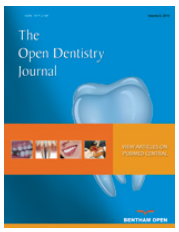

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RESEARCH ARTICLE

Evaluation of the Final Color of Ceramic Veneers with Different Self-Adhesive Resin Cements

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Abstract:

Background:

Proper selection of cement plays an effective role in the success of ceramic laminate veneers. The cement can affect the final color by changing the optical properties of the ceramic.

Objective:

Due to the ease of clinical use of the seventh generation of cement (Self-Adhesive Cement), this study aimed to evaluate the effect of this type of cement on the final color of Ceramic Veneers (CV).

Methods:

In this study, 21 IPS e.max ceramic disks (8mm× 0.7 mm) were used. They were divided into 3 groups of 7, depending on the type of cement. (Choice 2, RelyX U200, Speed Cem). In the first stage, ceramic disks were set on the facial surface of bovine's teeth by bonding agents and the color properties were analyzed by spectrophotometer. In the next stage, specimens were cemented on the prepared surfaces according to the manufacturer's instructions and their color was evaluated subsequently.

Results:

Results were analyzed by repeated measures two-way ANOVA and TAMHANE post hoc methods ($P < 0.05$). Results showed that cement influences the color of the ceramic laminate. ΔE values were reported to be higher than the critical point after cementation ($\Delta E > 2.69$).

Conclusion:

There was no significant difference between the effects of three cement types on the final color of the ceramic veneers.

Keywords: Dental veneer, Resin cements, Color, Cementoenamel junction, Spectrophotometer, Ceramic veneer.

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1. INTRODUCTION

Ceramic Veneer (CV) has been commonly used to achieve desirable esthetic outcome in anterior region [1]. Poor esthetic situation, such as discoloration, undesirable shape of teeth, fractured incisor teeth, and diastema may be effectively corrected with CV [2, 3]. The success of CV is related to good bond strength, high inherent strength, resistance to fluid absorption, superior esthetic and resistant to abrasion. CV failures include: adhesive, mechanical, biological and esthetic properties [3, 4]. A considerable element in esthetic restorations is the color match to the dentition [2]. The final color of CV is determined through a combination of translucency, opalescence, fluorescence, surface texture, number of firing, thickness of the

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Table 1. Resin cements used in this study.

Materials	Manufacturer	Composition	Type
Speed Cem	Ivocolar Vivadent, Liechtenstein	Dimethacrylates, Methacrylate, phosphoric esters, barium glass, Ytterbium trifluoride, copolymers, high depressed silica, initiators, catalysts and stabilizer	Self- adhesive
RelyX U200	3M ESPE,USA	Base paste: glass fiber, propeoinc acid,2-methyl 1,1'-(1-[hydroximetil]-1,2-ethanodlyl) ester dimethacrylate, TEGDEMA, silica treated with silane,sodium persulfate, glass powder, Sodium persulfate and per-3,55 trimethyl hexanoate t-butyl Catalyst paste: glass powder,substitute dimethacrylate,slica treated with silane,sodium p-toluene sulfonate,1-benzyl-5-phenyl-acid barium, calcium hydroxide,1,12-dodecane dimethacrylate, titanium oxide	Self- adhesive (Dual cure)
Choice 2	Illinois, USA	Bis-GMA, glass strontium, amorphous silica	Light cure
Bis –GMA: Bisphenol Glycol Dimethacrylate ; TEGDMA: Triethylene Glycol Dimethaceylate			

ceramic and, thickness and color of the cement [1, 2, 5].

Resin cements are the selective luting agents for cementation of ceramic restorations [1]. The use of these cements provides several advantages in comparison to the conventional cements, including satisfactory esthetics, little solubility in oral environment, greater mechanical, physical and adhesive properties, higher bond strength to tooth structure and creates greater support for ceramics [6, 7]. Recently, various types of resin cements have been introduced based on their polymerization mechanism. Self-Adhesive Cements (SACs) have been introduced to dentistry in the past decades and have gained popularity [8]. SACs propose the mechanical, adhesive and aesthetic advantages of usual resin cements, furthermore, they do not need the pretreatment of tooth structure, and are less technique sensitive [9, 10]. The results of the previous studies regarding the effect of resin cement (light and dual cure) on the final color of CV are conflicting [2, 7, 11 - 13]. There is no study available on the effect of SACs on the final color of CV. The purpose of this study was to compare the effect of SACs and light cure cements on the final color of CV. The null hypothesis was that the type of cement does not have an effect on the final color of CV.

2. MATERIALS AND METHODS

2.1. Materials

The performance of the three resin cements was assessed in this research. Compositions were listed in Table **1** based on the manufacturing information.

