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Effect of Color of Resin Cement on The Masking Ability of Different Translucent Ceramic Systems "An In-Vitro Study"

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ABSTRACT

Background: Ultra-Opaque resin cement is a promising material introduced in the market aiming to mask discolored substrates such as tooth, titanium implants, and metallic posts. ***Aim:*** To evaluate the masking ability of the ultra-opaque resin cement to different discolored substrates. ***Material and Methods:*** Sixty ceramic disks were fabricated with three ceramic materials (Lithium disilicate, zirconia reinforced lithium disilicate, and ultra-translucent zirconia) (N=20 each). Ceramic disks were cemented to Ni-Cr disks using two adhesive resin cements (Conventional resin cement and ultra-opaque resin cement). Color measurements were done before and after cementation and after thermocycling using spectrophotometer based on CIE L* a* b* relative to the standard illumination D65.Color difference was obtained by calculating the difference in color measurements using the formula ΔE=[(ΔL*)2 +(Δa*)2 +(Δb*)2] ½. ***Results:*** After thermocycling, ultra-opaque cement showed lower mean ΔE compared to conventional resin cement. Conventional resin cement showed a lower mean ΔE than the ultra-opaque one with the Katana group, while there was no statistically significant difference among other groups. ***Conclusions:*** whatever type of ceramic used, ultra-opaque resin cement has a higher masking ability than conventional resin cement.

***Keywords*:** color masking, resin cement, thermocycling.

INTRODUCTION

Catchy smile appearance is becoming increasingly an obsession for new generations. With newly innovative dental aesthetic materials and equipment, drawing and creating a pleasant smile became much easier than years ago. Aesthetic dentistry pursues to tangle both function and appearance for everyone with different scenarios and situations.[1,2] The development of newly ceramic materials widened the palette for several dental uses.[3] The privileges of using the new family of ceramic systems are their longevity, high flexure strength and fracture toughness, chemical

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durability, and biocompatibility.[4–6] Ceramic restorations were such a green light to seize the opportunity to eliminate and dispose of using porcelain fused metal ceramic restorations in both aesthetic and posterior zones.[3]

Recently, the development of CAD/CAM technology has made it easier and faster to fabricate milled aesthetic restorations. Monolithic chairside restorations are made by CAD/CAM and have the advantages of requiring less tooth preparation. They have higher fracture strength than bilayerd ones and require fewer manufacturing processes.[7] IPS e.max (Ivoclar – Vivadent), is a lithium disilicate glass ceramic (LDS) with improved translucency, toughness, and durability. It is one of the most widely used glass ceramic materials. Zirconia reinforced lithium silicate (ZLS) is a new innovation of glass ceramic material; with the aid of an innovative manufacturing process, the glass ceramic is enriched with approximately 10% zirconia by weight. This material has a great advantage in improving mechanical properties such as modulus of elasticity, flexural strength, fracture toughness, hardness, and marginal adaptation.[8] Ultra-Translucent Zirconia (UTZ) (e.g., katana Zirconia) has a superior esthetic appearance compared to conventional zirconia; katana UT came at the expense of lowering the strength because of decreased transformation toughing due to increased cubic zirconia content. Translucency is increased due to the coarser grain size and is optically isotropic, thus decreasing light scattering and improving its translucency. Ultra-translucent zirconia is restricted to certain indications such as single unit crowns and short span anterior bridges to maximize its advantage about translucency.[9]

Self-adhesive resin cement has been introduced to the market for easier and faster cementation of crowns, bridges, inlay, onlay, and posts by excluding individual etching, priming, bonding and mixing steps. In the case of metal-free restorations, in addition to the mechanical properties, the similarity to natural tooth tissues and the esthetic, predictable result are the decisive factors.[10]

Examining the optical properties of the ceramic materials is of great interest to the researchers to satisfy the expectations of the patients. Translucent materials have an adverse effect on their substrates and their translucency. Several studies showed that the abutment shade, thickness of material, and cement have a direct effect on the final appearance of ceramic restorations.[11] Lower color change is reported in opaque dental cements, thus providing the masking ability to the underlying substrate, consequently highly translucent ceramic materials could be used with corrected color in clinical situation.[12] Inorganic fillers and tint saturation accentuate masking ability of opaque dental cements to the discolored substrate.[13,14] However, White resin cement has its limitation in masking translucent ceramic material. Hence, masking dyschromic tooth or a metallic post-and-core build-up with metal-free restorations could be crucial in clinical cases.[15] This problem could be solved by layering a lighter opaque composite on the darker substrate so that providing lower ΔE values, thereby, positive color matching will be influenced.[16]

