Influence of different surface finishing techniques on machinable feldspathic and leucite-reinforced ceramics

Fehmi GÖNÜLDAŞ¹, Caner ÖZTÜRK², Pelin ATALAY¹ and Derya ÖZTAŞ¹

¹Department of Prosthodontics, Ankara University Faculty of Dentistry, İncitaş Street 06560 Ankara, Turkey

²Department of Prosthodontics, Mustafa Kemal University Faculty of Dentistry, Tayfur Sökmen Campus 31060 Hatay, Turkey

Corresponding author, Caner ÖZTÜRK; E-mail: caner_ozturk86@hotmail.com

The effect of surface finishing techniques on machinable ceramics to obtain optimum smoothness is unclear. The aim of the study was to evaluate the effects of surface finishing techniques on machinable feldspathic and leucite-reinforced ceramics. Forty specimens were divided into four subgroups according to surface finishing techniques and ceramic structure. A profilometer was used to evaluate surface roughness. A spectrophotometer was used to obtain the CIE L^* , a^* and b^* coordinates. All specimens were subjected to a three-point bending test to determine flexural strength. All data were analyzed with two-way ANOVA and Tukey's HSD tests ($p < 0.05$). Polishing techniques were found to be more effective than the glazing method to obtain smooth surfaces. Glazing technique increased the flexural strength of leucite-reinforced ceramics. Finishing procedures have different effects on the success of the restorations and must be considered by the clinicians.

Keywords: CAD/CAM, Flexural strength, Machinable ceramics, Surface roughness, Translucency

INTRODUCTION

Recently, all-ceramic restorations, including a large variety of glass-ceramics and polycrystalline ceramics, have been used in dentistry owing to their superior properties such as high flexural strength, biocompatibility and esthetics^{1,2}. Over the last two decades, with the development of CAD/CAM technology, chair-side dentistry has gained popularity and CAD/CAM fabricated all-ceramic restorations have been used instead of exhausting and time-consuming traditional techniques. CAD/CAM technology also allows clinicians to present complex forms of ceramic restorations such as inlays and onlays from the simply formed ceramic blocks³.

CAD/CAM fabricated all-ceramic restorations should offer superior mechanical, biological and aesthetic attributes to ensure long term success in oral conditions⁴. These materials must be resistant to the tension, pressure and wear induced by the recurrent forces of chewing and should also have smooth surfaces for the patient's comfort and periodontal health^{5,6}. Moreover, these materials should have high translucency, which is described as a basic criterion for the esthetic outcome^{4,6}. Therefore, surface roughness, flexural strength and translucency can be noted as the major factors for the long-term success of the restorations.

CAD/CAM systems use abrasive burs for production procedures, which may result in decreasing the strength and smoothness of ceramics. It is stated that rough surfaces may encourage plaque accumulation⁷, so periodontal problems, dental caries and loss of esthetic quality may occur as a result of bacterial efficiency and the host reaction. Smoothness of the restoration is also important to improve the color and esthetic aspect of the restorations and ensure a bright surface

which has reflection properties like natural teeth^{8,9}. Additionally, roughness of the restorations can cause stress concentrations and reduce the strength of the restoration¹⁰. A bright surface is also essential for reducing the wear of the opposing teeth and increasing the survival rate of the restorations and the longevity of the restored teeth⁵. Thus, ultimate finishing procedures are essential and major factors for the biological, esthetical and biomechanical success of CAD/CAM fabricated restorations.

Although many chair-side CAD/CAM glass-ceramic restorations are usually finished with glaze firing, two chair-side CAD/CAM materials can be completed in a single visit without a firing process by using manual polishing techniques¹¹. Leucite-reinforced glass ceramic blocks in which the leucite crystals (KAlSi_2O_6) have been formed in a controlled process, and fine grained feldspathic ceramic blocks are presented for chair-side CAD/CAM restorations, and these blocks can be polished manually or glazed. The finishing techniques to obtain a smooth surface with a glazing layer have been investigated in various studies¹²⁻¹⁴. Several reports supported the use of polishing as an alternative to glazing for ceramic restorations^{7,9}. However, little information is available about how to produce smooth, strong and esthetic restorations with different finishing methods, and all current studies have analyzed the dental materials in a high gloss polished condition¹⁵⁻¹⁷.

