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The Effect of Substrate and Resin Cement Shades on the Optical Properties of Two Ceramic Laminate Veneer Materials

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ABSTRACT

Purpose: The current study aimed to investigate the effect of substrate and resin cement shades on the optical properties of two ceramic laminate veneer materials. **Materials and Methods:** Sixty four thin slices of ceramics were made from the two materials (IPS e.max CAD, Vita Suprinity).They were divided into two equal groups (n=32). Each group was subdivided into two subgroups (n=16) regarding to substrate shade (A3,C4)on which each ceramic slice was cemented. Each Subgroup was further subdivided into 2 divisions (n=8) according to resin cement shade (A1,WO). Color measurement was done after cementation by using reflective spectrophotometer then thermal aging process was done for 5000 cycles.(ΔE) values from a reference color (A1 shade) was calculated.**Results:** By comparing ceramic types vita suprinity recorded statistically significant lower mean (ΔE) values than IPS e.max CAD.By comparing resin cement shade on (ΔE) ,white opaque cement recorded statistically significant lower mean (ΔE) value than A1 cement. As regards the effect of substrate,C4 composite recorded statistically significant higher mean(ΔE)value than A3 composite. Finally thermal aging effect on (ΔE),color change mean values after aging was statistically non-significant higher than that before aging. **Conclusion:** The mean color change (ΔE) was clinically acceptable for Vita Suprinity group than E.max CAD group, vita suprinity ceramic can mask dark substrate more than E.max CAD and white opaque cement shade also give better masking effect of dark substrate. After thermo cycling color change was statistically non-significant higher than that before aging.

KEYWORDS

Dental ceramics,
Optical properties,
Resin cement,
laminate veneer.

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INTRODUCTION

The evolution of laminate veneers as an elective cosmetic treatment rather than the traditional more aggressive full crown preparation made a huge shift in dentistry toward the world of minimally invasive dentistry which is the trend and the goal nowadays in all fields of dentistry. In 1980,when acid etched ceramics were introduced[1,2], laminates had been used in dental field[3].Ceramics which success to match natural teeth and have good optical and physical properties make patients with high esthetic expectations choose these restorations [4].

The final shade of a porcelain veneer is depended on several factors, among them is the original underlying tooth color, the porcelain shade, the composite resin cement opacity, and the ceramic thickness. Patients and clinicians always demand esthetically successful restorations with good mechanical strength and high biocompatibility [5].

Different laminate veneer ceramics were introduced for CAD/CAM system among which Feldspar in 1985, Lithium disilicate was in 2005 and in 2013: Zirconia reinforced lithium silicate ceramics was introduced to the market [6].

Color assessment is regarded as a complex psycho-biophysical phenomenon resulting from the behaviour of light through its wavelengths to the human eye. The real factor responsible for visual perception of color is light [5].

Color mismatch in dental practice between restorative materials and natural teeth is often predictable. The Munsell's color system was the first trial to organize dental colors as well as the "Commission International de color system, published at the same period ,established the first l`Eclairage "(CIE) standards for color matching. These were the most common systems for describing color ,due to their worldwide recognition, consistency, flexibility and simplicity[7,8].

Three coordinates express color in this system, CIE L*a*b* coordinates represents the color in a 3-dimensional color space. The L* color coordinate indicates brightness or lightness, a* when (positive) represents greenness and when (negative) indicates redness and b*when (positive) regards yellowness and(negative) represents blueness. The numerical distance between L*a*b* coordinates was represented by ΔE. When the ΔE of 2 colors is 0, the color is perfect; from 0.5 to 1.5 units is very good, 1 to 2 is good, 2 to 3.5 is clinically perceptible and >3.5 is unacceptable [9].

This color difference value was depended on the human perception of color. Color difference values which are smaller than 1 were considered not detected by the human eye, while values more than 1 and less than 3.3 ΔE units were detected by skillful clinicians, but within clinical acceptance. ΔE values more than 3.3 have been noticed by untrained observer as patients, and were considered unacceptable [10-12].

Among currently available electronic devices for absolute color measurement, the spectrophotometers are the most accurate. As the working life of them is long and not affected by the object metamerism like colorimeter [13-16].