The most used approach for measuring color differences is the CIE L*a*b* system. Three coordinates are used in this approach for denoting color: The degree of whiteness or blackness of an item is indicated by the L* Coordinate. The coordinates a* and b* denote, respectively, redness-greenness and yellowness-blueness.[7,17,18]

In the dental field, the ΔE values are used to indicate if a change in the overall shade is perceptible to a human observer. A color match is considered acceptable if it is at or below the acceptability threshold but perceptible if it is at or below the perceptibility level. According to Vichi et al.,[19] ΔE values below 1 unit are undetectable by the human eye; ΔE values between 1 and 3.33 are perceptible by experienced, skilled operators (with a well-trained eye); however, they are clinically acceptable; and ΔE values above 3.33 are thought to be detectable by untrained observers and therefore, are clinically unacceptable. Numerous authors regarded ΔE values more than 3.33 as clinically inappropriate.[7,19,20]

There are many factors contributing to the discoloration of dental materials in the oral environment. Discoloration can be induced by external factors such as heat, water, food coloring, and UV radiation. Color stability is undoubtedly a crucial clinical factor for aesthetic dental restorations. Additionally, the color stability, and translucency of ceramic restorations affect their aesthetic appearance and rate of survival.[21]

Thermocycling is a technique used in laboratories utilizing thermocycler to subject dental materials and teeth to temperature ranges that are comparable to those found in the oral cavity trying to imitate oral environment and that could have deleterious consequences due to the different thermal expansion coefficients of the tooth structure and the filling material.[22] The tested materials are subjected to a certain number of cycles, each number of cycles that indicates a period of time; 5000 cycles indicate 6 months, 10000 cycles indicate one year, 30000 cycles indicate 3 years, and so on .[23]

Therefore, the purpose of this study is to test the effectiveness of the new Ultra-Opaque luting cement on masking the opacity of discolored substrate covered with ceramic restorations after thermocycling. The null hypothesis was that there was no significant difference between the new Ultra-Opaque cement and conventional resin cement on the color masking of the metal substrate under ceramic restorations.

MATERIALS AND METHODS

Materials used in this study are shown in **Table (1).** The study workflow is schematically explained in **Figure (1).**

The sample size was calculated according to power analysis for a 3 x 2 factorial design using color change (ΔE) as the primary outcome. The first factor is ceramic type, which includes three levels and its effect size (f) = 1.04. The second factor is cement type, which includes two levels and its effect size (f) = 0.4. Effect sizes were calculated based upon the results of Dede DÖ et Al., [24] Using an alpha (α) level of (5%) and Beta (β) level of (20%) i.e., power = 80%; the minimum estimated sample size was 10 samples per cell giving a total of 60 samples. Sample size calculation was performed using IBM® SPSS® SamplePower® Release 3.0.1

A total of 60 disc-shaped samples were machined out of three types of monolithic CAD/CAM ceramic blocks: Lithium

Table (1): Materials used in the study.