The aim of this study was to evaluate the effects of different surface finishing techniques on machinable feldspathic and leucite-reinforced ceramics. The first null hypothesis of the study was that finishing techniques have no effect on the surface roughness of machinable ceramics. The second null hypothesis of the study was that finishing techniques have no effect on the flexural strength of machinable ceramics, and the third null

hypothesis was that finishing techniques have no effect on the translucency of machinable ceramics.

MATERIALS AND METHODS

The set-up of the study was presented in Fig. 1. In the present study, two different structural all-ceramic materials were used (CEREC® Blocs C, Sirona Dental Systems, Salzburg, Austria; IPS Empress CAD® blocks, Ivoclar Vivadent, Schaan, Liechtenstein, Table 1). Twenty specimens of machinable feldspathic blocks and 20 specimens of machinable leucite-reinforced glass-ceramic blocks were prepared using a diamond slicer (Micracut 201, Metkon Metallography, Bursa, Turkey) under wet conditions. The specimens were then ground under cooling water with 400, 600, 800 and 1000-grit silicon carbide abrasive paper, respectively, for 30 s to standardize the surfaces of the specimens and then cleaned for 10 min using an ultrasonic cleaner. All specimens were assigned to four subgroups according to surface finishing techniques as manufacturers' recommendations. Ten specimens of machinable leucite-reinforced glass-ceramic were polished manually with a ceramic polishing system (Optrafine®, Ivoclar Vivadent) and called Leucite-reinforced-Polished (LP). The other 10 specimens of machinable leucite-reinforced glass-

ceramic were glazed using glaze liquid (IPS Empress Universal Glaze Liquid, Ivoclar Vivadent), and firing was conducted in a compatible ceramic furnace according to the manufacturer's recommendation and called Leucite-reinforced-Glazed (LG). Ten specimens of machinable feldspathic blocks were polished manually with diamond finishing burs (8 µm) and flexible discs coated with Al₂O₃, polishing brushes and diamond polishing paste, and called Feldspathic-Polished (FP). The other 10 specimens of machinable feldspathic blocks were glazed with a glazing paste (Vita Akzent, VITA Zahnfabrik H. Rauter, Säckingen, Germany) according to the manufacturer's recommendation and called Feldspathic-Glazed (FG). Final dimensions of rectangular specimens were 14 mm length, 12 mm width, and 1±0.05 mm-thickness. The dimensions of all specimens were measured using a digital micrometer (Digital Micrometer IP65, Mitutoyo Europe, Neuss, Germany). Subsequently, all specimens were cleaned ultrasonically in distilled water for 10 min.

Translucency

A spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik H. Rauter) with "Tooth Single" mode was used to record the CIE L^* , a^* and b^* coordinates of each specimen. The spectrophotometer was calibrated before each measurement. Three measurements were

Fig. 1 Schematic set-up of the study.

Table 1 Overview of the experimental groups

Material	Type of Material	Manufacturer	Batch number	Composition ^a
EREC® Blocs C	Feldspathic ceramic	Sirona Dental Systems	45460	SiO ₂ , Al ₂ O ₃ Na ₂ O K ₂ O, CaO, TiO ₂
IPS Empress CAD®	Leucite glass-ceramic	Ivoclar Vivadent	U10309	SiO ₂ , Al ₂ O ₃ , K ₂ O Na ₂ O, Other oxides, Pigments

^a Information as provided by the manufacturers

taken at the center of all specimens placed on both the white (W) and black (B) backgrounds and the mean values were recorded. The Translucency Parameters (TP) were calculated using the following formula:

$$TP: ((L_b - L_w)^2 + (a_b - a_w)^2 + (b_b - b_w)^2)^{1/2}.$$

Subscript “b” refers to the color coordinates over the black background ($L_b^*=1.38$, $a_b^*=0.00$, $b_b^*=0.06$) and the subscript “w” refers to those over the white background ($L_w^*=94.44$, $a_w^*=0.26$, $b_w^*=1.69$).

Surface roughness

Surface roughness values (Ra), were measured with a profilometer (Perthometer M2, Mahr, Göttingen, Germany). The profilometer was calibrated before measurements for each group. All profilometer measurements were collected from three different lines which passed through the center each specimen. Three measurements for each line were determined over a transverse length of $L_t=5.600$ mm, with a cutoff value of 0.8 mm and a stylus speed of 0.5 mm/s. The mean values were calculated to determine the overall surface properties of the samples.

