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Optical properties of pre-colored dental monolithic zirconia ceramics

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ABSTRACT

Objectives: The purposes of this study were to evaluate the optical properties of recently marketed pre-colored monolithic zirconia ceramics and to compare with those of veneered zirconia and lithium disilicate glass ceramics.
Methods: Various shades of pre-colored monolithic zirconia, veneered zirconia, and lithium disilicate glass ceramic specimens were tested ($17.0 \times 17.0 \times 1.5$ mm, n = 5). CIELab color coordinates were obtained against white, black, and grey backgrounds with a spectrophotometer. Color differences of the specimen pairs were calculated by using the CIEDE2000 (ΔE_{00}) formula. The translucency parameter (TP) was derived from ΔE_{00} of the specimen against a white and a black background. X-ray diffraction was used to determine the crystalline phases of monolithic zirconia specimens. Data were analyzed with 1-way ANOVA, Scheffé post hoc, and Pearson correlation testing ($\alpha = 0.05$).
Results: For different shades of the same ceramic brand, there were significant differences in L^*, a^*, b^*, and TP values in most ceramic brands. With the same nominal shade (A2), statistically significant differences were observed in L^*, a^*, b^*, and TP values among different ceramic brands and systems ($P < 0.001$). The color differences between pre-colored monolithic zirconia and veneered zirconia or lithium disilicate glass ceramics of the corresponding nominal shades ranged beyond the acceptability threshold.
Conclusions: Due to the high L^* values and low a^* and b^* values, pre-colored monolithic zirconia ceramics can be used with additional staining to match neighboring restorations or natural teeth.
Clinical significance: Due to their high value and low chroma, unacceptable color mismatch with adjacent ceramic restorations might be expected.

1. Introduction

Zirconia ceramic has performed successfully as a framework material for dental restorations over a decade exhibiting good biocompatibility and high mechanical properties [1]. Due to its whitish-opaque appearance, zirconia ceramic would look unnatural for esthetic dental restorations. Recently, improved translucency [2,3] and various coloring technologies enable the matching of natural tooth color and thereby, zirconia ceramic as a monolithic design has vastly broadened the range of its applications in dentistry.

Zirconia ceramic can be colored by means of applying either a layer of stain or liner over the sintered zirconia surface [4]; immersion in [1,5,6] or painting with the coloring solution [7,8] in the partially sintered state; or fabricating pre-shaded porous zirconia blanks [9–15]. Application of a liner material could result in a weak link between the zirconia substrate and the veneering layer [4]. With regard to an infiltration technique, an additional step of dipping or painting is required [14]. Moreover, the resulting color would not be homogenous [14], and coloring ions only penetrate to a certain depth [16]. Thus, fabrication of pre-shaded zirconia blanks which have more uniform color [17] has been investigated. Several techniques, such as co-precipitation of coloring ions and subsequent calcination [9], a heterogenous nucleation method [13], and mixing metal oxides with the zirconia starting powder [14] have been introduced to obtain pre-shaded zirconia ceramics. Furthermore, the homogenous and even multi-colored zirconia blanks could be made through a specific approach in which zirconia powders are coated with coloring substrates [12,15]. It has been speculated that coloring pigments decreased the flexural strength [6,18,19] and fracture toughness [20] of

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zirconia ceramics. Unlike those studies, Pittayachawan et al. [21] and Sedda et al. [1] reported that coloring procedures did not have any adverse effects on the flexural strength of zirconia ceramics.

Several studies [22–24] investigated the optical properties of natural dentitions and therefore, the reproduction of color and translucency of natural teeth would be an ultimate goal for esthetic dental restorations. Recent study [8] evaluated the effect of coloring on the optical properties of monolithic zirconia ceramics. Translucency was not affected by the number of coloring. However, the study used a specific coloring technique, such as a brush-infiltration method. Since there have been very few studies regarding the optical properties of pre-shaded monolithic zirconia ceramics, the purposes of this in vitro study were to evaluate the color parameters and translucency of recently marketed pre-colored monolithic zirconia ceramics and to compare with those of veneered zirconia and lithium disilicate glass ceramics. In this study, the evaluation of the optical properties was made with a diffuse-reflected spectrophotometer which has been previously used for color assessments in the dental field [25,26]. The null hypotheses were that there would be no differences in the color and translucency among pre-colored monolithic zirconia ceramics of different brands and shades, that there would be no differences in the color and translucency among different shades of the same ceramic brand, and that there would be no differences in the color and translucency among different ceramic brands of the same nominal shade.

