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Analysis of color change and translucency of glass ionomer cements, a key material for older adults restorations

Análise da alteração de cor e translucidez de cimentos de ionômero de vidro, um material chave para restaurações em idosos

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ABSTRACT

Objective: This study evaluated color change (ΔE00) and translucency (TP) of GICs over 3 months. **Materials and Methods:** Discs (n = 5) of conventional (ION-Z [IZ], Maxxion R [MX], Vidrion R [VR], Riva Self Cure [RSC], GC Gold Label 9 [G9] and resin-modified GICs (GC Gold Label 2 [G2], Equia Forte [EF]) were prepared and stored in distilled water. Color measurements were taken (3x/disc) with a reflectance spectrophotometer at 5 experimental times: immediately after preparation; after 1 hour (1h), 1 day (1d), 1 week (1w), and 3 months (3m). Data were analyzed using two-way repeated-measures ANOVA/Tukey test (α= 0.05). **Results:** After 3 months, all GICs presented perceptible ΔE00, with MX and RSC exhibiting the highest values. EF consistently showed acceptable ΔE00 ($p< 0.05$). MX and RSC showed the highest TP after 1h and throughout ($p<0.05$). G2, RSC, G9, and VR showed their highest TP values at 1w and 3m, with no differences between these times ($p\geq0.05$). IZ showed the highest TP at 1d and 1w, and EF's greatest TP was at 3m. **Conclusion:** GICs showed perceptible color changes with unstable translucency. EF maintained acceptable color change.

KEYWORDS

Color; Dental care for aged; Dental restoration failure; Glass ionomer cements; Colorimetry.

RESUMO

Objetivo: Este estudo avaliou a alteração de cor (ΔE00) e a translucidez (TP) de CIVs ao longo de 3 meses. **Material e Métodos:** Discos (n = 5) de CIVs convencionais (ION-Z [IZ], Maxxion R [MX], Vidrion R [VR], Riva Self Cure [RSC], GC Gold Label 9 [G9]) e CIVs modificados por resina (GC Gold Label 2 [G2], Equia Forte [EF]) foram preparados e armazenados em água destilada. As medições de cor foram realizadas (3x/disco) com um espectrofotômetro de reflectância em 5 tempos experimentais: imediatamente após o preparo; após 1 hora (1h), 1 dia (1d), 1 semana (1s) e 3 meses (3m). Os dados foram analisados usando ANOVA de medidas repetidas de dois fatores com teste de Tukey (α= 0,05). **Resultados:** Após 3 meses todos os CIVs apresentaram ΔE00 perceptível, com MX e RSC exibindo os maiores valores. EF consistentemente apresentou ΔE00 aceitável ($p < 0{,}05$). MX e RSC apresentaram a maior TP após 1h e ao longo do tempo ($p < 0{,}05$). G2, RSC, G9 e VR apresentaram seus maiores valores de TP em 1s e 3m, sem diferenças entre esses tempos ($p \geq 0{,}05$). IZ apresentou a maior TP em 1d e 1s, e o maior TP de EF foi em 3m. **Conclusão:** Os CIVs apresentaram alterações de cor perceptíveis com translucidez instável. EF manteve uma alteração de cor aceitável.

PALAVRAS-CHAVE

Cor; Saúde bucal para idosos; Falha de restauração dentária; Cimentos de ionômero de vidro; Colorimetria.

INTRODUCTION

Glass ionomer cement (GIC) is a widely used restorative material in dentistry, particularly for the treatment of non-carious cervical lesions (NCCL) [1-5] and root caries [6,7]. It stands out due to its benefits, including fluoride release [8], biocompatibility [9], and chemical adhesion [10], which are essential characteristics for restorative materials, especially in older adults [7].

With the population aging [11], the older adults require more support regarding the maintenance of oral health. According to the literature [7], restorative materials for older populations must promote remineralization and have adhesive proprieties. Moreover, studies indicate that the retention rates of GICs, especially resin modified GICS (rmGICs), in NCCLs are comparable to or even superior to those of resin-based composites [1,2]. Also, aged dentin treated with GIC has shown less microleakage when compared to young dentin [12]. Therefore, GIC should be a material of choice for restoring NCCL in older adults [5].

