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Original Article

Effect of Accelerated Aging on the Color Stability of Light-cured Resin Cement and Flowable Composite Through Porcelain Laminate Veneer

M. Hoorizad Ganjkar [1], H. Heshmat [1], M. Gholamisinaki [2], M. Emami Arjomand [1].

[1] Assistant Professor, Department of Operative Dentistry, Dental Research Center, Islamic Azad University, Dental Branch, Tehran, Iran
[2] Dentist, Private Office, Tehran, Iran

Abstract

Background and Aim: Changing the color of resin luting cements could affect the aesthetic appearance of thin porcelain veneer. The aim of this in vitro study was to evaluate the effect of artificially accelerated aging on color stability of light-cured resin cement and flowable composite as a luting agent through the porcelain veneer.

Materials and Methods: This experimental study was carried out on 4 groups each contained 5 specimens with the dimension of 8 mm in diameter and 1 mm thickness. In group 1 and 2 five disks of resin cements and flowable composite were prepared, respectively. In group 3 and 4, the luting agent (1mm thickness) were bonded to feldspathic ceramic discs (1mm thickness). The color parameters of the samples in CIE Lab system were measured by spectrophotometer before and after artificially accelerated aging. The results were statistically analyzed by Two-way ANOVA and t-test.

Results: The highest color change was observed in Z350 flowable composite that showed a statistically significant difference with other groups ($P<0.001$). Differences between veneered groups were not significant ($P=0.04$). Color changes in groups 3 and 4 which covered with porcelain laminate were statistically lower than uncovered groups and the differences were significant ($P<0.001$).

Conclusion: Accelerated aging process could influence clinically unacceptable changes in the color of luting agents ($\Delta E>3.3$). However, porcelain laminate with 1 mm thickness could cover the color changes of luting agent.

Key Words: Aging, composite resins, Dental veneers, resin cements

Corresponding author:
M. Hoorizad Ganjkar, Assistant Professor, Department of Operative Dentistry, Dental Research Center, Islamic Azad University, Dental Branch, Tehran, Iran

mahoorizad@yahoo.com

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Introduction

One of the critical aspects of operative dentistry is the color stability of the luting cement especially at the margins, which can affect the aesthetic appearance of thin ceramic laminates [1,2]. As these restorations are mostly in the anterior region and are easily visible, any color changes can compromise person's smile. High expenses of restoration and the waste time for correction are considerable problems for both patients and dentist. Ceramic veneers possess characteristics which make them suitable restoration despite the above-mentioned problems, including higher resistance to color changes, compatibility with oral environment, clinical durability, natural appearance and translucency which render a natural tooth appearance [3].

Today, despite all the improvements and a wide range of ceramics available in the market, feldspathic porcelains are more popular because

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they have the most similarity in opalescence and fluorescence properties to the natural tooth structure, therefore, in the cases of the acceptable color match, feldspathic porcelains provide a more natural appearance to the restoration [4].

Several studies were conducted on the effect of accelerated aging on the color changes of different veneers with variety of ceramic types, thicknesses, and different types of resin cement [1,2,3,5,6].

Aging considered as one of the most important factors in discoloration of resin materials. Ceramic restorations in the oral cavity are exposed to a range of circumstances, such as temperature variations, and changes in chemical elements because of consumed food and beverages. Also, incisor teeth can be subjected to the visible light and UV irradiation. These factors can change the color of the luting resin cements of these restorations [7] which is one of the most important reasons for the color changes of laminate veneers. [2,8,9].

Accelerated Artificial Aging (AAA) process which is usually performed in a laboratory by controlled standard test methods, has been used in several studies in order to compare the color stability of a wide range of dental materials.(10) According to previous studies, AAA method is suitable for evaluating changes in the physical, chemical and optical structure of the none-metallic materials such as composites and resin cements [10-13]. AAA can cause irreversible discoloration of the materials by resonance conditions of light, temperature, and humidity [13].

According to several studies, light-cured resin cements are preferred for bonding the laminate veneers with the thickness less than 1mm, because of their color stability characteristics compared to self-cured and dual-cured resin cement which contains some amine that causes color instability [1,6,9,14]. Besides color stability, the most important advantages of light-cure resin cements are their longer working time compare to self and dual-cured resin cements. so it is more convenient to remove extra substances and it cause less time for finishing the procedure [15]. In some of the previous studies, flowable composites have been alternatively used instead of resin cements for luting of porcelain veneers due to their simplicity of application and cost-effectiveness [1].

Based on existing studies, the use of CIE L∗a∗b∗ system for evaluating the color changes in dental materials have been increased because of more reliable results [16]. The human eyes are unable to distinguish $\Delta E \leq 1$ and quantities between 1 and 3.3 only can be seen by the skilled practitioner [17]. The majority of studies have been reported that $\Delta E \leq 3.3$ is clinically acceptable [18,19] Spectrophotometers are useful, accurate, and replicable devices for comparing the shades and colors in dentistry. They also give numerical description for the color perception which could be evaluated and compared, statistically [20].

