

## Effect of Protective Surface Coating on Hardness of Recent Uncoated High Viscosity Glass Ionomer Cement

Chayanee Dulsamphan<sup>1</sup>, Tongjai Chotitanmapong<sup>1</sup>, Awiruth Klaisiri<sup>2,3</sup>, Nantawan Krajangta<sup>2,3,\*</sup>

1. Division of Pediatric Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani, Thailand.
2. Division of Restorative Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani, Thailand.
3. Thammasat University Research Unit in Restorative and Esthetic Dentistry, Faculty of Dentistry, Thammasat University, Pathumthani, Thailand.

### Abstract

This in-vitro study aimed to compare the Vickers hardness of glass ionomer cements between various surface coating procedures at different time-points. The 135 cylindrical samples (6x2 mm) were prepared and randomly divided into three types of GICs: Ketac™ Universal Aplicap™, Ketac™ Molar Aplicap™ and Ketac™ Fil Plus Aplicap™. Each GIC was equally divided into three coating procedures (n=15/group): uncoated, coated with Ketac™ Glaze and coated with G-Coat Plus. The average of the Vickers hardness was measured at 24 hours, 7 days and 30 days after incubation of specimens at 37°C in deionized water. A two-way ANOVA followed by post-hoc Tamhane multiple comparison test and a one-way repeated measures ANOVA were performed (P=0.05). The Vickers hardness was statistically significantly increased in both Ketac™ Glaze coated and G-Coat Plus coated groups compared to uncoated group at all time-points (p<0.001). However, there was no significant difference in the hardness between Ketac™ Glaze and G-Coat Plus coating of almost all the test materials. Although, G-Coat Plus coating significantly increased more hardness than Ketac™ Glaze coating in Ketac™ Universal Aplicap™ at 30 days (p<0.001). In conclusion, the application of coating agents especially nanofilled resin coating benefited the surface hardness of Ketac™ Universal Aplicap™.

Experimental article (J Int Dent Med Res 2022; 15(3): 1036-1042)

**Keywords:** High viscosity glass ionomer cement, Surface coating, Vicker hardness.

**Received date:** 03 May 2022

**Accept date:** 28 May 2022

### Introduction

Glass-ionomer cements (GICs) have interesting properties such as their chemical bonding to the tooth structure and fluoride releasing and recharging capacity to the restored and surrounding restored surfaces.<sup>1</sup> On the other hand, their major drawbacks are weak mechanical properties<sup>2</sup>, long setting time<sup>3</sup> and sensitivity to moisture in the early hardening stages.<sup>2, 4</sup> To overcome some limitations, the high viscosity GICs (HVGICs) were developed and considered to be an alternative restorative material to composite resin<sup>5</sup> and amalgam<sup>6</sup>.

The HVGICs present better mechanical properties and faster setting reaction than

conventional GICs (CGICs).<sup>3</sup> Nevertheless, the HVGICs are still sensitive to water sorption or dehydration.<sup>4, 7</sup> For this reason, the application of protective surface coating as a barrier to water exchange is recommended.<sup>4</sup> The previous studies reported that surface coating improved the mechanical properties such as surface hardness<sup>8, 9</sup>, however, decreased fluoride releasing and recharging capacity of some HVGICs<sup>10, 11</sup>. Considering the risks and benefits of coating, most commercially available HVGICs still require surface coating.

In 2016, Ketac™ Universal Aplicap™ (3M ESPE, Deutschland GmbH, Neuss Germany), a recent uncoated HVGIC, was introduced and claimed to eliminate coating steps. Moreover, the high surface hardness values were also claimed even in the early stages of setting reaction without coating application.<sup>12</sup> The earlier studies have evaluated the effect of coating on compressive strength, flexural strength, hardness and color change of this material. However, the publications investigating the hardness in

#### \*Corresponding author:

Asst. prof. Dr. Nantawan Krajangta  
Division of Restorative Dentistry, Faculty of Dentistry,  
Thammasat University, Pathumthani, Thailand.  
E-mail: [knantawa@gmail.com](mailto:knantawa@gmail.com)

different time intervals have been limited. Consequently, the purpose of this study was to compare the Vickers hardness of Ketac™ Universal Aplicap™ between different surface coating procedures, thus the results will be useful for the clinical application of this material.

