MASKING ABILITY OF OPAQUE THICKNESS ON LAYERED METAL-CERAMIC

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ABSTRACT

This study evaluated the masking ability of two opaques applied in different thicknesses. Eighty Ni-Cr metal discs 16 mm in diameter and 1.0 mm thick were prepared. The disks were divided into 8 groups (n = 10). Ceramic opaque in paste (groups 1 to 4) or powder (groups 5 to 8) presentations were applied. They were machined with aluminum oxide burs to the following thicknesses: G1 and G5 = 0.10 mm; G2 and G6 = 0.15 mm; G3 and G7 = 0.20 mm and G4 and G8 = 0.30 mm. Dentin ceramic 0.7 mm thick was applied over these discs, sintered and glazed according manufacturer's instructions. Color was assessed with a Minolta CR-10 spectrocolorimeter on the CIE-Lab scale. Powder opaque had higher values on (L) and (ΔE) variables, and lower values on (a) and (b) variables compared to paste opaque. For opaque thickness, 0.10 mm had higher ΔE than all other thicknesses. L values were higher for 0.20 mm and 0.30 mm. Lowest and highest a values were observed for 0.10 mm and 0.30 mm, respectively. No difference was observed for b* values. There were differences between paste and powder opaque types; 0.10 mm thickness behaves differently from the other thicknesses, with higher ΔE, while 0.15 mm does not differ statistically from thicker layers.*

Key words: *Metal ceramic alloys, ceramic, dental porcelain, color.*

CAPACIDADE DE MASCARAMENTO DE DIFERENTES ESPESSURAS DA CAMADA OPACA EM CERÂMICA ESTRATIFICADA

RESUMO

O objetivo deste estudo foi avaliar a capacidade de mascaramento de duas cerâmicas opacas para metalocerâmicas aplicadas em espessuras diferentes. Foram confeccionados 80 discos metálicos de Ni-Cr (High Bond) com 16 mm de diâmetro e 1,0 mm de espessura. Os discos foram divididos em 8 grupos (n=10) e aplicadas as cerâmicas opacas (Noritake) em pasta (grupos de 1 a 4) e em pó (grupos de 5 a 8). Estas foram usinadas com pontas de óxido de alumínio até atingir as seguintes espessuras: G1 e G5 = 0,10 mm; G2 e G6 = 0,15 mm; G3 e G7 = 0,20 mm e G4 e G8 = 0,30mm de espessura. A cerâmica de dentina opaca foi aplicada (0,7 mm) e realizado o glazeamento. A cor foi avaliada com Espectrocolorímetro (Minolta CR-10) e foi aplicada análise de variância com para p<5%. Resultados: O opaco em pó apresentou valores maiores estaticamente significantes nas variáveis (L) e (ΔE), ocorrendo o inverso nas outras duas variáveis. Quanto à espessura de opaco, os valores podem ser agrupados da seguinte forma, segundo os testes complementares aplicados: variável (L*): (0,10 = 0,15) < (0,20 = 0,30); variável (a*): (0,10) < (0,15 = 0,20) < (0,30); variável (b*): não houveram diferenças estatisticamente significantes; variável (ΔE): (0,10) < (0,15 = 0,20 = 0,30). Conclui-se que houve diferença entre os tipos de opaco em pasta e em pó e que todas as espessuras testadas, exceto a de 0,10 mm, podem ser usadas sem alteração significativa da cor.*

Palavras Chave: *Ligas metalo-cerâmicas. Cerâmica. Cor.*

INTRODUCTION

A esthetic dental restorations have always been one of the major challenges in prosthetic and restorative dentistry[1]. Even when dentists request an adequate color for an indirect dental restoration, the result is not always satisfactory and there may be a significant difference in color, the cause of which is difficult to ascertain[2].

