EFFECT OF THE FRAMEWORK MATERIAL ON THE FINAL COLOR OF ALL-CERAMIC RESTORATIONS

ABSTRACT

OBJECTIVES: to evaluate the effect of the type of ceramic framework material on the final color of all-ceramic restorations. The hypotheses tested were: (1) the final color of the restoration is different than the porcelain shade selected initially to veneer the framework and (2) different framework materials result in different colors of all-ceramic restorations. **METHODS**: Steel models simulating abutment teeth were used to design all-ceramic fixed partial dentures (FPDs). The FPDs were produced using three different framework materials (n=8): (YZ) yttria partially stabilized tetragonal zirconia polycrystal (LAVA, 3M); (IZ) glass-infiltrated alumina/zirconia (Vita In-Ceram Zirconia); (AL) polycrystalline alumina (Vita In-Ceram AL). Each framework was veneered with the recommended porcelain, VM9 for YZ and VM7 for IZ and AL groups (Vita). The porcelain shade used was 2M2. A uniform thickness of 1.2 mm of porcelain was applied around the retainers. The color difference (ΔE) and lightness difference (ΔL) between the selected porcelain shade (2M2) and the color of the final restoration were obtained using a clinical spectrophotometer (VITA Easyshade). Statistical analysis was performed using One-Way ANOVA and Tukey's test (α=0.05). **RESULTS**: The ΔE mean values, standard deviation and statistical ranking for the experimental groups were: (YZ) 2.38 ± 0.44b; (IZ) 2.92 ± 0.67ab; (AL) 3.43 ± 0.84a. AL group showed the highest ΔE and ΔL mean values. IZ showed an intermediate ΔE value and statistically similar to AL and YZ groups. There was no significant difference between ΔL values for YZ and IZ groups. **CONCLUSION**: Although the color difference between all experimental groups and the porcelain shade selected to veneer the restorations could be visually detected (ΔE>1.0), only AL showed a difference above the clinical threshold (ΔE>3.0). Thus, the first study hypothesis was partially accepted. In addition, the type of framework ceramic influenced the final restoration color, accepting the second study hypothesis.

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KEYWORDS

Color. Computed-aided design. Fixed partial denture. Ceramics.

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INTRODUCTION

The objective of the restorative procedure is to recover the function, the shape and the esthetics of the lost tooth structure. Therefore, not only the mechanical properties but also the optical behavior of restorative materials is an important factor to the success of the rehabilitation treatment. To fulfill people's desire for a good appearance the restorative material should mimic the color and translucency of the natural tooth. To achieve that, the professional must have a complete knowledge of the material's optical properties.

The development of high toughness ceramics improved the application of all-ceramic restorations. Ceramic materials with high crystalline content are stronger, however, highly opaque. Thus, these ceramics are indicated as a framework material and should be veneered with a glass-based ceramic (porcelain) that has superior optical properties, resulting in a bi-layered restoration [1, 2]. Although the ceramic framework material is opaque, the esthetics of the all-ceramic restoration is told to be superior to the esthetics achieved with metal-ceramic restorations. The final restoration has a more translucent and natural appearance than the metallic ones [3, 4]. In addition, ceramics have low thermal conductivity coefficient, preventing pulp aggression, and are biocompatible [1].

Different high toughness ceramics are available to produce dental restorations, showing different compositions and manufacturing processes [1, 5]. Thus, different optical properties are expected for these materials [3]. Among these systems are an yttrium partially stabilized tetragonal zirconia (YZ), an alumina-based zirconia reinforced glass-infiltrated ceramic (IZ), and a polycrystalline alumina (AL). YZ and AL ceramics are available as pre-sintered blocks for processing with CAD-CAM technology (computer aided design – computer aided manufactuirg). IZ is also available for CAD-CAM machining but as dry-pressed blocks that should be subsequently glass-infiltrated. These ceramic systems are indicated as framework materials for single and three-unit fixed partial dentures (FPDs) in anterior (AL) and posterior (YZ and IZ) areas of the mouth [1, 6].

A clinical challenge, when these bi-layered restorations are used, is the fact that the dentist chooses the shade of the porcelain layer without taking into consideration the shade of the framework material. Shade scales available for dental ceramic materials correspond only to the shade of the porcelain layer. As mentioned above, a series of high toughness ceramic are indicated as framework materials and their optical properties vary. Thus, the color initially selected by the dentist in the scale may not correspond to the color of the final restoration, as the framework material may interfere with the final color of the bi-layered structure [4, 7, 8].

