Original Article

Comparative Evaluation of the Masking Ability of Lithium Disilicate Ceramic with Different Core Thickness on the Shade Match of Indirect Restorations over Metallic Substrate: An *In vitro* Study

Abstract

Purpose: The purpose of this in vitro study was to comparatively evaluate the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate. **Materials and Methods:** A total of 30 heat pressed lithium disilicate ceramic discs of low translucency were fabricated with diameter 10mm and thickness of 1 mm, 1.3 mm and 1.6mm with each thickness consisting of 10 samples to be used in the study. Thirty Ni-Cr metal discs of diameter 10mm were used to simulate metallic substrates .The colour difference of the lithium disilicate ceramic disc before and after cementation were measured using CIE LAB system. **Results:** The mean colour difference (ΔE) of Group I,Group II, Group III before cementation with the Ni-Cr metal discs was 17.32,13.01 and 11.73 respectively. The mean colour difference (ΔE) of Group I,Group II, Group III after cementation with the Ni-Cr metal discs was 16.32,12.10, 11.05 respectively. **Conclusion:** The mean colour difference of the three groups were found to be more than the clinically acceptable perceptibility threshold (ΔE < 3.3) indicative of reduced masking ability of all the three groups of ceramic discs over metallic substrate used in this study.

Keywords: *Heat-pressed ceramic, L*a*b*, lithium disilicate, masking ability, nickel-chromium, translucency, spectrophotometer*

Priyadarshini Thilagar, Jayakrishnakumar Sampathkumar, Chitra Shankar Krishnan, Hariharan Ramakrishnan, Hariharan Ramasubramanian, N. S. Azhagarasan[1]

Affliated to the Tamil Nadu Dr. M.G.R Medical University, [1]Department of Prosthodontics and Implantology, Ragas Dental College and Hospital, Uthandi, Chennai, Tamil Nadu, India

Introduction

Porcelain-fused to metal restorations have been regarded the gold standard in fixed prosthodontics with 94% success rate over 10 years with good mechanical properties, reasonable esthetics and an acceptable biological quality required for its service. However, porcelain-fused to metal restorations prosthesis has some limitations, which include increased light reflectivity from the opaque porcelain used to mask the metal coping and occasional graying of the gingival tissues resulting in an unattractive appearance.[1,2] This has led to the introduction of metal-free restorations as an alternative to metal-ceramic restorations in daily clinical practice, especially for anterior esthetic zone.

Newer metal-free crowns are made from different ceramic materials such as leucite-reinforced glass, lithium disilicate, glass-infiltrated alumina and zirconia.[3,4] Among the semitranslucent glass-ceramic systems, lithium disilicate has gained popularity for both anterior and posterior crowns because of its superior esthetics, adequate strength, wear resistance and chemical durability.

Lithium disilicate is a ceramic material that contains 70% by volume, needle-like crystals in a glassy matrix.[5] The controlled size, shape and density of this structure result in restoration that demonstrates high flexural strength and increased fracture toughness. This material has a low refractive index, a characteristic that allows the material to exhibit phenomenal optical properties and optimal esthetics. Lithium disilicate glass-ceramic can be processed using either the lost-wax heat-pressed technique or computer-aided design/computer-aided manufacturing version. The popularity of heat-pressed ceramics has risen markedly due to its similarity to conventional lost-wax technique and relatively inexpensive equipment.[6]

Address for correspondence:
Dr. Hariharan Ramakrishnan, Department of Prosthodontics and Implantology, Ragas Dental College and Hospital, Uthandi, Chennai - 600 119, Tamil Nadu, India.
E-mail: abcv2005@yahoo.com

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IPS e.max Press lithium disilicate ceramic presents relatively high flexural strength (350–400 MPa) and increased fracture toughness due to its smaller and more homogeneous crystals.[7] IPS e.max Press has been used successfully for monolithic fixed partial dentures even in the posterior area for as long as 8 years.[8]

The translucent core of all-ceramic crowns when indicated for masking heavily discolored teeth, titanium abutments and pre-existing post and core metallic foundation will have a detrimental effect on the optical behavior of the final restoration.[9-11] The masking effect of the ceramic material is primarily dependent on its translucent property. The translucency is indirectly proportional to the thickness of the core ceramic utilized.[2] Increase in thickness of the restoration can solve the problem of masking heavily discolored abutment. However, extensive abutment preparation or over contouring the restoration may violate the biological principle.

