SHADE MATCHING OF TITANIUM PORCELAIN

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REZUMAT

Obiectiv: Scopul acestui studiu a fost de a evalua diferențele cromatice dintre trei sisteme ceramice pentru titan și cheile de culori corespunzătoare. **Material și metodă:** Treizeci și șase de cape metalice din titan au fost placate cu trei ceramici diferite. Culoarea fiecărei fațete ceramice a fost măsurată utilizând un spectrofotometru și s-au înregistrat valorile digitale pentru luminozitate (L*), direcția roșu-verde (a*) și direcția galben-albastru (b*). Ca și control, s-au înregistrat valorile cromatice digitale și pentru dinții din cheile de culori corespunzătoare pe baza cărora s-a ales nuanța maselor ceramice arse. După înregistrarea valorilor digitale ale culorii, s-au calculat diferențele cromatice dintre probele titan-ceramică și cheile de culori corespunzătoare. Rezultatele au fost analizate statistic. **Rezultate:** Cea mai mică diferență cromatică s-a observat în cazul ceramicii Triceram® ($\Delta E_{probe/cheie\ culori}$ = 1,002), iar cea mai pronunțată în cazul ceramicii Vitatitankeramik® ($\Delta E_{probe/cheie\ culori}$ = 1,982). Diferențe statistice foarte semnificative s-au obținut între masele ceramice privind modificarea cromatică totală (ΔE) după ardere pe titan. Privind direcția de modificare a culorii după ardere pe titan, s-au obținut diferențe foarte semnificative atât între masele ceramice, cît și între direcțiile cromatice. **Concluzii:** Arderea ceramicii pe titan a determinat modificări perceptibile, dar acceptabile clinic între nuanța fațetei ceramice și cheia de culori corespunzătoare, indiferent de sistemul ceramic. Toate cele trei mase ceramice au prezentat o tendință către verde după ardere pe titan. Cea mai pronunțată modificare cromatică a suferit-o ceramica Vitatitankeramik®.
Cuvinte cheie: titan, ceramică, culoare, nuanță, cromatică

ABSTRACT

Objective: The purpose of this study was to assess the chromatic difference of three titanium porcelains from the corresponding shade guides. **Matherial and method:** Thirty-six titanium copings were veneered with three different porcelains. The color of every porcelain veneer was measured using a spectrophotometer and digital values were recorded for luminosity (L*), red-green direction (a*) and yellow-blue direction (b*). As a control, digital chromatic values were recorded for the corresponding shade guide tabs, which were used for choosing the porcelains shades. Once the chromatic digital values were recorded, the color differences between titanium-porcelain samples and the shade guide tabs were computed. The results were statistically analyzed. **Results:** The least chromatic difference was observed for Triceram® porcelain ($\Delta E_{sample/shade\ tab}$=1.002), and the greatest one for Vitatitankeramik® porcelain ($\Delta E_{sample/shade\ tab}$=1.982). Very significant statistical differences were found between porcelains regarding the total color difference (ΔE) after firing on titanium ($p<0.0001$). Regarding the direction of chromatic modification (L*, a*, b*) after firing on titanium, very significant differences were found between porcelains ($p<0.0001$) as well as between chromatic directions ($p = 0.034$). **Conclusions:** Firing porcelain on titanium produced a perceivable, but clinically acceptable difference between the porcelain veneer shade and the desired shade from the corresponding shade guide, regardless the porcelain system. All the three porcelains exhibited a tendency to green. The greatest chromatic modification was observed for Vitatitankeramik®.
Key Words: titanium, porcelain, shade, chromatic, color

INTRODUCTION

One important element in the aesthetics of a dental restoration is color. Clinically, it is very difficult to obtain a perfect color match between a prosthetic restoration and the natural teeth on the arch.[1,2] The final color of PFM depends on several factors such as the dentist's accuracy in shade matching, properties of porcelain and titanium, and some technological variables.[3-12]

Some studies found that repeated firings tend to alter the original shade of porcelain.[13] There are dentists and dental technicians who state that sometimes, even if the manufacturer's indications are thoroughly followed, the final color of titanium-porcelain partial fixed prostheses is not the expected one because of the tendency to a darker shade. The explanation of this undesired eventual behavior could be the major difference between usual PFM porcelains and the porcelain fired on titanium, which is a special low fusing ceramic (LFC). The properties of such porcelain are requested by the special physical and chemical

