Current Science International
Volume: 15 | Issue: 02| April - June| 2026

EISSN:2706-7920 ISSN: 2077-4435
DOI: 10.36632/csi/2026.15.2.10
Journal homepage: www.curresweb.com
Pages: 115-127

Evaluation of Water Sorption and Solubility, Fluoride release and Microhardness of One Step Versus Conventionally Placed Glass Ionomer Restorative Material

Ahmed Abdelrazek[1], Yasser Fathy Hussain[2], Reem Gamal[3] and Hany Shamseldine Hanafy

[1]Dental Biomaterials Department, College of Oral and Dental Surgery, Misr University for Science and Technology (MUST), Egypt.
[2]Professor of Dental Materials, Faculty of Dentistry, Minia University, 61519 Minia, Egypt.
[3]Biomaterial Department, Faculty of Dentistry, Minia University, 61511 Minia, Egypt.
[4]Professor of Operative Dentistry, Conservative Dentistry Department, College of Oral and Dental Surgery, Misr University for Science and Technology (MUST), Egypt.

Received: 05 May 2026 **Accepted:** 10 June 2026 **Published:** 20 June 2026

ABSTRACT

Objectives: This *in vitro* study compared a one step placed glass ionomer (GI), Ketac Universal Aplicap (KUA), with a conventionally placed GI, Ketac Molar Aplicap (KMA), with and without resin coating, regarding water solubility and solubility, fluoride release, and microhardness.

Materials and Methods: A total of 120 samples were prepared, 40 for each test (n=10 per subgroup). Water sorption and solubility were determined according to ISO 4049 after 7 days of immersion. Fluoride release was quantified using calibrated fluoride ion selective electrode at 1 and 7 days. Vickers microhardness was measured under a 50 g load applied for 10 s. **Results:** coating statistically significantly reduced solubility in both materials (KMA: $p = 0.003$; KUA: $p = 0.001$) moreover, water sorption did not differ statistically significantly among the groups. Non coated KMA exhibited statistically significant higher solubility than non coated KUA (165.36 ± 3.110,137.23 ± 4.291 µg/mm³; $p = 0.001$) respectively, and coating also statistically significantly reduced fluoride release in both materials at 1 and 7 days ($p = 0.001$); release increased statistically significantly from day 1 to 7 days ($p < 0.05$), and coated KUA released more fluoride than coated KMA at 7 days (3.47 ± 0.316, 2.89 ± 0.422 ppm; $p = 0.039$) respectively. Coating statistically significantly improved microhardness only for KUA ($p = 0.043$). **Conclusion:** Resin coating improved the stability and microhardness of both GI but attenuated their fluoride release, and the one step material did not behave equivalently to the conventionally placed material under coating.

Keywords: *In vitro* study, glass ionomer, Resin coating, Ketac Universal Aplicap (KUA), Ketac Molar Aplicap (KMA), resin coating, fluoride, microhardness

1. Introduction

Glass ionomers (GI) continue to occupy an important place in restorative dentistry because of their chemical adhesion to enamel and dentine, sustained fluoride release, favorable biocompatibility, and thermal compatibility with tooth structure (Wilson and Kent, 1972; Sidhu and Nicholson, 2016). Because early moisture susceptibility remains their principal clinical weakness, surface protection with resin coatings was introduced. The recent marketing of single step placed GI, for which omission of the coating step is claimed not to compromise clinical performance, provided the rationale for the present comparative evaluation.

Corresponding Author: Ahmed Abdelrazek, Dental Biomaterials Department, College of Oral and Dental Surgery, Misr University for Science and Technology (MUST), Egypt.
Email: Ahmed.abdelrazek@must.edu.eg

Once set, GI exhibits several favorable properties that have sustained its clinical popularity. (Sheta *et al*. 2026) emphasize that GI demonstrates high adherence to tooth structure, a coefficient of thermal expansion comparable to natural tooth substance, sustained fluoride ion release that retards caries progression, and excellent biocompatibility without pulp irritation or carcinogenic potential. These characteristics render GI particularly well suited for use in cavity lining, luting of indirect restorations, pediatric restorations, and atraumatic restorative treatment. Furthermore, (Zhang *et al.*, 2026) note that GI's combination of good oral biocompatibility and ease of clinical operation continues to make it a first line material in many restorative scenarios, particularly where chemical adhesion and fluoride release are prioritized over peak mechanical performance.

Despite these advantages, conventional GIC formulations have long been constrained by comparatively poor mechanical strength and by a pronounced susceptibility to moisture during the critical early stages of setting (Sidhu and Nicholson, 2016).

Moisture susceptibility is a direct consequence of the setting chemistry of GI. Immediately after placement, the developing hydrogel matrix is highly vulnerable to desiccation, which disrupts the hydration shells surrounding ions and polyelectrolyte chains and thereby impairs ion mobility and cross linking; conversely, premature contact with saliva or water leaches unreacted polyacid and ions before they can be incorporated into the matrix, leaving a chalky, eroded surface with compromised properties (Shen *et al*., 2022). Surface protection was therefore developed to preserve the water balance of the material throughout setting by acting as a barrier against both salivary contamination and desiccation. Resin coatings have proved particularly effective for conventionally placed GI restorations (Panpisut *et al.,* 2024). Thus, it can be concluded that although coating improved properties of GI, it makes the placement procedure more complicated and time consuming for a material that used commonly in pediatric and atraumatic restorative technique (ART) which needs the easiest and most time and equipment saving methods for restoration placement.

Some recent types of GI offering improved handling and time saving were subsequently developed to overcome the limitations of conventional formulations (Sidhu and Nicholson, 2016). Among contemporary products, Ketac Universal Aplicap (KUA), (2023) represents a further step in this evolution and is marketed as a “one step” material, with the manufacturer claiming that omission of the coating step does not compromise clinical performance (3M Deutschland GmbH, 2016). This claim is of direct clinical relevance dispensing with the coating step simplifies the placement procedure and reduces chair time, yet it simultaneously removes the protection that conventionally placed GI are generally considered to require during early maturation.