### Materials and methods

The sample sizes (135 total specimens) were calculated using G\*Power 3.1.9.4 software (G\*Power software, Düsseldorf, Germany). The effect size, significance level ( $\alpha$ ) and power (1- $\beta$ ) were set at 0.4, 0.05 and 0.95, respectively.

#### Specimen preparation

The materials used in this study are shown in table 1. The 135 cylindrical specimens were prepared using splittable metallic molds with a central hole of 6 mm. in diameter and 2 mm. in thickness. The samples were randomly divided into three equal groups (n=45/group) based on type of the materials as followed; Ketac™ Universal Aplicap™ (U), Ketac™ Molar Aplicap™ (M) and Ketac™ Fil Plus Aplicap™ (F). Each material was randomly distributed into three equal subgroups (n=15/subgroup) based on surface coating procedures which were uncoated (U-), coated with Ketac™ Glaze (K-) and coated with G-Coat Plus (G-) groups.

The mold was placed on a microscopic glass slide covered with celluloid strip (3M ESPE, St. Paul, Minnesota, USA) and filled with the materials slightly excessively according to their manufacturer's instructions. To achieve smooth and flat surface, the material was immediately covered with another celluloid strip, then compressed with glass slide using a 200-gram of stainless-steel standard weight and kept in position for 7 minutes allowing for initial setting. The specimens with any void or rough surface were excluded.

The top of each specimen in coated subgroups was protected with G-Coat Plus (GU, GM and GF subgroups) or Ketac™ Glaze (KU, KM and KF subgroups) using a disposable brush following manufacturer's recommendations. Another celluloid strip was gently pressed and light curing for 20 seconds per each side using LED curing light. The specimens with a coating thickness of more than 0.05 mm were excluded. Then, all of the prepared specimens were completely submerged in 6 individual groups of 100-ml beaker glasses containing 50 ml of

deionized water and placed in a 37°C incubator.

#### The Vickers hardness test

The Vickers hardness test was performed at 24 hours, 7 days and 30-days using a hardness tester (FM-800, Future Tech corp., Kawasaki, Japan). A 100-gf load was applied through a diamond indenter with a 15-seconds dwell time. Four random spot indentations were done on the top surface of each specimen which was at each of four quadrants. The diagonals' lengths of the indentations were examined by an objective lens of 50X magnification. The mean ( $\pm$ SD) of the Vickers hardness number (VHN) of each sample was recorded. The deionized water was replaced every time interval of measurements.

#### Statistical analysis

Statistical analysis was conducted using SPSS Statistics Version 22 for Windows (IBM, USA). The level of significance was set at 0.05. Two-way analysis of variance (ANOVA) followed by post-hoc Tamhane multiple comparison test was performed to analyze the effect of type of material, surface coating procedure and interaction effect of type of material\*surface coating procedure on the Vickers hardness. For the effect of time interval of immersion, one-way repeated measures ANOVA was performed.

### Results

The summarized result was presented in table 2-4. The type of material did not have a statistically significant effect on the VHN at all time-points: 24 hours, 7 days and 30 days. In contrast, there was a statistically significant effect of the surface coating procedure on the VHN at all time-points ( $p<0.001$ ); 24 hours, 7 days and 30 days. The VHN was statistically significantly increased in both Ketac™ Glaze coated and G-Coat Plus coated groups compared to uncoated group at all time-points ( $p<0.001$ ). However, no statistically significant difference in the VHN was found between Ketac™ Glaze and G-Coat Plus coating of almost all test materials. Conversely, G-Coat Plus coating significantly increased more hardness than Ketac™ Glaze coating in Ketac™ Universal Aplicap™ at 30 days ( $p<0.001$ ). Additionally, the VHN was statistically significantly increased as the immersion time increased ( $p<0.001$ ) in all groups.