Despite the high acceptability and longevity of metal-ceramic, its aesthetics in anterior teeth are still a major challenge as a result of the underlying metal structure [3,4]. To camouflage the metal, a layer of opaque porcelain about 0.3 mm thick is applied[4], which affords masking ability due to its high metal oxide opacifier content.[5]

The most commonly used system for evaluating color change was established by CIE – *Commission Internacionale de E'clairage* in 1976[3]. The CIE color system considers the light transmitted or reflected from an object. Since the CIE 1931 diagram did not have visual uniformity, mathematicians changed the colors in order to facilitate color readings. This improved system, called CIEL*a*b* color space or CIELab[1] color space can be used to study color in dental materials.

Previous studies have established the influence of each metal-ceramic layer on color and determined the influence of the layering pattern on the final color of dental restorations, concluding that the thickness of the layers affects the final color of a dental restoration [5-7]. The opaque ceramic application method had also been studied, evaluating its bond strength and the final metal-ceramic color[8]. No visible differences have been found in the final porcelain color between application methods. Although many studies evaluate the effect of the thickness of different layers of opaque dentin on ceramic color, few studies show which thickness suffices to mask the underlying metal. The study of opaque layer thickness is clinically relevant because it influences the amount of tooth reduction necessary to make aesthetically appropriate metal-ceramic prostheses. The aim of this study is to evaluate whether there is a thickness lower than the recommended 0.3 mm which would have comparable masking ability, using a Ni-Cr (High Bond) metal alloy and Super-Porcelain EX-3 (Noritake) ceramic.

MATERIALS AND METHODS

Eighty circular wax discs 16 mm in diameter and 1.0 mm thick (Newwax, techNew) were obtained from a circular pattern and molded in phosphate-bonded investment (Heat Shock, Polidental). Ni-Cr discs (High Bond, Leona Indústria e Comércio de Materiais e LigasOdontológicas e Médicas Ltda.) were obtained from these molds. The discs were removed from the molds, cleaned and sandblasted with 200 µm aluminum oxide particles to remove the excess covering and the oxide layer produced by the casting. Discs were manually sanded on both sides using 200-grit water sandpaper until they formed flat, but not polished, surfaces. The discs were left in ultrasonic baths for 10 minutes with distilled water to remove debris and dried with paper towels. Using a diamond drill (1012 KG Sorenson), four marks were made on the side of the discs at 90 degrees from one another. Guided by these marks, a digital caliper (Mitutoyo, Digimatic Caliper) was used to measure disc thickness. The specimens were randomly divided into 8 groups (n=10) to be covered in one of two opaque types: G1, G2, G3 and G4 paste opaque (Noritake paste opaque, Noritake, Kizao CO.) and G5, G6, G7 and G8 powder opaque (Super Porcelain EX-3 Noritake Kizao CO.). Opaques were applied in the following thickness: G1 and G5 = 0.1 mm; G2 and G6 = 0.15 mm; G3 and G7 = 0.2 mm and G4 (control) and G8 = 0.3 mm. The discs were washed with distilled water in an ultrasonic bath and dried. Dentin opaque ceramic (Super Porcelain EX-3 Color A3 or Noritake Kizao CO.) was applied in two layers, totaling 0.7 mm thick altogether. After obtaining the adequate dentin thickness, the discs were glazed. All the sintering steps were done according to the manufacturer's recommendations. The color of the discs was measured with a portable spectro-colorimeter (Minolta CR-10) according to the CIEL*a*b* scale. The mean values of L*a*b* readings for G4 were used as control to calculate ΔE. Statistical analysis was performed on four variables (L*, a*, b* e ΔE), with two variation factors: opaque type (paste or powder) and opaque thickness (0.10 mm; 0.15 mm; 0.20 mm or 0.30 mm). All the variables fit the normal curve and homogeneity of errors. Under these circumstances, 2-way ANOVA was performed, followed by post-hoc Tukey´s test when needed, at 5% significance level.

RESULTS

Tables 1 to 3 show means and standard deviation (L*, a*, b* and ΔE respectively) and their grouping according to post-hoc Tukey's tests. For opaque type, Tables 1 to 4 show significant statistic differences for all variables. The (L*) and (ΔE) values in groups G5, G6, G7 and G8 were greater than in groups G1, G2, G3 and G4, the opposite being true for the other two variables.