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properties of titanium. The sintering temperature of porcelain must be as low as possible, less than 800ºC due to an internal structure change of titanium at 882.5 ºC, which is incompatible with porcelain firing.[14-17] Decreasing aluminum oxide and increasing sodium oxide in the chemical composition obtains the low fusing temperature of titanium porcelain. Moreover, the thermal expansion of porcelain should match that of titanium, which is lower than the thermal expansion of regular alloys.[14,18] The concordance between the two thermal expansion coefficients is achieved by increasing the vitreous phase as a result of replacing leucite with mulite. Nevertheless, complete removal of the crystal phase (leucite) would result in poor mechanical and optical properties that are desired characteristics of ceramic materials. To solve this problem, other crystal oxides replace leucite, such as alumina (Al_2O_3), baddeleyite (ZrO_2) and cassiterite (SnO_2).[17] Elements such as lanthanum[19] and barium[20] are also added to the chemical composition of titanium porcelain for increasing the optical and mechanical properties. All these chemical and physical changes in porcelain structure could influence the chromatics of the final titanium-porcelain restoration.

Standardization of chromatics for an aesthetic prosthetic restoration - related to the shade guide and the natural teeth – needs a mathematical formula to express the color difference (δE). The International Commission on Illumination (CIE)[21] defines a color space (*L*a*b**) in which L* represents luminosity, a* represents the chromaticity coordinate for red-green (+a* is the red direction and –a* is the green direction), and b* represents the chromaticity coordinate for yellow-blue (+b* is the yellow direction and –b* is the blue direction). (Fig. 1)

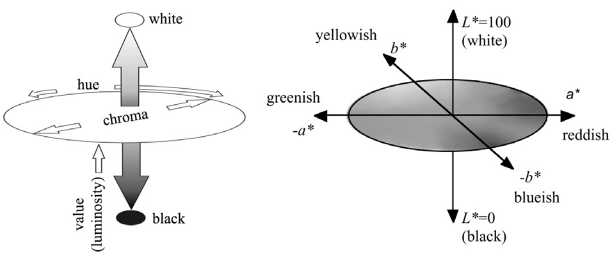

Figure1. CIE L*a*b* color system (CIE, 1976).

Color difference (δE) is defined by the following equation:[22]

$$\Delta E = \sqrt{(L_f^* - L_i^*)^2 + (a_f^* - a_i^*)^2 + (b_f^* - b_i^*)^2}$$

where the initial (*i*) and final (*f*) are color descriptors. This formula has been used extensively in dental research.[12]

The purpose of this study was to assess the chromatic difference of three titanium porcelains from the corresponding shade guides.

MATERIAL AND METHOD

Thirty-six titanium copings were obtained by casting commercial pure titanium grade II (IMNR, Bucharest, Romania). The molds were obtained by embedding in Trinell (Espident, Ispringen, Germany) thirty-six wax patterns fabricated in similar and reproducible conditions. The wax patterns were obtained using 0.4-mm calibrated wax and the same master cast abutment. Titanium copings were then sandblasted with 110 μm alumina particles at 4 bar pressure. Three porcelains were then fired on the prepared copings: Ti22® (Noritake Dental Supply Co. Ltd., Nishikamogun, Japan), Triceram® (Esprident, Isprigen, Germany) and Vitatitankeramik® (Vita, Bad Säckingen, Germany). Producers' indications were thoroughly followed during the layering and firing of porcelains. The following shades were chosen: A3 for Ti22 and Triceram porcelains and 2M3 for Vitatitankeramik, according to Noritake, Vita Classical and Vitapan 3D Master shade guides, respectively. The porcelain layers fired on titanium are presented in Table 1. The mean thickness of porcelain veneer was 1,5 mm with a 0,5-mm-thick opaque layer.

