RESEARCH PAPER

Color Match of Porcelain Veneer Light-Cure Resin Cements with Their Respective Try-in Pastes: Chemical Stability

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ARTICLE INFO

Article History:
Received 09 Feb 2023
Accepted 21 May 2023
Published 27 May 2023

Keywords:
Color
Spectrophotometry
Resin Cements
Dental Veneers

ABSTRACT

This study aimed to assess the color match of porcelain veneer light-cure resin cements with their respective try-in pastes. Ten disc-shaped specimens with 0.5 mm thickness and 7 mm diameter were fabricated from Choice 2, Panavia V5, and Variolink Esthetic resin cements using silicon molds, and then light-cured. A cuvette was used for evaluating uncured resin cements and try-in paste specimens. The cured (n=30) and uncured (n=30) resin cement specimens as well as the try-in paste specimens (n=30) underwent reflectance spectrophotometry for determining their L*, a* and b* color parameters. The color difference (ΔE) between the cement specimens and their try-in pastes in the three groups was calculated and analyzed using one-way ANOVA and Tukey's test. Minimum ΔE was observed between the cured Variolink and its try-in paste (ΔE=6.5), as well as between its cured and uncured specimens (ΔE=6.2). The mean L* value of cured Variolink and its try-in paste was higher than the corresponding values for the other two cements. The cured specimens of Variolink showed higher mean a* and b* values than the cured specimens of the other two cements. The mean a* and b* parameters of Variolink try-in paste were also higher than the corresponding values in the other two try-in pastes. Try-in pastes can be used for the assessment of final color of cemented restorations. Cured Variolink and its try-in paste were lighter and yellower than the other two cements and their try-in pastes.

How to cite this article
Zadeh Dadashi M., Kazemian M., Malekipour Esfahani M., Color Match of Porcelain Veneer Light-Cure Resin Cements with Their Respective Try-in Pastes: Chemical Stability. Nanochem Res, 2023; 8(3): 205-214 DOI: 10.22036/ncr.2023.03.006

INTRODUCTION

Patients often prioritize the appearance of their teeth and prefer tooth-colored restorations, which can be either direct or indirect [1]. Indirect restorations are created outside of the mouth, either in a laboratory or chairside, and are then secured in place using resin cements [2]. These restorations can take the form of full crowns, inlays, onlays, or veneers, which are thin layers of ceramic restoration that cover the front and some of the sides of a tooth [3][4]. Resin cements are a type of dental cement used to secure indirect restorations, and they can bond to both tooth structure and the internal surface of restorations. They are composed of the same primary components as composite resins but with a lower filler content. Compared to traditional cements, resin cements have higher tensile, flexural, and compressive strength, making them suitable for use with nearly all types of restorative materials [5]. Self-cure resin cements often contain tertiary amine benzoyl peroxide, which can darken over time; however, some cements, such as Panavia V5, include other initiators to prevent discoloration [6].

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The monomer composition of resin cements often includes HEMA, TEGDMA, UDMA, BISGMA, and GDMA, which are responsible for the durability, strength, water sorption, and solubility of resin cements [7]. The resin cement fillers typically include fluorosilicate, strontium glass, barium glass, zirconia oxide, silica oxide, pyrogenic silica, and ytterbium fluoride. These fillers are responsible for the radiopacity, strength, fluoride release potential, polishability, and film thickness of cements [8]. Resin cements are available in a variety of colors, including white, brown, universal, clear, and opaque; those with opaque color are often self-cure [6]. Resin cements can be divided into three categories based on their curing mechanism: light-cure, self-cure, and dual-cure. In light-cure and dual-cure forms, a photo initiator such as camphorquinone or acyl phosphine oxide is activated by a light-curing unit, resulting in the formation of free radicals, which react with the polymer matrix and form a cross-linked network. Camphorquinone has a low tendency to generate free radicals on its own. However, when combined with an amine, its reactivity increases. Recently, thiocarbamide has been used instead of amine groups (as in Variolink Esthetic dual-cure cement), leading to higher color stability of the final product [4].

