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Özgün Araştırma Makalesi

Final Color of CAD-CAM Produced Thin Lithium Disilicate Ceramics Cemented With Different Colored Resin Cements on Darker Backgrounds

Koyu Arka Plan Üzerine Farklı Renkteki Simanlarla Simante Edilen İnce Lityum Disilikat Seramiklerin Sonuç Rengi

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ABSTRACT

Aim: The aim of the present study was to evaluate the final color of CAD-CAM produced thin lithium disilicate ceramics cemented with A2, opaque, and bleach resin cements on darker backgrounds.

Materials and Method: Nine different experimental groups (n=10) were generated according to the colors of resin backgrounds (ND3:A3, ND4:A3.5, and ND8:A4) and cements (A2, opaque, and bleach). Target specimen was prepared by cementing lithium disilicate ceramic layer onto ND2 (A2) background by using translucent resin cement. The color difference values between experimental groups and target specimen were calculated according to CIEDE2000 formula. The data were statistically analyzed by using Kruskall Wallis test (α=0.05).

Results: The results showed that most of the experimental groups had higher color difference values than acceptability threshold (1.8) except ND3-A2 and ND3-opaque groups. It was observed that when the background got darker, the color difference values increased.

Conclusion: The darker backgrounds (A3, A3.5, and A4) and resin cement color (A2, opaque, and bleach) affected the final color of the lithium disilicate ceramics in 1 mm thickness. Color difference values were found in clinically acceptable limits for cementing lithium disilicate ceramics with A2 and opaque resin cements on A3 background.

Keywords: Color; Computer-aided design; Lithia disilicate

ÖZET

Amaç: Bu çalışmanın amacı, koyu arka plan üzerine farklı renklerdeki (A2, opak ve bleach) rezin simanlar ile simante edilen CAD-CAM sisteminde üretilen ince lityum disilikat seramiklerin sonuç rengini değerlendirmektir.

Gereç ve Yöntem: Farklı arka plan (ND3:A3, ND4:A3.5 ve ND8:A4) ve rezin siman renklerine (A2, opak ve bleach) göre dokuz farklı deney grubu oluşturuldu (n=10). Hedef renge sahip örnek, lityum disilikat seramik tabakanın ND2 (A2) arka plan üzerine translusent rezin siman ile simantasyonuyla hazırlandı. Hedef örnek ve deney grupları arasındaki renk farkı değerleri CIEDE2000 formülü kullanılarak hesaplandı. Veriler Kruskall Wallis testiyle istatistik olarak analiz edildi (α=0.05).

Bulgular: ND3-A2 ve ND3-opak grupları dışındaki deney grupları, kabul edilebilirlik eşik değerinin (1.8) üzerinde renk farkı değerleri gösterdi. Arka plan rengi koyulaştığında, renk farkı değerlerinin yükseldiği belirlendi.

Sonuç: Daha koyu arka plan (A3, A3.5 ve A4) ve siman rengi (A2, opak ve bleach) 1 mm kalınlığındaki lityum disilikat seramiklerin sonuç rengini etkilemektedir. A2 ve opak renklerdeki rezin simanlar ile A3 arka plan üzerine simante edilen lityum disilikat seramiklerde renk farkı değerleri klinik olarak kabul edilebilir sınırlar içindedir.

Anahtar kelimeler: Bilgisayar yardımlı tasarım; Lityum disilikat; Renk

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INTRODUCTION

Color matching between restorations and natural teeth is important for esthetically satisfying and successful restorations.[1] Although all ceramics are used to fabricate natural-looking restorations, several factors such as optical properties of ceramic material, luting cement, color of the underlying structure, and ceramic thickness are effective on the appearance of these restorations.[1,2] Thus, color selection of ceramic shade should be performed according to the shade of adjacent teeth and also the underlying tooth and resin cement colors.[3] Developments in both the ceramic industry and adhesive technologies enable to fabricate thin restorations; however, obtaining the desired color match is often clinically challenging, especially when restoring discolored teeth with these restorations.[1,4]