Even though the human being is capable of detecting small color variations between two objects, color identification is still a major challenge since it is highly subjective. A series of conditions might affect the color perception, such as the type of light source, surface conditions, the observer position, size differences and the background. Thus, colorimeters and spectrophotometers were developed to perform more objective color identification [7,9]. Vita Easyshade is a spectrophotometer used by dentist and laboratories with the objective of assisting the restorations color selection [10]. With this equipment it is possible to identify the color in the Vita Classical and Vita 3D Master scales, and also to obtain L*a*b coordinates. L*a*b coordinates belong to the CIELAB color system that was developed in 1976 and is usually used in Dentistry. In this color space, color is described by three coordinates: L* indicates lightness; a* indicates chromaticity (green to red); b* indicates chromaticity (blue to yellow) [11]. The perception of color mismatch depends on ΔE values, which represent the difference between two colors through the following formula [12]:

$$\Delta E = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}.$$

Thus, considering the importance of the esthetics for the clinical success and the obstacles that involve the perfect restoration color match, the objective of this study was to evaluate the effect of the type of ceramic framework material on the final color of all-ceramic restorations. The hypotheses tested were: (1) the final color of the restoration is different than the porcelain shade selected initially to veneer the framework and (2) different framework materials result in different colors of all-ceramic restorations.

MATERIAL AND METHODS

The restorations were produced using three different framework materials as described in Table 1 (n=8).

A stainless steel model simulating prepared abutment teeth was constructed. The prepared die has 4.5 mm height, 6° of taper and 120° chamfer as finish line, as proposed by Sundh et al. [13] (2005). The distance between the centers of the dies was 16 mm, corresponding to the distance between a lower second premolar and a lower second molar (span of 10 mm). An artificial gingiva was produced with acrylic resin (JET, Classico, Sao Paulo, SP, Brazil). A polyvinyl siloxane impression of the model was taken (AquasilTM, Dentsply, Petropolis, RJ, Brazil) using the double impression technique. A working cast was made using type IV special CAD/CAM stone (CAM-base, Dentona AG, Dortmund, Germany).

AL and IZ frameworks were produced using CEREC inLab CAD-CAM system (Sirona Dental Systems, Charlote, NC, USA). The stone cast was digitized by the internal laser scanner component of CEREC inLab unit to generate a tridimensional image that was used to design the FPDs frameworks. After the milling process, AL frameworks were sintered using the Zyrcomat furnace (Vita Zahnfabrik, Bad Sackingen, Germany) and IZ frameworks were glass infiltrated using the Inceramat 3 furnace (Vita Zahnfabrik, Bad Sackingen, Germany). The glass infiltration cycle was performed at 1110°C for 6 hours, according to the manufacturer's instruction. The excess glass (Zirconia Glass Powder, Vita Zahnfabrik, Germany) was removed with air-borne particle abrasion using 50 µm aluminum oxide particles. Only the external surface of the FPDs was air abraded.

Table 1: Materials identification.

Groups	Framework material	Basic composition	Porcelain*
YZ	LAVA Zirconia Frame**	yttria partially stabilized tetragonal zirconia polycrystal	Vita VM9
IZ	Vita In-Ceram Zirconia*	glass infiltrated zirconia-reinforced alumina-based ceramic	Vita VM7
AL	Vita In-Ceram AL*	polycrystalline alumina	Vita VM7

* Vita Zahnfabrik, Bad Sackingen, Germany; **3M ESPE, St. Paul, MN, USA.

YZ frameworks were produced by LAVA™ CAD-CAM system (3M ESPE, St. Paul, MN, USA). The stone cast was digitized and the FPD framework was designed by LAVA™ Scan ST Design System (3M ESPE, St. Paul, MN, USA). Frameworks were milled with LAVA™ CNC 500 Milling Machine using LAVA Zirconia Frame material (Y-TZP - 3M ESPE, St. Paul, MN, USA). The frameworks were sintered using LAVA™ Furnace 200 (3M ESPE, St. Paul, MN, USA).

