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Coverage error of gingival shade guide systems in measuring color of attached anterior gingiva

Funda Bayindir, DDS, PhD^a, Yusuf Ziya Bayindir, DDS, PhD^b, David J. Gozalo-Diaz, DDS, MSC^c, and Alvin G. Wee, BDS, MS, MPH^d

College of Dentistry, The Ohio State University, Columbus, Ohio; Faculty of Dentistry, Ataturk University, Erzurum, Turkey; College of Dentistry, University of Colorado Health Science Center, Denver, Colo; College of Dentistry, University of Nebraska Medical Center, Omaha, Neb

Abstract

Statement of problem—It remains unclear which gingival shade guide is most effective in producing the best visual shade match.

Purpose—The purpose of this study was to determine and compare the coverage errors (CEs) of 2 different gingival shade guides and their combination in a selected population.

Material and methods—The CEs of the following gingival shade guides were evaluated: (1) Lucitone 199, (2) IPS Gingiva, and (3) a combination of the 2 shade guide systems. The spectral reflectance values of the center of each gingival shade tab (1.5 mm in diameter) were measured (without a backing) with a spectroradiometer and an external light source at wavelengths from 380 nm to 780 nm at 2-nm intervals. All spectral reflectance measurements were made using 0-degree observer and 45-degree illumination and then converted to CIE values. The attached gingiva of 120 subjects was measured with the same protocol. The CEs of each of the 120 subjects' attached gingiva for each of the 2 shade guide systems and their combination were determined and averaged. The mean minimum CEs were analyzed with repeated measures ANOVA and the post hoc Tukey HSD for multiple comparison ($\alpha = .05$).

Results—A significant difference ($P < .001$) was found among the mean minimum CEs of the 2 gingival shade guide systems and their combination. The Tukey HSD test revealed that the mean minimum CEs for Lucitone 199 ($\Delta E 10.8 \pm 4.4$) were significantly different from the IPS Gingiva ($\Delta E 8.6 \pm 3.6$) shade guide system. However, the combination of the 2 gingival shade guide systems ($\Delta E 7.9 \pm 3.4$) was not significantly different from the IPS Gingiva system, but a significant difference was found among races ($P = .016$). No interactions were found between the other tested groups. The mean CE for white individuals ($\Delta E 8.3 \pm 2.5$) is significantly different and less than the mean CE for African Americans ($\Delta E 10.0 \pm 4.4$). The CEs for Asians ($\Delta E = 9.1 \pm 4.3$) and others ($\Delta E 9.0 \pm 4.4$) are not significantly different from CEs for whites or African Americans.

Conclusions—The IPS Gingiva shade guide system resulted in the lowest CEs compared to the Lucitone 199 shade guide system. The mean CE for Lucitone 199 was significantly greater than the mean CE for IPS Gingiva and for the combination of the 2 guides. The mean CE for whites is

Corresponding author: Dr Funda Bayindir, Ataturk University, Faculty of Dentistry, Department of Prosthodontics, 25240, Erzurum, TURKEY, Fax: 0090 442 2360945, E-mail: bayindirf@atauni.edu.tr.

^aFormer Visiting Research Fellow, College of Dentistry, The Ohio State University; Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Ataturk University.

^bFormer Visiting Research Fellow, College of Dentistry, The Ohio State University; Associate Professor, Department of Restorative Dentistry, Faculty of Dentistry, Ataturk University.

^cClinical Assistant Professor, Department of Restorative Dentistry, College of Dentistry, University of Colorado Health Science Center.

^dAssociate Professor and Director, Division of Oral Facial Prosthetics/Dental Oncology, Department of Otolaryngology, University of Nebraska Medical Center.

significantly different and less than the mean CE for African Americans. The CEs for Asians and others are not significantly different from CEs for whites or African Americans.

Clinical Implications

The IPS Gingiva shade guide provides higher potential for more accurate visual shade matching of gingival tissues compared to the Lucitone 199 shade guide or their combination. The potential to achieve a good visual shade match of gingival tissue is different for various racial groups.