## Discussion

The surface hardness test seems to be an appropriate and frequently used method for investigating the surface degradation, scratching occurrence and durability of dental materials.<sup>13</sup> In this study, all specimens were prepared and tested under the standard conditions by the same operator to eliminate human variables. Moreover, the thickness of the coating which might be the main confounding factor was controlled. The coating thickness in this study was 20-40 µm, therefore, no sample was excluded.

The results of the present study revealed that the VHN of Ketac™ Universal Aplicap™, Ketac™ Molar Aplicap™ and Ketac™ Fil Plus Aplicap™ was no statistically significant difference in both uncoated and coated specimens, at all time-points (24 hours, 7 and 30 days). This outcome was opposed to the manufacturer's claim that the VHN of Ketac™ Universal Aplicap™ was higher than Ketac™ Molar Aplicap™.<sup>12</sup> However, this finding corresponded well with Abdel-Hamid et al. that no significant difference in the VHN was found between Ketac™ Universal Aplicap™ and Ketac™ Fil Plus Aplicap™ in Ketac™ Glaze coated specimens, at 24 hours, 7 and 30 days.<sup>14</sup> Also, Soliman et al. revealed that there was no significant difference in VHN between Ketac™ Universal Aplicap™ and Ketac™ Molar Quick Aplicap™ at 24 hours.<sup>15</sup> Maybe explained by, all test materials in this study which are the product of 3M ESPE corporation have almost the same main compositions with different %weight and powder/liquid ratio. Although the differences in the composition of each GICs might affect some of their mechanical properties<sup>16</sup>, the GICs with the same manufacturer and the similar main compositions might have no significant difference in hardness.

In addition, this study found that the application of coating which was Ketac™ Glaze and G-Coat Plus significantly enhanced the VHN of all test materials (Ketac™ Universal Aplicap™, Ketac™ Molar Aplicap™ and Ketac™ Fil Plus Aplicap™) at all time-points (24 hours, 7 and 30 days). Because the GICs are susceptible to water sorption and dehydration during the initial hardening stage. Water contamination leads to the dissolution of metal cations<sup>4, 17, 18</sup> and consequently, decreases in physical and mechanical properties of GICs<sup>19</sup> The coating

agent acts as a barrier to the water exchange.<sup>4</sup> As in a previous study reported that improvement in the surface hardness was found in Fuji II and Fuji IX coated with G-Coat Plus in comparison with uncoated specimens.<sup>9</sup> Additionally, the application of nano-filled resin coating (EQUIA Forte Coat) promoted higher hardness than uncoated EQUIA Forte<sup>8</sup> and Fuji IX GP<sup>20</sup>. On the other hand, Zoergiebel et al. reported that the application of coating agent had no significant effect on the hardness while coating on Riva Self Cure, Fuji IX Fast, Fuji IX GP EXTRA and ChemFil Rock with the coating agents: Riva Coat, GC Fuji Coat LC, GC G-Coat Plus and Seal & Protect TF, respectively.<sup>19</sup> Soliman et al. also revealed that coating of EQUIA Coat on Fuji IX GP FAST did not affect the hardness.<sup>15</sup> Conversely, a reduction in the hardness was found while the coating of G-Coat Plus and Margin bond on EQUIA compared to the uncoated group.<sup>21</sup> Ryu et al. also reported that coated Fuji IX GP EXTRA presented lower hardness than uncoated specimens.<sup>22</sup> This might be caused by the uncontrolled thickness of the coating layer which generally softer than the subsurface material<sup>22, 23</sup>, in combination with the depth of indenter penetration.<sup>23</sup> To eliminate the confounding factors, controlling coating thickness following the manufacturer's recommendation is necessary.

