A Study on Color Differences Between Composite Resins and Shade Guides

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국문초록

복합레진과 shade guide의 색차에 관한 연구

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복합레진은 조작이 용이하고 강도가 우수하며 중합시간이 짧고 법랑질과 상아질에 접착이 가능하며 연마성이 뛰어나고 자연스러운 색상을 나타내므로 심미적 수복에 가장 일반적으로 선택되는 재료의 하나이다. 대부분의 복합레진 kit에는 shade guide가 포함되어 있어 이를 기준으로 중합된 후의 복합레진 색조를 예상하여 선택하게 된다. 그러나 이러한 shade guide들은 대개 복합레진이 아닌 plastic으로 제조된 것으로 중합된 복합레진의 실제 색조와는 차이가 생기게 되며 결국 shade guide 자체의 문제점으로 인해 이상적인 색조선택이 어려워진다. 이에 본 연구에서는 국내에 시판되고 있는 5종의 복합레진 제품을 선정하여 분광광도계를 이용해서 shade guide와 중합된 복합레진 사이의 색조차이를 측정, 비교 연구하였다.

직경 16mm, 두께 1.6mm의 plastic mold에 5종의 광중합형 복합레진(Z100, Prisma TPH, Tetric, Silux Plus, Herculite XR)을 충전하고 응축기에 넣어 압축한 후 제조사의 지시에 따라 광중합기로 중합시킨 후 mold에서 시편을 제거하여 보관했다가 젖은 sandpaper 상에서 순차적으로 연마하였다. shade guide는 step부분을 갈아내어 복합레진 시편과 동일한 두께로 만든후 연마하였다. 분광광도계에 shade guide를 넣고 CIE illuminant D65 하에서 spectral reflectance를 측정하고 해당 색조의 복합레진 시편도 동일한 방법으로 측정하고 L*, a*, b*값과 ΔE^*값을 얻은후 분석하여 다음과 같은 결과를 얻었다.

1. Z100의 D3, A3, B2 shade와 Prisma TPH의 B2 shade를 제외한 모든 시편에서 shade guide와 복합레진간에 육안으로 인지할 수 있는 색차($\Delta E^* > 1.0$)가 관찰되었다.

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2. 평균적으로 Z100이 가장 적은 색차를 나타내었고 Prisma TPH, Tetric, Silux Plus, Herculite XR 순으로 색차가 증가하였다.
3. Prisma TPH의 A2 shade, Tetric의 W shade, Silux Plus의 YB, U shade, Herculite XR의 L, LY shade는 ΔE*값이 3.3 이상으로 나타났다.
4. Z100, Prisma TPH, Tetric, Silux Plus에서는 복합레진보다 shade guide가 더 높은 L*값을 보이는 경향이 나타났으며, Herculite XR에서만 복합레진이 더 높은 L*값을 나타냈다.
5. 모든 시편에서 b*값은 (+)로 관찰되었고, Z100, Prisma TPH, Tetric, Silux Plus의 shade guide는 복합레진에 비해 높은 b*값을 보였다.
6. 모든 시편에서 a*값은 (−)로 관찰되었고, Herculite XR 및 Silux Plus에서는 복합레진이 shade guide에 비해 낮은 a*값을 나타냈다.

주요어 : 색차, 복합레진, shade guide, 분광광도계, ΔE*

I. Introduction

Today, dentists have to think of not only the proper functioning of the teeth but also the esthetics. This means that restorative work must result in teeth of a shape and color that harmonize imperceptibly with the surrounding natural teeth.

Tooth-colored, resin-based composite resins have been used as dental restorative materials to meet esthetic requirements. The demands made on resin-based restorative materials are therefore considerable. These materials are used because of their good handling properties, strength, short curing time, lasting adhesion to the enamel and the dentin, excellent polishability and the natural colors of the materials. Resin-based restorative materials make it possible to produce restorations that are virtually indistinguishable from natural teeth.

Since resin-based restorative materials are a particularly good alternative to other restorative materials for anterior teeth, esthetic aspects are of prime importance. But the dental profession has long been hampered with the problem of matching the color of restorative materials to a patient's natural dentition. A majority of the problems associated with esthetic restorative procedures is concerned to some degree with shade control[1].

Shade selection for composite resin is frequently difficult, despite the increasing number of shades and opacities available. Even with a correct shade, changes in the background and thickness of a composite resin can alter its appearance[2,3]. Many composite resins are still marketed in shades such as universal, light, yellow, etc. These shade designations are both arbitrary and subjective, and they vary substantially among manufacturers. The problem of shade matching is also complicated by the shade guides provided with many products. The shade guides are generally made of plastic (rather than the actual composite material) and do not accurately depict the true shade, translucency, or opacity of the composite resin after polymerization[2,4].