Several modalities have been employed in attaining an esthetic restoration. One such method makes use of translucent core ceramic with an opaque cement to mask the substrate. A far more predictable approach is to use a crown with a more opaque core that is less affected by the abutment color.[12,13]

Quantitative analysis of color coordinates using CIELAB color system with a spectrophotometer has been regarded a benchmark for research purposes and helps scrutinize the results with those obtained from the conventional shade tabs.[14-17] Compared with observations by the human eye or conventional techniques, it was found that spectrophotometers offered a 33% increase in accuracy and a more objective match in 93.3% of cases.[18]

The difference in color (ΔE) between two objects can then be determined by comparing the differences between respective coordinate values of each object.

The capacity of the human eye to notice differences in color varies among individuals; different ΔE values are used to distinguish differences in color: ΔE values <1 is considered undetectable by the human eye. Studies have used different ΔE values as clinically acceptable: 3.3 as the perceptibility limit and 5.5 as the acceptability tolerance.[9]

In view of the above, the purpose of this study was to evaluate the cumulative effect of the metal substrate, cement color and ceramic thickness on the optical resultant color of a glass-ceramic lithium disilicate-reinforced disc produced by heat press technology. The null hypothesis of the present study is that different core thicknesses of lithium disilicate ceramic material will not have any significant difference in masking ability over metallic substrates.

Materials and Methods

A custom-made metallic mold [Figure 1] was used to obtain plastic disc patterns of 10 mm diameter, for fabricating lithium disilicate ceramic discs and nickel-chromium (Ni-Cr) metal discs. The acetyl plastic

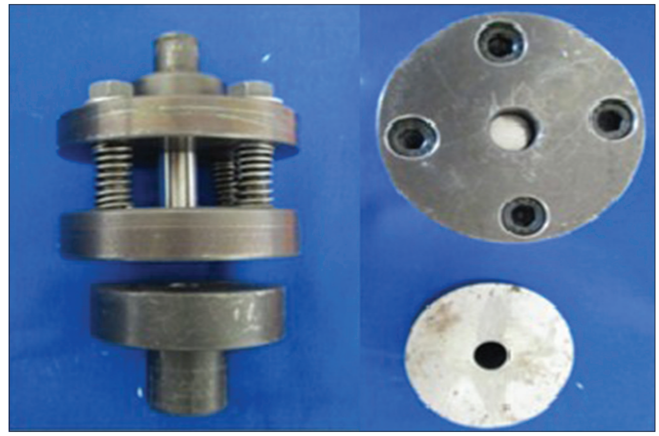


Figure 1: Parts of metallic mold

sheets of thickness 1 mm/1.3 mm/1.6 mm (Plastic House, Parrys Corner, Chennai) were placed between the base and the upper counterpart of the metallic mold, when the entire assembly was placed on the hand press machine [Figure 2]. Ten discs for each thickness of 1 mm/1.3 mm/1.6 mm were obtained making a total of 30 plastic disc patterns, for the fabrication of the lithium disilicate ceramic discs. Similarly, 30 plastic disc patterns of thickness 2.5 mm were obtained for the fabrication of metal substrate [Figure 3].

The patterns for fabrication of lithium disilicate ceramic discs were invested in phosphate-bonded investment (Bellavest SH, Bego, Germany) and heat pressed using low-translucency (LT) lithium disilicate pressable ingot (Ivoclar vivadent, USA) according to the manufacturer’s instructions. The ceramic discs were separated using a fine diamond disc (Dentorium, New York, USA) and finished using silicon carbide sheets of different grits [Figure 4]. The thickness of all the finished ceramic discs were verified with a digital vernier caliper. A total of 30 lithium disilicate ceramic discs were divided into 10 discs for each core thickness employed in this study. To mimic discolored substrates, thirty Ni-Cr metal discs of thickness 2.5 mm were fabricated [Figure 5]. The surface of metal to be luted with the resin cement was cleaned with pressurized steam for removal of any surface contaminants using a steam cleaner. The surface was air-abraded with 50 µm aluminum oxide at 75 Psi pressure. Ten metal discs were randomly assigned to each of the groups of lithium disilicate ceramic.

