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Does Light Curing Affect the Water Sorption and Water Solubility Properties of Alkasite and Bulk-Fill Glass Hybrid Materials?

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Abstract: *The purpose of this research was to determine and compare the impact of light curing on the water sorption and solubility properties of alkasite and bulk-fill glass hybrid materials. An alkasite self-adhesive bulk-fill material (Cention® N, Ivoclar Vivadent AG, Schaan, Liechtenstein; CEN) and a bulk-fill glass material hybrid (EQUIA Forte™ HT, GC Corp., Tokyo, Japan; EFT) were utilized. Each material was prepared in accordance with the manufacturer's recommendations. Specimens were placed in disk-shaped molds and divided into two subgroups: light-cured (LC) and non-light-cured (NLC) ($n = 5$). Sorption and solubility tests were performed in accordance with ISO 4049 standards. Statistical analysis was conducted using one-way ANOVA, Tamhane's T2 post hoc, Pearson's correlation coefficient, and independent samples t-tests ($p < 0.05$). The highest water sorption was observed in Group EFT (63.022 ± 6.772 µg/mm^3), while the lowest was observed in Group CEN (4.447 ± 0.412 µg/mm^3). No significant differences were detected among Groups CEN and CEN LC and Groups EFT and EFT LC ($p > 0.05$). Regarding water solubility, Group EFT LC (-99.534 ± 2.008 µg/mm^3) exhibited the lowest values, while Group CEN (-2.728 ± 0.499 µg/mm^3) demonstrated the highest values. No significant difference was found between Group CEN and CEN LC ($p > 0.05$), while a statistically significant difference was found between Group EFT and Group EFT LC ($p < 0.05$). A statistically significant difference was identified between Group CEN and Group EFT and between Group CEN LC and Group EFT LC in terms of both water sorption and solubility values ($p < 0.05$). The correlation analysis found no significant relationship between the sorption and solubility values for the materials examined ($p > 0.05$). Regarding water sorption, the self-adhesive bulk-fill material was superior to the bulk-fill glass hybrid material, whether light-cured or not. For water solubility, the bulk-fill glass hybrid material was superior to the self-adhesive bulk-fill material, whether light-cured or not. The bulk-fill glass hybrid material exhibited reduced resistance to water sorption but a positive characteristic for water solubility. This short-term in vitro study provides a foundation for the evaluation of early-stage water-material interaction, which is essential for comprehending the behaviour of the material.*

Keywords: *Water sorption, water solubility, alkasite, bulk-fill glass hybrid, light curing*

1. Introduction

Composite resins offer an excellent aesthetic appearance and durability and allow for minimally invasive applications. However, these materials have a few drawbacks, including poor handling characteristics and polymerization shrinkage [1,2]. Moreover, the time-consuming technique required for their application, especially in deep cavities, poses a significant obstacle [3]. In an effort to streamline

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procedures and minimize time loss, a range of materials known as bulk-fill materials has been developed. One of these materials is high-viscosity glass ionomer cement (HVGIC).

The ancestors of HVGICs are glass ionomer cements (GICs), which have been utilized as restorative materials since the 1960s [4]. Owing to their properties, such as chemical bonding to the teeth, fluoride release, biocompatibility, and a similar coefficient of thermal expansion to dentin tissue, GICs are considered a suitable restorative material for deciduous and permanent teeth [5,6]. However, GICs have disadvantages, including the need for prolonged setting times, dehydration during the first setting process, and suboptimal mechanical features [7]. Considering these limitations, HVGICs have emerged to mitigate these drawbacks [7].

EQUIA Forte™ HT represents the latest version of HVGIC and is categorized as a bulk-fill glass hybrid restorative material [8]. Despite the superior mechanical, physical, and aesthetic properties exhibited by HVGICs compared to conventional GICs, moisture sensitivity remains a salient issue with HVGICs [8,9]. Hydrolysis of the matrix has been shown to exert a detrimental impact on the surface quality, marginal integrity, and aesthetics of the material [9]. To address these concerns, using a nanofilled coating material, EQUIA Forte™ Coat, is recommended to protect the material from the effects of the oral environment [10]. The application of resin coating has also been demonstrated to enhance surface hardness and roughness, flexural strength, and initial wear resistance [11,12].

Recent advancements in adhesive dentistry have produced composite resins that do not need preliminary tooth surface preparation and can bond to tooth tissue on their own [13]. These materials, designated self-adhesive composites, contain an all-in-one resin that incorporates acid, primer, and bonding agent. The utilization of these materials may prove advantageous in cases with challenging applications [14].