The success of ceramic veneers depends on the color stability of the cement layer over time and the bond strength between the porcelain and enamel [9]. Correct patient selection, shade selection, tooth preparation, impression technique, and flawless fabrication of ceramic veneers are all essential for achieving a successful outcome. Additionally, the color of the cement is a major factor that can significantly influence the final result. To enhance the predictability of the outcome following the cementation of ceramic veneers, try-in pastes are used during the try-in step of the veneers. Water, water-soluble gels, coconut oil, or try-in pastes can be employed for the try-in of ceramic veneers [10]. The color of try-in pastes should precisely match the color shade of the respective resin cement in order to allow the dental clinician and patient to assess the final color of the veneers after cementation and curing. This is necessary to ensure the selection of the correct cement color [9]. Thus, it is imperative to ensure the reliability of the color of try-in pastes and their color match with the cement [9].

Several tools are commonly used for color assessment in dentistry such as spectrophotometers and colorimeters [4], which easily and accurately analyze the tooth color [11]. A spectrophotometer can analyze the color by measuring the three parameters of value, hue, and chroma, which can then be used to calculate color change or color difference (ΔE). In the CIE L*a*b* color space, defined in 1931 for color perception, L* indicates lightness, a* denotes redness-greenness, and b* represents yellowness-blueness. Xu et al, [12] and Rigoni et al. [13] found that some try-in pastes provided satisfactory color matches, but not for all. Considering all the above, this study aimed to compare the color match of the clear shade of three commonly used resin cements and their respective try-in pastes, namely Variolink Esthetic (Ivoclar), Choice 2 (Bisco), and Panavia V5 (Kuraray).

MATERIALS AND METHODS

Color Difference Evaluation of Resin Cements and Their Try-in Pastes

This in vitro, experimental study evaluated disc-shaped specimens fabricated from the clear shade of Variolink Esthetic (Ivoclar, Lichtenstein), Choice 2 (Bisco, USA), and Panavia V5 (Kuraray, Japan) in cured and uncured forms, and their respective try-in pastes. The sample size was calculated to be 10 in each group considering α=0.05, beta=0.2, and 80% study power. Table 1 presents the composition of the cements used in this study. Disc-shaped specimens with 0.5 mm thickness and 7 mm diameter were fabricated from the translucent shade of Choice 2 and its try-in paste, neutral shade of Variolink Esthetic and its try-in paste, and clear shade of Panavia V5 and its try-in paste using silicon molds. To fabricate the cured specimens from each cement type, circles with 7 mm diameter were punched out of a silicon sheet with 0.5 mm thickness. The diameter of the circles was measured by a caliper, while the thickness of silicon was measured by a porcelain gauge to ensure the correct dimensions of the molds.

Ten disc-shaped specimens with the abovementioned dimensions were fabricated from the specified resin cements in the silicon molds and placed against a dark background to decrease light reflection from the underlying surface. They were also cured with an LED curing unit (Demi; Kerr, Orange, CA, USA) with a light intensity of 1100=1330 mW/cm^2, wavelength of 450-470 nm, a curing time of 20 s for each specimen, and distance 1 mm between the curing tip and specimen surface. All specimens were then incubated for 24 h. Since

Table 1. Composition of cements used in this study

Cement name	Manufacturer	Cure mode	Composition of cement	Composition of Try-in paste	Fillers	Initiator	Shades	Lot No.
Choice 2	Bisco Inc., (USA)	Light	Bis-GMA	Glycerin Gel, Pigments	Strontium Glass, Amorphous Silica	Amine Free Initiator	A_1, A_2, A_3, B_1, C_2, Translucent, Universal, milky, Milky Brown	1700002351
Variolink Esthetic	Ivoclar Vivadent (Germany)	Light Dual	Bis-GMA TEGDMA UDMA	Glycerin Gel, Pigments	Barium Glass, Ytterbium Trifluoride, Glass Fluorosilicate Barium, Aluminum Mixed Oxide Spheroidal	Ivocerin	Light, Light +, Neutral, Warm, Warm +	V44691
Panavia V5	Kuraray (Japan)	Dual	Paste A: Bis-GMA, TEGDMA, Hydrophobic Aromatic Dimethacrylate, Hydrophilic Aliphatic Dimethacrylate. MDP. Paste B: Bis-GMA, Hydrophobic Aromatic Dimethacrylate, Hydrophilic Aliphatic Dimethacrylate.	Glycerin Gel, Pigments	Silanated Barium Glass Filler, Silanated Fluoroaluminosilicate, Glass Filler, Colloidal Silica, Silanated Aluminum Oxide Filler	Dl-Camphorquinone	Universal A_2, Clear, Brown A_4, White, Opaque	260009

