Tufts UNIVERSITY | School of Dental Medicine

The Effect of Ceramic Thickness and Resin Cement Shade on the Color of Porcelain Laminate Veneers upon Discolored Substructure

A Thesis

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ABSTRACT

Objectives:

Using the porcelain veneers with stained or discolored teeth, such as those stained by tetracycline is reliable and can be a satisfactory choice for aesthetic restoration with Porcelain Laminate Veneers (PLV) with thicknesses between 0.50 mm and 1.00 mm. [1, 2, 7] The primary purpose of this study was to evaluate the effect of the different thicknesses of veneers, shades of the resin cements, and thermocycling on the final color of the porcelain laminate veneers used on discolored substructures.

Materials and Methods:

A total of 48 disks were made with B1 shade of Lithium disilicate CAD/CAM blocks (IPS e.max, Ivoclar, Buffalo, NY) with 0.50 mm and 1.00 mm thicknesses. One light polymarizable resin cement system (Variolink II base, Ivoclar Vivadent) with a total of two shades was used for cementation (opaque and bleached). Each porcelain disk was cemented to composite resin blocks of C4 shade with 5.0 mm thickness (n=12). Color changes in the porcelain substructures after cementation were examined with a SpectroShade spectrophotometer, and then the samples were thermocycled for 5000 cycles. Color differences (ΔE) were calculated before and after thermocycling, and the results were tested using three way ANOVA tests (α = 0. 05).

Results:

A significant difference was found in the comparison of the two shades of cement on the final color of the veneer restoration at an alpha of 0.05. The opaque shade had a significantly lower mean ΔE than the bleach shade. Significant differences in final color of the restoration

were also found in the comparison of two different ceramic thicknesses (0.50 mm and 1.00 mm). No significant differences were found in comparison of pre-thermocycling and post-thermocycling.

Conclusions:

1. The final color of laminate veneer restorations is affected by the color of the resin cement. When used with different thicknesses, opaque resin cement has a better masking effect on the final color of the restoration compared to the bleach resin cement.
2. The thickness of the restoration has a direct effect on the final color of the restoration. A 1.0 mm ceramic thickness enhanced the final color of the restoration compared to the 0.5mm thickness.
3. Accelerating aging (thermocycling) had no significant effect on the color of the cemented laminate veneers.

The results of this study will demonstrate that careful selection of resin cement color and/or the thicknesses of PLVs are critical factors in obtaining optimal esthetics in porcelain laminate restorations.

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Introduction

Over the last decade, prosthetic dentistry has made spectacular headway in mimicking the natural color of teeth with use of restorative material.[1] Developments in the production of ceramic materials and cements have allowed more widespread use of all ceramic restorations and a conservative approach to esthetic dentistry especially with porcelain laminate veneers (PLVs).[2, 3]

While achieving an optimal color outcome may not be of clinically determining in the success of dental restorations, to the patient it is often a significant subjective psychological benchmark by which s/he judges the outcome. [4]

In 1997, Magne and Belser presented a classification of the indication for PVSs. The Type I indication is for teeth resistant to bleaching or other changes in the color of the teeth requested by the patient; dark shades such as C3, C4 and tetracycline-stained teeth fall into Type I.[5] The Type II indication is for morphological changes, while the Type III indication is for teeth that have extensive restorations.[6] Using the porcelain veneers on stained or discolored teeth is challenging and can be a satisfactory choice for aesthetic restoration.[1] Although color matching can be challenging when restoring discolored teeth especially when a conservative approach that uses thin and translucent restorations such as a PLV with a limited tooth preparation (between 0.50 and 1.00 mm) is used.[1, 2, 7]

Achieving a correct color match between natural dentition and a restoration or prosthesis is a complex process that consists of two specific procedures: color selection and color reproduction. [2] Clinicians must select the proper shade of the ceramic veneer, mask the underlying tooth color and match the optical properties of the teeth by reproducing their natural translucency. [8]

The optical behavior of a ceramic restoration is determined by the combination of tooth structure color, ceramic layer thickness, and cement color.[2, 3, 9] Placing the ceramic restoration on a dark underlying tooth structure will result in discoloration and shadowing of the restoration, particularly in the cervical areas.[2] Thus, if the color of an esthetic dental material of any thickness, used with any background color, could be predicted precisely, shade selection could be optimized. [20]

Various materials have been used for ceramic veneers, including leucite, feldspathic and lithium disilicates. Recently, leucite-based glass ceramics have shown adequate integration with the tooth structure in terms of bonding strength and appearance. Currently, a machinable version of leucite-based ceramic CAD/CAM blocks with varying levels of translucency and shade are in use. [2, 11] Translucency has been shown to be lower in ceramics than in natural tooth enamel.[12] IPS e.Max CAD/CAM Block is an innovative lithium disilicate glass-ceramic (LS_2) block suitable for the efficient fabrication of esthetic high-strength single-tooth restorations, such as veneers.

