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Spectrophotometric Investigation into the Impact of Try-in Paste, Uncured and Light-cured Resin Cement on the Final Color of Ceramic Laminate Veneers: Clinical Study

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Abstract: Objective: To clinically assess the accordance of try-in paste and corresponding resin cement on the final color of ceramic laminate veneers (CLVs). **Material and methods:** Twenty-eight CAD/CAM CLVs (n = 28) were fabricated from IPS e. max CAD. All CLVs were scanned on the cast followed by fabrication of three-dimensional (3D) printed stent using 3D printer. CLVs were tried in the patient mouth using try-in paste. Bonding of all CLVs was performed using light-cured resin cement. Color measurement was performed using intraoral spectrophotometer (Vita Easyshade V). Color differences were calculated between: try-in paste and uncured resin (tr-ur), 2) try-in paste and light-cured resin cement (tr-lcr), 3) uncured and light-cured resin (ur-lcr) immediately after cementation and 4) light-cured resin and 24 hour after curing (lcr-24). Comparison of ΔE*measurements within the same teeth at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) were done using repeated measure ANOVA followed by paired t test. All *P* -values are two-sided and *P*-values < 0.05 were considered significant. **Results:** The mean of ΔE*0 (tr-uc) was 2.35±0.74, mean ΔE*1 (tr-lcr) was 2.15± 0.84, mean ΔE*2 (tr-24) was 2.13±0.87, the mean ΔE*3 (un-lcr) was 0.69±0.44, the mean ΔE*4 (un-24) was 0.84±0.44 and was 0.35±0.10 for ΔE*5 (lcr-24). Comparing mean ΔE at different evaluation stages were statistically significant ($p<0.05$) except comparing ΔE*2 (tr-24) with ΔE*1 (tr-lcr) which give p value of 0.302. **Conclusion:** The color match obtained by the try-in paste was similar to cured resin, therefore, enhancing clinician ability to achieve the desired esthetic outcome. Small change between uncured and light-cured resin cement was found. **Clinical Significance:** It is advised to use uncured resin cement as a try-in paste for color matching rather than try-in pastes.

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1. Introduction

Ceramic laminate veneers (CLVs) are considered one of the most common restorations used in the field of esthetic dentistry owing to many reasons, optical properties, durability, biocompatibility and patients' satisfaction. To achieve a clinical success, many steps should be followed which include, treatment planning and digital smile design (DSD), ceramic material selection, preparation design and finally bonding protocol.[1-4]

Light-cured resin cements are specifically used for bonding CLVs. These cements possess many advantages when compared with chemically cured and dual-cured resin cements which are stability in color increased working time allowing the clinician to easily remove excess material before final polymerization, consequently, reducing finishing time.[5]

In addition, light-cured resin cement supplied by the manufacturers consists of numerous colors and try-in paste, allowing the clinicians to easily modify the final color of veneer achieving the desired esthetic results and therefore ensuring patient expectation is achieved.[6,7]

CLV try-in step is essential to predict the final esthetic results which is done using try-in pastes which are water-soluble paste simulating resin cements in consistency, handling and color allowing both the patient and the dentist a visual evaluation of the final restoration color commencing final bonding. Matching between try-in paste and resin cement color is a controversial issue in the literature and in-vitro studies, with authors being with and others being against[8-12] thus, the clinical question whether try-in pastes match the color of the corresponding resin cement still not answered. In addition, no clinical studies have been conducted evaluating if there is a color difference exist between try-in paste and light-cured resin cement used for bonding CLV. Thus, the hypothesis to be tested was that there will be no difference between the color of CLV with try-in paste and corresponding light-cured resin cement.

2. Materials and Methods

1. Inclusion and Exclusion Criteria

Patients with esthetic problems in the maxillary teeth presented to Mansoura University, faculty of dentistry, department of Fixed Prosthodontics were enrolled in this clinical study and receive CLV on the maxillary teeth. The inclusion criteria were as follows: patients at least 18 years old with fractured tooth, mild malposed tooth, erosion or abrasion; had no active periodontal or pulpal diseases and who were able to attend the clinic on predetermined days. Six participants were included in this study and received thirty-two (n=28) CLVs. They were treated with minimum of one up to a maximum of seven CLVs.

