INFLUENCE OF LUTING RESIN CEMENT POLYMERIZATION MODE AND VENEER THICKNESS ON THE COLOR STABILITY OF FELDSPATHIC CAD/CAM VENEERS

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ABSTRACT

INTRODUCTION: The color stability of the resin-based cement employed for the cementation procedure may be as important for the long-term clinical success of the restoration as the mechanical properties of the veneer.

OBJECTIVES: The aim of this study was to evaluate the effect of different polymerization modes of resin cements and ceramic thicknesses on the color stability of feldspathic CAD/CAM veneers.

MATERIALS AND METHODS: Sixty-four sound human maxillary central incisor teeth were divided according to ceramic veneer thickness used into two main groups (n = 32); Group I; 0. 5 mm ceramic thickness and Group II; 1 mm ceramic thickness, each group was then subdivided according to the type of resin cement received (Light cure LC or Dual cure DC) into four sub groups of 16 specimens each: Group I A:(0.5 + LC); Group I B:(0.5 + DC); Group II A:(1 + LC); Group II B (1 +DC) . Sixty four Ceramic discs were prepared; for group I, 32 discs of diameter 7 mm and height 0.5mm while for group II, 32 discs of diameter 7mm and height 1mm. The shade was measured using digital spectrophotometer at 3 different time intervals.

RESULTS: Ceramic thickness alone revealed statistically significant effect on the ΔE values of all groups (p ≤ 0.05), irrespective of the type of the resin cement. The highest mean ΔE values were recorded in group I A and the lowest ΔE values were recorded in group II B .There was statistically significant difference in ΔE 2 between groups IA and IB.

CONCLUSIONS: All studied cements showed ΔE within clinically acceptable range in both dual cure and light cure resin cements. Increasing ceramic thickness can serve to mask the underlying color change.

KEYWORDS: Porcelain laminate veneers, ceramic thickness, resin cement, Vita Easyshade.

RUNNING TITLE: Color stability of ceramic veneers.

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INTRODUCTION

Laminate veneers are indirect restorations performed by conservative techniques with the purpose of harmonizing the smile, restoring the adequate color, shape and function of esthetically compromised teeth (1). With the great emphasis placed on esthetics by today's society, the color stability of esthetic restorative materials is gaining critical importance (2).

In the clinical condition, only the margin of the luting agent film of the ceramic veneers that are cemented to tooth structures is exposed to the oral environment, which may result in its discoloration. Discoloration of resin cements is a common problem, particularly in translucent restorations. In fact, color changes in the restorations and the surrounding tissues are the primary reasons for the replacement of esthetic restorations (3).

However, the success of clinical treatment is multifactorial and depends on the perfect combination of colors between the restoration and remaining teeth, the color of the supporting tooth substructure, thickness, shade and type of ceramic and resin cement. Moreover, the restorative material's translucency shown by the amount of reflection and scattering of light is another factor (4-7). Together with all-ceramic

materials, resin-based cements are considered an essential part of the success and quality of esthetic treatments (8-9).

In the case of ultrathin restorations, such as ceramic veneers, the color stability of the resin-based cement employed for the cementation procedure may be as important for the long-term clinical success of the restoration as the mechanical properties of veneering material (10). The longevity of laminate veneer restoration is related to the material's color stability (11, 12) and the cementation technique (13, 14).

An important concern regarding the cementation step is to ensure optimal polymerization of the resin cement, since this influences its long-term color stability (15).

Adhesive technologies have improved significantly in the last few years, and both dual- and light-cure adhesive resins have been used as luting agents with porcelain laminate veneers (PLVs) (16-17). Light-curing materials used as luting agents are easily handled and are characterized by controllable hardening times and long-term color stability (4, 15, 19, 20). They also allow precise seating of the veneer and accurate removal of the excess cement. The dual-curing materials are advantaged by their self-curing component,

which favors conversion even in the presence of scarce radiant energy (21). Recently, new resin cements without a benzoyl peroxide/amine redox initiator system have been shown to be more color- stable (22).

Considering the importance of the color stability of a porcelain laminate veneer (PLV) for its long-term success, the aim of the study was to evaluate the effect of different polymerization modes of resin cements on the color stability of feldspathic CAD/CAM veneers of different thicknesses.

The null hypothesis tested was that the mode of polymerization of luting resin cement and veneer thickness used will not affect the color stability of feldspathic CAD/CAM veneers.