The long-term success of PLVs is affected by the color stability of the resin cement that is used. [13] It is important that the color of the veneer remain consistent throughout a restoration's lifetime.[14]

Different methods have been used to accelerate the aging of the dental restorations *in vivo* and *in vitro.* One common in vitro method, "temperature cycling" or thermocycling, ages an extracted tooth with a restoration by subjecting it to temperature extremes that duplicate those found in the oral cavity. [18] Laboratory simulations of clinical treatment are often performed because clinical trials are costly and time consuming. [19]

The objective of this work was to establish whether a reliable pattern of interaction exists between PLVs of various thicknesses, cements of different colors, and the background tooth color.

Specific Aims and Hypothesis

Hypothesis 1

The opaque shade of resin cements will mask the substructure more than the bleach shade and when used, the restoration will be opaque.

Hypothesis 2

Ceramic veneers with 1mm thickness will mask substructure color better than ceramic veneers with 0.50 mm thickness.

Hypothesis 3

The color of the ceramic veneer restorations will be the same after thermocycling.

Aims

The study was conducted to evaluate the effects of the different shades of the resin cements on the final color of the PLVs with 2 thicknesses (1 mm and 0.5 mm) used on discolored substructure and the effect of thermocycling on the final color of the cemented PLV on the discolored substructures.

Clinical Implications

The results of this study will demonstrate that careful selection of resin cement color and/or the thicknesses of PLVs are critical factors in obtaining optimal esthetics in porcelain laminate restorations.

Study Variables and outcome

The variables in this study were

Cement Shade (Opaque and Bleach).

Veneer (Ceramic) thickness (0.50 mm and 1.00 mm).

Thermocycling.

The outcome variable in this study was the color difference (ΔE) achieved by using different ceramic thicknesses, cement shades and thermocycling.

Research Design and Methods

I. Research Design

The study was designed as an experimental in vitro study in order to test the effects of ceramic thickness, cement shades and thermocycling on the final color of PLVs. The study was conducted at Tufts University School of Dental Medicine (TUSDM). (Tables 1, 2)

II. Research Methods

i. Sample size calculation

A power calculation was performed using the statistical software package R (Version 2.11.1). Assuming ΔE means of 3.2 for the 0.5mm/opaque group, 2.6 for the 0.5mm/bleach group, 2.7 for the 1mm/opaque group, and 2.3 for the 1mm/bleach group [3], as well as a common standard deviation of 0.2 [2], a sample size of n=12 per group is adequate to obtain a Type I error rate of 5% and a power greater than 99% for both the opaque/bleach comparison and the comparison of 0.5 mm and 1 mm ceramic thicknesses.

ii. Sample preparation and testing

The substructure was fabricated using composite resin shade C4 (Filtek Supreme Ultra, 3M ESPE, St. Paul, MN, USA) that mimics discolored human teeth. The substructures had the same dimensions as the CAD/CAD block, with 5.00 mm thickness designed to mimic the buccolingual thickness of the central incisors. The composite discs were prepared by creating a custom-made mold from heavy putty following the dimensions above. The specimens were covered with a clean glass plate to obtain a smooth surface, then light polymerized for 40 seconds. After polymerization, the composite discs' L*a*b color readings were checked for standardization using a SpectroShade Micro (MHT, Italy), then divided randomly into four groups for cementation. Lithium disilicate CAD/CAM blocks (IPS e.max, Ivoclar, Buffalo,NY) with a shade of B1 were cut to a thickness of 0.50 mm for Group 1 and a thickness of 1.00 mm for Group 2. The blocks were cut using a sectioning machine (isoMet 1000) with a diamond blade 0.5 mm thick under a constant flow of water that served as a lubricant and coolant. To compensate for the 0.50 mm thickness of the disc, the target number on the machine was increased by 0.5 mm. Before firing and glazing, the sectioned discs were polished using an Ecomet 3 with diamond discs of 320, 600, 6 microns, 3 microns and 1 micron grit and a monocrystalline diamond suspension of 6, 3 and 1 microns, respectively. After sectioning and polishing, the thicknesses of the sectioned discs were rechecked for standardization with a digital gauge (Erskinedental, no.1) sensitive to 0.001 mm. The specimens were cleaned ultrasonically for 10 minutes with distilled water. Each specimen was then coated with a neutral-shade glaze and fired at 820 C. The specimens were again cleaned ultrasonically with distilled water for 10 minutes before the cementation procedure. The samples were then divided randomly into Subgroups A and B.

