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Studies on the Color of Calcium-phosphate-based Castable Glass-ceramic CD203

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Introduction

A calcium-phosphate-based castable glass-ceramic CD203 has been developed by Nippon Electric Glass Co. (Shiga, Japan). The dental restoration such as inlay and crown is first made of wax. The wax pattern is mounted in the SiO_2-based exclusive investment, followed by burning out the wax at 800°C. The glass, originally transparent with light brown shade, is then melted at 1535°C and poured into the investment by an experimental vacuum-pressurized casting machine, followed by ceramming (held at around 910°C for 2 hours) so that crystals precipitate in the glass matrix, producing esthetic appearance with translucency and adequate mechanical strength[1]. The ceramming temperature, sample thickness and background color significantly affect the color of heat-treated CD203 glass-ceramic. There have been, however, few studies to examine these influences. The purpose of this investigation was, thus, (1) to evaluate the effects of the ceramming temperatures on the color, expressed in the CIE-L*a*b* coordinate, of glass-ceramic CD203, (2) to investigate the effects of the sample thickness on the said color, and (3) to assess the effects of the background color on the said color.

Materials and methods

Table 1 shows the chemical composition of castable glass CD203. Disks, 20 mm in diameter and 1.3, 2.6 and 3.9 mm thick consisting of base-plate paraffin wax (GC Co., Tokyo, Japan) were transformed into CD203 glass castings by the lost wax method outlined above, utilizing a casting machine (Type II, Morita Co., Kyoto, Japan). Subsequently, while embedded in the investment, the glass-castings were heat-treated (cerammed) in an electrically heated furnace (Type I, Morita Co., Kyoto, Japan). Ceramming conditions evaluated were as follows, at which the standard condition recommended by the manufacturer was italicized: 870°C 2 hr; 890°C 2 hr; *910°C 2 hr*; 930°C 2 hr; and 950°C 2 hr. The surfaces of cerammed CD203 specimens were not polished. The mean surface roughness (Ra) of these specimens was about 2 micron-meter. Dental porcelain VITA 541 (Vita Co., Germany), which represents the color of dentin of adult human, were also fabricated into disks 20 mm in diameter and 1.3, 2.6 and 3.9 mm thick, by the standard firing procedure. Their surfaces were not finished, either, the mean surface roughness (Ra) of which was about 0.5 micron-meter.

Table 1 Chemical composition of calcium-phosphate-based castable glass CD203

Oxide batch	Weight percentage
SiO_2	48.5
CaO	18.5
P_2O_5	8.5
Al_2O_3	14.0
MgO	10.5
Others	($B_2O_3+CaF_2$: minute)

While placed either on white plate (MgO, 20×20×10 mm) or on black plate (Obsidian, 20×20×10 mm), the disk specimens were examined for their color with a chroma-meter reflectance instrument (CR-121, Minolta Camera Co., Osaka, Japan), equipped with a standard illuminant (xenon lamp) D65 (color temperature, 6504K). The incident light hit the specimen at a 45 degree angle, and the light reflected perpendicularly to the specimen (0 degree) was detected by three sensors having a spectrum

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sensitivity almost identical to the human eye. Tristimulus values of X, Y and Z were thus directly obtained and automatically calculated into color readings expressed as CIE-L*a*b* coordinates where L* is brightness, a the (+) red/green (−) coordinate and b* the (+) yellow/blue (−) coordinate. The (L_0*, a_0*, b_0*) values of white and black plates were (89.45, −0.28, 0.73) and (21.21, −1.11, −1.21), respectively. All color measurements were made three times, and the mean values were used for the color analyses.

Results and discussion

Fig. 1 shows the effects of the thickness on L* values of CD203 glass-ceramics heat-treated at 910°C and placed on white and black plates. When the thickness was small, the color of CD203 glass-ceramics was affected by two background color. With incrementing the thickness, the background color effect disappeared, and the CD203 glass-ceramics attained their intrinsic L* values. When the difference in any color coordinate of two specimens becomes less than 1.5, human eye can not discriminate the difference in the color of two specimens. By plotting the L*, a* and b* values with white and black backgrounds against the sample thickness, the critical thickness at which the background color effect disappeared and the intrinsic color (L*, a* and b* values) were obtained.

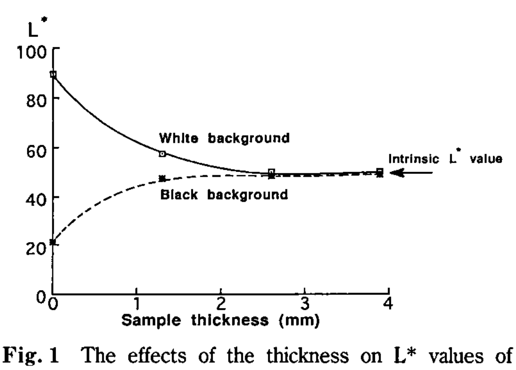

Fig. 1 The effects of the thickness on L* values of CD203 glass-ceramics heat-treated at 910°C and placed on white and black plates.