Cention® N, a self-adhesive bulk-fill restorative material, was launched in 2016 [15]. It is designed to neutralize acids and prevent demineralization [16]. Unlike other restorative materials, Cention® N contains alkaline fillers called alkasites [15,16]. Despite its classification as a subgroup of resin-based composites, Cention® N can release fluoride, calcium, and hydroxyl ions, which possess anti-cariogenic properties. The utilization of an adhesive material is optional, and Cention® N exhibits self-curing and light-curing properties [17].

Water sorption and solubility are pivotal to the mechanical durability and longevity of restorative materials. The initial sorption of restorative materials occurs within a matrix structure [18]. However, due to the hydrolysis process in the matrix structure, the material deteriorates over time, resulting in the disappearance of the surface character and marginal form and a degraded aesthetic appearance [19]. Solubility can be defined as the dissolution of materials in water or other solutions, leading to weight loss [20]. This process can have a detrimental effect on the material's biocompatibility, leading to its incompatibility with biological structures [21].

The application of light to glass ionomer-based restorative materials during setting reactions has been demonstrated to improve the material's mechanical and physical features [22]. In the context of GIC-based materials, the transfer of heat from light sources has been observed and shown to reduce the viscosity of the material, thereby protecting the restoration from the deleterious effects of moisture during the early setting stage. Notably, the combination of heat reinforcement with light-curing applications has been found to reduce the fracture rate of restorations. Cention® N can be light cured due to the incorporation of Ivocerin as a highly reactive photoinitiator, and this dual-curing property facilitates a decrease in setting time [23].

The purpose of this research was to determine the impact of light curing on the sorption and solubility properties of alkasite and bulk-fill glass hybrid materials. The alternative hypotheses are: The application of light curing with a resin coating agent would reduce the mean water sorption and water solubility values of the bulk-fill glass hybrid restorative material. The application of light curing would decrease the mean water sorption and solubility values of the alkasite material. Additionally, it was hypothesized that there would be a statistically significant linear relationship between the water sorption and water solubility values of each material.

2. Materials and methods

Tested materials in the research are in Table 1.

Table 1. Materials composition according to manufacturers

Material	Main composition	Manufacturer	Type
Cention® N	Powder: Calcium fluoro-silicate (alkaline) glass (25–35%), Barium aluminum silicate glass (20–30%), Calcium-barium-aluminum fluoro-silicate glass (10–20%), Ytterbium trifluoride (5–10%), Iso-filler (15–25%) (78.4 wt%, 57.6 v% of inorganic filler) (0.1–35 μm of particle size range) Liquid: Dimethacrylates (UDMA, DCP, Aromatic Aliphatic-UDMA, PEG-400 DMA), ivocerin, hydroperoxide, stabilizers, additives Powder/liquid ratio (g/g) = 4.6/1.0	Ivoclar Vivadent AG, Schaan/Liechtenstein LOT: Z0054T	Alkasite, self-adhesive bulk-fill restorative material
EQUIA Forte™ HT	Powder: Strontium fluoro aluminosilicate glass (95%), polyacrylic acid (5%), iron oxide Liquid: Polybasic carboxylic acid (5%–10%), water	GC Corp., Tokyo, JapanLOT: 210504A	Bulk-fill glass hybrid restorative material
EQUIA Forte Coat	MMA, photoinitiator, synergist, phosphoric acid ester monomer, BHT	GC Corp., Tokyo, Japan LOT: 2104211	Light-cure resin coating agent

Note: UDMA: Urethane dimethacrylate, DCP: Tricyclodecane dimethanol dimethacrylate, Aromatic Aliphatic-UDMA: Tetramethyl-xylylenediurethane dimethacrylate, PEG-400 DMA: Polyethylene glycol 400 dimethacrylate, MMA: Methyl methacrylate, BHT: butylated hydroxytoluene.

A priori sample size estimation was carried out using G*Power 3.1 for a one-way ANOVA with four groups ($\alpha = 0.05$ and $1-\beta = 0.80$). Previous *in vitro* investigations on water sorption and solubility of restorative materials have consistently demonstrated substantial differences among materials and polymerization protocols under comparable ISO-based testing conditions [24–26]. Therefore, this study was designed to detect significant differences between groups with a minimum 20 specimens required ($n = 5$ per group).