The purpose of this in vitro study was to investigate the effect of aging on light-cured resin cement and flowable composite discoloration through feldspathic porcelain discs.

Materials and Methods

In this experimental study, four groups each containing 5 specimens, were compared. The materials information are presented in Table 1, resin cement (Rely X veneer, 3M ESPE, USA) and flowable composite (Z350 Filtek, 3M ESPE, USA) were of the A1shade and the shade of the feldspathic porcelain (Noritake, Kuraray, Japan) was A2.

A stainless steel mold with 8 mm diameter and 1 mm height was used to fabricate the resin cement and flowable composite samples in groups 1 and 2, respectively. Stainless steel mold was placed over a glass slab, covered with a Mylar sheet on a dark background. The mold was filled with each material, covered with a Mylar sheet and a glass slab, and 10 N force was applied for 20 seconds at the top of each sample [6]. After removing excess cement, each specimen was cured by means of a LED device (Demetron, Kerr, USA), using overlapping method for 40 seconds in each area. The light intensity of LED curing unit was 700 mw/cm^2 which initially was measured at the beginning of sample preparation and then after every 3 specimens were cured. The thickness of all samples was measured by digital caliper (Electronic digital caliper, Shan, China).

In groups 3 and 4, feldspathic porcelain discs (8mm∅×1mm) were luted to the resin cement and flowable composite, respectively. Porcelain discs were fabricated according to the manufacturer's

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Table1. Materials used in the study

Materials	Manufacturer	Composition
Rely X Veneer	3M-ESPE, USA	Bis-GMA, TEGDMA, zirconia/silica filler Filler:66Wt%
Filtek Z350 Flow	3M-ESPE, USA	Bis-GMA, Bis-EMA, TEGDMA, zirconia/silica filler Filler: 65Wt%
Feldspathic porcelain	NORITAKE, kuraray, Japan	Alumina, lusite, silicon dioxide
Porcelain Etch	ULTRADENT, USA	9% Buffered Hydrofloric Acid
Silane	ULTRADENT, USA	3-methacryloxypropyltimethoxysilane (MPTS)
Bonding (single bond)	3M-ESPE, USA	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system, methacrylate functional copolymer of polyacrylic and polyitaconic acids

instruction. The porcelain discs were cleaned ultrasonically for 10 min and their bonding surfaces were treated according to the manufacturer's manual as follows: first, 9% Hydrofluoric acid (porcelain Etch, Ultradent, USA) was applied for 90 seconds, then specimens were rinsed with water and dried with oil-free air for 90 seconds. Subsequently, a layer of silane (Ultradent, USA) was applied and gently dried with an oil-free air spray. Then a thin layer of bonding (Single Bond, 3MESPE, USA) was applied and cured for 40 seconds using the overlapping method. After preparation of the unglazed surface, porcelain discs were placed over the stainless steel mold filled with either resin cement (group 3) or flowable composite (group 4) and subjected to 10 N force for 20 seconds [6]. After removing the excess cement, samples were cured with the same method which explained for groups 1 and 2.

Initial color measurement in all 4 group was performed on a white background according to the ISO7491 [9] utilizing a spectrophotometer device (Ihara-spcam spectrophotometer, CS-2000, Nederland), and color of each sample was measured three times in the CIE L a b system. Afterwards, specimens were subjected to accelerated artificial aging according to the ASTM G154-06 [12] protocol using a weathering machine (QUV/Spray, USA, New York) for 300 hours which is equal to 1 year of clinical function [10]. After accelerated aging, the final color of each sample was measured the same way as described before. ΔE was calculated according to the following formula:

$$\Delta E=\sqrt{(\Delta a^2)+(\Delta b^2)+(\Delta L^2)}$$

in which L* represents the lightness of the color (L*=0 is black and L*=100 is white), a* represents the position between red and green (−a=green, +a=red), and b* shows the position between yellow and blue (−b=blue, +b=yellow).

Two-way ANOVA was used to evaluate the differences between groups and T-test was used to compare the color changes before and after aging. The significance level was considered equivalent to $P<0.05$.

Results

Results of the present study are summarized in Table 2. Two-way ANOVA showed that the most color changes happened in group 2 (flowable composite) with the ΔE=18.16±1.71 followed by group1 and 3with the ΔE=5.41±1.05 and ΔE=1.65±0.27, respectively. The lowest value of color changes was observed in group 2(veneered flowable composite) with the ΔE=1.21±0.55.