All ceramic restorations are one of the best treatment options to alter the appearance of the anterior teeth in terms of color and shape.[4,5] New all ceramic and adhesive systems allow clinicians to make minimally invasive tooth preparations and fabricate thinner restorations (1.0 to 1.5 mm).[6] However, color matching becomes more difficult for thinner restorations.[7] The colors of underlying tooth structure and luting cement have a significant impact on the desired restoration color with thin restorations because these restorations allow more light to enter and scatter.[7] One of the most preferred materials are lithium disilicate ceramics for minimally invasive restorations because of their high mechanical and esthetical properties.[2,5] Partially crystallized lithium disilicate ceramics are composed of 40% lithium metasilicate crystals which are 0.2 to 1 μm in size. The main shade of these blocks is controlled by dispersing staining ions in the glassy matrix and different translucencies arise from the size and distribution of the crystals in the glassy matrix.[9,10] Lithium disilicate blocks are produced in different shades (bleach, A-D), translucencies (high, medium, and low), opacities, and opalescent effects. And also, different shades of resin cements are produced to modify the final color of restorations. Furthermore, the cement color is important to mask undesirable results when restoration thickness is less than 1.5 mm, particularly on dark backgrounds.[2,7] Ellakany *et al*.[2] stated that ceramic thickness had a significant effect on color masking ability of the underlying structures and lithium disilicate ceramics in 0.5 mm and 1 mm thicknesses exhibited clinically unacceptable color change values against different dentin shades. In many cases, the color of underlying tooth color may differ when restoring multiple teeth. Maintaining a proper balance between ceramic thickness and cement color is needed. Begum *et al*.[11] concluded that the color masking ability of 0.5 mm veneer with an opaque resin cement could be similar to a 1 mm veneer with a translucent shade of resin cement. Thus, knowing the effect of the color of the cement on the final color may be clinically beneficial.

The purpose of the present study was to evaluate the final color of CAD-CAM produced thin lithium disilicate ceramics cemented with A2, opaque, and bleach resin cements on darker backgrounds. The null hypothesis was that the color of resin cement would not be effective on the final color of the thin lithium disilicate restorations when placed onto darker backgrounds.

MATERIALS AND METHOD

Lithium disilicate ceramic blocks (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein) in A2 shade and low translucency were used to prepare the ceramic specimens. Ceramic blocks were sectioned in 1 mm thickness to mimic the thin and minimally invasive restorations by using a precision sectioning machine (Isomet 1000, Buehler; Lake Bluff, IL, USA). All lithium disilicate specimens were mechanically polished according to the manufacturer's recommendations after crystallization. OptraFine ceramic polishing system (Ivoclar Vivadent) was used by using the low speed hand-piece (Supreme H50; B.A. International Ltd., Northampton, England) with a rate of 10000 rpm. The polishing system had three steps as finishing with OptraFine F (light-blue), polishing with OptraFine P (dark-blue), and high-gloss polishing with OptraFine HP nylon brushes and polishing paste. Totally, 3 min polishing was applied to each specimen. The thicknesses of specimens were controlled with a digital caliper.

Three different backgrounds which mimic the dark tooth colors were prepared from the composite resin die materials (IPS Natural Die Material, Ivoclar Vivadent). Resin die material was inserted into metal molds (10 mm x 10 mm x 2 mm) and polymerized by using a light polymerization device (Valo Cordless;

Ultradent Products, Inc., South Jordan, USA) to prepare different colored (ND3, ND4, and ND8) resin backgrounds. ND3 approximately simulates A3, ND4 approximately simulates A3.5, and ND8 approximately simulates A4 colors. Then, the ceramic specimens were cemented onto the resin backgrounds under finger pressure. All surfaces and margins of each specimen were light cured for 20 seconds (Valo Cordless). Then, excess cement was removed and margins were smoothed. The total thickness of each specimen was 3.1 mm. In the cementation procedures, three different colors (A2, bleach, and opaque) of light curing cement (G-Cem Veneer; GC Dental Products Corp, Aichi, Japan) were used. The materials used in the study were presented in Table 1.

