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Evaluation of Surface Microhardness of Silver and Zirconia Reinforced Glass-ionomers with and without Microhydroxyapatite

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Abstract

Statement of problem: Hardness of restorative materials like glass-ionomer is an important factor in the longevity of restoration.
Objectives: The aim of this study was to evaluate the microhardness of glass-ionomer modified with different materials.
Materials and Methods: Sixty disk-shaped specimens were examined in six groups in this study, including conventional glass-ionomer (Shofu, Japan), zirconia-reinforced glass-ionomer (Zirconomer, Shofu, Kyoto, Japan), silver-reinforced glass-ionomer (HI-DENSE XP, Shofu, Kyoto, Japan) and mixture of these three types of glass-ionomer with 20 wt% of microhydroxyapatite (Sigma-Aldrich, St. Louis, USA). All the specimens were stored in deionized water for 24 hours. Then Vickers microhardness test was carried out and the results were analyzed by using two-way ANOVA test and paired t-test ($P<0.05$).
Results: Zirconia-reinforced glass-ionomer with microhydroxyapatite exhibited significantly higher microhardness in comparison with other groups ($P<0.001$). Conventional glass-ionomer with microhydroxyapatite showed the lowest microhardness ($P<0.001$). After incorporation of microhydroxyapatite in both conventional and silver-reinforced glass-ionomer groups, microhardness decreased significantly ($P<0.001$).The microhardness of top and bottom of all groups was significantly different. ($P<0.001$).
Conclusions: Incorporation of 20% microhydroxyapatite to zirconia-reinforced glass-ionomer can improve microhardness.

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Introduction

Since the development of glass-ionomers in the early 1970s, its application in dentistry as a restorative material is inconceivable [1].

Direct bonding to tooth structure is one of the most important advantages of glass-ionomers [2]. Biocompatibility and anticariogenic action , due to the release of fluoride, are other unique properties of glass-ionomers [3].While certain drawbacks such as low mechanical properties limits its use,efforts have been made to overcome these shortcomings [4]. Addition of fillers like silver, gold, and stainless steel powders has been investigated [5, 6]. These reinforced glass-ionomers exhibit reduced abrasion, but they have poor aesthetics. Polyethylene fiber also enhanced the mechanical properties [7]. It appears incorporation of zinc does not change the properties significantly [8]. Nonoclay could improve the mechanical properties to some extent [9]. Zirconium and its oxide were used to improve the strength of glass-ionomers due to their good dimensional stability and toughness [10]. In order to introduce a more biocompatible restorative material, bioactive glass and hydroxyapatite were incorporated into glass-ionomers to replace damaged tissues [11-13] and their effect on mechanical properties of cement were investigated [14,15].Hydroxyapatite, the main mineral component of the tooth structure and bone, is a bioceramic containing calcium and phosphorus [16,17]. It was reported that many mechanical properties of glass-ionomer improved by mixing the powder with bioceramics [14, 18, 19]. It can enhance the flexural strength of the demineralized dentin by remineralization [20]. Zirconia fillers provide mechanical strength and dimensional stability. Therefore, incorporation of zirconia and hydroxyapatite into glass-ionomer can enhance both the mechanical properties and bioactivity of the cement [10, 21].The present study was conducted to determine surface microhardness of silver-reinforced and zirconia-reinforced glass-ionomer with and without microhydroxyapatite particles.

