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## Laboratory Research

# Influence of Cement Shade and Water Storage on the Final Color of Leucite-reinforced Ceramics

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### Clinical Relevance

Luting cement under 0.8 mm thick leucite-reinforced ceramic changed the final color of the ceramic and could be seen by the human eye. Therefore, clinicians may prefer to use try-in pastes or polymerized luting composite shade guides to compensate for the change in color of definitive restorations, such as laminate veneers. The final color differences between ceramics luted with cements in A1 and A3 shades were not clinically perceivable at each measurement. Within the limitations of this study, changing the color of an IPS Empress laminate veneer restoration via the shade of the cement seems not to be a preferred method.

### SUMMARY

**Leucite-reinforced ceramics have a translucent structure, which may have an advantage when fabricating esthetic restorations. However, the different shades of cement and water storage may adversely affect the final color of translucent restorations. Over time, the final color of a restoration may be significantly affected by the shade of the cement. This *in vitro* study evaluated the effect of two different cement shades (Vita $A_1$ and $A_3$) and water storage on the final color of leucite-reinforced ceramics over time. Twenty disks of standardized thickness (0.8 mm), diameter (5 mm) and color (shade 110, Chromascope) were prepared from leucite-reinforced glass-ceramic (IPS Empress). Ten freshly extracted human molars were used as the underlying structure, and both the buccal and lingual surfaces of each tooth were prepared with a diamond rotary cutting instrument and flat surfaces were created. Initially, all of the disks were bonded to the flat surfaces of the teeth with a thin layer of bonding agent (Single Bond, 3M Dental Products) to ensure immobilization of the specimens (baseline). The teeth and ceramic specimens were not etched and silanated for easy removal of the**

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**specimens. The color of the ceramic specimens was measured with a colorimeter. All disks were gently removed from the tooth surfaces, and 10 specimens (Group $A_1$) were luted to the buccal surfaces of teeth using a dual-polymerizing resin composite cement (Vita $A_1$, Rely X ARC), while the remaining 10 specimens (Group $A_3$) were luted to the lingual surfaces of the teeth with a different shade (Vita $A_3$, Rely X ARC) of the same cement. The final color of the specimens was measured immediately after cementation and at 3-, 30- and 90-day intervals after cementation. Color coordinates L*, a*, b* were recorded. The teeth were stored in 37°C saline solution during measurement intervals. The Mann–Whitney *U*-test (post-hoc test) was performed to compare the results ($\alpha$=0.05). The color difference of specimens luted with the two cements with different shades was not perceivable ($\Delta E$<3.7) for AC (after cementation), AC/3, AC/30 and AC/90 measurements. The color alteration between baseline and immediately after cementation (AC) was not perceivable for each cement group. However, after water storage, color differences between the baseline and AC/3, AC/30 and AC/90 were above this limit in bo th cement groups. The shade of the luted 0.8 mm IPS Empress porcelain specimens became darker after cementation, particularly on the third day, regardless of the cement shade tested. When the final color of ceramics luted with cements in two different shades was compared, it was observed that the final color differences were not perceivable for each measurement session.**

## INTRODUCTION

Teeth that are discolored, damaged by trauma or, in some respect altered by developmental disturbances or caries, have traditionally been restored by complete coverage restorations. Complete coverage tooth preparation requires significant tooth reduction and occasionally results in pulpal involvement, particularly when performed on young patients.[1]

Problems, such as unesthetic existing resin composite restorations, fractured teeth, diastemas and discoloration may be successfully corrected with the use of a conservative restorative technique, such as porcelain veneers.[2-3]

The use of ceramic veneers for the esthetic restoration of anterior teeth has increased considerably in recent years.[4] Porcelain laminate veneers have several advantages; namely, good bond strength, resistance to abrasion, inherent porcelain strength, resistance to fluid absorption and superior esthetics.[2] Failures in porcelain laminate veneer restorations can be adhesive, mechanical, biologic, esthetic or due to color mismatch or color change.[5]

