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The Color Differences Between Different Thicknesses of Resin Veneered Over Amalgam

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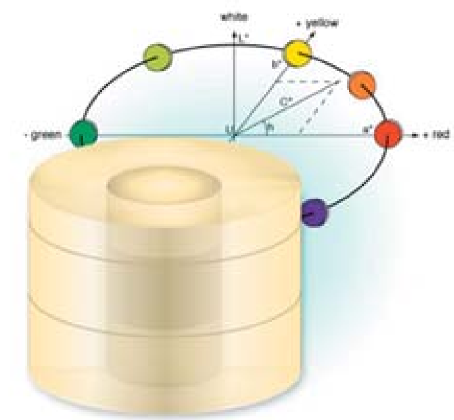

Abstract

Statement of Problem: Composites and compomers are popular in dental practice. However, little is known about their esthetic appearance as veneering restorative materials over amalgam restorations.

Purpose: This *in vitro* study was designed to assess the color differences of composite and compomer restorative materials, placed in thicknesses of 1 mm and 2 mm over amalgam.

Material and Methods: Thirty six cylindrical Teflon molds were filled with amalgam (13 mm diameter, 2 mm thickness) and stored at 37°C and 100% relative humidity for 7 days. Nine veneers (for each thickness of 1 and 2 mm) were fabricated from four types of tooth-colored restorative material, Dyract AP (DYR), Compoglass F (COMP), Herculite XRV (XRV), and Vitalecense (VIT), over amalgam specimens using Teflon-split molds and following the manufacturers' instructions. A spectrophotometer was used to measure the color difference ΔE* between the two thicknesses.

Results: Color difference ΔE* values for 1 mm thickness veneers [XRV (2.52), Comp (5.46), VIT (6.73), and DYR (6.88)] were statistically significantly higher than the 2 mm thickness [XRV (1.32), Comp (3.24), VIT (4.89), and DYR (4.83)]. Although the XRV material had the lowest ΔE* values, no statistically significant difference was found between the two thicknesses. The color measurements at L*, a*, and b* showed most materials became darker in color at either thickness.

Conclusion: The thicker veneer specimens were found to be closer in color to the controls than the thinner specimens. Only XRV had color differences (ΔE^*) small enough to be considered clinically acceptable (2.52 and 1.32 at 1 mm and 2 mm, respectively).

Clinical Implications: In this *in vitro* study the color of XRV was affected the least when veneered on amalgam. Opaquers may be needed to be used with thinner veneers to minimize the effect of amalgam background.

Keywords: Opaquers, composite resin, veneer, esthetic, color stability

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Introduction

An esthetic appearance is important for restored teeth. Increased demand for esthetic dentistry has led to the development of new adhesive tooth-colored materials. Composite restorative materials have been improved dramatically in their mechanical and optical properties over the last decade.[1, 2] However, despite the major developments in their physical properties, composite restorative materials are still unsuitable for direct, extensive restoration of the functioning surfaces of posterior teeth.[3]

Many problems such as wear, restoration fracture, marginal deterioration, discoloration, polymerization shrinkage, marginal leakage, and secondary caries associated with the direct placement of large posterior composite restorations can be overcome with the use of the indirect composite or ceramic inlay and onlay techniques.[4] However, the strict patient selection criteria, the need for additional removal of sound tooth structure, the need for special equipment, and increased cost have discouraged the routine use of such restorations.[3] These aspects in addition to the proven clinical behavior of dental amalgam, its durability, low cost, ease of manipulation, and long-term performance[5] suggests replacement of well functioning amalgam restorations with composite has no therapeutic value, except in those situations where an allergic reaction to mercury has been diagnosed.[6] Conversely, the color of amalgam is a major disadvantage that prevents its use for restoration of buccal cusps and surfaces of maxillary premolars and first molars.

In an effort to overcome the esthetic problem of amalgam restorations, methods of combining tooth-colored materials with amalgam restorations have been introduced.[7-9] Composites or compomers[6] can be used to mask the visible unesthetic areas of amalgam restorations.