Table (1):Distribution of CLVs per tooth.

Tooth	Number of CLVs
Maxillary central incisor	10
Maxillary lateral incisor	8
Maxillary canine	8
Maxillary 1st premolar	2
Total	28

2. Planning

Full-arch upper and lower impressions were taken with alginate irreversible hydrocolloid material (Hydrogum 5, Zhermack, Rovigo, Italy). Photographs were taken followed by DSD using presentation software (Keynote iWork, Apple, Cupertino, USA). Digital diagnostic mock-up was performed using CAD software (Exocad GmbH, Darmstadt, Germany) followed by fabrication of diagnostic wax-up using 5-axis CAD/CAM machine (Ceramill motion II, Amann Girrbach, Germany). Modification of the design was checked and discussed with the patient before teeth preparation.

3. Preparation

Teeth preparations were performed with butt joint incisal preparation design and with 0.5 mm preparation depth. Final impression was performed using putty wash technique and sent to the lab. Fabrication of CLVs (IPS e.max CAD, IvoclarVivadent AG, Schaan, Lichtenstein) was performed by the same certified dental technician. Film thickness was set at 50 µm for all CLVs.

4. Three-dimensional (3D) Printed Stent

After fabrication of CLV, scanning while CLVs on the cast and a 3D printed stent was fabricated covering the labial, incisal, occlusal and lingual surface of maxillary teeth with an open aperture of diameter 5mm at the middle third of the labial tooth surface using Exocad® software (Exocad GmbH, Darmstadt, Germany) (Figure 1). Fabrication of 3D printed overly stent was performed using 3D printer (Mogassam®, Greek campus, Cairo, Egypt).

Bonding

After phonetic, esthetic, and functional evaluation of the CLVs in the patient mouth, bonding procedures were carried out. The teeth and veneers were cleaned and dried before cementation. Try-in past with A1 color (Choice 2 Try-in paste shade: A1, Bisco Choice 2™ Light-cured Veneer Cement, Schaumburg, USA) of all CLVs was placed into fitting surface and they was inserted into patient mouth.

After trial insertion, washing try-in paste from the fitting surface using water for 10 seconds, followed by etching of fitting surface using hydrofluoric acid (9.5% PORCELAIN ETCHANT, Bisco Choice 2™ Light-cured Veneer Cement, Schaumburg, USA) for 25 seconds. The fitting surface of CLVs is rinsed, dried followed by application of silane coupling agent (BIS SILANE Parts A & B, Bisco Choice 2™ Light-cured Veneer Cement, Schaumburg, USA) after mixing part A and B. Bonding of CLVs was done using light-cured resin cement (Bisco Choice 2™Light-cured Veneer Cement, Schaumburg, USA). Etching the teeth for 30 seconds using phosphoric acid etchant (UNI-ETCH, Bisco Choice 2™ Light-cured Veneer Cement, Schaumburg, USA) followed by washing and drying teeth surfaces. Bonding agent (ALL BOND UNIVERSAL®, BiscoChoice 2™ Light-cured Veneer Cement, Schaumburg, USA) was applied using microbrush to teeth surfaces, air thin then polymerized for 10 seconds using cordless LED light cure (BlueLEX LD-106, Monitex, New Taipei, Taiwan).

Composite resin cement was applied to the fitting surface of the CLVs (Syringe CHOICE 2 Shade: A1, Bisco Choice 2™ Light-cured Veneer Cement, Schaumburg, USA) and initial light curing for 1-2 seconds was performed followed by excess cement removal using dental explorer and dental floss. Final curing for 40 seconds was performed.

Color Measurement

Color measurements (Readings of L*, a* and b*) of the CLVs was performed using an Easyshade® spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Bad Sackingen, Germany) by placing its probe tip into the 3D printed stent open aperture (figure 1). These measurements were performed for CLVs with try-in paste, uncured resin cement and immediately after light curing the composite resin cement and after 24 hours. Moreover, they were performed three times during each stage and the average was recorded.

The CIE color difference was calculated with the equation $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, where $\Delta L^* = (L1^* - L2^*)$, $\Delta a^* = (a1^* - a2^*)$, and $\Delta b^* = (b1^* - b2^*)$ are the differences in lightness-darkness, green-red coordinate and blue-yellow coordinate, respectively. ΔE* is the color difference between two objects that the high value of it refers to the big color difference between the objects and consequently the more perceptible color difference to the human eye.