However, despite their clinical advantages, GICs may be underused due to their esthetic limitations when compared to resin composites. Resin-modified GIC is preferred when esthetics are a concern, as it provides improved color matching and faster setting time, mainly due to its resin components, including inorganic fillers and photoinitiators; while conventional GIC is recommended for patients with xerostomia or those at high risk of caries due to its sustained fluoride release, which provides effective control of caries lesion, making it suitable for both routine clinical care and functionally dependent patients [5,7]. Additionally, GIC is an appropriate option for treating root caries in elderly individuals [6], a population at increased risk for such lesions [13-16] due to reduced salivary flow [17] and gingival recession [18], which are common in this age group. Although GIC has lower mechanical proprieties compared to other materials [19], these proprieties are adequate for older adults who typically do not exert high occlusal forces [7].

Esthetic considerations also play an important role in restorative dentistry for older adults. Research shows that individuals entering their 60s place significant value on dental aesthetics [20]. Another study conducted on 75-year-olds demonstrated that dental appearance remains a priority, influencing how elderly individuals are perceived socially and professionally [21]. As such, a restorative material must not only have satisfactory mechanical properties but also meet esthetic demands, which can contribute to the well-being and quality of life of older adults.

A restoration is considered aesthetically appropriate when it accurately reproduces the optical properties of the natural tooth structure [22], with color and translucency playing an important role in achieving this outcome [23]. However, GIC undergoes color and translucency changes over time [24] due to water sorption and solubility within the oral cavity [25,26], which can vary across brands. While GICS may have lower abrasion resistance and inferior mechanical properties compared to composite resin [27], they offer advantages such as reduced chair time [2], lower costs [3], and a lower risk of restoration loss in NCCLs [5].

Thus, understanding the optical properties of GICs is crucial for predicting color and translucency changes over time, especially for treatments in esthetically affected areas, such as root caries, or NCCLs in older adults anterior teeth. Therefore, this study aimed to evaluate the color change ($\Delta E00$) and translucency (TP) of commercially available conventional restorative GICs and resin-modified GICs over three months. The hypothesis was: GICs analyzed in this study presented color and translucency change, affecting color selection and aesthetics of restorations.

MATERIAL AND METHODS

Specimen preparation

Discs were prepared using commercially available GICs: 5 conventional restorative and 2 resin-modified (n = 5) (Table I). The sample size was based on a previous similar study [28]. The GIC discs were prepared using a metal mold measuring 15 mm in diameter and 2 mm in height. Each material was manipulated according to the manufacturer's instructions for use. Subsequently, the material was inserted into the mold to fill it, using a Centrix syringe to minimize the inclusion of voids and bubbles. Two glass plates were pressed against each other with the mold in between to ensure compression and uniformity of the material in the mold. The resin-modified materials were light cured from

Table I - GICS investigated in this study

Group	Product	Code	Composition
Conventional	Ion-Z (FGM, Joinville, SC, Brazil) (A3)	IZ	FASV, AP e TA
	Maxxion R (FGM, Joinville, SC, Brazil) (A3)	MX	FASV e AP
	Vidrion R (SS White, Rio de Janeiro, RJ, Brasil) (A3,5)	VR	Sodium Fluorosilicate, Calcium, aluminum, barium sulfate, AP and pigments.
	GC Gold Label 9 R (GC Corporation, Tóquio, MT, Japão) (A3,5)	G9	FASV, AP and polybasic carboxylic acid.
	Riva Self Cure (SDI, Melbourne, VIC, Australia) (A3)	RSC	FASV, AP and TA
Resin-modified	GC Gold Label 2 LC R (GC Corporation, Tóquio, MT, Japão) (A3)	G2	FASV, AP and distilled water
	Equia Forte (GC Corporation, Tóquio, MT, Japão) (A2)	EF	FASV, AP, pigments, distilled water and polybasic carboxylic acid.

Abbreviations: AP: polyacrylic acid; TA: tartaric acid; FASV: fluoraluminosilicate glass.

the top surface through the glass plate for the time recommended by the manufacturer (Valo, Ultradent Product Inc, South Jordan, USA), with the radiance being checked by a radiometer (Ecel RD-7, Ribeirão Preto, Brasil), while for the conventional materials, the initial setting was awaited and the GIC discs were removed from the mold.

Analysis of color change and translucency

Ten minutes after light curing or initial setting, all specimens' color was measured using a light spectrophotometer (CM-3700A, Konica Minolta, Kojimachi, Tokyo). The light source was provided by a wavelength range of 360 nm to 740 nm, standard illuminant D65, a 10-degree standard observer, and a black background. The color and translucency were obtained according to the CIEDE 2000 parameters L*, C* and h°, and for whiteness evaluation, the L*, a* and b* coordinates were used. L* stands for lightness, a* stands for red/green coordinate, b* for yellow/blue coordinate, C* for chroma coordinate (distance for the lightness axis), and h° for the hue angle, in degrees. Each specimen was measured three times and the average initial color and translucency values were obtained. The specimens were stored in distilled water (10 mL per specimen) at 37 °C. The same procedure was performed at 4 experimental intervals: 1 hour (1h), 1 day (1d), 1 week (1w), and 3 months (3m). These intervals were selected to simulate the progression of color and translucency changes as the sorption and solubility dynamics evolve in the oral environment, considering initial and final setting, and aging. Specimens were removed from the water before each measurement, and the excess water was removed using absorbent paper. The mean value of the 3 readings performed at each experimental time was considered for the statistical analyses.