This study used an alkasite self-adhesive bulk-fill material (Cention® N, Ivoclar Vivadent AG, Schaan, Liechtenstein; CEN) and a bulk-fill glass hybrid material (EQUIA Forte™ HT, GC Corp., Tokyo, Japan; EFT).

2.1. Sample preparation

For Cention® N, following the manufacturer's recommendations, the powder and liquid were mixed on a mixing pad at a powder/liquid ratio of 4.6:1.0 until a homogeneous mixture was obtained with a smooth consistency. The mixing process lasted 45–60 s.

For EQUIA Forte™ HT, following the manufacturer's recommendations, the capsule was mixed using a capsule mixer for 10 s, applied with a syringe, and self-cured for 2.5 min.

Ten samples were placed in disk-shaped molds with a height and diameter of 2 and 10 mm, respectively. Mylar strips and glasses were used to ensure the attainment of a flat surface. Subsequently, the samples were divided into two subgroups: light-cured (LC) and non-light-cured (NLC) (n = 5 per group).

2.2. Experimental groups

The polymerization protocols were applied in accordance with the manufacturers' instructions and were consistent with previously published experimental approaches evaluating comparable restorative materials [24,27], as follows:

- Group CEN LC (Cention® N with light curing): The mixed material was applied in the molds and polymerized (Demi Ultra, LED Ultracapacitor, Kerr, USA) for 20 s (1100 mW/cm²).
- Group CEN (Cention® N without light curing): The mixed material was applied in the molds but not polymerized.
- Group EFT LC (EQUIA Forte™ HT with light curing): The mixed material was applied in the molds, sealed with a resin coating agent (EQUIA Forte™ Coat), and polymerized (Demi Ultra, LED Ultracapacitor, Kerr, USA) for 20 s (1100 mW/cm²).
- Group EFT (EQUIA Forte™ HT without light curing): The mixed material was applied in the molds but not sealed with a resin coating agent.

The upper surfaces of the EQUIA Forte™ HT specimens were subjected to a polishing procedure that involved the utilization of disks (Sof-Lex, 3M ESPE, St. Paul, MN, USA) in the same way. Following the stipulations set out in ISO 4049, the surfaces of the Cention® N specimens were smoothed (Sof-Lex, 3M ESPE, St. Paul, MN, USA) [22]. After each disk replacement, the specimens were thoroughly washed and dried. Before the light curing procedure in each group, the battery status and intensity of the light source were measured using an LED Radiometer (SDI Ltd., Australia).

2.3. Characterization

Analysis of water sorption and water solubility

Water sorption and solubility were determined in accordance with the ISO 4049 recommendations for polymer-based restorative materials following previously described protocols for specimen preparation, conditioning, and mass measurements [28]. The samples were inserted in a desiccator (Vacucell, MMM, Germany), held in a vacuum oven at 37 ± 1°C for 22 h, and then placed on a bench at 23 ± 1°C for 2 h to complete the 24-h cycle. The specimens were weighed every day using an analytical scale (Precisa, ES 225SM-DR, Switzerland). The cycle was repeated each day until the loss of mass was less than 0.1 mg per 24-h cycle. This constant mass, M1, was taken as the initial sample mass expressed in micrograms (μg). The diameter and thickness were measured three times using a caliper. The sample volume (V) was calculated in mm³. Each sample was submerged in 20 mL of distilled water for 1 week and kept in an oven (Stuart Orbital Incubator SI500, Bibby Scientific Ltd., UK) at 37 ± 1°C. At the end of the storage period, the specimens were retrieved from the oven and kept for 2 h at 23 ± 1°C. The samples were dried for 15 s and placed in a sterile container for 1 min. The specimens were reweighed to achieve the mass M2. Using the same cycle as for M1, the samples were reconditioned until M3 was received. The values for sorption (WSP) and solubility (WSL) (μg/mm³) were calculated using the formulas given in ISO 4049 [28]:

$$\mathrm{WSP} = (\mathrm{M2} - \mathrm{M3})/\mathrm{V}$$

$$\mathrm{WSL} = (\mathrm{M1} - \mathrm{M3})/\mathrm{V}$$

2.4. Statistical analysis

The data analysis was conducted using SPSS, version 24 (SPSS Inc., Chicago, IL, USA). The normality assumption was evaluated using the Shapiro–Wilk W test ($n < 50$); the data were normally distributed in all material groups ($p > 0.05$). An independent samples *t*-test was performed to identify any disparities among sorption and solubility for the pairs of materials. Levene's test was employed to ascertain the homogeneity of variances in each group.