MATERIALS AND METHODS

The study was conducted after receiving the approval of the ethical committee at Faculty of Dentistry, Alexandria University, Egypt.

Sixty- four extracted human maxillary central incisor teeth were used to evaluate the effect of different modes of polymerization of resin cements and ceramic thicknesses on the color stability of ceramic veneers. Two resin cements Rely X Veneer (light cure) and Rely X ultimate (dual cure), (Ivoclar Vivadent, Schaan, Liechtenstein) – and glass-ceramic– IPS empress CAD (Ivoclar Vivadent, Schaan, Liechtenstein) – were selected for this study. The descriptions of the adhesives and the ceramic included in this study are summarized in (Table 1).

Selected teeth were free of caries, attrition, abrasion, cracking or previous restoration. The teeth were thoroughly debrided from all soft tissues or bone, and stored in chloramine solution at room temperature until use.

The root portion of all teeth was removed using carborundum discs, and the crown part was inserted into self-curing acrylic resin using a custom made split metallic copper mold with a fixed diameter exposing the labial surface upwards. The 64 specimens were randomly divided according to ceramic thickness into two main groups of 32 specimens each; Group I represented 0.5mm ceramic veneer thickness and Group II represented 1 mm ceramic veneer thickness, then each group was subdivided according to the type of adhesive resin cement used for cementation of the ceramic discs into four sub groups (Group I A, I B and Group II A, II B) of 16 specimens each.

Facial surfaces of the teeth were initially prepared by placing depth-orientation grooves (0.5 mm in depth) with a depth preparation bur. (Microdont , Rodovia Fernao Dias, Sao Paulo, Brazil).Then, the specimens were prepared without exceeding the depth-orientation grooves to provide flat enamel surface area, 5 mm in diameter, measured by a periodontal probe , for luting the ceramic discs to the middle third of the facial surface.

A total of 64 Empress CAD ceramic discs were obtained from multilayered glass-ceramic blocks (IPS Empress CAD HT I12 A1) using a microtome precision cutter (Isomet ™ 4000 linear precision saw, Buehler, USA), cutting at a speed of 350 rpm with a water cooling unit attached to the cutter. For group I, 32 discs were obtained of thickness 0.5 mm, diameter 7mm. (Figure 1) for group II, 32 discs were obtained of thickness 1mm, diameter 7 mm. (Figure 2)

The ceramic discs were bonded to the prepared teeth, specimens of groups IA, IB were cemented with light cure resin cement (Rely X veneer resin cement), while specimens of groups II A, II B were cemented with dual cure resin cement (Rely x ultimate resin cement). The cementation was performed under a constant load of 2.0 kgs for two minutes using a custom made static loading device to ensure uniform thickness of the cement during curing (custom made at Bio-Dental materials Department, Alexandria university).

The bonded specimens were thermocycled 1000 cycles between 5 °C and 55 °C with a dwell time of 15 seconds at each temperature (16).

All specimens were submitted to color readings using a digital Spectrophotometer (Vita Easyshade; VITA Zahnfabrik, Bad Säckingen, Germany) against a white background at three different time intervals; after the preparation (only the tooth substrate), after the cementation and polymerization of the veneers and after the accelerated artificial ageing (AAA) process. (Figure 3)

Figure (1): 0.5 mm thickness ceramic specimen

Figure (2): 1 mm thickness ceramic specimen

Figure (3): Calibration of Vita Easy Shade spectrophotometer against white background