Color measurements using instruments such as a colorimeter or spectrophotometer have been established in literature[10-12] as a means of measuring color stability of tooth colored restorative materials. These instruments can detect color differences both objectively and meterically using the CIE LAB system that was established by Commission Internationale de l'Eclairage (CIE).[13]

There is some controversy between authors on the determination of the acceptability levels for color matches. According to Keuhni and Marcus[14], a ΔE^* value of more than 3.02 indicates the material is discolored. Ruyter et al.[15] reported a ΔE^* value of 3.3 indicates the material's color is clinically unacceptable. Furthermore, O'Brien rated ΔE^* values 1-2 as good color-matching, 2-3.5 as clinically acceptable, and above 3.5 as a mismatch.[16] Seghi et al. studied the relation between measured color difference values and human observer response and found a ΔE^* greater than 2 was correctly judged 100% of the time, while a ΔE^* value of 1-2 was frequently incorrectly judged by the observers.[10] According to Johnston and Kao[11] the average color difference between compared teeth was rated ΔE^* 3.7 as a match in the oral environment.[11]

Table 1. Different restorative materials used in the study.

Restorative Materials	Code	Shade	Lot No.	Manufacturer
Dispersed Amalgam Alloy				Johnson & Johnson, East Windsor, N.J, USA
Herculite XRV	XRV	A2	002063	SDS Kerr, Orange,CA, USA.
Compoglass F	COMP	A2	D00201	Vivadent Ets., FL-9494 Schaan / Liechtenstein
Dyract AP	DYR	A2	000649	DeTrey, Dentsply, Konstanz, Germany
Vitalecense	VIT	A2	3WG9	Ultradent, South Jordan, UT, USA

Several studies have investigated the factors affecting the appearance of composite restorative materials.[16, 19-22] The factors are discoloration due to exposure to artificial daylight[19], staining from solutions[20], background[22], and characteristic of resin materials.[16, 21-22] Abu-Baker et al. investigated the color stability of compomer, composite, and glass ionomer in four types of solutions.[20] They concluded compomer and the resin modified glass ionomer were susceptible to discoloration, while resin composite showed minimum color changes. However, Schulze et al.[23] concluded tooth colored restorative material had significant color changes after using accelerating aging (xenon light and water).[23] Light curing materials were significantly more stable than chemical curing restorative material.

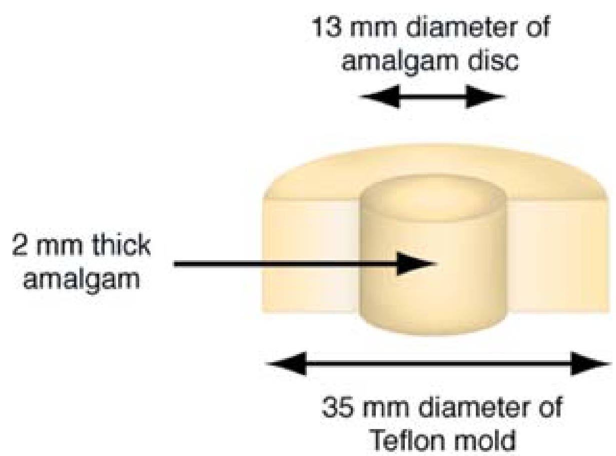


Figure 1a. Diagram of theTeflon mold.

Craig stated the thicknesses of composite resins can eliminate the effect of the background of materials.[22] Furthermore, the appearance of composite resins can be enhanced by the characteristic of materials (absorption and scattering of the light).

However, little is known about the effect of the amalgam background on the esthetic appearance of tooth-colored restorative materials.

The purpose of this in vitro study was to investigate the color differences between different thicknesses (1 mm and 2 mm) of composite and compomer restorative materials veneered over amalgam.

Material And Methods

Specimen Fabrication and Procedure

In this *in vitro* study four types of resin-based tooth-colored restorative materials were used (Table 1). A total of 36 Teflon molds (E.I. du Pont de Nemours and Co, Wilmington, DE, USA) 35 mm diameter x 2 mm thickness with 13 mm diameter holes in the center were used to fabricate 36 specimens of amalgam (Figure 1a). Dispersalloy amalgam (Johnson & Johnson, East Windsor, NJ, USA) was condensed into the mold placed on a glass slab and carved on each side with a carver (Hollenbeck, HuFriedy, USA) flush with the Teflon surface to yield a disc-shaped specimen. Specimens were stored at 37°C and 100% relative humidity for 7 days before adding tooth-colored restorative materials as veneers.