The color parameters (L*a*b*) of the ceramic discs were determined against a standard white background [Figure 6] (A4 sheet, 75 Gsm ,JK Copier ,JK Paper Limited, Chennai) with CM-3600d spectrophotometer in wavelength of 360–740 nm.

The L*, a*, and b* parameters were measured according to the Commission Internationale de I’Eclairage (CIE) using D-65 illuminant and observer function at 10°. To measure the color parameters of the lithium disilicate ceramic discs when placed over Ni-Cr metal substrates before cementation, a drop of distilled water with a refractive

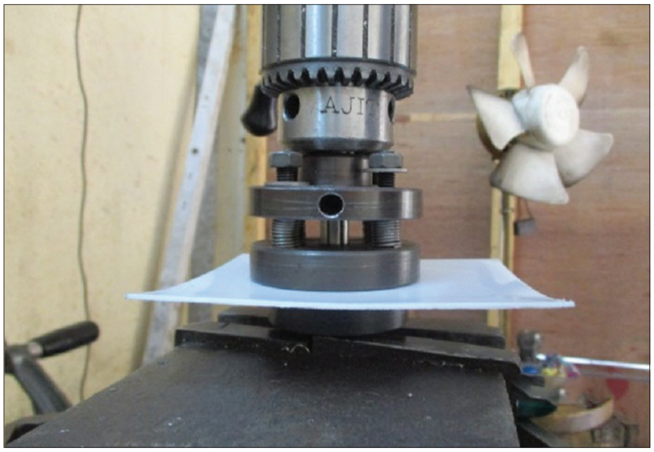


Figure 2: Metallic mold in hand press machine

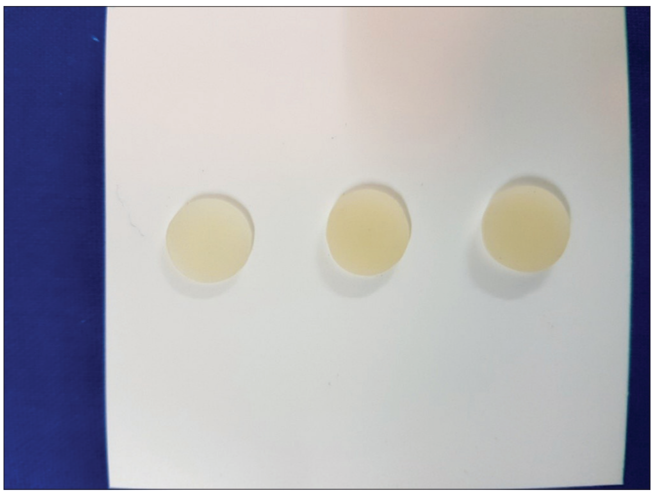


Figure 4: Lithium disilicate ceramic discs of varied core thickness

index of 1.7 was placed between the discs when they were brought together, so that a good optical contact is possible during the spectrophotometric measurement [Figure 7]. The optically connected ceramic disc and metal disc were embedded within silicone putty in a metal ring to avoid the influence of external light before measurement.

A custom-made metallic template [Figure 8] was used to ensure the space required for the luting cement. The Ni-Cr metal disc was embedded in template with putty. A brass sheet of 40 μm thick verified using a digital micrometer (Mitutoyo, Japan) was used as a spacer. The brass sheet was held in position by the space created at the three corners of the base engaging the upper counter [Figure 9].

The resin luting cement (Maxcem Elite, Kerr, USA) was delivered using automix system on to the sandblasted Ni-Cr metal disc substrate and over this, the ceramic disc was placed and held with finger pressure to maintain the cement thickness at 40 μm [Figure 10]. The resin cement is a dual cure, self-etching, self-adhesive cement and hence it was tack cured for 3 sec using light cure unit (3M ESPE,3M India