Materials and Methods

In this experimental study, 60 specimens were prepared from three types of glass-ionomers (Shofu, Kyoto, Japan) and hydroxyapatite (Sigma-Aldrich, St. Louis, USA) in 6 groups (n=10). The experimental groups were categorized based on the materials used as Group 1: Conventional glass-ionomer (GIC), Group 2: Conventional glass-ionomer with 20 wt% of hydroxyapatite (GIC+HA),Group 3: Silver-reinforced glass-ionomer (HI-DENSE XP), Group 4: Silver-reinforced glass-ionomer with 20 wt% of hydroxyapatite (HI-DENSE XP+HA),Group 5: Zirconia-reinforced glass-ionomer (Zirconomer), and Group 6: Zirconia-reinforced glass-ionomer with 20 wt% of hydroxyapatite (Zirconomer+HA). The test specimens were prepared using a cylindrical plastic mold with a diameter of 6 mm, and height of 2 mm. In the group 1, conventional glass-ionomers powder was mixed with the liquid on a clean cold glass slab with a plastic spatula according to manufacturer's instructions (powder-to-liquid ratio was 1:1). Mixing procedure ended in 25 seconds. The mold was placed on a Mylar strip and a glass plate. Then the mold was overfilled with this mixture; a Mylar strips was placed on the top surface and compressed between two glass plates. In the group 2, glass-ionomer powder and hydroxyapatite powder were weighed carefully using a weighing machine accurate to 0.0001 g (A&D, GR+360, Tokyo, Japan). Then 80% of glass powder and 20% of hydroxyapatite were mixed. To achieve a homogenous mixture, the mixing procedure was carried out using an amalgam capsule and an amalgamator (Ultramat2, SDI, Bayswater, Victoria, Australia). Then it was mixed with glass-ionomer liquid similar to that in the group 1. The procedures were carried out in the same manner. In the groups 3 and 4, the powder-to-liquid ratio was 2:1. All the procedure was similar to those in previous groups. In groups 5 and 6, the powder-to-liquid ratio was 2:1.

All the specimens were prepared at the room temperature and humidity. A layer of varnish (Hoffmann, Berlin, Germany) was applied on the surfaces of all the specimens. The bottom surfaces were marked with a dot. The specimens were stored in distilled water at room temperature for 24 hours, with specimens in each group being stored individually.

After 24 hours, both sides of each disk were polished with polishing paper dicks (Poli-pro Disks, Premier Dental Products, Plymouthmeeting, Pennsylvania, USA), using a low-speed rotary instrument with air coolant. The microhardness test was performed with digital Vickers microhardness tester (MHV-1000Z, Sinowon, DongGuan, China) with a load of 300 gf in 15 seconds. Three Vickers tests were carried out on each surface (Figure1) and the mean value was calculated. Data were analyzed with SPSS. Two-way ANOVA and paired t-test were used.

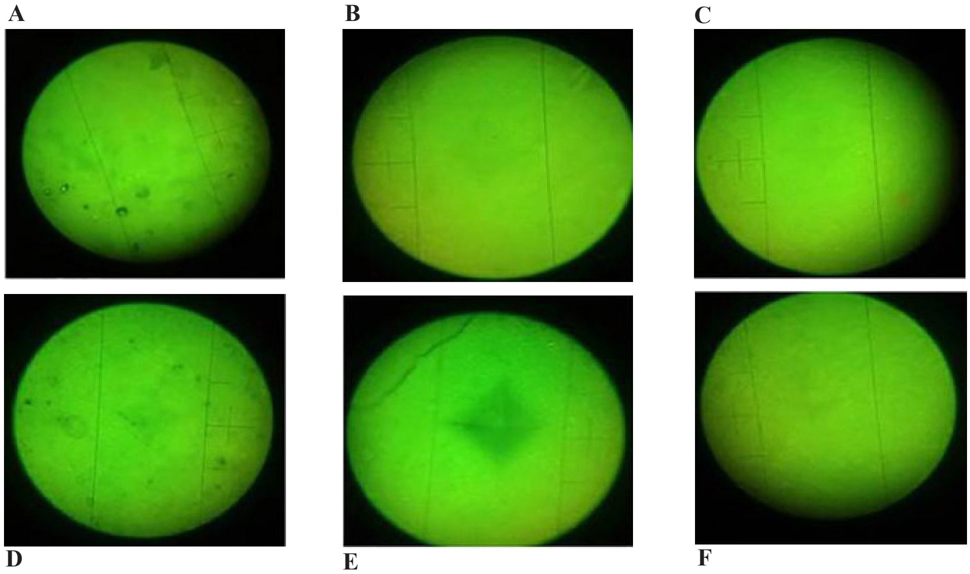

Figure1: Images of microhardness test of 6 experimental groups with stereomicroscope (40X). (A) Conventional glass-ionomer (B) Conventional glass-ionomer with hydroxyapatite (GIC+HA) (C) Silver-reinforced glass-ionomer (D) Silver-reinforced glass-ionomer with hydroxyapatite (E) Zirconia-reinforced glass-ionomer (Zirconomer) (F) Zirconia-reinforced glass-ionomer with hydroxyapatite