Table 1. Porcelain layers fired on titanium and the corresponding shade

	Porcelain system		
	Ti-22	Triceram	Vitatitankeramik
Layer	Bonding Porcelain Ti22 (adhesive)	Bonder Triceram (adhesive)	Bonder Vitatitan keramik (adhesive)
	Opaque (A3O)	Opaque (O A3)	Opaque (OP3)
	Body (A3B)	Opaque Dentine (OD A3)	Dentine (2M3)
	Enamel (E3)	Dentine (D A3)	Enamel (EN2)
	Glaze	Incisal (IT 59)	Glaze
		Glaze (NT)	

Twelve veneer crowns for each porcelain type were obtained.

Once the specimens were ready, the color of porcelain was measured using a spectrophotometer for small surfaces (CM-2600d; Minolta, Tokyo, Japan). Analyses were made using the Ø8 mm reading aperture, under 2 degrees viewing conditions and type C illuminant (settings offered by the spectrophotometer). During the exposure, the reading aperture of the spectrophotometer was placed 1 mm above the middle of the buccal surface of the titanium-porcelain specimens and the shade guide tabs. The reading aperture was also parallelly maintained with the examined surfaces by using the direct visual control offered by the viewfinder of the spectrophotometer. Digital values were read on the display of the spectrophotometer for luminosity (L*), red-green direction (a*) and yellow-blue direction (b*) for each porcelain veneer of the titanium-porcelain specimens. As a control, L*, a* and b* values were recorded for the corresponding shade guide tabs (A3 tabs from Noritake Shade Guide and Vita Classical Shade Guide and 2M3 tab from Vitapan 3D Master Shade Guide).

Once the chromatic digital values were recorded, the color differences between titanium-porcelain samples and the shade guide tabs ($\Delta E_{sample/shade\ tab}$) were computed. The results were statistically analyzed using ANOVA, followed by Bonferroni post-hoc test, when necessary.

RESULTS

The results of the study are presented in tables 2 and 3. The mean values of total color difference (ΔE) of titanium-porcelain samples from the shade guide tabs, as well as the modifications on the three directions of the chromatic L*a*b* space (ΔL*, Δa*, Δb*) are presented in Figure 2.

The least chromatic difference was observed for Triceram porcelain ($\Delta E_{sample/shade\ tab}$=1.002), and the greatest one for Vitatitankeramik porcelain ($\Delta E_{sample/shade\ tab}$=1.982).

Very significant statistical differences were found between porcelains regarding the total color difference (δE) after firing on titanium (p<0.0001). (Table 4)

Table 2. Digital values (mean) of the color measured for titanium-porcelain samples and the corresponding shade guide tabs

		Mean value	Shade tab
Ti22	L*	75.830	76.290
	a*	1.020	1.440
	b*	18.536	18.310
Vitatitankeramik	L*	74.317	75.480
	a*	-0.330	0.400
	b*	18.480	19.650
Triceram	L*	75.634	75.360
	a*	0.660	1.380
	b*	16.429	19.640

Table 3. Mean values of the quantitative color modification on every chromatic axis (L*,a*, b*) and the total color modification (ΔE) from the corresponding shade guide tabs for each titanium-porcelain sample

		Ti22	Vitatitankeramik	Triceram
Sample-shade tab	ΔL*	-0.460	-1.162	0.274
	Δa*	-0.419	-0.730	-0.719
	Δb*	0.226	-1.170	-0.210
	ΔE*	1.010	1.982	1.002

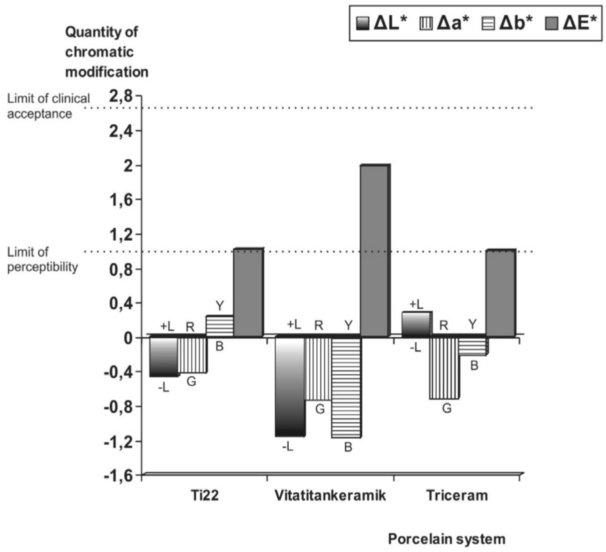

Figure 2. Mean values of total color modifications (ΔE) and color differences on each chromatic axis (ΔL*, Δa*, Δb*) of titanium-porcelain samples from the corresponding shade guide tabs (L=luminosity, R=red, G=green, Y=yellow, B=blue)