Differences (ΔE) were calculated between: 1) try-in paste and uncured resin (tr-ur), 2) try-in paste and light-cured resin cement (tr-lcr), 3) uncured and light-cured resin (ur-lcr) and 4) light-cured resin and 24 hour after curing (lcr-24) (Table 1). The study was approved by the Human Ethical Research Committee of the Faculty of Dentistry, Mansoura University.

Figure (1) showing Easyshade probe placement into 3D printed stent in the middle third of the CLV.

Table (2): color difference (ΔE*) used in this study

ΔE^*_0	Color change between CLVs with try-in paste (L_0^*, a_0^* and b_0^*) and uncured resin (L_1^*, a_1^* and b_1^*)
ΔE^*_1	Color change between CLVs with try-in paste (L_0^*, a_0^* and b_0^*) and light-cured resin cement immediately after cementation (L_2^*, a_2^* and b_2^*)
ΔE^*_2	Color change between CLVs with try-in paste (L_0^*, a_0^* and b_0^*) and light-cured resin cement after 24 hours (L_3^*, a_3^* and b_3^*)
ΔE^*_3	Color change between CLVs with uncured resin (L_1^*, a_1^* and b_1^*) and light-cured resin cement immediately after cementation (L_2^*, a_2^* and b_2^*)
ΔE^*_4	Color change between CLVs with uncured resin (L_1^*, a_1^* and b_1^*) and light-cured resin cement after 24 hours (L_3^*, a_3^* and b_3^*)
ΔE^*_5	Color change between CLVs light-cured resin cement immediately after cementation (L_2^*, a_2^* and b_2^*) and light-cured resin cement after 24 hours (L_3^*, a_3^* and b_3^*)

Statistical analysis

Data management and statistical analysis were performed using Statistical Package for Social Sciences (SPSS, Chicago, IL) version 24.

For color results (L*, a*, b*), mean, median and standard deviation were done, in addition, comparison within the same teeth at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) were done using Friedman test followed by post hoc Dunn test. Comparison of ΔE*measurements within the same teeth at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) were done using repeated measure ANOVA followed by paired t test. All *P* -values are two-sided and *P*-values < 0.05 were considered significant.

3. Results

2.1 Color results using L*, a* and b*

Mean, Standard deviation, median, range of L*, a* and b* and Freidman test for comparing color at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) were done in this study. (Table 2)

L*:

- Try-in paste evaluation between 28 veneers used in the study: the mean was 0.9 ± 1.9 and the median was 0.9, ranged from -2.50 to 3.5.
- Uncured resin cement evaluation between 28 veneers used in the study: the mean was 1.3 ± 2 and the median was 2.3, ranged from -2.70 to 3.8.
- Light cured resin cement evaluation between 28 veneers used in the study: the mean was 1.2 ± 1.9. and the median was 1.9, ranged from -2.10 to 4.
- Light cured resin cement evaluation after 24 hours between 28 veneers used in the study: the mean

was 1.3 ± 2 and the median was 2.1, ranged from -2.30 to 4.2.

P-values were as 0.06 between uncured resin cement (uc) - try-in paste (tr), 0.183 between light-cured resin cement (lcr) - try-in paste (tr), 0.158 between light-cured resin cement (24 hours) - try-in paste (tr), 0.102 between light-cured resin cement (lcr) - uncured resin cement (uc), 0.558 between light-cured resin cement (24 hours) - uncured resin cement (uc) and 0.159 between light-cured resin cement (24 hours) - light-cured resin cement (lcr). All P-value were considered statistically non-significant regarding L* between different color evaluation stages.

a*:

- Try-in paste evaluation between 28 veneers used in the study: the mean was 0.1 ± 2 and the median was 0.5, ranged from 3.3 to 5.2.
- Uncured resin cement evaluation between 28 veneers used in the study: the mean was 0.4 ± 2.7 and the median was 0.4, ranged from 3.8 to 5.2.
- Light cured resin cement evaluation between 28 veneers used in the study: the mean was 0.3 ± 2.7 and the median was 0.05, ranged from 3.9 to 5.5.
- Light cured resin cement evaluation after 24 hours between 28 veneers used in the study: the mean was 0.3 ± 2.7 and the median was 0.05, ranged from 3.7 to 5.7.