Results

The mean microhardness (VHN) values of all the groups are presented in Table 1. The results showed that microhardness of conventional glass-ionomer and silver-reinforced glass-ionomer decreased due to the incorporation of microhydroxyapatite ($P<0.001$).In contrast, the microhardness of Zirconomer increased significantly after mixing with microhydroxyapatite ($P<0.001$).

The microhardness of the top and the bottom surfaces of the disks were analyzed with paired t-test. In all groups, the microhardness of the top and the bottom surfaces showed significant differences ($P<0.05$). The mean values are presented in Table1. Among all groups, Zirconomer with microhydroxyapatite (group 5) exhibited the highest values and the lowest values were recorded in conventional glass-ionomer with microhydroxyapatite (group 2).

Discussion

Hardness influences resistance to in-service scratching which compromises fatigue strength, leading to premature failure. It was reported that surface hardness of conventional glass-ionomer was higher than resin modified glass-ionomer[15]. Therefore, use of conventional glass-ionomer and its modifications can be more applicable. Hydroxyapatite is the main mineral component of tooth structure; therefore, incorporation of hydroxyapatite into glass-ionomer can affect some of its properties, including an increase in its fracture resistance [4].

Acris *et al.* [22] added hydroxyapatite to light-cured monomers and the results indicated that 50–60 wt% of hydroxyapatite enhanced Young's modulus and hardness. This large volume of hydroxyapatite was used because no other filler was used. In the present study smaller volume of microhydroxyapatite was mixed with glass powder (20 wt %) that was consistent with similar

Table 1: Mean ± SD of microhardness and P. Value the top and bottom surfaces in all groups(GIC: Glass ionomer cement, HA: Hydroxyapatite)

Group	Materials		Mean	P. Value
1	Conventional GIC	Top	40.739±1.078	0.006
		Bottom	46.139±1.078	
2	Conventional GIC+HA	Top	27.892±1.078	0.007
		Bottom	33.291±1.078	
3	Silver-reinforced GIC	Top	65.106±1.078	0.001
		Bottom	70.506±1.078	
4	Silver-reinforced GIC+ HA	Top	43.411±1.078	0.01
		Bottom	48.810±1.078	
5	Zirconomer	Top	48.817±1.078	0.046
		Bottom	54.116±1.078	
6	Zirconomer+HA	Top	67.660±1.078	0.042
		Bottom	73.060±1.078	

study. Improved mechanical behavior with apatite formation of hydroxyapatite in combination with release of ions from glass-ionomer can be advantageous. The results of a study by Mohammed and Raghd [14] showed that adding hydroxyapatite at a concentration of 15–20% resulted in optimal hardness. According to the results of our study, although hydroxyapatite has some benefits, it seems that a mixture of microhydroxyapatite and glass-ionomer has reduced microhardness. To achieve a uniform material, the powder should have the same particle size and structure. This can only be achieved by sintering the glass powder and hydroxyapatite. In the present study, we made efforts to produce a uniform mixture by mixing the powders using an amalgamator; however, some parts of the surface of the material could possibly be only hydroxyapatite or only glass-ionomer. It seems this factor accounts for the decrease in hardness of glass-ionomer and silver reinforced glass-ionomer.