The color change ($\Delta E00$) was calculated according to the equation: $\Delta E00 = [(\Delta L/kLSL)2 + (\Delta C/kCSC]2 + (\Delta H/kHSH)2 + RT (\Delta C^*\Delta H/SC^*SH)]1/2$ [29] considering the initial time (10 minutes after photoactivation or initial setting), and experimental time intervals. Color changes were considered according to the previously reported visual perceptibility and acceptability thresholds for evaluation of the clinical relevance of the results. Perceptibility indicates that values above 0.81, according to CIEDE00, are visually perceptible to the human eye. Values between 0.81 and 1.77 indicate that the color change is visually perceptible and considered acceptable, and values above 1.77 indicate that the color change is visually perceptible and unacceptable [30]. The translucency (TP), was obtained by calculating the color difference against a white background and against a black background in each experimental time interval [30].

Statistical analyses

Two-way repeated-measures ANOVA and Tukey tests were applied for all performed tests.

A significance level of 5% was considered for all the tests. The statistical analyses were performed using the Jamovi software version 2.3.28.0 (The Jamovi Project, Sydney, Australia).

RESULTS

ΔE00 analysis

Figure 1 presents ΔE00 values for different GICs at different experimental times. In the first hour, there was no statistically significant difference in ΔE between the GICs studied ($p \geq 0.05$). On the first day, MX (6.88 ± 1.02) and IZ (4.55 ± 1.46) presented the highest ΔE00 values, with no significant difference between them ($p \geq 0.05$). After 1 week, MX (7.74 ± 1.70) continued to show the highest color change, with no statistically significant differences from IZ (5.36 ± 3.36) and RSC (5.22 ± 0.44) ($p \geq 0.05$). After 3 months, MX (7.34 ± 0.82) and RSC (6.35 ± 0.94) presented the greatest color changes ($p < 0.05$).

The analysis of the results obtained at the experimental times for each material indicated that IZ, VR, G9, G2, and EF exhibited stable ΔE00 values ($p < 0.05$) throughout the 3-month evaluation period. RSC showed an increase in ΔE00 ($p < 0.05$) between the first day and 1 week (Figure 1). MX increased between 1 hour (3.82 ± 1.59) and 1 day (6.88 ± 1.02) ($p < 0.05$), and then stabilized until the final evaluation.

EF was the only material that did not exhibit unacceptable ΔE00 values at any of the experimental times evaluated. IZ, MX, and G9 showed ΔE00 values that were visually unacceptable during all the experimental times. G2 presented visually unacceptable ΔE00 at the 1-week and 3-month assessments. VR only showed a visually acceptable color change in the first week, presenting unacceptable color changes at the remaining experimental times.

Resin-modified GICs' color remained stable ($p \geq 0.05$) throughout the assessment period, as shown in Table II. There were no significant differences in conventional GICs between 1 week (4.51 ± 3.07) and 3 months (3.14 ± 3.88) or between 1 day (2.72 ± 2.8) and 3 months, but there were significant differences between the other studied periods. There was a significant difference between resin-modified and conventional GICs only on the first day (Table II).

TP analysis

Table III shows the translucency at different experimental times. After 1 hour, MX (0.79 ± 0.09) and RSC (0.90 ± 0.10) showed the highest TP values. After 1 day, MX (7.97 ± 0.49) continued to exhibit the highest TP mean, followed by RSC (3.7 ± 0.14) ($p < 0.05$). After 1