Four properties are particularly informative when judging whether coating can safely be omitted. Water sorption and solubility describe the uptake of water into the cement matrix, and the leaching of unreacted components and thus directly indicates early hydrolytic stability. Moreover, fluoride release underlies the cariostatic potential that distinguishes GI from other restorative materials. Finally, microhardness characterizes the resistance of the surface to indentation and serves as an indirect marker of the degree of maturation of the cement matrix.

Although resin coating of GI has been investigated for decades, independent evidence directly comparing one step and conventionally placed GI ‘coated and non coated’ on these specific outcomes remains limited, and published studies report heterogeneous findings. (Nicholson, 2018) (Ryu *et al.,* 2019). Therefore, The present *in vitro* study was conducted to compare a one step placed GI (KUA) with a conventionally placed placed GI (Ketac Molar Aplicap; KMA), with and without coating, regarding water sorption and solubility, fluoride release and microhardness. The null hypothesis tested was that there is no difference between the one step placed and the conventionally placed glass ionomer restorative materials regarding the investigated properties.

2. Materials and Methods

2.1. Ethical regulations

This *in vitro* study was conducted at the Biomaterials Department, Faculty of Dentistry, Minia University. The research protocol was approved by the ethics committee of the Faculty of Dentistry, Minia University (approval number 723,95,28/3/2023), and the regulations governing *in vitro* research were followed.

2.2. Materials

Two encapsulated glass ionomer restorative materials and one resin coat used as a protective coating were investigated (Table 1).

Table 1: Materials used in the study with description, manufacturer, batch number, and composition.

Material (trade name)	Description	Manufacturer	Batch number	Composition
One step placed glass ionomer (Ketac Universal Aplicap; KUA)	Capsules, shade A2	3M Deutschland GmbH Dental Products, Carl Schurz Str. 1, 41453 Neuss, Germany	LOT 9771356	Powder: aluminum calcium lanthanum fluorosilicate glass. Liquid: water, copolymer of acrylic acid maleic acid, and tartaric acid
Conventionally placed (GI) (Ketac Molar Aplicap; KMA)	Capsules, shade A2		LOT 954411	Powder: aluminum calcium lanthanum fluorosilicate glass. Liquid: polycarboxylic acid, tartaric acid, and water
Resin coating (Single Bond Universal)	Single component universal light cured adhesive in a bottle		LOT 11215B	Methacryloyloxydecyl dihydrogen phosphate (MDP), hydroxyethyl methacrylate (HEMA), filler, ethanol, water, initiators, and silane

2.3. Sample size calculation and grouping

The sample size was calculated with G*Power software (Heinrich Heine University, Düsseldorf, Germany) with input parameters of (1 − β error probability) of 0.80 and an α error probability of 0.05. Based on the data reported by Tolidis *et al.* (2016), the effect size (F) was calculated to be 0.95. A minimum of five samples per subgroup were found. Five additional samples per subgroup were added by the researcher to confirm the results. Giving n = 10 per subgroup for each test. For each of the three test methods, a total of 120 samples 40 for each test were prepared and allocated to two groups regarding the material and each group subdivide into coated and noncoated subgroups (n = 10 for each subgroup). Water sorption and water solubility were determined on the same samples.

2.4. Sample preparation

All materials were manipulated according to the manufacturer's instructions. The capsules were activated and mixed using an amalgamator for 10 s. The mixed material was injected into custom made split Teflon molds which were prepared specifically for each test. Teflon mold was positioned over a glass slap covered with a polystyrene strip. The samples were then overlaid with a second polystyrene strip and pressed between two glass slaps under a load of 200 g weight to obtain samples with minimal voids and flat surfaces, and they were left for 10 min to reach the initial set. After removal from the molds, the samples were finished and polished with a finishing disc kit (TOR VM Ltd., Moscow, Russia) mounted on a low speed handpiece. The yellow discs were used for finishing and the white discs for polishing with time of 30 s for each one. For the coated subgroups, resin coat was applied to the sample surfaces with a bond brush and light cured (for 20 s using an 1800 mW/cm² (RTA mini S light cure device 1800MW/CM^2 Guilin Woodpecker Medical Instrument Co) Then, all samples were stored at 100% relative humidity at 37°C for 24h in an incubator (PS.3A, Advanced Technology, Egypt) before testing.

2.5. Water sorption and water solubility test

A split Teflon mold 15 mm in diameter and 1 mm in thickness was used for samples preparation and the test was performed according to the International Organization for Standardization (ISO) 4049 specification. After preparation of the samples, they were desiccated in a glass desiccator containing anhydrous calcium chloride and weighed three times using a digital precision balance (Sartorius, Biopharmaceutical and Laboratories, Germany). This cycle was repeated until a constant mass of the

sample (M1) was obtained. The discs of each subgroup were then transferred to separate plastic containers filled with 20 mL of deionized water and stored at 37°C for 7 days. After storage, the samples were removed from the containers, waved in the air for 15s, gently blotted with absorbent paper, and weighed 3 times until the mass after immersion in water (M2) was obtained. Each disc was then redesiccated and weighed until the constant dry mass after immersion and redesiccation (M3) was obtained.

Water sorption and water solubility were calculated for each disc using equation (1,2) respectively and the results were expressed in μg/mm³.

$$\text{Water sorption} = (M2 - M3) / V \quad (1)$$
$$\text{Water solubility} = (M1 - M3) / V \quad (2)$$

Where V is the sample volume in (mm³) and it was calculated using equation (3)

$$\text{Sample volume (V)} = [(\pi \times D^2)/4] \times L \quad (3)$$

where D the sample diameter (mm), and L the sample thickness (mm) and $\pi = 3.1416$

2.6. Fluoride release test

A split teflon mold 8 mm in diameter and 2 mm in thickness was used for samples preparation and the test was conducted according to Habib (2020). The samples were immersed and stored in individual plastic containers holding 10 mL of deionized water at 37°C for 1day and 7days. At each measurement interval, the sample was removed from its container and the storage solution was decanted for analysis. Then, the sample was returned to a new container with 10 mL of fresh deionized water and storage was continued. Fluoride release was measured using a fluoride ion selective electrode (ise). A mixture of 3 mL of the storage solution and 0.3 mL of Total Ionic Strength Adjustment Buffer (TISAB III; Orion Research Inc., Beverly, MA, USA) was used, and fluoride concentrations were measured with a calibrated fluoride specific combination electrode (96 09BN; Orion Research Inc.) attached to an ion meter (model 720A; Orion Research Inc.) to an accuracy of 0.1 ppm. Fluoride concentrations were expressed in ppm (mg/L).