P-values were 0.776 between uncured resin cement (uc) - try-in paste (tr), 0.882 between light-cured resin cement (lcr) - try-in paste (tr), 0.918 between light-cured resin cement (24 hours) - try-in paste (tr), 0.691 between light-cured resin cement (lcr) - uncured resin cement (uc), 0.904 between light-cured resin cement (24 hours) - uncured resin cement (uc) and 0.564 between light-cured resin cement (24 hours) - light-cured resin cement (lcr). All P-value were considered statistically non-significant regarding a* between different color evaluation stages.

b*:

- Try-in paste evaluation between 28 veneers used in the study: the mean was 0.4 ± 3.8 and the median was 3.1, ranged from 5.9 to 4.3
- Uncured resin cement evaluation between 28 veneers used in the study: the mean was 0.5 ± 3.5 and the median was 0.7, ranged from 4.3 to 4.5.
- Light cured resin cement evaluation between 28 veneers used in the study: the mean was 2 ± 2.9 and the median was 3.5, ranged from 3.7 to 4.2.
- Light cured resin cement evaluation after 24 hours between 28 veneers used in the study: the mean was 2 ± 2.9 and the median was 3.5, ranged from 3.9 to 4.3.

P-values were 0.425 between uncured resin cement (uc) - try-in paste (tr), 0.077 between light-cured resin cement (lcr) - try-in paste (tr), 0.133 between light-cured resin cement (24 hours) - try-in paste (tr), 0.393 between light-cured resin cement (lcr) - uncured resin cement (uc), 0.459 between light-cured resin cement (24 hours) - uncured resin cement (uc) and 0.419 between light-cured resin cement (24 hours) - light-cured resin cement (lcr). All P-value were considered statistically non-significant regarding b* between different color evaluation stages.

Table (3): Mean, Standard deviation, median, range and Freidman test for comparing color at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours)

				95% Cl for Mean				
		Mean	**SD**	**Lower**	**Upper**	**Median**	**Min.**	**Max.**
L*	**Try-in paste (tr)**	0.9	1.9	-0.1	1.3	0.9	-2.50-	3.5
	Uncured resin cement (uc)	1.3	2.0	0.5	2.1	2.3	-2.70-	3.8
	Light-cured resin cement (lcr)	1.2	1.9	0.4	1.9	1.9	-2.10-	4
	Light-cured resin cement (24 hours)	1.3	2.0	0.5	2.0	2.1	-2.30-	4.2
a*	**Try-in paste (tr**	0.1	2.0	-0.7	0.9	0.5	-3.30-	5.2
	Uncured resin cement (uc)	0.4	2.7	-0.6	1.5	-0.4	-3.80-	5.2
	Light-cured resin cement (lcr)	0.3	2.7	-0.7	1.3	0.05	-3.90-	5.5
	Light-cured resin cement (24 hours)	0.3	2.7	-0.7	1.4	-0.05	-3.70-	5.7
b*	**Try-in paste (tr**	0.4	3.8	-1.1	1.9	3.1	-5.90-	4.3
	Uncured resin cement (uc)	0.5	3.5	-0.8	1.9	0.7	-4.30-	4.5
	Light-cured resin cement (lcr)	2.0	2.9	0.9	3.1	3.5	-3.70-	4.2
	Light-cured resin cement (24 hours)	2.0	2.9	0.8	3.1	3.5	-3.90-	4.3

SD: standard deviation, min: minimum, max: maximum analysis done by Friedman test, followed by Dunn test, similar letters are statistically significant

1.2 Color results using ΔE

The color results using ΔE at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) were done using repeated measure ANOVA followed by paired t-test (Tables 3) and (figure 2).

The mean of ΔE*0 (tr-uc) was 2.35±0.74, mean ΔE*1 (tr-lcr) was 2.15± 0.84, mean ΔE*2 (tr-24) was 2.13±0.87, the mean ΔE*3 (un-lcr) was 0.69±0.44, the mean ΔE*4 (un-24) was 0.84±0.44 and was 0.35±0.10 for ΔE*5 (lcr-24).