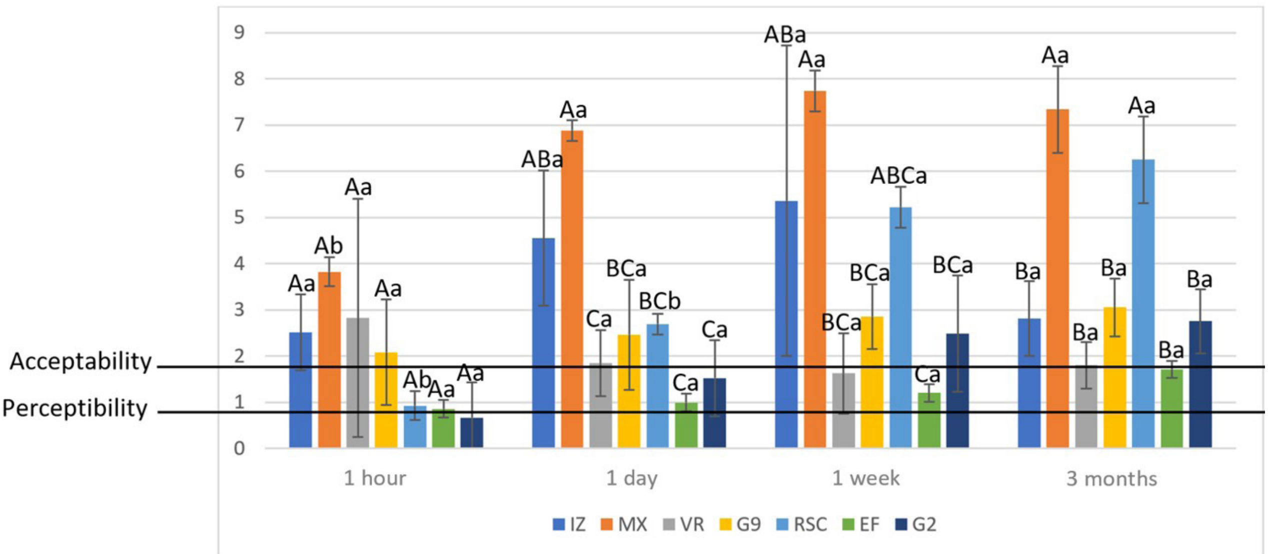

Figure 1 - Mean and standard deviation of ΔE of GICs studied at different times. *Different capital letters indicate statistical difference (p<0.05) between materials, and lowercase letters indicate statistical difference (p<0.05) between experimental times. *Baseline: 10 minutes; Legend: IZ – Ion-Z, MX – Maxxion R, VR – Vidrion R, G9 – GC Gold Label 9 R, RV – Riva Self Cure, G2 – GC Gold Label 2 LC R, EF – Equia Forte.

Table II - Mean and standard deviation of △E00 of conventional and modified GIC at different times

Glass ionomer	Experimental times			
	1 hour	1 day	1 week	3 months
Conventional	2.43(1.68)^{Ad}	3.68(2.1)^{Abc}	4.56(2.71)^{Aa}	4.25(2.3)^{Aac}
Resin-modified	0.76(0.54)^{Aa}	1.26(0.66)^{Ba}	1.84(1.15)^{Aa}	2.23(0.75)^{Aa}

Different capital letters indicate statistical difference (p<0.05) between conventional and resin-modified glass ionomer cements, and lowercase letters indicate statistical difference (p<0.05) between experimental times.

Table III - Mean and standard deviation of TP of GICs in different times

Ionomer	Experimental times			
	1 hour	1 day	1 week	3 months
IZ	0.21 (0.10)^{Cb}	2.26 (0.21)^{CDa}	2.64 (0.15)^{Ca}	1.57 (0.14)^{Cab}
MX	0.79 (0.09)^{Ac}	7.97 (0.49)^{Aa}	5.63 (0.09)^{Ab}	4.96 (0.75)^{ABb}
VR	0.58 (0.05)^{Bc}	1.86 (0.12)^{Db}	3.07 (0.47)^{Ca}	2.52 (1.63)^{BCab}
G9	0.43 (0.04)^{Bc}	1.74 (0.08)^{DEb}	2.79 (0.06)^{Ca}	2.61 (0.94)^{BCab}
RSC	0.90 (0.10)^{Ac}	3.7 (0.14)^{Bb}	6.15 (0.15)^{Aa}	7.32 (0.72)^{Aa}
EF	0.08 (0.03)^{Cc}	1.12 (0.24)^{Eb}	1.43 (0.05)^{Db}	3.79 (0.95)^{BCa}
G2	0.18 (0.07)^{Cc}	2.66 (0.31)^{Cb}	3.86 (0.22)^{Ba}	3.15 (0.89)^{BCab}

Different capital letters indicate statistical difference (p<0.05) between materials, and lowercase letters indicate statistical difference (p<0.05) between experimental times.

week, EF (1.12 ± 0.24) presented the lowest TP value, while MX and RSC presented the highest values. MX (4.96 ± 0.75). RSC (7.32 ± 0.72) were the materials that presented the highest TP values after 3 months. MX reached its peak value after 1 day (Table III).