The frameworks were veneered with the manufacturer recommended porcelain: VM9 for YZ, and VM7 for AL and IZ (Figure 1). Keramat I furnace (Knebel, Porto Alegre, Brazil) was used to perform the porcelain sintering. Before veneering, a bonding agent (Effect Bonder, Vita Zahnfabrik, Bad Sackingen, Germany) was applied on the YZ framework and sintered according to the manufacturer instructions. Three porcelain applications were performed and a polishing bur was used to obtain a uniform thickness of, approximately, 1.2 mm around the crowns and pontic and 0.6 mm around the connectors. The porcelain thickness was measured in six different points as proposed by Sundh et al. (2005) [13].

Finally, all FPDs were subjected to a glaze cycle using Keramat I furnace at 900°C for 1 min with a rate of 80°C/min and slow cooling (~6 min). The same porcelain shade was used to veneer all

FPDs, shade 2M2. The framework and final restoration for each experimental group are shown in Figure 2.

Vita Easyshade spectrophotometer (Vita Zahnfabrik, Bad Sackingen, Germany) was used to identify the restorations shade. The spectrophotometer probe was placed in the center of the crown (vestibular area) using a silicon device to standardize the angle between the extremity of the probe and the restoration surface. Then, the equipment was activated to measure the color. A white background was used to perform the color evaluation.

The "restoration mode" of the Easyshade menu was used to calculate the color difference (ΔE) and lightness difference (ΔL) between the selected porcelain shade (2M2) and the color of the final restoration.

Statistical analysis was performed using One-Way ANOVA and Tukey's test (α=0.05).

RESULTS

The mean and standard deviation values for color difference (ΔE) and lightness difference (ΔL) between the porcelain shade (2M2) and the color of the final restoration, for each experimental group, are described in Table 2.

For AL group, the mean ΔE value was higher and significantly different than the value observed for YZ. IZ showed an intermediate ΔE mean value and statistically similar to AL and YZ groups. AL group showed the highest ΔL mean values. There was no significant difference between ΔL mean values for YZ and IZ groups.

Table 2: Mean and standard deviation (SD) values for color difference (ΔE) and lightness difference (ΔL) between the porcelain shade (2M2) and the color of the final restoration, for each experimental group.

Groups	ΔE		ΔL	
	Mean	SD	Mean	SD
YZ	2.38[b]	0.44	-0.36[b]	0.16
IZ	2.92[ab]	0.67	-0.84[b]	0.23
AL	3.43[a]	0.84	2.80[a]	0.57

*Values followed by similar letters in the same column are statistically similar (p>0.05)

Figure 1: Framework ceramic before and after veneering with porcelain.

