Masking Ability of Prosthetic Substrates by a Conventional Resin Luting Agent and the Effect of the Core on the Final Color of Lithium Disilicate Crowns

Keywords

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ABSTRACT

*Introduction: Thin all-ceramic restorations enhance esthetics but are less predictable, especially with dark substrates, where opaque resin luting agents may be needed, though not always available. This study aimed to evaluate the influence of a resin luting agent on the final color of lithium disilicate crowns and masking of two prosthetic substrates (esthetic and metallic). Methods: Eighty prostheses with ceramic crowns were simulated from bovine roots. The specimens were randomized, according to the intraradicular retainer used, and divided into 2 groups (n=40): metallic (cast post and core) and esthetic (glass fiber post with composite resin core). The crowns were attached to their cores and the first CIELAB scale was measured with a spectrophotometer. The second color measurement was performed after cementation with a dual resin luting agent. The results were submitted to color variation calculation and statistical analysis. Results: Coordinate * L and * b values increased significantly ($p<0.05$) after cementation for both groups and there was no statistical difference between the groups for the ΔE00 value ($p=0.242$). Conclusions: Resin luting agent positively impacted the final crown color and aided in masking both substrates. The effect of the substrate was attenuated on the final color of ceramic crowns.*

INTRODUCTION

The increasing requirements and demands of patients seeking esthetic restorations are well known; in such cases, clinical success depends on the perfect combination of color and optical properties between the restoration and the adjacent natural teeth[1-3]. These expectations have led dentists to choose lithium disilicate-based ceramics as the material of choice for indirect restorations in esthetic areas due to their high translucency combined with a high crystalline content, which provides good mechanical resistance, addressing both functional needs and patient satisfaction[4-8]. The challenge becomes even greater when the tooth has extensive coronal decay, requiring an intraradicular retainer, which can be a glass fiber post associated with a composite resin core or a cast post and core[9,10]. It is known that the final color of indirect lithium disilicate restorations

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depends on the translucency and thickness of the ceramic, as well as the color and opacity of the luting agent and substrate, which together function as a single unit[2,11-14].

All-ceramic and thin restorations (e.g., 1.0-1.5 mm) allow for greater translucency, which is desirable for esthetic demands, although it makes the outcome less predictable[4,12,13,15]. This is especially true in cases involving metallic or darkened substrates, which can create a shadow-like effect in the restoration due to the obstruction of light transmission, making it difficult to mask with more translucent ceramics such as lithium disilicate[4,13,16]. The use of resin luting agents (RLA) has been discussed as a strategy to help mask prosthetic substrates; however, the cement layer is very thin and may not significantly influence the final result[2,6,11,17]. Preheated composite resin can be used as both a cementation material and a masking agent; however, it has a higher film thickness, which may compromise the restorative complex[18]. Flowable composite resin is another option, but achieving an ideal outcome on darkened substrates remains challenging regardless of the material used[19]. The use of opaque resin luting agents is also well-documented, as they aid in masking by preventing light transmission[6,11,13,14]. However, this type of material is not always readily available to dentists, as it is used only in specific cases.

Although the use of opaque resin luting agents for masking is well established[6,11,13,14], few studies have evaluated the effect of a conventional resin luting agent on the final shade of indirect restorations. Furthermore, the vast majority of studies use disc-shaped specimens to obtain color coordinates[20]. However, the surface of this type of sample does not replicate the curvatures and anatomy of the buccal surface of a tooth or crown, which may impact the accuracy of color coordinate readings. Therefore, this study aimed to evaluate the influence of a conventional resin luting agent on the final color of lithium disilicate crowns and the masking ability of two prosthetic substrates (esthetic or metallic) using a study design that better mimics a realistic clinical situation. The study hypothesis is the following: (i) the color of lithium disilicate crowns will differ depending on the type of substrate when no luting agent is applied; and (ii) the color of lithium disilicate crowns will be similar regardless the type of substrate upon the presence of luting agent.