the chamber of spectrophotometer is vertical and designed for solid specimens, the evaluation of viscous or liquid materials such as try-in pastes or uncured cements could yield unreliable results due to the potential for flow of the substrate. Thus, for this purpose, we designed a costume-made, disc-shaped glass cuvette with an internal diameter of 7 mm, a maximum external diameter of 10 mm, and a depth of 0.5 mm to match the dimensions of specimens.

Fabrication and Spectrophotometric Analysis of Custom Cuvettes for Accurate Color Difference

Pipettes with an external diameter of 9 mm and internal diameter of 7 mm were used to fabricate cuvettes. These pipettes were laser-sectioned to a height of 0.5 mm, and their dimensions were then measured with a caliper and a gauge to ensure they met the desired specifications (Fig. 1). Next, a reflectance spectrophotometer (Data Color International, NJ, USA) was first adjusted with the cuvette to eliminate any confounding effects of the optical properties of the cuvette on the results. Subsequently, 30 cured specimens, 30 uncured specimens, and 30 try-in paste specimens all in cuvettes were subjected to spectrophotometry against a white background and irradiated with light at 360-740 nm wavelength. By measuring the reflected light, the spectrophotometer measured the L*, a* and b* color parameters according to the CIE L*a*b* color space, and the color difference (ΔE) was then calculated accordingly.

Statistical Analysis of Color Difference between Resin Cements

Data were analyzed by SPSS version 22 at 0.05 level of significance. The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. One-way ANOVA followed by Tukey's test (for pairwise comparisons) were then applied to compare the ΔE values between the cements and their respective try-in pastes.

RESULTS AND DISCUSSION

Comparative Analysis of Color Differences in Resin Cements and Their Try-in Pastes

According to the Kolmogorov-Smirnov test, the L*, a*, b* and ΔE data had a normal distribution in all three groups. Subsequently, parametric tests were applied to compare the mean ΔE between the cured cements and their respective try-in pastes, as well as cured and uncured cement specimens in the three