Material	Brand Name	Chemical Composition	Manufacturer
IPS e.max CAD	Lithium disilicate glass ceramic	SiO_2 (57.0-80.0wt%), Li_2O (11.0 – 19.0 wt%), K_2O (0.0 – 13.0 wt%), P_2O_5 (0.0- 11.0 wt%), ZrO_2 (0.0 –8.0 wt%), ZnO (0.0-8.0 wt%), Coloring oxides (0.0 – 8.0), Others (0.0 – 10.0).	Ivoclar Vivadent, Liechtenstein
VITA SUPRINITY PC	Zirconia Reinforced Glass-Ceramic	ZrO_2 8-12%, SiO_2 56-64%, Li_2O 15-21%, Various > 10 %.	Vita Zahnfabrik, Bad Sackingen, Germany
KATANA Zirconia	Ultra-Translucent Multi Layered Zirconia	Al_2O_3 0.13%, Y2O3 10.91%, ZrO2 86.50%, HFO2 2.46%.	Kurary Noritake, Japan
Breeze Resin Cement	Self-adhesive Resin Cement	Bis-GMA, TEGDMA, UDMA, HEMA, 4-META, Silane treated barium glass, Silica (amorphous), Minor additives, BIOC, Curing system, Ca-Al-F-silicate.	Pentron Clinical West Collins Orange, USA
VITA ADIVA IA-CEM	Ultra-Opaque implant abutment composite	Bis-GMA resin, Catalysts, Stabilizers, Pigments, Inorganic fillers in a distribution of 0.05 - 1µm (61%).	Vita Zahnfabrik, Bad Sackingen, Germany
VS Ni-2	Nickel - Chromium alloy	Nickel 70%, Chrome 18%, Molybdenum 8%, Beryllium 1.7 %, others 2%.	Vsmile Happy Zir

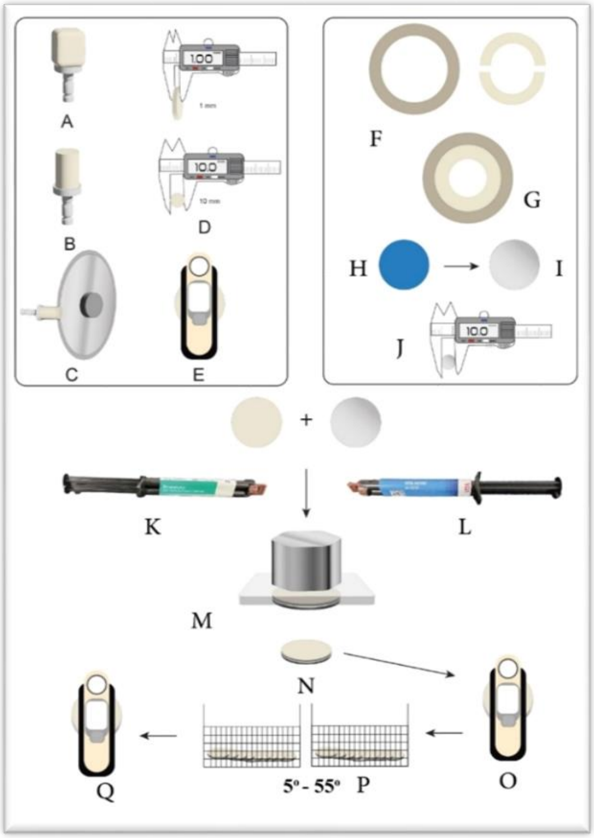

Figure (1): schematic presentation of the specimen preparation and the performed test in the study. A, The CAD/CAM block before milling. B, The CAD/CAM block after being milled to cylindrical shape by CAD/CAM machine. C, Slicing the cylinder using ISOMET sawing machine. D, Verification of the diameter and thickness of the cylinder using digital caliber. E, Baseline color measurement for specimen by Spectrophotometer. F, Construction of customized split Teflon mold. G, Assembled Teflon mold. H, Disc shaped wax patterns. K, Metal disc fabrication by casting process. L, Verification of the dimensions of metal disc using the digital caliber K&L. Cementation of ceramic disk over the metal disk using two different cements group for breeze and the other one for ADIVA. M, cementation of ceramic disk over metal disk using a standard weight, N, Specimens after cementation. O, Color measurements using spectrophotometer after cementation, P, specimens subjected to thermocycling. Q, Final color measurements after thermocycling.

disilicate (LDS), Zirconia reinforced Lithium disilicate (ZLS), and ultra-translucent zirconia (UTZ) 20 samples for each material. Shade A2 MT was chosen for the three materials. A total of 60 Ni-Cr metal discs were manufactured to be adhesively cemented to ceramic ones.