iii. Testing of the final color outcome

The final color outcome was tested using a SpectroShade Micro (MHT, Italy), which measures the color of the samples and presents the results numerically. A 2.0 mm porcelain block of shade B1 was used as a control group and L*, a* and b* were measured. Samples from Subgroups 1A and 2A were cemented to their respective composite resin C4 discs using white opaque shade resin cement (Variolink II base, Ivoclar Vivadent), while samples from Subgroups 1B and 2B were cemented to their respective composite resin C4 discs using Bleach XL 010 shade resin cement (Variolink II base, Ivoclar Vivadent). Before cementation, porcelain surfaces were treated for 60 seconds with hydrofluoric acid (IPS Etching Gel; Ivoclar Vivadent) and air-dried. Ceramic primer (Monobond S; Ivoclar Vivadent for Variolink II and Variolink Veneer, Ivoclar Vivadent) was applied for 5 seconds. Bonding was performed with resin cement (Variolink II base, Ivoclar Vivadent) applied directly from the syringe (light-polymerizable resins) onto the unglazed surface of the specimens. The specimens were light cured for 10 seconds and excess cement was removed followed by 50 seconds of light curing. After cementation, irregularities from excessive resin cement were adjusted using wet silicon carbide paper (320, 600 grit). Cementation of the porcelain veneers to their respective composite resin C4 discs was performed according to the manufacturer's instructions. Cement thickness was managed using meter ring to 0.1 mm ±0.01 mm, and the specimen thickness was recalibrated again and standardized at 5.6 mm and 6.1 mm for each group.[28-30] After cementations the color of the cemented samples were measured using a spectrophotometer SpectroShade Micro (MHT, Italy), and L*a*b for each were recorded, the color difference (ΔE) between the cemented samples and the control group (the 2 mm ceramic sample shade B1). ΔE was calculated using the following equations:

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

Where $\Delta L^* = L^*$cemented sample - L^*control group, $\Delta a^* = a^*$cemented sample - a^*control group, $\Delta b^* = b^*$ cemented sample - b^*control group.[2]

A tungsten halogen lamp was used according to CIE standards during spectrophotometer measurements of the readings. [31] Gale and Darvell posited that 10,000 cycles of thermocycling might represent one year in function based on the fact that cycles might occur between 20 and 50 times in a day.[19] Further, according to the International Organization for Standardization (ISO), the temperature range from 5°C to 55°C. Therefore each subgroup (1A, 2A, 1B and 2B) was subjected to the thermocycling (Proto-Tech) process for 10,000 cycles with a dual time of 15 seconds and temperature range from 5 C (VWR bath) to 55 C (VWR 1156 bath). Measuring and comparing the ΔE of all cemented samples before and after thermocycling made evaluation of the thermocycling on the final color of the restoration. [18] The color difference ΔE of the samples after the thermocycling were measured using a spectrophotometer SpectroShade Micro (MHT, Italy) and L*a*b for each were recorded then compared to the control group (the 2 mm ceramic sample shade B1) using the previous equation. The same operator performed all of the spectrophotometric measurements blindly using SpectroShade Micro (MHT, Italy).

Results

Statistical Analysis

All analyses, including initial descriptive statistics, were performed using SPSS version 19.0 (SPSS). This includes descriptive analyses (means, standard deviations, standard errors, and confidence intervals), correlations and box plots. All data files obtained from the software are attached to this document. Independent t-tests were conducted to evaluate the effect of different shades of resin cements on the final color of porclein laminate veneers at alpha 0.05. Levene's test for equality of variances was used to evaluate the equal variance assumption. Independent t-test was also used to evaluate the effect of the different veneer thickness on the final color of the PLV used with the discolored substructure. A multi-factor analysis of variance was conducted to evaluate the thermocycling on the final color of the PLV when controlling for both thickness and shade and interaction of both.

Part 1: Testing the effect of the cement shade on the final color of the restoration

The result of the comparison between the opaque and bleach cement are presented using the means and standard deviations (SD). Comparisons of ΔE between the L*a*b readings of Subgroup 1A and 2A and subgroups 1B and 2B were made and compared to the readings of the control group of 2.00 mm thickness of ceramic with B1 shade .The means and standard deviations (SD) for each subgroup are as follow: Subgroups 1A and 2A were 10.78(1.81) and Subgroups 2A and 2B were 16.28(1.49). The assumption of equal variances was violated, as per Levene's test for Equality of Variances. The independent t-test assuming uequal variances showed a significant difference between the two shade groups means, t=-11.50 (p-value<0.001). (Tables 3, 4) The comparison of the two shades showed a significant difference in hiding the discolored substructure between the opaque and bleach shades of the cements on the final color of the restoration. Thus, the null hypothesis was rejected.