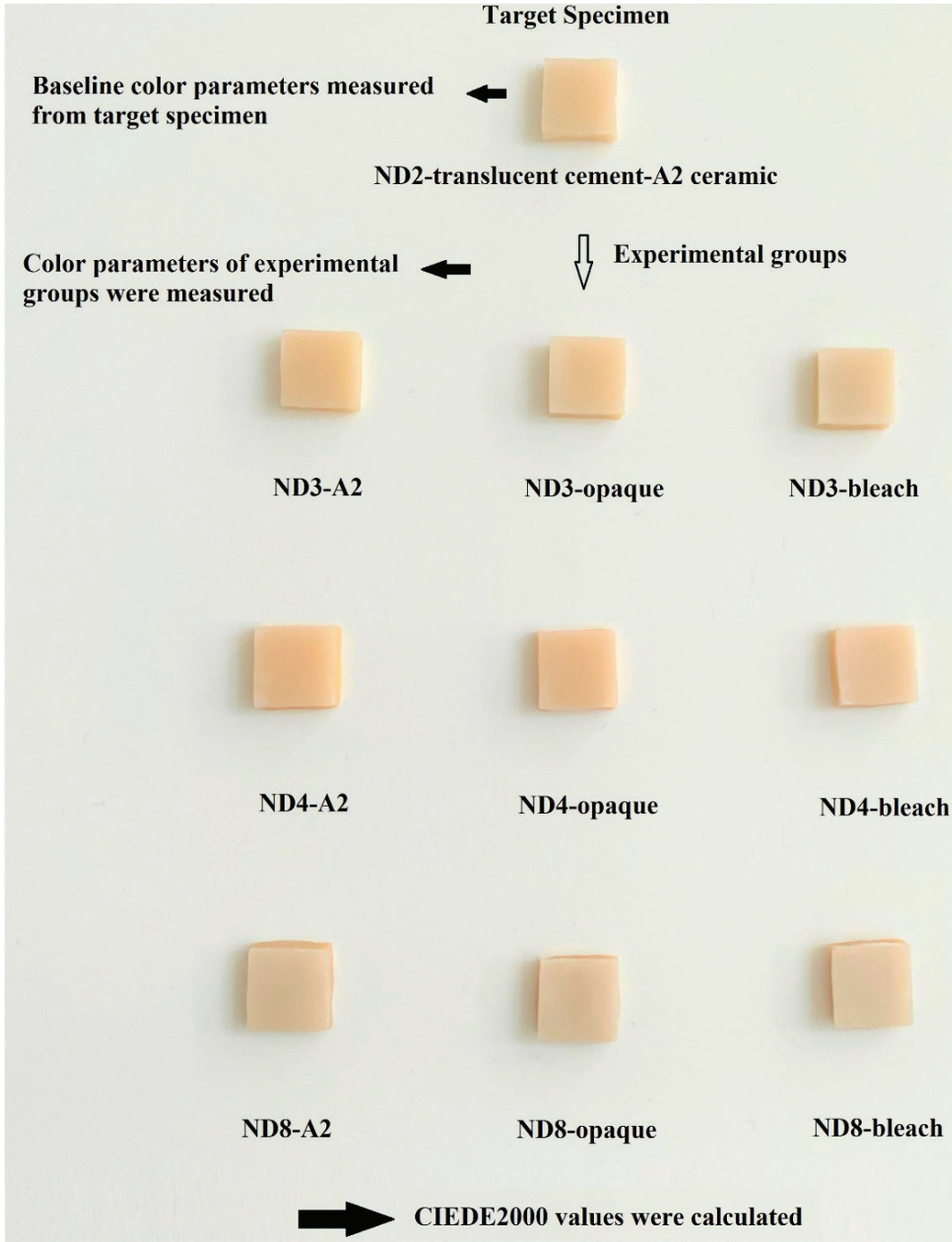

Figure 1. Study design.

Table 1. Materials used in the study.