The color change ΔE* values produced at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours) ranged from 0.35 to 2.35.

Comparing mean ΔE at different evaluation stages were statistically significant ($p<0.05$) except comparing ΔE*2 (tr-24) with ΔE*1 (tr-lcr) which give p value of 0.302.

Table (4): Mean, Standard Deviation and paired t-test for comparing ΔE at different evaluation stages (try-in paste, uncured resin cement, light-cured resin cement and light-cured resin cement after 24 hours)

Group 1			**Group 2**			**95% CI of difference**		
	Mean	**SD**		**Mean**	**SD**	**Lower**	**Upper**	**P value**
ΔE*0 (tr-uc)	2.35	0.74	**ΔE*1 (tr-lcr)**	2.15	0.84	0.03	0.52	0.028
			ΔE*2 (tr-24)	2.13	0.87	-0.01	0.47	0.019
			ΔE*3 (un-lcr)	0.69	0.44	1.41	2.08	<0.001
			ΔE*4 (un-24)	0.84	0.44	1.26	1.93	<0.001
			ΔE*5 (lcr-24)	0.35	0.10	1.80	2.36	<0.001
ΔE*1 (tr-lcr)	2.15	0.84	**ΔE*2 (tr-24)**	2.13	0.87	-0.14	0.05	0.302
			ΔE*3 (un-lcr)	0.69	0.44	1.03	1.91	<0.001
			ΔE*4 (un-24)	0.84	0.44	0.88	1.76	<0.001
			ΔE*5 (lcr-24)	0.35	0.10	1.46	2.15	<0.001
ΔE*2 (tr-24)	2.13	0.87	**ΔE*3 (un-lcr)**	0.69	0.44	1.09	1.94	<0.001
			ΔE*4 (un-24)	0.84	0.44	0.93	1.80	<0.001
			ΔE*5 (lcr-24)	0.35	0.10	1.51	2.20	<0.001
ΔE*3 (un-lcr)	0.69	0.44	**ΔE*4 (un-24)**	0.84	0.44	-0.23	-0.07	<0.001
			ΔE*5 (lcr-24)	0.35	0.10	0.17	0.50	<0.001
ΔE*4 (un-24)	0.84	0.44	**ΔE*5 (lcr-24)**	0.35	0.10	0.33	0.64	<0.001

SD: standard deviation, CI: confidence interval, $p<0.05$ is statistically significant, analysis done by paired t test

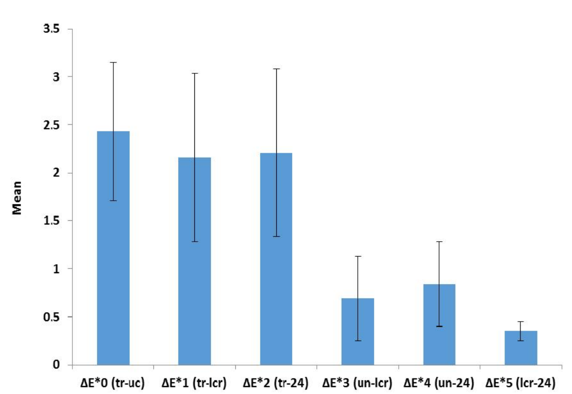

Figure (2): Bar chart representing mean and SD of ΔE

4. Discussion

CLVs color is one of the most important aspects in esthetic dentistry and a fundamental factor for achieving both dentist and patient satisfaction. The most commonly used method for color selection in clinical practice is the visual methods which depends on observers. However, in research world, this is not applicable methods and since spectrophotometry is considered a precise method for color measurement.[12,13] Therefore, Easyshade® spectrophotometer (Vita Easyshade V) with CIE L*a*b* system for assessment of color difference was used in this clinical study.

Dozic et al., (2007)[14]found in their study comparing five different dental color-measuring devices that Vita Easyshade device was the most reliable in a clinical setting while the other tested devices were more reliable *in vitro* than *in vivo.* Klotz et al., (2018)[15]evaluated the repeatability of Vita Easyshade Advance 4.0 and the Easyshade V and found that both devices produce accurate measurements under both clinical and laboratory conditions. Hence, in this study, Vita Easyshade V was used for color measurement.