The longevity of the restoration is affected by color stability of dental materials [17,18]and cementation technique which was used [18,19]. For bonding these restorations resin cements are used as the conservative preparations decreased the retention[17]. Multiple types of resin cements are developed for bonding of ceramic veneers[20] and the light-activated resin cements was preferred by many clinicians, due to activation was controlled by light, that gives simplicity and longer clinical working time of the technique. Moreover, light cured resin cements are often likely to be used than chemically cured and dual-cured ones due to their color stability and polymerization characteristics [21].

Accelerated Artificial Aging (AAA) was an efficient method for in vitro studies to investigate different dental materials' longevity. This method resembles the clinical conditions[22] as far as possible, because of the impact of different media to which the restoration is subjected, such as UV light, continuous alterations of humidity and temperature, and to evaluate the restorations' color stability, including color of ceramics and cement used[23].

MATERIAL AND METHODS

1- Fabrication of ceramic specimens:

Sixty four ceramic slices; 32 IPS e.max CAD and 32 vita suprinity were cut at dimensions (10×10×0.8 mm) with a low speed diamond saw under water cooling. Then crystallization, finishing, polishing and glazing were done for each type according to manufacturer's instructions.

2- Experimental design:

The sixty four slices of ceramics were divided into two equal groups(n=32).

- Group A: 32 slices of IPS e.max CAD ceramic.
- Group B: 32 slices of Vita suprinity ceramic .

Each group was subdivided into two subgroups (n=16) according to substrate shade:

- Subgroup 1:16 slices of ceramic were cemented to composite resin substrate of shade A3.
- Subgroup 2:16 slices of ceramic were cemented to composite resin substrate of shade C4.

Each Subgroup was further subdivided into 2 divisions (n=8) according to resin cement shade:

- Division I: 8 slices of ceramic were cemented using resin cement of shade A1.
- Division II: 8 slices of ceramic were cemented using resin cement of shade WO.

3- Construction of composite resin substrate samples:

A total of Sixty four samples were made from light cured composite resin material with A3 (n=32) and C4 (n=32) shades to simulate different shades of the esthetic core foundations (light and dark) with dimensions (10×10×4mm) by using square copper mold.

4- Cementation of Ceramic Veneer:

9% hydrofluoric acid was used for surface treatment of ceramic veneer by etching for 20 seconds then rinsing the fitting surface with water then application of silane coupling agent (Rely X Ceramic Primer) was done for 60 seconds. 35% phosphoric acid for 15 seconds was used for surface treatment of composite substrate and then rinsed with water, applying two coats of single bond universal adhesive onto the composite substrate surface and dried for 10 seconds using a gentle stream of air. Application of luting cement by using a second copper mold with dimensions (10×10×5mm) to centralize the ceramic specimen over the composite substrate, standardize and ensure 0.1-0.2mm cement thickness in all the specimens. The composite substrate was placed inside the mold, then the selected shade of the cement was applied. A 250 g of load was put over the ceramic specimen for 20 seconds to get a uniform thickness of cement, a brush was used to remove excess cement. Initial polymerization of the resin cement was started under load for 10 seconds, then light curing for 40 seconds had done for final polymerization of the resin cement. Cemented veneer to composite substrate as in (fig.1).

Figure (1): Ceramic veneer cemented to composite resin substrate

5- Color measurement:

A reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany) was used to measure the colors of samples. The size of aperture had set to 4 mm and the samples had aligned with the device. Measurements had been done over a white background according to the CIE L*a*b* color space relative to the CIE standard illuminant D65 to prevent any interface of the background color. A slice of A1 ceramic with (0.8 mm) thick had been as a control of each type. Color difference (ΔE) between the values of L*, a*and b*obtained after the cementation and the one obtained by the measurement of the A1 shade ceramic control was calculated according to the following formula:

$$\Delta E_{CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½$$

Where: ΔL* = lightness (0-100), Δa* = (color variation axis red/green) and Δb* = (change the color of the yellow/blue).

6- Thermocycling Procedure

Thermal aging process was done to all the specimens for 5000 cycle which equals 4 years and 6 months. Dwell times were 25 seconds in each water bath with a lag time 10 seconds. The low-temperature point was 5^0C and the high temperature point was 55 ^{0}C. New color readouts were taken by spectrophotometer just after thermal aging. Color difference (ΔE) between the color parameters of the control and color parameters after aging had been calculated.