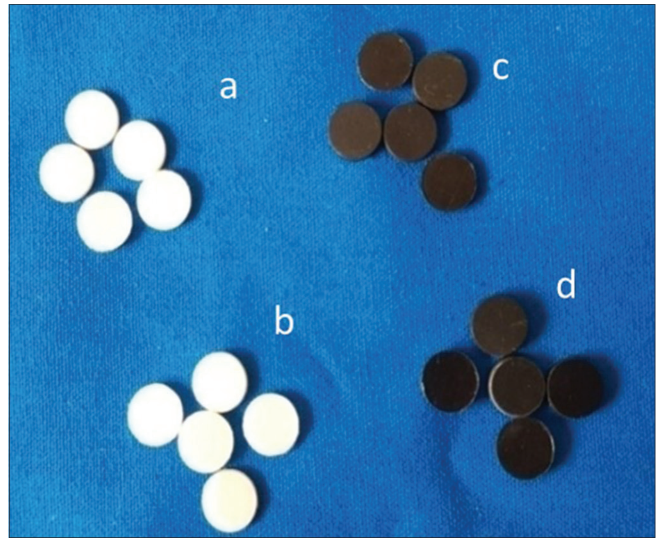


Figure 3: Patterns for ceramic disc fabrication: (a) 1 mm, (b) 1.3 mm, (c) 1.6 m, and (d) 2.5 mm patterns for Nickel-chromium metal discs fabrication

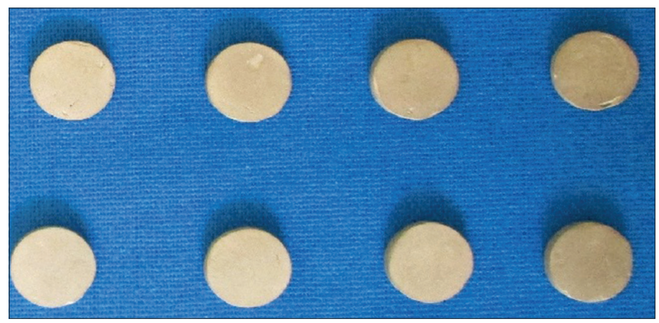


Figure 5: Finished nickel-chromium metal discs

Limited) and the excess cement was removed from the edges with a straight probe followed by 40 sec of light curing. The cemented lithium disilicate disc–Ni-Cr metal disc assembly was then suspended in distilled water for 24 hr in a closed airtight dark container to allow complete polymerization. Following complete polymerization, the cemented ceramic specimen was embedded within silicone putty in a metal ring, to avoid the influence of external light. The color parameters of the lithium disilicate discs after cementation are measured [Figure 11].

The masking ability of a specimen was evaluated by calculating the color difference of the ceramic discs over white and Ni-Cr metal backgrounds using the equation.[8]

$\Delta E = ([\Delta L]^2 + [\Delta a]^2 + [\Delta b]^2)^{1/2}$.

The ΔE (color difference) was obtained by comparing the color parameters of ceramic disks against white background and against Ni-Cr metal discs before and 24 hr after cementation.

The ΔE results were calculated and the mean values were statistically analyzed. The ΔE values were analyzed both before and after cementation using one-way ANOVA analysis and paired *t*-test.

Results

Table 1 reveals the mean L *a*b * values of the three groups against different substrates. Table 2 reveals the mean of ΔE values of the three groups of ceramic disc against Ni-Cr metal substrates before cementation. One-way ANOVA analysis revealed significant differences among the three groups. Table 3 reveals the mean of ΔE values of the three groups of ceramic disc against Ni-Cr metal substrates after cementation using resin cement. One-way ANOVA revealed significant differences among the three groups. Table 4 reveals *post hoc* Tukey's analysis of the mean ΔE values between three groups before and after cementation. Group III (1.6 mm) ceramic disc exhibited significantly lowest ΔE value compared to Group I (1 mm) and Group II (1.3 mm) and the highest ΔE was exhibited by 1 mm. To analyze the effect of cement, the mean ΔE values [Table 5] of cemented and noncemented specimens were submitted to paired t-test. Cemented ceramic discs of all three groups revealed lower ΔE compared to ΔE values before cementation [Graph 1].

Discussion

The present *in vitro* study was conducted to comparatively evaluate the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate. The successful outcome of fixed dental prosthesis, especially in the anterior esthetic zone, relies mainly on the biomaterials selected and the astuteness of the dentist/laboratory technician. The dynamic environment of the oral cavity presents a challenging situation in obtaining a predictable shade match and also the materials employed in the fabrication should meet certain prerequisites such as superior optical properties and minimal wear, essential for a durable service.