Flexural strength

All specimens were subjected to a three-point-bending test using a universal testing machine (Lloyd Instruments, LRX, Lloyd Inst., Hampshire, United Kingdom). Samples were placed on a metal fixture with a 10 mm support distance and centered under a loading rod which was 2 mm in diameter. The test was performed at a crosshead speed of 1 mm/min. Each specimen was loaded to failure, and the flexural strength was calculated according to the following formula:

$$\sigma = 3NI/2bd^2$$

σ : flexural strength

N: fracture load (N)

l: distance between supports (mm)

b: width of the specimen (mm)

d: thickness of the specimen (mm)

Weibull analysis

Weibull analysis was carried on the flexural strength data to obtain Weibull modulus and characteristic strength. Weibull distribution was determined using the following formula:

$$P_{\text{uff}} = 1 - \exp\left[-\left(\frac{\sigma}{\sigma_0}\right)^m\right]$$

(Pf: fracture probability, σ : flexural strength, σ_0 : characteristic strength at fracture probability of 63.21%, and m: Weibull modulus which is equal to the slope of the $\ln(\ln[1/(1-P_f)])$ versus $\ln \sigma$ plots).

Statistical analysis

All data were evaluated by Saphiro-Wilks test for normality and the homogeneity of the variances were evaluated with Levene's test. The two-way ANOVA and Tukey's HSD *post hoc* multiple comparison tests ($p < 0.05$) were performed using a software program (SPSS version 20, IBM, Armonk, NY, USA).

RESULTS

The two-way ANOVA analysis indicated that finishing technique were found to be significant for surface roughness. Finishing technique, material type and interaction between these factors were found to be significant for flexural strength, and material type was found to be significant for translucency parameters ($p < 0.05$).

According to the results of the Tukey's HSD *post hoc* test, the specimens treated with polishing techniques showed significantly lower Ra values than the specimens treated with glazing techniques ($p < 0.05$). Group FP showed the least surface roughness and group FG showed the highest surface roughness values. Differences between group LG and FG and between groups LP and FP were not statistically significant ($p < 0.05$, Fig. 2).

Fig. 2 Mean values, standard deviations of surface roughness and 95% confidence interval for mean values of each group. Different superscripted letters indicate significant differences ($p < 0.05$).

Fig. 3 Mean values, standard deviations of translucency parameters and 95% confidence interval for mean values of each group. Different superscripted letters indicate significant differences ($p < 0.05$).

Table 2 Mean and standard deviations of Flexural strength values (MPa), Weibull modulus, Characteristic Strength and 95% Confidence Interval for mean values of groups

Groups	Flexural strength (Mpa)	Weibull modulus (m)	Characteristic strength (MPa)	95% Confidence interval
LP	82.83 (± 23.51) ^b	4.69	90.29	14.57
LG	152.87 (± 14.50) ^a	5.50	164.71	8.99
FP	77.42 (± 12.07) ^b	5.77	83.12	7.48
FG	67.98 (± 10.21) ^b	5.63	73.17	6.33

Different superscript letters in the same column indicate statistically significant difference ($p < 0.05$).

Fig. 4 Weibull analysis plot for groups.

Leucite-reinforced ceramics showed higher translucency than feldspathic ceramics regardless of surface finishing techniques. LP showed significantly higher translucency values than FP and FG ($p < 0.05$). LP showed higher translucency values than LG, but these differences were not statistically significant. FG showed significantly lower translucency values than the other groups ($p < 0.05$, Fig. 3).

The results of the three-point bending test revealed that group LG showed significantly higher flexural strength (MPa) values than the other groups ($p < 0.05$). Differences between group LP, FP and FG were not statistically significant (Table. 2). Weibull analysis of the three-point flexural strength data yielded Weibull modulus values ranging from 4.69 to 5.7. The highest Weibull modulus was obtained with group FP and the lowest modulus value was determined in group LP. Characteristic strength values were in the same order found in three-point flexural strength results. The highest and lowest characteristic strength values were detected in group LG and FG, respectively (Table 2). Weibull analysis plot was presented in Fig. 4.