Part 2: Testing the effect of the ceramic thickness on the final color of the restoration

The results of the comparison between the different ceramic thicknesses (0.5mm and 1.00 mm) are presented using the means and SDs of the ΔE in Subgroups 1A and 1B and Subgroups 2A and 2B by comparison to the control group of 2.00 mm ceramic thickness with B1 shade. The means and SDs of each subgroup were as follows: 1A and 1B was 15.03(2.71) and Subgroups 2A and 2B was 12.04(3.04). An independent t-test assuming equal variances was conducted at alpha 0.05 indicated a difference between the two thickness groups, t=3.59 (p-value=0.001) was significant. (Tables 7, 8)

Part 3: Testing the effect of thermocycling on the final color of the restoration

The means and standard deviations of ΔE of each subgroup before and after thermocycling were presented.ΔE. ΔE obtained from the L*a*b readings for each subgroup was compared to the control group of 2 mm ceramic thickness with B1 shade. The means and standard deviationss for each subgroup were as follow: subgroup 1A was 12.38(0.32), Subgroup 1B was 17.62(0.85), Subgroup 2A was 9.10(0.72), Subgroup 2B was 14.96(0.35) Table 9. A multi-factor analysis of variance was conducted to evaluate the aging effect (thermocycling) on the final color of the PLV when controlling for both thickness and shade and interaction of both. Both thickness and shade were still significant in relationship with ΔE after thermocycling even after adjusting for each other and possible interaction (p-values <0.001) while interaction of thickness and shade was not significant after thermocycling (p-value=0.07). (Tables 9, 10)

Discussion

After testing the samples with different ceramic thicknesses and different shades of cement, the study rejected the null hypotheses and showed that there were significant differences between the different thicknesses and different shades of cement selected for this study. According to the test results, it showed that the opaque shade of resin cement had a greater effect on the final color of the ceramic veneer restoration compared to the bleach shade of resin cements.

The ΔE values have an adverse relationship with the ceramic thickness. This study confirmed that a thinner ceramic thickness could affect the overall color of a restoration as the ΔE values increased. Previous studies confirmed that the mean values of ΔE decreased when the thickness of ceramic increased from 0.5 mm to 0.7 mm. [4]

The results of previous study showed that 2 mm-thick ceramic crowns were not affected by the substrate color, but when the ceramic thickness was 1 to 1.5 mm, visibly appreciable differences in color were observed. [20]

Previous studies references that the ceramic color changed after using different cement shades and the final color difference (ΔE) of cemented veneers decreased when ceramic thickness increased. [3] The results of this study are consistent with those findings.

In this study, using thermocycling to mimic the oral environment had no significant effect on the final color of the restorations and showed no significant effect on the readings of L*a*b of all samples in each subgroup. The fact that thermocycling had no significant effect on ΔE is important to know, as it shows that the color of the restorationcan be maintained after placement overtime.

This study had several limitations, that may have a direct bearing on the L*a*b readings and the final outcome of the study. These limitations are:

1. Using a single shade of cement, such as C4, to mimic tooth discoloration is one limitation, as the discoloration could be a different shade or intensity such as A4, C3 or D4.

2. Using composite resin discs to simulate discolored tooth substructure is a further limitation. Natural teeth have different optical properties than do composite resin and it is difficult to standardize those properties. Tooth structure also has different L*a*b readings compared to the composite resin blocks that were used in this study. Due to the difficulty of obtaining natural teeth with the required discoloration, composite resin was chosen to mimic the discolored substructure.

3. The study used only one type of cement, (Variolink II, Ivoclar Vivadent). It is considered one of the most desirable dental cements, especially for veneers. It has a good adhesion and color stability compared to other veneer cements; however, this is nonetheless considered to be limitation in this study.

4. Ceramic thickness is another limitation. While the study used thicknesses of 0.5 mm and 1.0 mm, in clinical settings other thicknesses of 0.3 mm, 0.7 mm, 1.5 mm or more might be used depending on the amount of enamel removed or the shade of the substructure found. [2, 9]

Nonetheless, This study may help the clinicians to have a better idea about the ceramic thickness and cement resin shade selection and their relationship when treating the discolored teeth substructure. With consideration of the limitations of this study, further studies with different shades of cement, brands and ceramic thicknesses are recommended to evaluate their effect on the final color outcome.

Conclusion

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1. The final color of laminate veneer restorations is affected by the color of the resin cement. When used with different thicknesses, opaque resin cement has a better masking effect on the final color of the restoration compared to the bleach resin cement.

2. The thickness of the restoration has a direct effect on the final color of the restoration. A 1.0 mm ceramic thickness enhanced the final color of the restoration compared to the 0.5mm thickness.