Materials	Properties	Color Information	Manufacturer	Lot no
IPS e.max CAD	Lithium disilicate CAD-CAM ceramic	A2/LT	Ivoclar Vivadent, Schaan, Liechtenstein	X16590
G-Cem Veneer	Light-cured adhesive resin cement for restorations lower than 2 mm thick		GC Dental Products Corp, Aichi, Japan	
	The standard for luting most of prosthetic restorations	A2		2110011
	Used for very thin restorations to preserve the natural shade	Translucent		2201261
	Used to mask discolored backgrounds	Opaque		2206241
	Used to increase opacity and brightness when pearly white teeth are desired	Bleach		2205091
IPS Natural Die Material	Light curing shaded die material		Ivoclar Vivadent, Schaan, Liechtenstein	Z003WM Y48142
ND2		Simulates A2 color		Y23360
ND3		Simulates A3 color		X29013
ND4		Simulates A3.5 color		
ND8		Simulates A4 color		

The study design was presented in Figure 1. A total of nine different experimental groups (n=10) were generated according to the colors of resin backgrounds and cements.

Group 1: Cemented with A2 resin cement on ND3 resin background (ND3-A2),
Group 2: Cemented with opaque resin cement on ND3 resin background (ND3-opaque),
Group 3: Cemented with bleach resin cement on ND3 resin background (ND3-bleach),
Group 4: Cemented with A2 resin cement on ND4 resin background (ND4-A2),
Group 5: Cemented with opaque resin cement on ND4 resin background (ND4-opaque),
Group 6: Cemented with bleach resin cement on ND4 resin background (ND4-bleach),
Group 7: Cemented with A2 resin cement on ND8 resin background (ND8-A2),
Group 8: Cemented with opaque resin cement on ND8 resin background (ND8-opaque),
Group 9: Cemented with bleach resin cement on ND8 resin background (ND8-bleach).
The color parameters of all the specimens were measured under a standard illuminant D65 (daylight) and on a neutral gray background with a spectrophotometer (CM-2300d; Konica Minolta, Inc., Tokyo, Japan). Measuring characteristics of the spectrophotometer were standard illuminant D65, illumination geometry d/8 degrees, 10 degrees colorimetric standard observer, SCE mode, and measurement area of 8 mm in diameter. The spectrophotometer was calibrated with the white calibration plate of the spectrophotometer before each measurement.

To evaluate the effect of the color of resin cements, baseline color parameters were measured from the target color specimen. Target color specimen was prepared by cementing lithium ceramic layer with translucent resin cement on ND2 (A2) resin background. Then the color parameters of all specimens in the experimental groups were measured. The color differences were calculated by using the ΔE_{00} formula[6,7] by the spectrophotometer. The color differences of lithium disilicate ceramics were evaluated according to perceptibility (0.80) and acceptability (1.8) thresholds.[12-14]

The normality of the color difference data was evaluated by using Shapiro-Wilk test. The color difference data were not normally distributed; thus Kruskall Wallis test was used to analyze the color difference values. Results were considered as significant for α=0.05.

RESULTS

The results of color differences between target specimen and each experimental group, and the comparisons among the experimental groups were shown in Table 2 and Figure 2. The results showed that most of the experimental groups had higher color difference values than acceptability threshold (1.8). Only ND3-A2 and ND3-opaque groups had higher color difference values than perceptibility (0.80) threshold; however, these values were in acceptable limit. It was observed that when the background got darker, A2, opaque, and bleach resin cements could not able to mask the darker color and color difference values increased.

Table 2. Color differences between target specimen and each experimental group.

Group	ΔE_{00} Mean (± SD)	ΔE_{00} Median	
ND3-A2	0.97 (±0.20)	0.94 B	Perceptible but acceptable
ND3-opaque	0.93 (±0.10)	0.93 B	Perceptible but acceptable
ND3-bleach	2 (±0.18)	1.98 BC	Not acceptable
ND4-A2	3.32 (±0.34)	3.43 A	Not acceptable
ND4-opaque	2.75 (±0.18)	2.71 AB	Not acceptable
ND4-bleach	2.67 (±0.10)	2.69 AB	Not acceptable
ND8-A2	3.87 (±0.75)	3.56 A	Not acceptable
ND8-opaque	3.83 (±0.62)	3.87 A	Not acceptable
ND8-bleach	3.22 (±0.76)	2.97 AC	Not acceptable

Same uppercase letters indicate that ΔE_{00} values were not significantly different among the experimental groups (P>0.05).