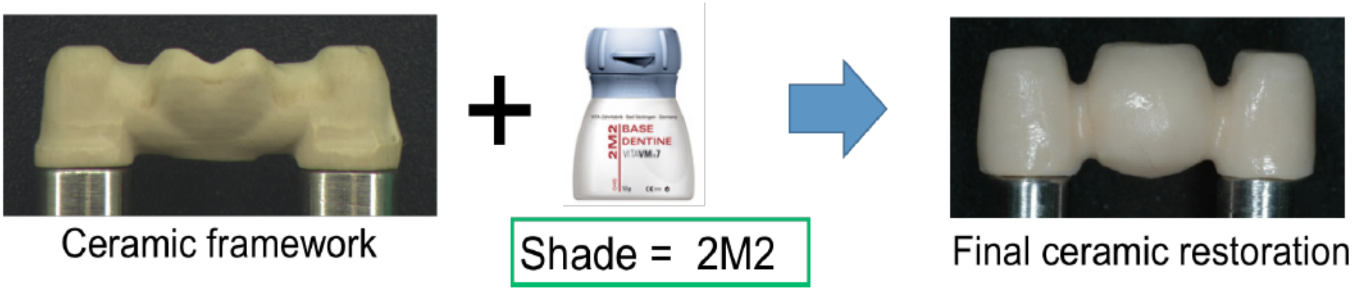
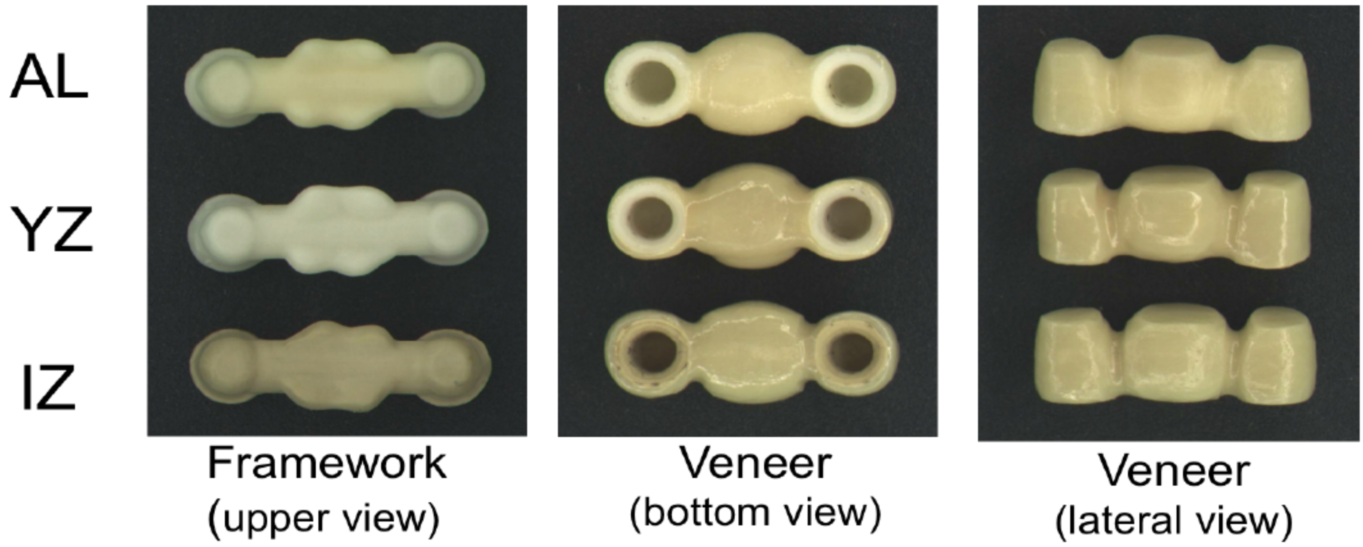


Figure 2: Upper view of the three types of framework ceramics; bottom and lateral view of the restorations after veneering.



DISCUSSION

To suggest that a color difference between two objects is clinically perceptible a ΔE value of reference should be chosen. However, there is not a consensus in the literature regarding the ΔE value that corresponds to the threshold in which the human eye starts to detect a color difference between two materials[14]. Kuehni and Marcus (1979)[15] reported that a ΔE value smaller than 1 represents a color mismatch that was not perceptible for most people with normal color vision. Other studies showed that restorations with a ΔE varying from 2.7 to 3.3 may have a perceptible color mismatch, however this difference can be considered clinically acceptable[16-18]. In the present study, a ΔE value of 3.0 was chosen as a clinical threshold. Thus, the first study hypothesis was partially accepted as for AL material the final color of the restoration was clinically different than the porcelain shade selected initially to veneer the framework. AL showed a color mismatch slightly above the proposed clinical threshold

(ΔE>3.0), suggesting a visible mismatch that could compromise the restorative treatment.

On the other hand, although the ΔE values observed for YZ and IZ groups were higher than 1.0, which is considered a perceptible color change to most subjects[15], these ΔE values were within the proposed threshold (ΔE<3.0) for clinical acceptability. Thus, these ceramics may be chosen as framework for all-ceramic restorations without compromising the final shade desired by the dentist.

Significant differences of ΔE and ΔL mean values between the experimental groups were observed. Therefore, the type of framework ceramic influenced the final color of the restoration, accepting the second study hypothesis. The framework materials IZ and YZ presented similar ΔE and ΔL mean values, which means that both materials have a similar optical behavior after veneering. AL showed the highest ΔL mean value, indicating that this framework material produced whiter restorations. The color and lightness differences between the three types of framework materials can be observed in Figure 2, before and after veneering with porcelain.