Amalgam specimens were divided into four groups to be veneered: Dyract AP (DYR), Compoglass F (COMP), Herculite XRV (XRV), and Vitalecense (VIT). A split-Teflon mold (13 mm x 1 mm thick) was placed around one side of the amalgam disc to be filled with 1 mm tooth-colored restorative material over amalgam. Using a similar procedure, a 2 mm thick x 13 mm

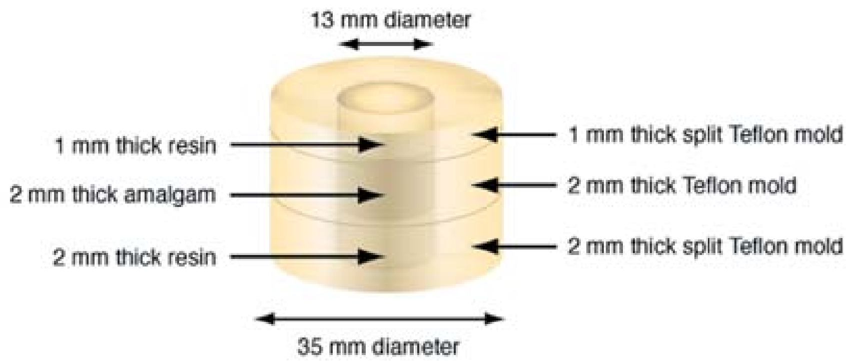


Figure 1b. Diagram of the full assembly of amalgam veneered to tooth-colored material for both thickness.

split-Teflon mold was placed around the other end of the amalgam disc to be filled with 2 mm tooth-colored restorative material over amalgam (Figure 1b).

The adhesive, supplied by manufacture, of each restorative system was applied to the amalgam surface following their instructions. The tooth-colored restorative material was packed into the split mold with a large amalgam condenser and covered with a glass slide using thumb pressure. In addition, a total of three disc specimens of each tooth-colored restorative material were fabricated using a Teflon mold (13 mm x 3 mm thick) to serve as a control specimen.

During the bonding procedure, the tip of the polymerizing unit (Coltene, Alstatten, Switzerland) was positioned in contact with the surface of the glass slide placed over the specimen in the mold and cured for 40 sec with a light intensity of 450 nm. Verification of the intensity of the light output was checked after polymerizing every three specimens using the digital read-out light meter available with the unit.

Color Measurements

All specimens were subjected to measurement of color utilizing a spectrophotometer (Color-Eye 7000A, Gretag Macbeth, New Windsor, NY, USA). This instrument compares the amount of light that illuminates an object with the amount of light that is reflected. The spectrophotometer was calibrated with white and black ceramic tiles provided by the manufacturer. The color parameters CIE LAB13 (L*, a*, and b*) were used in this study.

L*, a*, and b* were measured for all control specimens of the restorative materials under a white-tile background. For each tooth-colored restorative material, an average reading (L*, a*, and b*) of the three control specimens was recorded and compared to the nine experimental specimens (L*, a*, and b*).

The differences in the lightness and chromaticity coordinates (ΔL*, Δa*, and Δb*) between the control and experimental specimens were determined. and the total color change (ΔE* ab) was calculated using the following formula:[16]

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

Statistical Analysis

Mean values were analyzed using independent 2-tailed t-test for ΔE* comparing each material versus thickness (1 and 2 mm). Furthermore, one-way ANOVA was performed to compare between four materials versus thickness (1 and 2 mm). Multiple range test post hoc (Student-Newman-Kreuls test) was performed for ΔE* at level $P< 0.05$.