Statistical differences between the materials were investigated using a one-way ANOVA. The variances were not equal among the materials in terms of sorption and solubility ($p < 0.05$). Pairwise comparisons were conducted using Tamhane's T2 post hoc test to account for unequal variances among the groups. For the within-material comparisons between the self-cured and light-cured protocols, Welch's independent samples *t*-test was applied. Pearson's correlation coefficient was employed to determine the linear correlation between sorption and solubility in each material, with a significance level of 95% for all tests.

Water sorption and solubility were analyzed as independent outcomes. Although the experimental design incorporated two materials and two polymerization protocols, the light-curing condition was not equivalent across the materials. The EQUIA Forte™ HT protocol required the application of a resin coat followed by light curing, whereas the Cention® N protocol involved light curing only. As this lack of methodological equivalence prevented a valid interpretation of a shared polymerization factor, a two-way ANOVA was deemed inappropriate for this dataset. Instead, the four combinations of material and protocol were treated as distinct experimental groups and compared using a one-way ANOVA for each outcome. For within-material comparisons, effect sizes were calculated using Hedges's g with 95% confidence intervals to provide an unbiased estimate of the standardized mean differences in the presence of small sample sizes.

3. Results and discussions

Table 2 presents the mean values, standard deviations, and correlation analysis results for each material's water sorption and solubility values.

Table 2. Mean ± SD and correlation analysis of water sorption and water solubility (µg/mm^3) for the tested materials

Materials	Water sorption[3]	Water solubility[3]	*r*	*P*[4]
Cention® N (CEN)[1]	4.447 ± 0.412^{B}	-2.728 ± 0.499^{C}	−0.304	0.619
Cention® N light cured (CEN LC)[1]	5.113 ± 0.520^{B}	-2.953 ± 0.447^{C}	−0.740	0.153
EQUIA Forte™ HT (EFT)[2]	63.022 ± 6.772^{A}	-88.007 ± 4.421^{B}	−0.036	0.954
EQUIA Forte™ HT light cured (EFT LC)[2]	56.104 ± 1.504^{A}	-99.534 ± 2.008^{A}	−0.250	0.685

Note: The presence of different uppercase letters within the same column indicates significant mean differences between materials at the 5% level. [1,2]Independent *t*-test $p < 0.05$, [3]One-way Anova test $p < 0.05$, [4]Significance of Pearson's correlation coefficient between water sorption and water solubility for each material.

3.1. Water sorption and water solubility

The highest sorption value was detected in Group EFT (63.022 ± 6.772 µg/mm^3), while the lowest was observed in Group CEN (4.447 ± 0.412 µg/mm^3). No statistically significant differences were found between Groups CEN and CEN LC ($p = 0.297$). A similar outcome was found for Groups EFT and EFT LC ($p = 0.408$) (Table 3; Figure 1).

Table 3. Post-hoc pairwise comparison for WSP

Pairs	Mean difference	95% CI	t(*df*)	*p*
CEN vs. CEN LC	−0.666	−1.357 to 0.025	−2.242 (7.61)	0.297
CEN vs. EFT	−58.575	−66.976 to −50.174	−19.303 (4.03)	<0.001
CEN vs. EFT LC	−51.657	−53.499 to −49.815	−74.022 (4.60)	<0.001
CEN LC vs. EFT	−57.909	−66.305 to −49.513	−19.063 (4.05)	<0.001
CEN LC vs. EFT LC	−50.991	−52.828 to −49.154	−71.606 (4.94)	<0.001
EFT vs. EFT LC	6.918	−1.401 to 15.236	2.230 (4.39)	0.408

Note: Mean differences with corresponding 95% confidence intervals were calculated using Welch's *t*-test, and adjusted *p* values were derived in accordance with the Tamhane's T2 procedure.