Goodkind and Loupe's recent survey disclosed that, regarding shade guides, most respondent felt that manufacturers' shade guides were inadequate for porcelain (61% inadequate) and composite (58% inadequate) restorations. Almost (85%) felt that there was a need to develop a new shade guide[5].

The purpose of this study is to compare the color of the shade guides provided with the products and the color of the actual composite materials. Color differences between the shade guides and composite resins are presented.

II. Method and Materials

Specimen preparation

The five light activated, resin-based materials provided with plastic shade guides were used in this study (Table 1). Three specimens of each material/shade combination were made. Composite resin was condensed into plastic mold with a diameter of 16mm and a thickness of approximately 1.6mm and pressed between glass plates to flatten the surfaces. The materials were handled according to each manufacturer's instructions. Care was taken to avoid porosities by entrapment of air bubbles. The material was polymerized using a Visilux II (3M) visible light-activation unit, with the specimen kept directly in the beam. The light-polymerizing unit was monitored using a light meter (Curing Radiometer, Demetron, Danbury, CT) to ensure consistent output. After removal of excess, the surfaces were polished sequentially on wet 320-, 400-, 600-, 800-, 1000-, and 1200-grit sandpaper (Daesung Abrasive Co., Korea).

Shade guides were ground with polishing stone and rubber point(Shofu Inc., Kyoto, Japan) to a thickness of approximately 1.6mm. Then the surfaces were polished on wet sand-

Table 1. Products, shades, filler composition and manufacturers of composite resin tested

Product	Shade	Filler composition	Manufacturer
Z100	A2 A3 A3.5 A4	hybrid	3M Co.
	B2 B3	zirconia/silica	
	C2 D3	87% wf*, 71% vf**	
Prisma TPH	A2 A3.5	hybrid	L.D Caulk Co.
	B1 B2 B3	barium glass	
	C1 C2 D3 DY	77.5% wf	
Herculite XR	L LY LG	hybid	Kerr-Sybron
	U DG DY	barium glass	
		78% wf, 59% vf	
Tetric	W U LY	hybrid	Vivadent
	B YG YB	barium glass	
		82% wf, 62% vf	
Silux Plus	XL U L	microfill	3M Co.
	G YB DG	colloidal silica	
	DY	52% wf, 40% vf	

*wf : weight fraction of filler content **vf : volume fraction of filler content paper.

Color measurements

The color characteristics and the changes in the color characteristics (L*, a*, b* and ΔE^*_{ab}) were measured by a computer controlled spectrophotometer. A reflection spectrophotometer (COLOR-EYE 3000, MacBeth, Division of Kollmorgen Instruments Corporation, USA) was used to determine CIELAB coordinates of each specimen[6]. Illumination corresponding to average daylight (CIE illuminant D65) was used as the light source. The spectrophotometer was calibrated at each measurement period using the white calibration tile supplied by the manufacturer. The spectrophotometer system was connected to a computer system. The spectrophotometer software (Optiview, MacBeth) automatically measured each sample three times and reported an average value. The manufacturer states that the precision of the spectrophotometer is within 1%[7].

Reflectance values versus wavelengths were obtained for each specimen at 20-nm intervals between 360 and 740 nm. CIE color tristimulus values, X,Y and Z were computed from the reflectance curves obtained. The calculation was performed for standard light source D65, 2° standard observer. Subsequently, the tristimulus values (X, Y, Z) were transformed into L*a*b* color coordinates[6]. CIELAB color difference values (ΔE^*) were calculated for each corresponding pair of shade guide and composite resin samples.

The CIELAB measurements make it possible to evaluate the amount of perceptible color change in each sample. The CIELAB is an approximately uniform color space with coordinates for lightness : i.e., white-black (L*), redness-greeness (a*), and yellowness-blueness (b*)[8]. This color system have a meaningful relation to human visual perception of color differences. Total color differences can be calculated from the equation[9].

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

SAS, a statistical software package (SAS Institute, Cary, NC), was used to calculate the means and standard deviations for the L*a*b* coordinates of each group. Duncan's multiple range test was used to detect differences between mean ΔE^* values at the .05 siginificance level.

III. Results

L*a*b* values for each composite and shade guide are listed in Table 2 to 6, and the L*, a*, b* values are also shown in Figures 1 to 5. Differences in the L*, a*, b* parameters (ΔL^*, Δa^*, Δb^*) and total color differences (ΔE^*) are listed in Table 7 to 11, and the ΔE^* values are shown in Figures 6 to 10. The mean color differences between composites and shade guides of various products are shown in Figure 11.