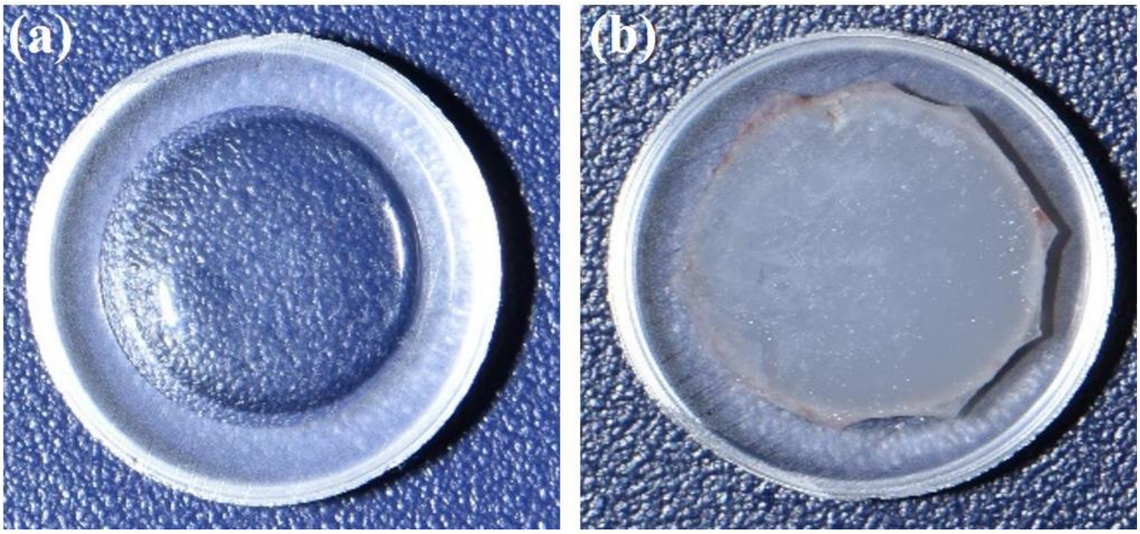

Fig. 1. Custom-made cuvettes a) with and b) without the specimen

groups (Table 2). A one-way ANOVA revealed a significant difference in the mean ΔE between cured specimens and their try-in pastes among the three groups (P<0.001). Tukey's test was then applied for pairwise comparisons, and no significant difference was found in the mean ΔE between cured cement specimens and their respective try-in pastes in comparing Choice 2 and Panavia V5 (P=0.91). However, the mean ΔE between the cured cement specimens and their respective try-in pastes in both Choice 2 and Panavia V5 groups was significantly higher than that in the Variolink group (P<0.001). An independent sample t-test also indicated that the mean ΔE between the cured cements and their respective try-in pastes in all three groups was significantly higher than 3 (P<0.001). The one-way ANOVA also revealed a significant difference in the mean ΔE between cured and uncured cement specimens among the three groups (P<0.001). Tukey's test showed no significant difference in this respect between Choice 2 and Panavia V5 (P=0.32). However, the mean ΔE between cured and uncured cement specimens in Choice 2 and Panavia V5 was significantly higher than that in the Variolink group (P<0.001). The independent sample t-test also indicated that the mean ΔE between cured and uncured specimens in all three groups was significantly higher than 3 (P<0.001).

Table 3 shows the mean L* parameter in cured cements and their respective try-in pastes in the three groups. A one-way ANOVA revealed a significant difference in the mean L* of cured specimens in the three groups (P=0.01). Tukey's test found no significant difference in the mean L* between Choice 2 and Panavia V5 (P=0.96). However, the mean L* in Choice 2 and Panavia V5 groups was significantly lower than that of the Variolink group (P<0.05). In addition, the one-way ANOVA indicated a significant difference in the mean L* of try-in pastes of the three groups (P=0.01). This value was not significantly different between Choice 2 and Panavia V5 according to Tukey's test (P>0.05). However, the mean L* of Choice 2 and Panavia V5 was significantly lower than that of the Variolink group (P<0.006). Comparing ΔL between the cured cements and their respective try-in pastes among the three groups revealed a significant difference (P=0.01). Tukey's test showed no significant difference in this respect between Variolink and Choice 2, and this difference was mainly attributed to the difference between ΔL of Panavia V5 and that of other two groups.

Table 4 presents the mean a* parameter of cured cements and their respective try-in pastes in the three groups. A one-way ANOVA revealed a significant difference in the mean a* of cured specimens among the three groups (P<0.001). Additionally, pairwise comparisons showed that the mean a* in Choice 2 was significantly lower than that of Panavia V5 (P=0.007). Further, the mean a* of Panavia V5 was significantly lower than that of the Variolink group (P=0.03). The mean a* of try-in pastes was significantly different among

Table 2. Mean ΔE between the cured cements and their respective try-in pastes, and cured and uncured cement specimens in the three groups

ΔE	Cement	Mean	Std. deviation	P-value
Between cured specimens and their try-in paste	Choice 2	14.4	2.6	<0.001
	Variolink	6.5	0.7	
	Panavia V5	14.03	1.2	
Between cured and uncured specimens	Choice 2	14.1	1.5	<0.001
	Variolink	6.2	0.9	
	Panavia V5	14.9	1.4	

Table 3. Mean L* in cured cements and their respective try-in pastes in the three groups

Mean L*	Cement	Mean	Std. deviation	P-value
Cured cements	Choice 2	84.8	2.03	0.01
	Variolink	86.9	0.9	
	Panavia V5	85.01	1.7	
Try-in pastes	Choice 2	84.4	2.01	0.01
	Variolink	86.4	0.8	
	Panavia V5	85.04	1.8	