MATERIALS AND METHODS

STUDY DESIGN

This *in vitro* 2 × 2 factorial study (n = 40) evaluated two factors: post-core restorative system (esthetic or metallic) and the presence of a resin luting agent (with RLA or without RLA). The sample size was calculated using the SigmaPlot (Systat Software Inc., USA) sample size calculator and was based on a previous study[21], considering a comparative design with four dependent groups, an average difference in color alteration between groups of 1.8, an average standard deviation of 3.4, $\alpha = 0.05$, and a test power of 0.9. The response variables evaluated in the study were color alteration (ΔE00), darkness scores (Vitapan scale), and changes in the L*, a*, and b* color coordinates (ΔL*, Δa*, and Δb*, respectively).

SAMPLE PREPARATION AND GROUP ALLOCATION

Eighty bovine central incisors were selected, cleaned with a #11 scalpel blade, and disinfected by immersion in a 1.23% chlorhexidine solution for 2 hours. The teeth were then stored in distilled water at 4ºC until use, with a maximum storage period of 3 months. The coronal portion of the teeth was removed using a high-speed handpiece and a #1048 diamond bur (KG Sorensen, Brazil) under constant air-water spray irrigation. The root samples were manually instrumented using a crown-down technique under continuous irrigation with 2.5% sodium hypochlorite. The root canal space of each tooth was filled with a second-series main gutta-percha cone, accessory cones (Dentsply Maillefer, Switzerland), and a calcium hydroxide-based sealer (Sealer 26; Dentsply Maillefer) using the lateral condensation technique. After one week of wet storage in a dark environment at 37°C, the root canals were unfilled, leaving a 4 mm apical portion of root filling material. To achieve this, a #3 Fiber Post Drill (FGM, Brazil) was used to remove the root filling material up to the intended position, followed by cleaning of the intracanal space with distilled water. The samples were then randomly allocated (using the Random Allocator computer software) into two groups according to the post-core restorative system (n = 40 per group): esthetic or metallic. In the esthetic group, the teeth were restored using glass-fiber posts and composite resin as the core, whereas in the metallic group, the post-core system was made of cast metal.

FABRICATION AND CEMENTATION OF THE POST-CORE SYSTEMS

For the esthetic post-core system, a #3 glass-fiber post (White Post DC; FGM) was fitted into the root canal and sectioned using high-speed diamond burs, leaving a 4 mm coronal portion. The post was cleaned with 70% alcohol and treated with a silane coupling agent (ProSil; FGM) according to the manufacturer's instructions. Each root canal was acid-etched with 37% phosphoric acid gel (Condac; FGM) for 15 seconds, followed by thorough rinsing with an air-water spray, drying with paper points, and treatment with a two-step etch-and-rinse adhesive system (Ambar; FGM). The adhesive was actively applied for 20 seconds, and the solvent was volatilized for 10 seconds. Light activation was performed for 40 seconds using a light-emitting diode (LED) curing unit (Radii; SDI, Australia) with an irradiance of 1600 mW/cm², which was connected to a power source during use. The irradiance was verified before each step. Next, the silane-treated glass-fiber post was cemented into the root canal using a resin luting agent (AllCem; FGM) in shade A2; any excess material was removed, and light activation was performed for 40 seconds on each surface. After post cementation, the core was built using a standardized transparent plastic mold and a micro-hybrid composite

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resin (Opallis; FGM, shade A2) applied using the incremental technique. Light activation was performed for 20 seconds on each resin increment. Each composite resin core was refined by an experienced operator using #4138F, #4138FF, #3118F, and #3118FF diamond burs (KG Sorensen®, Brazil). The core design included a cervical third inclination between 2° and 5° toward the incisal surface and an axial face inclination between 5° and 10° in the incisal third to ensure stability and retention of the crown restoration. The preparation depth was standardized at 1.2 mm in all regions.

