Evaluation of Surface Roughness and Compressive Strength of Modified Glass Ionomer Cement with Coumarin Derivatives

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ABSTRACT

The objective of the present study was to evaluate the effect of incorporation of synthesized coumarin derivatives, hydrazinyl thiosemicarbazide (HZTC), an antibacterial agent on the surface roughness and compressive strength of glass ionomer cements (GICs). Two commercial GICs, Fuji II LC and Fuji VII were used in this study and act as control groups. HZTC was incorporated into GIC during its manipulation at the weight percentage of 1% and 2%. The surface roughness and compressive strength of the samples were prepared and analysed using Profilometer and universal testing machine Shimadzu AGX-Plus respectively. The data were analysed statistically to determine the significant differences among groups using Kruskal Wallis and Man Whitney test for the surface roughness, and one-way ANOVA with post-hoc Bonferonni test for the compressive strength. Statistically, the surface roughness value of Fuji II LC was significantly increased ($p<0.05$) at both weight percentages while the decrease value of Fuji VII was insignificant at 1% (w/w) compared to the control GICs. The compressive strength of both Fuji II LC and Fuji VII showed significantly decreased in strength values ($p<0.05$) at both weight percentages compared to the control GICs. Based on the results of this study, it can be concluded that the incorporation of HZTC gave measurable effects on the surface roughness and compressive strength values.

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Introduction

The use of tooth coloured dental restoration in treating caries has drawn much attention due to its aesthetic properties and glass ionomer cement (GIC), is not an exception. Introduced by Wilson and Kent in early 1970s, GIC is made up of fluoroaluminosilicate glass powder and polyacrylic acid [1]. Several other desirable characteristics of GIC such as adhesion to moist dental hard tissue, biocompatible to pulpal and gingival tissues, fluoride release, and antibacterial activity has made this material gain rapid acceptance in the recent years [2]. GIC is also a material of choice in Atraumatic Restorative Treatment (ART) or as Interim Therapeutic Restorations (ITR) procedure where the dental restorative material are placed rapidly, without the use of drills or anaesthetics [3]. This procedure is particularly favourable for caries stabilizations where conventional restoration and behaviour management are unfeasible particularly in patients with high caries risk.

The release of fluoride differentiates GIC from other restorative materials. Although the released fluoride ions are capable in inhibiting the growth of bacteria which decreases the number of residual bacteria in cavities, it is not sufficient enough to combat the bacterial destruction for a longer period of time [4,5]. Furthermore, several researchers has recently advocated for a combined fluoride-antimicrobial approach since fluoride alone is insufficient to prevent caries, and that there is a need for antimicrobial agents that have the mode of action synergistic or complementary with that of fluoride [6]. Thus, the inclusion of antibacterial compounds into GIC could prove to be of practical benefit in caries prevention.

Several efforts have been done to enhance the antibacterial properties of GICs, including incorporating GICs with bacteriacides such as chlorhexidine gluconate [7], chlorhexidine acetate [8], chlorhexidine diacetate [4] and quarternary ammonium salt [5], however, none of them has been successful without jeopardizing the physical and mechanical properties of GICs. Therefore, the selection of antibacterial agent and its quantity for the incorporation with GIC are at utmost important.

Knowing that further improvements are required in enhancing the antibacterial effect, the addition of coumarin derivatives into GIC probably a better choice as coumarin and its derivatives contribute significant pharmacological interest where they showed a wide spectrum of biological activities including antibacterial, antifungal, and antitumor [9]. Hydrazinyl thiosemicarbazide (HZTC), a derivative of coumarin used in this study has been synthesized in-house [10]. To date, the data available [11] for the coumarin derivative incorporation in GIC is still new. The exploration on the physical and mechanical properties of GIC is not that broad. The effective performances in the oral environment as well as the ability to withstand mechanical forces are among the crucial factors in determining the excellence of dental restoration [12]. Therefore, this study aims to focus on the physical and mechanical properties of the incorporation of antibacterial agent, HZTC, in GIC towards surface roughness and compressive strength.