Preparation of teeth and ceramic veneers: 21 disk-like ceramic (8mm× 0.7mm) specimens were fabricated and tested according to the manufacturer's instructions. The 0.7mm thickness consisted of a 0.5mm thick framework materials (IPS e.max press, shade HT, Ivocolar Vivadent, Schaan, Liechtenstein) and 0.2mm thick layering material (e.max, Ceram, Ivoclar Vivadent). Heat pressing of the specimens for framework ceramic was done with IPS Empress EP 600 press (Ivoclar Vivadent) furnace at 920°C. The thickness of specimens at the end of each part of preparation was checked using digital five-point caliper of each disk. The specimens were ultrasonically freshened in distilled water for 10 min and excess water was removed by absorbent paper. Finally, glazing was done based on the manufacturer's instruction.

21 bovine central incisors with the same size and thickness were collected. Soft tissues were removed manually, and the teeth were cleaned with a pumice and water slurry. The root of the teeth was cut in 1/3 gingivally to Cementoenamel Junction (CEJ) with diamond disk (Degussa Dental, Hanau, Germany). The teeth were mounted with white stone in (2×2×2cm) metal mold. The buccal surface of the tooth was embedded in stone parallel to the upper side of the mold to maintain the veneer in horizontal level for color assessment. A circle (8mm diameter) was drawn up in 1/3 middle of buccal surface of each tooth with a water proof marker, this area was flattened with medium and fine Sof-flex disk (3M; ESPE). The CV and teeth were randomly allocated to the three groups based on the type of cements.

2.2. Color Measurement

Color assessment was done in two steps:

[1] Ceramic veneer against teeth without resin cement: To avoid any error in the color evaluation caused by a wrong placement, 4 marks were placed at the edge of the disks and the teeth to reposition the disk against the teeth in the same manner in both steps of color assessment. CV was fixed against the teeth with three pinpoint spot of single bond (3M; ESPE) without any pretreatment in CV. Each tooth after placement of CV was exposed with 5-second light curing (Optilux, Kerr, Orange, CA, USA). A spectroradiometer (Konica, Minolta, CS-2000) and light source were placed at the optical configuration of 0^{o} observation and from an illumination angle of 45^{o} to the object. This device measures the reflectance spectra from 380 to 780 nm and then transforms it to CIE L* a* b* values (1^{o} observer and illuminant D65). All the steps of color assessment were performed based on ISO 7941. Before each color assessment, the instrument calibration was done based on the manufacturer's instruction. The instrument was placed in the middle of each ceramic veneer. Three readings were done for each ceramic veneer and the mean of these readings was calculated. After color assessment, all the CVs were detached from teeth with application of little force by a scalar.

[2] Ceramic veneer against tooth with resin cement: Before cementation of ceramic veneers, the internal surface of the ceramic disks were etched with 9.5% HF (Bisco,Inc., Schaumburg,IL) for 20 seconds, washed for 30 seconds, and air-dried for 30 seconds. The etched ceramic surfaces were ultrasonically cleaned in

distilled water for 5 min. The use of the silane coupling agent (Bisco,Inc., Schaumburg, IL) was done with a clean micro brush in one layer based on manufacturer's instruction. The surface of teeth in Speed Cem and RelyX U200 groups were not pre-treated in any manner. All the CVs were bonded to the surface of the teeth based on the manufacturer's instruction (Table **2**).

Then the CIE L* a* b* values were recorded as the same, was previously explained. ΔE and ΔC were calculated as follows:

$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]1/2$ where (ΔL, Δa and Δb were different in color factors for two phases of color assessment)

C_1 (Chroma) $= (a_1{}^{*2} + b_1{}^{*2})1/2$, C_2 (Chroma)$=(a_2{}^{*2} + b_2{}^{*2})1/2$, $\Delta C = C_2 - C_1$

2.3. Statistical Analysis

The data were analyzed using SPPSS 18 (SPSS Inc., Chicago, USA). Repeated measures analysis of variance (ANOVA) was applied for analysis (type of cement, veneer color). Tamhane post hoc test was used to carry out pair-test comparison. ($P < 0.05$)

3. RESULTS

3.1. Color Similarity

Mean and standard deviation of L*, a*, b* and C values at the baseline and after cementation are presented in Table **3**. The significant decrease in L* value and hence the darker manifestation of the cemented laminate as compared with non-cemented laminate was shown in all groups ($p < 0.05$). The two experimental groups (Choice 2 and Speed Cem) did not differ significantly in C value after and before cementation, however, RelyX U200 showed a significant difference ($p < 0.05$). There were significant differences in a* values (after and before cementation) in Choice 2 and RelyX U200 groups ($p < 0.05$). Only RelyX U200 demonstrated a significant difference between b* before and after cementation ($p < 0.05$).

