In vitro application of a nano-filled coating agent to improve the diametral tensile strength of glass ionomer cement

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Abstract. During dental restoration, if the intraoral fluid comes into contact with the cement before it has hardened, the matrix-forming ions (Ca and Al) can be washed out, resulting in improper matrix formation and inferior mechanical properties. To prevent this, glass ionomer cement can be supplemented with a surface coating to protect it from water contamination in the early stages of setting and from moisture contamination and desiccation 10–30 min after insertion. This study aimed to investigate the influence of a nano-filled coating agent as a surface coating on the mechanical properties of glass ionomer cement, Fuji IX GP Extra. The glass ionomer cement specimens (6.00 mm in diameter and 3.0 mm in height) with and without the coating agent were stored in aqua bidest for 1 h, 1 day, and 1 week. Then, the diametral tensile strengths of the samples were measured and compared using an unpaired t-test. The coated glass ionomer cement exhibited significantly higher strengths than the uncoated samples after 1 h and 1 week, indicating that the nano-filled coating agent can be used in dental restoration to ensure mechanical strength of the cement.

1. Introduction

Glass ionomer cement (GIC) is being developed as a material for dental restoration, as a lining or base material, or as a bonding material for bridges [1]. GIC was first made by Wilson and Mclean in a chemical laboratory owned by the English government in 1965 and first introduced to the public in 1971 [2,3]. GIC is formed from a polyenoic acid liquid and calcium/strontium aluminosilicate glass fluor [4]. It is desirable because of its low thermal expansion coefficient that is similar to that of teeth, its high bonding strength to enamel and dentin, and its tendency to release fluoride ions to the tooth structure. However, GIC is also difficult to polish, porous, and easily worn and has a low fracture resistance [1,5,6]. Moreover, it has a long setting time of about 6–8 min after mixing [7,8] and is very sensitive to water during this period; if the intraoral liquid comes into contact with GIC before it sets, the matrix-forming ions (Ca and Al) can be washed out, leading to improper matrix formation and inferior mechanical properties.

To prevent these issues, a surface-coating agent can be applied to the GIC to protect it from liquid contamination and from humidity or dryness during the initial setting phase 10–30 min after insertion [9,10]. Resin-based photo-cured surface-coating materials with low viscosities are preferred over varnish-based surface coatings to prevent water penetration [9]. Nano-filled coating agents and their effectiveness in preventing wear and improving the hardness and flexural strength have been studied previously [11,12].
Mechanical strength is one of the most important factors of a restoration material to ensure clinical success. One type of mechanical strength is tensile strength, which is particularly important to allow normal chewing [13]. Measuring the diametral tensile strength is one simple way to characterize the tensile strength of a fragile material like GIC [14,15]. Therefore, this study aimed to characterize the effect of a nano-filled coating agent on the diametral tensile strength of GIC.

2. Methods
To create the GIC samples, disc-shaped molds of 6.00 mm in diameter and 3.0 mm in height were cleaned to remove all dust and dirt and covered in silicone oil. The GIC was prepared according to the manufacturer’s instructions and loaded into the mold. Matrix strips and preparation glass were placed on the mold, and pressure was applied using a finger above the preparation glass for 2 s to remove excess material beneath it. Three minutes after GIC mixing, the preparation glass and matrix strips were removed. The specimens were taken out from the molds using a pair of tweezers. All excess GIC materials were removed using lecron wax carver to form samples into perfect circles. Then, the surfaces of half of the samples were coated with GC Coat Plus 30 min after the initial mixing, and the coating was cured using a light curing unit for 20 s. The samples were immersed for 1 h, 1 day, or 1 week. Thus, of the 36 samples prepared, there were six subgroups, each comprising six samples: groups 1–3 included specimens with the nano-filled coating agent, and groups 4–6 included uncoated specimens. Samples from groups 1 and 4 were immersed in a plastic pot containing aqua bidest at 37°C for 1 h, those from groups 2 and 5 were immersed for 1 day, and those from groups 3 and 6 were immersed for 1 week.