It is not only important to have good dental esthetics, but also good gingival esthetics. Esthetic considerations in prosthetic restorations, such as fixed, implant-supported, and removable prostheses, have focused primarily on the anterior region. An attractive or pleasing smile involves the harmonious interaction of 3 primary components: the lip position, teeth, and associated gingival architecture.¹ As a consequence, variables such as the number of teeth visible in a smile, size, shape, position, and color of artificial teeth, as well as margin placement of fixed prostheses, must be considered during the fabrication of prostheses. The soft tissues surrounding prosthetic restorations are as important as the appearance, form, and color of the prosthetic teeth. It has been proposed that the color of the teeth, gingiva, lips, skin, hair, and eyes harmonize to provide a pleasing facial appearance.² Unfortunately, only limited scientific information exists on the relationship between tooth shade, skin, lip, and gingival color.^{3–5} The characterization of healthy gingival color ranges from pale pink⁶ and pink⁷ to dark red⁸ or purple.³ Several attempts have been made to describe and document the color of craniofacial structures. Color assessments of the attached gingiva,^{9,10} papillae, and alveolar mucosa¹⁰ of humans have been evaluated using Munsell color tabs. The use of a helium-neon gas laser to record the reflectance of the interdental papilla was documented, although no actual color was reported.¹¹ Another study used digital images of gingiva and converted the color of gingiva into its corresponding wavelength, but without any documentation of validity or reliability.¹⁰

The Munsell system is the oldest color order system.¹² Its use has been documented in dentistry.^{13–15} Although Munsell color tabs are easy to use, their lack of translucency and a glossy surface (or glossy surface color) limit their color stability.¹⁰ The modest interest in the topic of gingival color is most likely a consequence of the difficulties of finding a suitable system for soft tissue color measurement and matching. Dummett^{3,6} was among the first to describe the color of intraoral soft tissues. From clinical experience, Dummett³ concluded that the color of the healthy gingiva is variable, ranging from a pale pink to a deep bluish purple. Color variations may be uniform, unilateral, or bilateral and may involve the gingival papilla alone or extend throughout the gingiva and into other oral tissues. Nonpigmented gingiva is found more often in fair-skinned individuals, while pigmented gingiva is usually seen in dark-skinned individuals. Although a correlation was observed, the amount of variance⁴ precludes the clinical use of facial skin complexion to predict gingival pigmentation or to determine the colors of the labial flange for removable prostheses. The factors that influence gingival and mucosal pigmentation have been previously reported: gender and age, location (left, right, mandibular, or maxillary),^{9,11} skin type,¹⁶ melanin content¹⁷ modulated by hormonal influences,^{18,19} blood pressure,^{20,21} and gingival inflammation.^{21–24} External sources of gingival discoloration include the type and location of prosthetic restoration,^{22,24} as well as smoking.^{11,20}

Color assessment of human gingival and mucosal tissues is an essential first step to developing an intraoral soft tissue shade guide. Necessary color measurements can be performed using visual, spectrophotometric, or photographic techniques. Knowledge of the distribution of gingival and mucosal shades is important to achieve individual customization of denture base color.^{25,26} Currently, methyl methacrylate is the most frequently used acrylic resin for

fabrication of removable partial and complete denture bases.^{26,27} However, one shade of pink for partial dentures is not acceptable for all patients, especially when the acrylic flange is adjacent to gingiva in the esthetic zone. The color of denture base acrylic resin is not as critical in complete dentures. Fortunately, individual tinting of denture base resins has been described using stain kits and other nonstandardized methods.²⁸

The most popular method of shade selection in dentistry is through the use of visual selection with prefabricated shade guides.^{29,30} Colors in the shade guides should be based on a representative selection of intraoral human soft tissue colors.^{6,8} There are some commercially available shade guides for oral soft tissues to be used for finding a corresponding acrylic denture base resin. The Lucitone 199 shade guide system (Dentsply Trubyte, York, Pa) consists of 4 glossy shade tabs of the same shape in original, light, light reddish pink, and dark shades. The Ivoclar Plus gingiva indicator set (Ivoclar Vivadent, Schaan, Liechtenstein) consists of 4 shades as well: pink, fibered light pink, fibered pink, and "Preference" (a shade which should correspond to the original shade of Lucitone 199). The IPS Gingiva shade guide system (Ivoclar Vivadent) offers 10 shades: 5 regular shades, 4 gingival modifier shades, and 1 gingival opaquer shade.¹²

The accuracy of measurement of any colorimetric device is dependent upon the geometry of the device.⁹ Edge loss is the phenomenon that occurs when light strikes a translucent or turbid material and some of the light is scattered to points distant to the point of entry of the incident light. This means that instruments with different geometries will be affected differently by this edge loss phenomenon. The ideal optical geometry for measurement of color for translucent objects is 0 degrees/45 degrees without an aperture. Edge loss occurs during conventional reflectance measurements of translucent materials, when both the illuminant and observation light path travel through an aperture. These edge losses do not depend upon the measuring methods, but upon the optical measurement configuration. Edge loss can be avoided by ensuring that there is no aperture between the external light source, spectroradiometer, and object.³¹