For the metallic post-core system, the entire root canal extension was molded using prefabricated plastic posts (Pinjet; Angelus, Brazil) and acrylic resin (Duralay; USA). A standardized core was also used, based on plastic matrices simulating the core of lower premolar teeth. The acrylic resin patterns were cast using nickel-chrome alloys, following the manufacturers' recommendations, and this procedure was carried out in a prosthetic laboratory. After casting, the metallic post-core systems were evaluated for fit in the respective root canals using liquid carbon; once the fit was smooth, the post-core system was cleaned with isopropyl alcohol, followed by blasting the root portion with aluminum oxide particles (110 µm; 2.8 bar pressure; at a distance of 10 mm) for 15 seconds. The cementation of the post-and-core system and the refinement of the core with diamond burs were performed as previously described for the esthetic group. No resin or other masking agent was added to the metallic core prior to the cementation of the crowns

FABRICATION OF THE CERAMIC CROWN RESTORATIONS AND COLOR EVALUATION

Eighty crowns made from monolithic lithium disilicate ceramic (IPS e.max Press; Ivoclar Vivadent, Schaan, Liechtenstein) simulating a second premolar were fabricated using the thermo-injection technique, with standardized thicknesses of 1.5 mm and 1.2 mm at the margins. The color of the translucent ingots was HT A3.5, according to the manufacturer's recommendation. After fabrication, the crowns were placed onto their respective core systems using glycerin, as it has a refractive index similar to that of glassy ceramics[22,23]. The color of each crown was measured using a digital spectrophotometer (Vita Easyshade; Vita Zahnfabrik, Bad Sackingen, Germany), previously calibrated, using the CIELab* color system. Each measurement was the average of three readings taken at the middle third of the crown, using a white background. All measurements were performed at the same time under standardized ambient light conditions (artificial light).

CEMENTATION OF THE CERAMIC CROWNS AND RE-EVALUATION OF THE COLOR COORDINATES

After the baseline color measurement, the coronal remnant of each tooth was acid-etched with 37% phosphoric acid (Condac; FGM) for 15 seconds, and the Ambar adhesive system was applied for 20 seconds, followed by volatilization of the solvent for 10 seconds. Light activation was performed using the LED for 20 seconds. The inner surface of the ceramic crowns was acid-etched with 10% hydrofluoric acid (Condac Porcelain 10%; FGM) for 20 seconds, followed by air-water spray washing and air-drying. A silane coupling agent (Prosil; FGM) was applied according to the manufacturer's instructions, and after 1 minute, the dual resin luting agent AllCem (FGM, shade A2) was applied to the ceramic crown, which was then placed onto the respective core. Any excess material was removed, and each surface of the crown was light-activated for 40 seconds with the LED. After cementation of the crowns, a new color measurement was performed as described previously, using exactly the same standards as the first measurement.

CALCULATION OF THE COLOR VARIATION AND STATISTICAL ANALYSIS

The color variation (ΔE_{00}) derived from the cementation procedure was calculated using the following equation according to CIEDE2000 method[24]:

$$\Delta E_{00} = [(\Delta L'/K_L S_L)^2 + (\Delta C'/K_C S_C)^2 + (\Delta H'/K_H S_H)^2 + R_T(\Delta C'/K_C S_C)(\Delta H'/K_H S_H)]^{½}$$

where ΔL', ΔC', and ΔH' are the differences in lightness, chroma, and hue between two sets of color coordinates. R_T (rotation term) is a function that accounts for the interaction between chroma and hue differences in the blue region, improving the color difference equation performance. The $K_L S_L$, $K_C S_C$ and $K_H S_H$ are empirical terms used for weighting the metric differences to the CIEDE2000 differences for each coordinate. Parametric factors were set to K_L=2, K_H=1 and K_C=1. A ΔE_{00} value of 0.8 was considered a threshold for visually detectable color change since it corresponds to 50% visual perceptibility under clinical conditions[23]. The obtained data was analyzed with SigmaPlot (version 12.0) and with SPSS (version 22; IBM). The homoscedasticity of the data were checked using Shapiro-Wilk (p=0.002) and Levene's (p=0.023) tests, and considering the results, the data were statistically analyzed using Analysis of Variance on Ranks, Mann-Whitney, and Student-Newman-Keuls (as *post hoc* test) when appropriate.