Goenka *et al.* [16] reported that increasing hydroxyapatite up to 15 wt% in conventional glass-ionomer resulted in a decrease in the microhardness of the mixture. In the present study, the results were consistent with the reports of Goenka who showed a decrease in surface hardness. Yli Urpo *et al.* [23] reported that incorporation of bioactive glass into glass-ionomer decreased the mechanical properties of conventional glass-ionomer during immersion in deionized water.

It was reported that the microhardness of one type of silver-reinforced glass-ionomer was greater than that of conventional glass-ionomer, [24] but incorporation of microhydroxyapatite resulted in a decrease in surface microhardness to the range of conventional glass-ionomer, which might be attributed to lower microhardness of hydroxyapatite particles in comparison with silver particles. Furthermore, the concentration of hydroxyapatite might affect the mechanical properties. The volume of hydroxyapatite can change the amount of liquid that is needed to complete the reaction of particles. In the present study we used the same ratio as the manufacturer had suggested; therefore, it seems inadequate amount of liquid in the mixture can alter the mechanical properties.

Incorporation of zirconia into dental ceramics doubled their hardness; therefore, incorporation of zirconia into restorative glass-ionomer can enhance its microhardness [25]. In the present study, the microhardness of Zirconomer was higher in comparison with conventional glass-ionomer.

Gu *et al.*[21] reported that microhardness of zirconia-reinforced glass-ionomer was 20% higher than the miracle mix but in the present study, the microhardness of Zirconomer was lower than that of silver-reinforced glass-ionomer. The microhardness of Zirconomer and metal-reinforced glass-ionomer is almost in the same range; hence, Zirconomer is preferred to metal-reinforced glass-ionomer due to its white color that is similar to tooth color.

In the current study, the results indicated that Zirconomer had a higher surface hardness after incorporation of microhydroxyapatite in comparison with other groups, consistent with a study of GU *et al.* [21] It seems that calcium ions of microhydroxyapatite, participating in the reaction of Zirconomer powder and liquid, alter the structure of the material, showing higher microhardness. Incorporation of nano- and micro-particles of silica could enhance the hardness of conventional glass-ionomer [26] but in the current study, incorporation of microhydroxyapatite decreased it. It seems that the size of the particles can affect the chemical reaction of the powder and liquid. Smaller particle size provides greater surface area that can alter the reaction. It seems even by using nano hydroxyapatite; it is possible to achieve higher microhardness values. Adequate mixing is also an important factor that affects the mechanical properties of the mixture. In the current study, the mixing time was the same as what was suggested by the manufacturer; however, subsequent to adding microhydroxyapatite, the mixing time might be changed. Therefore studies should determine the best mixing time.

In one study, it was reported that the microhardness of the top surface of resin-modified disks was higher than that of the bottom surface [27] but in the present study, in all the experimental groups the hardness of the bottom surfaces was higher than the top surface. Glass-ionomers used in this study were not light-cured; therefore, it seems presence of voids on the top surface can account for its lower microhardness. As the differences in all the groups were in the same pattern, it is more probable that the difference in the hardness of the top and the bottom surface was due to the better packing force, which compressed the material in the bottom surface.

Among all the materials used in this study, initial surface hardness of silver-reinforced glass-ionomer was higher but after incorporation of microhydroxyapatite, Zirconomer exhibited a great improvement. Further investigations should be carried out into other properties of the mixture of Zirconomer and hydroxyapatite. Zirconomer was introduced as white amalgam; therefore, the mechanical properties of the mixture of white amalgam with hydroxyapatite, with higher mechanical properties and mercury amalgam should be compared. May be, it can be a substitute for amalgam that aroused concerns about its mercury.

Nano-particles can affect the reaction due to their smaller size; hence, studies should be designed to evaluate the physical and mechanical properties of the mixture of nano hydroxyapatite particles and glass-ionomer.

Conclusions

Within the limitations of this study, it can be concluded that the incorporation of 20% concentration of microhydroxyapatite into Zirconomer can improve the surface microhardness. On the contrary, adding hydroxyapatite to conventional glass-ionomer and silver-reinforce glass-ionomer results in adverse effect.

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Conflict of Interest: None declared.

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