The intense quests among the dental professionals toward dentofacial esthetics have paved the way for greater utilization of anterior esthetic restorative materials, especially the all-ceramic systems. All-ceramic based materials possess excellent optical properties such as

Figure 6: Placement of ceramic discs against white background

Table 1: The mean L*a*b* values of three groups of lithium disilicate ceramic discs against different substrates

Substrate	Thickness (mm)	Mean L*	Mean a*	Mean b*
White background	1	76.95	−0.48	9.4
	1.3	74.48	0.003	10.85
	1.6	72.44	0.017	11.50
Ni-Cr metal substrate before cementation	1	61.26	−1.26	2.07
	1.3	63.80	−1.19	3.40
	1.6	63.79	−1.46	3.68
Ni-Cr metal substrate after cementation	1	62.27	−1.29	2.35
	1.3	64.72	−1.38	3.77
	1.6	64.16	−1.68	4.37

Ni-Cr: Nickel-chromium

Table 2: One-way ANOVA analysis of the meanΔE values of three groups before cementation

Group	MeanΔE	SD	*P*
I	17.32	0.441	<0.001*
II	13.01	0.658	
III	11.73	0.766	

**P*<0.05, statistically significant. SD: Standard deviation

Table 3: One-way ANOVA analysis of the meanΔE values of three groups after cementation

Group	MeanΔE	SD	*P*
I	16.32	1.051	<0.001*
II	12.10	0.743	
III	11.05	0.499	

**P*<0.05, statistically significant. SD: Standard deviation

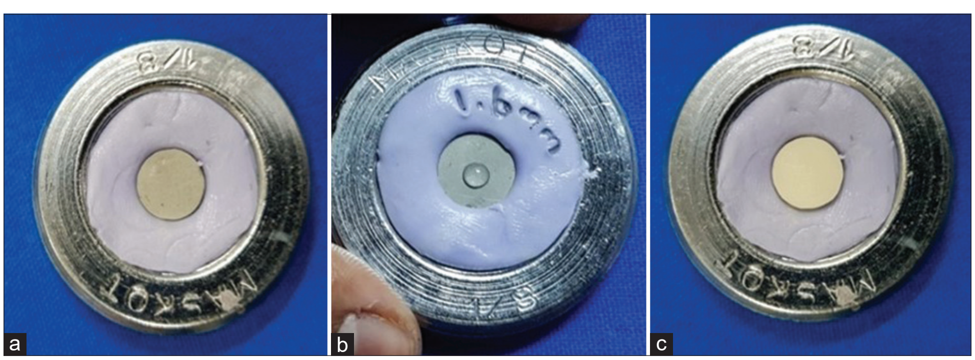


Figure 7: (a) Embedding metal disc in template with putty. (b) Placement of distilled water on metal disc. (c) Optical connection of the ceramic disc and nickel-chromium metal disc with distilled water

opalescence, translucence and resistance to wear and also exhibit excellent marginal adaptation.[6,19] The esthetic limitation imposed by porcelain-fused to metal restorations has led to the usage of metal-free restorations, especially lithium disilicate ceramic and zirconia in recent years.[1]

Various aspects of lithium disilicate ceramic such as optical properties, composition and surface luster have been investigated *in vitro* to simulate the lifelike appearance of a natural tooth. Studies conducted by Harada *et al*. on the color matching abilities have proven superior optical behavior of lithium disilicate ceramic and this has prompted its use in the fabrication of esthetic crowns, veneers and onlays in fixed prosthodontics.[20]

IPS e.max press lithium disilicate ceramic with flexural strength of 360–400 MPa has been used widely as a core ceramic on which veneering ceramic is layered. The overall optical behavior of all-ceramic restoration is dependent on three factors: (a) underlying abutment substrate, (b) resin luting agent and (c) the structure of ceramic material.[7,19] A chief concern toward the use of lithium disilicate ceramic in the anterior visible zone for

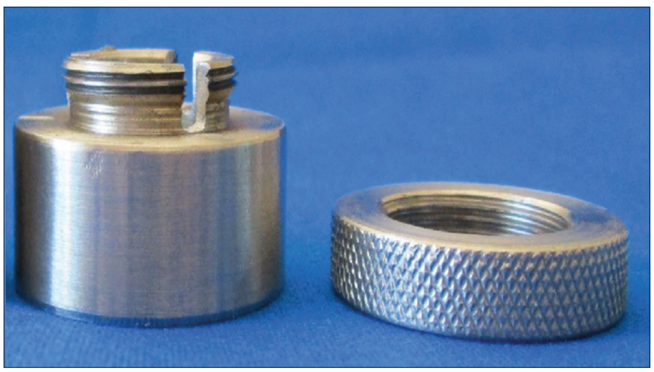


Figure 8: Metallic template to maintain cement space

Table 4: *Post hoc* Tukey's honest significant difference analysis between Group I, Group II and Group III before cementation and after cementation