2.7. Microhardness test

A split Teflon mold 4 mm in diameter and 6 mm in thickness was used for samples preparation and the test was conducted according to Soliman and Othman (2017). Microhardness was determined using a digital display Vickers microhardness tester. A load of 50 g was applied to the surface of each sample for 10 s. Three indentations not closer than 0.5 mm to each other or to the border were made on the surface of each sample. The length of the indentation diagonals was measured with the built in scaled microscope and the mean of them was calculated. Microhardness was calculated using equation (4)

$$HV = 1.854\ P/d^2 \quad (4)$$

where HV is the Vickers hardness number (VHN) in Kgf/mm², P is the applied load in Kgf, and d is the diagonals in mm. The three readings of each sample were averaged and considered the sample hardness.

2.8. Statistical analysis

The data were collected, tabulated, coded, and analyzed using IBM SPSS Statistics for Windows, version 29 (IBM Corp., Armonk, NY, USA). Normality of the data distribution was assessed with the Kolmogorov Smirnov and Shapiro Wilk tests. The data were normally distributed and descriptive statistics were expressed in the mean and standard deviation (SD). Two way ANOVA was employed for data and Tukey's honestly significant difference (HSD) post hoc tests and independent t tests were used for pairwise comparisons between groups. For the fluoride release test, the dependent t test was used to compare the 1 day and 7 days measurements within each material. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Water sorption and water solubility

The water sorption and water solubility results are presented in Table 2 and figure 1,2. Within each material, coating produced a statistically significant reduction in water solubility, both for KMA ($p = 0.003$) and for KUA ($p = 0.001$). Water sorption did not differ statistically significantly between KMA and KUA under either the non coated ($p = 0.058$) or the coated ($p = 0.074$) condition. Within each material, the coated samples showed numerically lower sorption values than their non coated counterparts, but these differences did not reach statistical significance for KMA ($p = 0.081$) or for KUA ($p = 0.057$). Under the non coated condition, KMA exhibited statistically significantly higher water solubility than KUA ($p = 0.001$) and after coating application, this between material difference was no longer statistically significant ($p = 0.204$).

Table 2: Mean ± standard deviation (SD) and level of significance of water sorption and water solubility (µg/mm³) between non coated and coated KMA and KUA (n = 10 per subgroup).

Property	Coating condition	KMA	KUA	p value (between materials)
Water sorption	Non coated	227.16 ± 12.612	209.88 ± 13.946	0.058
	Coated	207.74 ± 17.738	188.83 ± 7.048	0.074
	p value (within material)	0.081	0.057	
Water solubility	Non coated	165.36 ± 3.110	137.23 ± 4.291	0.001*
	Coated	122.10 ± 15.349	111.61 ± 3.567	0.204
	p value (within material)	0.003*	0.001*	

* The mean difference is significant at the 0.05 level.

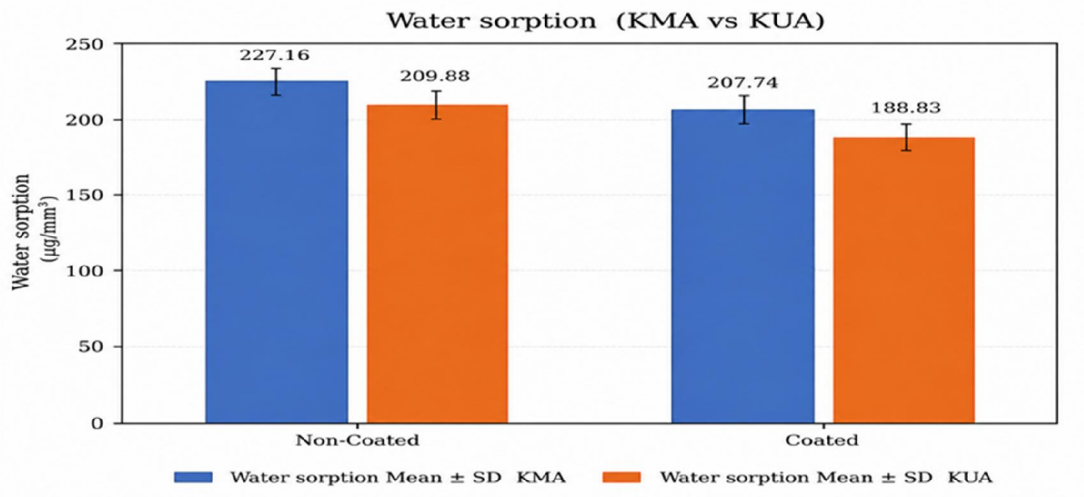

Fig. 1: Bar chart reveals the average water sorption mean ± SD between non coated and coated KMA and KUA.

