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Effect of thickness on optical properties of monolithic CAD-CAM ceramics

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ABSTRACT

Objective: To compare the effect of material and thickness on the color stability and relative translucency parameters (RTP) for monolithic ceramics subjected to coffee thermocycling.
Methods: Four specimens each at thicknesses of 0.5, 0,7 and 1 mm were sectioned from monolithic ceramics [preshaded monolithic zirconia (MonZr), lithium disilicate (LDS) and zirconia reinforced lithium silicate (ZLS)]. The specimens were glazed and subjected to 5000 coffee thermocycling. The color coordinates of specimens were determined with a spectroradiometer and color differences and RTP values were calculated with CIEDE2000 color difference and $TP_{CIEDE2000}$ formulas. ANOVA was used to analyze CIEDE2000 color difference and RTP values ($\alpha = .05$).
Results: For the color difference data, the 2-way ANOVA revealed a significant interaction between material and different thickness ($P = .002$). Except for 0.5 mm thick ZLS material, all materials in all thicknesses studied presented color changes within the clinically acceptable limits after coffee thermocycling. For the RTP data, the 3-way ANOVA revealed a highly significant interaction between material and different thicknesses ($P < .001$).
Conclusions: Material type and thickness can be expected to affect color change and relative translucency of the restorations made with preshaded MonZr, LDS and ZLS materials. Except for 0.5 mm thick ZLS material, color changes of all studied materials were within the clinically acceptable limits. Except ZLS material, color changes of other materials were not significantly affected by thickness. Staining in coffee was not found to affect translucency, and the materials' translucency parameters were ranked from high to low as LDS, ZLS and MonZr at each thickness studied.

Clinical Significance

Monolithic ceramic type and thickness should carefully be selected to minimize color changes in restorations. Clinicians should keep in mind that ZLS material's color may change due to coffee consumption more noticably when its thickness decreases to 0.5 mm.

1. Introduction

Ceramic systems have been advocated for prosthetic restorations because they have favorable optical properties [1,2]. Ceramic restorations can be manufactured using different systems such as heat pressing, infiltrated systems or computer-assisted design and computer-assisted manufacturing (CAD-CAM) systems [2]. As compared to the other ceramic systems, the advent of CAD-CAM technology has facilitated the design of frameworks and complete contour restorations [3]. The advantages of CAD-CAM are standardized production process, time saving and producing almost defect-free restorations [4]. Recently, monolithic restorations with CAD-CAM technology have become widely used because of high mechanical properties, reasonable esthetics without requiring a veneering ceramic, simple clinical technique and good biocompatibility [5,6]. Different type of monolithic ceramic materials can be milled using CAD-CAM systems [7].

Lithium disilicate ceramic has been used in dentistry [8,9]. Recently a zirconia reinforced lithium silicate glass ceramic (VITA Suprinity PC) for dental CAD-CAM applications has been introduced. It is claimed by its manufacturer that this new glass ceramic material is enriched with zirconia and combines the material characteristics of both zirconia and glass ceramic. It is recommended to be used anatomically contoured as a monolithic restoration due to its translucency and availability of

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different shades [10].

Despite the esthetic advantage of glass ceramics, the demands for stronger ceramic restorations have increased. As a result, high-strength zirconia-based ceramics combined with CAD-CAM technology have broadened the range of their applications in dentistry [11]. There is a trend toward anatomical contour zirconia restorations without veneering porcelain called monolithic zirconia that has good optical and mechanical properties [12–14]. High translucency monolithic zirconia has been developed for clinical use [14] to overcome the lack of translucency of conventional zirconia.

In prosthetic dentistry, the reproduction of color and translucency of natural teeth would be an ultimate goal for esthetic dental restorations. Color stability throughout the functional lifetime of a restoration is as important as the mechanical properties of the material because the longevity and esthetic appearance of tooth-colored restorations depends on the color stainability of the material [15,16].

The effect of thickness on the optical properties of monolithic zirconia ceramics have been studied [17–20]. Further, the optical properties of monolithic zirconia with lithium disilicate materials [19–23]. Although some work has established the effect of coffee thermocycling on the color stainability of lithium disilicate glass-ceramic and other composite resins [15], comparative information regarding the effect of different thicknesses on the optical properties of different monolithic CAD-CAM ceramics after coffee thermocycling is lacking.

The translucency of a material may be characterized by the translucency parameter (TP), defined as the color difference of a material which is optically uniform over its thickness and which is in optical contact with ideal white and black backgrounds [24,25]. A TP value of zero is indicative of a completely opaque material, with the maximum TP value of the color difference ($\Delta E = 100$) between the ideal backings [26], thus allowing for comparisons of TP universally. Recently, the use of the CIEDE2000 color difference formula has been suggested for use in calculating TP [27], which would result in a change in scale but with the same maximum. Further, the relative TP (RTP), relative to the color of the actual backings used in the color difference determinations, is required when there is not optical uniformity throughout the thickness of the material [28,29]. This results in a new maximum RTP value, but RTP would be valid for relative translucency comparisons within a study.