Fig. 2 indicates the critical thickness, at which the background color effect disappeared, of L*, a* and b* values of CD203 glass-ceramics and VITA 541. It became evident that the increase in the ceramming temperature lead to the decline in the critical thickness of L*, a* and b* values. This means that higher the ceramming

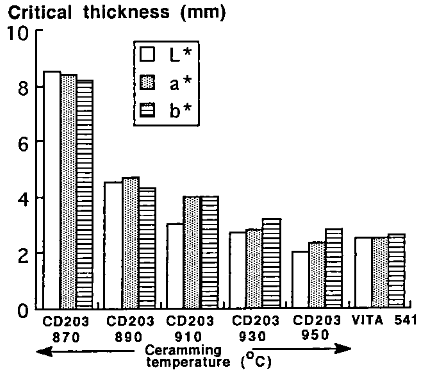

Fig. 2 The critical thickness, at which the background color effect disappeared, of L*, a* and b* values of CD203 glass-ceramics and VITA 541.

temperature, more opaque CD203 glass-ceramics. VITA 541 had the critical thickness of L*, a* and b* values, analogous to those of CD203 glass-ceramics heat-treated at 930°C and 950°C.

Fig. 3 shows the intrinsic L* values of cerammed CD203 samples and VITA 541. As the ceramming temperature increased, L* values of CD203 glass-ceramics increased. CD203 glass-ceramic heat-treated at 930°C had the L* value, similar to that of VITA 541. Fig. 4 indicates the intrinsic a* values of cerammed CD203 samples and VITA 541. With increasing the ceramming temperature, a* values of CD203 glass-ceramics decreased. All cerammed CD203 specimens had a* values favoring green, compared with that of VITA 541. Fig. 5 shows the intrinsic b* values of cerammed CD203 and VITA 541. Increasing the ceramming temperature from 870°C to 910°C lead to the decrease in b* values of CD203 glass-ceramics. From 910°C to 950°C, however, the

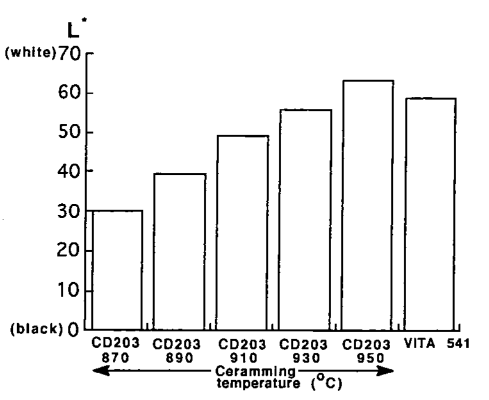

Fig. 3 The intrinsic L* values of cerammed CD203 glass-ceramics and VITA 541.

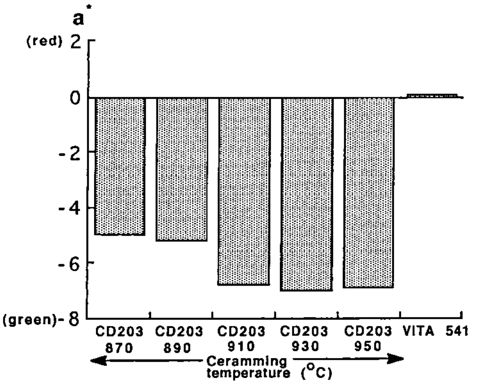

Fig. 4 The intrinsic a* values of cerammed CD203 glass-ceramics and VITA 541.

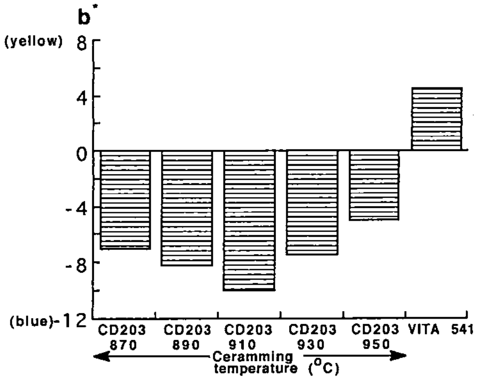

Fig. 5 The intrinsic b* values of cerammed CD203 glass-ceramics and VITA 541.

increment in the ceramming temperature brought about the increase in b* values. All cerammed CD203 glass-ceramic specimens had b* values favoring blue, compared with that of VITA 541.

The change of color of CD203 glass-ceramics stems from the alteration in the type and quantities of crystals precipitating in the glass matrix. It has been reported that CD203 glass-ceramics contained three crystals, namely apatite, tri-calcium phosphate and diopside[1]. Increasing the ceramming temperature tends to multiply the amounts of these three crystals, causing the color change. It became apparent from the results obtained that incrementing the ceramming temperature produced the addition in L* and a* values and moderate change in b* values. To simulate the color of human dentin represented by VITA 541, yellow and red color must be added into CD203 glass-ceramics while maintaining the satisfactory L* values. This might be done by the incorporation of pigment oxide (e.g. Fe_2O_3)[2] into the original CD203 glass. With this manipulation, it appears that CD203 glass-ceramics might be more clinically feasible as dental restorations such as inlay and crown.

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