The methods for evaluating color can be divided into two primary categories: visual and instrumental.[6] Visual shade match is a qualitative assessment made by the visual comparison of a specimen (ceramic restoration) with a target (shade tab or natural dentition). Color assessment is a complex psychophysical process that is subject to numerous variables. Inconsistencies in an individual's ability to select color matches reliably are well documented.[6-7] As a result of the subjective nature of color perception, instrumental colorimetric techniques have been used in dentistry to achieve objective, quantitative evaluation of color differences. Instrumental shade determination methods can be performed with colorimeters or digital cameras.[8-9]

The color of dental materials may be expressed in L*, a*, b* coordinates.[10-11] These coordinates, obtained from spectral reflectance measurements using a spectrophotometer, provide a numerical description of the color position in three-dimensional color space. The L* color coordinate represents lightness; the a* color coordinate represents red on the positive axis and green on the negative; the b* color coordinate represents yellow (positive b*) and blue (negative b*). The advantage of this system over the Munsell system (hue, chroma and value) is that CIELab units are evenly spaced in terms of visual perception, so that the spectral readings can be correlated with subjective operations.[10] The color difference ($\Delta E$) between two specimens whose color is expressed in L*, a*, b* coordinates is derived from the following equation:[12-19]

$$\Delta E_{(L,a,b)} = [(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2]^{1/2}$$

Instrumentally determined color differences ($\Delta$E) have been used in dental research, for example, by Seghi and others[13] to describe color differences between porcelain systems and by Douglas and Brewer[14] to describe differences between the instrumental color measurement and the observer assessment of color differences in metal ceramic crowns. The $\Delta$E values are used to ascertain whether the changes in the overall shade are perceptible by a human observer. This magnitude of the color difference is based on the human perception of color; color differences greater than 1 $\Delta$E unit are visually detectable by 50% of human observers.[13] However, under uncontrolled clinical conditions, such small differences in color would be unnoticeable, because average color differences below 3.7 are rated as a match in the oral environment.[15-16,20] To date, the number of studies reporting the influence of color of luting cements on the final color of porcelain laminate veneers is limited. This study evaluated the influence of two different cement shades and water storage on the final color of a leucite-reinforced ceramic, which is used for the fabrication of porcelain laminate veneers.

## METHODS AND MATERIALS

Freshly extracted human molars ($n$=10) were cleaned with pumice. Both the buccal and lingual faces were symmetrically abraded to the dentin layer with a diamond rotary cutting instrument (Medin, Nove Mesto, Czech Republic) to create flat surfaces. Porcelain ingots (IPS Empress, Ivoclar Vivadent, Schaan, Liechtenstein), each in the same shade (110 Chromascope, Ivoclar Vivadent), were pressed according to the manufacturer's recommendations to a diameter of 5 mm. A precision cutter (Micracut, Metkon, Bursa, Turkey) was used to obtain specimens ($n$=20) with significantly smooth, flat surfaces and for ensuring standardization of thickness (0.8 mm), which was aimed to reflect the size of a porcelain laminate veneer. The ingots were embedded into a polymethylmethacrylate (Meliodent, Heraeus Kulzer GmbH, Hanau, Germany) index to prevent any damage during the cutting process. One surface of each disk-shaped specimen was glazed (Figure 1). Initially, 10 disks were bonded to the buccal surfaces and the remaining 10 disks were bonded to the lingual surfaces of the teeth using a thin layer of bonding agent (Single Bond, 3M ESPE, St Paul, MN, USA) as baseline. For this process, the tooth and ceramic surfaces were not etched, and the ceramic surfaces were not silanated in order to obtain a slight bonding that would allow easy removal of the specimens from the tooth surface. The first shade determination, named before cement application (BC), was performed at this stage. The color coordinates of ceramic specimens on the tooth surface without the use of cement but only with bonding agent were obtained with a colorimeter (ShadeEye NCC, Shofu Dental, Menlo Park, CA, USA).