For ceramic materials, the type of material and thickness are considered important parameters for optical properties [15,30] and changes in color and translucency may be expected when the thickness of porcelain layer changes. In prosthetic dentistry, depending on the restoration type, different thicknesses of monolithic restorations can be used because of esthetic considerations. To improve the esthetic outcome of restorations, it is important to evaluate the effect of thickness on the optical properties of monolithic ceramic restorations. The purpose of this study was to compare the effect of material and thickness on the color stability and translucency of different monolithic ceramics (preshaded zirconia, lithium disilicate and zirconia reinforced lithium silicate) subjected to coffee thermocycling. The first null hypothesis was that the material type and thickness would not affect the color stability of monolithic ceramics. The second null hypothesis was that the material type, thickness and staining by coffee thermocycling would not affect the translucency of monolithic ceramics.

2. Materials and methods

Three types of CAD-CAM monolithic ceramic materials listed in Table 1 were tested for their color stability and relative translucency after coffee thermocycling. The CAD-CAM blocks were sectioned using a cutting machine (Vari/cut VC-50; Leco Corporation, St Josephs, MI, USA) and a slow-speed diamond-wafering blade (Buehler series 15 LC diamond; Illinois Tool Works Inc, Lake Bluff, Illinois, USA) to obtain rectangular plates of 3 different thicknesses (0.5, 0.7, 1 mm; n = 4 per material and thickness subgroup).

MonZr specimens were sintered in a sintering furnace (Programat S1 1600; Ivoclar Vivadent AG, Liechtenstein, Austria) according the manufacturer's recommended heating rate, holding time and temperature parameters. According to the manufacturer's recommendations, the ZLS and LDS specimens were cleaned with distilled water in an ultrasonic bath and the crystallization firing was performed in a ceramic furnace (Programat EP5000; Ivoclar Vivadent AG, Liechtenstein, Austria) at 840 °C for 8 min and at 850 °C for 10 min, respectively. Then, the sintered and crystallized specimens were polished for 20 s with silicon carbide abrasive papers (600-grit) using an automatic grinder/polisher (Model AP 50; Leco, St Joseph, MI) under running tap water by one operator. The final thicknesses of each specimen were measured with a digital caliper (Model number NB60; Mitutoyo American Corporation, Providence, RI, USA).

A thin layer of glaze material was applied to the specimens by the same operator and glaze firings were performed for ZLS (VITA AKZENT Plus Glaze LT powder; VITA Zahnfabrik, Bad Sackingen, Germany) and MonZr (VITA AKZENT Plus Glaze powder; VITA Zahnfabrik, Bad Sackingen, Germany) specimens at 800 °C for 1 min, and LDS (IPS e.max Ceram; Ivoclar Vivadent AG, Liechtenstein, Austria) specimens at 770 °C for 1.5 min. After glazing, the specimens were stored in distilled water at 37 °C for 24 h to mimic the oral environment.

The baseline radiance spectra of each specimen was measured on 3 different backings black, gray and white, using a non-contact spectral radiance measuring system. This system consisted of SpectraScan PR-705 spectroradiometer (Photo Research Inc.; Chatsworth, CA, USA) and a fiber optic light cable (Model 70050; Newport Stratford Inc., Stratford, CT) with a xenon arc lamp (300W; Oriel Instruments, Stratford, CT, USA) positioned on a custom-made optical table to provide a 0° observation and 45° illumination configuration [31,32]. The distance between the specimen and the lens was set to 80 mm and the measuring diameter was 1.1 mm. Optical contact between the backing and specimen was obtained using saturated sucrose solution. Spectral radiance ($W/sr/m^2$) measurements were obtained in the visible spectrum from 380 to 780 nm with a 2 nm interval using SpectraWin software (v 2.0; Photo Research Inc., Chatsworth, CA, USA). A certified white reflectance standard (S3796A; Labsphere Inc. North Sutton, NH) was measured with the spectroradiometer to monitor the stability of radiance measurements before and after each specimen, and the average radiance was used for reflectance calculations.

Reflectance calculations were performed as previously described [33]:

$$\text{Reflectance}_{\text{Specimen}} = (\text{Radiance}_{\text{Specimen}}/\text{Radiance}_{\text{Standard}}) \times \text{Reflectance}_{\text{Standard}}$$

Each reflectance spectra was converted to Commission Internationale de l'Eclairage L*, a* and b* color parameters (CIELAB)

Table 1
CAD-CAM Monolithic Ceramic Materials Studied.

Material	Composition	Manufacturer.	Shade	Lot No.	Lot No.
VITA Suprinity PC	Zirconia reinforced lithium silicate glass-ceramic	ZLS	VITA Zahnfabrik	A3-HT	36851
IPS e.max CAD	Litihium disilicate glass-ceramic	LDS	Ivoclar Vivadent AG	A3-HT	V12245
İnCoris TZI C	Preshaded zirconium oxide	MonZr	Sirona Dental Systems GmbH	Translucent A3	2015518043