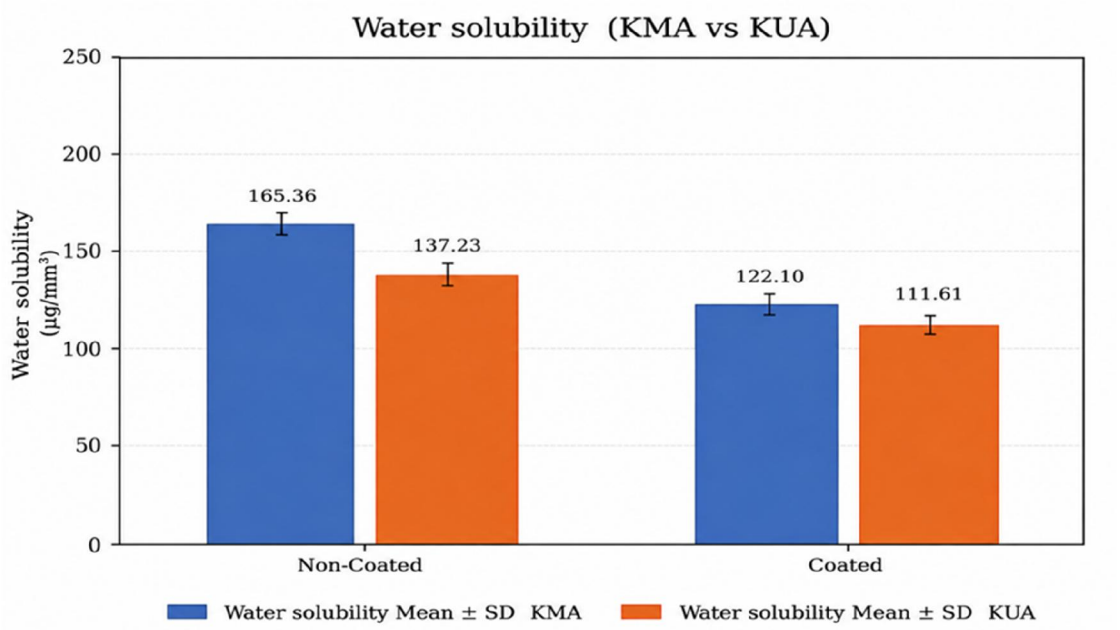

Fig. 2: Bar chart reveals the average water solubility mean ± SD between non coated and coated KMA and KUA.

3.2. Fluoride release

The fluoride release results at 1 and 7 days are presented in Table 3 and figure 3,4. At one day, KMA and KUA did not differ statistically significantly under either the non coated ($p = 0.976$) or the coated ($p = 0.273$) condition. Within each material, coating produced a statistically significant reduction in fluoride release at one day (KMA: $p = 0.001$; KUA: $p = 0.001$). At 7days, the non coated samples of the two materials still did not differ statistically significantly ($p = 0.539$), whereas the coated samples differed statistically significantly, with KUA releasing more fluoride than KMA ($p = 0.039$). The within material reductions in fluoride release upon coating remained significant for both materials at 7days (KMA: $p = 0.001$; KUA: $p = 0.001$). In addition, fluoride release increased statistically significantly from 1 day to 7 days in both materials where $p < 0.05$).

Table 3: Mean ± standard deviation (SD) and level of significance of fluoride release (ppm) between non coated and coated KMA and KUA at 1 day and 7 day intervals (n = 10 per subgroup).

Time	Coating condition	KMA	KUA	p value (between materials)
One day	Non coated	5.60 ± 0.689	5.61 ± 0.765	0.976
	Coated	2.68 ± 0.449	2.99 ± 0.381	0.273
	p value (within material)	0.001*	0.001*	
7days	Non coated	6.36 ± 0.841	6.64 ± 0.493	0.539
	Coated	2.89 ± 0.422	3.47 ± 0.316	0.039*
	p value (within material)	0.001*	0.001*	

* The mean difference is significant at the 0.05 level.

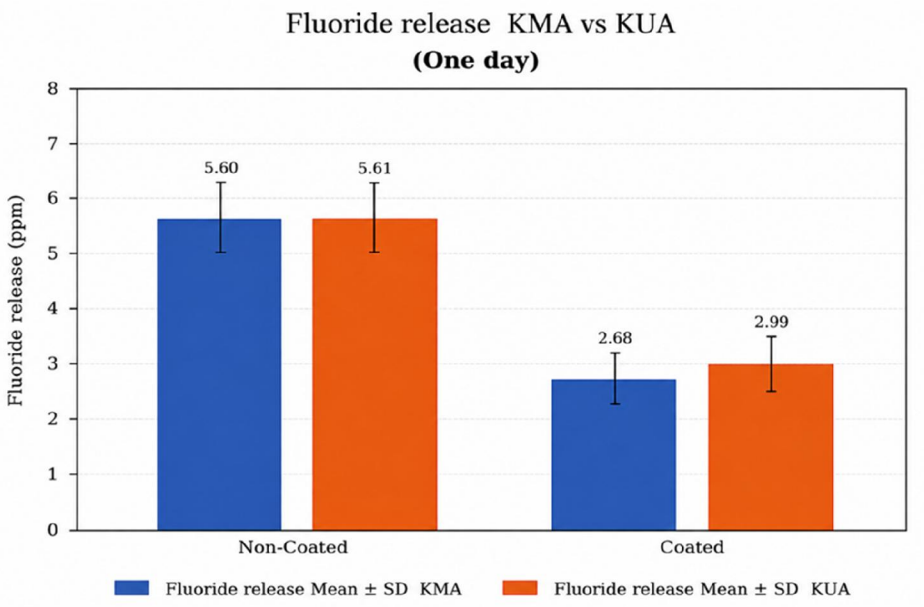

Fig. 3: Bar chart reveals the average fluoride release mean ± SD between non coated and coated KMA and KUA after one day.

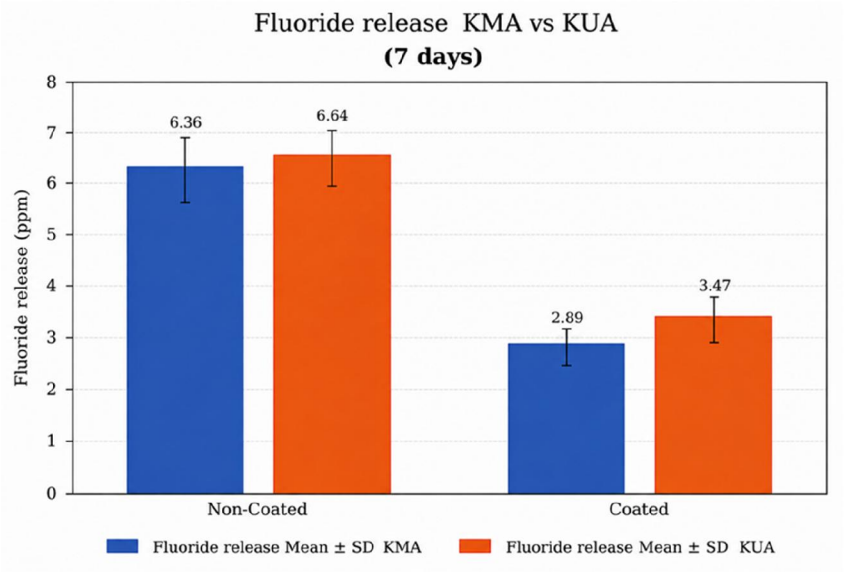

Fig. 4: Bar chart reveals the average fluoride release mean ± SD between non coated and coated KMA and KUA after 7 days.