The optical properties of dental ceramics are directly related to the type of microstructure and processing. The crystalline content, their chemical nature, the size of the particles, and the presence or absence of an amorphous phase influence the way light interacts with the structure[1,3,7,19]. The veneering ceramic (porcelain) is a glass-based material with superior optical properties and high translucency[3]. In the present study, although the porcelain shade was the same, there were minor differences in the composition of the two types of porcelain used to veneer the framework materials. VM7 porcelain has a microstructure constituted only by a glass phase. On the other hand, VM9 porcelain shows a glass matrix reinforced with leucite crystals[5]. However, as the refraction index of the leucite crystal is similar to the amorphous matrix, the interference of the leucite particle in the light transmission through the porcelain is almost non-existent[20]. Thus, differences in the optical behavior found between experimental groups may not be attributed to differences in the composition of the porcelain.

The optical behavior of the prosthetic restorations may be partially explained by differences in the composition of the framework material. YZ and AL ceramics have high crystalline content and very low porosity (0.1-0.2%)[5]. Both ceramics are polycrystalline, however, AL ceramic is a more translucent material than zirconia-based ceramics[3,7,21]. This is probably due to differences in the chemical nature, particle size and refractive indices[3]. IZ ceramic presents two types of crystals (alumina and zirconia) and a glass phase (lanthanum oxide-based glass)[5]. The fact that IZ is composed by three distinct phases affects its optical properties. In addition, a study reported that zirconia-based all-ceramic layered structures (framework/veneer) show an optical behavior similar to the one observed for metal-ceramic specimens[4]. In the present study, there was no control group, thus it is not possible to determine if the ceramic systems evaluated show similar or different optical behavior compared to metal-ceramic restorations. However, both zirconia-based ceramics were able to produce restorations with a color mismatch that was not significant, which was not true for the alumina-based ceramic.

The optical properties are also dependent on factors related to processing such as the porosity, superficial cracks and the structure thickness[7,8,22]. As the thickness increases more difficult is the light transmission, due to a larger scatter inside the material, which results in restorations with inferior optical quality[23]. Thus, a framework ceramic with high crystalline content could show the same opacity as a framework with low crystalline content, as long as the last one is thicker[24]. In the present study, the thickness of the framework material and the porcelain veneer were standardized for all experimental groups and corresponded to the thickness recommended for clinical application. An important factor related to the porcelain processing is the presence of porosity because pores can act as centers of light scatter, resulting in an opaque material[22]. As all restorations from the present investigation were veneered with the same technique by one researcher, a similar degree of porosity and superficial finishing may be expected for all specimens. Thus, no influence of different thickness or different porcelain processing should be expected for the present investigation.

It is important to emphasize the fact that a multi-layered restoration is a complex structure. Differences between the refraction index of the materials result in light scattering[7]. A study reported that the opacity of the framework material increased after they were veneered with porcelain. The authors believe that this change in the optical behavior may be related to factors such as the increased specimen thickness, reflectance at the interface between materials, porosity between the layers and changes in the framework material with additional firing cycles[4]. The combination of an opaque framework material and the translucent porcelain may be a challenge when a natural color tooth will be restored. On the other hand, this multi-layered structure may be a solution for darkened tooth or metallic root retainers, since the opaque ceramic could mask the dark background. Studies reported adequate masking capability when framework ceramics such as litium dissilicate[25], polycrystalline alumina[26] and In-Ceram Zirconia[3,7] were used to produce all-ceramic restorations.

The present study shows that the color initially desired by the dentist may be compromised by the type of framework material chosen to produce the all-ceramic restoration. However, a series of other tools are available for the dentist and laboratory to control the esthetic outcome of all-ceramic restorations such as the use of appropriate porcelain layering technique and an adequate selection of the resin cement shade. In addition, for the ceramic system In-Ceram the manufacturer also provides different glass shades as an alternative to control the influence of the framework color in the final restoration[8]. Thus, the success of the restorative procedure could be guaranteed by a complete knowledge of the factors that influence the optical behavior of the materials and by a good communication between dentist and laboratory.

CONCLUSION

The color difference between all experimental groups and the porcelain shade selected to veneer the restorations could be visually detected (ΔE>1.0). However, only AL material showed a difference above the clinical threshold (ΔE>3.0). Thus, the first study hypothesis was partially accepted.

In addition, the different types of framework ceramics evaluated resulted in different colors of all-ceramic restorations, accepting the second study hypothesis.

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REFERENCES

1. Della Bona A. Bonding to ceramics: scientific evidences for clinical dentistry. . 1 ed. São Paulo: Artes Médicas; 2009.