In the second stage, the disks were separated from the teeth with a slight levering force using an explorer, and both the teeth and porcelain-luting surfaces were gently cleaned and air-abraded with 50-µm aluminum oxide (Korox 50, Bego GmbH, Bremen, Germany). The bond surfaces of the specimens were etched with 9.6% hydrofluoric acid (Pulpdent, Pulpdent Corp, Watertown, MA, USA) for two minutes, then washed with ethyl alcohol (Dry-Rite, Pulpdent Corp) and gently dried. The specimens were silanized with an agent (Rely X Ceramic Primer, 3M ESPE).

The prepared teeth were acid-etched with 37% phosphoric acid (Scotchbond Etchant, 3M Dental Products) for 15 seconds. The tooth surfaces were carefully washed and gently dried in preparation for application of the bonding agent (Single Bond, 3M Dental Products).[21-22] The porcelain disks were luted with one of two different shades of dual-polymerizing resin composite cement (Rely X ARC, 3M ESPE). Vita $A_1$ shade was used for the buccal faces (Group $A_1$) and Vita $A_3$ shade was used for the lingual faces (Group $A_3$) of the teeth for cementation. One investigator seated the disks on the prepared teeth using light finger pressure and any excess cement was removed with an explorer.[23] The luting cements were carefully polymerized with visible light according to the manufacturer's instructions. Before each exposure, the light output of the curing unit was measured with a built-in radiometer (Expert, Hilux, Benlioglu Dental Inc, Ankara, Turkey). The second shade determination was performed at this stage and named immediately after cementation (AC). The teeth were stored in 37°C saline solution in dark bottles during the measurement intervals. The sequential measurements, three days after cementation (AC/3), 30 days after cementation (AC/30) and 90 days after cementation (AC/90) were done in order to evaluate the shade difference from baseline (BC).

Figure 1. *IPS Empress porcelain specimen bonded to the flat surface of the tooth.*

Each shade determination was made in a viewing booth with standardized daylight illumination (D65).[14,24-25] Prior to each session, the colorimeter used for color measurements (ShadeEye NCC, Shofu Dental) was calibrated against a white working standard according to the manufacturer's recommendations. Because repositioning errors could affect accuracy of the assessments of the specimens, an index for each specimen was prepared and a standardization device was used for the instrument. The standardization device was a custom-made instrument, which ensured the vertical and horizontal immobilization of the colorimeter during measurements. The indexes were prepared from white vinyl polysiloxane putty (Speedex, Coltène/Whaledent Inc, Cuyohoga Falls, OH, USA) and placed in line with the tip of the instrument. Each specimen was placed in its correct position and colorimetric assessments were made. The L*, a*, b* color notation of both surfaces of each specimen was measured three consecutive times, and the average value of the three readings was determined to produce the initial color of the specimen. Delta *E* values between the baseline (BC) and sequential measurements (AC, AC/3, AC/30, AC/90) were calculated with these coordinates. Those ΔE values below 3.7 were considered clinically acceptable and were not perceivable in this study.[15]

For each measurement time, the comparison of results obtained from different cement shades was performed with the Mann–Whitney *U*-test. Statistical software (Version 11.5; SPSS, Chicago, IL, USA) was used for the statistical evaluation ($\alpha$=0.05).

## RESULTS

The color differences (Δ*E*) between specimens luted with distinct cement shades are shown in Figure 2. The Δ*E* values were within clinically acceptable limits (Δ*E* <3.7). No significant differences have been observed between the final color of the specimens with $A_1$- and $A_3$-shade cements with time ($p$>0.05) (Figure 2).

According to the Mann–Whitney *U*-test, there were no significant differences observed between the Δ*E* values of specimens luted with $A_1$ and $A_3$ dual-polymerizing resin composite cement (Table 1) (p>0.05). Delta *E* values obtained between immediately after cementation and baseline were within clinically acceptable limits (BC-AC)(Δ*E* <3.7), which means the color differences were not perceivable. However, the Δ*E* values were over clinically acceptable limits, especially for the third day measurements, compared with the baseline, which means that all Δ*E* values after the third day were clinically perceivable (>3.7) (Table 1).