Table 2 and Figure 1 show the L*, a*, b* values of Z100 composite and shade guide. The ranges of L* and a* values were wider with the composite resins. If D3 and B2 shade are disregarded, the composite resins were more green. The shade guides were slightly lighter than composite resins. The shade guides showed a wider distribution of b* values and were more yellow than composite resins except A2 and D3.

Table 3 and Figure 2 show the L*, a*, and b* values of Prisma TPH. The ranges of L* and b* values were wider with the shade guides. The shade guides were more yellow except C2, C1, B2 and lighter except A3.5, C2 than composite resins.

Table 2. L*a*b* values of Z100 composite (CR) and shade guide(SG).

		L	a	b
C2	SG	70.564	-1.634	7.348
	CR	67.652	-1.624	6.664
A3.5	SG	70.559	-1.648	8.915
	CR	67.832	-1.819	7.645
A2	SG	71.864	-1.864	5.182
	CR	68.980	-2.905	5.429
A4	SG	69.335	-1.238	8.737
	CR	69.038	-1.659	7.636
B3	SG	71.463	-1.519	9.056
	CR	71.043	-2.026	8.282
D3	SG	69.243	-1.400	4.229
	CR	69.522	-0.962	4.892
A3	SG	71.270	-1.249	6.806
	CR	70.426	-1.339	6.505
B2	SG	72.211	-2.039	5.139
	CR	71.674	-1.936	5.062

Table 3. L*a*b* values of Prism TPH composite(CR) and shade guide(SG).

		L	a	b
A2	SG	72.120	-2.059	7.096
	CR	70.039	-1.850	3.399
DY	SG	67.651	-0.859	11.716
	CR	66.523	-0.544	9.302
C2	SG	70.436	-2.293	3.021
	CR	71.101	-2.763	5.384
B3	SG	70.421	-1.710	7.064
	CR	70.502	-1.796	5.127
D3	SG	69.096	-1.869	5.725
	CR	67.981	-1.772	4.125
B1	SG	75.483	-2.414	1.214
	CR	73.920	-2.475	0.542
A3.5	SG	68.895	-1.664	5.543
	CR	70.438	-1.338	5.206
C1	SG	73.000	-2.287	2.316
	CR	70.891	-2.531	3.438
B2	SG	72.579	-2.717	5.712
	CR	72.295	-2.749	5.992

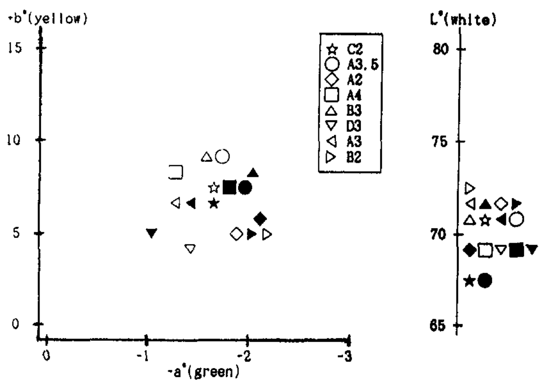

Fig. 1. Graph of L*a*b* values for the various shades of Z100 composite(black) and shade guide(white)

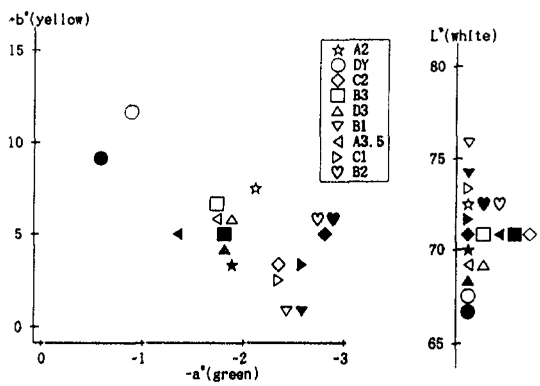

Fig. 2. Graph of L*a*b* values for the various shades of Prisma TPH composite (black) and shade guide(white)

Table 4 and Figure 3 show the L*a*b* values of Herculite XR. The composite resins had wider distribution of L* and a* values and were lighter and greener than the shade guides except DY. The range of b* values was wider with the shade guides. If DY shade is disregarded, shade guides were less yellow than composite resins.

Table 5 and Figure 4 give the L*a*b* values of Tetric. The shade guides showed wider distribution of L*a*b* values and were lighter and more yellow except W and U shade.