The CIE L*a*b* system is the most widely used color specification system and was developed by the International Commission on Illumination (Commission Internationale de l'Éclairage).¹² The advantage of the CIE L*a*b* system is that color differences can be expressed in units that can be related to visual perception and clinical significance. Comparison of different shade guides and the color range of soft tissues may be performed using coverage error (CE). CE is the index that shows the mean value of the minimal color differences among one set of specimens (in this case, gingival shade guides) compared to another set of specimens (in this case, attached gingiva). The average of these color differences is defined as the CE.^{32,33} Ranges of magnitude of perceptible and acceptable color differences^{34–36} have been evaluated for teeth and restorative materials, except for gingival restorative materials.

Previous studies of color assessment of human gingiva and mucosa were not sufficient for the development of an ideal gingiva shade guide. So far, no representative selection of soft tissue colors has been published.²⁵ In a previous study,³⁷ the CE of the current shade guide systems for teeth were evaluated; however, this has not been accomplished for gingival shade guides. Accurate and objective color data on attached gingiva or gingival shade guides have not been published using appropriate instruments that do not induce edge loss or require tissue contact. Therefore, the purpose of this clinical study was to determine and compare the CEs of 2 different gingival shade guide systems and the combination of the 2 shade guide systems by using the CIE color system. The null hypothesis for this study was that the CEs for the 2 shade guide systems for measuring attached gingiva and the combination of the 2 guides would be similar.

MATERIAL AND METHODS

Approval was obtained from The Ohio State University institutional review board (Protocol # 2003H0001, dated January 2003). The color of 3 sets of 2 different gingival shade guide systems and the color of the attached gingiva of 120 human subjects were measured. The CE for each of the 120 subjects and their mean was determined for the 2 gingival shade guide systems and their combination.

Potential subjects responded to the advertisements posted around the medical center by calling the clinic and were then screened using a telephone screening form. This screening process ensured that potential subjects satisfied the inclusion criteria for this study. Included subjects were generally healthy, between the ages of 18 and 85, willing to spend approximately an hour for this study, and able to sign informed consent and HIPAA forms. Excluded were subjects with spontaneous bleeding from their gingiva due to periodontal disease, prisoners, pregnant subjects (eliminating the possibility of any misunderstanding that color measurement instruments may cause harm to the unborn child), and subjects with psychiatric, cognitive, or social conditions (for example, alcoholism or drug abuse) that would interfere with giving consent and cooperation.

The color measurement apparatus consisted of a spectroradiometer (PR 705; Photo Research, Inc, Chatsworth, Calif) and fiber optic light cable (#70050; Oriel Instruments, Stratford, Conn) that were fixed on an optical table (Mecom, Inc, Risingsun, Ohio). The fiber optic light cable was connected to a xenon arc lamp (300W; Oriel Instruments). The spectroradiometer and the optic light cable, positioned at a 45-degree angle inferior to the horizontal plane, provided an optical configuration of 0-degree observation and 45-degree illumination to the object. For all color measurements in this study, spectral reflectance was obtained from 380 nm to 780 nm with a 2-nm interval (SpectraWin 2.0; Photo Research, Inc) and subsequently converted to CIE $L^*a^*b^*$ values (D65 illumination and 2-degree observer). The stability of the light source to be used was evaluated prior to establishing the color measurement protocol for the study. This allowed determination of the amount of warm-up time necessary to obtain relative stability prior to color measurement, and the intervals at which recalibration was necessary. To evaluate for light source stability, a smooth and homogenous white tile was used as the specimen. The measurements were made after turning on the light source and the spectroradiometer. The spectroradiometer was standardized to 8 cm from the measured object, with a measurement aperture size of 1 mm. Edge loss was avoided in this color measurement experimental design, as there was no aperture between the external light source, spectroradiometer, and the object; thus, no shadows were cast on the object. Color measurement protocol, validity, and reliability have been published in previous studies.^{38,39}