## DISCUSSION

Colorimeters are capable of detecting color differences beyond the threshold of visual perception. The practical application of technology to quantify color differences first requires that parameters denoting visual significance be established.[14] It is not sufficient to quantify color changes without specifying the degree of color difference that is usually perceptible. Although Δ*E* values can serve as approximate tolerances, some individuals perceive color differences as low as 0.5, whereas others do not see differences of 4.[19] Standardization during shade determination has a significant role in the accuracy of the results. The benefits of performing color matching under controlled standard illumination have been reported.[14,25]

Unfortunately, there are some disadvantages associated with the use of colorimeters. Results from a colorimetric device can be altered, because the standardized illuminating light emitted from the device can be scattered, absorbed, transmitted, reflected and even displaced in a sideways direction as a result of the translucent optical properties of teeth and dental ceramics.[7] When using an instrument with a small aperture for both illumination and the collection of light, the amount of reflected light is reduced, causing an inadequate reading of lightness.[6] The curved surface of a tooth may have a negative impact on the uniform reflectance of light to the colorimeter.[26] Therefore, in this project, flat porcelain disks over flat tooth surfaces were used to minimize inaccurate measurement results. Moreover, an index for each specimen and an immobilization device for the instrument were used for the standardization of color measurements.

The final color of translucent ceramic restorations is determined by the thickness of the porcelain, the thickness and color of the luting agent and the color of the underlying tooth structure.[2,7,18] It was reported in a previous study that there may not be great variation in the color of a single tooth.[24] The tooth color is predominantly determined by dentin rather than enamel.[11] In this study, to standardize background color, buccal and lingual faces of the same tooth were symmetrically abraded to the dentin layer. Additionally, the thickness (0.8 mm) and color (110, Ivoclar Vivadent) of the porcelain specimens were kept constant.

The variables in the current study were two different cement shades ($A_1$–$A_3$) and time. The measurement periods began at the baseline, where the effect of cement was precluded (BC). After the application of cement, immediate (AC), short-term (AC/3) and long-term (AC/30, AC/90) measurements were performed. As it takes at least 72 hours for the resin composites to completely polymerize,[2] three days after cementation was considered to be short-term. The long-term measurements were made to evaluate the shade changes after complete polymerization.

The color difference values obtained between baseline and immediately after cementation (AC) were not perceivable (Δ*E*<3.7) for both Vita A subgroups. However, the color difference values obtained between baseline and the sequential measurements (BC-AC/3, BC-AC/30, BC-AC/90) were perceivable (Table 1). The final shade changed over time, compared with the baseline. In addition, most resin composite luting agents will undergo a further shift in color over the following three days in a moist oral environment.[2] Similarly, in the current study, the first perceivable color difference Δ*E*>3.7 occurred during the third day measurement (Table 1).

A dual-polymerizing luting composite must have low absorption of

Table 1: *Mean ΔE Values (standard deviations) for Specimens Luted with A1 and A3 Shade Cements Compared to Baseline Over Time*

| | BC-AC | BC-AC/3 | BC-AC/30 | BC-AC/90 |
|---|---|---|---|---|
| $A_1$ | 3.42 (1.26) | 4.88 (2.55) | 4.72 (2.68) | 4.34 (2.47) |
| $A_3$ | 3.59 (1.65) | 5.11 (2.43) | 4.73 (2.47) | 5.32 (3.18) |

water, low solubility and high color stability for esthetic and functional reasons. Water absorption may adversely affect the color stability of a dual-polymerizing luting resin composite by changing the refractive index of the material. Water absorption is reported to be a factor affecting short-term discoloration and, in the current study, the color change on the third day resembles previous studies[17] and could be due to water absorption.