Table 4. Statistical assessment (ANOVA) of the differences between porcelains regarding the total color modification (ΔE) by comparison to the corresponding shade guide tabs

Tests of Between-Subjects Effects
Dependent Variable: ΔE

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	2244,667	2	1122.333	22.579	0.000
Intercept	12321.000	1	12321.000	247.872	0.000
PORCELAIN	2244.667	2	1122.333	22.579	0.000
Error	1640.333	33	49.707		
Total	16206.000	36			
Corrected Total	3885.000	35			

αR Squared = 0,578 (Adjusted R Squared = 0,552)

Bonferroni test showed very significant differences between Ti22 and Vitatitankeramik (p< 0.0001), and between Triceram and Vitatitankeramik (p<0.0001). No significant differences were found between Ti22 and Triceram. (Table 5) Regarding the direction of chromatic modification (L*, a*, b*) after firing on titanium, very significant differences were found between porcelains (p<0.0001) as well as between chromatic directions (p=0.034).

Table 5. Bonferroni test for detection of significantly different porcelains regarding the total color modification (ΔE) from to the corresponding shade guide tabs

Multiple Comparisons, Dependent Variable: ΔE Bonferroni

(I)PORCELAIN	(J) PORCELAIN	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
					Lower Bound	Upper Bound
Triceram	Ti22	0.17	2.878	1.000	-7.09	7.43
	Vitatitankeramik	-16.67	2.878	0.000	-23.93	-9.41
Ti22	Triceram	- 0.17	2.878	1.000	-7.43	7.09
	Vitatitankeramik	-16.83	2.878	0.000	-24.09	-9.57
Vitatitankeramik	Triceram	16.67	2.878	0.000	9.41	23.93
	Ti22	16.83	2.878	0.000	9.57	24.09

Based on observed means.
* The mean difference is significant at the 0.05 level.

Very significant differences were found for the interaction between porcelain and direction of chromatic modification (p < 0,0001) (table 6). The statistical comparison between porcelains regarding the color modification on each chromatic direction showed significant differences on axes L* and b* between each pair of porcelains. Not significant differences were found between porcelains regarding the color modification on axis a* (Table 7).

Table 6. Statistical assessment (two-way ANOVA) of the differences between porcelains regarding the direction of color modification on each chromatic axis (L*, a* and b*) by comparison to the corresponding shade guide tabs

Tests of Between-Subjects Effects, Dependent Variable

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	36075.963	8	4509.495	14.117	0.000
Intercept	230833.787	1	230833.787	722.650	0.000
PORCELAIN	20442.241	2	10221.120	31.998	0.000
DIRECTION	2232.907	2	1116.454	3.495	0.034
PORCELAIN * DIRECTION	13400.815	4	3350.204	10.488	0.000
Error	31623.250	99	319.427		
Total	298533.000	108			
Corrected Total	67699.213	107			

α R Squared = 0,533 (Adjusted R Squared = 0,495)

Table 7. Assessment of the statistical differences (Bonferroni test) between each pair of porcelains regarding the color modification on each chromatic axis (L*, a* and b*) by comparison to the corresponding shade guide tabs.