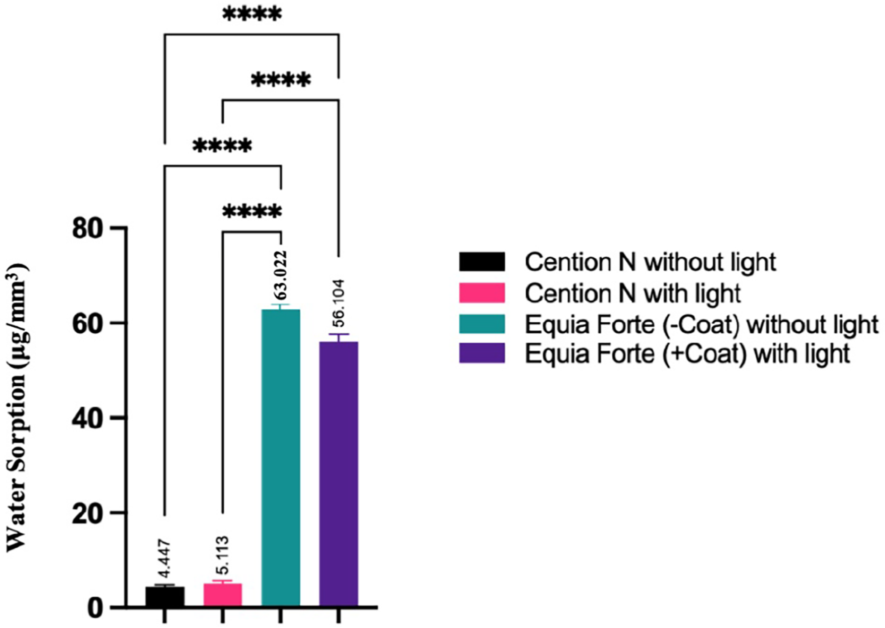

Figure 1. Pairwise comparisons of water sorption values for the tested materials. Note: The lower water sorption values observed in the CEN and CEN LC groups are primarily attributable to the resin-based matrix composition of Cention® N, which includes relatively hydrophobic monomers and a dual-cure system, rather than to the application of light curing. Non-significant pairwise comparisons have not been included in the figure, ****$p < 0.0001$.

Group EFT LC (−99.534 ± 2.008) exhibited the lowest water solubility, while Group CEN (−2.728 ± 0.499) demonstrated the highest value. No statistically significant difference was found between Groups CEN and CEN LC ($p = 0.979$). However, a statistically significant difference was identified between Groups EFT (−88.007 ± 4.421) and EFT LC (−99.534 ± 2.008) ($p = 0.014$) (Table 4 and Figure 2).

Statistically significant differences were identified among Groups CEN and EFT, CEN LC and EFT LC, in terms of both sorption and solubility values ($p < 0.05$) (Table 2, Figures 1 and 2).

In addition to between-group comparisons, within-material analyses were performed to evaluate the effect of light curing on water sorption and solubility. For Cention® N, no statistically significant differences were observed between the self-cured and light-cured protocols for either water sorption ($p = 0.057$) or water solubility ($p = 0.476$). In contrast, for EQUIA Forte™ HT, light curing was associated with significantly less negative water solubility compared with the non-light-cured protocol ($p = 0.002$), whereas the difference in water sorption did not reach statistical significance ($p = 0.084$). Effect size estimates indicated a large magnitude of the light-curing effect on water solubility for EQUIA Forte™ HT (Table 5).

Table 4. Post-hoc pairwise comparison for WSL

Pairs	Mean difference	95% CI	t(*df*)	*p*
CEN vs. CEN LC	0.225	−0.469 to 0.918	0.748 (7.91)	0.979
CEN vs. EFT	85.278	79.807 to 90.750	42.853 (4.10)	<0.001
CEN vs. EFT LC	96.806	94.343 to 99.268	104.573 (4.49)	<0.001
CEN LC vs. EFT	85.054	79.579 to 90.528	42.793 (4.08)	<0.001
CEN LC vs. EFT LC	96.581	94.114 to 99.048	104.934 (4.40)	<0.001
EFT vs. EFT LC	11.527	6.116 to 16.940	5.308 (5.58)	0.014

Note: Mean differences with corresponding 95% confidence intervals were calculated using Welch's *t*-test, and adjusted *p* values were derived in accordance with the Tamhane's T2 procedure.