RESULTS

The results analysis was done by using Graph Pad Instat software. A value of $P \leq 0.05$ was considered statistically significant with the satisfactory level of power set at 80% and a 95% confidence level. Continuous variables were expressed as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, multi-factorial analysis of variance MANOVA was performed. One-way ANOVA was done for compared subgroups followed by Tukey's pair-wise (if showed significant) and student t-test were used between groups interaction.

Color changes (ΔE):

Descriptive statistics showing mean values and standard deviation of color changes test results measured in (ΔE) for both ceramic materials cemented with both cements shades to different composites before and after thermal aging were summarized in table (1) and graphically drawn in (fig.2).

Table (1) *Color changes test results (Mean±SD) for both ceramic materials cemented to different composites with both cements before and after thermal aging.*

Ceramic		e.max		V suprinity	
Composite	Thermal aging / Cement	Before	After	Before	After
A3 composite	WO cement	2.49^D±0.07	3.49^D±0.3	1.73^C±0.15	2.14^C±0.2
	A1 cement	3.97^C±0.1	4.01^C±0.14	1.64^C±0.3	1.85^C±0.1
C4 composite	WO cement	4.43^B±0.3	5.17^B±0.06	3.19^B±0.38	3.18^B±0.4
	A1 cement	4.81^A±0.13	6.33^A±0.2	4.53^A±0.5	4.39^A±1.1
ANOVA	P value	<0.0001*	<0.0001*	<0.0001*	<0.0001*

different letters in the same column indicating significant (P<0.05)

ns; non significant (P>0.05) **; significant (P<0.05)*

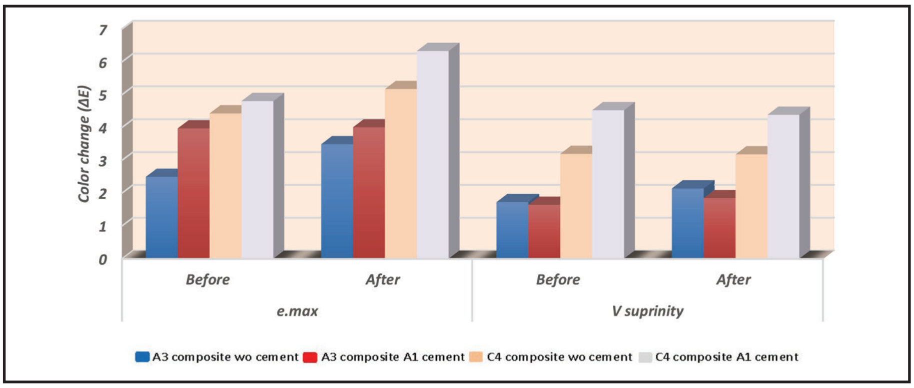

Figure (2): Column chart showing the mean values of color changes for both ceramic materials cemented to different composites with both cements before and after thermal aging

DISCUSSION

Esthetic restorations should represent the color and translucency of the adjacent natural teeth, to give similarity in shade. The restorative material's translucency gives the vitality and the natural appearance of the restoration [24]. The color of the tooth/substrate, ceramic material type, and resin cement shade selected are all contributing factors that provide the esthetic outcome of laminate veneers [25].

According to the present study's results,the null hypothesis had rejected, since the color difference (ΔE) of ceramic veneer restoration is affected by the color of tooth abutment ,color of the cement, and not significantly affected by thermal aging.

Samples of 0.8 mm thick were used and the standard thickness of laminate veneer is 0.7 mm. However, it is not always possible in a clinical situation to get exact thickness of laminate, so it valuable to investigate what was happened when greater thicknesses were used [26] .The high translucency (HT) and shade A1 was selected for this study to facilitate assessment the effect of the resin cement shade and the substrate rather than the low translucency ceramic veneer [27]. Composite resin specimens of uniform 4.0 mm-thick had been used to assembly the different shades of esthetic core foundations [28-30].For standardization of cementing load (250gm) a specially designed loading device was used to ensure uniform thickness of the cement to exclude the consideration of the cement thickness that might affect the final shade of ceramic restoration.[15,31,32] .

Thermo cycling procedure is a laboratory simulation of clinical situations and it was done as clinical investigations are time consuming and costly [33]. In clinical dentistry for color assessment during the construction of indirect restorations is perceptional method. It depends on color perception by human eyes, which differs from person to person and is sensitive to errors resulting from perceptual inconsistencies. A means to improve assessment of tooth color is using spectrophotometer or colorimeters [34].