3.3. Microhardness

The microhardness results are presented in Table 5 and figure 4. Microhardness did not differ statistically significantly under either the non coated ($p = 0.751$) or the coated ($p = 0.521$) condition. The coated samples showed slightly higher microhardness values than the non coated samples; however, the within material increase with coating reached statistical significance only for KUA ($p = 0.043$), whereas the corresponding change for KMA was not statistically significant ($p = 0.057$).

Table 4: Mean ± standard deviation (SD) and level of significance of microhardness (VHN) between non coated and coated KMA and KUA (n = 10 per subgroup).

Coating condition	KMA	KUA	p value (between materials)
Non coated	61.93 ± 1.227	62.20 ± 1.380	0.751
Coated	64.32 ± 1.296	63.87 ± 0.705	0.521
p value (within material)	0.057	0.043*	

* The mean difference is significant at the 0.05 level.

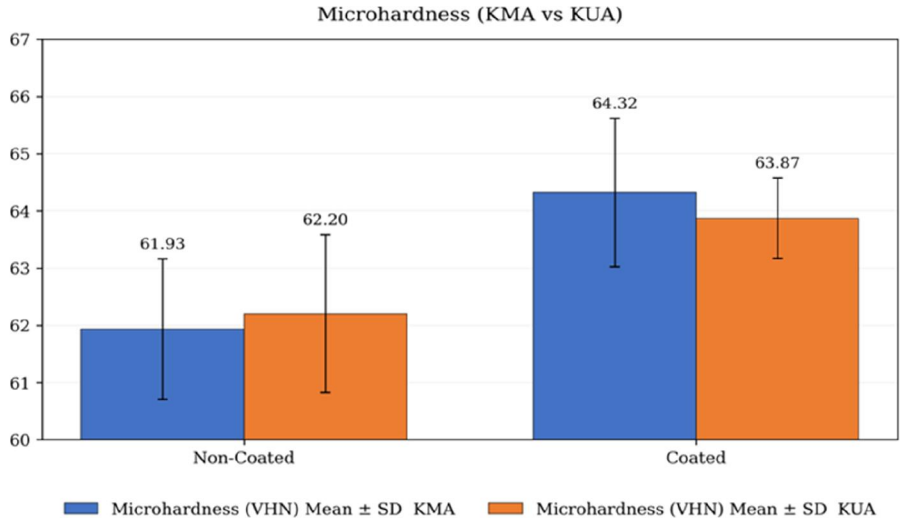

Fig. 5: Bar chart reveals the average microhardness mean ± SD between non coated and coated KMA and KUA.

4. Discussion

Glass ionomer (GI) occupies a distinctive and enduring position within restorative dentistry, sitting at the intersection of preventive and restorative care. Since Wilson and Kent first introduced the material in 1971, GI has been valued for its ability to bond chemically to tooth structure, release fluoride over extended periods, and exhibit biocompatibility that closely mimics the modulus of elasticity and thermal behavior of natural dentine Sheta *et al*. (2026) Despite more than five decades of clinical use, the material remains the subject of intense ongoing research.

Water sorption and solubility test was performed as the previous studies stated that water sorption and solubility influence the physical and mechanical performance and durability of the restoration (Alqasabi *et al*., 2024) and materials that absorb or lose excessive water may fail prematurely through margin breakdown, microleakage, secondary caries, or fracture, as documented in long term clinical evaluations of recent glass ionomer restorative systems (Wafaie *et al*., 2023).

Coating statistically significantly reduced the water solubility of both KMA ($p = 0.003$) and KUA ($p = 0.001$). A resin coating layer acts as a barrier against both water contamination and desiccation, preserving the water balance of the cement during the critical early stages of setting, when premature water contact leaches unreacted polyacid and ions and desiccation disrupts the hydration shells essential for ion mobility and cross linking (Bonifácio *et al*., 2012; Shen *et al*., 2022). By limiting water diffusion into and out of the cement, the coating promotes more complete maturation and thereby reduces the leachable fraction of the matrix (Nicholson, 2018). The present findings agree with Aydın *et al*. (2020) who demonstrated that surface protection reduced the water sorption and solubility of GI and with Jafarpour *et al*. (2019) who reported statistically significantly lower sorption and solubility in coated than in non coated GI groups, an effect attributed to the resin barrier. Also, in agreement with Alqasabi *et al*. (2024), who found that coated samples showing lower water uptake. These observations are also consistent with the systematic review of Al Zangana *et al*. (2025), which concluded that resin coatings improve the performance of GI, particularly during the critical initial setting period. In contrast, Zambon *et al*. (2025) found no significant differences in

water sorption or solubility between certain coated and non coated GI groups. Furthermore, Yilmaz *et al*. (2020) reported the highest 7 days water sorption values for coated group which may be attributed to difference in the tested materials.

Under the non coated condition, KMA exhibited statistically significantly higher water solubility than KUA (p = 0.001), indicating lower early hydrolytic stability of the conventionally placed material when the protective step is omitted. The compositional differences between both materials in powder to liquid ratio, powder size and distribution which stated by manufacturer (3M Deutschland GmbH) may modify the maturation behavior and the resistance of the developing matrix to hydrolytic dissolution during early storage (Nicholson, 2018; Nicholson *et al*., 2020). The present findings agree with Dionysopoulos *et al*. (2018), who reported low water solubility values for KUA relative to other conventionally placed GI tested under the same method.

Water sorption did not differ statistically significantly between KMA and KUA under either coating condition, and within each material the reduction observed after coating did not reach statistical significance. These findings align with (Hasanain *et al*., 2026) who found that no significant correlation existed between water sorption and water solubility among the investigated materials, indicating that the extent of water uptake does not necessarily predict the degree of material dissolution. This distinction highlights the importance of assessing both properties separately when evaluating the hydrolytic stability of restorative materials.