RESULTS

The results for the average color shade (darkness scores according to the Vitapan shade guide) of teeth restored with different post-core materials are shown in Figure 1. The factors 'post-core restorative system (esthetic or metallic)' and 'availability of conventional resin luting agent (RLA)' were not significant ($p > 0.05$), although their interaction was significant ($p = 0.018$). In the absence of RLA, teeth restored with metallic post-core systems exhibited a darker color appearance than teeth restored with the esthetic system ($p < 0.001$). The use of RLA made the color shade of all restorations lighter ($p < 0.001$), regardless of the post-core system. The esthetic and metallic groups showed similar color shades in the presence of RLA ($p = 0.226$).

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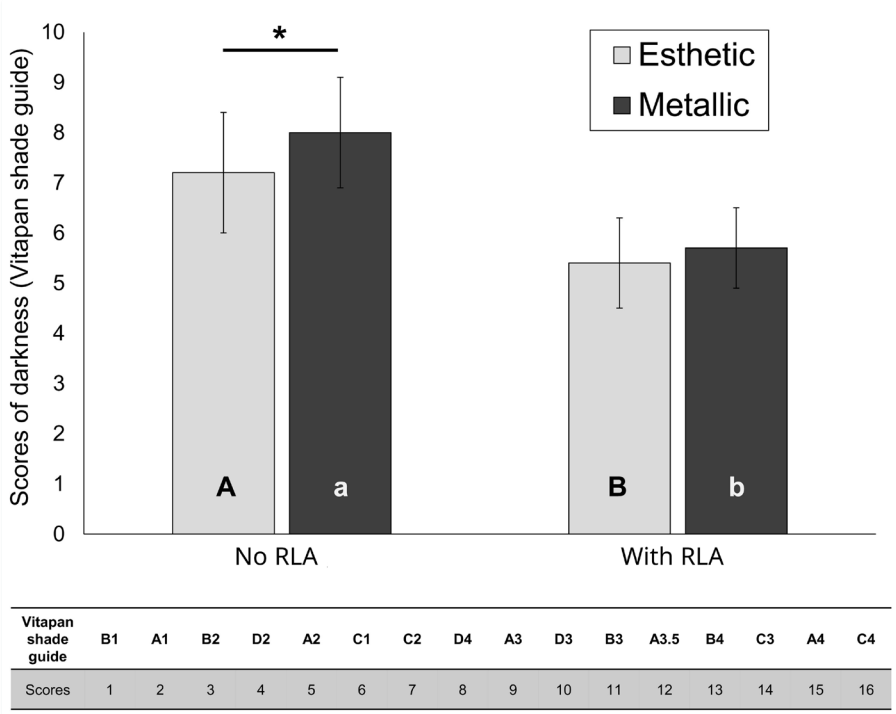

Vitapan shade guide	B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3.5	B4	C3	A4	C4
Scores	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Figure 1: Graph showing the results for the average color shade (scores of darkness according to the Vitapan shade guide) of teeth restored with different post-core materials. The presence of an asterisk above the bars indicates a statistically significant difference between the connected groups; also, different uppercase (for the esthetic group) and lowercase (for the metallic group) letters indicate significant differences between the absence or presence of resin luting agent (RLA).

The results for the modification of the L*, a*, and b* color parameters are shown in Figure 2. The L* coordinate value for the esthetic group was 73.3 ± 4.3 prior to cementation, statistically higher than the metallic group ($p < 0.001$), which showed a value of 70.1 ± 4.4. After cementation, both groups showed a statistically significant increase ($p < 0.001$) and remained different from each other ($p = 0.006$). The b* coordinate followed the same pattern as the L* coordinate. For the a* coordinate, there was no statistical difference between the values before and after cementation, only between the groups at both time points ($p = 0.044$ and $p < 0.001$).

The presence of the RLA resulted in similar color alteration for both types of post-core systems ($p=0.242$), and the ΔE_{00} median (minimum – maximum) values were as follows: ΔE_{00} = 3.3 (1.1 – 6.7) for the esthetic post-core group; and ΔE_{00} = 4.8 (0.6 – 10.2) for the metallic post-core group. All groups resulted in color alteration values above the threshold for visually detectable color change.