Spectrophotometer which is the most accurate device to get correct color measurement, can evaluate metamerism in contrast to colorimeters that cannot quantify metamerism and have poor repeatability and reproducibility due to aging of the filters.[35] Spectrophotometers used the CIE L*a*b* color system which close between the color coordinates while the visual color space was entirely covered. This system was accurate due its ability to be clinically interpreted, as uniform steps in human color perception was represented by equal differences across the CIE L*a*b* color space (ΔE),improving the interpretation of color measurements [36,37].

Concerning the effect of the ceramic material, it was found that E.max group recorded statically significant higher color change mean values than Vita Suprinity group and so the last one is better in masking ability. The higher masking ability of Vita Suprinity than IPS e.max CAD could be attributed to difference in chemical composition as incorporation of 8–10 wt. % zirconium oxide. Zirconia reinforced lithium silicate ceramics consist of a dual microstructure: lithium disilicate with very fine lithium metasilicate [38].

The high ΔE values of IPS E.max CAD may be due to the optical properties of the material itself. The optical compatibility between the lithium disilicate crystalline phase and the glassy matrix that the light was scattered internally as it passes through the material made it to have high translucency [39], this was proved by our results in which E.max group recorded statically significant higher translucency change mean values than Vita suprinity group .

Our finding were in agreement with the study that compare the color stability of two hybrid ceramic (Suprinity and Enamic) veneers versus Lithium disilicate ceramic veneers and Suprinity exhibited the best colour stability values (ΔE=3.52) followed by Enamic (ΔE=4.14) and then e-max (ΔE=4.4) [18].

Our results is contradictory with the study[40] which evaluate mechanical and optical properties of monolithic CAD-CAM restorative materials that found vita suprinity has the highest translucency mean value and biaxial flexural strength than resin nanoceramic, feldspathic ceramic, lithium disilicate ceramic, and dual-network ceramic.

Shade of substrate or the esthetic core foundation had a great effect on the final shade of porcelain laminate veneer whatever the ceramic shade was. This was in acceptance with other studies which investigated that the shade of substrate was among the important variables which influenced the color and esthetics of the ceramic restoration [20,41].

Also when ceramic restoration had suitable veneer thickness, it not easy to achieve clinical shade matches, especially on a dark tooth color. this problem has been solved by producing a variety of newly resin cement shades, so that some resin cements should mask the discolored teeth where the final color of the restoration may be mismatched [16]. Two shades of the same cement (A1 shade and white opaque shade) were used as A1 shade represents the desired shade to reach in our study, while WO shade is usually advised to use it to mask discolored substrate.

In our study, it is preferred to use light cured resin cements over dual-cured or self-cured cements as their working time and color stability were the best[42-44]. In order to lighten the color of ceramic restoration cemented over a dark tooth, an opaque or bleach shade resin cement is preferred[44]. Regarding the resin cement shade, the results of our study support some these findings, indicating that the opaque cement showed the lower (ΔE) values and better masking of the background color than A1 cement.

Results of current study were in accordance with another study[42] in where the use of an opaque cement increased the L*values, resulting in lighter specimens irrespective of the ceramic thickness. So the opaque cement seem to be more valuable in masking a darkened background, on the other hand there was another study[32] which stated that the shade of the resin cement has less effect on the final shade of the laminate veneers than the other variables have.

Regarding the color stability,it was found that there was color change for both groups after thermal cycling recording that e.max group showed higher mean values than vita suprinity group and that was statistically insignificant.

Our results become in agreement with the study[45] which evaluate the effect of surface treatments and coffee thermocycling on the color and translucency in which IPS e.max CAD and vita suprinity ceramic specimens of 1.5 mm-thick and coffee thermocycling was done for 5000 cycle and color were measured before and after thermocycling by using spectrophotometer. It was found that coffee thermocycling decrease both materials translucency and they were clinically acceptable color changes.

A disagreement with our results, a research[46] evaluated color stainability and relative translucency of six CAD-CAM restorative materials for laminate veneers (Celtra Duo, IPS e.max CAD, Lava Ultimate,Vita Enamic ,Vita Suprinity and Vita YZ HT) of 0.7 mm thick and full crowns of 1.3-1.5 mm thick. It was found that the color change was non-significant after coffee thermocycling between any 2 materials in crown and veneer thickness. Translucency was found to be higher after thermocycling for IPS e.max CAD at laminate veneer thickness.