Results

Group mean and standard deviation color differences ΔE* and CIE LAB between 1 and 2 mm specimens are presented in Table 2. Independent 2-tailed t-test for ΔE* value was also conducted between two different thicknesses (1 and 2 mm) for each material separately (Table 2). It was evident from the t-test (Table 2) that XRV had no statistically significantly differences between 1 and 2 mm thicknesses $p>0.05$ (2.52 and 1.32, respectively), while the rest of the materials showed statistically significant differences ($p<0.05$) for both thicknesses.

One way ANOVA (Table 3) showed there were statistically significant differences between the four materials at each thickness ($p< 0.05$).

Multiple range test post hoc was carried out to arrange the results into statistically significant differences at different thicknesses (Table 4). From Table 4, DYR had a ΔE* value of 6.7 for 1 mm and 4.84 for 2 mm, and VIT had a ΔE* value of 6.8 for 1 mm and 4.89 for 2 mm; both materials

Table 2. Means and SD of color analysis for materials vs. thickness (1 mm and 2 mm) and independent 2-tailed t-test for ΔE* comparing for each material vs. thickness.

Parameter	Material	thickness	N	Mean	SD
ΔE*	XRV	1 mm	9	2.52	0.18
	XRV	2 mm	9	1.32	0.52
	Comp	1 mm	9	5.46	0.65
	Comp	2 mm	9	3.24	0.69
	VIT	1 mm	9	6.73	0.55
	VIT	2 mm	9	4.89	0.71
	DYR	1 mm	9	6.88	0.53
	DYR	2 mm	9	4.83	0.68
ΔL*	XRV	1 mm	9	-0.82	1.25
	XRV	2 mm	9	0.16	1.32
	Comp	1 mm	9	-2.77	0.73
	Comp	2 mm	9	-1.60	0.35
	VIT	1 mm	9	-3.70	0.34
	VIT	2 mm	9	-2.86	0.75
	DYR	1 mm	9	-3.83	0.46
	DYR	2 mm	9	-0.08	2.55
Δa*	XRV	1 mm	9	2.52	0.18
	XRV	2 mm	9	-0.15	0.12
	Comp	1 mm	9	5.46	0.65
	Comp	2 mm	9	-1.61	0.47
	VIT	1 mm	9	6.73	0.56
	VIT	2 mm	9	-1.79	0.56
	DYR	1 mm	9	6.88	0.53
	DYR	2 mm	9	-1.02	0.37
Δb*	XRV	1 mm	9	1.93	0.71
	XRV	2 mm	9	0.53	0.54
	Comp	1 mm	9	4.16	0.40
	Comp	2 mm	9	2.29	0.52
	VIT	1 mm	9	5.15	0.54
	VIT	2 mm	9	3.48	0.33
	DYR	1 mm	9	5.47	0.38
	DYR	2 mm	9	4.06	0.37

Group means are statistically significant differences in t-test samples ($P = 0.05$).
Note: The post hoc test was performed for ΔE* values only.

Table 3. ANOVA results at thickness 1 and 2 mm vs. four materials.

Thickness ΔE* values	Source	DF	Mean squares	F Ratio	Sig. P.
1 mm	Between Groups Within Groups	3 32	36.84 0.27	134.52	0.000
2 mm	Between Groups Within Groups	3 32	25.48 .43	59.59	0.000

Table 4. Summary of multiple range test post hoc test (Student-Newman-Keuls) for ΔE* values at 1 and 2 mm thickness vs. materials.

Materials thickness		N	Subset for alpha = 0.05		
			1	2	3
XRV		9	2.5		
COMPG	1 mm	9		5.46	
DYR		9			6.73
VIT		9			6.88
Sig. P value					0.536
XRV		9	1.32		
COMPG	2 mm	9		3.24	
DYR		9			4.83
VIT		9			4.89
Sig. P value					0.831

Means for groups in homogeneous subset are displayed.

Table 5. Color measurement at L*, a*, and b* for materials under different thickness.