3. Accelerating aging (thermocycling) had no significant effect on the color of the cemented laminate veneers.

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APPENDICES

Appendix A: Tables

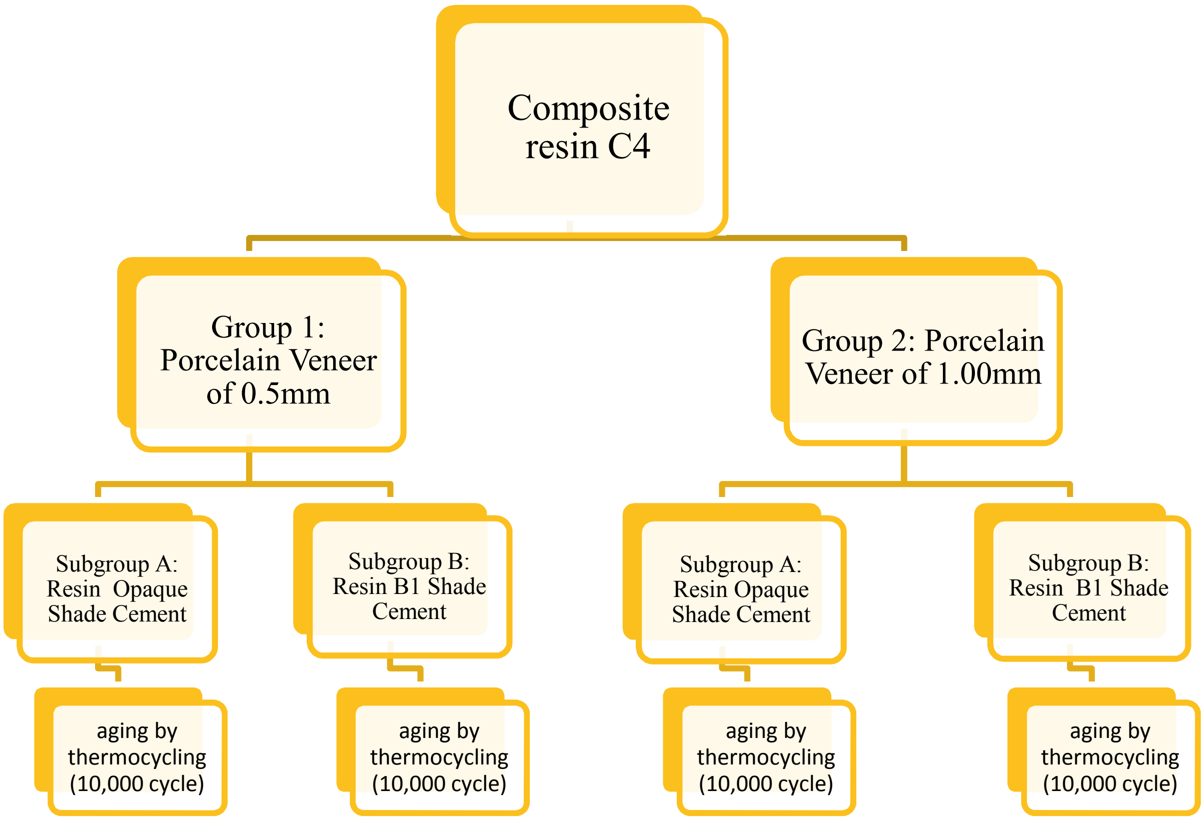

Table 1. Study Groups and Subgroups.

Cement Color / **Porcelain Thickness**	**Bleach**	**Opaque**
0.5 mm thickness	ΔE	ΔE
1.00 mm thickness	ΔE	ΔE

Table.2 shows the calculation of ΔE after cementation of both groups.

Group Statistics

Shade	N	Mean	Std. Deviation	Std. Error of Mean
Opaque	24	10.78	1.81	.37
Bleach	24	16.28	1.49	.30
Total	48	13.53	3.23	.47

Table.3 Means, standard deviation of two different shade of cement.

Independent Samples Test

ΔE	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	3.5	.07	-11.50	46	.000	-5.50	.48	-6.46	-4.54
Equal variances not assumed			-11.50	44	.000	-5.50	.48	-6.46	-4.54

Table.4 Equal variances not assumed with $p < 0.05$

Paired Samples Statistics

ΔE		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Opaque/0.5 mm	12.44	12	.36	.10
	Opaque/1.0 mm	9.12	12	.81	.24
Pair 2	Bleach/0.5 mm	17.61	12	.85	.24
	Bleach/1.0 mm	14.96	12	.35	.10

Table. 5 Paired samples test for subgroups 1A and 1B and 2A and 2B

Paired Samples Test

ΔE	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
(Opaque/0.5 mm) - Opaque / 1.0 mm	3.32	.83	.24	2.8	3.85	13.90	11	.000
(Bleach/0.5 mm) - (Bleach / 1 mm)	2.65	1.03	.30	1.99	3.30	8.91	11	.000

Table.6 Paired samples T-Test

Group Statistics

ΔE

Thickness	N	Mean	Std. Deviation	Std. Error of Mean
0.5	24	15.03	2.71	.55
1.0	24	12.04	3.04	.62
Total	48	13.53	3.23	.47

Table. 7 Group Statistics for ΔE for Ceramic Thickness.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
ΔE	Equal variances assumed	3.50	.07	3.59	46	.001	2.99	.83	1.31	4.66
	Equal variances not assumed			3.59	45.40	.001	2.99	.83	1.31	4.66

Table.8 Equal variances not assumed with $p<0.05$.