For LDS and ZLS samples, a cylindrical shape of the ceramic sample was designed with a diameter of 10 mm and 14 mm long using AutoCAD software, saved, and exported as an STL file. For UTZ samples, another cylindrical shape with dimensions 11mm diameter and 14 mm long was designed and then milled using CORiTEC 250i CAD/CAM machine. The cylinders were then sliced using a linear precision sawing machine (IsoMet 4000 Linear Precision Saw, Buehler, USA) to get final disc shaped specimens with 1mm thickness.[7] IPS e.max and vita Suprinity samples were crystalized and glazed in one step inside a firing furnace. Glaze paste (Ivoclar) was used to apply a single coat using a brush to be applied in a uniform thickness. The firing protocol was 850°C for 25 minutes under vacuumed pressure.[7] All zirconia discs were sintered and glazed in a single step as the previous two materials in sintering oven. zirconia specimens were placed inside the oven under 1530 temperature for 210 minutes to be fully sintered.[25] Final zirconia samples dimensions were verified after sintering to be 10 mm diameter and 1 mm thickness using a digital caliber (INSIZE digital caliber, Insize measuring tool, India).[7]

A customized circular split Teflon mold was constructed to fabricate metal discs with 10 mm diameter and 1 mm thickness. Sixty disc-shaped wax patterns with dimensions 10 mm diameter and 1 mm thickness were prepared in the custom-made split Teflon mold and then were burnt out using a casting machine to produce the metal discs. For LDS and ZLS samples, surface treatment was done using 9% hydrofluoric acid for 20 seconds, rinsed with air water spray for one minute, and dried. After that, the silane coupling agent was applied for one minute and was left to dry. For UTZ group, zirconia primer was used to apply one drop on the zirconia specimens before cementation as well.

The metal discs were then placed inside another custom-made split Teflon mold machined with the dimensions of 10 mm X 2.1 mm for holding the ceramic and metal dick specimens and providing a standard thickness of 0.1mm for cement layer and then the cement was applied using mixing tip. The ceramic specimens were applied over the metal discs and then a glass slab was applied over with 1 Kg standard weight. [26]A light cure (Woodpecker I LED) was used for 20 seconds. After that, the cemented specimens were removed carefully from the split molds and the excess cement was removed.

A portable Spectrophotometer (X–Rite RM200QC) was used to measure the baseline color of the specimens over a white background. The specimens were perfectly aligned within the apparatus, and the aperture size was fixed to 4 mm.[7] The CIE L*a*b* color space system was used for measurements, and the CIE standard illuminant D65 was selected. The CIE L*a*b* parameters were computed and recorded. All samples are measured again after cementation and after subjecting to the thermocycling process for 5000 cycles under temperatures 5-55 ^{0}C in a thermocycling machine (Robota automated thermal cycle machine), equivalent to 6 months. [22] Color change was calculated using the equation $\Delta E= [(\Delta L^*)^2 + (\Delta a^*)^2 +(\Delta b^*)^2]^{½}$.

Statistical Analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Parametric

data were presented as mean and standard deviation (SD) values, while non-parametric data were presented as median and range values. For parametric data, two-way ANOVA test was used to study the effect of ceramic type, cement type, and their interactions on color changes. Bonferroni's post-hoc test was used for pair-wise comparisons. For non-parametric data, the Kruskal-Wallis test was used to compare the three ceramic types. Dunn's test will be used for pair-wise comparisons. Mann-Whitney U test was used to compare between the two cement types. The significance level will be set at P ≤ 0.05. Statistical analysis will be performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Whether with Breeze or Vita cements**,** there was no statistically significant difference between ΔE of ceramic types (*P*-value = 0.122) (*P*-value = 0.059), respectively**.** Breeze cement showed statistically significantly higher mean ΔE than Vita cement (*P*-value <0.001), (*P*-value <0.001 and (*P*-value <0.001), respectively, whether using katana, vita suprinity as well as e.max as shown in **Table (2)**.

Table (2): The mean, standard deviation (SD) values and results of two-way ANOVA test for comparison between ΔE of cement types regardless of ceramic type.

Breeze		Vita Adiva		*P*-value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD		
22.58	5.35	8.63	3.18	<0.001*	0.773

**: Significant at P ≤ 0.05.*

After thermocycling, there was no statistically significant difference between ΔE of ceramic types (*P*-value = 0.611) and (*P*-value = 0.068) respectively, when using both types of cement as shown in **Table (3)**. While Breeze cement with the Katana group showed statistically significantly lower median ΔE than Vita cement (*P*-value = 0.046). There was no statistically significant difference between the two cement types (*P*-

Table (3): Descriptive statistics and results of Kruskal-Wallis test for comparison between ΔE of ceramic types.