Table (1): Materials composition

Brand name	Manufacturer	Composition
IPS empress CAD (Shade A1)	Ivoclar Vivadent, Liechtenstein	• SiO2 60.0 - 65.0 % by wt • Al2O3 16.0 - 20.0% by wt • K2O 10.0 - 14.0 % by wt • Na2O 3.5 - 6.5%by wt • Other oxides 0.5 - 7.0% by wt • Pigments 0.2 - 1.0% by wt • 1 – 5 µm leucite crystals (35–45 % by volume)
Rely X Veneer	3M Deutschland, Neuss, Germany	• Silane--treated ceramic (55-56% byWt) • TEGDMA (triethylene glycol dimethacrylate) (10-20-% by wt) • bisphenol a diglycidyl ether dimethacrylate (BISGMA)(10-2-% by wt) • silane treated silica(1-10% by wt) • reacted polycarpolactone polymer(1-10% by wt) • titanium dioxide(<1% by wt) • diphenyliodoniumhexafluorophosphate • Triphenylantimony
Rely X Ultimate	3M Deutschland, Neuss, Germany	**Base paste:** Silane--treated glass powder (50-60% by Wt) modified with 2-propenoic acid (20-30% by Wt),2-methyl-, reaction products with 2-hydroxy-1,3-propanedyl dimethacrylate and phosphorus oxide, TEGDMA (triethylene glycol dimethacrylate) (10-20-% by Wt), silane--treated silica, (1-1-% by Wt),Oxide glass chemicals (<3% bywt), sodium persulfate (<1%by Wt),Tertbutyl peroxy-3,5,5-trimethylhexanoate (0.25%byWt),copper acetate monohydrate(0.1% by Wt) **Catalyst paste** Silane-treated glass powder, substituted dimethacrylate,1,12-dodecane dimethacrylate, silane--treated silica1-benzyl-5-phentyl-barbic-acid, calcium salt, sodium p-toluenesulfinate, 2-propenic acid, 2-methyl-, di-2,1-ethanediyl ester, calcium hydroxide, titanium dioxide.

The color was evaluated according to the color system CIE La*b* (The LAB color model is a three axis color system where L axis represents lightness, a* axis goes from red to green, b* axis goes from yellow to blue) (28).

The difference in color was expressed as ΔE and is measured by the following equation (25).

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$; where ΔL^* is the variation of L^*, Δa^* is the variation of a^*, and Δb^* is the variation of b^*

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level.

The used tests were

1 - Student t-test

For normally distributed quantitative variables, to compare between two studied groups

2 - F-test (ANOVA)

For normally distributed quantitative variables, to compare between more than two groups, and Post Hoc test (Tukey) for pairwise comparisons

3 - Two way (ANOVA)

Was used to assess the effect of each factor and the interaction between them

RESULTS

By using Post Hoc test (Tukey) and Anova test for pairwise comparison between each 2 studied groups, it was found that light-cure resin cements showed lower Δ**E** values than dual cure resin cements in all studied intervals. Although there was no significant difference between the two resin cements in all studied intervals at 1mm thickness.

On comparing between types of resin cement (light cure/dual cure) used in each subgroup. Regarding ΔE 1, the highest mean ΔE was recorded in group **IA** (Dual cure +0.5mm) 14.67 ± 1.80, followed by group **IB** (Light cure +0.5mm) 13.74 ± 1.99, then group **IIA** (Dual cure +1mm) 9.11 ± 1.07, and the lowest Δ**E**1 was recorded in group **IIB** (Light cure +1mm) 8.42 ± 1.32. There was no statistically significant difference in Δ**E**1 between groups IA and IB (p1=0.358), and no statistically significant difference between groups II A and II B (p4=0.613); However statistical significance was found between group IB and IIB (p3<0.001) as well as between group IA and IIA (p2<0.001) (**Table 2**).

Table (2): Comparison between the different studied groups according to ΔE1

	Group IA (n = 16)	Group IB (n = 16)	Group IIA (n = 16)	Group IIB (n = 16)	F	p
ΔE1						
Min. – Max.	10.73–10.73	11.64–17.81	6.09–10.80	7.29 – 10.77		
Mean ± SD.	13.74 ± 1.99	14.67 ± 1.80	8.42 ± 1.32	9.11 ± 1.07	63.717*	<0.001*
Median	13.61	15.07	8.58	9.18		
Sig. bet. grps	p1=0.358, p2<0.001*, p3<0.001*, p4=0.613					

F: F for ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)
p: p value for comparing between the studied groups
p1: p value for comparing between Group IA and Group IB
p2: p value for comparing between Group IA and Group IIA
p3: p value for comparing between Group IB and Group IIB
p4: p value for comparing between Group IIA and Group IIB
*: Statistically significant at p ≤ 0.05

On comparing between types of resin cement (light cure/dual cure) used in each subgroup. Regarding Δ E 2,the highest mean delta E was recorded in group **I A** (Dual cure +0.5mm) 3.15 ±0.40, followed by group **IB** (Light cure +0.5mm), 2.45 ± 0.42 then group **II A** (Dual cure +1mm), 2.06 ± 0.34 and the lowest Δ E 2 was recorded in group **II B** (Light cure +1mm) 1.89 ± 0.42. There was no statistically significant difference in Δ**E2** between groups IIA and II B (p4=0.618). However statistical significance was found between group IA and IB (p1<0.001)*, as well as between group IA and IIA p2<0.001and between groups IB and IIB (p3=0.001) (**Table 3**).

