of the cements [36,37]. An acid-base reaction occurs during the setting procedure and forms a salt hydrogel, acting as the binding element in matrix within which the glass plays a reinforcing role. Releasing metal ions can take place upon the introduction of acid into the powders and the released metal ions operate as cross-linking species, allowing the formation of stable cement [35].

Gu et al. [37] also state that better interfacial bonding between the particles and the matrix; propose that the aluminum and zirconium ions may have reacted with the Polyacrylic acid, forming the cross-linking in the YSZ-GIC samples. Similarly, it seems that good interfacial bonding as well as crosslinking between Al₂O₃ nano particles and the cement matrix, resulted from the formation of aluminum salt bridges among trivalent aluminum ions in the glass as well as aluminum and titanium ions from the nano powders, provides the final strength of Al₂O₃ -GICs. Thereby, this may present another reason for the increase of mechanical properties in GICs as a result of applying Al₂O₃ nano particles in our study. However, ionic interactions and ionic bonding between the reinforcing particles (Al₂O₃ and/or TiO₂) as well as the polyacrylic acid seem to be in need of additional investigations [35].

Conclusion

In general the addition of 3% and 5% Al₂O₃ enhanced the mechanical properties of the GIC,

According to test results the following results were found; GI-containing 5% (w/w) Al₂O₃ nanoparticles is a promising restorative material with improved mechanical properties. This novel experimental GI may be potentially used for higher stress-bearing site restorations.

The ratio (3 % -5%) amount had no difference on the compressive strength of GI cement groups.

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