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Comparison of light transmission of multilayered zirconia materials produced using different sintering methods

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Abstract

Aim: In multilayered zirconia blocks, the enamel layer consists of 5Y-TZP, whereas the transition and body layers consist of 3Y-TZP content. Zirconias, which have different compositions, can be sintered quickly and conventionally, but the effect of speed-sintering on light translucency is not fully known. The aim of this study was to investigate the effect of speed-sintering protocols on the light translucency of multilayered monolithic zirconia materials.

Methodology: In this study, multilayered blocks underwent a speed-sintering protocol: Katana Zirconia YML (Kuraray) and IPS e.max ZirCAD Prime (Ivoclar Vivadent). The samples were designed with a post-sintering diameter of 12 mm and thickness of 1 mm, and they were manufactured using a CAD/CAM milling machine (Onex Dental Coritec 350i). Samples obtained from the blocks were randomly divided into two groups and sintered in two different ways according to the sintering protocol (n=16). After sintering, L*, a*, b* values of all samples were measured with a spectrophotometer, and the measurements were recorded using black and white backgrounds. Translucency (TP) values were analyzed using a two-way analysis of variance (ANOVA) test to examine the effects of zirconia firing. Statistical analysis was performed using IBM SPSS.

Results: The light translucency values of the ZirCAD Prime subgroup subjected to speed sintering were higher than those of the other groups. In the Katana YML group, no significant difference (p=0.161) was observed between the subgroups that sintered speed and conventionally.

Conclusion: The differences in light translucency values may be attributed to variations in the amount and thickness of 5Y-TZP zirconia in the enamel layer. The light translucency of the Katana Zirconia YML block was not affected by the sintering protocol, demonstrating that this block can be safely speed-sintered.

Keywords: Monolithic zirconia, multilayered zirconia, speed-sintering, light translucency, 3Y-TZP, 5Y-TZP

Introduction

With the increase in aesthetic expectations of patients, the materials used for restorations are gradually developing and gaining a more natural appearance (1). Currently, zirconia restorations are one of the most preferred materials owing to their high mechanical properties, high biocompatibility, and aesthetic properties; however, owing to the high opacity of zirconia, efforts have been made to increase its aesthetic properties using various methods (2, 3). Substructure zirconias have been layered with aesthetic felsdpathic ceramics, but frequent chipping is one of the biggest disadvantages of this solution. The use of monolithic zirconia is gradually increasing owing to its low cost and lack of chipping. To increase the translucency of monolithic zirconia, the yttria content (3-4-5 mol%) has been increased, and multilayered zirconia has been developed (4, 5, 6).

Multilayered zirconia can be produced in two ways: either by pre-coloring or by combining layers of zirconia with different yttria contents. The yttria content in each layer of multilayered zirconia varied. Generally, 5 Y-TZP zirconia with high cubic content and low durability is used in the upper layers, whereas 3 Y-TZP zirconia with high durability is used in the lower layers (7, 8).

Transparency is observed owing to the effects of the reflection, absorption, or transmission of light when it encounters the material. The molecular size of ZrO_2, yttria ratio, molecular boundaries, and micropores are factors that affect the translucency of zirconia (5).

The sintering time and temperature of zirconia cause changes in zirconia particle size, resulting in an increase in the cubic phase (9). In materials such as zirconia, the strength and other properties are closely related to the porosity in the microstructure. The sintering procedure plays an important role in determining the permeability of zirconia. With an increase in the sintering temperature, the grain size becomes larger, and the sintered density increases and the porosity decreases. This results in zirconia having a more compact crystal structure. However, larger grains can make the material more susceptible to phase transformation while increasing the permeability of zirconia, which can reduce its mechanical properties (5, 10).

The sintering process is expected to increase the density of zirconia by reducing the gaps within the material. This allows for less light scattering and more light transmission. It has also been reported that prolonged sintering time can improve the flexural strength of translucent monolithic zirconia, correlating with grain size change and phase transformation (11,12).

In a study examining the effect of speed-sintering in multilayered zirconia, Michalova et al. reported that the difference in translucency is due to the different Y-TZP contents of the different layers and is related, in particular, to the high cubic phase (5Y-TZP) in the enamel layers (13).