Glass ionomer is the most widely used fluoride releasing restorative material in dentistry which has an anticariogenic property and plays a crucial role in decreasing recurrent caries, this may be affected by application of resin coating so, the fluoride release test was done to evaluate the effect of resin coating on both materials. Deionized water was used as a storage solution as it contains no fluoride traces or minerals and thus can accurately indicate the fluoride ions released from GI; it should nevertheless be noted that the storage medium, pH cycling, and environmental parameters significantly affect fluoride release kinetics (Nicholson *et al*., 2023; Dobrzyński *et al*., 2025)

In this study Fluoride release increased statistically significantly from day 1 to 7 days in both materials (p =0.002, 0.006, 0.014 and 0.001). The continuing maturation of the glass ionomer matrix during the first week most likely accounts for this increase, because the setting reaction continues well beyond the initial setting time, with aluminum polyacrylate cross linking and matrix densification progressing over days to weeks and modifying the balance between water mediated ion mobility and matrix integrity (Nicholson, 2018). These observations are consistent with the continued maturation model of conventionally placed glass ionomers, in which the amount of fluoride released reflects the evolving structure of the maturing matrix (Nicholson, 2018). However, this pattern deviates from the classical biphasic fluoride release profile of glass ionomers an initial burst followed by a sustained, diffusion controlled decline described by Nicholson *et al*. (2023) and Dobrzyński *et al*. (2025), and recent evaluations of contemporary GI formulations documented maximal early release followed by a decline (Dcruz *et al*., 2024; Dhivyasri *et al*., 2025). Such discrepancies between studies may be explained by variations in coating permeability and degradation over time, sample surface area to volume ratios affecting diffusion gradients, and material specific matrix cross link density and porosity governing fluoride mobility (Nicholson *et al*., 2023; Dobrzyński *et al*., 2025)

Coating has statistically significantly reduced the fluoride release of both materials at 1 and 7 days (p = 0.001 for all within material comparisons). Fluoride release from glass ionomers is a diffusion driven ion exchange process that requires water penetration into the matrix, and a resin layer restricts both the inward sorption of water and the outward leaching of loosely bound fluoride ions, thereby attenuating the amount available for immediate release (Hattab and Amin, 2001; Nicholson *et al*., 2023). The present findings agree with the systematic review of Hattab and Amin (2001) Krajangta *et al*. (2022), Arthilakshmi *et al*. (2025) and Al Zangana *et al*. (2025), which concluded that resin coatings generally diminish fluoride release from GI by acting as a diffusion barrier that restricts ion movement from the cement matrix and reported that protective coatings reduced, but did not prevent, fluoride release, implying that resin layers remain partially permeable to fluoride diffusion. Alebady *et al*. (2024) demonstrated that surface coatings did not completely inhibit fluoride release from contemporary GI although they found that a coated conventionally placed GI exhibited statistically significantly higher fluoride release at day 21 than non coated counterparts which not agree with the findings of this study suggesting that ion diffusion may continue through the coating layer or via marginal pathways; the discrepancy with the present results may be explained by the

considerably longer observation period and by differences in coating chemistry, thickness, and permeability (Tokarczuk *et al*., 2024).

Moreover, at 7 days, coated KUA released statistically significantly more fluoride than coated KMA ($p = 0.039$). This finding suggests material specific interactions with the coating, which may be attributed to differences in matrix composition and glass reactivity affecting diffusion kinetics (Nicholson *et al*., 2023). The present findings agree with Tezel *et al*. (2025), who tested different GI formulations and found material specific fluoride release and microhardness responses to surface coating, and with Piszko *et al*. (2025), who showed that pH and material composition strongly influence fluoride release patterns in fluoride releasing dental materials. Variations in powder composition, powder to liquid ratio, powder size and cross linking density among GI formulations govern ion mobility and determine how each material interacts with a resin coating layer (Nicholson *et al*., 2020).

Coating statistically significantly increased the microhardness of KUA ($p = 0.043$), whereas the corresponding increase for KMA did not reach statistical significance ($p = 0.057$), and the two materials did not differ statistically significantly under either coating condition. The improvement observed in coated subgroups can be attributed to the coating permitting uninterrupted matrix maturation during the critical early setting period (Shen *et al*., 2022). Because the resin coating was applied after an initial 10 min set, the acid base reaction within the bulk was already largely established, so that the coating acted mainly as a mechanical shield rather than interfering chemically with the setting cement (Nicholson, 2018). Furthermore, the superficial resin layer itself may have contributed to the higher indentation resistance recorded during Vickers testing (Faraji *et al*., 2017). The present findings agree with Alqasabi *et al*. (2024) and with Faraji *et al*. (2017), who reported that protective coating enhance the early microhardness of GI by minimizing moisture imbalance, and with Tezel *et al*. (2025), who documented material dependent microhardness responses to surface coating in different GI formulations.

Conversely, several well conducted studies have reported no significant benefit of coating on GI hardness, or even lower hardness of coated samples. Bagheri *et al*. (2013) found that application of the resin coating was associated with a statistically significant decrease in the Vickers hardness of conventionally placed Ryu *et al*. (2019) likewise reported statistically significantly lower surface hardness in surface coated conventionally placed and resin modified GI than in non coated samples. These divergent results can be reconciled largely on methodological differences such as differences in storage or aging.

The null hypothesis was not accepted regarding all tests expect water sorption as the study found that coating statistically significantly reduced the solubility of both materials, whereas water sorption did not differ statistically significantly among the groups. Coating statistically significantly reduced the fluoride release of both materials at 1 and 7 days. Regarding microhardness, coating produced a statistically significant increase.

5. Limitations and recommendations

Taken together, the findings of this study should be interpreted in the light of its *in vitro* design, and short term storage period which cannot reproduce the intermittent moisture exposure, ionic composition, pH fluctuations, and mechanical challenges of the oral environment., water sorption and solubility were measured over a 7days immersion period, fluoride release was recorded at one and 7 days and microhardness was measured after 24hrs. These constraints limit the extrapolation of the results to long term service so, aging is recommended for long term evaluation of the material properties along with clinical studies.