Descriptive Statistics

Shade	Thickness	Mean	Std. Deviation	N
Bleach	0.5 mm	17.62	.85	12
	1.0 mm	14.96	.35	12
	Total	16.29	1.50	24
Opaque	0.5 mm	12.38	.32	12
	1.0 mm	9.10	.72	12
	Total	10.74	1.76	24
Total	0.5 mm	15.0	2.75	24
	1.0 mm	12.03	3.05	24
	Total	13.52	3.24	48

Table 9. Comparing the mean and SDs for each subgroup after thermocycling.

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	476.87	3	158.96	436.04	.000
Intercept	8768.85	1	8768.85	24054.35	.000
Shade	369.73	1	369.73	1014.23	.000
Thickness	105.95	1	105.95	290.62	.000
Shade * thickness	1.20	1	1.20	3.28	.077
Error	16.04	44	.37		
Total	9261.76	48			
Corrected Total	492.91	47			

Table.10 comparing ΔE before and after Thermocycling

Appendix B: Figures

Figure.1 Teeth discolored by Tetracycline.

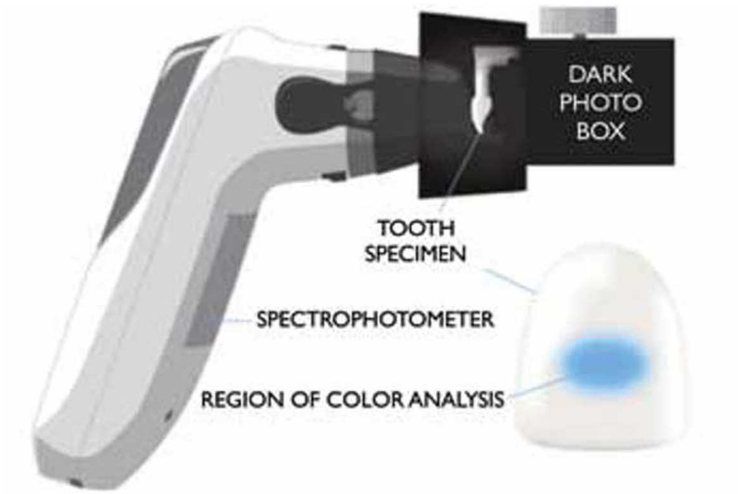

Figure 2 SpectroShade Micro (MHT, Italy).

Figure 3 IsoMet 1000 (Sectioning Machine)