DISCUSSION

In this study, the investigated surface finishing

techniques have different effect on the surface roughness of the machinable ceramics, but translucency parameters of the ceramics were not influenced by the finishing techniques. Flexural strength of the feldspathic ceramic was similar for both polished and glazed groups. On the other hand, glazing increased the strength of the leucite reinforced ceramics. The first null hypothesis of the study, that finishing techniques have no effect on the surface roughness of the machinable ceramics, was rejected. According to the results of the study, smoother surfaces were obtained with the polishing technique. The smoothing mechanism of polishing and glazing differ from each other. The ability of polishing to eliminate various defects and flaws from the treated surface is considered responsible for creating uniform particles and decreasing roughness. The glaze layer which results from application of a low fusing glass overcoat, fills microcracks, covers the porosities on the porcelain and decreases the depth and sharpness of the cracks on the surface¹⁰. Previous studies that investigated surface roughness of dental ceramics showed that smooth surfaces similar to glazed surfaces could be obtained with the polishing technique^{13,18-20}. In this study, parallel to the previous studies, it was observed that the polishing technique created more smooth surfaces than glazing techniques. These differences can be attributed to the

ability of the finishing techniques to reduce depth and/or sharpness of critical flaws, regardless of material type. According to result of the study, it can be concluded that polishing kits and disc systems had better effects on the surface roughness of ceramics compared to glazing, and polishing techniques can be used to obtain a satisfactory smoothness of surfaces comparing with glazing methods.

Various techniques have been used to quantify surface roughness using Ra values, the most common being a tactile profilometer⁸⁾. This parameter can be defined as whole surface roughness, and the arithmetical average value of all absolute distances of the roughness profile from the center line within the measuring length⁸⁾. Many studies can be found in the literature that evaluated surface roughness using Ra^{19–21)}. Therefore, a tactile profilometer was used to determine the surface roughness in this study.

The second null hypothesis of the study, that finishing techniques have no effect on the flexural strength of machinable ceramics, was partially rejected. According to the results of this study, flexural strength of leucite-reinforced ceramics varied depending on surface finishing procedures. In addition, the flexural strength of feldspathic ceramics was not affected by the finishing technique. Flexural strength of polished leucite reinforced ceramics was similar both for polished and glazed feldspathic ceramics. Awada and Nathanson²²⁾ reported that the resilience modulus of machinable feldspathic blocks (Vita Mark II) and machinable leucite-reinforced glass ceramic blocks (Empress CAD) were not significantly different. More homogeneous materials with increased fracture toughness could be produced by the CAD/CAM systems, but the machining process accumulates residual stresses on the ceramic components, and these stresses cause different failures. On the other hand, it is believed that thin compressive stresses on the surface of the ceramic that increased the strength could be achieved with the machining procedure. Glazing and polishing are believed to increase the strength because they decrease the stress concentration and depth of the cracks on the surface²³⁾. Moreover, the compressive surface stresses that occur on the compression layer formed during polishing also strengthen the ceramics. However, the strengthening effect of glazing on porcelain is uncertain²³⁾. Leucite-reinforced glass ceramics consist of different phases (glassy and crystalline) and these phases behave differently during heat treatment procedures. Therefore, it is essential to obtain thermal balance between phases for structural stability during the heat treatment procedures. Many studies showed that glazing did not increase the biaxial flexural strength of the ceramics^{10,24,25)}. Fraga, *et al.*²⁶⁾ concluded that glaze firing for machinable leucite-reinforced glass-ceramic blocks (Empress CAD) reduced the strength characteristics and suggested that alteration of the material microstructure and the growth of micro cracks and residual stress occur due to the large mismatch in coefficients of thermal expansion between the leucite crystals and the glass matrix. According to

the results of the study, glazing technique increased the flexural strength of machinable leucite-reinforced glass ceramic. Parallel to our study, Aurélio, *et al.*²⁷⁾ concluded that extended glaze firings increased the flexural strength of leucite-reinforced ceramics. This result could be related to obtain favorable stress concentration, reduce surface roughness, maintain thermal balance between the phases and shaping the crack formation on the ceramic surface by glazing techniques.