As with any technology, pros and cons exist. Spectrophotometers is affected by the tooth surface convexity, which complicates the accuracy of probe tip placement and causing edge loss. [16]Therefore, establishing a method to reduce errors with intraoral spectrophotometric color measurement devices by correct positioning of device probe tip is an important step for dental researchers in the field of color science. Hemming et al., (2015)[17] conducted a study evaluating the repeatability of Vita Easyshade device by fabricating vacuum formed stent for multiple tooth color measurements with open aperture for each tooth. They concluded that these stents could improve Vita Easyshade color measurement repeatability. In addition, Karamouzos and his colleagues evaluated the precision of intraoral spectrophotometer device in color measurement of different tooth areas and found that middle third of labial surface maxillary anterior teeth exhibited the most accurate results. [18] In this study, 3D printed stent with an open aperture at the middle third of the labial tooth surface was used for repeatability, accuracy of Vita Easyshade V probe tip placement and therefore technique standardization during color measurement of CLVs with try-in paste, uncured resin, immediately after light curing and 24 hours after curing. This increased the precision and accuracy level of reading.

Manufacturers of light-cured resin cement produce a cementation kit containing try-in pastes with corresponding resin cement to allow clinicians to determine best color match for patient satisfaction. For ideal conditions, manufacturers should produce try-in paste similar in structure to the resin cement used for bonding CLVs but without curing ability to allow extended working time for CLVs try-in. Hence, achieving perfect color matching. Nevertheless, manufacturers provide the clinician with a water-soluble try-in pastes containing colorless transparent glycerininstead of methacrylate monomer. Filler and pigments are added to the try-in paste to mimic the optical properties of the light-cured resin cement. [10]

In color science, determination of ΔE value is considered challenging to researchers. Perceptible and acceptable threshold are used by color researchers to determine the color difference between two materials. Color difference detection between a tooth and adjacent colored restoration is defined as perceptibility, whereas to accept the color difference for restoration or not accept is called acceptability. The acceptable threshold of color difference is greater than the perceptible threshold. Khashayar et al, (2014)[19] in a clinical review concluded that the perceptible and acceptable threshold of color is difference to human observer is 1and 3.7 respectively. Therefore in this clinical study ΔE= 3.7 was used for acceptable threshold of color difference and ΔE= 1 was used as a threshold of perceptible color difference.

Cement thickness may play a role in color difference as according to Vichi et al., (2000)[20], 100 µm luting agent thickness of might be able to affect the color of the restoration. Thus, standardization of all veneers film thickness to50 µm is used in this study.

Ceramic thickness may also affect the color measurement between try-in pastes and their corresponding light-cured resin cements. However, Ceramic veneer thickness is determined by the tooth preparation amount. Anatomical studies evaluated enamel thickness of maxillary anterior teeth and a range of 0.4-1.3 mm wasfound.[21] Thus, thickness of ceramic veneer ranging from 0.5-1 mm is usually bonded to enamel.[22]According to Mourouzis et al., (2018)[23] different thickness of IPS e.max CAD restorations has a major effect on ΔE value. In addition Xing et al., (2010)[9] and Vaz et al., (2019)[12] findings suggested that ceramic thickness influences the final color of restoration. Hence, standardization of ceramic thickness of IPS e.max CAD veneers to 0.5 mm was performed in this study.

Ceramic translucency is a considered a key factor for CLVs final outcome. Translucency is defined as the ability of material to transmit most of the light without scattering. All-ceramic restorations are inherited with higher translucency in comparison to metal ceramic restorations. Nonetheless, manufacturers had developed all-ceramic systems with variable translucency (HT which referred to high and LT which referred to low translucency) to help clinician to choose the recommended translucency and opacity according to the patient's needs. Thus, translucent material would be affected by the underlying resin cement which consequently, would affect the final color of CLVs.[24,25] In this study, all CLVs were fabricated from HT IPS e.max CAD for standardization of the translucency and thus, limiting the variables.

According to authors' knowledge, there was no clinical study comparing try-in pastes and light-cured resin cement, however, various in-vitro studies[9-12,23,26,27] were existed. Therefore, results of the present study were discussed in the context of results of these in-vitro studies.