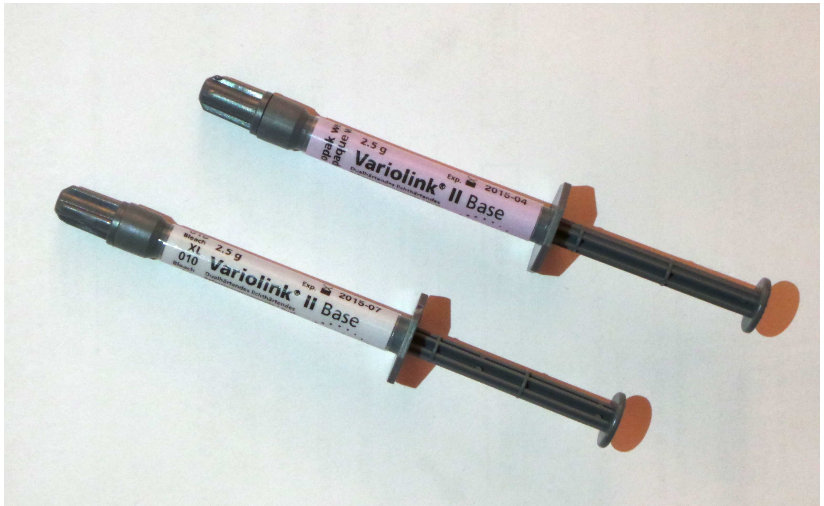

Figure 4 Variolink II Base, Ivoclar Vivadent

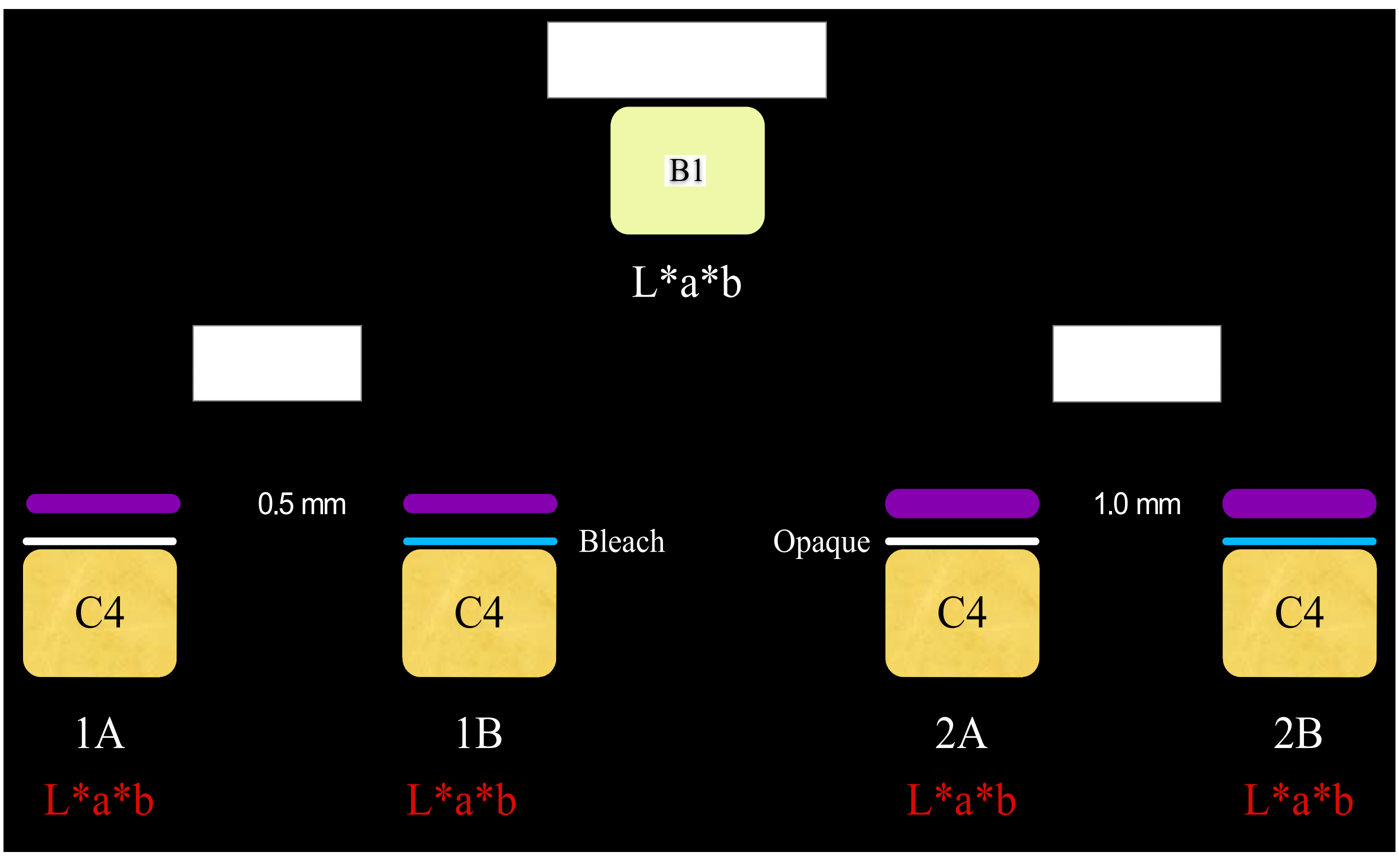

Figure. 5 Calculating L*a*b for the control group (2 mm thickness) and each Subgroup (1A, 1B, 2A and 2B)