CONCLUSION

The mean color change (ΔE) was clinically acceptable for Vita Suprinity group than IPS e.max CAD group, vita suprinity ceramic can mask dark substrate more than IPS e.max CAD and white opaque cement shade also give better masking effect of dark substrate than A1 cement. After thermo cycling color change was statistically non-significant higher than that before aging.

REFERENCES

1. Calamia JR. Etched porcelain facial veneers.A new treatment modality based on scientific and clinical evidence. N Y J Dent 1983;53: 255-9.
2. Horn HR. A new lamination : porcelain bonded to enamel. N Y State Dent J 1983; 49:401-3.
3. Christensen GJ. Thick or thin veneers?. J Am Dent Assoc 2008; 139:1541-3.
4. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent. 1996; 75:18-32.
5. Volpato CÂ, Frede MC, Philippi AG, Petter CO. Ceramic materials and color in dentistry. InTech; 2010: 155–74
6. Yousef A, Maryam S B. The Success of Dental Veneers According To Preparation Design and Material Type. J Med Sci. 2018; 6:2402-08.
7. Inokoshi S, Burrow M.F, Kataumi M ,Yamada .T, Takatsu. T. Opacity and color changes of tooth colored restorative materials. J Oper Dent. 1997; 21:73-80.
8. Kim H.S, Um C.M. Color differences between resin composites and shade guides. Quintessence Int.1996; 27:559-67.
9. Douglas R.D, Steinhauer.T, Wee A.G. Intra oral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent. 2007; 97: 200-8.
10. Kamada K, Yoshida K, Atsuta M. Effect of ceramic surface treatments on the bond of four resin luting agent to ceramic material. J Prosthet Dent. 1998; 79 : 508-13.
11. Xing W, Jiang T, Ma X, Liang S, Wang Z, Sa Y, Et al. Evaluation of the esthetic effect of resin cements and try-in pastes on ceromer veneers. J Dent. 2010; 38 : 87-94.
12. Myers ML, Caughman WF, Rueggeberg FA. Effect of restoration composition, shade, and thickness on the cure of photo-activated resin cement. J Prosthodont. 1994; 3: 149-57.
13. Yilmaz B, Karaagaclioglu L. Comparison of visual shade determination and an intra-oral dental colorimeter. J Oral Rehabil. 2008; 35: 789-94.
14. Hitz T, Stawarczyk B, Fischer J, Hämmerle CH, Sailer I. Are self-adhesive resin cements a valid alternative to conventional resin cements? A laboratory study of the long-term bond strength. Dent Mater J.2012; 28:1183-190.
15. Alghazzawi TF, Lemons J, Liu PR, Essig ME, Janowski M. Evaluation of the optical properties Of CAD/CAM generated yttria-stabilized zirconia and glass-ceramic laminate veneers .J Pros Dent.2012; 107: 300-8.
16. C,¨omleko˘glu ME, Tan F, Ozcan M. Evaluation of Different Thickness, Die Color, and Resin Cement Shade for Veneers of Multilayered CAD/CAM Blocks. J. Pros. 2016; 25 : 563-69.
17. Tariq FA, Jack L, Perng-Ru L. Evaluation of the optical properties of CAD-CAM generated yttria-stabilized zirconia and glass-ceramic laminate veneers. J Prosthet Dent .2012; 107 :300-8.
18. Marwa T, Essam O, Mohammad R, Ehab A. F. Fracture Resistance and Color Stability of Two Hybrid Ceramic Veneers Versus Lithium Disilicate Glass Ceramic Veneers. E.D.J. 2018; 64 : 2.
19. Stevenson B, Ibbetson R. The effect of the substructure on the colour of samples/restorations veneered with ceramic: a literature review. J Dent. 2010; 38: 361-68.

20. Chaiyabutr Y, Kois JH, Lebeau D. Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass ceramic lithium didsilicate reinforced crown. J Prosthet Dent. 2011;105:83-90.

21. Hosoya Y. Five-year color changes of light-cured resin composites: influence of light-curing times. Dent Mater.1999; 15 : 268-74.