Chromatic axis	Porcelain(1)	Porcelain(2)	p
L*	Triceram	Ti22	0.009
		Vitatitankeramik	0.000
	Ti22	Triceram	0.009
		Vitatitankeramik	0.025
	Vitatitankeramik	Triceram	0.000
		Ti22	0.025
a*	Ti22		0.068
	Triceram		
	Vitatitankeramik		
b*	Triceram	Ti22	0.028
		Vitatitankeramik	0.001
	Ti22	Triceram	0.028
		Vitatitankeramik	0.000
	Vitatitankeramik	Triceram	0.001
		Ti22	0.000

DISCUSSIONS

In this study, a less than the unit value of the total color difference (ΔE < 1) was considered to be undetectable for the human eye.[23-25] Regarding the shade match between natural teeth and prosthetic restorations, the differences are considered clinically acceptable if total color difference is below 2.75.[26] However, some authors consider that mismatch between a restoration and the adjacent teeth is clinically acceptable even when ΔE is higher than 2.75.[27] Natural teeth are polychromatic with an irregular translucency, textured surface, covered by saliva, and observed under subjective conditions of illumination. Considering these factors, it might be possible that the color difference between an *in vivo* restoration and the adjacent teeth is clinically acceptable even for values of ΔE higher than 2.75.

In this *in vitro* study the specimens were monochromatic with a uniform translucency, no surface texture, uncovered by the saliva film, and analyzed under ideal illumination. Thus, color differences higher than 2.75 were considered clinically unacceptable. With this assumption, all the assessed porcelains are suitable for firing on titanium to obtain veneer crowns because the total chromatic differences from the corresponding shade guides were lower than 2. (Fig. 2) In other words, the chromatic aspect of a titanium-porcelain restoration is clinically acceptable as long as the color chosen by the means of the shade guide matches the shade of the natural teeth.

There are studies that rated the colors of the tabs from different shade guides and assigned them digital values according to CIE L*a*b*.[28] The digital values recorded in this study for A3 shade from Vita Classical shade guide correspond to those in the literature.

Many studies assessed the color of PFM and found different results depending on the metallic coping to which porcelain was fired.[5,7,29-31] However, titanium porcelain has not been paid enough attention by now.

The chromatic differences of titanium-porcelain samples from the corresponding shade guides were assessed for every porcelain type. Figure 2 shows perceivable chromatic differences (ΔE), regardless the porcelain system. The color modification consists in a decrease of luminosity and a tendency to green and yellow for Ti22 porcelain, a significant luminosity decrease and a great tendency to green and blue for Vitatitankeramik, a slight luminosity increase and a tendency to green and blue for Triceram porcelain. Nevertheless, the fact that the differences were clinically acceptable ($\Delta E_{sample/shade\ tab}<2.75$) suggests that the correspondence between all the three porcelains and the respective shade guides is satisfactory, at least for the chosen shades.

Significant differences were found among porcelains regarding the total color difference between titanium-porcelain specimens and the corresponding shade tabs ($\Delta E_{sample/shade\ tab}$). (Tables 4,5) All the three porcelains exhibited perceivable color discordance after firing on titanium (ΔE>1), as shown in Figure 2. Significant differences were found between Ti22 and Vitatitankeramik as well as between Triceram and Vitatitankeramik. Regarding the direction of color modification of titanium-porcelain samples, significant differences were found among the three porcelain systems. All the porcelains tended to green on the chromatic axis a* with not significant differences between samples. Significant differences were found on chromatic axis b* between each pair of porcelains by the tendency to yellow (Ti22) and blue (Triceram and Vitatitankeramik), with the greatest difference (Δb*) recorded for Vitatitankeramik (Fig. 2). Regarding the luminosity (chromatic axis L*), significant differences were also found between each pair of porcelains by a luminosity decrease for Ti22 and Vitatitankeramik, whereas Triceram exhibited a slight luminosity increase. Thus, the significant and perceivable chromatic modification to a dull shade of Vitatitankeramik after firing on titanium seems to be caused by a quite strong tendency to green and blue supplemented by the luminosity decrease.

Further analysis of the titanium-porcelain chromatics should be performed in order to establish whether the color modification is due to titanium or to an intrinsic chromogenic behavior of the porcelain.

CONCLUSIONS

Within the limits of this study, the following conclusions can be drawn:

1. Firing porcelain on titanium produced a perceivable difference between the porcelain veneer shade and the desired shade from the corresponding shade guide, regardless the porcelain system.
2. The chromatic modification of the porcelain fused to titanium was clinically acceptable, regardless the porcelain system.
3. All the three porcelains exhibited a tendency to green.
4. The greatest chromatic modification was observed for Vitatitankeramik.

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