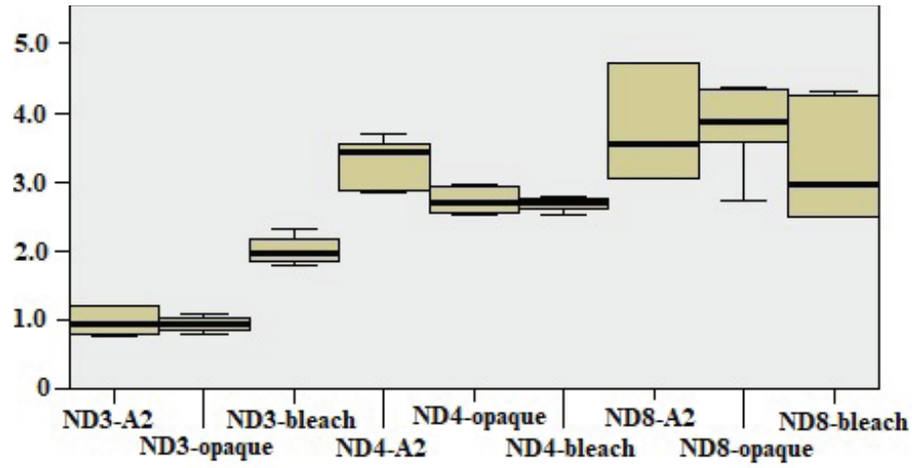

Figure 2. Graphical view of the color difference data of the experimental groups.

DISCUSSION

In the present study, cementing 1 mm lithium disilicate specimens on darker backgrounds affected the final restoration color in case of using different colored cement including A2, opaque, and bleach. Therefore, the null hypothesis that the color of resin cement would not be effective on the final color of the thin lithium disilicate restorations when placed onto darker backgrounds was rejected.

Restoring discolored teeth with thin monolithic ceramic restorations is a conservative treatment option instead of multilayered restorations. However, masking discolored teeth is a challenge for clinicians.

Masking ability and achieving desired color of a ceramic restoration are affected by critical factors such as structural translucency and thickness of ceramic, abutment tooth color, and color and opacity of resin cement.[15] To reach a target tooth color with a ceramic restoration; resin cement color, restoration thickness, ceramic color, and translucency parameters can be controlled by the clinicians by taking abutment tooth color into consideration.[16] In the present study, the ceramic specimens were prepared from A2 lithium disilicate ceramic which has gained popularity in the fabrication of ceramic restorations due to its superior esthetic properties and mechanical strength.[17]

The thickness of the ceramic material is an important feature for ceramic restorations. In all ceramic esthetic restorations, the ceramic thickness differs from the gingival margin to the incisal edge which is 1 to 1.5 mm on the axial walls. To simulate clinical conditions for thin ceramic restorations in the present study, 1 mm ceramics and minimal cement thickness were used on the background materials.[17,18] Thereby the effects of both material and cement thickness were eliminated and the color of the background and the cement color could be tested.

Thin ceramic restorations applied on a darker abutment tooth compared with lighter adjacent teeth may be challenging in terms of color harmony. In the present study, the target color specimen was consisted of ND2 resin background (A2), translucent resin cement, and a lithium disilicate ceramic layer (A2). This specimen simulated the restoration of a tooth in A2 color with an A2 ceramic restoration. Darker abutments in colors ND3 (A3), ND4 (A3.5), and ND8 (A4) were simulated with natural die materials. The evaluation of the color of resin cements revealed that A2 and opaque resin cements on the ND3 background showed acceptable color differences with the target specimen. The ND4 and ND8 backgrounds simulating A3.5 and A4 abutment teeth revealed unacceptable color differences from the target specimen when cemented with all cements. Clinically, this finding may indicate that thin lithium disilicate restorations could not not mask A3.5 and A4 abutment teeth color, and color cannot be matched with lighter adjacent dentition regardless of the luting cement color. To mask the dark color of an abutment tooth, other affecting factors can be arranged. For this purpose, thickness of the restoration can be increased to a minimum thickness of 1.5 mm.[2] It was stated the cement color was not effective when the lithium disilicate ceramic thickness is 2 mm.[15] Therefore, conservative lithium disilicate restorations with thin ceramic thickness may not be an esthetic treatment alternative for discolored or dark teeth. In case of a conservative preparation being desired, an opaquer restorative material can be selected as zirconia or zirconia-reinforced lithium silicate materials. In accordance with the findings of present study, Basso *et al*.[17] reported that the thinner lithium disilicate ceramic resulted in greater translucency and higher color difference values. They also compared monolithic and bilayered specimens and suggested bilayered structures for masking dark substrates than monolithic structures.