6. Conclusion

Within the limitations of this *in vitro* study, coating did not influence water sorption but limits water solubility in both materials. Furthermore, non coated KMA shows more water solubility than non coated KUA, which might indicate lower early hydrolytic stability. Moreover, coating reduced fluoride release in both materials and Both materials showed increasing fluoride release from one days to 7 days which might reflect continued post setting maturation. Coating has improved the initial microhardness for both materials

References

Alebady, M.H., H.H. Hamama and S.H. Mahmoud, 2024. Effect of Various Surface Coating Methods on Surface Roughness, MicromorpholoGIal Analysis and Fluoride Release from Contemporary Glass Ionomer Restorations. BMC Oral Health, 24(1): 504. DOI: 10.1186/s12903 024 04234 5

Alqasabi, S.Y., A.M. Sulimany, T. Almohareb, A.S. Alayad and O.A. Bawazir, 2024. The Effect of Different Coating Agents on the Microhardness, Water Sorption, and Solubility of EQUIA Forte HT. Coatings, 14(6): 751. DOI: 10.3390/coatings14060751

Al Zangana, T., N. Tuygunov, N.A. Yahya and A. Abdul Aziz, 2025. The Impact of Resin Coatings on the Properties and Performance of Glass Ionomer Cements: A Systematic Review. Journal of the Mechanical Behavior of Biomedical Materials, 169: 107044. DOI: 10.1016/j.jmbbm.2025.107044

Arthilakshmi, C.U., C. Vishnurekha, P.N. Baghkomeh and S.D. Ditto, 2025. Influence of Nano Filled Surface Coating on Fluoride Release Patterns of Conventionally placed Glass ionomer and Resin Modified Glass Ionomer Cements. International Journal of Clinical Pediatric Dentistry, 18(11): 1305 1310. DOI: 10.5005/jp journals 10005 3335

Aydın, N., S. Karaoğlanoğlu, E. Aybala Oktay, S. Çetinkaya and O. Erdem, 2020. Investigation of Water Sorption and Aluminum Releases from High Viscosity and Resin Modified Glass Ionomer. Journal of Clinical and Experimental Dentistry, 12(9): e844 e851. DOI: 10.4317/jced.56381

Bagheri, R., N.A. Taha, M.R. Azar and M.F. Burrow, 2013. Effect of G Coat Plus on the Mechanical Properties of Glass Ionomer Cements. Australian Dental Journal, 58(4): 448 453. DOI: 10.1111/adj.12122

Bonifácio, C.C., A. Werner and C.J. Kleverlaan, 2012. Coating Glass ionomer with a Nanofilled Resin. Acta OdontoloGIa Scandinavica, 70(6): 471 477. DOI: 10.3109/00016357.2011.639307

Dcruz, M.M., S. Tapashetti, B. Naik, M.A. Shah, P. Mogi and P. Horatti, 2024. Comparative Evaluation of Fluoride Release Profiles in New Glass ionomer and Conventionally placed Type II GI: Implications for Cariostatic Efficacy. Bioinformation, 20(12): 2009 2014. DOI: 10.6026/9732063002002009

Dhivyasri, E., J. Jessy Paulraj and S. Maiti, 2025. Comparative Evaluation of Fluoride Releasing Properties in Nano Formulated and Conventionally placed Glass Ionomer Cements: An in Vitro Study. Journal of Clinical and Diagnostic Research, 19(4): ZC07 ZC12. DOI: 10.7860/JCDR/2025/76895.20826

Dionysopoulos, D., K. Tolidis, D. Strakas, P. Gerasimou, T. Sfeikos and N. Gutknecht, 2018. Effects of Blue Diode Laser (445 nm) and LED (430 480 nm) Radiant Heat Treatments on Dental Glass Ionomer Restoratives. Optics and Laser Technology, 99: 249 255. DOI: 10.1016/j.optlastec.2017.09.009

Dobrzyński, M., S. Klimas, A. Kotela, Z. Majchrzak, J. Kensy, M. Laszczyńska, W. Świenc, N. Grychowska Gąsior, M. Fast and J. Matys, 2025. Evaluation of Factors Affecting Fluoride Release from Dental Sealants: A Systematic Review. Materials, 18(23): 5350. DOI: 10.3390/ma18235350

Faraji, F., H. Heshmat and S. Banava, 2017. Effect of Protective Coating on Microhardness of a New Glass Ionomer Cement: Nanofilled Coating versus Unfilled Resin. Journal of Conservative Dentistry, 20(4): 260 263. DOI: 10.4103/jcd.jcd_83_16

Habib, S.I., 2020. Fluoride Releasing/Recharging Ability of Bulk Fill and Resin Modified Glass ionomer after the Application of Different Surface Coating Agents: An in Vitro Study. Advanced Dental Journal, 2(3): 80 92.

Hasanain, F.A., R.M. Abulaban, N.S. Almeganni and H.M. Nassar, 2026. Beverage Induced Staining and Water Sorption/Solubility of Conventionally placed and Resin Modified Glass Ionomer Restoratives. Biomimetics, 11(4): 249. DOI: 10.3390/biomimetics11040249

Hattab, F.N. and W.M. Amin, 2001. Fluoride Release from Glass Ionomer Restorative Materials and the Effects of Surface Coating. Biomaterials, 22(12): 1449 1458. DOI: 10.1016/S0142 9612(00)00253 2

Jafarpour, D., A. Mese, M. Ferooz and R. Bagheri, 2019. The Effects of Nanofilled Resin Based Coatings on the Physical Properties of Glass ionomer Restorative Materials. Journal of Dentistry, 89: 103177. DOI: 10.1016/j.jdent.2019.07.015

Ketac Universal Aplicap (KUA), (2023) Ketac™ Universal Aplicap™ Glass Ionomer Restorative: Technical Data Sheet [Internet]. St. Paul (MN): 3M; 2023 Available from: https://multimedia.3m.com/mws/media/1244268O/ketac-universal-aplicap-glass-ionomer-restorative.pdf