	Groups	MeanΔE	*P*
Before cementation	I and II	17.32/13.01	0.000*
	I and III	17.32/11.73	0.000*
	II and III	13.01/11.73	0.000*
After cementation	I and II	16.32/12.10	0.000*
	I and III	16.32/11.05	0.000*
	II and III	12.10/11.05	0.000*

**P*<0.05, statistically significant

Table 5: Paired *t*-test analysis of meanΔE values of before and after cementation for Group I (1 mm), Group II (1.3 mm) and Group III (1.6 mm)

Group	Mean color difference (ΔE)	SD	*P*
I			
Before	17.32	0.441	0.002*
After	16.32	1.051	
II			
Before	13.01	0.658	0.001*
After	12.10	0.743	
III			
Before	11.73	0.766	0.008*
After	11.05	0.499	

**P*<0.05, statistically significant. SD: Standard deviation

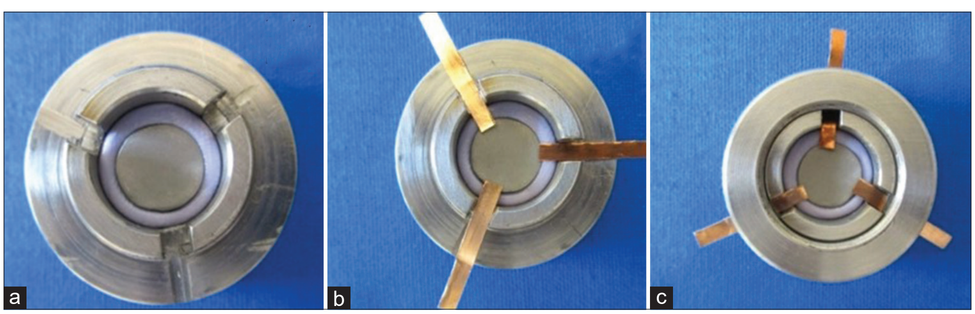


Figure 9: (a) Embedding metal disc in template with putty. (b) Positioning of spacer at the edge of the metal disc. (c) Stabilization of the spacer with the upper member of template

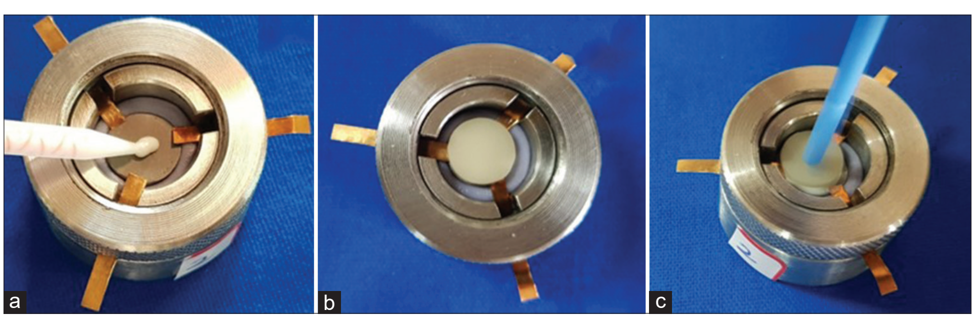


Figure 10: (a) Dispensing of resin cement. (b) Placement of ceramic disc. (c) Pressure applied to remove excess cement