The resin cement color can alter the final color of the restoration depending on the restoration thickness, or has a color corrective effect on dark substrates.[16] In the present study, A2 and opaque resin cements resulted in limits of perceptible but acceptable color differences from the target specimen on ND3 background. This finding shows that clinicians have limitations on the resin cement color in thin and translucent restorations. On the other hand, bleach cement color on ND3 background showed a significantly higher color difference than A2 and opaque cements. This may be interpreted as intense coloring agents in resin cements may have adverse effects on restoration color in translucent restorations. Further research including change of color coordinates (L*, a*, and b*) of ceramic restorations after cementing with different cements would be beneficial to predict the effects of cement color on the final color of ceramic restorations. Similarly, Dai *et al*.[19] reported that selecting an appropriate resin cement shade is necessary for high-translucent monolithic zirconia to achieve ideal masking ability on the dark tooth. They found out that opaque or bleach cements were not effective for masking the discolored teeth. Similarly, research with different colors of resin cements reported that white-opaque cements resulted in the largest color difference values, and the application of white-opaque cement presented the higher color errors.[20]

The color difference value is evaluated with visual color difference thresholds in order to indicate the

color match or mismatch of the restorations.[13,14] Masking abilities of the ceramic materials on the dark colored backgrounds are widely measured using CIELAB (ΔE*ab) and CIEDE2000 (ΔE_{00}) color difference formulas. Color differences which have perceived by the human eye could be better indicated by CIEDE2000 color formula rather than the CIELAB formula. In the present study, CIEDE2000 color formula was used to calculate the color differences. Color parameters measured on ND2 substrate and translucent cement were used as the first measurements because it has a similar color shade to A2 according to Vita Classical Shade Guide. Then color parameters were measured on the other substrates and ΔE_{00} values were calculated for each group. The color difference results were interpreted according to perceptibility (0.8) and acceptability (1.8) thresholds[12-14] in the present study.

This study has some limitations. The material thickness and shape of an all ceramic crown restoration clinically differ. The square-shaped and uniform 1 mm thick specimens do not reflect the clinical situations. However, curved surfaces of the teeth may have a negative effect on the light reflectance, leading to inaccurate results.[2] In the present study, three background colors were tested simulating dark abutment teeth. The selected three background colors ND3 (A3), ND4 (A3.5), and ND8 (A4) were the most frequent abutment teeth colors. Studies on the effects of several abutment tooth colors on the final restoration color would be beneficial. Currently, a wide range of ceramic materials became available with the advance of CAD-CAM technology. While lithium disilicate ceramics are popular, the color corrective effects of current materials on dark backgrounds can be evaluated in further research. In addition, the surfaces of the specimens were mechanically polished. It should be noted that the optical properties of the specimens with a polished and flat surface in standardized thickness do not clinically mimic crown restoration. Future studies regarding the masking ability of different ceramics for thin restorations will provide useful information for clinical applications.

CONCLUSION

The darker backgrounds (ND3:A3, ND4:A3.5, and ND8:A4) and resin cement color (A2, opaque, and bleach) have an effect on the final color of the low translucent CAD-CAM produced lithium disilicate ceramics in 1 mm thickness. Color difference values were found in clinically acceptable limits for cementing lithium disilicate ceramics with A2 and opaque resin cements on A3 background.

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