Concerning opaque thickness, the tables show that the values can be grouped as follows, according to the complementary tests applied: variable (L*): (0.10mm = 0.15mm) < (0.20mm = 0.30mm); variable (a*):(0.10mm) < (0.15mm = 0.20mm) < (0.30mm); variable (b*): there was no statistically significant difference, variable (ΔE): (0.10mm) < (0.15mm = 0.20mm = 0.30mm). Since the behavior of the two opaque types was different in all cases, a complementary statistical analysis was performed (ANOVA with a single variation factor – thickness) to see how the variable (ΔE) behaved for each opaque type separately (Table 5). The means and standard deviation values used in this analysis are the same as those shown in Table 4.

Fig. 1 shows the respective curves for (ΔE) values according to opaque type and thickness.

DISCUSSION

The CIE-L*a*b* scale was used, which represents color in a three-dimensional space represented by axes L* (black-white axis), a* (green-red axis) and b* (blue-yellow axis). The distance between any two points on this scale, represented by ΔE, can be obtained from the formula $\Delta E = (((L^*1-L^*2)^2+(a^*1-a^*2)^2+(b^*1-b^*2)^2)^{0.5})$ [3,4,9].

The opaque type significantly influenced the color of metal-ceramics, since they presented significant differences for all variables tested (ΔE, L*, a* and b*). Although color perception is closely linked to variations in ΔE [2,3, 5,7,9-11] it is important to evaluate

Table 1. Means and standard deviation for L* values.

	Opaque thickness (mm)				
	0.1	0.15	0.2	0.3	Means
Paste	74.6(0.8)	75.2(0.6)	76.3(0.6)	75.6(1.0)	75.50 (α)
Powder	75.4(0.6)	75.8(0.9)	76.5(0.3)	76.9(0.4)	76.12 (β)
Means	75.00	75.49	76.39	76.2	
	(a)	(a)	(b)	(b)	

Groups with same letters were not statistically different. Lowercase represents grouping among opaque thickness while Greek letters represent grouping among opaque types.

Table 2. Means and standard deviation for a* values.

	Opaque thickness (mm)				
	0.1	0.15	0.2	0.3	Means
Paste	2.5 (0.2)	3.3 (0.4)	3.0 (0.3)	3.2 (0.2)	3.00 (α)
Powder	0.4 (0.3)	1.1 (0.3)	1.4 (0.3)	2.7 (0.1)	1.38 (β)
Means	1.45	2.16	2.21	2.93	
	(a)	(b)	(b)	(c)	

Groups with same letters were not statistically different. Lowercase represents grouping among opaque thickness while Greek letters represent grouping among opaque types.

Table 3. Means and standard deviation for b* values.

	Opaque thickness (mm)				
	0.1	0.15	0.2	0.3	Means
Paste	20.6 (0.6)	20.8(0.3)	19.7(0.6)	20.1(0.6)	20.26 (α)
Powder	18.4(0.7)	19.0(0.9)	19.3(0.8)	19.5(0.3)	19.05 (β)
Means	19.49	19.90	19.41	19.81	
	(a)	(a)	(a)	(a)	

Groups with same letters were not statistically different. Lowercase represents grouping among opaque thickness while Greek letters represent grouping among opaque types.

Table 4. Means and standard deviation for ΔE values.

	Opaque thickness (mm)				
	0.1	0.15	0.2	0.3	Means
Paste	1.6 (0.2)	1.0(0.4)	1.0(0.6)	1.0(0.6)	1.14 (α)
Powder	3.4(0.5)	2.7(0.5)	2.3(0.4)	1.5(0.3)	2.48 (β)
Means	2.49	1.83	1.64	1.25	
	(a)	(b)	(b)	(b)	

Groups with same letters were not statistically different. Lowercase represents grouping among opaque thickness while Greek letters represent grouping among opaque types.