Ketac™ Universal Aplicap™, the recently introduced uncoated HVGICs, was claimed to be restored without coating due to the special filler composition and the co-polymeric acid, as well as the accelerated setting reaction.<sup>12</sup> Nevertheless, the outcome of this study was contrary to the manufacturer's claim that no significant difference in the VHN between coated and uncoated samples.<sup>12</sup> However, this finding corresponded well with Abdel-Hamid et al. that Ketac™ Glaze coated specimens presented more hardness than uncoated specimens while aging in coke for 30 days.<sup>14</sup> In contrast, Soliman et al. found that the unfilled resin coating (Single Bond Universal adhesive) did not affect the hardness of Ketac™ universal Aplicap™ at 24 hours.<sup>15</sup>

Although the application of the coating improved surface hardness in this study, there was no significant difference in the hardness between Ketac™ Glaze and G-Coat Plus coated on Ketac™ Universal Aplicap™ at 24 hours and 7 days. However, G-Coat Plus coated group

presented higher hardness than Ketac™ Glaze coated groups at 30 days. Ketac™ Glaze (3M ESPE, Germany), a light-cured unfilled coating agent, was claimed to protect GICs materials from dehydration and moisture during the setting reaction. Meanwhile, G-Coat Plus (GC, Japan) was a nanofilled self-adhesive light-cured coating agent.<sup>24</sup> Incorporation of fillers enhanced the mechanical properties such as hardness and wear resistance of the restorative material.<sup>21, 22</sup> Additionally, the nanofilled coating materials promoted micro-mechanical interlocking which could fill the superficial cracks and pores of GICs<sup>17</sup>, and provided a tough coating layer resulting in improving the physical properties of GICs.<sup>25</sup> On the other hand, the unfilled resin coating agent (Single Bond Universal adhesive) had no micro-mechanical interlocking with Ketac™ Molar Aplicap™ and Ketac™ Universal Aplicap™ in SEM images.<sup>15</sup> In addition, hydrolysis of unfilled resin over time could occur and consequently lead to degradation of the unfilled resin component.<sup>21</sup> For the outcome of this study, the variation in the hardness value of G-Coat Plus coated specimens which is slightly higher, lower or the same hardness as Ketac™ Glaze coated specimens might be caused by the dispersion of the filler particles. The indentation at the filler component might present higher hardness than the indentation at the matrix component.

Furthermore, this study found that the hardness was gradually increased from 24 hours to 30 days in both uncoated and coated specimens of all test materials. Despite a short setting time of GICs for a few minutes, the final setting or maturation occurred gradually and was long-lasting up to several weeks afterward<sup>6</sup> as a result of the prolonged process of acid-base reaction and cross-linking of GICs' polymers. The surface hardness of GICs increased and achieved the highest values when the hardening process was completed.<sup>13</sup> Shintome et al. presented that accentuated increase in the hardness of HVGICs was found in 24 hours to 7 days of storage.<sup>13</sup> In agreement with Ellakuria et al., the gradual increase in the hardness of Ketac™ Molar and Ketac™ Fil Aplicap™ was found from 1 day to 1 month, however, no change in the hardness was found in 1, 3, 6 and 12 months.<sup>26</sup> It might be assumed that the application of coating did not affect the maturation of GICs.

The limitations of this study were a short-term laboratory study design. The in-vitro study does not totally reflect clinical condition which is dynamic and has many factors that differ from laboratory situation such as the masticatory and brushing force, change in temperature and pH. These factors could interfere the adhesion between coating agent and GICs, and might affect the hardness of GICs over time. Therefore, further long-term clinical study or long-term laboratory design simulated oral conditions such as simulated toothbrushing test in combination with storing the specimens in various storage media or pH such as artificial saliva, coke or cyclically exposed to various pH, should be conducted. Moreover, the effect of coating on fluoride releasing and recharging capacity of GICs should be concerned. As the previous literature reported that application of coating reduced fluoride release and recharge<sup>10, 11</sup> which are the important properties of GICs. For clinical decision-making of coating application, the practitioner should concern about which factor, hardness or remineralization is the main purpose of each restoration.