G2, RSC, G9 and VR presented their highest TPs at the 1-week and 3-month evaluations, with no significant difference between these experimental times ($p \geq 0.05$). TP values for IZ increased from 1 hour to 1 day and then remained stable. MX presented an important increase from 1 hour (0.79 ± 0.09) to 1 day (7.97 ± 0.49), decreased from 1 day to 1 week (5.63 ± 0.09), and then stabilized thereafter. EF values did not significantly differ from 1 day (1.12 ± 0.24) to 1 week (1.43 ± 0.05) and increased at 3 months (3.79 ± 0.95). All GICs showed an increase in TP from 1 hour to 3 months, except for IZ, which showed no difference at 3 months but still showed increases at 1 day and 1 week compared to the 1-hour assessment.

DISCUSSION

It is expected that the color of a restorative material will be stable from its initial setting throughout its lifetime. Based on the results of this study, it was observed that different GICs exhibited varying behaviors in terms of color change and translucency, highlighting the difficulty in achieving predictable aesthetic outcomes with these materials.

Among the GICs studied, Equia Forte was the most stable material in terms of color change and acceptable color throughout the experimental period; even though it exhibited translucency alterations. Vidrion R, Gold Label 2, and Gold Label 9 also demonstrated some color stability. These findings suggest that these materials may meet the esthetic expectations of older adults, for whom natural appearance [20] in restorations are of great importance. Conversely, Riva Self Cure and Maxxion R exhibited the most pronounced color changes and highest translucency values at 3 months, indicating limited esthetic predictability. Ion Z, Maxxion R, and Gold Label 9 showed visually unacceptable color changes at all time points, underscoring the difficulty in maintaining shade stability with many GICs currently available.

None of the GICs showed translucency stability across all experimental time points. Therefore, according to the results, the hypothesis was partially accepted, as color and translucency changes were observed for all the analyzed GICs in the long term, except for EF, which presented color change considered acceptable.

All materials exhibited increased translucency over time, which was especially notable for Maxxion R and Riva Self Cure. The incorporation and loss of water is a major fact influencing GIC translucency. These findings are consistent with the understanding that water incorporation is a key factor influencing translucency in GICs. Water acts as a solvent for polyacrylic acid and facilitates the acid-base setting reaction but also interacts with the cement matrix by binding to metal ions and filling voids during the setting reaction [25,26]. The gradual hydrolysis of Si–O–Si bonds allows water molecules to occupy space within the matrix, decreasing light scattering and increasing translucency [25,26]. This process continues over time with material exposure to saliva or, in this study, distilled water, explaining the translucency increase observed over 3 months. The need to protect restorations during the early setting stage is therefore crucial. Preventing the evaporation of unbound water is essential to avoid surface microfractures and increased opacity. Finishing glosses, petroleum jelly, or light-cured coatings, depending on the material and manufacturer's instructions, help to decrease these risks [31].

In esthetic areas, such as root caries and cervical lesions in anterior teeeth, color and translucency stability are essential for successful shade matching and long-term esthetic outcomes. Carious dentin often presents altered coloration, which makes color matching more complex. Studies with composite resins [32,33] have demonstrated that substrates with discoloration often require more opaque restorative materials to achieve proper masking. Vattanaseangsiri et al. (2022) [34] compared the translucency of a conventional GIC to that of various resin-based composites and demonstrated that the GIC had the highest opacity, and it provided a less natural aesthetic effect [34]. The study demonstrated that the GIC showed increased translucency after simulating a 3-year aging process, but after 4 to 5 years of aging, the translucency decreased again [34]. In the present study, this difference was evaluated for 3 months, and during this period there was also an increase in translucency, as previously discussed. While such an increase may improve esthetic integration by approximating natural tooth translucency, long-term stability is even more critical to ensure predictable outcomes—especially in anterior teeth of elderly patients [5,6]. showed that 10-minute delayed light-curing reduced color and translucency change of a resin-modified GIC while maintaining the mechanical characteristics [35], suggesting this protocol could be a valuable strategy for improving esthetic reliability.

A 72-month clinical study comparing a RMGIC, Riva Light Cure, and resin composite for carious cervical lesion found no significant difference in retention or marginal adaptation between them, but greater color alteration was noted for the RMGIC [36]. The RMGIC employed by those authors [36] is from the same manufacturer than Riva Self Cure, the conventional GIC with the worst results in our study. These findings emphasize that color and translucency instability can compromise the long-term esthetic outcomes of GICs in anterior teeth, raising doubts about their use in highly esthetic zones.