Dual-polymerizing cements are prone to slight changes in value due to a degradation of benzoamines in the luting agent.[5] The specimens were stored in dark conditions and the degradation of benzoamines was considered not to be a factor in changing the shade. However, in spite of this condition, clinically perceivable color differences occurred. In the case of using conventional aging procedures in this study, it may be predicted that further perceivable changes would occur compared to the baseline for each cement group.

Vichi and others[18] reported a minimal effect of the shade of a cement on the final color of a restoration, which might be instrumentally detectable but clinically not relevant. The effect of cement shade on the final color of a ceramic specimen was not perceivable, as shown in Figure 2. The greatest shade difference occurred immediately after cementation between the $A_1$ and $A_3$ groups. The difference lessened over time. However, further *in vitro* and *in vivo* examinations should be performed to compare different shade groups of luting cements with the use of different porcelain shades, thicknesses, forms (curved) and types.

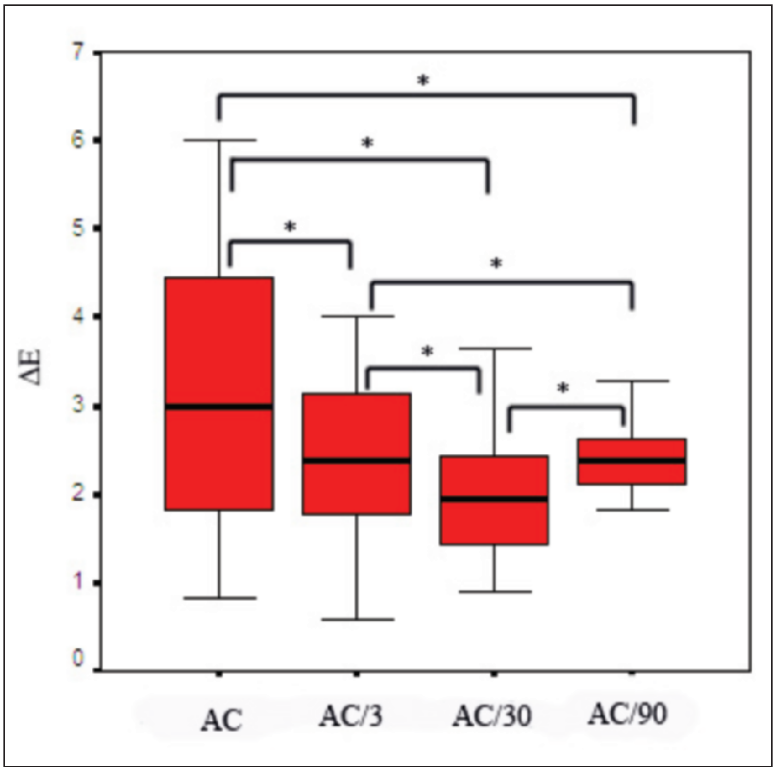


Figure 2. *Mean ΔE values (standard deviations) calculated in different measurement sessions between specimens luted with different cement shades (A1-A3) *p>0.05. AC: Immediately after cementation, AC/3: 3 days after cementation, AC/30: 30 days after cementation, AC/90: 90 days after cementation.*

The available manufactured shade guides are not ideal for porcelain laminate veneers. They are too thick and are composed of several different layers, including opaque layers.[2] It would be preferable to have a ceramist prepare a shade guide of porcelain laminates exactly as they would be fabricated. The try-in pastes with different shades can also be useful for successful color determination. It is generally accepted that a color difference will most likely occur between the same colored dual- or light-polymerizing resins before and after being polymerized.[3,28] The color determination procedure may be more accurate with the help of a polymerized luting composite shade guide behind the porcelain shade guide. Clinicians may prefer using try-in pastes or polymerized luting composite shade guides to compensate for the change in color of the definitive restoration.

## CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The shade of the final IPS Empress porcelain specimen changed after cementation regardless of cement shade, and major shade changes occurred during the first three days.
2. When the final colors of ceramics luted with cements in two different shades were compared, it was observed that the final color difference was not clinically perceivable ($\Delta E$<3.7) after each measurement session.

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