## Conclusions

Within the limitation of the present study, the impact on Vickers hardness was material's independent, however, surface coating application was the main factor that enhanced the hardness. Application of coating agents especially nanofilled resin coating improved the surface hardness of Ketac™ Universal Aplicap™.

## Acknowledgments

This study was funded and supported by the Thammasat University Research Unit in Restorative and Esthetic Dentistry and the Division of Pediatric Dentistry, Faculty of Dentistry, Thammasat University.

## Declaration of Interest

The authors declare that they have no conflict of interest.



Materials	Composition
Ketac™ Fil Plus Aplicap™ (3M ESPE, Deutschland GmbH, Neuss, Germany)	Powder: glass powder (>99 wt %)  Liquid: water (40–55 wt %), copolymer of acrylic acid – maleic acid (35–55 wt %), tartaric acid (5–10 wt %)  Powder/liquid ratio: 3.0/1.0 wt
Ketac™ Molar Aplicap™ (3M ESPE, Deutschland GmbH, Neuss, Germany)	Powder: glass powder (93-98 wt %)  Liquid: water (60–65 wt %), copolymer of acrylic acid – maleic acid (30–40 wt %), tartaric acid (5–10 wt %)  Powder/liquid ratio: 3.4/1.0 wt
Ketac™ Universal Aplicap™ (3M ESPE, Deutschland GmbH, Neuss, Germany)	Powder: oxide glass (> 95 wt %)  Liquid: water (40–60 wt %), copolymer of acrylic acid– maleic acid (30–50 wt %), tartaric acid (1–10 wt %), benzoic acid (<0.2wt %)  Powder/liquid ratio: 3.2/1.0 wt
Ketac™ Glaze (3M ESPE, Deutschland GmbH, Neuss, Germany)	Dicyclopentylidimethylene diacrylate (> 95 wt%), [(3-methoxypropyl)imino]di-2,1-ethanediyl bismethacrylate (1-5 wt %), 2-[(2-hydroxyethyl) (3-methoxypropyl)amino]ethyl methacrylate (< 1 wt %), 2,2- dimethoxy-1,2-diphenylethan-1-one (< 0.5 wt %)
G-Coat Plus (GC, Japan)	Methyl methacrylate 40-50 %, Multifunctional Methacrylate 30-40%, Silicon dioxide 10-15%, Phosphoric ester monomer 1-5%, Camphorquinone <1%

**Table 1.** Materials used in the study.

Coating procedure Type of material	Vickers hardness at 24 hours (Mean ± SD) (HV)		
	uncoated	Ketac™ Glaze	G-Coat Plus
Ketac™ Universal Aplicap™	49.39 ± 3 <sup>Aa</sup>	63.66 ± 2.47 <sup>Ab</sup>	65.34 ± 2.89 <sup>Ab</sup>
Ketac™ Molar Aplicap™	50.4 ± 4.11 <sup>Aa</sup>	63.83 ± 1.7 <sup>Ab</sup>	62.44 ± 1.55 <sup>Bb</sup>
Ketac™ Fil Plus Aplicap™	50.23 ± 2.18 <sup>Aa</sup>	64.33 ± 1.87 <sup>Ab</sup>	61.9 ± 2.29 <sup>Bb</sup>

Different uppercase letters for each column and different lowercase letters for each row indicate statistically significant differences (p<0.05).

**Table 2.** Means ± standard deviation (SD) and statistically significant difference of the Vickers hardness number (VHN) of each type of material and coating procedure at 24 hours.