A similar study evaluating translucency in GICs [28], that compared common materials, evaluated only 1 week after restoration and the results differed from those of the present study in this same experimental time. A hypothesis for this difference might be the variation in the specimens' dimensions [37] because thickness is an important factor while measuring translucency. Uchimura et al. [28] analyzed specimens with a thickness of 1 mm, while in the present study, the specimens were prepared with a 2-mm thickness. Furthermore, the use of different equipment for evaluation can affect the sensitivity of the readings. In both studies, the samples were stored under similar conditions.

Some researchers have reached a consensus that translucency would be of secondary importance in the evaluation of a GIC, while compressive strength, microhardness, degradation, and fluoride release would be considered primary factors [38]. Nonetheless, it would be interesting to develop GICs with satisfactory mechanical properties while maintaining their aesthetic aspects, considering the growth of the population's aesthetic demand [9]. Resin-modified GICs showed more stable esthetic behavior than conventional ones, as expected [39], particularly Equia Forte, which maintained acceptable color stability and is supported in the literature for having acceptable mechanical performance within the first six months [3]. Although Gold Label 2 exhibited an unacceptable color change after one week, its behavior stabilized thereafter, and it has also demonstrated satisfactory mechanical properties according to prior studies [38]. Therefore, these materials appear to be moving towards a combination of aesthetic and mechanical properties.

Despite the well-defined results of this research, under controlled aging conditions in distilled water, its three-month evaluation period represents a limitation; therefore, a longer follow-up could provide a greater representation of the color and translucency behavior of GICs over time. Also, only a limited range of resin-modified GICs was tested, and the in-vitro design may not fully replicate the clinical conditions. All specimens were standardized at 2 mm to enable consistent comparisons; however, translucency is thickness-dependent, which may limit generalization to restorations of different dimensions. Previous studies by Dinakaran (2014) and Lima et al. (2018) [40,41] have evaluated water sorption and solubility of GICs in different storage solutions, but did not focus on optical behavior. In clinical practice, external factors such as exposure to pigmented beverages, tooth brushing, and pH changes also affect optical properties. Therefore, future research should include clinically relevant conditions, such as artificial saliva, extrinsic pigments, varied thicknesses, and longer observational periods, to deepen our understanding of the long-term esthetic performance of GICs.

CONCLUSION

Within the limitations of the current study, it was concluded that conventional and resin-modified GICs showed perceptible color changes after the initial setting, and over time. Additionally, none of the GICs showed translucency stability across all the experimental times. Equia Forte was the only material that showed acceptable color changes at all experimental times.

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Author's Contributions

CAA: Data Curation, Formal Analysis, Visualization, Writing – Original Draft Preparation. LMSR: Data Curation, Investigation. EMS: Validation, Writing – Review & Editing. CAKS: Validation, Writing – Review & Editing. MAPS: Conceptualization, Methodology, Project Administration, Supervision, Writing – Review & Editing

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

Ethics committee approval was not required.

REFERENCES

1. Bezerra IM, Brito ACM, Sousa SA, Santiago BM, Cavalcanti YW, Almeida LFD. Glass ionomer cements compared with composite resin in restoration of noncarious cervical lesions: A systematic review and meta-analysis. Heliyon. 2020;6(5):e03969. http://doi.org/10.1016/j.heliyon.2020.e03969. PMid:32462087.
2. Patano A, Malcangi G, De Santis M, Morolla R, Settanni V, Piras F, et al. Conservative treatment of dental non-carious cervical lesions: a scoping review. Biomedicines. 2023;11(6):1530. http://doi.org/10.3390/biomedicines11061530. PMid:37371625.
3. Schwendicke F, Müller A, Seifert T, Jeggle-Engbert LM, Paris S, Göstemeyer G. Glass hybrid versus composite for non-carious cervical lesions: Survival, restoration quality and costs in randomized controlled trial after 3 years. J Dent. 2021;110:103689. http://doi.org/10.1016/j.jdent.2021.103689. PMid:33979577.
4. Santos MJ, Ari N, Steele S, Costella J, Banting D. Retention of tooth-colored restorations in non-carious cervical lesions--a systematic review. Clin Oral Investig. 2014;18(5):1369-81. http://doi.org/10.1007/s00784-014-1220-7. PMid:24671713.
5. Kampanas NS, Antoniadou M. Glass ionomer cements for the restoration of non-carious cervical lesions in the geriatric patient. J Funct Biomater. 2018;9(3):42. http://doi.org/10.3390/jfb9030042. PMid:29986535.
6. Amer RS, Kolker JL. Restoration of root surface caries in vulnerable elderly patients: a review of the literature. Spec Care Dentist. 2013;33(3):141-9. http://doi.org/10.1111/j.1754-4505.2012.00302.x. PMid:23600986.
7. Huang Y, Song B, Zhou X, Chen H, Wang H, Cheng L. Dental restorative materials for elderly populations. Polymers. 2021;13(5):828. http://doi.org/10.3390/polym13050828. PMid:33800358.
8. Forsten L. Fluoride release and uptake by glass-ionomers and related materials and its clinical effect. Biomaterials. 1998;19(6):503-8. http://doi.org/10.1016/S0142-9612(97)00130-0. PMid:9645556.
9. Pucinelli CM, Silva RAB, Borges LL, Borges ATN, Nelson-Filho P, Consolaro A, et al. Tissue response after subcutaneous implantation of different glass ionomer-based cements. Braz Dent J. 2019;30(6):599-606. http://doi.org/10.1590/0103-6440201902619. PMid:31800755.
10. Lin A, McIntyre NS, Davidson RD. Studies on the adhesion of glass-ionomer cements to dentin. J Dent Res. 1992;71(11):1836-41. http://doi.org/10.1177/00220345920710111401. PMid:1401448.
11. Ismail Z, Ahmad WIW, Hamjah SH, Astina IK. The impact of population ageing: a review. Iran J Public Health. 2021;50(12):2451-60. http://doi.org/10.18502/ijph.v50i12.7927. PMid:36317043.