Table 5. Grouping of ΔE values considering each opaque type separately.

	Opaque thickness (mm)				
	0.1	0.15	0.2	0.3	Control
Paste	A	B	B	B	B
Powder	∑	Ω	Ω	ψ	ψ

Groups with same letters were not statistically different. Capital letters represent grouping of ΔE varying thickness for paste opaque while Greek letters represent grouping of ΔE varying thickness for powder opaque.

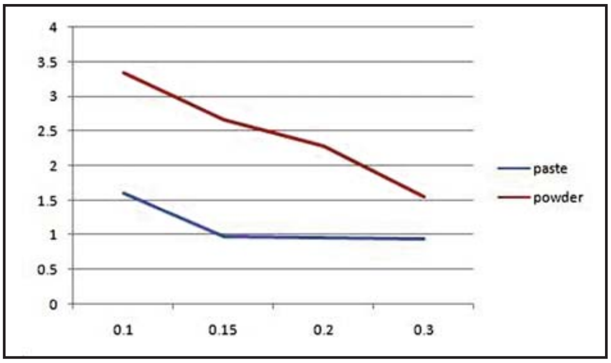

Fig. 1: ΔE values according opaque thickness.

the axes separately in order to understand which one contributed most to this color difference. The paste opaque was more uniform and easier to use than the powder opaque. Powder opaque tends to be more difficult to spread uniformly because of the presence of water, its surface tension and the contact angle between its surface and the metal. This may explain why paste is easier to apply, as well the differences found in all variables. Nevertheless, according to the intensity which each axis was affected, it is possible to say that the opaque type affects the "a*" axis more and the "L*" axis less, ($\Delta a^*=1.62$; $\Delta b^*=1.21$; $\Delta L^*=0.62$). The paste opaque presented greater redness and yellowness and was slightly less brilliant than the powder opaque. The presence of oxides tends to turn ceramic color green, and the lack of uniformity of powder opaque may lead to lower control of oxide formation, explaining this greater variation on the a* axis. Since the red color component is less present in teeth than the yellow component and variations in the red color are less tolerable than the yellow variations[2], the main variation on axis "a*" is a very important factor when choosing the opaque type to be used.