Materials and Method

Preparation of GIC incorporated HZTC

Two different commercially available GICs, Fuji II LC and Fuji VII (GC Tokyo, Japan) were used. The materials consist of powder and liquid. The powder-to-liquid ratio for both Fuji II LC and Fuji VII were 1:2 and 1:1 respectively, as recommended by the manufacturer and they act as control groups. The experimental specimens were prepared by incorporating in-house HZTC at weight percentages of 1% and 2%. Seven specimens (n=7) were fabricated for each group.

Surface roughness

The surface roughness of the specimens were prepared in acrylic mould (5 mm in diameter, 2 mm in thickness) and placed in distilled water at 37°C for 24 hours. A surface profilometer (Surfcom Flex, Tokyo Seimitsu KA 1125 LG) was used to obtain the surface profile. Three measurements were made for each specimen by passing through the centre of the specimens.

Compressive strength

The cylindrical specimens were prepared in stainless steel mould (4 mm in diameter, 6 mm in height) and immersed in distilled water at 37°C for 24 hours. The specimens were then evaluated using a universal testing machine (Shimadzu AGX-Plus) at a crosshead speed of 1.0 mm/min and fitted with 20 kN load cell.

Statistical analysis

Kruskal Wallis and Man Whitney tests were used for surface roughness and one-way analysis of variance (ANOVA) with post-hoc Bonferroni test for compressive strength analyses were used to determine the significant differences among all samples. The data was analysed using SPSS version 23 and the level of significance was set at 0.05.

Results and Discussion

Maintaining smooth surfaces with the capability to resist masticatory forces are among the important aspects for restorative materials to sustain their long-term clinical performance.

Surface roughness

Smooth surfaces are among the factors that contribute to successful restorations. In the present study, the result in Figure 1 showed the surface roughness value of HZTC incorporation into Fuji II LC increased significantly compared to the control group. In contrast, the surface roughness value for Fuji VII decreased as the HZTC were added. However, the decrease is insignificant at 1% compared to the control group. The average Rα values for all tested specimens were within the range of 0.068-0.219 µm for Fuji II LC and 0.157-0.185 µm for Fuji VII.

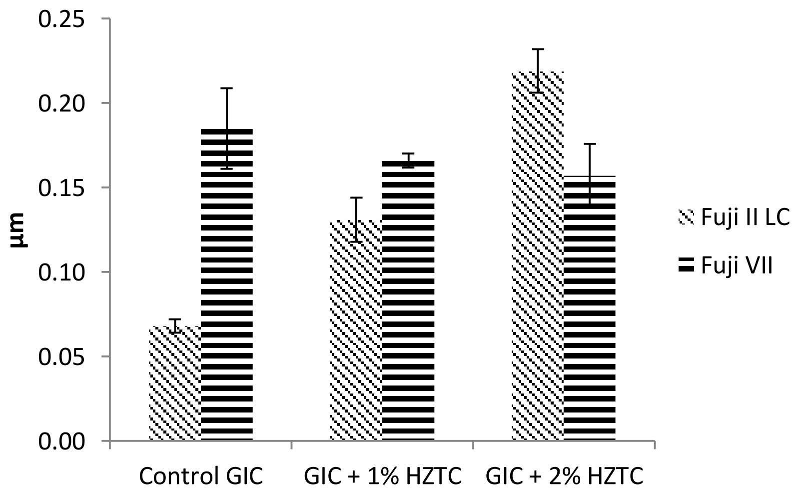

Figure 1 : Bar chart of the surface roughness values

The surface roughness value of 0.2 µm is considered as the critical threshold value for bacterial retention, as being reported by Bollen et al. [13]. The surface roughness value greater than 0.2 µm would result in an increase of plaque accumulation, thus increasing the risk for caries development and gingival inflammation. The surface value obtained in this study however, did not exceed much from the designated threshold level.