A convenience sample of 120 subjects was recruited at The Ohio State University Health Sciences Center. Six subjects with equal gender balance (3 men and 3 women) from 4 ethnic groups (white, African American, Mongol/Pacific Islander, and Others, which included Middle Eastern/Indian and American Indian/Alaskan Native) were recruited into each of the following 5 age groups: 18–29 years, 30–39 years, 40–49 years, 50–59 years, and 60–85 years. The attached gingiva, 3.5 mm apical from the free gingival margin on one of the maxillary central incisors, was measured. The CIE $L^*a^*b^*$ values for the attached gingival measurements were published in a previous study that used the same color measurement protocol, instrumentation, and optical configuration as this study for measurements for gingival shade tabs.³⁸

Three sets of shade guides from 2 different shade guide systems (3 sets $\times$ 4 Lucitone 199 and 3 sets $\times$ 10 IPS Gingiva) were selected based on their common use in the institutions involved. One shade guide for acrylic denture base resin (Lucitone 199 shade guide system; Dentsply Trubyte) and one for porcelain (IPS Gingiva shade guide system; Ivoclar Vivadent) were

measured for color. The shade tabs were first cleaned with a disinfecting towel (DisCide ULTRA; Palmero Health Care, Stratford, Conn) and placed in a specimen holder fabricated specifically to hold the shade tabs for color measurements. The specimen holder ensured that the surface being measured was at the center of the shade tab and was perpendicular to the color measurement axis of the spectroradiometer. Four shade tabs were selected from the shade guide system to assess reliability of the experimental design. Each shade tab was measured 10 times after removing the tabs from the specimen holder and replacing it back on the holder. The spectral reflectance data was then converted to CIE L*a*b* values, and standard deviations were calculated.

The mean CIE L*a*b* values for the 3 sets of shade guides for each shade guide system were calculated. The CE was calculated for each of the 2 shade guide systems and the combination of the 2 shade guide systems. For a particular shade guide system, the CIE L*a*b* color difference was calculated for each attached gingiva color measurement (n=120) and all the mean CIE L*a*b* values (3 sets of shade guides) for all the shade tabs in that shade guide system. For each of the 120 attached gingiva colors, the shade tab with the smallest ΔE was determined for the shade guide system. The average minimum ΔE for that shade guide system was then computed. The CE for a shade guide system was therefore the average ΔE between each of the 120 gingiva colors and the corresponding shade tab with the minimum ΔE to that gingiva. The following formula was used to calculate the average ΔE and is an index of the CE of the shade guide.^{33,37} where ΔL^* , Δa^* , and Δb^* are the differences in color parameters between individual attached gingival and closest shade guide colors selected by a computer algorithm. The total sample size was 120 for the pooled data. The average error, therefore, is the average difference between the gingiva colors and the nearest shade guide match.

$$CE = \frac{\sum \Delta E_{\min}}{n} = \frac{\sum \text{Min} \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}}{n}$$

Parametric statistical analyses were performed at a 95% confidence interval (CI) using statistical software (SPSS 13.0 for Windows; SPSS, Inc, Chicago, Ill). The mean minimum CEs between the 3 groups (Lucitone 199, IPS Gingiva, and combination) were statistically analyzed using a repeated measures analysis of variance (ANOVA) to evaluate the CE within factors and the variables' interaction effect. Thereafter, a post hoc multiple comparison of the CE between groups was analyzed with Tukey HSD. The alpha was set to .05 for all statistical analyses.

RESULTS

The pooled standard deviation for the 10 repeated comparisons involving the 3 selected shade tabs showed good experimental design repeatability: $L^*=0.42$, $a^*=0.14$, and $b^*=0.10$. The mean CIE L*a*b* values for the 2 shade guide systems are shown in Table I. The mean CE and standard errors of color difference in different race and gender groups are given in Table II. The repeated measures ANOVA (Table III) indicated a significant difference ($P<.001$) in the CE between groups, and significant differences were found for the mean CE within the groups, as well as among races ($P=.016$). No interactions were found between the other tested groups.

Figure 1 represents the coordinates (a^* and b^*) of 120 attached gingival colors and mean color of the shade tabs of the 2 gingival shade guide systems. Figure 2 shows the coordinates (L^* and a^*) of 120 attached gingival colors and mean color of the shade tabs for the 2 gingival shade guide systems. The attached gingival color measured was L^* with a mean (SD) of 52.06

± 8.73 and a range from 27.34 to 80.87; a^* with a mean of 25.90 ± 5.17 and a range from 4.19 to 38.22; and b^* with a mean (SD) of 17.78 ± 3.33 and a range from 5.31 to 26.90.