The aim of this study is to investigate the effect of a speed-sintering protocol on the light transmittance of multilayer monolithic zirconia materials. The null hypothesis of this study was that different sintering protocols have no effect on the light transmission of multilayered monolithic zirconia materials.

Materials and Methods

The light transmission factors of two different blocks of multilayered monolithic zirconia, Katana Zirconia YML (Kuraray, Tokyo, Japan) (YML) and IPS e.max ZirCAD Prime (Ivoclar Vivadent, Schaan, Liechtenstein) (Prime) blocks, were examined. According to the information provided by the manufacturer, the YML block consists of enamel and three body layers, whereas Prime consists of enamel, transition, and body layers. The layer thicknesses are different in both the blocks, as shown in Figure 1.

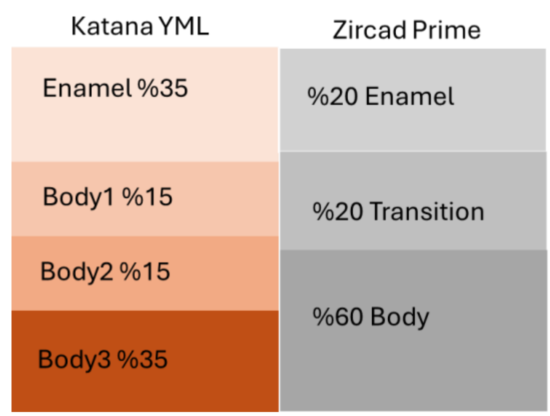

Figure 1. Layer thickness of materials

According to the G*power analysis, a total of 64 specimens (16 in each subgroup) was determined at a power level of (f) 0.90.

The specimens were organized using the ExoCAD (Exocad DentalCAD; Exocad GmbH, Germany) program, with a post-sinter diameter of 12 mm and thickness of 1 mm, and were produced using a CAD/CAM milling device (Onex Dental Coritec 350i, İstanbul, Türkiye). Each group was randomly divided into two and accelerated sintering (SS) and conventional sintering (CS) protocols were applied at the temperature levels in Table 1 for YML and at the temperature levels in Table 2 for Prime, following the sintering protocols of the manufacturer. Thus, 4 subgroups were produced as YMLSS, YMLCS, PrimeSS and PrimeCS.

After sintering, L*, a*, b* values were measured at 400 and 500 nm wavelengths on black and white backgrounds with a spectrophotometer (Lovibond, RT series, London, UK). A Standard Commission

Internationale de L' Éclairage (CIE) D65 illuminator and 2-degree observer function were used to determine the CIELab coordinates of the samples. The L*, a *, and b *values of each sample were measured three times and averaged. According to the CIELab system, translucency is the color difference measured on a black and white background and is calculated by the following formula (9) (Fig. 2).

$$TP=[(L^*_B-L^*_W)^2+(a^*_B-a^*_W)^2+(b^*_B-b^*_W)^2]^{½}$$

Figure 2. Translucency formula

Table 1. YML sintering protocol

	˚C/min	Temperature 2	˚C/min	Temperature 3	˚C/min	Temperature 4	Holding	Cooling ˚C/min
YMLSS	50 ˚C	1400 ˚C	4 ˚C	1500 ˚C	10 ˚C	1560 ˚C	16 min	50˚C-800
YMLCS	10 ˚C	1550 ˚C	-	-	-	-	120 min	50 ˚C

Table 2. ZirCAD Prime Protocol

	˚C/min	Temperature 2	Holding	˚C/min	Temperature 3	Holding	Cooling ˚C/min
PrimeSS	60˚C	1000 ˚C	10 min	3 ˚C	1530 ˚C	60 min	50˚C-1100
PrimeCS	10˚C	900 ˚C	30 min	3.3 ˚C	1500 ˚C	120 min	10 ˚C-900

Statistical analysis

Data were analyzed using IBM SPSS V25 statistical software (SPSS version 25, IBM, Armonk, NY, US).

The effects of different zirconia materials and production techniques on the translucency measurement values were analyzed using a two-way factorial ANOVA. If there was a difference as a result of the two-way factorial ANOVA, a Tukey multiple comparison test was used to investigate the groups that caused the difference.

The statistical significance level was set at $p<0.05$.