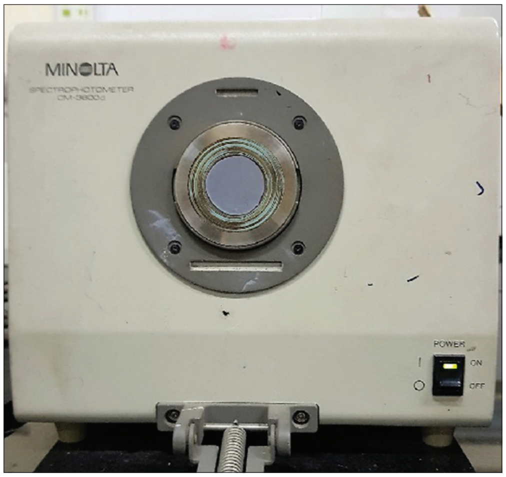
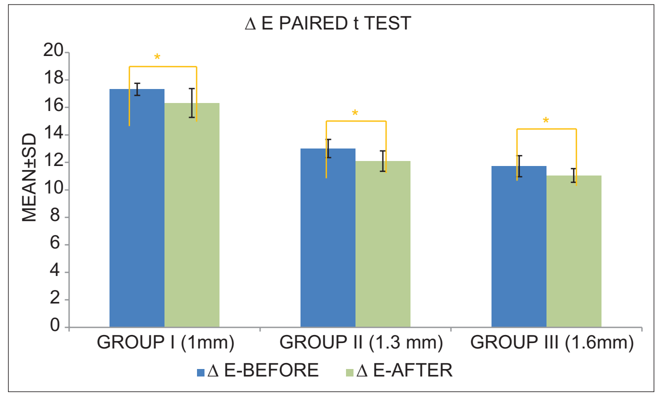


Figure 11: Color measurement following complete polymerization



Graph 1: Comparison of the mean color difference (ΔE) of before and after cementation for Group I (1 mm), Group II (1.3 mm), and Group III (1.6 mm)

masking discolored substrates is the shade mismatch, especially in situations where the substrates are metallic cast post and titanium implant abutment. To overcome this problem, blanks of different translucencies are used.[21]

In the present study, lithium disilicate ceramic discs of varied thickness were used to simulate the core portion of an all-ceramic restoration.

A spectrophotometer was used to measure the L*a*b* values of the test samples over white and black backgrounds, and the color difference (ΔE) is then calculated from the L*a*b* values obtained.[14,15] In this study, a standard white A4 sheet was used as white background and Ni-Cr metal disc to simulate the black background. Distilled water was used between lithium disilicate ceramic disc and Ni-Cr alloy disc during the precementation color analysis.[22] This is to ensure that light scattering between the interfaces is minimal. A similar protocol was followed in a study done by Basso *et al*.[23] All the test samples were subjected to CIELAB analysis before and after cementation and the values were computed and tabulated.

The results of the present study revealed that the L* values of lithium disilicate ceramic against white background decreased as the thickness increased [Table 1]. The reduction in L* value is based on the phenomenon that more light is absorbed with the thicker specimens and less light is reflected resulting in decrease in the brightness. These results are in agreement with the results obtained from the study conducted by Shono *et al*.[24]

The influence of Ni-Cr metal disc on the lithium disilicate ceramic when analyzed before and after cementation exhibited a decrease in L*a*b* values in all the three groups [Table 1]. However, on increasing the thickness of lithium disilicate ceramic, the effect of Ni-Cr metal disc produced an increase in L* and b* values and a reduction in a* values which is substantiated in a study done by Shimada *et al*.[25]

The ability of the human eye to notice differences in color varies among individuals; different ΔE intervals are used to distinguish differences in color: ΔE values <1 are considered undetectable by the human eye. The literature provides different values of color difference for the perceptible and acceptable thresholds when examined *in vitro*/*in vivo* conditions. The perceptible threshold ΔE in different investigations ranges from 1.0 to 3.7 and the acceptable ΔE threshold ranges from 1.7 to 6.8. In this study, the ΔE >3.3 suggests perceptible color change. If a ΔE value is >5.5, it is regarded as a clinically unacceptable color change.[9]

The increase in color difference (ΔE) of lithium disilicate disc under the influence of Ni-Cr metal discs is due to reduction in L*a*b* values. As the thickness of the ceramic discs increased, there seemed to be reduction in ΔE and this can be correlated to the increase in L* and b* values and reduced a* values. This increase in thickness resulting in lower ΔE values is in agreement with a study done by Vichi *et al*.[26] In the present study, the Ni-Cr metal alloy used as metal substrates yielded higher ΔE values, which is suggestive of major difference in color when compared to the perceptible threshold, whereas studies done using noble metal alloy substrates containing gold produced ΔE values closer to the perceptible range and this is attributed to the yellowish hue of the noble metal alloys used.[10]