3.2. Color Difference

ΔE*, ΔL*, Δa*, Δb* and ΔC values are shown in Table **4**. The entire tested groups verified a noticeable degree of color change (ΔE) after cementation. Application of ANOVA demonstrated no statistical differences in ΔE*, ΔL*, Δb* and ΔC among the groups ($p > 0.05$) yet, the Δa* value was affected by the type of cement ($p < 0.001$). The Δa* value of the Speed Cem group is significantly different from the other two groups. The Δa* value of Choice 2 and RelyX U200 shifted towards red (Δa*> 0), a converse exception was found in the Speed Cem group (Δa*< 0). All specimens became darker after cementation (ΔL*< 0).

Table 2. Methods of application of cements based on manufacturer's instructions.

Speed Cem	1- Mixed cement with dual syringe cartridge, apply an amount of cement to the internal surface of veneer, apply light cure (2 sec) and remove excess, light cure 20 s per surface
Choice 2	Etch tooth surface with UNI-ETCH for 15 sec, rinse and remove excess water, mix part A & B ALL-BOND 3 in 1:1 ratio and apply 2 coats and gently air dry, apply amount of cement to the internal surface of veneer, light cure for 3-5 s and remove excess cement, light cure for 40 s per surface.
RelyX U200	Using a brush, apply RelyX primer to the pretreat veneer surface and dry, Mixing catalyst and base pate, apply the cement into the pretreated veneer, light cure for 2 s and remove excess cement, light cure for 20 s per surface.

Table 3. Mean(SD) (L*, a*, b*, C) values at before and after cementation laminate.

Color Coordinates		L*	a*	b*	C
Choice 2	Before	78.09(2.34)	2.57(0.38)	21.76(1.73)	21.92(1.68)
	After	73.17(2.01)	3.15(0.57)	21.88(1.24)	22.12(1.22)
RelyX U200	Before	77.87(91.64)	2.09(0.59)	20.32(1.33)	20.43(1.30)
	After	73.88(1.85)	2.87(0.56)	21.29(0.92)	21.49(0.93)
Speed Cem	Before	79.12(1.86)	2.05(0.30)	21.76(1.08)	21.85(1.81)
	After	76.05(2.08)	2.72(0.44)	21.85(1.54)	21.95(1.52)

Table 4. Change in color parameter and color change after cementation.

-	ΔL*	Δa*	Δb*	ΔC	ΔE
Choice 2	-4.91(1.35)[a]	0.58(0.27)[b]	0.12(1.63)[d]	0.196(1.64)[e]	5.2(1.33)[f]
RelyX U200	-3.98(2.29)[a]	0.78(0.57)[c]	0.96(0.98)[d]	1.05(0.96)[e]	4.40(2.11)[f]
Speed Cem	-3.03(3.54)[a]	-.003(0.55)[b]	0.96(3.03)[d]	0.10(3.03)[e]	4.84(2.67)[f]

*Values in parenthesis show standard deviation

Similar superscripts demonstrate mean values with no significant differences ($p > 0.05$) among the cement tested groups.

4. DISCUSSION

The predictable ΔE threshold in different studies varies from 1 to 3.7, and the acceptable ΔE threshold varies from 1.7 to 6.8 [13]. Chang *et al*., verified the gold standard threshold of 2.0 for the optical effect of resin cement [14]. ΔE value of 2.7 for resin disk, 3.3 for direct resto- rative materials and 5.5 for dentures were reported as acceptability thresholds in literature [12]. The average ΔE value of a clinically acceptable ceramic restoration was determined 2.69 [14]. Some researchers expressed that the ΔE value less than 3.7 was clinically acceptable in uncontrolled clinical situations [15]. There is no standard ΔE threshold for clinical color predictability of dental materials. Most of these thresholds were documented based on *in vitro* research.

If ΔE between 1.7 to 6.8 was considered as acceptable threshold, all ranges of ΔE (4.4 to 5.2), in this study, were regarded as acceptable. If the ΔE >2.69 was considered as clinically unacceptable color change of ceramic restoration, the whole specimens show unacceptable color change after cementation. All types of cements affected the final color of CV. Due to the selection of different ΔE thresholds by authors, various discussions arise. According to a previous study, clinical acceptability and predictability ΔE thresholds were higher than *in vitro* ΔE thresholds [16]. With regard to the above mentioned subject, simultaneous color assessment of samples with visual and laboratory approaches provides more relevant results.

Based on the outcome of this study, the null hypothesis that there would be no effect of the type of cement on the final color of CV was accepted. No significant difference was established between ΔE, ΔL*, Δb* and ΔC with the cement types. The manufacturer's instruction states that Speed Cem is self-adhesive, self-curing cement with optional light curing. RelyX U200 and Choice 2 are categorized in self adhesive-dual cured cement and light cured cement groups, respectively. Therefore, all tested cements contained photo initiator. Manufacturers do not give exact information about cement composition. A number of resin cements include camphor- quinone as a photo initiator, which creates a residual yellow color following light curing [17]. Therefore, the authors re- commended that the camphorquinone content of the investi- gated cements could possibly influence b* coordinate, so the b axis moves towards yellow.