Variations in surface roughness values could be attributed to the differences in particle size. Particle size plays crucial role in determining surface roughness. Larger particle size would result in higher surface roughness [14,15]. In contrast, small particle size has also been reported to contribute to higher surface roughness [16]. Therefore, other factors such as particle distribution, amount of particles added and the interfacial bonding between the HZTC and GIC matrix may lead to the distinct of surface roughness values. The storage media of materials are also responsible for the distinct value of surface roughness. In this study, in order to mimic the oral condition, the specimens were immersed in water at 37 °C for 24 hours. This immersion results in chemical dissolution process thus, increases the surface roughness value [16].

Compressive strength

Compressive strength was used to measure the ability of a material to withstand masticatory forces [17]. The result for compressive strength shown in Figure 2 revealed that the incorporation of HZTC at both weight percentages were significantly lower compared to the control group for both materials.

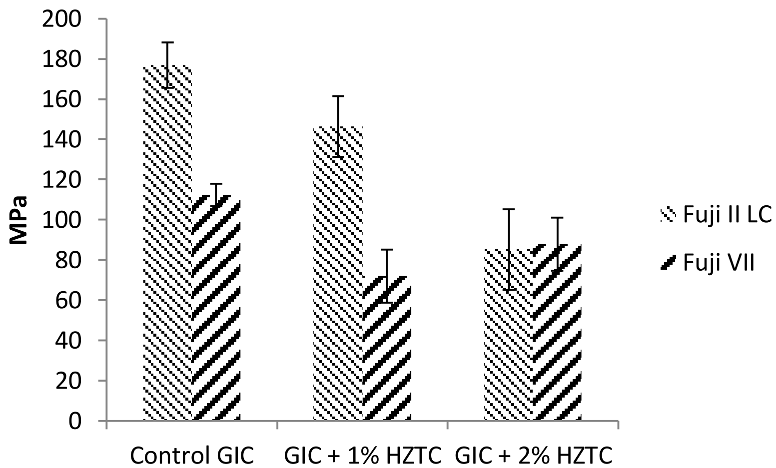

Figure 2 : Bar chart of the compressive strength values

The addition of HZTC to GIC yielded a lower compressive strength compared to the control group as its microstructure is affected. However, some of the value falls within the range required by ISO 9917-1 standard, which is 100 MPa for restoration and 50 MPa for the base and lining [I8].

The differences in powder-to-liquid ratio of GIC [19] and the addition of HZTC into the mixture may alter this proportion and consequently affect the mechanical properties of materials. The integrity of the interface between glass particles and polymeric matrix, particle size, the amount and size of voids in the material are among the determinant factors influencing the compressive strength [6].

The resistance of GIC is also influenced by the factor of internal porosity, depending on the method of manipulation. The GIC used in this study is hand-mixed and is very technique-sensitive as it increases the chance for air bubbles to be entrapped into the GIC matrix [20]. The generalized and inherent formation of pores within the GIC lessens its strength to cohesion and flexion [21]. These pores are the area of high concentration of stress, enhancing the likelihood of fracture of the material and thus reducing the compressive strength [22].

Palmer et al. (2006) incorporated chlorhexidine acetate into GIC. Their result revealed a similar trend as in this study, whereby, the compressive strength decreases as the percentage of additives increases [8]. Likewise, the results were consistent with those reported by Xie et al. (2011) which they used quartenary ammonium salt (QAS) as antibacterial agent incorporated in GIC [5].

Conclusion

Although the incorporation of coumarin derivative, HZTC, as antibacterial agent into GICs at both weight percentages of 1% and 2% reduces the compressive strength, the value still meets the requirement provided by ISO standard. Similarly, the increased surface roughness does not exceed much from the threshold level. Therefore, the incorporation of HZTC may have the potential of improving the antibacterial activity of GIC without compromising its physical and mechanical properties.

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