Table 6 and Figure 5 give the L*a*b* values of Silux Plus. The shade guides showed wider distribution of L*a*b* values and were lighter, more yellow and less green. There were no exceptions. Differences along the red/green and yellow/blue color axes were very obvious.

Table 7 gives the variations in L*, a*, b* (ΔL*, Δa*, Δb*) and total color differences

Table 4. L*a*b* values of Herculite XR composite(CR) and shade guide(SG).

		L	a	b
L	SG	66.697	-1.311	0.610
	CR	72.225	-1.705	1.437
LY	SG	66.759	-1.269	4.764
	CR	70.898	-1.457	5.323
LG	SG	67.323	-1.330	2.465
	CR	70.370	-1.539	3.478
U	SG	67.860	-1.015	4.414
	CR	70.905	-1.442	4.969
DG	SG	65.637	-0.601	4.348
	CR	66.436	-0.675	6.381
DY	SG	67.096	-1.204	8.228
	CR	68.026	-0.720	7.868

Table 5. L*a*b* values of Tetric composite (CR) and shade guide(SG).

		L	a	b
W	SG	74.182	-2.259	3.268
	CR	70.184	-1.881	6.199
LY	SG	72.437	-1.579	5.326
	CR	69.584	-1.799	3.159
YG	SG	69.205	-1.885	6.128
	CR	67.775	-1.876	4.724
B	SG	67.643	-0.376	8.190
	CR	65.787	-0.496	7.289
U	SG	69.403	-2.400	3.886
	CR	70.839	-1.811	4.951
YB	SG	68.006	-1.213	8.864
	CR	67.678	-1.826	7.178

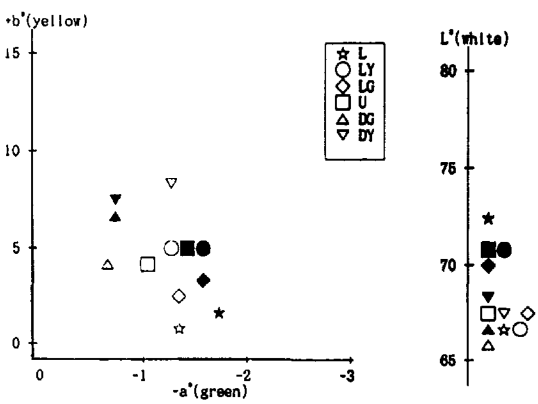

Fig. 3. Graph of L*a*b* values for the various shades of Herculite XR composite (black) and shade guide(white)

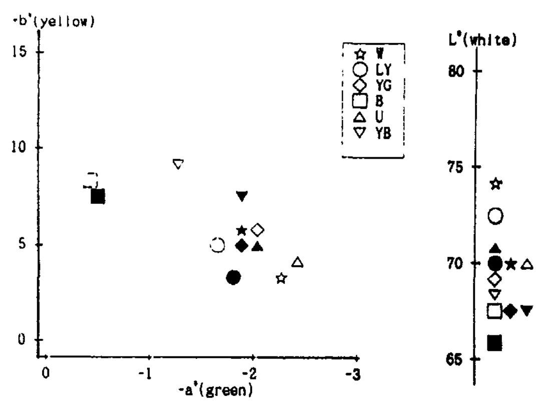

Fig. 4. Graph of L*a*b* values for the various shades of Tetric composite(black) and shade guide(white)

Table 6. L*a*b* values of Silux Plus composite(CR) and shade guide(SG).

		L	a	b
YB	SG	65.571	-0.199	13.106
	CR	68.565	-1.868	10.127
U	SG	74.543	-1.028	7.280
	CR	71.195	-2.866	5.851
G	SG	70.495	-1.709	5.685
	CR	69.426	-2.908	3.786
L	SG	75.008	-1.800	3.280
	CR	73.608	-2.807	1.491
XL	SG	79.263	-1.881	6.723
	CR	78.399	-2.974	4.659
DG	SG	65.540	-0.653	6.758
	CR	66.704	-2.693	6.382
DY	SG	69.362	-0.230	8.812
	CR	69.315	-2.268	9.127