DISCUSSION

The present study assessed the influence of a RLA on the final color of lithium disilicate crowns applied to two prosthetic substrates: metallic and esthetic. The first hypothesis was accepted, as the groups showed statistically different values for darkness scores and CIELab coordinates prior to cementation. The second hypothesis was also accepted, as the RLA influenced the final color of restorations, aiding in masking the color of the core substrates. The crowns exhibited lighter and similar shades on the Vitapan Shade Guide after cementation, with the color variation being above the perceptibility threshold of 0.8[25], and significantly increased the values of the L* and b* coordinates.

Prior to cementation, the translucent (HT) monolithic ceramic was unable to mask both substrates, as they exhibited darker shades than A3.5 on the Vitapan scale, which was the shade choice for the ceramic. These results corroborate with previously published studies in the literature, evaluating 1.5 mm-thick lithium disilicate ceramics[4,6,11,14,26,27]. This material is composed of a crystalline phase containing elongated crystals within a randomly oriented scaffold, and a vitreous phase containing lithium metasilicate, responsible for the material's translucency[14]. HT ceramics have a lower quantity of crystals that prevent light dispersion through the material, and a higher vitreous portion, ensuring greater translucency[4,6]. However, in addition to composition and opacity level, the fraction of pigments and opacifiers added to achieve the desired color, as well as the manufacturing processes, can also influence the color and translucency of the material[28,29]. An increase in the ceramic thickness is suggested to aid in masking, but it would require a greater reduction of the retainers and cores, which could potentially compromise the mechanical properties of the restoration[30]. The study used a HT ceramic due to its desirable esthetic properties and because it allows easier visualization of the RLA's effect. If an opaque ceramic with a high masking ability was used, it would not be possible to observe the true impact of the RLA on the final color outcome.

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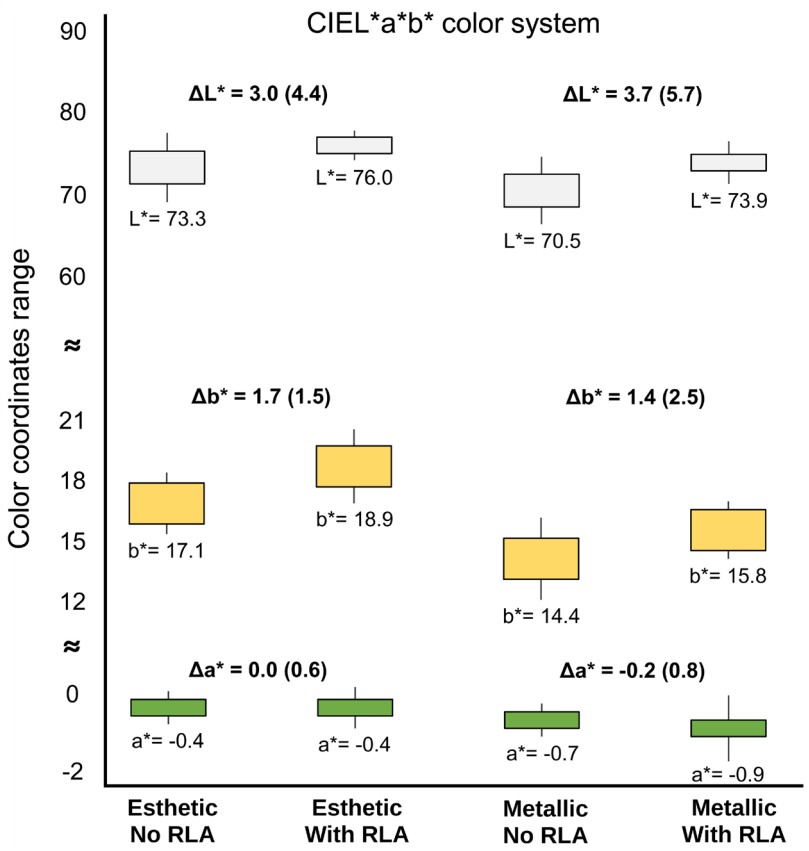

Figure 2: Boxplot graph showing the results of the L*, a*, and b* color parameters before and after the cementation for esthetic and metallic groups. The variation of the L*, a*, and b* parameters before (No RLA) and after (With RLA) cementation using the resin luting agent (RLA) are given as mean and standard deviation (SD) values.