T-test showed that the aging process caused significant color changes in resin cement and flowable composite groups ($P<0.001$), whilst aging did not have a significant effect on color changes in veneered groups ($P=0.04$).

according to the CIELAB analysis, the changes in lightness (L) was not significant in all groups

Table 2. Results of color measurements in experimental groups
(values are presented as mean ± standard deviation)

Groups	L*			a*			b*			ΔE
	BA	AA	ΔL	BA	AA	Δa	BA	AA	Δb	
1	89.88±0.74	88.70±1.51	1.18±0.86	-0.35±0.86	-2.00±0.14	1.35±0.11	3.18±0.27	8.20±1.41	5.01±1.22	5.41±1.05[a]
2	93.19±1.27	87.81±0.91	5.38±0.65	-0.66±0.15	-1.76±0.35	1.9±0.25	2.81±0.63	20.05±1.92	17.24±1.59	18.16±1.7[b]
3	95.36±0.59	94.93±0.79	0.43±0.97	-1.39±0.10	-0.85±0.106	0.54±0.09	8.75±0.31	10.00±0.34	1.24±0.15	1.65±0.27[c]
4	95.57±1.22	94.99±1.70	0.58±0.81	-0.95±0.22	-0.62±0.21	0.33±0.09	9.54±1.14	10.31±1.19	0.76±0.42	1.21±0.55[c]

BA= before aging; AA= after aging. Same superscript means no statistical differences (P<0.05).

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(P=0.164). Changes in the redish green Hue (a) in all groups was not significant (P=0.075). The changes in bluish-yellow Hue (b) in group 1 and2 were significant (P=0.001).

Discussion

The present study was performed in order to compare the effect of artificial accelerated aging on color changes of resin cement and flowable composite resin and to evaluate the effect of porcelain veneer on this color change. The results showed that aging caused significant changes in the ΔE of luting materials, however, porcelain veneer would be able to cover it. Previous studies showed that porcelain veneers are relatively color stable however, it has been mentioned that in order to cover the color changes of the underlying substrate, the ceramic thickness should be at least 2mm [6,10,21,22]. Nevertheless, based on the results of the present study, 1mm thickness of feldspathic porcelain veneer could cover the color changes of resin cements. Another probability might be due to the barrier effect of veneers which prevent luting cements from receiving aging elements such as UV light, humidity, and temperature changes. Furthermore, several studies have shown that color changes of resin cements were more prominent when cements were not covered with ceramic veneers [1,2,9,23]. However, it should be considered that color stability of uncovered cement groups is a matter of concern because they are representing the exposed cement at the margin of the restorations.

In this study, based on the ASTM G154-06, the UVA-340 nm was used for AAA which was intended to reproduce the exposure of the material to the sunlight in actual usage [12]. Specimens were located in QUV/Spray device for 300 hours which according to the ASTM protocol, is equivalent to one year of clinical function [13,23].

The results of the present study showed that color changes of resin cement were significantly less than flowable composite, although the value of ΔE was higher than 3.3in both groups which mean the color changes were clinically detectable. In spite of the similarity in filler type and their volume percentage, the color stability of two luting cements was different which could be attributed to the differences in filler size, weight percentage, distribution, and their activator-initiator system.

Feldspathic porcelain veneer could cover the color change as it was shown in the present study; theΔE value in both veneered groups was less than the clinically detectable value (ΔE<3.3).

Similar to the previous studies, the result of the present study confirmed that light-cured resin cements could be recommended for cementation of anterior veneers. [2,24-26] Light-cured cements contain aliphatic amines in their structure which over time, is more color stable compared todual-cured cements [9,27]. On the other hand, thecolor stability of dual-cured resin cementsis lower due to oxidation of the aromatic and aliphatic amines which are responsible for initiating the polymerization [28]. Therefore, they are not suitable for cementing feldspathic porcelain veneers, especially when veneer's thickness is less than 1mm. While According to some studies, remaining camphorquinone in light activated resin cements and exposure of Bis-GMA based material to the heat and ultraviolet light would be the reason for the yellowish color change over the time [1,28,29].

Similar to the previous studies, the ΔL* value was negative in all specimens in the present study which means the specimens have become darker after changes was not statistically significant [1,6]. In a * value which represent the green–red aspect of a material, the changes were not significant too. In the b* value which represents yellow-blue chroma perception, changes were significant specially in flowable composite, which might have been changed due to the presence of camphorquinone and Bis-GMA resin in both materials. The high changes in the b* value of Z350 flowable composite resin may also be due to filler particle size [1,6].

Based on the results of present study the Accelerated Aging would cause the luting cements' color to changes", whilst accelerated aging didn't significantly affect the total porcelain veneer-luting cement appearance and both veneered groups had clinically acceptable color stability after accelerated aging (ΔE ≤ 3). However, marginal discoloration of resin cement could still anesthetic problem especially in anterior teeth.

Conclusion

Based on the results of the current study, accelerated aging process could produce clinically

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unacceptable changes in the color of luting agents (ΔE>3.3), however, porcelain laminate with 1 mm thickness could cover the color changes of luting cement.

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