The third null hypothesis of the study, that finishing techniques have no effect on the translucency of machinable ceramics, was partially rejected. Translucency of feldspathic ceramics differs due to surface finishing procedures. Furthermore, translucency of leucite reinforced ceramics was similar for both polishing and glazing technique. Leucite reinforced ceramics in glazed conditions showed the highest translucency values. The results of this study suggested that different types of ceramics present different translucency parameters. Although conventional feldspathic ceramics are considered to be the most translucent system, according to the findings of the present study machinable leucite-reinforced glass-ceramic (IPS Empress CAD[®] blocks) showed higher translucency than machinable feldspathic blocs (Cerec Blocs) regardless of surface finishing techniques. Barizon, *et al.*²⁸⁾ also reported similar results to our study and found statistically significant differences in the translucency parameters of porcelains with following rank: Empress CAD>Mark II. On the other hand, Awad *et al.*²⁹⁾ showed that the tested monochromatic fine-structure feldspathic ceramic VITA Mark II provided statistically equal translucency values to IPS Empress CAD in a polished situations. In a previous study, the translucency parameters of natural dentin and enamel with 1 mm thickness under the same condition (no coupling medium) as in our study were determined as 16.4 and 18.7, respectively⁵⁾. According to the result of our study, translucency parameters were similar to those of natural dentin and enamel tissue in both groups. With these results, it can be concluded that it is possible to produce restorations with translucency parameters close to the enamel and dentin tissue with both ceramic and finishing techniques. Parallel to our study, Nogueira and Della Bona³⁰⁾ also reached similar results. However, they additionally concluded that coupling medium (glycerin) is an important factor for the evaluation of translucency parameters to simulate the oral environment as a result of the refractive index of light in humid conditions. Thus, the aspect of the study mentioned above and the limitations of our study (that is, no coupling medium) should be taken into account to evaluate the results of the present study.

Various factors such as the ability of the technicians, applied pressure, rotation speed, angle between the samples and the grinders, polishing duration, grain size and thickness of the glaze layer may affect the results of polishing or glazing procedures and may cause microstructural failures of constituent materials. Additionally, there are various factors that

can considerably affect the surface roughness, flexural strength and translucency of materials in the oral environment. Therefore, further *in vitro* and *in vivo* investigations are necessary to evaluate these properties of different all-ceramics systems after treated with polishing or glazing techniques.

CONCLUSIONS

Within the limitation of the study, it was concluded that polishing techniques were more effective than the glazing method for surface roughness, regardless of ceramic type. Glazing significantly increased the flexural strength of machinable leucite-reinforced ceramics. Translucency parameters of all-ceramic systems were altered depending on material structure, and different surface finishing techniques have significant effects on the translucency of feldspathic ceramics. Machinable leucite-reinforced ceramic blocks showed significantly ($p < 0.05$) higher translucency values than machinable feldspathic ceramics.

ACKNOWLEDGMENTS

This study was not supported by any financial individual or organization. The authors declare no conflict of interest.