Results

Descriptive statistics for the translucency values of the different zirconia materials and sintering protocols are given in Table 3. The effects of different zirconia materials and sintering protocols on translucency values were analyzed using two-way differential ANOVA and the ANOVA test results are given in Table 4. Tukey's multiple comparison test was used to compare the subgroups that differed according to material and sintering protocol as a result of ANOVA. According to the results of Tukey's analysis; in the multiple comparison of YMLCS, YMLSS, PrimeCS, PrimeSS, there was no statistically significant difference between only YMLCS and YMLSS subgroups in terms of translucency values ($p=0.161$), while a statistically significant difference was found in the comparison of other subgroups ($p<0.001$).

Table 3. Comparison of the translucency results (mean values ± SDs) and their significance between both materials and as a function of sintering protocol

Sintering Protocol		ZirCAD Prime	Katana YML
Conventional	Mean ± SD	10.59±0.70	12.26±0.85
Speed	Mean ± SD	14.35±0.35	11.77±0.62

Table 4. Two-way ANOVA for combined effect of materials and sintering protocols

Change Source	df	Sum of Square	Mean of Square	F	*p*
Material	1	3.288	3.288	7.706	**0.007**
Sintering protocol	1	42.896	42.896	100.548	**<0.001**
Material*Sintering protocol	1	72.280	72.280	169.423	**<0.001**
Error	60	25.597	0.427	---	---
Total	63	144.061	---	---	---

S=0.6534; **R2**=%82.2; **Corrected R2**=%81.3; **df;** Degress of Freedom

Discussion

The null hypothesis that different sintering protocols will have no effect on the light transmittance of multilayer monolithic zirconia materials was rejected. Speed sintering protocols for Katana Zirconia YML and IPS e.max ZirCAD Prime are recommended by the manufacturer as an alternative to conventional sintering to save time. According to the results of the study, speed-sintering of multilayer zirconia material has a significant effect on translucency.

In their study on multilayer monolithic zirconia, Kolakarnprasert et al. reported that multilayered zirconias, which have 5Y-TZP and 4Y-TZP content, have high translucency values due to high yttrium content (14). In a study investigating translucency, Kwon et al. 5Y-TZP zirconia was higher than 3Y-TZP zirconia (15). Masanao Inokoshia et al. showed that sintering temperature affects particle size and that at 1550 °C, the particle size of 5Y-TZP zirconia increased and contained a significant amount of cubic phase (16). Similarly, some studies have reported that particle size increases with increasing sintering temperature (10).

Cocic et al. reported that the phase composition of 3 Y-TZP zirconia was affected by speed-sintering, but not the phase content of 5Y-TZP zirconia, and that a speed-sintering protocol can be used in the final stage of sintering to maintain a fine microstructure and prevent grain growth (17). Consistent with the findings of previous studies, the speed-sintering translucency values of ZirCAD prime were significantly higher than the conventional sinter TP values. In their study on ZirCAD Prime and Katana YML, Labetić et al. reported that the grain size and cubic phase content of the enamel layer consisted of 5Y-TZP, and the body layer consisted of 3Y-TZP and the enamel region had larger grain size and cubic phase content (18). Strasser et al. in their study on the phase composition of ZirCAD and YML, reported that the content of 3Y-TZP to 5Y-TZP from the body layer to the enamel layer, and this supports the findings of previous studies (19). In accordance with the findings of our study, the thicker enamel layer of YML compared to Prime resulted in a higher TP value after conventional sintering owing to the high 5 Y-TZP content. The pigmentation rate of zirconia increases chroma and affects light scattering, resulting in a low TP value (20). Additional pigmentations in YML (according to the manufacturer's information) can be explained by the fact that speed-sinter TP values are lower than those of conventional YML and Prime speed-sinter TP values. The close sintering temperatures of the YML speed and conventional sintering may have resulted in a lack of significant results on the TP. It was shown that dyed yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) containing Fe_2O_3 pigments had transparency comparable to that of undyed zirconia ceramics, but colored zirconia ceramics had a lower translucency value (21, 22).

Conclusion

The differences in light transmittance values are likely due to the different proportions and thicknesses of 5 Y-TZP zirconia in the enamel layer of the blocks. The light transmittance of the Katana Zirconia YML is not affected by the sintering protocol and can safely undergo speed-sintering.

Disclosures

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