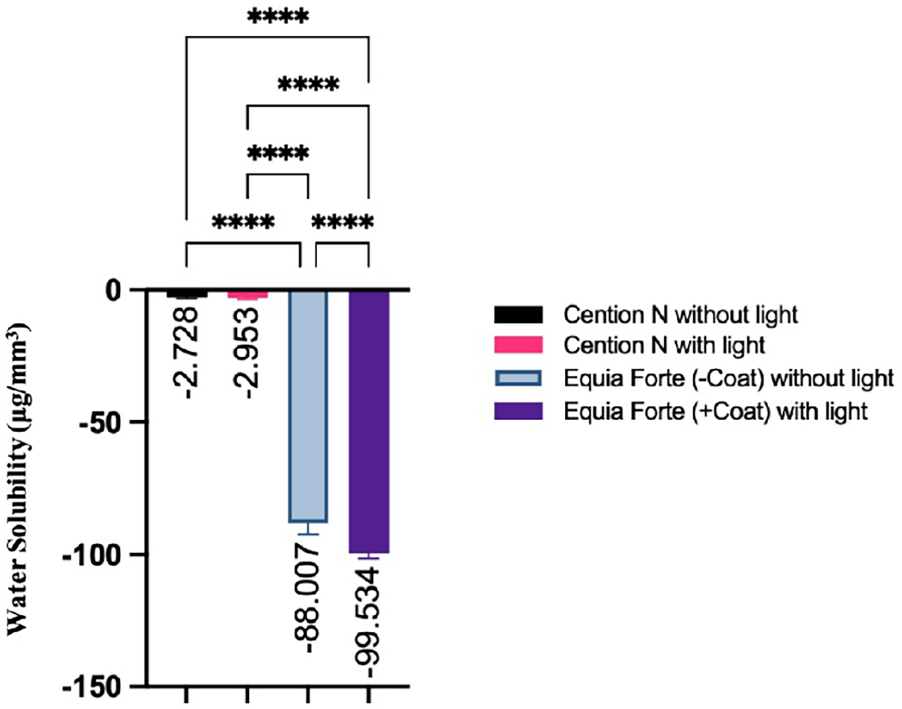

Figure 2. Pairwise comparisons of water solubility values for the tested materials. Note: Non-significant pairwise comparisons have not been included in the figure, $^{****}p < 0.0001$.

No statistically significant correlation was observed among the water sorption and water solubility values for each material ($p > 0.05$) (Table 2).

Table 5. Within material analysis for WSP and WSL

Variable	Pairs	Mean difference	95% CI	t(*df*)	*p*	Hedges-g
WSP	CEN vs. CEN LC	−0.666	−1.357 to 0.025	−2.242 (7.61)	0.057	−1.280
WSP	EFT vs. EFT LC	6.918	−1.401 to 15.236	2.230 (4.39)	0.084	1.274
WSL	CEN vs. CEN LC	0.225	−0.469 to 0.918	0.748 (7.91)	0.476	0.428
WSL	EFT vs. EFT LC	11.528	6.116 to 16.940	5.308 (5.58)	0.002	3.032

Note: Within-material comparisons were conducted to evaluate the effect of light-curing on water sorption and water solubility for each restorative material. Welch's independent samples *t*-test was used for comparisons between self-cured and light-cured protocols.

3.2. Discussion

Composite resin materials are the most preferred dental restorative materials. However, applying the incremental layering technique is time-consuming [29], and clinicians often prefer bulk-filled materials to reduce chair time. Therefore, in this study, two distinct bulk-fill restorative materials, namely, bulk-fill glass hybrid and self-adhesive bulk-fill materials, were selected as alternatives to conventional composite resin materials for the restoration of posterior teeth.

Evidence exists that the water sorption and solubility features of materials can have a detrimental effect on mechanical and physical features [30,31]. In the case of glass ionomer-based materials, the placement of a light-curing resin coating agent on the surface appears to preserve the water balance and enhance the material's features [29]. Furthermore, penetration of the coat into the material's porosities provides intrinsic protection against cracking, which can reduce sorption and solubility [31]. Under ISO 4049 standards, the sorption and solubility values must be lower than 40 and 7.5 $\mu g/mm^3$, respectively [32]. The findings of this study demonstrated that the water sorption values were under the threshold limits for CEN and CEN LC but above the threshold values for EFT and EFT LC. Concerning water solubility, all the groups examined fell below the specified threshold values.

The study design incorporated two materials and two polymerization methods. However, as the light-curing procedure differed between the materials, a two-factor ANOVA could not be applied. Consequently, the outcomes were interpreted based on established within-material comparisons and overall group disparities, as these more accurately reflected the effects of the protocol in a clinical context.