Cement type	Katana		Vita Suprinity		e.max		*P*-value	Effect size *(Eta squared)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Breeze	4.3 (2.82-6.35)	4.52 (1.39)	5.47 (2.98-7.21)	5.17 (1.58)	3.85 (2.74-9.95)	4.75 (2.64)	0.611	0.060
Vita	6.97 (3.36-9.27)	6.6 (1.78)	4.66 (3.55-6.65)	4.77 (0.96)	6.03 (3.24-8.19)	5.98 (1.64)	0.068	0.187

**: Significant at P ≤ 0.05.*

value = 0.406) and (*P*-value = 0.142), respectively, as shown in **Table (4)**.

Table (4): The mean, standard deviation (SD) values and results of two-way ANOVA test for comparison between ΔE of different interactions of variables.

Cement type	Katana		Vita Suprinity		e.max	
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)
Breeze	4.3 (2.82-6.35)	4.52 (1.39)	5.47 (2.98-7.21)	5.17 (1.58)	3.85 (2.74-9.95)	4.75 (2.64)
Vita	6.97 (3.36-9.27)	6.6 (1.78)	4.66 (3.55-6.65)	4.77 (0.96)	6.03 (3.24-8.19)	5.98 (1.64)
***P*-value**	0.046*		0.406		0.142	
Effect size *(d)*	1.333		0.455		0.854	

**: Significant at P ≤ 0.05.*

DISCUSSION

The purpose of this study was to test the effectiveness of the new Ultra-opaque luting cement in masking the opacity of metal Ni-Cr substrate covered with three ceramic materials and evaluating its color stability after thermo-cycling. The null hypothesis that there will be no significant difference between the new Ultra-opaque cement and conventional resin cement on color masking of the metal substrate under ceramic restoration was partially rejected as the conventional resin cement showed statistically significant higher ΔE than ultra-opaque regarding color masking, but after thermocycling, there was no statistically significant difference between ΔE of different ceramic types weather with the conventional or ultra-opaque resin cement.

The demand for aesthetic dentistry made resin cements came to the forefront. Resin cement is the material of choice for veneers and all ceramic crowns because of its high strength, low film thickness, and very low oral solubility. It can be bonded to etched enamel, ceramics, resins, and etched or treated metal surfaces.[27]

Masking discolored substrate is a challenging step to accomplish, because mismatching between dental restorations and natural teeth is frequently predictable.[28] LDS was selected due to its higher flexure strength 400 MPa, higher esthetics and translucency, and abundant shade variety.[29,30] ZLS was selected as it represents both advantages of lithium disilicate and zirconia properties attributed to its composition of lithium meta silicate glass ceramic (Li2SiO3) and reinforced with 10% zirconia dioxide (ZrO2).[8]

Katana Zirconia was chosen over other monolithic zirconia for its superior esthetic appearance. Translucency is increased due to the coarser grain size and is optically isotropic, thus decreasing light scattering and improving its translucency. This came at the expense of lowering the strength because of decreased transformation toughing due to increased cubic zirconia content.[9]

In the present study, two colored self-adhesive resin cements were used. A significant influence on the translucency of different ceramic materials was achieved by ultra-opaque resin cement rather than the conventional resin used. These results were comparable with Chaiyabutr et al.,[15] who stated lower values of ∆E in the group of opaque cement color. Inorganic fillers and tint saturation are the main reason of accentuating the masking ability of opaque dental cements to discolored substrate.[13,14]

The three materials used in this study have the same shade and are prepared with the same thickness and diameter aiming for standardization. Thickness of the ceramic sample is 1mm, whereas the diameter was 10mm to prevent edge loss during color measurements. Samples of the three ceramic materials were crystallized and glazed according to the manufacturer’s instructions and to stimulate clinical conditions.[31]