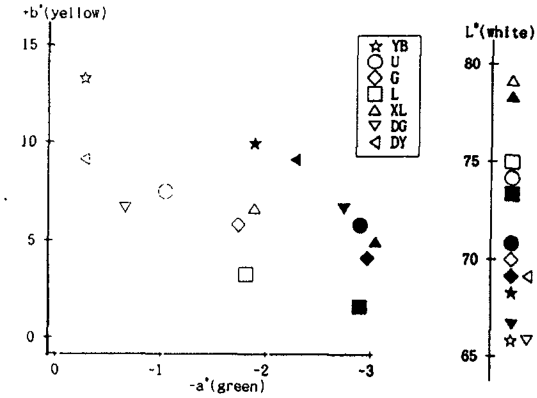

Fig. 5. Graph of L*a*b* values for the various shades of Silux Plus composite(black) and shade guide(white)

Table 7. Variation in L*a*b* and color difference(ΔE^*) of Z100

	ΔL	Δa	Δb	ΔE
A3.5	-2.727	-0.171	-1.270	3.013
C2	-2.912	0.020	-0.683	2.998
A2	-2.884	-0.231	0.247	2.905
A4	-0.298	-0.421	-1.101	1.219
B3	-0.421	-0.507	-0.770	1.016
D3	0.278	0.438	0.664	0.971
A3	-0.844	-0.890	-0.301	0.904
B2	-0.537	0.103	-0.077	0.553
mean	1.363	0.348	0.630	1.697

*vertical bar : No difference between groups at<0.05 level

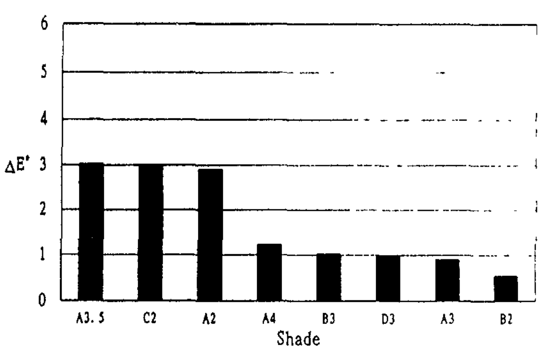

Fig. 6. Total color differences(ΔE^*) for the various shades of Z100

(ΔE^*) between the shade guides and composite resins of Z100. The greatest variation was seen in the A3.5 shade designation with the least variation in the B2 shade. These variations are also shown graphically in Figure 6. In the A3.5, C2, A2 and B2 shade designation there were large differences in the lightness value (L*). For the A4, B3 and D3 shade, large variations in b* (yellow-blue) were observed. Large variation in a* (red-green) was observed for the A3 shade. Generally, variations in a* were smaller than variations in L* or b*.

Table 8 presents the variations in L*, a*, b* and total color differences between the shade guides and composite resins of Prisma TPH. The A2 shade showed the greatest variation, and the B2 shade showed the least variation. These variations are shown graphically in Figure 7. Large ΔL* values were observed in the B1, A3.5 and large Δb* values in the remaining shades. Generally, variations in b* were larger than variations in L* or a* with the smallest variation in a*.

Table 9 lists the ΔL*, Δa*, Δb* and ΔE* values between the shade guides and composite resins of Herculite XR. The L shade had the greatest total color differences, and the DY shade had the least ΔE*. Total color differences of Herculite XR are shown in Figure 8. The L, LY, LG, U, DY shade showed large differences in the lightness value. For the DG shade, large differences in b* were observed. Variations in a* values were smaller than variations in L* or b*. Herculite XR showed the largest ΔL* values, indicating greater differences in lightness than the other materials.

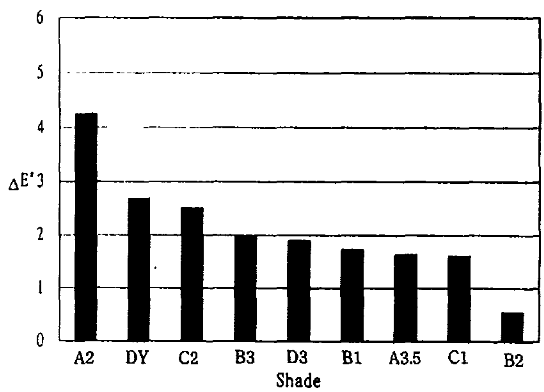

Fig. 7. Total color differences(ΔE*) for the various shades of Prisma TPH

Table 10 gives the ΔL*, Δa*, Δb* and ΔE* values of Tetric. The greatest variation was seen in the W shade with the least variation in the B, U, YB shade (No significant difference at the 95% confidence level was found between the ΔE* values of the B, U, YB shade.). Figure 9 shows the ΔE* values of Tetric graphically. In the W, LY, B, U shade there were large variations in the lightness value. For the YG and YB shade large differences in b* were observed. Generally, Δa* values were smaller than ΔL* and Δb* values. In the LY shade, the Δa* value was quite close to 0.00.