Table 4. Mean a* in cured cements and their respective try-in pastes in the three groups

Mean a*	Cement	Mean	Std. deviation	P-value
Cured cements	Choice 2	-2.1	0.4	<0.001
	Variolink	-3.1	0.3	
	Panavia V5	-2.6	0.2	
Try-in pastes	Choice 2	-2.5	0.5	<0.001
	Variolink	-3.7	0.4	
	Panavia V5	-2.9	0.3	

Table 5. Mean b* in cured cements and their respective try-in pastes in the three groups

Mean b*	Cement	Mean	Std. deviation	P-value
Cured cements	Choice 2	4.9	0.7	
	Variolink	7.9	0.4	<0.001
	Panavia V5	7.2	0.6	
Try-in pastes	Choice 2	4.6	0.8	
	Variolink	7.95	0.5	<0.001
	Panavia V5	8.91	0.7	

the three groups as well (P<0.001). The mean a* in Choice 2 was notably lower than that of Panavia V5 (P=0.008), and the mean a* of Panavia V5 was significantly lower than that of Variolink (P=0.04).

Table 5 displays the mean b* in cured cements and their respective try-in pastes in the three groups. A one-way ANOVA revealed a significant difference in the mean b* of cured specimens among the three groups (P<0.001). Pairwise comparisons demonstrated that the mean b* of Choice 2 was significantly lower than that of Panavia V5 (P<0.001). Furthermore, the mean b* of Panavia V5 was markedly lower than that of Variolink (P=0.02). The mean b* of try-in pastes was also significantly different among the three groups (P<0.001). The mean b* of Choice 2 was significantly lower than that of Panavia V5 (P<0.001), and the mean b* value of Panavia V5 was notably lower than that of Variolink (P=0.03).

This study compared the color match of the clear shade of three commonly used resin cements and their respective try-in pastes namely Variolink Esthetic (Ivoclar), Choice 2 (Bisco), and Panavia V5 (Kuraray). The literature has reported different ΔE values ranging from 1.5 to 3.7, and 0.32 to 11.49 for the try-in pastes and 0.59 to 12.1 between the cured and uncured cements [14,15]. The quality of visual assessment depends on individual color perceptions [16], and cement thickness is a critical parameter in achieving the desired color [17]. In the present study, the cement thickness was 0.5 mm, since different thicknesses can affect the color of the final restoration.

Optimal Cement Thickness and its Effect on Color and Translucency of Resin Cement

In the clinical setting, the uniformity of cement thickness depends on the adaptation of the internal surface of restoration and prepared tooth surface. Magne et al. [18] reported that a cement thickness of 0.1-0.5 mm is required for optimal adaptation and adequate stress distribution in the cement. Another study reported that a thickness of 0.1-0.5 mm is needed for favorable optical properties of resin cements [19]. Chen et al. [20] demonstrated the significant effect of resin cements on the final color of ceramic veneers. Furthermore, evidence suggests that inorganic fillers present in the cements may lead to colors different from that of the main cement matrix and result in varying degrees of translucency [21]. In the present study, a significant difference in ΔE was observed between the cured cements and their respective try-in pastes among the three groups. Choice 2 (14.4) and Panavia V5 (14.5) had significantly higher ΔE than Variolink (6.5) (P<0.001). This finding in this respect is in line the results of many previous studies that reported a significant difference between the color of cured cements and their respective try-in pastes [1,10,13-15,22-30]. Although try-in pastes are used to assess the final color of restorations prior to their final cementation, the use of uncured resin cements has also been suggested for the try-in of restorations. This suggestion stems from the limitation of try-in pastes, which can differ in color from the cement [1]. The present study revealed a color difference of 14.1, 6.2, and 14.9 for Choice 2, Variolink, and Panavia V5, respectively. ALGhazali et al. [1]