Table (3): Comparison between the different studied groups according to ΔE2

	Group IA (n = 16)	Group IB (n = 16)	Group IIA (n = 16)	Group IIB (n = 16)	F	p
ΔE2 Min.-Max.	1.71– 3.28	2.13 – 3.77	0.71 – 2.42	1.0 – 2.55		
Mean ± SD.	2.45 ± 0.42	3.15 ± 0.40	1.89 ± 0.42	2.06 ± 0.34	31.701[*]	<0.001[*]
Median	2.31	3.15	2.01	2.17		
Sig. bet. Grps	$p_1<0.001^*$, $p_2<0.001^*$, $p_3=0.001^*$, $p_4=0.618$					

F: F for ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)
p: p value for comparing between the studied groups
p_1: p value for comparing between Group IA and Group IB
p_2: p value for comparing between Group IA and Group IIA
p_3: p value for comparing between Group IB and Group IIB
p_4: p value for comparing between Group IIA and Group IIB
*: Statistically significant at $p \leq 0.05$

On comparing between types of resin cement (light cure/dual cure) used in each subgroup. Regarding Δ E3, the highest mean delta E was recorded in group **I A** (Dual cure +0.5mm) 11.95 ± 1.85,followed by group **IB** (Light cure +0.5mm), 11.94 ± 2.65 then group **II A** (Dual cure +1mm) 7.58 ± 1.23, and the lowest Δ E was recorded in group **II B** (Light cure +1mm) 4.89 ± 1.28.There was no statistically significant difference in ΔE3 between groups IIA and II B (p4=0.817) as well as groups IA and IB (p1=1.000). However statistical significance was found between group IA and IIA (p2<0.001) as well as between groups IB and IIB (p3<0.001).

DISCUSSION

A requirement for successful esthetics of ceramic restorations over the years is its color stability. In general, laminate veneer restorations are relatively thin and reflect the color of the cement. However the final color of translucent ceramic restoration is influenced by several factors such as ceramic type, color of underlying tooth structure and more importantly the luting cement type and ceramic thickness (2).

The results of the study indicate that the first hypothesis was partially accepted, it could be said that amine free dual cure resin cements performed as well as light-cured cements in terms of color stability. The results of the study indicate that the second hypothesis was rejected because the restoration thickness was a significant factor for color stability of feldspathic veneers.

The type of substructure of a translucent restoration may influence the color readout. In the present study, color readouts were taken before and after aging, so the substrate would not interfere in the final color results (23).

In this study, samples 0.5 and 1.0 mm thick were used; it is known that a standard laminate thickness is 0.7 mm (24). However, in a clinical situation, it is not always possible to get laminates of that exact measure, so it was considered important to foresee what would happen with greater or lesser thicknesses.

The Vita Easyshade compact digital spectrophotometer was used as a standard quantifying device for measuring color difference, it uses the ΔE from the Commission International d'Eclairage CIE (L*a*b*) color system. Some researchers reported that a unit of color difference in CIE L*a*b* color system is a visual color change which can be detected with human eye (6, 15). On the other hand, there are several opinions in literature about the threshold value for a clinically acceptable and visual color difference. This value is reported over 3.33 (6, 16-19), 3.5 (15) or 3.7 (20). We adopted the threshold value of 3.5 for clinically accepted color difference when interpreting the results of this study.

In this study, 1000 cycles were used to represent a year of aging, this is similar to the work of Diamantopoulou et al (25) where he suggested that 1500 thermal cycles would be similar in physiologic normal conditions to the period of 1 and a half of year for resins. For the thermocycling process the temperature regimen of 50 –550 C proposed in ISO 11405 recommendations (International Standards Organization, 1994) was used in this study (26), dwell time of 30 seconds was chosen similar to other studies.

Both the dual and light-cured resin cements presented higher ΔE1 ΔE2, ΔE3 values (i.e greater color change) when used for bonding 0.5mm veneers in all studied intervals, with statistically significant difference (p<0.05) in comparison with the 1.0 mm thick veneer. Previous studies showed that in order to cover the color changes of the underlying cement, the ceramic thickness should be at least 2mm (27, 28). Nevertheless, based on the results of the present study, 1mm thickness of feldspathic porcelain veneer serves to mask the color change of the underlying cement since the opacity of ceramic increases with increased thickness.