Table 11 presents the ΔL*, Δa*, Δb* and ΔE* values between the shade guides and co-

Table 8. Variation in L*a*b* and color difference(ΔE*) of Prisma TPH

	ΔL	Δa	Δb	ΔE
A2	-2.081	0.209	-3.698	4.249
DY	-1.128	0.315	-2.413	2.684
C2	0.665	-0.469	2.363	2.509
B3	0.075	-0.086	-1.938	1.977
D3	-1.118	0.097	-1.510	1.885
B1	-1.563	-0.061	-0.672	1.712
A3.5	1.543	0.327	-0.365	1.620
C1	-1.109	-0.24	1.122	1.597
B2	-0.284	-0.023	0.841	0.546
| mean |	1.063	0.203	1.658	2.088

*vertical bar : No difference between groups at<0.05 level

Table 9. Variation in L*a*b* and color difference(ΔE^*) of Herculite XR

	ΔL	Δa	Δb	ΔE
L	5.528	-0.394	0.827	5.610
LY	4.379	-0.188	0.572	4.184
LG	3.051	-0.628	1.015	3.222
U	3.045	-0.427	0.555	3.126
DG	0.799	-0.081	2.033	2.819
DY	0.930	0.483	-0.360	1.114
| mean |	2.955	0.367	0.894	3.241

*vertical bar : No difference between groups at$<$0.05 level

Table 10. Variation in L*a*b* and color difference(ΔE^*) of Tetric

	ΔL	Δa	Δb	ΔE
W	-3.977	0.378	-0.070	4.022
LY	-2.853	0.009	-1.404	3.181
YG	-1.430	-0.220	-2.157	2.606
B	-1.856	-0.120	-0.901	2.072
U	1.436	0.588	1.065	1.884
YB	-0.051	-0.613	-1.686	1.867
| mean |	1.937	0.321	1.214	2.605

*vertical bar : No difference between groups at$<$0.05 level

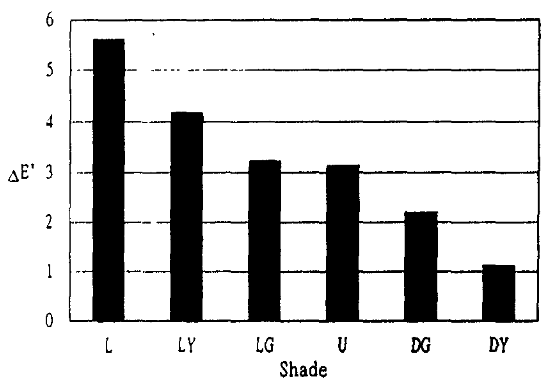

Fig. 8. Total color differences(ΔE^*) for the various shades of Herculite XR

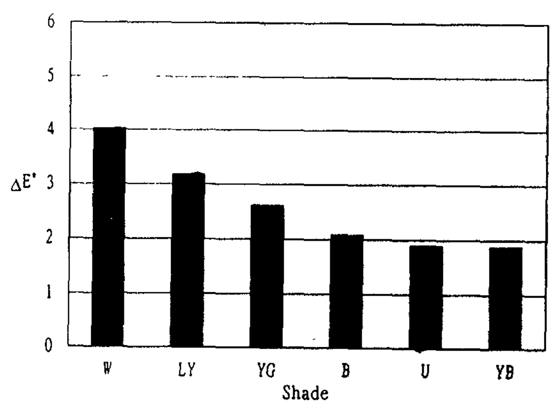

Fig. 9. Total color differences(ΔE^*) for the various shades of Tetric

mposite resins of Silux Plus. The YB shade showed the greatest total color difference, and the DY shade showed the least ΔE^*. ΔE^* values of Silux Plus are shown in Figure 10. In the YB, G, L, XL shade there were large differences in the b* values. Large variations in a* were observed in the DG, DY shade, large difference in lightness in the U shade. Generally, ΔL^* values were smaller than Δa^* or Δb^*. For the Δa^* values, Silux Plus showed the largest, indicating greater differences in the redness-greeness than the other materials.