	Control			After bonded to amalgam			
Code	L*	a*	b*	Thick	L*	a*	b*
XRV	56.35	-0.47	3.20	1 mm	55.50	-0.58	1.26
				2 mm	56.51	-0.64	3.57
DYR	59.61	-0.10	7.9	1 mm	55.88	-1.26	2.63
				2 mm	59.67	-0.76	3.94
COMP	67.74	0.51	14.56	1 mm	64.68	-1.32	10.42
				2 mm	66.21	-0.89	12.36
VIT	66.41	0.26	8.73	1 mm	62.83	-1.47	3.36
				2 mm	63.65	-1.21	5.36

had the highest ΔE* values in both thicknesses, and there were no statistically significant differences ($p< 0.05$) between them. XRV had the lowest ΔE* value of tested materials (2.5 and 1.32 at 1 and 2 mm, respectively).

The values for each parameter of color L*, a*, and b* were compared for the control and tested specimens as shown in Table 5. Graphical illustrations of the values in Table 5 are presented in Figure 2 and Figure 3. These figures demonstrate the 2 mm thickness specimens experienced smaller color changes towards a* and b* values than the 1 mm thickness specimens.

Discussion

A spectrophotometer was used in this study to measure the color stability of resin materials veneered over amalgam. The CIE Lab color order system provides a useful tool for quantifying color properties of dental materials. Color is described using a mathematic three dimension system based on L* and is measured for value or brightness. The a* measures hue-chroma in the red-green direction, while b* measures hue-chroma in the blue-yellow axis.[16]

Due to a lack of clear parameters (ΔE* values) to compare color differences of materials as clinically acceptable (match) or unacceptable (mismatch), Johnston and Kao[11] parameter ΔE* value 3.7 was adopted in this study to rate the material as a match in the oral environment.[11]

Investigation of the overall color changes of ΔE* showed a 1 mm thickness veneer had a statistically significant higher ΔE* values than at 2 mm thickness for most materials tested ($p<0.05$) except XRV, which had no statistical significant difference between both thicknesses (Table 2). XRV was the only material that had the lowest ΔE* values both for 1 mm thickness (2.52 ± 0.18) and for 2 mm thickness (1.32 ± 0.52) and was rated as clinically acceptable and good color matching for both thicknesses. COMP, VIT, and

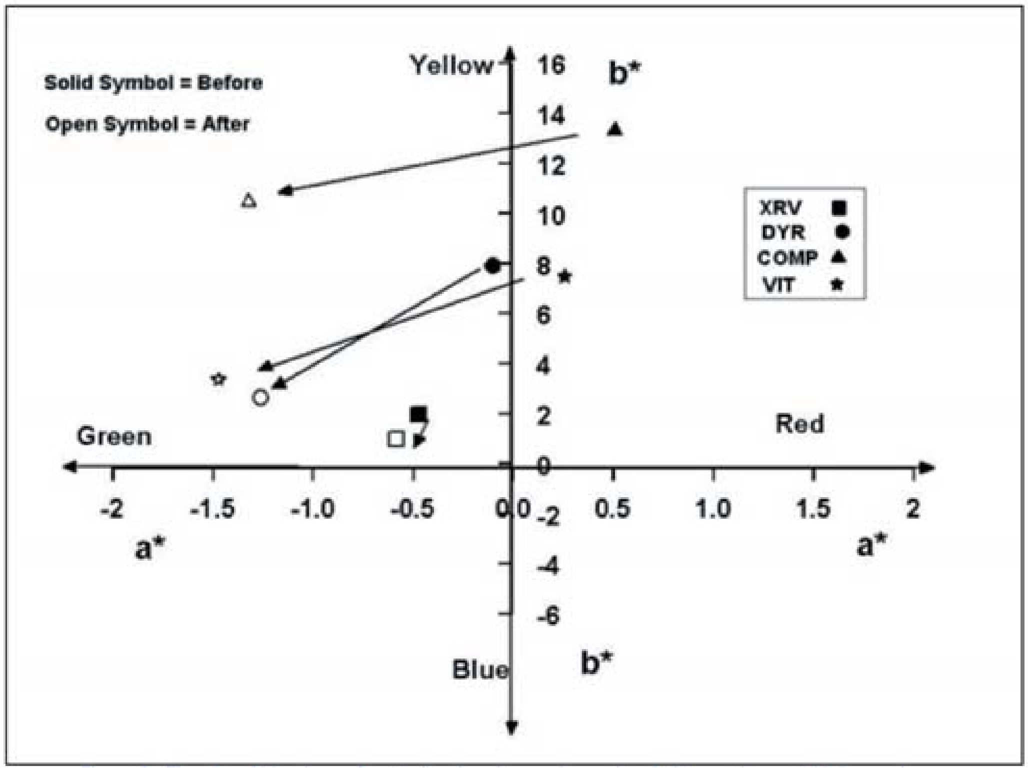


Figure 2. The a* and b* values of control and resin specimens bonded to amalgam at thickness 1 mm.