There was statistically significant differences ($p<0.05$) of mean ΔE at different evaluation stages (try-in paste, uncured, light-cured resin cement immediately after cementation and after 24 hours) except comparing ΔE*2 (tr-24) with ΔE*1 (tr-lcr) which give p value of 0.302. This is in agreement with Xing et al., (2010)[9], Vaz et al., (2016)[11] and Vaz et al., (2019)[12]. This may be attributed to type and amount of fillers as well as suitable selection of combined pigments by manufacturer.[10]

The try-in paste should help the clinician to choose the accurate shade reflecting the desired final color. In the present study, the color differences between try-in paste and light-cured resin cement immediately after cementation and after 24 hours were perceptible to the human eye ($\Delta E^*_1$was 2.15 ± 0.84 and ΔE^*_2 was 2.13 ± 0.87), however, they were below clinically acceptable threshold ($\Delta E^*= 3.7$). This means that try-in paste used in this study are clinically useful as a guide for choosing the desired color and thereby, patient satisfaction. Hence, the hypothesis of this study was accepted. Nevertheless, other authors have different results with being against the present study.[10,23,26,27] The explanation of this heterogeneity in published results was probably owing to differences in materials and its composition (which differ in quantities of colorant ingredients), shades, brands, curing mode (light/dual cure), ceramic thickness and material, cement space thickness and methods used for color evaluation.[8-12,23,26,27]

Color measurement differences between uncured and light-cured resin cement was not clinical significant, since theywere0.69 ± 0.44 for uncured and light-cured resin cement immediately after cementation (ΔE^*_3) and 0.83 ± 0.43 for uncured resin cement and light-cured resin cement after 24 hours (ΔE^*_4); which are within the range of perceptible threshold. Decrease in blue light absorption by photo-initiators after curing, which might affect the b* coordinates, was blamed to be the cause of such difference. These color difference were below that measured between try-in paste and uncured and light-cured resin cement. This suggested that uncured resin cement can be used as a guidance for final color selection instead of try-in paste.

Therefore, for clinical application, the final color can be assessed by placing the uncured resin cement and either cleaned from the surface before polymerization by solvent (ethanol, acetone and methanol) to remove uncured resin cement remnants if unaccepted without affecting bond strength, or light-cured if accepted.[8,26]

Color difference (ΔE^*_5) between cured and 24 hours after curing was not clinical significant, since it ranged from (0.1–1) which is within the range of perceptible threshold. This small difference is explained by initiation of aliphatic amines and camphorquinone (CQ) used in light-cured resin cements. In addition, TEGDMA and BisGMA hydrolytic degradation in light-cured resin cements could be the reason of yellowing effect after polymerization.[27]

In summary, in order to control all variables which could influence measurement of color, numerous efforts were made through study steps standardization from the preparation to bonding and final color measurement. All measurements were performed under the same illumination factors and in the same area, hence, standardizing the surrounding environment. Only one clinical examiner performed all color measurements and calculation, avoiding variability of different examiner. For each tooth, three measurements were taken and average were used. To ensure the reliability of the results, Vita Easyshade V was recalibrated after each tooth reading to ensure results' reliability; moreover, 3D printed stent to ensure correct probe tip placement aiming to reduce errors caused by inaccurate positioning. This can be considered as strengths in the present study, and no statistical significant difference observed confirmed accuracy, control over different variables and overcoming all obstacles.

However, there is no research without limitations. Color difference measurements of only one type of resin cement, as well as one shade (A1) were evaluated. Also, one ceramic material was used. Moreover, lack of standardization of teeth color, translucency and surface curvatures, age, gender, as well as, small sample size remained a major limitations. Therefore, further studies are needed to evaluate the influence of a wider range of cement colors, ceramic types, ceramic translucency, ceramic colors and different veneer thicknesses on the final color outcome.

Conclusion

Within the limitation of the study, it is possible to conclude that:

1- Light-cured resin cements are highly recommended for bonding CLVs.

2- The color match obtained by the try-in paste was similar to cured resin, therefore, enhancing clinician ability to achieve the desired esthetic outcome.

3- Small change in color between uncured and light-cured resin cement was found so, it is advised to use uncured resin cement as a try-in paste for color matching rather than try-in pastes.

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Conflict Of Interest

The authors declare no potential conflicts of interest in respect of authorship and/or publication of this article.

Disclosure

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