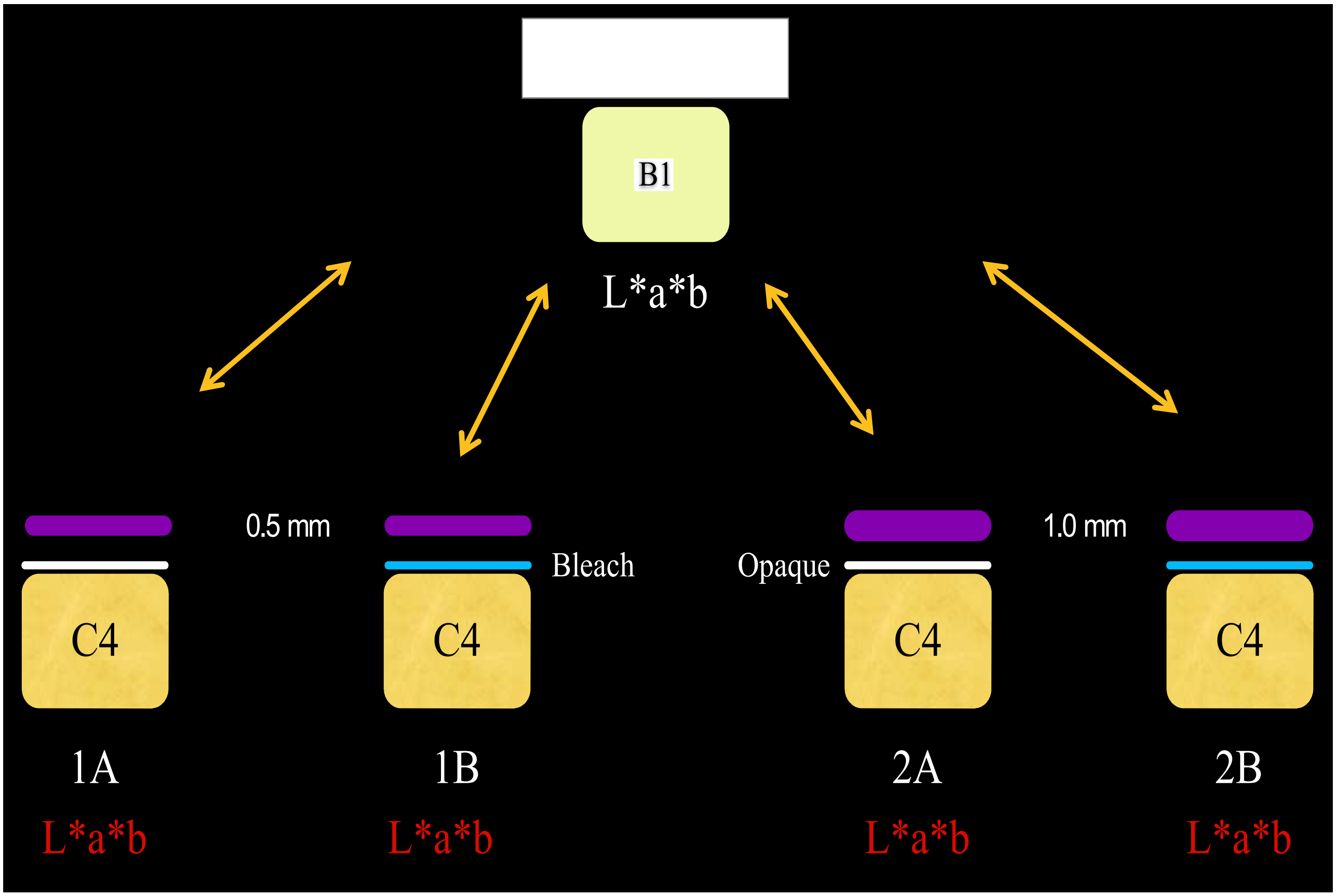

Figure. 6 Calculating ΔE for each subgroup.

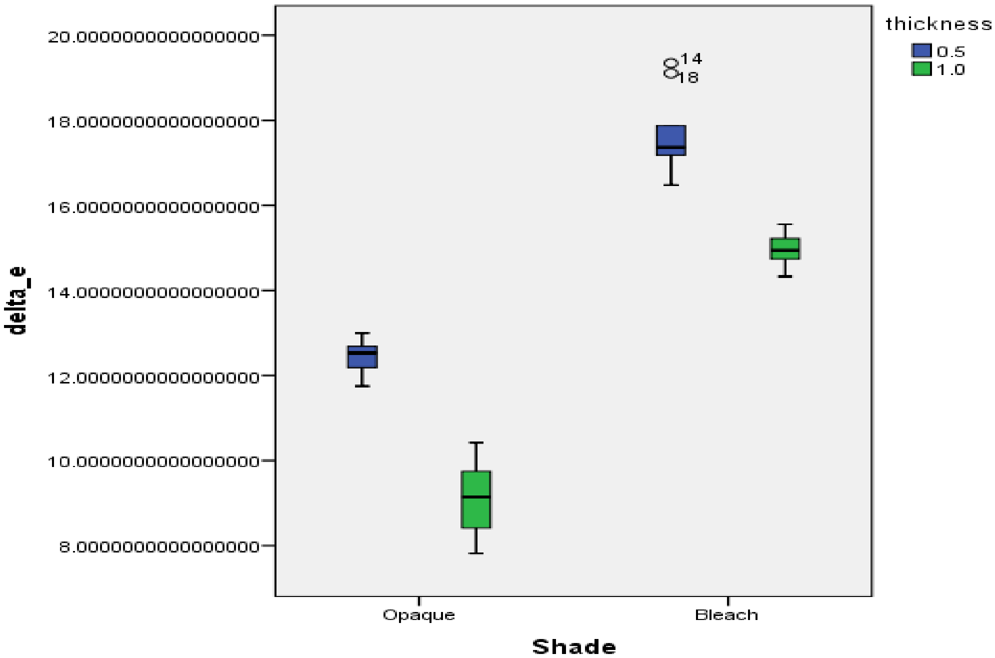

Figure.7 Boxplots showing the groups of shade and thickness with the means and interquartile ranges of ΔE outcome.