Our findings are in corroboration with the study of, Archegas et al. (29) and Alqahtani et al. (30) who concluded that 0.7 mm thickness produces a better masking effect when compared to 0.5mm thickness. Thus the results of the present study support the rejection of the second null hypothesis that ceramic thickness does not influence the color stability of feldspathic veneers.

Regarding **ΔE1**, representing the period immediately after cementation, results of the current study showed significant detectable color changes (ΔE1 >3.3) for both RelyX Ultimate and rely x veneer composite resin cements regardless of ceramic thickness. However there was no significant difference between the two resin cements at same thickness. These results are consistent with the study of Qahtani et al (30), which concluded that restoration with veneers results in the final color. These results could be justified by the fact that most of the color changes of the resin cement occur during the first 24 hours of polymerization.

After aging of the tooth ceramic specimens, represented in this study as **ΔE2,** color changes were evident in all groups regardless of restoration thickness, however all within clinically acceptable range (<3.3). As expected, light cured resin cements showed lower **ΔE** values in comparison with the dual cure resin cements. These findings are in accordance with the results of Smith et al, (31) who showed that resin cements lacking benzoyl peroxide and an amine redox initiator system are more color stable.

However, statistically significant difference was evident between the two resin cements at o.5 mm thickness with slightly lower values for the light cure resin cement. This

114

could be explained by the fact that light cure cements contain aliphatic amines in their structure which over time, is more color stable compared to dual- cured cements.

Our study has similar findings to Silami et al (32) who concluded that the thickness of the restoration influences color and luminosity changes for conventional dual and light-cured cements, however, in their study there was significant difference between the cements at 0.5 and 1mm thickness.

This comes in opposition to the studies of Almeida et al (33), Hao Yu et al (34) stating that dual cure resin cements show inferior color stability. However, we found in their studies that the dual cure resin cement tested contains aromatic amine responsible for the color shift. Dual polymerizing cements have tertiary amines in their composition that act as chemical initiators for the polymerization reaction. For this reaction to occur, oxidation of the amine reactive groups is necessary and this may cause color changes (16). These materials contain a combination of different amines. One amine reacts with benzoyl peroxide (chemical polymerization/redox polymerization reaction) that is generally aromatic and more prone to degradation and another amine reacts with camphorquinone (light polymerizing). The latter is usually aliphatic and chemically more stable. In the chemical reaction, the unreacted benzoyl peroxide may also cause color instability (15, 16, 23).

Our results are supported by Ghavam el al.(35), and Magalhaes et al (36) who had similar results and statistical findings to the ones in our study, where the color content of the resin\ceramic specimens was measured, and a conclusion that there were no significant differences (after artificial accelerated aging) between dual- and light-cured modes of both cements like in our study where all of the resin cements showed a ΔE that remained in the range of clinical acceptance, although in our study there was a significant statistical difference between the dual and light cured groups in 0.5 mm thickness.

Also, Lucia et al (37) and Nijad et al (38) had similar findings to the ones in our study that most color variations occurred in the first 24 hours of polymerization, with relatively nonsignificant variations afterwards.

Also, Mesbah et al (39) concluded that the Rely X Ultimate (dual cured) resin cement could be used to cement veneers with a high final esthetic outcome and color stability like that of the light cured resin cements, however, contrary to our study the dual cure resin cements showed lower delta e values compared to light cured cements.

Thus, the first null hypothesis can be accepted. In agreement with the findings of Alkurt et al (40), it can be said that dual-curing resin cements performed as well as light curing resin cements within the limitations of this study.

The results of this study demonstrated that the effect of ceramic thickness on the color stability of veneers was much higher than the effect of the resin cement type, according to the results of the statistical analysis of the tested resin cements, there was no significant difference between the 2 different resin cements on comparing between groups of same thickness

CONCLUSION
1) The color changes of both light- and dual-cure resin cements were within clinically acceptable limits.

2) Although light cure resin cements had lower ΔE values than dual cure cements, the difference was not significant.
3) Increasing ceramic thickness serves to mask the underlying color change.

CONFLICT OF INTREST

The authors declare that they have no conflicts of interest.

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