2. Borba M, de Araujo MD, de Lima E, Yoshimura HN, Cesar PF, Griggs JA, et al. Flexural strength and failure modes of layered ceramic structures. Dent Mater. 2011 Dec;27(12):1259-66.

3. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent. 2002 Jul;88(1):4-9.

4. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. J Prosthet Dent. 2002 Jul;88(1):10-5.

5. Borba M, de Araujo MD, Fukushima KA, Yoshimura HN, Cesar PF, Griggs JA, et al. Effect of the microstructure on the lifetime of dental ceramics. Dent Mater. 2011 Apr 30;27:710-21.

6. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc. 2008 Sep;139 Suppl:8S-13S.

7. Pinto MM. Propriedades ópticas e microestrutura de materiais cerâmicos de restauração dentária São Paulo: Universidade de São Paulo; 2009.

8. Charisis D, Koutayas SO, Kamposiora P, Doukoudakis A. Spectrophotometric evaluation of the influence of different backgrounds on the color of glass-infiltrated ceramic veneers. Eur J Esthet Dent. 2006 Aug;1(2): 142-56.

9. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: three distinct observer populations and shade matching protocols. Dent Mater. 2009 Feb;25(2):276-81.

10. VITA. VITA Easyshade: manual de instruções. In: VITA, editor. Bad Säckingen, Alemanha: H. Rauter GmbH & Co. KG Postfach; 2006.

11. Colorimetry: official recommendations of the International Comission on Illumination., E-1.3.1 (1976).

12. Cheng HD, Jiang XH, Sun Y, Wang JL. Color image segmentation: advances and prospects. Pattern Recognition. 2001;34(12):2259-81.

13. Sundh A, Molin M, Sjogren G. Fracture resistance of yttrium oxide partially-stabilized zirconia all-ceramic bridges after veneering and mechanical fatigue testing. Dent Mater. 2005 May;21(5):476-82.

14. Azer SS, Ayash GM, Johnston WM, Khalil MF, Rosenstiel SF. Effect of esthetic core shades on the final color of IPS Empress all-ceramic crowns. J Prosthet Dent. 2006 Dec;96(6):397-401.

15. Kuehni RG, Marcus RT. An experiment in visual scaling of small color differences. . Color Res Appl. 1979;4:83-91.

16. Chu FC, Chow TW, Chai J. Contrast ratios and masking ability of three types of ceramic veneers. J Prosthet Dent. 2007 Nov;98(5):359-64.

17. Ragain JR, Johnston WM. Color acceptance of direct dental restorative materials by human observers. Color Res Appl. 2000;25(4):278-85.

18. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater. 1987 Oct;3(5):246-51.

19. Callister Jr WD. Ciência e Engenharia de Materiais: Uma Introdução. 5 ed. Rio de Janeiro: LTC - Livros Técnicos e Científicos Editora S.A.; 2002.

20. Lee HH, Kon M, Asaoka K. Influence of modification of Na2O in a glass matrix on the strength of leucite-containing porcelains. Dent Mater J. 1997 Dec;16(2): 134-43.

21. Chen YM, Smales RJ, Yip KHK, Sung WJ. Translucency and biaxial flexural strength of four ceramic core materials. Dent Mater. 2008;24:1506-11.

22. Zhang Y, Griggs JA, Benham AW. Influence of powder/liquid mixing ratio on porosity and translucency of dental porcelains. J Prosthet Dent. 2004;91:128-35.

23. Antonson SA, Anusavice KJ. Contrast ratio of veneering and core ceramics as a function of thickness. Int J Prosthodont. 2001;14(4):316-20.

24. Brodbelt RH, O'Brien WJ, Fan PL. Translucency of dental porcelains. J Dent Res. 1980;59(1):70-5.

25. Volpato CA, Monteiro SJ, de Andrada MC, Fredel MC, Petter CO. Optical influence of the type of illuminant,

substrates and thickness of ceramic materials. Dent Mater. 2009;25(1):87-93.

26. Koutayas SO, Kakaboura A, Hussein A, Strub JR. Colorimetric evaluation of the influence of five different restorative materials on the color of veneered densely sintered alumina. J Esthet Restor Dent. 2003;15(6): 353-60.