reported a color difference between the cured and uncured cements due to the polymerization of cement and decreased absorption of blue light by the light-cure photo-initiator. However, they demonstrated that resin cements became darker after polymerization. This color change may be due to external factors such as heat, water, exposure to environmental factors, or UV light. Additionally, internal factors such as the amount and size of filler particles, their distribution in the matrix, the interaction of resin materials with fillers, type of photo-initiator, and the percentage of residual carbon-carbon double bonds after curing, can contribute to the color change. Moreover, intensity and duration of polymerization can lead to discoloration [31]. UV light chemically changes the photo-initiator system, activator and resin itself, resulting in the color change of restorative materials. The destruction of residual amines and oxidation of unreacted carbon-carbon double bonds can also lead to the formation of yellow compounds [32,33]. The present results indicate a significant color difference between the cured and uncured cements and try-in pastes, which could eventually result in substantial alteration in the final color of the restoration.

Comparative Analysis of Lightness in Try-in Pastes of Three Resin Cements

The mean L* in try-in pastes of the three groups was compared, revealing that Variolink had a higher mean L* than Panavia V5, whereas Panavia V5 had a higher mean L* than Choice 2. This finding indicates the greater lightness of Variolink compared to the other two cements. The effect of core color on the final color of restorations should also be considered. It has been documented that dentin is the main source of tooth color, and the thickness and translucency of enamel covering the dentin can alter the tooth shade. Heffernan and colleagues (2019) indicated that the composition of restorative materials plays a significant role in determining the translucency and color of dental restorations. Nonetheless, there are several limitations to their study. Firstly, the experiement was conducted in a laboratory setting and their evaluation did not account for the underlying tooth structure. Moreover, the study solely assessed the pure color of each cement and its respective try-in paste, which may not accurately reflect the clinical setting. Therefore, future research should investigate the color of restorative materials in conjunction with the underlying tooth structure to obtain more clinically relevant results. Additionally, the study had other limitations, such as the absence of ceramic specimens over the discs and the lack of aging to simulate the clinical setting, both of which should be addressed in future investigations. One noteworthy strength of this study, however, was its comparison of three commonly used resin cements. Furthermore, their clear shade was evaluated since this shade is more commonly used by dental clinicians. However, future studies should evaluate other color shades of resin cements to expand the scope of research in this field. Moreover, it would be valuable to investigate the effect of different thicknesses of ceramics in combination with cements on the final color of restorations [34-37]. A compilation of academic papers covering diverse topics in engineering such as tissue engineering, nanocomposites, mechanical structures, molecular modeling to predict physical and mechanical properties, bone tissue repair, and surface engineering have been reviewed [29,37-43]. These articles covered a range of research topics, such as the utilization of smart wound dressings containing microcapsules, the strengthening of lithium disilicate ceramics with titanium nanoparticles, the adhesion strength of composites to deep and superficial teeth, bone reinforcement using alginate gel, optimization of manufacturing methods for nanostructured composites using molecular modeling, and improvement of the quality of copper oxide films through strong biaxial rotation under high acceleration conditions [44-53].

CONCLUSION

This study aimed to evaluate the color match of three different light-cure resin cements (Variolink, Choice 2, and Panavia V5) with their respective try-in pastes. The results indicated that Variolink had the most accurate color match, with the lowest color difference observed between the cured cement and its try-in paste, as well as between cured and uncured specimens. Moreover, the value of L*, which represents the lightness or darkness of a color, was higher for cured Variolink and its respective try-in paste compared to Choose 2 and Panavia V5. However, the difference in L* value between the cured cement and its respective try-in paste was not significant in the case of Variolink, indicating that they had similar lightness values. Furthermore, the study found that the cured Variolink cement and its try-in paste were lighter in color than the other two cements, possibly due to the lower concentration of pigments in the Variolink formulation compared to Choose 2 and Panavia V5. Additionally, the cured Variolink cement and its try-in paste had a more yellow hue compared to the other two cements and their respective try-in pastes. This could be attributed to the presence of a yellow pigment in the Variolink formulation, which gives it a warmer color tone. The study suggests that Variolink may be a suitable choice for achieving a more consistent and aesthetically pleasing color match between the cement and the tooth surface. However, it is important to note that color matching is only one aspect of successful dental restorations and other factors such as bond strength, durability, and biocompatibility should also be considered when selecting a resin cement.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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