Hatirli et al. compared EQUIA Forte™ Fil with a light-cured coating and Cention® N with/without light curing for seven days [24]. In their study, EQUIA Forte™ Fil with a light-cured coating demonstrated the highest water sorption value (28.68 ± 6.64), while Cention® N with/without light curing exhibited the lowest values (2.64 ± 0.92 and 3.34 ± 0.99, respectively). Ramos et al. [33]. investigated the 7-day water sorption of chemically activated Cention® N, light-cured Cention® N and light-cured EQUIA Forte™ Fil without a coat (2024). They found that light-cured EQUIA Forte™ Fil without a coat (42.29 ± 13.57) showed more sorption than light-cured Cention® N (29.81 ± 8.75) and chemically activated Cention® N (27.13 ± 12.70). Their results are in line with those of the present study, in which EFT (63.02 ± 6.77) and EFT LC (56.10 ± 1.50) displayed similar values to each other but higher sorption values than CEN (4.447 ± 0.412) and CEN LC (5.113 ± 0.520). The elevated sorption values obtained for both EFT groups may be attributable to the composition of the material. The EFT material includes a very high percentage (95%) of strontium fluoro aluminosilicate glass particles, which are engineered to deliver a sustained high release of fluoride ions. This release could raise the void volume of the material, allowing for higher water sorption. Another reason may be the method of applying the resin coating. In the clinical setting, the resin coating is applied exclusively to the surface of the restoration that comes into contact with the oral environment. In this *in vitro* study, the resin coating was also applied exclusively to the upper surface of the material, which may have resulted in the samples being exposed to more liquid and left unprotected.

The utilization of coat material on the EFT surface has been documented as a method of protecting against cracks and filling porosities, which may result in reduced water sorption [34]. In this study, although there was no statistically significant difference ($p > 0.05$), the coat application for Group EFT LC demonstrated a numerical reduction in water sorption value. Therefore, the hypothesis related to water sorption values was accepted.

Groups CEN® and CEN® LC demonstrated comparable sorption values (4.45 ± 0.41, 5.11 ± 0.52), exhibiting no statistically significant difference ($p > 0.05$). This result suggests that the light application did not have a significant impact on the water sorption values. Therefore, the hypothesis regarding the water sorption values was partially rejected. However, the presence of UDMA, PEG-400 DMA, DCP, and double-cure initiators in the liquid part of the material may be responsible for the lower sorption values when compared to EFT and EFT LC [23]. A combination of these monomers has been demonstrated to enhance the material's mechanical properties and ensure long-term stability. Additionally, UDMA is recognized as a hydrophobic monomer that exhibits reduced water sorption properties [35]. UDMA creates rigid networks, which absorb lower water and release higher unreacted monomers [36]. Manual handling of Cention® N cement has been demonstrated to have the capacity to influence the sorption of liquids. This process can result in the development of porosity, thereby enhancing the material's capacity for liquid absorption [37]. Notwithstanding this disadvantage, the material's low sorption property is also related to its composition. In line with the findings of the present research, Hatirli et al. [24] and Ramos et al. [33] found no statistically significant difference between Cention® N with and without light curing (2.64 ± 0.92, 3.34 ± 0.99, 29.81 ± 8.75, and 27.13 ± 12.70, respectively; $p > 0.05$).

Beyond water sorption, the within-material evaluation indicated that light curing did not result in a significant change in water solubility for Cention® N, further supporting the limited influence of the curing protocol on the water-related properties of this material. The chemical structure and cross-link density of the polymer network are known to play a central role in determining water sorption and solubility behavior, as increased fluid uptake may be associated with surface degradation and matrix softening. In this study, the lowest water sorption values were consistently observed in the CEN groups, which may be attributed to the resin-based structure of Cention® N, classifying it as a subgroup of composite materials [35].

Applying EQUIA™ Coat to two different HVGICs (EQUIA Fil and Riva Self Cure) has been found to raise wear resistance [38]. This means that the resin may also protect the material regarding water sorption and solubility. Aydin et al. [39] evaluated the differences between different glass ionomer-based materials (EQUIA Forte, IonoStar Plus, and Riva Self Cure) and resin-modified GICs (Ionolux and Riva Light Cure) with and without coating by keeping them in a chloride solution for 24 h. Following a period of seven days, the samples of EQUIA Forte™ with EQUIA™ Coat demonstrated the lowest solubility (1.74 ± 0.44) among the glass-ionomer-based materials. In the present research, in parallel with the findings of the aforementioned study, the lowest water solubility value was observed in Group EFT LC (−99.534 ± 2.008). In addition, a statistically significant difference was detected between the Groups EFT LC and EFT ($p < 0.05$). This result means that application of the coat to the upper surface of the samples had a positive impact on the water solubility values. Therefore, the hypothesis related to water solubility values was accepted. The observed phenomenon can be attributed to the coat's protective function, which effectively preserves the solubility of the material in wet/moist environments, such as the mouth. The coat's protective function has a direct impact on human health. Aluminum ions are released from the surface layer during the acid-base setting reaction of the bulk-fill glass hybrid (EQUIA Forte™ HT) [40]. Aluminum is known to have harmful effects, such as accumulation in the brain, kidneys, and bones [41]. In this study, application of the coat was found to successfully in impact the solubility values. It is therefore vital to include this step because failure to do so could increase the amount of aluminum released.