Coating procedure Type of material	Vickers hardness at 7 days (Mean ± SD) (HV)		
	uncoated	Ketac™ Glaze	G-Coat Plus
Ketac™ Universal Aplicap™	54.16 ± 3.51 <sup>Aa</sup>	67.36 ± 3.21 <sup>Ab</sup>	70.49 ± 2.13 <sup>Ab</sup>
Ketac™ Molar Aplicap™	54.42 ± 4.5 <sup>Aa</sup>	69.15 ± 2.62 <sup>Ab</sup>	69.91 ± 1.65 <sup>Ab</sup>
Ketac™ Fil Plus Aplicap™	55.24 ± 1.9 <sup>Aa</sup>	69.35 ± 2 <sup>Ab</sup>	66.87 ± 1.74 <sup>Bc</sup>

Different uppercase letters for each column and different lowercase letters for each row indicate statistically significant differences (p<0.05).  
**Table 3.** Means ± standard deviation (SD) and statistically significant difference of the Vickers hardness number (VHN) of each type of material and coating procedure at 7 days.

Coating procedure Type of material	Vickers hardness at 30 days (Mean ± SD) (HV)		
	uncoated	Ketac™ Glaze	G-Coat Plus
Ketac™ Universal Aplicap™	60.83 ± 3.39 <sup>Aa</sup>	69.5 ± 3.69 <sup>Ab</sup>	75.84 ± 1.29 <sup>Ac</sup>
Ketac™ Molar Aplicap™	59.8 ± 3.84 <sup>Aa</sup>	72.77 ± 3.22 <sup>Ab</sup>	72.52 ± 2.37 <sup>Bb</sup>
Ketac™ Fil Plus Aplicap™	61.35 ± 1.83 <sup>Aa</sup>	71.06 ± 1.62 <sup>Ab</sup>	69.52 ± 2.04 <sup>Cb</sup>

Different uppercase letters for each column and different lowercase letters for each row indicate statistically significant difference (p<0.05).  
**Table 4.** Means ± standard deviation (SD) and statistically significant difference of the Vickers hardness number (VHN) of each type of material and coating procedure at 30 days.

## References

- Sidhu SK, Nicholson JW. A Review of Glass-Ionomer Cements for Clinical Dentistry. *J Funct Biomater.* 2016;7(3).
- Garain R, Abidi M, Mehkri Z. Compressive and Flexural Strengths of High-strength Glass Ionomer Cements: A Systematic Review. *Int J Exp Dent Sci.* 2020;9:25-9.
- Park EY, Kang S. Current aspects and prospects of glass ionomer cements for clinical dentistry. *Yeungnam Univ J Med.* 2020;37(3):169-78.
- Ugurlu M. Effects of surface coating on the flexural strength of fluoridereleasing restorative materials after water aging for one year. *Eur Oral Res.* 2020;54(2):62-8.
- Aydın N, Karaoğlanoğlu S, Aybala-Oktay E, Çetinkaya S, Erdem O. Investigation of water sorption and aluminum releases from high viscosity and resin modified glass ionomer. *J Clin Exp Dent.* 2020;12(9):e844-e51.
- Kielbassa AM, Oehme EP, Shakavets N, Wolgin M. In vitro wear of (resin-coated) high-viscosity glass ionomer cements and glass hybrid restorative systems. *J Dent.* 2021;105:103554.
- Utain Klamun PP. Effects of Surface Pre-Treatments on Leakage of Resin-Modified Glass Ionomer Cement as the Restorative Material of Invasive Cervical Resorption on Root Dentin. *J Int Dent Med Res.* 2018;11(3):799-803.
- Fuhrmann D, Murchison D, Whipple S, Vandewalle K. Properties of New Glass-Ionomer Restorative Systems Marketed for Stress-Bearing Areas. *Oper Dent.* 2020;45(1):104-10.
- Sukumaran V.G, Rathakrishnan M. To Evaluate the Effect of Surface Coating on Three Different Types Glass Ionomer Restorations. *Biomed Pharmacol J.* 2015;8:445-9.
- Habib S. Fluoride Releasing/Recharging Ability of Bulk-Fill and Resin Modified Glass Ionomer Cements After the Application of Different Surface Coating Agents: An In -Vitro Study. *Adv Dent J.* 2020;1-13.
- Kelić K, Par M, Peroš K, Šutej I, Tarle Z. Fluoride-Releasing Restorative Materials: The Effect of a Resinous Coat on Ion Release. *Acta Stomatol Croat.* 2020;54(4):371-81.
- Ketac™ Universal Aplicap™ Glass Ionomer Restorative Technical Product Profile. Available at: "https://www.3m.com/3M/en\_US/p/d/hcbgefr000008/". Accessed January 23, 2021.
- Shintome LK, Nagayassu MP, Di Nicoló R, Myaki SI. Microhardness of glass ionomer cements indicated for the ART technique according to surface protection treatment and storage time. *Braz Oral Res.* 2009;23(4):439-45.
- Mohamed Abdel-Hamid D, Mohamed G, El-sharkawy F, Abou-Auf E. Effect of surface protection, staining beverages and aging on the color stability and hardness of recently introduced uncoated glass ionomer restorative material. *Futur Dent J.* 2018;4.
- Soliman T, Othman M. Mechanical properties of the new Ketac™ Universal glass ionomer restorative material: effect of resin coating. *Egypt Dent J.* 2017;63:1027-35.
- Bala O, Arisu HD, Yikilgan I, Arslan S, Gullu A. Evaluation of surface roughness and hardness of different glass ionomer cements. *Eur J Dent.* 2012;6(1):79-86.
- Hesse D, Bonifácio CC, Kleverlaan CJ, Raggio DP. Clinical wear of approximal glass ionomer restorations protected with a