In this study, the conventional RLA demonstrated a positive effect on the restorative system, making it lighter on the Vitapan scale and rendering both post-core systems similar after cementation, with a significant influence on the final color and masking ability. This result differs from the findings of another study that also investigated the influence of the core and RLA on the color of 0.8 mm lithium disilicate crowns, where the RLA in shade A2 did not cause color changes beyond the perceptibility threshold[31]. However, this discrepancy between the results may be attributed to the analysis of only the composite cores, the type of specimen (discs), and the brand of RLA used. RLAs labeled with the same shade name (e.g., A1, A2, C1) may exhibit different colors and opacities[28]. According to our findings, the use of the RLA induced a color variation above the perceptibility threshold ($\Delta E_{00} > 0.8$)[23], a characteristic often desirable in masking measurements[28]. Of note, this result was obtained only upon the use of yellow and white luting cements, as demonstrated elsewhere[32]. Also, the L* and b* coordinates increased after cementation, making the restoration brighter and more yellowish, and this may be explained because different hues and chromas can exhibit similar values. No less important, it is known that there can be a correlation between the L* coordinate and the translucency of the restorative system, with a higher value indicating lower translucency[27]. An A2 RLA was chosen instead of an A3.5 RLA corresponding to the ceramic because more saturated chroma shades can be more opaque[14] and the study's objective was to assess the influence of a RLA with a neutral opacity—neither translucent nor overly opaque.

The color change obtained in the post-core esthetic and metallic systems was similar, and considering the Vitapan scale, both groups showed similar shades after cementation. This corroborates the results of another study that assessed a metallic core and an A3 composite resin core, exhibiting similar behaviors, although under translucent zirconia[33]. Metallic cores can induce a darker appearance in the final color of crowns, attributed to heightened light absorption and reduced light transmission and reflection by the metal structure[34], as observed prior to crown cementation. However, with the presence of conventional RLA, this effect was attenuated since the L* coordinate (luminosity axis) had a statistically significant increase after cementation. Of note, the L*, a*, and b* coordinates in the esthetic group were statistically greater than those in the metallic group, corroborating the findings of another study that assessed the effect of metallic and composite resin substrates on lithium disilicate, demonstrating that the metallic core reduced the L* and b* coordinate values[30].

In this study, it was possible to investigate the influence of a conventional RLA on the final color of lithium disilicate crowns on different prosthetic substrates through a methodology that, despite being laboratory-based, closely resembles clinical reality, using teeth and post-core systems. Only four studies have reported similar methodologies for investigating

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color in indirect restorations[1,4,29,32], with the majority of studies using disc-shaped specimens with a smooth surface, which does not resemble the clinical scenario where we have a tooth with a vestibular surface that has varying curvatures due to its anatomy, potentially affecting light transmission and reflection[35]. Additionally, a significant sample size was used, providing greater reliability to the results. However, some limitations of the study include the use of only one shade of the resin luting agent and only one type of restorative material without thickness variation. Moreover, although the specimens represent restorative systems identical to those used in clinical settings, it is never possible to fully replicate in the laboratory all the conditions that can affect the color of crowns in the oral environment. It is important to highlight that new *in vitro* and *in vivo* studies should be conducted with different material options. Conducting a systematic review to compile existing literature would also be interesting. The final esthetic appearance of indirect restorations, especially in teeth with extensive coronal destruction, is often unpredictable for dentists. Therefore, results from this study, along with many others investigating the optical properties of restorations, are essential to guide the dentist's decision-making process, enabling them to achieve the desired outcome with greater confidence

CONCLUSION

It is possible to achieve adequate masking of prosthetic substrates using a conventional resin luting agent associated with lithium disilicate ceramics. After cementation, the effect of the post-core system used on the final color can be minimized.

ETHICAL CONSIDERATIONS

According to the local Ethical Review Board, the use of bovine teeth for research purposes is exempt from Ethical Approval.

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