The ΔE values for paste are within the ΔE values considered little or not clinically noticeable (1 to 2), while the values for powder are within the limit of 2 to 3.3 ΔE units, considered perceptible, but clinically acceptable [9, 12-15]. A change in the referential (control group) could lead to a change in the order of this observation. The results of our study differ from Waddell and Swain,[8] who found no color difference according to the type of opaque used. This difference may be due to the opaque/ ceramic system used or to the fact that Waddel and Swain used discs without metal substrate as control. Thicker opaque layers increased the values of "L*", in contrast to other studies that used pure ceramic [16,17] or metal-ceramics [18], which stratified the dentin layer and not the opaque layer. Some studies found no (L*) variation from the opaque dentin layers [5, 7, 11]. The lack of agreement with these studies may be explained considering that the metal used in the substructure turns dark after oxidation, and smaller, or more irregular, opaque layers tend to favor light absorption by this oxidized metal. As the metal becomes adequately covered by the opaque, light absorption is expected to decrease until it is stable at a certain value of L*. On the other hand, the dentin layer can lead to greater light scattering and/or light absorption by the pigment oxide particles present in it [4, 16]. Variations in dentin and enamel thickness lead to variations in the final color of the ceramics and this was the reason why in this study it was chosen to add a simple opaque dentin layer 0.7 mm thick. Future studies can evaluate the effect of the opaque layer stratification in combination with stratification of the dentin and enamel layers to better understand the interference of these factors in the final color of metal-ceramic restorations. The variations in the values of a* represented a single axis where the values of 0.20 thickness differed from the values of 0.30 thickness. Generally the values of 0.30 thickness were more reddish than in 0.20 and 0.15 thicknesses; however, despite being statistically significant, this difference was in the order of 0.7 points, which constitutes color variation which is not noticeable *per se*. Although Douglas and Brewer[2] report major perception capacity of changes in the red color component, they claim that these changes in the red component are noticeable just above 1.1 points, which did not usually happen between the 0.15 and 0.30 thicknesses. The results show that the paste opaque was even more effective in this aspect, because the component (a*) variations were at most 0.3 points between the 0.15 and 0.30 thicknesses. To calculate the values of ΔE, the average values of opaque paste L*a*b* of "0.30" thickness were used, because it is considered an adequate thickness for metal-ceramic dental restorations and because it is easier to cover with this opaque. It is relevant that on all axes, the 0.10 thickness differed from the others and thus presented higher ΔE than the control group. Other authors report the inability of a 0.10 mm layer to mask non-noble metals [19] or metals with high palladium content [20,21], which is in agreement with our study. The observation that 0.20 mm opaque thickness is sufficient to mask the metal is consistent with previous findings [22], but differs from what the same author mentioned in another study, which found similarity only in the color [23]. In our study, however, statistically, even 0.15 mm thickness can be considered the same as 0.30 mm thickness. This statement is particularly true to the paste opaque, where it is possible to graphically observe the stabilization of the ΔE value in all the thickness from 0.15. This graphic observation confirms the statistic result that the color variations from one 0.15 mm paste opaque thickness derive from the inherent variations in the making process of the metal-ceramic dental restoration and not from the thickness variation in the opaque layer, which are all below the 1 point perceptible limit. In a specific analysis on paste opaque, it is noteworthy that although there is a statistically significant difference between the 0.10 thickness and the others, ΔE for this thickness is within the range of not clinically perceptible (ΔE "0.10" =1.6), which is even more significant when we consider the color variation inherent to the ceramic production process found in the other thickness (e.g.: ΔE "0.30" = 0.95). In "0.10" thickness, and for this opaque type, color was affected most by the "L*" and "a*" axes. Future studies can ascertain whether the 0.10 mm thickness can be clinically acceptable when compared to the 0.30 mm thickness and/or if the addition of pigments can improve it at this thickness. For the powder opaque, however, it should be observed that the values of ΔE for "0.30" thickness differ from the ΔE values for "0.20" and "0.15" thicknesses, which are both the same. The data axes analysis, in particular, shows that the axis which contributed the most to this variation was the "a*" axis. Future studies can help elucidate whether the addition of red pigments to the powder opaque would enable its application in layers thinner than 0.30 mm, such as 0.20 mm and 0.1 5 mm. Some studies noted that the kind of metal used may change the color values in the metal-ceramic final restoration [14-16] as well as in the color of the opaque layer [19, 21, 24, 25]. In this regard, our study has the limitation of having used only the Ni-Cr alloy, which was chosen because it is a type of alloy very often used in the Brazilian market due to its low price. The influence of opaque type used combined with the metal variations may be the subject of a future study. Furthermore, and taking into consideration the limitations of our study, only the opaque dentin color was used (A3), without adding enamel. This decision was taken because earlier observations showed that thicker ceramic layers provide less noticeable background color, in this case, from the opaque layer, which is why we did not use enamel ceramic [4, 16]. Another reason for not using more than one color or layering dentin/enamel was to simplify the statistic model. Other studies may be necessary to clarify whether the stratification of these layers allows the use of the thickness mentioned or whether the 0.10 mm thickness is feasible with the stratification of the upper layers.

Based on the experimental procedures performed and taking into consideration the limitations of this study, it is possible to conclude that:

a) There is a difference between the powder and paste opaque; the paste opaque provides more predictable results than the powder opaque;
b) The 0.10 mm thickness behaves differently from the other thickness, showing greater ΔE; the 0.10 mm thickness proved unsatisfactory for masking the metal substructure;
c) The ΔE for 0.15 mm thickness is statistically the same as the others, showing that it is sufficient to mask the metal used in both ceramic systems.

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