Two split molds were fabricated to ensure uniform thickness of the applied cement. The two open ends were to ease light curing direct contact with the specimen and to remove the excess cement. This mold was constructed to standardize the cement thickness used; this comes in accordance with a study done by Kilinc E et al.[32] Metal discs were fabricated to represent the discolored substrate that could be titanium abutment, discolored tooth, or metal core buildup. Cementation LDS and ZLS specimens required hydrofluoric acid for mechanical interlocking and silane coupling agent for chemical bonding to their surface treatment prior to cementation, then both cements conventional resin cement ultra-opaque resin cement.[33] Cementation of zirconia requires zirconia primer to be applied before cementation to enhance the bond between indirect restorative materials, composite resin cements, and resin-based bonding agents when preparing the restorations for cementation.[33]

In the current study, the metal discs were then placed inside the custom-made split Teflon mold, and then the cement was applied. 1 Kg loading weight used for standardization purposes and to achieve a minimum uniform thickness of the cement in all cemented specimens.[26]

Thermocycling influences color stability, as it affects aesthetic appearance and rate of survival.[34] It is used in labs using thermocycler to expose dental materials and teeth to temperature ranges that are similar to those found in the oral cavity, aiming to mimic the oral environment, and that could have deleterious consequences due to the different thermal expansion coefficients of the tooth structure and the filling material.[21] Color difference detected after thermocycling for all specimens by spectrophotometer using the equation $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$. The tested materials were subjected to 5000 cycles, which indicates a 6 month period.[35]

Results of this study showed that the color masking ability of ultra-opaque resin cement (ΔE = 8.63) is superior to conventional resin cement (ΔE = 22.58); this was attributed to the chemical composition of ultra-opaque itself, which contains pigments, stabilizers, and a higher percentage of inorganic fillers.[36] In the Katana group, conventional resin cement showed better results than ultra-opaque resin cement (conventional resin cement has a lower ΔE value) due to the increase of yttria content. Cubic zirconia could have a relatively low ΔE value due to its electrical neutrality, which is attained by the formation of O2 vacancies that become stable in the cubic phase, Since cubic zirconia is more resistant to aging than normal zirconia, T-M transformation in cubic zirconia will require a higher temperature and longer time, Even though the T-M transformation allowed for the presence of the tetragonal phase, there was still a noticeable color variation after aging.[37] These findings were in accordance with Putra et al[38] & Muñoz et al.[39]

ZLS and LDS, both materials, whether cemented with ultra-opaque resin cement or conventional resin cement, are comparable after thermocycling because of the glassy phase contributed in both types; the increase in temperature time and grain size, and a decrease in porosity, thus forming a highly ordered crystalline structure that allows light reflection, which may be the main factor affecting the color difference. Water sorption due to aging is the reason why lithium disilicate had high ΔE.[37] Our findings were in accordance with Heffernan et al.[40]

Discoloration also may be attributed to the composition of dual cured resin cement, which is composed of camphorquinone and a tertiary amine to initiate the light activated reaction.[41] Schneider et al.,[42,43] Found that the concentration of the Photo initiator/coinitiator system was discovered to be the cause of a greater degree of composite yellowing. Large amounts of aromatic tertiary amines are employed in chemically cured systems, but less amounts are used in some light activated.[44] Camphorquinone is necessary for starting the setting reaction in both light-cured and dual-cured resin cements. It is a solid yellow compound with an unbleachable chromophore group, so the additional amount of camphorquinone in resin formulations leads to a more unfavorable yellow color, affecting the final esthetic appearance of the cured material.[45] Atay et al.,[46] revealed that the color change after the thermocycling in dual-cure resin cements was higher than the light-cure resin cements. This result was based on the oxidation of amine molecules that react with benzoyl peroxide in dual-cure systems.

Further clinical and in-vitro studies are recommended to assess color masking of ultra-opaque resin cement using thermocycling and presence in saliva, and different beverages and light to represent clinical situations more accurately, using increased thickness of discs.

CONCLUSION

Based on the findings of this in vitro study, the following points could be concluded:

1. Color masking effect of ultra-opaque resin cement (Vita Adiva) showed better results than conventional resin cement (breeze) in all ceramic groups.
2. Ultra-opaque resin cement (Vita Adiva) and conventional resin cement (Breeze) were comparable regarding color change after thermocycling in ZLS and LDS
3. Conventional resin cement (Breeze) with UTZ showed a better result than ultra-opaque resin cement after thermocycling.

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