In this study, all materials tested had solubility values below the ISO 4049 standard (7.5 mg/mm^3) and were consequently evaluated negatively. According to the extant literature, two rationales exist for these negative values. First, it is proposed that the materials do not undergo complete dehydration, resulting in low solubility [42]. A secondary rationale for the negative values is that these materials exhibit superior water sorption properties. One study revealed that sorption might have obscured true solubility, as the water sorption capacity exceeded solubility [43]. We concur with both rationales, and the outcomes of the present study align with these explanations.

Although there were no statistically significant differences between Groups CEN and CEN LC in terms of water solubility values ($p > 0.05$), a reduction was observed in the values of Group CEN LC. This outcome indicates that utilization of a coat with light curing had a highly positive effect on Cention® N. Consequently, the hypothesis regarding the water solubility values was partially accepted.

A statistically significant difference was detected between Groups EFT LC and CEN LC in terms of sorption and solubility ($p < 0.05$), which is in line with the findings of a study investigating sorption and solubility of the same materials [27]. Additionally, a statistically significant difference was identified between Groups EFT and CEN for both water sorption and solubility ($p < 0.05$). The observed statistically significant differences between these groups can be attributed to the structural variances in the materials used. In this study, no significant relationship was found between water sorption and solubility values for each material ($p > 0.05$). Therefore, the last hypothesis was rejected.

This study has some limitations. It was conducted under *in vitro* conditions. Furthermore, sorption and solubility were evaluated for only one week, which corresponds to a short-term study. Under oral conditions, the restorations were exposed to various mechanical forces with oral fluids under different temperatures. The principal limitation of this study was the inaccurate stimulation of the oral situation. The relatively small sample size and high standard deviations, particularly in the EQUIA Forte™ HT groups, may limit the generalizability of our findings. The chosen sample size was considered sufficient to identify significant between-group differences. However, this design may exhibit constrained sensitivity for identifying small or moderate impact sizes. Another limitation concerns the polymerization protocols, which were not identical across the tested materials. As light curing and surface coating were applied differently depending on the material type, direct factorial analysis using a standard two-way ANOVA model was not appropriate. This methodological constraint was addressed by applying within-material comparisons and variance-robust statistical procedures; however, it should be considered when interpreting the comparative results. Further research is needed to examine other properties affected by the light-curing process.

In recent dental materials research, multi-criteria decision making (MCDM) approaches have increasingly been used to integrate multiple physicochemical and mechanical parameters into a single comparative framework [44,45]. Such methods allow simultaneous evaluation of competing performance criteria, including water sorption, solubility, mechanical strength, and durability, thereby facilitating a more comprehensive material ranking. Although this study focused on isolated ISO-defined water-related properties, the incorporation of MCDM techniques may provide added value in future investigations under complex clinical decision scenarios. Studies employing larger sample sizes, a broader scope, and considering all limitations are necessary to obtain more accurate values.

4. Conclusions

Concerning water sorption, Cention® N, a self-adhesive bulk fill material, demonstrated superior performance compared to a bulk-fill glass-hybrid restorative material, irrespective of whether it was light-cured or not. Concerning water solubility, EQUIA Forte™ HT, the bulk-fill glass hybrid, demonstrated superior performance in comparison to a self-adhesive bulk-fill material, irrespective of whether it was light-cured or not. The self-adhesive bulk-fill material exhibited reduced resistance to water solubility but had positive characteristics for water sorption. The bulk-fill glass hybrid material exhibited reduced resistance to water sorption but had positive characteristics for water solubility. This short-term *in vitro* study provides a foundation for the evaluation of early-stage water-material interaction, which is essential for comprehending the behaviour of the material.

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