2. Materials and methods

Four different brands of various shades of pre-colored monolithic zirconia, 5 different shades of veneered zirconia, and 3 different shades with different levels of translucency of lithium disilicate glass ceramics were tested in this study, and un-colored monolithic zirconia served as a control (Table 1). For the tested specimens, nominal Vita A shades from each manufacturer were selected as this group represented common clinical shade selections [27,28]. The shade B2 veneered zirconia which displayed a yellow shade range was also compared. Square-shaped specimens were prepared ($17.0 \times 17.0 \times 1.5$ mm, n = 5) by using a horizontal grinding machine (HRG-150, AM Technology, Asan, Korea). For multi-colored monolithic zirconia blanks, the specimens were cut from both the uppermost and the lowermost layers. For veneered zirconia specimens, 0.5-mm thick un-colored zirconia cores were veneered with 5 different shades of feldspathic porcelain. All specimens were then sequentially polished (coarse, medium-coarse, and super-fine grit, Edenta AG, Hauptstrasse, Switzerland) to diamond paste (LegabrilDiamond, Metalor Dental AG, Biel/Bienne, Switzerland). The final thicknesses of all specimens were set to 1.5 mm and the thicknesses were measured at each of 4 locations by a single operator with a digital caliper (Digimatic micrometer, Mitutoyo, Tokyo, Japan) with a resolution of 0.01 mm. The specimens were cleaned in an ultrasonic bath of isopropyl alcohol for 5 min before the measurements.

Relative spectral reflectance against a white polytetrafluoroethylene (PTFE) background (GM29021020, X-Rite, Melbourne, Australia; CIE $L^* = 93.95$, $a^* = -0.64$, and $b^* = 2.04$), a black ceramic tile (CM-A101B, Konica Minolta, Tokyo, Japan; CIE $L^* = 0.01$, $a^* = -0.02$, and $b^* = -0.01$), and a neutral grey ceramic tile (CM-A101DFG, Konica Minolta, Tokyo, Japan; CIE $L^* = 56.79$, $a^* = -2.25$, and $b^* = 3.02$) were measured with a spectrophotometer (Color i5, X-Rite, Melbourne, Australia) from 360 to 750 nm at 10-nm intervals. The optical configuration of the instrument was tri-beam

Table 1
Materials used in this study.

Material/Brand	Group	Manufacturer	Lot No.	Composition (wt.%)
Monolithic zirconia				
Rainbow Shade A05	RS05	Genoss	14G18-01	ZrO_2, Y_2O_3 4–6%, $HfO_2 \leq 5\%$, $Al_2O_3 \leq 1\%$, Other oxides
Rainbow Shade A2	RS2		14I22-03	
Rainbow High Shine A0	RHS0		14I02-01	ZrO_2, Y_2O_3 9–11%, $HfO_2 \leq 5\%$, $Al_2O_3 \leq 1\%$, Other oxides
Rainbow High Shine A1	RHS1	Genoss	14I05-01	
Rainbow High Shine A2	RHS2		14K20-01	
Katana ML A Light	KML	Kurary	DIAAR	ZrO_2, Y_2O_3 7.12–7.16%, etc.
Katana ML A Dark	KMD	Noritake	DIHYI	
ST pre-shade A1	ST1		L2250423546-4	Nanometer zirconia powder >98%, Fe_2O_3 <0.3%, Pr_2O_3 <0.3%,
ST pre-shade A2	ST2	UPCERA	L2250307155-71	Er_2O_3 <0.3%, Other oxides <0.5%
ST pre-shade A3	ST3		L2241202060-8	
Rainbow Trans	RT	Genoss	14C28-01	ZrO_2, Y_2O_3 4–6%, $HfO_2 \leq 5\%$, $Al_2O_3 \leq 1\%$, Other oxides
Veneered zirconia	VRT			
Rainbow Trans		Genoss	14C28-35	ZrO_2, Y_2O_3 4–6%, $HfO_2 \leq 5\%$, $Al_2O_3 \leq 1\%$, Other oxides
				SiO_2 60–64%, Al_2O_3 13–15%, K_2O 7–10%, Na_2O 4–6%, Other oxides
VM9 (Dentin A1, A2, A3, A3.5, B2, Enamel)		VITA Zahnfabrik	17900, 32430, 39440, 15530, 12610, 44480	
Lithium disilicate glass ceramic				
IPS e.max CAD LT A1	EL1		T10405	SiO_2
LT A2	EL2		U36939	Additional contents: Li_2O, K_2O, MgO, Al_2O_3, P_2O_5, Other oxides
LT A3	EL3	Ivoclar	U36562	
HTA1	EH1	Vivadent	N57963	
HTA2	EH2		T02466	
HTA3	EH3		U17061	
IPS e.max CAD Crystall./Glaze		Ivoclar Vivadent	T25180	Oxides, Glycols
IPS e.max CAD Crystall./Glaze Liquid		Ivoclar Vivadent	R43498	Butandiole