Table 11. Variation in L*a*b* and color difference(ΔE^*) of Silux Plus

	ΔL	Δa	Δb	ΔE
YB	2.594	-1.669	-2.978	4.288
U	-2.340	-1.838	-1.429	3.308
G	-1.069	-1.199	-1.899	2.489
L	-1.440	-1.007	-1.789	2.486
XL	-0.864	-1.093	-1.864	2.330
DG	1.030	-2.040	-0.385	2.311
DY	-0.047	-2.039	0.314	2.064
| mean |	1.341	1.555	1.524	2.869

*vertical bar : No difference between groups at<0.05 level

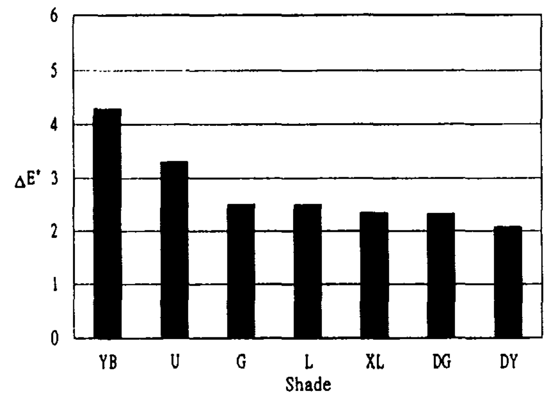

Fig. 10. Total color differences(ΔE^*) for the various shades of Silux Plus

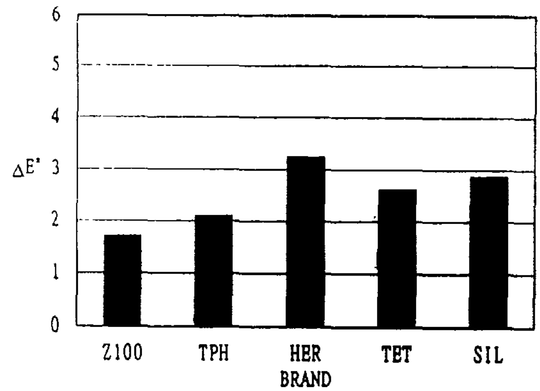

Fig. 11. Mean color differences(ΔE^*) of tested products

The mean color differences (ΔE^*) between the shade guides and the composite resins of different materials are shown in Figure 11. Z100 showed the least total color differences, with the greatest ΔE^* values for Herculite XR.

Ⅳ. Discussion

Discoloration can be evaluated visually and by instrumental techniques. Visual color determination is based on visual comparison of the object with color standards. This method is most frequently applied in dentistry. Shade guides commonly serve as color standards with which the color of a tooth is matched. Nevertheless, three distinct disadvantages concerning this method are reported : First, the range of available shades is not logically distributed. Second, there is a lack of consistency among individual dentists in matching tooth colors. Third, it is not possible to translate the results obtained into CIE color specifications[10].

The use of color measurement equipment makes it possible to overcome these basic difficulties of color evaluation. In the dental industry, color monitoring and evaluation are carried out by both tristimulus colorimeters and spectrophotometers. The tristimulus colorimeter analyzes three values for the red, green and blue portions of the reflected ray of light by use of three color filters with the same characteristics as the receptors of the human eye. The spectrophotometer measures the spectral power distribution in the range of visible wavelength of the reflected light[1]. Therefore, data obtained from the spectrophotometer are inherently more informative, and the X, Y and Z tristimulus values calculated from the reflection curves remain the standard with which others are compared[11].

ΔE^* values indicate overall color differences, taking into account differences in the L*a*b* coordinates of different specimens or changes in the same specimen over time. In dentistry, a discoloration that is perceptible to human eye ($\Delta E^* > 1.0$) will be referred to as acceptable up to the value $\Delta E^*=3.3$, which is considered to be the upper limit of acceptability in subjective visual evaluations[9]. Discoloration above this level will be referred to as unacceptable[8].

Based on the results of Seghi et al[12] with dental porcelain, it can be inferred that under ideal viewing conditions (e.g., in a laboratory setting), ΔE^* values greater than 2 can be easily perceived by most observers, while ΔE^* values less than 1 are less discernible[1,7]. However, clinical detection of color differences is less precise. Johnston and Kao[13] found that the mean ΔE^* values for visual mismatch between composite resin and tooth structure intraorally were 6.8 ± 2.7[2].

All specimens of Herculite XR, Tetric and Silux Plus showed perceptible color differences. Color differences in D3, A3, B2 shade of Z100, B2 shade of Prisma TPH were imperceptible. The ΔE^* values of Z100 were within the acceptable range. For Prisma TPH, A2 shade only showed the unacceptable color difference. And W shade of Tetric, YB and Y shade of Silux Plus, L and LY shade of Herculite XR showed the ΔE^* values above 3.3.

