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Correlations between spectroradiometric and spectrophotometric colors of all-ceramic materials

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ABSTRACT

Objectives. Color coordinates of translucent esthetic materials measured by traditional spectrophotometers (SP) would deviate from those measured by newly introduced spectroradiometers (SR), which might simulate the clinical viewing condition better. This study aimed to determine the correlations in the SP- and SR-based color coordinates and color differences of all-ceramic materials.
Methods. Specimens for seven A2 shade core ceramics ($n = 7$) and corresponding A2 and A3 shades veneer ceramics ($n = 7$) were fabricated in clinically relevant thicknesses (1.5 mm after layering). Color of layered specimens was measured according to the CIELAB color scale by a SP and a SR. Color differences (ΔE^*_{ab}) between the reference ceramics and the corresponding layered ceramics were calculated. Correlations between SP- and SR-based color coordinates and color difference values were determined ($\alpha = 0.05$).
Results. SR-based color coordinates were significantly different from the SP-based values; however, general shifting trends by the instrument were observed. SP- and SR-based CIE a^*, b^* and chroma values showed significant correlations ($p < 0.05$); however, the CIE L^* values and the color differences with the reference showed no significant correlations ($p > 0.05$).
Significance. The color coordinates representing the hue attribute (CIE a^*, b^* and chroma) measured by a spectrophotometer and a spectroradiometer showed significant correlations; however, the color coordinates and the color difference values were significantly different by the instrument. Therefore, color coordinates and the color difference values based on different instruments should not be compared directly.

1. Introduction

Application of all-ceramic materials in the fabrication of esthetic restoration is a focus of interest in modern dentistry. As ceramic materials evolve and patients' demands for esthetic restorations increase, dental practitioners should keep up with the science for the ceramic materials as well as the demands of patients. Although varied all-ceramic restorations with improved color and translucency were introduced into dentistry [1], a perfect esthetic tooth-colored restoration cannot always be ensured [2].

Esthetic value of restorations is partly determined by its color and translucency [3], and visual and instrumental

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Table 1 – All-ceramic materials investigated.

Type	Code	Brand (shade)	Thickness (mm)	Manufacturer
Core				
Slip-cast block	ICS	In-Ceram Spinell Blanks	0.5	Vita Zahnfabrik, Bad Sackingen, Germany
	ICA	In-Ceram Alumina Blanks	0.5	
Zirconia block	AZC	ADENS Zi-Ceram	0.4	ADENS, Seoul, Korea
	DIZ	Digident Digizon	0.4	Hint-ELS, Griesheim, Germany
	VIZ	Vita 2000 YZ Cubes	0.4	Vita Zahnfabrik
Feldspathic block	MK2	Vitablocks Mark II	0.7	
Hot pressing	EM2	IPS Empress 2	0.8	Ivoclar Vivadent, Schaan, Liechtenstein
Sintering	VM7	Vita VM7	0.5	
Veneer	V72	Vita VM7 (2M2/2M3)	1.0	Vita Zahnfabrik
	V9-1	Vita VM9 (2M2/2M3)	0.8	
	V9-2		1.1	
	ER	IPS ERIS (120/210)	0.7	
	OM	Omega 900 (2M2/2M3)	1.0	

methods have been used for the specification and matching of color. For the instrumental color measurements, the Commission Internationale de l'Eclairage (CIE) LAB system is usually used. In this system, the CIE L^* is a measure of the lightness, the CIE a^* is a measure of redness (positive direction) or greenness (negative direction) and the CIE b^* is a measure of yellowness (positive direction) or blueness (negative direction) of an object [4].

If restorative materials are opaque, the influences of color measurement methods such as the type of instrument, the illuminating and measuring configuration and/or the kind of illuminant would be limited. However, it was reported that the color measurement of translucent materials performed by a small-window spectrophotometer (SP) resulted in deviated color coordinates compared with the real color perceived by the naked eyes [5]. These deviations were mainly caused by the edge-loss effect [6], the thickness of translucent layer and the background condition [7,8]; therefore, these variables should be considered when interpreting the SP-based color coordinates [7,8].

Edge-loss effects that are reflected in the SP-based color coordinates might be eliminated if the color is measured by a spectroradiometer (SR). In the SR measurement, there are no apertures restricting the light source, the instrument and the specimen [9], and the illuminating configuration is similar to that of an ambient condition. Therefore, it might be assumed that the SR-based color coordinates would have higher correlations with the real values perceived by the naked eyes than the SP-based values. In the field of dental color studies, SR has been used to determine the color of natural tooth [10] and shade guides [2,11], and it was reported that the correlations between the SP- and SR-based color coordinates of shade guide tabs were strong [11].

Threshold values for the visual perceptible or acceptable color differences based on the instrumental color measurements have been investigated [12–15]; however, only a few were determined under clinical conditions [12,15]. As to a clinical perceptible threshold, a value of 3.7ΔE^*_{ab} units was rated based on a SP measurement [12], while that based on a SR was rated as 2.6ΔE^*_{ab} units [15]. As a clinical acceptable threshold based on a SP, a color difference of 6.8ΔE^*_{ab} units was rated [12], while a color difference of 5.5ΔE^*_{ab} units was rated based on a SR [15]. Although the experimental conditions for the threshold determinations varied by the study, it is evident that the threshold values for the instrumental color differences varied by the instrument.

The amounts of deviations in the color coordinates between the SP- and SR-based values of esthetic materials might be influenced by many factors such as the shade and the translucency of materials, the measuring geometry, the illumination and the kind of color coordinate [2,11,16]. Besides, the measuring area in the SR measurements might cause variations in the color coordinates similar to those in the SP measurement [17,18]. However, there have been no identified studies on the influence of the color instruments such as the SP and the SR on the discrepancy between the SP- and the SR-based colors based on esthetic restorative materials.

The purpose of this study was to determine the correlations between the SP- and SR-based color coordinates and color differences in layered all-ceramic core and veneer combinations, which simulated clinical all-ceramic restorations. The null hypotheses assumed in the present study were (1) the measured color coordinates (CIE L^*, a^*, b^* and chroma) would not be influenced by the measurement method (instrument and measuring area), the shade designation and the brand of all-ceramic materials, and (2) there would be no significant correlations between the SP- and SR-based color coordinates. Based on the results of the present study, a suggestion for the interpretation of the color coordinates and the color differences based on two instruments would be provided.

2. Materials and methods

Specimens for 7 ceramic core materials were fabricated, 11 mm in diameter, following the manufacturers' instructions (Table 1). A2 corresponding shade (VITA Lumin; VITA Zahnfabrik, Bad Säckingen, Germany) was selected for all core ceramics. A sintering ceramic (VITA VM7; VITA Zahnfabrik) was used as a reference material for core ceramics. Veneer ceramics were selected for each core material (Tables 1 and 2) and the final thickness of the layered specimens was set at 1.5 mm [19]. The shades for the veneer ceramics were selected to correspond to the A2 and A3 shades in the VITA Lumin shade guide. Seven specimens were prepared for each core and veneer ceramic. Detailed preparation procedures for