Almeida *et al*., mentioned that the increments of the content of pigment in the material may increase darkness [18]. They said that "the reactive and oxidizing components from the polymerization system may act as an intrinsic pigment". The different polymerization systems might be one of the contributing factors leading to the difference in the content of unreacted components in these three groups. On this basis, it was expected that shifting of the lightness varies in the tested groups. However, there was no significant difference in ΔL* values between the groups.

There were significant differences between all groups for Δa* value. After cementation of CV, there was a raise in Δa* value, which shows that CVs become more reddish in all groups, except in the Speed Cem group (Δa*< 0). The cement color coding system was different in these tested cements. A2 shade was selected in Choice 2 & RelyX U200 and transparent shade in Speed Cem. The dissimilar shade coding in Speed Cem may explain the different Δa* shift, given that A2 shades have more red pigment.

The highest ΔC changes are seen in RelyX U200 and the lowest in Speed Cem group. A2 shade cement showed a greater increase in chroma. Although, these differences were not statistically significant. The translucency parameters are affected by the chroma that influences the final color. Therefore, high chromatic shades exhibit fewer translucencies [2]. It means that this cement shade might have more masking ability compared to the transparent cements.

Previous studies state that high translucent ceramics have approximately the same translucency parameters as enamel [19]. Due to this similarity, prediction of CV translucency parameters should be done according to the use of these cements under the veneer and the interaction between ceramic, cement and teeth occur.

Our findings of this study are in agreement with the results of Omar *et al.* that showed the final color of 0.7mm thickness CV was not affected by the type of cement. Omar's study did not report the ΔL*, Δb* and ΔC values [17]. The results of Chen *et al.*'s investigation are different from our study. They found that all the CVs after cementation became lighter and the final color of CV after cementation could be affected by the type of the cement and the results differed along with cement shades [13].

About the color similarity, the change in L* and C values in all groups demonstrated a dissimilar trend. It means all the samples after cementation show C value enhancement and L* value reduction. These findings are in contrast to the outcome achieved in Chen's study [13]. These differences may be due to the dissimilarity between the substrate used in these two studies. a* and b* values changed in our study and Chen's study did not follow a comparable pattern in these studies.

The range of ΔE changes in Chen's study was (1.38 ± 0.34) to (7.16 ± 1.27) (13). While Omar *et al.*'s study (2010) [17] showed ΔE changes in the range of (1.13 ± 0.23) to (2.8 ± 0.3). In our study, this range was (4.4 ± 2.11) to (5.2 ± 1.33). The final color evaluation in our research was done in layered specimens including flat enamel bovine teeth, cement and layered ceramic sample of Chen's investigation was 4mm composite disk, cement and ceramic disk. The combination of the flat enamel surface human molar teeth, cement and ceramic disk was the layered substrate in Omar's research. As demonstrated, the exact comparison of these research studies is not possible due to the differences in variables.

The effect of substrate on the final appearance of ceramic restorations has been proven [20]. Therefore, the selection of the substrate that is most related to the clinical conditions is considered. Nonetheless, standardization of the color and surface properties of substrate is difficult, most research studies used composite substrate [5, 9, 10, 13] or no substrate [4, 19, 21]. Some studies used human molar [3, 17] or bovine teeth [2] to stimulate clinical conditions. A previous study showed that

curved surface of the teeth has a negative effect on the homogenous light reflectance to colorimeter [3]. It is difficult to provide an 8mm surface of human enamel without any dentine exposure due to tooth curvature. As a result, providing a smoother enamel surface with less curvature in the bovine teeth is more feasible than human teeth.

The cement composition varies according to the polymerization, volumetric shrinkage and size of filler. We expected that this difference can affect the optical behavior of the materials. Whatever our findings are, they were different from what was estimated.

The limitation of this research study included the *in vitro* use of one instrumental assessment to evaluate color parameters from exerting 1 shade of 1 type of ceramic veneer to bovine teeth with three types of resin cements, exactly after cementation without any aging. Consequently, future research on the clinical color matching of ceramic veneers with different resin cement types is required. Within the limitations of this study, ceramic veneer ΔE changes are clinically unacceptable (ΔE >2.69) after cementation, hence, care must be taken in the choice of cement to reach the best final color match possible. Nevertheless, there was no statistical difference between the types of cements. Ceramic veneers were darker after cementation with three different cements.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Tehran University of medical science ethical committee has approved this study. (Code: 96-03-70-36890)

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

This study is laboratory based, there is no need for written informed consent of participants.

AVAILABILITY OF DATA AND MATERIALS

The data sets analyzed during the current study are available from the corresponding author on request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest financial or otherwise.

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