In comparing the mean ΔE^* values of materials, ΔE^* values ranged from 1.7 (Z100) to 3.2 (Herculite XR). None of these 5 products showed the mean ΔE^* values below 1.0. Herculite XR showed the mean color differences close to unacceptable level. The remaining 4 products had acceptable color differences.

Colorimetric evaluations of composite resins have been reported. Swift et al[2] compared the shades of several composite resins (Pertac-Hybrid, Prisma APH, XRV Herculite) keyed to Vita Lumin shade guide. They reported L* values ranging from 51.02 to 61.55, a* values from -3.02 to -0.89, b* values from 0.94 to 7.09. Therefore, Z100 and Prisma TPH composite resins evaluated in this study had higher L* values than those reported by Swift.

O'Brien et al[14] compared Bioform and Vita Lumin shade guides spectrophotometrically. L* values in excess of 70, a* values ranging from -0.22 to 0.62, b* values of 16 or greater were observed. In general, Z100 and Prisma TPH shade guides had lower L*, a* and b* values than those of Vita Lumin shade guide report by O'Brien.

Shade guides add a weak link in the shade matching process. Several studies[5,14-17] have evaluated a large number of natural teeth by using the Munsell color system and CIE LAB system. When comparing the range of color space for available shade guides and natural teeth, they found that (1) available guides did not cover the volume of color space required ; (2) there was no logical or systematic arrangement of the tabs ; and (3) clustering and duplication of colors existed in some areas of the color space and voids in other regions.

The problem of shade matching is also complicated by the shade guides provided by many products. Most composite resin kits provide a shade tab that is designed to match the shade of the composite being polymerized. Unfortunately, the majority of these stock shade guides are manufactured from unfilled methacrylates and do not accurately depict the true shade, translucency, or opacity of the composite resin after polymerization[2,4].

Hosoya[18] investegated color differences between shade guides and light-cured composite resins. Color measuring was performed with the Murakami Color Research Laboratory Fast Spectrophotometer CMS-500 and the Flexible Sensor FS-1. The ΔE^* values between all shade guides and resin specimens showed color differences detectable to the naked eye. Color differences were greatest for the incisal colors and the deep and dark colors. Color differences were relatively small for the general colors.

Manufacturers are cognizant of these problems and many have developed composite resins that are keyed to the Vita Lumin shade guide (Vita Zahnfabrik, Bad Sackingen, Germany). The Vita guide was designed for porcelain, and there are many technical problems involved in the development of composite resins to match a porcelain shade guide. In fact, even with porcelain, there appears to be little standardization between shade guides and manufacturing procedures and products[2,19].

Due to these inherent shortcomings in almost all stock shade guides, clinicians have often recommended the fabrication of custom shade guides[4,15,20]. Jordan states that a practical solution to this problem is to make shade guides from the material itself. Albers concurs in that custom shade guides made of composite are considerably more accurate. A University of Florida study that evaluated composite shade selection with the use of stock shade guides versus custom shade guides yielded the following conclusion : The use of a custom tab for shade matching leads to a higher percentage of excellent color matching of the final restoration.

Because of the labor involved and the often inconsistent results obtained, many dentists have decided they can manage without custom shade guides, or they devise other shade selection techniques.

One such technique is the "dab on" technique. A small amount of resin is placed on the tooth to be restored and is then polymerized. The shade of this dab is compared to the shade of the tooth to be restored. Two pitfalls are evident with this method. First, material and time are wasted with each dab placed. Second, most light-cured composites change their shade when they undergo curing. Only during subsequent appointments can the final shade of these restorations be accurately determined.

V. Conclusions

Color comparisons of shade guides and composite resins of 5 commercially available products were measured by means of spectrophotometry. Under the conditions of this study :

1. Color differences between all shade guides and resin specimens except D3, A3, B2 of Z100 and B2 of Prisma TPH were detectable to the naked eye($\Delta E^* > 1.0$).
2. In comparing the mean ΔE^* values of materials, Z100 showed the least followed by Prisma TPH, Tetric, Silux Plus, Herculite XR in increasing order.
3. A2 of Prisma TPH, W of Tetric, YB and U of Silux Plus, L and LY of Herculite XR showed ΔE^* values above 3.3.
4. The L^* values of the shade guides were higher than those of the composite resins in Z100, Prisma TPH, Tetric, Silux Plus. For Herculite XR, the composite resin showed higher L^* values.
5. The b^* values of all specimens were (+)

values. The shade guides showed higher b* values than those of the composite resins in Z100, Prisma TPH, Tetric, Silux Plus.

6. The a* values of all specimens showed (−) values. The a* values of the composite resins were lower than those of the shade guides in Herculite XR, Silux Plus.

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