REFERENCES

- 1) Ironside JG, Swain MV. Ceramic in dental restorations — a review and critical issues. *J Aust Ceram Soc* 1998; 34: 78-91.
- 2) Yin L, Song XF, Song YL, Huang T, Li J. An overview of *in vitro* abrasive finishing & CAD/CAM of bioceramics in restorative dentistry. *Int J Mach Tool Manu* 2006; 46: 1013-1026.
- 3) Rekow ED, Erdman AG, Riley DR, Klamecki B. CAD/CAM for dental restorations-some of the current challenges. *IEEE Trans Bio-Med Eng* 1991; 38: 318-414.
- 4) Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. *Aust Dent J* 2011; 56: 84-96.
- 5) Yu B, Ahn JS, Lee YK. Measurement of translucency of tooth enamel and dentin. *Acta Odontol Scand* 2009; 67: 57-64.
- 6) Pires-de-Souza Fde C, Casemiro LA, Garcia Lda F, Cruvinel DR. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. *J Prosthet Dent* 2009; 101: 13-18.
- 7) Quirynen M, Bollen CM. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. A review of the literature. *J Clin Periodontol* 1995; 22: 1-14.
- 8) Lee YK, Lim BS, Kim CW. Effect of surface conditions on the color of dental resin composites. *J Biomed Mater Res* 2002; 63: 657-663.
- 9) Sarikaya I, Guler AU. The effects of porcelain polishing systems on the color and surface texture of feldspathic porcelain. *J Prosthet Dent* 2011; 6: 122-128.
- 10) Albakrya M, Guazzato M, Swain MV. Effect of sandblasting, grinding, polishing and glazing on the flexural strength of two pressable all-ceramic dental materials. *J Dent* 2004; 32: 91-99.
- 11) Lawson NC, Burgess JO. Gloss and stain resistance of ceramic-polymer CAD/CAM restorative blocks. *J Esthet Restor Dent* 2016; 28(suppl 1): S40-45.
- 12) Chen HY, Hickel R, Setcos JC, Kunzelmann KH. Effects of surface finish and fatigue testing on the fracture strength of CAD-CAM and pressed ceramic crowns. *J Prosthet Dent* 1999; 82: 468-475.
- 13) Fasbinder DJ, Neiva GF. Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials. *J Esthet Restor Dent* 2016; 28: 56-66.
- 14) de Jager N, Feilzer AJ, Davidson CL. The influence of surface roughness on porcelain strength. *Dent Mater* 2000; 16: 381-388.
- 15) Barizon KT, Bergeron C, Vargas MA, Qian F, Cobb DS, Gratton DG, Geraldini S. Ceramic materials for porcelain veneers. Part I: Correlation between translucency parameters and contrast ratio. *J Prosthet Dent* 2013; 110: 397-401.
- 16) Azzopardi N, Moharamzadeh K, Wood DJ, Martin N, van Noort R. Effect of resin matrix composition on the translucency of experimental dental composite resins. *Dent Mater* 2009; 25: 1564-1568.
- 17) Bagis B, Turgut S. Optical properties of current ceramics systems for laminate veneers. *J Dent* 2013; 41: e24-30.
- 18) Wright MD, Masri R, Driscoll CF, Romberg E, Thompson GA, Runyan DA. Comparison of three systems for the polishing of an ultra-low-fusing dental porcelain. *J Prosthet Dent* 2004; 92: 486-490.
- 19) Sarikaya I, Guler AU. Effects of different polishing techniques on the surface roughness of dental porcelains. *J Appl Oral Sci* 2010; 18: 10-16.
- 20) Glavania D, Skrinjaric I, Mahovic S, Majstorovic M. Surface quality of cerec CAD/CAM ceramic veneers treated with four different polishing systems. *Eur J Paediatr Dent* 2004; 5: 30-34.
- 21) Happe A, Röling N, Schäfer A, Rothamel D. Effects of different polishing protocols on the surface roughness of Y-TZP surfaces used for custom-made implant abutments: A controlled morphologic SEM and profilometric pilot study. *J Prosthet Dent* 2015; 113: 440-447.
- 22) Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. *J Prosthet Dent* 2015; 114: 587-593.
- 23) Salihoglu Yener E, Özcan M, Kazazoglu E. The effect of glazing on the biaxial flexural strength of different zirconia core materials. *Acta Odontol Latinoam* 2011; 24: 133-140.
- 24) Fairhurst CW, Lockwood PE, Ringle RD, Thompson WO. The effect of glaze on porcelain strength. *Dent Mater* 1992; 8: 203-207.
- 25) Bona AD, Anusavice KJ, DeHoff PH. Weibull analysis and flexural strength of hot-pressed core and veneered ceramic structures. *Dent Mater* 2003; 19: 662-669.
- 26) Fraga S, Valandro LF, Bottino MA, May LG. Hard machining, glaze firing and hydrofluoric acid etching: Do these procedures affect the flexural strength of a leucite glass-ceramic? *Dent Mater* 2015; 31: e131-140.
- 27) Aurélio IL, Fraga S, Dorneles LS, Bottino MA, May LG. Extended glaze firing improves flexural strength of a glass ceramic. *Dent Mater* 2015; 3: e316-24.
- 28) Barizon KT, Bergeron C, Vargas MA, Qian F, Cobb DS, Gratton DG, Geraldini S. Ceramic materials for porcelain veneers: part II. Effect of material, shade, and thickness on translucency. *J Prosthet Dent* 2014; 112: 864-870.
- 29) Awad D, Stawarczyk B, Liebermann A, Ilie N. Translucency of esthetic dental restorative CAD/CAM materials and composite resins with respect to thickness and surface roughness. *J Prosthet Dent* 2015; 113: 534-540.
- 30) Nogueira AD, Della Bona A. The effect of a coupling medium on color and translucency of CAD-CAM ceramics. *J Dent* 2013; 41 Suppl 3: e18-23.