The diametral tensile strength tests were conducted on the samples following these incubation periods. The diametral tensile strength tests were conducted using a Universal Mechanical Testing Machine (Shimadzu Autograph AG 5000 E) with a crosshead speed of 0.50 mm/min and a maximum load of 250 KgF. The center of the circular surface of each sample was aligned under the guiding needle, and a load was applied until the specimen fractured into two pieces. The values from the machine were converted into MPa via the counting formula, and the results from each group were averaged. The groups were compared using an unpaired t-test.

3. Results
The results are shown in Table 1 and Figure 1. After 1 h of immersion, the p-score for the difference between the diametral tensile strengths of GIC with and without the nano-filled coating was 0.001. After 1 day of immersion, the p-score was 0.309, and after 1 week of immersion, the p-score was 0.038. In this study, p < 0.05 were considered statistically significant. Thus, these findings indicate that there were significant differences between the diametral tensile strengths of GIC with and without the nano-filled coating after 1 h and 1 week of immersion.

| Specimen                        | N | Mean Diametral Tensile Strength (MPa) |
|---------------------------------|---|--------------------------------------|
|                                 |   | 1 hour                  | 1 day                  | 1 week                  |
| GIC without Nano-Filled Coating Agent | 6 | 8.68 ± 1.54               | 13.79 ± 3.43           | 12.05 ± 1.83            |
| GIC with Nano-Filled Coating Agent | 6 | 12.96 ± 1.72              | 15.56 ± 2.15           | 14.57 ± 1.82            |
Figure 1. Diametral tensile strength for GIC with and without the coating agent after 1 h, 1 day, and 1 week periods (mean values shown with error bars representing the mean and standard deviation)

4. Discussion
Comparing the diametral tensile strength of the GIC coated with the nano-filled coating agent with that of the non-coated GIC, the statistical test revealed that only the differences after 1 h and 1 week of immersion were significant; the difference after 1 day was not statistically significant based on the data obtained in this study (i.e., the observed difference may have been due to random error).

Fuji IX GP Extra was created with superior strength compared to a similar product, Fuji IX GP. These GIC cement materials are almost the same in most aspects but differ slightly in that Fuji IX GP Extra has more reactive glass particles, so that it offers a faster setting time, and has greater translucence and better fluor release compared to Fuji IX GP. However, the flexural strength and modulus of elasticity of Fuji IX GP Extra are not significantly different from those of Fuji IX GP after 24 h.

The diametral tensile strength of Fuji IX GP has been previously measured by Yap et al. and reported to be around 11–13 MPa after 1 h and 1 week of immersion. Another previous study reported a similar value of 12.7 MPa. The diametral tensile strength values of around 12–14 MPa after 1 day and 1 week of immersion are consistent with these previous findings.

There is a theoretical basis for the hypothesis that the GIC strength is improved by applying a surface protection agent to maintain the water balance within the cement. Kato et al. studied the effects of many types of coatings, including unfilled and nano-filled resin coatings, on the flexural strength of GIC [12]. The results of this prior study showed that the nano-filled resin coating provides a better bonding strength between the coating and the GIC surface than the uncoated GIC alone because of the self-adhesive ester phosphoric monomer in the coating, which bonds chemically to other components like GIC. Moreover, the results showed that this coating increases the flexural strength of the GIC. This is presumed to be because the protective coating agent filler is silica with 40 nm particles dispersed evenly throughout the low-viscosity solution; thus, the resin coating forms a 40 nm-thick layer, filling the pores and micro-spaces on the GIC and other composite resin surfaces, thus protecting the surface of the material and promoting equal distribution of the mechanical load throughout the cement.
5. Conclusion
On the basis of the results of this study, it can be concluded that the application of the nano-filled coating agent to GIC provides the cement with better mechanical strength in terms of the diametral tensile strength compared to GIC without the protective coating.

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