Studies have also suggested that the thickness for an all-ceramic restoration for a standard vital tooth preparation should be 2 mm to reproduce the normal contour and optical properties, but achieving such axial reduction for esthetic reasons in discolored abutments can be deleterious to the pulpal health and can also result in a less retentive or unesthetic over contoured restoration.[10] To achieve ideal esthetic outcomes, restorative materials should have proper opacity that can mask the underlying substrate color and offer optimum translucency to represent that of the natural teeth. Analysis of color difference using different core thickness has been evaluated in earlier studies; Zhou *et al*. conducted a study using high opaque series of lithium disilicate ceramic for masking Ni-Cr metal abutments and suggested use of 0.6 mm and 0.8 mm thick high opaque lithium disilicate ceramic for better masking of discolored substrates.[27] In addition, increasing the opacity of the ceramic core adversely affects the esthetic properties of the restoration. Thus, an LT material can mask underlying dark backgrounds, but might not create natural tooth characteristics. Therefore, using a multilayer ceramic restoration including an opaque core for masking the underlying discolored substrate and veneering ceramic is recommended to achieve predictable esthetic results.[12]

White opaque cement has demonstrated better masking ability than cements of other shades. White opaque cement yielded an acceptable shade match when tested at 50 µm and 100 µm film thickness against silver-palladium metal substrate as studied by Niu *et al*. In the present study, thickness of the resin luting cement was standardized at 40 µm which is well within the film thickness range for resin luting agent (25–40 µm). On analyzing the influence of white opaque cement on the color difference of lithium disilicate against Ni-Cr metal disc, decrease in ΔE was observed in all the three groups which is due to the increased L* and b* values with decrease in a* values and this is in accordance to the study made by Niu *et al*. Thus, in the present study, the white opaque resin cement did not show marked decrease in the ΔE value after cementation.[10]

On statistical comparison, the mean color difference (ΔE) before cementation and after cementation revealed statistically significant difference ($P < 0.05$) among the three groups [Tables 2-4]. On statistical comparison, the mean color difference before and after cementation within the three groups revealed that Group I, Group II and Group III are statistically significant ($P < 0.05$) [Table 5]. Group III had the least mean color difference, followed by Group II with a relatively higher mean color difference and Group I with the highest mean color difference (Group III < Group II < Group I), indicative of better masking ability of Group III compared to Group I and Group II before and after cementation [Graph 1].

Lithium disilicate exhibits good translucency because the refractive index of crystal is close to that of glass matrix, resulting in less scattering.[28,29] The low translucent blank used in this present study contains increased number of lithium phosphate and lithium zinc silicate nanocrystals resulting in improved opacity providing acceptable masking ability with exceptional aesthetics. In the present study , the masking ability of lithium disilicate ceramic on Ni-Cr metal substrate did not yield ΔE < 3.3 for all the three groups. This increase in ΔE is because of the optical characteristic of the material.

It must be noted that, when the underlying abutment tooth discoloration is too intense, the option of using heat-pressed LT lithium disilicate ceramic blank may be limited. Ceramic blanks of medium opacity or high opacity (HO) that are designated for fabrication of core structures might be suitable for this situation. Since the opaque color core structure is of HO, it is suggested that the core structure be veneered with veneering ceramic to enhance esthetic results.

Limitations

The present study has some limitations, for better understanding of the optical properties, translucency parameter and contrast ratio could have been analyzed to yield more predictable results. Newer metal-free core materials such as polyether ether ketone and nano-sized zirconia with different levels of opacity should be evaluated for their masking ability.

The present study provided additional scientific support to overcome the clinical challenge of esthetically masking dark substrates, such as metal foundation, using all-ceramic restorations. So far, there is a need for further investigation on whether increasing the thickness of the framework as well as the use of opaque cements and/or opaque pigments could offer acceptable masking of metal substrates.

Clinical significance

The translucent core of all-ceramic crowns when indicated for masking heavily discolored teeth, titanium abutments, and preexisting post and core metallic foundation will have a detrimental effect on the optical behavior of the final restoration. Thus, in clinical situations, masking of discolored abutments requires an increase in both ceramic core thickness and the opacity to achieve optimal esthetics.

Conclusion

The different thicknesses of LT lithium disilicate ceramic used in this study were not able to mask the color of the metal substrate efficiently. Hence, the indication of LT lithium disilicate ceramic should be used judiciously. Thus, in clinical scenarios, where metal substrates are encountered, an increase in the ceramic core thickness, selection of MO/HO opaque blanks and use of opaque luting agent would result in a predictable esthetic restoration.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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