The Tukey HSD test showed that the mean CE for IPS Gingiva ($\Delta E 8.6 \pm 3.6$) and the combined guides ($\Delta E 7.9 \pm 3.4$) were not significantly different. The mean CE for Lucitone 199 ($\Delta E 10.8 \pm 4.4$) was significantly greater than the mean CE for IPS Gingiva and for the combination of the 2 guides. The Tukey HSD test for race showed that the mean CE for whites ($\Delta E 8.3 \pm 2.5$) is significantly different and less than the mean CE for African Americans ($\Delta E 10.0 \pm 4.4$). The CEs for Asians ($\Delta E 9.1 \pm 4.3$) and others ($\Delta E 9.0 \pm 4.4$) are not significantly different from the CEs for whites or African Americans.

DISCUSSION

The data and analysis of this study support rejection of the null hypothesis. In this study, it was determined that subject effects were statistically significant ($P < .001$), and the potential best matches were obtained with the IPS Gingiva shade guide system (Ivoclar Vivadent) ($\Delta E 8.6 \pm 3.6$) compared to the Lucitone 199 shade guide system (Dentplys Trubyte) ($\Delta E 10.8 \pm 4.4$). The IPS Gingiva shade guide system offers 10 shade tabs, compared to the Lucitone 199 shade guide system that has 4 shade tabs; this may account for the difference. It has been reported that human observers can detect a color difference of 1 ΔE unit under standardized laboratory conditions,³⁴ and ΔE of >2.75 is considered a clinically unacceptable color difference.³⁵ In addition, Douglas et al³⁶ reported that the predicted color difference at which 50% of the dentist observers could perceive a color difference was 2.6 ΔE units. The predicted color difference at which 50% of the subjects would have the restoration remade due to color mismatch (clinically unacceptable color match) was 5.5 ΔE . Acceptability and perceptibility color tolerances at the 50/50 level were significantly different ($P < .05$), as their 95% confidence limits did not overlap. Nevertheless, it is important to note that the difference between the coverage errors of the 2 guides might not be perceptible by the majority of individuals. Thus, although there is a statistically significant difference between the CEs of the 2 shades guides, it may not be clinically significant.

Previous studies used the Munsell color system^{9,10,16} and a helium-neon gas laser¹¹ to measure gingival tissues. Although no actual instrumental CIE $L^*a^*b^*$ values of attached gingiva have been identified, the conversion of the visually matched Munsell color tab data could be used as a comparison for the data of the present study.¹⁵ The maxillary attached gingiva color of 150 subjects was between 8 Munsell color tabs of 7/6 2.5R to 8/4 10R, which, when converted to CIE $L^*a^*b^*$ values, are the following: L^* , 41.2 to 81.4; a^* , 15 to 26; and b^* , 8.1 to 17.6. The color range of gingiva for the present study was generally wider than that of the visually matched Munsell color tab study, with results showing darker (lower L^*), more red and green (lower and higher a^* range), and more yellow and green (lower and higher b^* range). This difference may be due to decreased reliability when using visual shade selection as compared to the use of a color-measuring instrument.^{29,30} Although not reported, the 150 subjects may have come from a homogenous sample of white subjects, given that the study was performed in Germany, as compared to the stratified sampling into 4 different racial groups in the present study.

The increased emphasis on dental esthetics in recent years has driven the search for more accurate shade matching and replication procedures. It is clear that having only a single shade of pink for denture base resin cannot be a universal color reproduction solution for the wide variety of shades of human gingiva and the other soft tissues, especially with removable partial dentures that are adjacent to attached gingiva in the esthetic zone. The color range of gingival tissues seems to be even broader than the tooth color range (the lightness and hue range are wider and the chroma range is narrower).¹² Since the number of the shade tabs is limited, some

CE will always exist. Shade guides currently in use contain a limited selection of colors, so a combined shade guide could be used to reduce the coverage error. However, in this study of gingival shade guides, the use of IPS Gingiva alone is sufficient, as there were no statistically significant differences compared to the combination of both shade guides. In addition, it is also recommended that shades be mixed together during processing. In this manner, more accurate shade replication can be obtained.²⁸

Limitations of this study include the small sample size and the limited regional sample of the population, since the sample used in this study is only from a stratified convenience sample in one state in the United States. Sampling a population that is representative of the general population of the United States would be ideal, but difficult to perform. Other limitations of this study are that measurements were made only on the attached gingiva and not from several sites from the same structure, such as interdental papilla, marginal, and nonattached gingiva. In addition, only 2 gingival shade guides and their combination were evaluated in this study. More research is needed to evaluate the other gingival shade guide systems. Further investigations of color assessment of human gingiva and mucosal tissues are needed to improve the replication process to match gingival acrylic or porcelain. Knowledge of the distribution of different gingival and mucosal shades is important, since both are crucial for the individual configuration of denture base color.¹⁰ Future studies could measure the color of several sites from the same structure to provide a better sampling of the color of gingiva structures and to determine which site(s) most accurately represents the color of the structures for subjects.