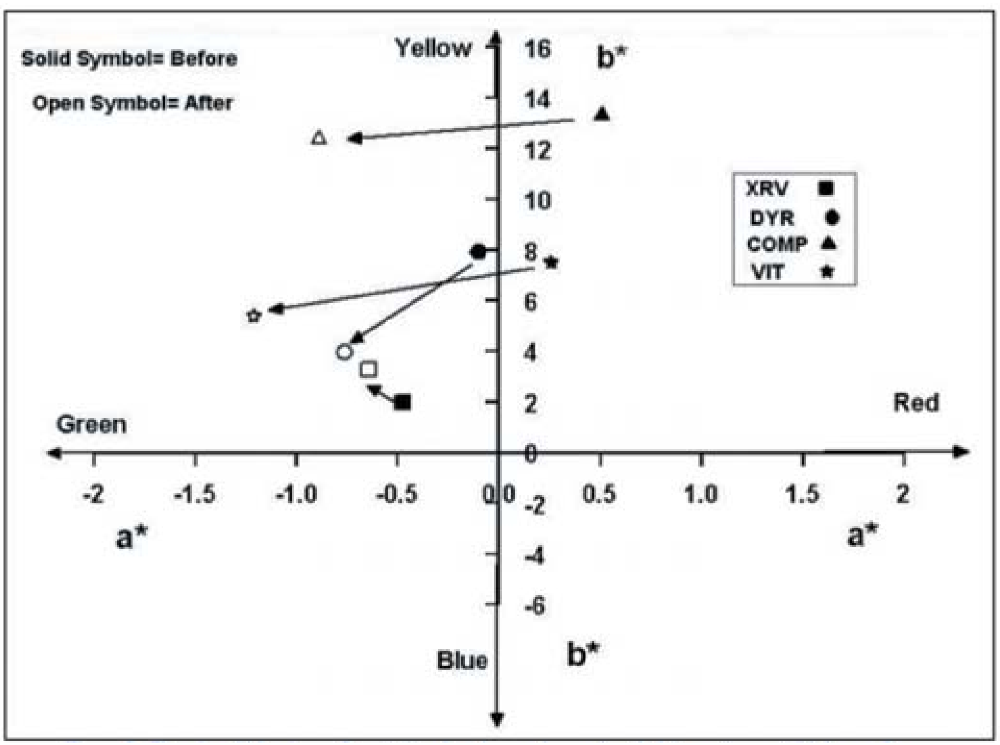
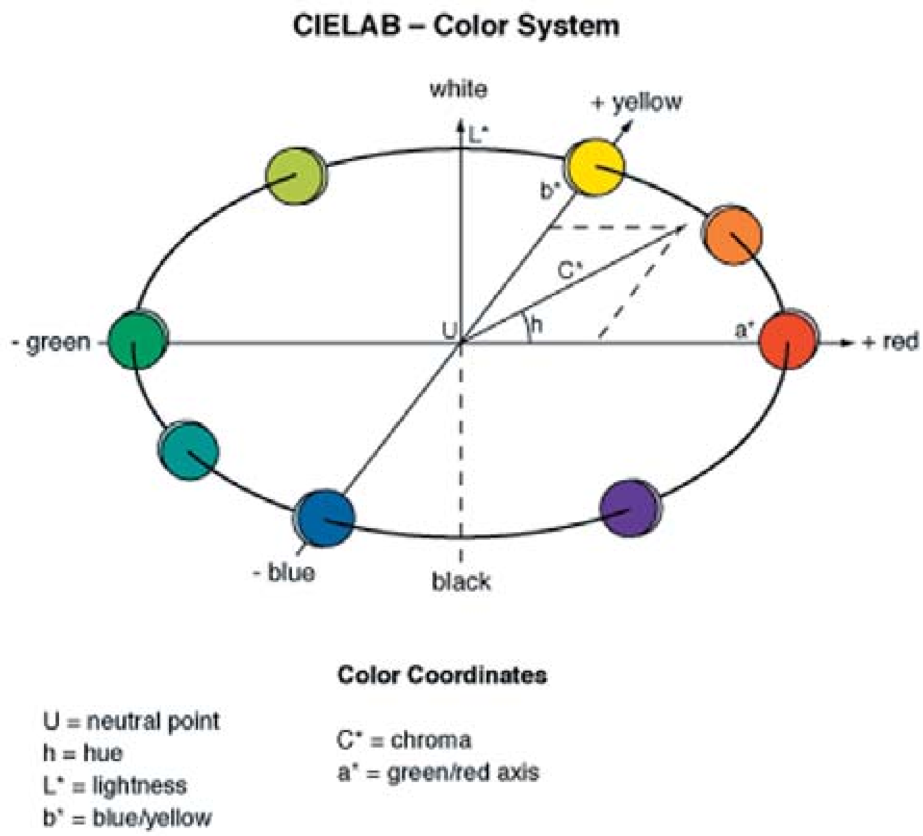