Krajangta, N., C. Dulsamphan and T. Chotitanmapong, 2022. Effects of Protective Surface Coating on Fluoride Release and Recharge of Recent Uncoated High Viscosity Glass Ionomer Cement. Dentistry Journal, 10(12): 233. DOI: 10.3390/dj10120233

Nicholson, J.W., 2018. Maturation Processes in Glass Ionomer Dental Cements. Acta Biomaterialia et OdontoloGIa Scandinavica, 4(1): 63 71. DOI: 10.1080/23337931.2018.1497492

Nicholson, J.W., S.K. Sidhu and B. Czarnecka, 2020. Enhancing the Mechanical Properties of Glass Ionomer Dental Cements: A Review. Materials, 13(11): 2510. DOI: 10.3390/ma13112510

Nicholson, J.W., S.K. Sidhu and B. Czarnecka, 2023. Fluoride Exchange by Glass Ionomer Dental Cements and Its Clinical Effects: A Review. Biomaterials Investigations in Dentistry, 10(1): 2244982. DOI: 10.1080/26415275.2023.2244982

Panpisut, P., A. Toneluck, C. Khamsuk, S. Channasanon, S. Tanodekaew, N. Monmaturapoj and P. Naruphontjirakul, 2024. The development of resin coating materials for enhancing elemental release of coated glass ionomer cements. Heliyon, 10(14): e34512.

Piszko, P.J., M. Kulus, A. Piszko, J. Kiryk, S. Kiryk, J. Kensy, A. Małyszek, M. Michalak, W. Dobrzyński, J. Matys and M. Dobrzyński, 2025. The Influence of Calcium Ions and pH on Fluoride Release from Commercial Fluoride Gels in an in Vitro Study. Gels, 11(7): 486. DOI: 10.3390/gels11070486

Ryu, W., H. Park, J. Lee and H. Seo, 2019. Effect of Nano Filled Protective Coating on Microhardness and Wear Resistance of Glass Ionomer Cements. Journal of the Korean Academy of Pediatric Dentistry, 46(2): 226 232. DOI: 10.5933/JKAPD.2019.46.2.226

Shen, C., H.R. Rawls and J.F. Esquivel Upshaw (Eds.), 2022. Phillips' Science of Dental Materials, 13th Edition. St. Louis, MO: Elsevier.

Sheta, M. S., E. R. Kenawy and S. A. Khattab, 2026. Effect of addition of hydroxyapatite nanofibers to glass ionomer on fracture toughness, microhardness, and fluoride release. Odontology. Advance online publication. https://doi.org/10.1007/s10266 026 01308 4

Sidhu, S.K. and J.W. Nicholson, 2016. A Review of Glass ionomer for Clinical Dentistry. Journal of Functional Biomaterials, 7(3): 16. DOI: 10.3390/jfb7030016

Soliman, S. and M. Othman, 2017. Microhardness and Compressive Strength of Three Types of Conventionally placed Glass Ionomer Restorative Materials. Egyptian Dental Journal, 63(4): 3329- 3337.

Tezel, H., M. Mulabdic, D. Akin, F.S. Barhan, C. Atalayin Ozkaya, T. Kose and O. Sogut, 2025. The Effect of Different Glass ionomer and Surface Coating Applications on Fluoride Release and Microhardness Values. BMC Oral Health, 25(1): 1730. DOI: 10.1186/s12903 025 07099 4

Tokarczuk, D., O. Tokarczuk, J. Kiryk, J. Kensy, M. Szablińska, T. Dyl, W. Dobrzyński, J. Matys and M. Dobrzyński, 2024. Fluoride Release by Restorative Materials after the Application of Surface Coating Agents: A Systematic Review. Applied Sciences, 14(11): 4956. DOI: 10.3390/app14114956

Tolidis, K., D. Dionysopoulos, P. Gerasimou and T. Sfeikos, 2016. Effect of Radiant Heat and Ultrasound on Fluoride Release and Surface Hardness of Glass Ionomer Cements. Journal of Applied Biomaterials and Functional Materials, 14(4): e463 e469. DOI: 10.5301/jabfm.5000292

Ugurlu, M., 2020. How Do the Surface Coating and One Year Water Aging Affect the Properties of Fluoride Releasing Restorative Materials? Nigerian Journal of Clinical Practice, 23(5): 720 728. DOI: 10.4103/njcp.njcp_591_19

Wafaie, R.A., A. Ibrahim Ali, S.A.E. El Negoly and S.H. Mahmoud, 2023. Five Year Randomized Clinical Trial to Evaluate the Clinical Performance of High Viscosity Glass Ionomer Restorative Systems in Small Class II Restorations. Journal of Esthetic and Restorative Dentistry, 35(3): 538 555. DOI: 10.1111/jerd.13000

Wilson, A.D. and B.E. Kent, 1971. The Glass Ionomer Cement, a New Translucent Dental Filling Material. Journal of Applied Chemistry and Biotechnology, 21(11): 313. DOI: 10.1002/jctb.5020211101

Wilson, A.D. and B.E. Kent, 1972. A New Translucent Cement for Dentistry. The Glass Ionomer Cement. British Dental Journal, 132(4): 133 135. DOI: 10.1038/sj.bdj.4802810

Yilmaz, M.N., P. Gul and A. Kiziltunc, 2020. Water Sorption and Solubility of a High Viscous Glass ionomer after the Application of Different Surface Coating Agents. European Journal of General Dentistry, 9(3): 118 121. DOI: 10.4103/ejgd.ejgd_50_20

Zambon, G., M.G. Cagetti, S. Cirio, G. De Bortoli, A. Allam and A.C. Ionescu, 2025. Surface Treatments and Coatings of Hybrid Glass ionomer to Improve Mechanical and Physical Properties. Scientific Reports, 16(1): 571. DOI: 10.1038/s41598 025 30202 2

Zhang, Q., Y. Huang, J. Li, X. Yan, R. Ma, F. Song, B. Liu and Y. Yang, 2026. Recent research progress on antibacterial modifications of conventional glass ionomer cement for dental restorations: A narrative review. Journal of Clinical Pediatric Dentistry, 50(1), 11–26. https://doi.org/10.22514/jocpd.2026.002