CONCLUSIONS

Within the limitations of this study, a significant difference ($P<.001$) was found between the mean CE of the 3 gingival shade guides groups. The CE for the Lucitone 199 ($\Delta E 10.8 \pm 4.4$) and the IPS Gingiva ($\Delta E 8.6 \pm 3.6$) were statistically different from each other. However, the combination of the 2 gingival shade guide systems ($\Delta E 7.9 \pm 3.4$) was not significantly different from the IPS Gingiva system. The IPS Gingiva resulted in the lowest CEs compared to the Lucitone 199 and the combination of the 2 guides. The CE for white individuals ($\Delta E 8.3 \pm 2.5$) is statistically significantly different and less than the CE for African Americans ($\Delta E 10.0 \pm 4.4$). The CEs for Asians ($\Delta E 9.1 \pm 4.3$) and Others ($\Delta E 9.0 \pm 4.4$) are not statistically significantly different from the CEs for whites or African Americans.

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1.
 a^* versus b^* for 120 subjects and average color of 2 shade guide systems.

2.
L* versus a* for 120 subjects and average color of 2 shade guide systems.

Table I
Mean (SD) of L*, a*, and b* values for Lucitone 199 and IPS Gingiva shade guides systems

Type	Shade	Mean (SD) L*	Mean (SD) a*	Mean (SD) b*
Lucitone 199	DARK	41.3 (0.0)	13.3 (0.2)	3.4 (0.1)
	LRP	55.4 (0.2)	30.9 (0.0)	8.2 (0.1)
	LT	57.1 (0.3)	26.3 (0.3)	6.3 (0.2)
	OR	53.4 (0.4)	30.2 (0.1)	11.9 (0.1)
IPS Gingiva	G1	57.8 (0.3)	14.1 (0.2)	17.1 (0.1)
	G2	52.1 (0.6)	14.9 (0.1)	14.5 (0.1)
	G3	55.8 (0.5)	13.7 (0.3)	7.8 (0.2)
	G4	50.3 (0.2)	18.3 (0.1)	11.7 (0.0)
	G5	46.6 (0.5)	11.2 (0.1)	1.5 (0.1)
	GOP	70.3 (0.7)	15.6 (0.1)	12.8 (0.1)
	IG1	50.6 (0.2)	21.9 (0.1)	25.3 (0.1)
	IG2	49.1 (0.2)	24.0 (0.0)	16.1 (0.1)
	IG3	63.4 (0.3)	19.3 (0.1)	11.6 (0.0)
	IG4	44.2 (0.8)	12.0 (0.1)	-0.6 (0.0)

Table II
Mean CE and standard errors of color difference in different race and gender groups

Type	Gender	Mean (ΔE)	Standard Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Asian	female	7.76	1.8	6.16	9.36
	male	10.26	1.8	8.66	11.86
African American	female	11.13	1.8	9.52	12.73
	male	8.51	1.8	6.91	10.11
Other	female	8.16	1.8	6.56	9.76
	male	9.39	1.8	7.79	10.99
White	female	7.81	1.8	6.21	9.42
	male	9.06	1.8	7.46	10.66

Table III
Repeated measures ANOVA results for between-group effects for coverage error

Source	Type III Sum of Squares	df	Mean Square	F	P
Shade guides	595.37	2	297.69	59.45	<.001
Shade guides $\times$ race	100.50	6	16.75	3.35	.004
Shade guides $\times$ age	42.65	8	5.33	1.07	.391
Shade guides $\times$ gender	1.70	2	0.85	0.17	.844
Shade guides $\times$ race $\times$ age	45.60	24	1.90	0.38	.996
Shade guides $\times$ race $\times$ gender	32.24	6	5.37	1.07	.381
Shade guides $\times$ age $\times$ gender	35.10	8	4.39	0.88	.538
Shade guides $\times$ race $\times$ age $\times$ gender	57.08	24	2.38	0.48	.983
Error	801.20	160	5.01		