Figure 3. The a* and b* values of control and resin specimens bonded to amalgam at thickness 2 mm.



The CIELAB Color System is a transformation of the XYZ Color System which improves agreement between measured and perceived color differences.

DYR, for 1 mm thickness, had ΔE* values of 5.46, 6.73, and 6.88, respectively which, according to Johnston and Kao[11], were clinically unacceptable (mismatch) (Table 4). On the other hand, COMP, for the 2 mm thickness, had a ΔE* value of 3.24 and was rated as clinically acceptable, but the ΔE* values with DYR (4.89) and VIT (4.89) were clinically unacceptable (mismatch) (Table 4).

The color measurements at L*, a*, and b* (Table 5) showed there was a color shift from red to green (negative Δa*) and from yellow to blue (negative Δb*) for both thicknesses (Figure 2 and Figure 3).

This is an increase in green saturation for most specimens and a decrease in yellow saturation in most specimens. Table 5 indicates most tested materials had negative ΔL* values, which means all specimens were darker than the controls for both thicknesses. However, XRV showed a minimal color shift toward the darkness compared to the rest of materials.

The appearance of resin restorative materials is affected by the type of the background.[21-22] The background effect can be eliminated by the following factors: (1) light absorption and internal scattering characteristics of the resin-material[24], (2) the thickness of the resin-material[21], and (3) the light reflecting properties of the background.[22-24]

Absorption and scattering of the light can affect the translucency and the opacity of the resin materials. O'Brien defines the translucency as the amount of incident light transmitted and scattered by the object.[16] A more translucent material will show more effect of the backing on the color and appearance. Translucency decreases with increased scattering within the material.[22] Opacity is the opposite to the translucency in which the material prevents the passage of light.

The thickness of composite resin restoration can affect its appearance. Craig stated there is an increase in opacity as the thickness increases for composite resin.[22] Resin material thicker than 2 mm appears more opaque and losses its translucency.[22] For these findings, the authors chose the control specimens of 4 mm thickness to override any effect of the background on the color of the resin materials. In this study 2 mm thickness specimens showed lower ΔE^* values compared to 1 mm thickness. This may be attributed to the effect of light absorption and scattering characteristics of the resin restorative material.

The light reflecting properties of the background (amalgam) had a major influence on the esthetic appearance of the resin materials used in this study. Within the limitation of the finding of this study, the need of an opaque material to mask the effect of the amalgam background may be necessary to enhance the esthetic appearance of the tooth-colored restorative materials when used for veneering.

Conclusions

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

1. Smaller color differences from controls were found in the thicker specimens compared to the thinner specimens ($p< 0.05$).
2. All resin-materials investigated, except XRV (1.32), had color differences that were larger than the clinically acceptable threshold (3.7) used for this study.
3. Most materials were darker than their control specimens at either thickness.

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