12. Techa-Ungkul C, Sakoolnamarka R. The effect of dentin age on the microshear bond strength and microleakage of glass-ionomer cements. Gerodontology. 2021;38(3):259-66. http://doi.org/10.1111/ger.12520. PMid:33354808.

13. Zhang J, Leung KCM, Sardana D, Wong MCM, Lo ECM. Risk predictors of dental root caries: a systematic review. J Dent. 2019;89:103166. http://doi.org/10.1016/j.jdent.2019.07.004. PMid:31301318.

14. Fure S. Ten-year cross-sectional and incidence study of coronal and root caries and some related factors in elderly Swedish individuals. Gerodontology. 2004;21(3):130-40. http://doi.org/10.1111/j.1741-2358.2004.00025.x. PMid:15369015.

15. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. J Dent Res. 2015;94(5):650-8. http://doi.org/10.1177/0022034515573272. PMid:25740856.

16. Gavinha S, Melo P, Costa L, Monteiro PM, Manso MC. Dental tooth decay profile in an institutionalized elder population of Northern Portugal. Braz Dent Sci. 2020;23(2). http://doi.org/10.14295/bds.2020.v23i2.1940.

17. Diaz de Guillory C, Schoolfield JD, Johnson D, Yeh CK, Chen S, Cappelli DP, et al. Co-relationships between glandular salivary flow rates and dental caries. Gerodontology. 2014;31(3):210-9. http://doi.org/10.1111/ger.12028. PMid:23289887.

18. Lamster IB, Asadourian L, Del Carmen T, Friedman PK. The aging mouth: differentiating normal aging from disease. Periodontol 2000. 2016;72(1):96-107. http://doi.org/10.1111/prd.12131. PMid:27501493.

19. Nicholson JW, Sidhu SK, Czarnecka B. Enhancing the mechanical properties of glass-ionomer dental cements: a review. Materials. 2020;13(11):2510. http://doi.org/10.3390/ma13112510. PMid:32486416.

20. Carlsson GE, Johansson A, Johansson AK, Ordell S, Ekbäck G, Unell L. Attitudes toward dental appearance in 50- and 60-Year-old subjects living in Sweden. J Esthet Restor Dent. 2008;20(1):46-55. http://doi.org/10.1111/j.1708-8240.2008.00148.x. PMid:18237340.

21. Johansson A, Omar R, Carlsson GE, Sannevik J, Mastrovito B, Johansson AK. Satisfaction with dental appearance in two cohorts of 75-year-olds examined in 2007 and 2017: a repeated cross-sectional study. J Oral Rehabil. 2022;49(11):1060-8. http://doi.org/10.1111/joor.13361. PMid:35962634.

22. Schmeling M, Andrada MA, Maia HP, Araújo EM. Translucency of value resin composites used to replace enamel in stratified composite restoration techniques. J Esthet Restor Dent. 2012;24(1):53-8. http://doi.org/10.1111/j.1708-8240.2011.00419.x. PMid:22296696.

23. Lee YK. Translucency of human teeth and dental restorative materials and its clinical relevance. J Biomed Opt. 2015;20(4):045002. http://doi.org/10.1117/1.JBO.20.4.045002. PMid:25875626.