22. Doğu ÖD, Gözlem C, Burak Y. Effect of brand and shade of resin cements on the final color of lithium disilicate ceramic. J prosth Dent .2016; 117.

23. AL Ghazali N, Laukner J, Burnside G, Jarad FD, Smith PW, Preston AJ. The effect of try-in pastes, uncured and cured resin cements on the overall color of ceramic veneer restorations: an in vitro study. J Dent. 2010; 38 : 78-86.

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

25. Li Q, Yu H, Wang YN. Spectrophotometric evaluation of the optical influence of core build-up composites on all-ceramic materials. Dent Mater. 2009; 25:158–65.

26. Mohamed EG, Manal RH. Influence of Cement Type on the Color Stability of Aged Laminate Veneer Ceramics of Two Different Thicknesses. EC Dental Science. 2019; 18:461-69

27. Daiana KH, Cesar AG, José AR. Influence of resin cement shade on the color and translucency of ceramic veneers. J Appl Oral Sci . 2016; 24:391-6.

28. Kilinc E, Antonson SA, Hardigan PC, Kesercioglu A. Resin cement color stability and its influence on the final shade of all-ceramics. J Dent. 2011; 39 : 30-36.

29. Shereen SA, Stephen FR, Robert RS, William MJ . Effect of substrate shades on the color of ceramic veneer .J Prosthet Dent .2011;106:179-18.

30. Bassem S.M, Amena MH, Ahmed KA, Mohamed El-Anwer. Effect of ceramic translucency and luting cement shade on the color masking ability of laminate veneers. Dent Res J . 2019; 16 : 193–99.

31. Turgut S, Bagis B. Colour stability of laminate veneers: An in vitro study. J Dent. 2011;39: 57–64.

32. Karaagaclioglu L, Yilmaz B. Influence of cement shade and water storage on the final color of leucite-reinforced ceramics. Oper Dent. 2008; 33: 386-91.

33. Schmid-Schwap M, Graf A, Preinerstorfer A, Watts DC, Piehslinger E, Schedle A. Microleakage after thermocycling of cemented crowns-a meta-analysis. Dent Mater.2011; 27: 855-69

34. Gale, MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent. 1999; 27: 89-99.

35. Pande N, Kolarkar MS. Spectrophotometric evaluation of shade reproduction of pressable all-ceramic system on un-stained and stained tooth: An in vitro study. J Indian Prosthodont Soc. 2016; 16 :63–69.

36. Chu SJ , Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent. 2010; 38 :e2-16.

37. Wyszecki G, Stiles WS. Color science : Concepts and methods ,quantitative data and formulae. 2nd ed . New York :John Wiley& Sons.1982 :45-7.

38. Diana M, Maha T, Rabab M . Effect of resin cement shades & thickness of zirconia reinforced lithium silicate ceramics (Vita Suprinity) on the optical properties using dark background compared to lithium disilicate glass ceramics. JDMS. 2019; 18 : 77-86.

39. Van Noort R. Introduction to dental materials. 2nd ed. St. Louis: Elsevier; 2007: 247-50.

40. Sen N, Us YO. Mechanical and optical properties of monolithic CAD-CAM restorative materials. J Prosthet Dent. 2018; 119 :593-9.

41. Crispin BJ, Okamoto SK, Globe H. Effect of porcelain crown substructures on visually perceivable value. J Prosthet Dent. 1991; 66:209-12.

42. Gloria BA, Guilherme BC, Tatiana PC. The effect of luting agents and ceramic thickness on the color variation of different ceramics against a chromatic background. Eur J Dent. 2011; 05: 245-52.

43. Turgut S, Bagis B. Effect of resin cement and ceramic thickness on final color of laminate veneers: An in vitro study. J Prosthet Dent. 2013; 109:179–86.

44. Calgaro PA, Furuse AY, Correr GM, Ornaghi BP, Gonzaga CC. Post-cementation colorimetric evaluation of the interaction between the thickness of ceramic veneers and the shade of resin cement. Am J Dent. 2014; 27:191–4.

45. Gulce A, Meryem G, William M, Burak Y . Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass ceramic. J Prosthet Dent. 2018 ;120 :263-8.

46. Arif R , Yilmaz B , Johnston WM . In vitro color stainability and relative translucency of CAD-CAM restorative materials for laminate veneers and complete crowns. J Proth Dent.2019; 122: 160-66.