- nanofilled self-adhesive light-cured protective coating. *J Appl Oral Sci.* 2018;26:e20180094.
18. Brzović Rajić V, Ivanišević Malčić A, Bilge Kütük Z, Gurgan S, Jukić S, Miletić I. Compressive Strength of New Glass Ionomer Cement Technology based Restorative Materials after Thermocycling and Cyclic Loading. *Acta Stomatol Croat.* 2019;53(4):318-25.
  19. Zoergjebel J, Ilie N. Evaluation of a conventional glass ionomer cement with new zinc formulation: effect of coating, aging and storage agents. *Clin Oral Investig.* 2013;17(2):619-26.
  20. "Ruangdit B, Pithpornchaiyakul S, Kukiattrakoon B." Effect of Coating Agents on Surface Microhardness of Highly Viscous Glass Ionomer Cement/Resin Coatings for Atraumatic Restorative Treatment after an Acid Challenge. *J Int Dent Med Res.* 2021;14(3):982-7.
  21. Faraji F, Heshmat H, Banava S. Effect of protective coating on microhardness of a new glass ionomer cement: Nanofilled coating versus unfilled resin. *J Conserv Dent.* 2017;20(4):260-3.
  22. Ryu W, Park H, Lee J, Seo H. Effect of Nano-filled Protective Coating on Microhardness and Wear Resistance of Glass-ionomer Cements. *J Korean Acad Pediatr Dent.* 2019;46(2):226-32.
  23. Bagheri R, Palamara J, Mese A, Manton DJ. Effect of a self-adhesive coating on the load-bearing capacity of tooth-coloured restorative materials. *Aust Dent J.* 2017;62(1):71-8.
  24. G-Coat Plus. Available at: "[https://www.gcamerica.com/products/operator/G-Coat\\_Plus/](https://www.gcamerica.com/products/operator/G-Coat_Plus/)". Accessed January 23, 2021.
  25. Habib SI, Yassen AA, Bayoumi RE. Influence of Nanocoats on the Physicomechanical Properties and Microleakage of Bulk-fill and Resin-modified Glass Ionomer Cements: An In Vitro Study. *J Contemp Dent Pract.* 2021;22(1):62-8.
  26. Ellakuria J, Triana R, Mínguez N, Soler I, Ibaseta G, Maza J, et al. Effect of one-year water storage on the surface microhardness of resin-modified versus conventional glass-ionomer cements. *Dent Mater.* 2003;19(4):286-90.