24. Prabhakar A, Pattanshetti K, Sugandhan S. A comparative study of color stability and fluoride release from glass ionomer cements combined with chlorhexidine. Int J Clin Pediatr Dent. 2013;6(1):26-9. http://doi.org/10.5005/jp-journals-10005-1181. PMid:25206183.

25. Sidhu SK, Nicholson JW. A review of glass-ionomer cements for clinical dentistry. J Funct Biomater. 2016;7(3):16. http://doi.org/10.3390/jfb7030016. PMid:27367737.

26. Nicholson JW. Chemistry of glass-ionomer cements: a review. Biomaterials. 1998;19(6):485-94. http://doi.org/10.1016/S0142-9612(97)00128-2. PMid:9645554.

27. Boing TF, Geus JL, Wambier LM, Loguercio AD, Reis A, Gomes OMM. Are glass-ionomer cement restorations in cervical lesions more long-lasting than resin-based composite resins? a systematic review and meta-analysis. J Adhes Dent. 2018;20(5):435-52. PMid:30349908.

28. Uchimura JYT, Sato F, Santana RG, Menezes-Silva R, Bueno LS, Borges AFS, et al. Translucency parameter of conventional restorative glass-ionomer cements. J Esthet Restor Dent. 2021;33(6):935-42. http://doi.org/10.1111/jerd.12685. PMid:33188585.

29. Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. Color Res Appl. 2001;26(5):340-50. http://doi.org/10.1002/col.1049.

30. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont. 1995;8(1):79-86. PMid:7710631.

31. Yilmaz MN, Gul P, Kiziltunc A. Water sorption and solubility of a high-viscous glass-ionomer cement after the application of different surface-coating agents. Eur J Gen Dent. 2020;9(3):118-21. http://doi.org/10.4103/ejgd.ejgd_50_20.

32. Perez BG, Gaidarji B, Palm BG, Ruiz-López J, Pérez MM, Durand LB. Masking ability of resin composites: effect of the layering strategy and substrate color. J Esthet Restor Dent. 2022;34(8):1206-12. http://doi.org/10.1111/jerd.12942. PMid:35851989.

33. Perez BG, Gaidarji B, Righes DZ, Pecho OE, Pereira GKR, Durand LB. Masking ability of resin composites: a scoping review. J Esthet Restor Dent. 2023;35(2):333-44. http://doi.org/10.1111/jerd.12976. PMid:36260930.

34. Vattanaseangsiri T, Khawpongampai A, Sittipholvanichkul P, Jittapiromsak N, Posritong S, Wayakanon K. Influence of restorative material translucency on the chameleon effect. Sci Rep. 2022;12(1):8871. http://doi.org/10.1038/s41598-022-12983-y. PMid:35614191.

35. Nejatifard M, Panahandeh N, Ghasemi A, Torabzadeh H. Effect of delayed light-curing on solubility, color stability, and opacity of Fuji II LC glass ionomer cement: original article. Braz Dent Sci. 2022;25(2):e2467. http://doi.org/10.4322/bds.2022.e2467.

36. Koç-Vural U, Kerimova-Köse L, Kiremitci A. Long-term clinical comparison of a resin-based composite and resin modified glass ionomer in the treatment of cervical caries lesions. Odontology. 2025;113(1):404-15. http://doi.org/10.1007/s10266-024-00958-6. PMid:38837034.

37. Navarro MFL, Pascotto RC, Borges AFS, Soares CJ, Raggio DP, Rios D, et al. Consensus on glass-ionomer cement thresholds for restorative indications. J Dent. 2021;107:103609. http://doi.org/10.1016/j.jdent.2021.103609. PMid:33610589.

38. Moshaverinia M, Navas A, Jahedmanesh N, Shah KC, Moshaverinia A, Ansari S. Comparative evaluation of the physical properties of a reinforced glass ionomer dental restorative material. J Prosthet Dent. 2019;122(2):154-9. http://doi.org/10.1016/j.prosdent.2019.03.012. PMid:31326149.

39. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27(1, Suppl 1):S1-9. PMid:25886208.

40. Dinakaran S. Sorption and solubility characteristics of compomer, conventional and resin modified glass-ionomer immersed in various media. IOSR J Dent Med Sci. 2014;13(3):41-5. http://doi.org/10.9790/0853-13314145.

41. Lima RBW, Farias JFG, Andrade AKM, Silva FDSCM, Duarte RM. Water sorption and solubility of glass ionomer cements indicated for atraumatic restorative treatment considering the time and the pH of the storage solution. RGO. 2018;66(1):29-34. http://doi.org/10.1590/1981-863720180001000043100.

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