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SHORT COMMUNICATION

Effects of refractive index solutions on the color of different luting cements

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Abstract

Purpose. The purpose of this study is to determine the effects of refractive index solutions on the color of different luting cements at different periods. ***Materials and methods.*** Fourteen disc-shaped specimens were prepared for three different universal shade luting cements. All specimens were divided into two groups and a phthalate ester and glycerol refractive index solution was applied to the specimens at different periods. Color differences (ΔE*) were calculated for before and after 5, 15, 60 min and 24 h periods of applying refractive index solutions. Data were analyzed with multiple analysis of variance (ANOVA) and mean values were compared by the Tukey HSD test ($\alpha = 0.05$). ***Results.*** Periods and periods–cement interaction were statistically significant ($p \leq 0.05$). There was no statistically significant difference between the mean ΔE values of refractive index solutions and cement groups ($p > 0.05$). ***Conclusion.*** Refractive index solutions affected the color of luting cements.

Key Words: *color change, luting cement, refractive index, refractive index solution*

Introduction

Refractive index or index of refraction is a measure of bending of a ray of light when passing from one medium into another [1]. The refractive index plays a vital role in many branches of physics, biology and chemistry [2,3]. Refractive index materials reduce or eliminate internal reflectance and so increase the transmittance of light [4]. They do this by having a refractive index and dispersion that are similar to many glasses and optical plastics and closely match the refractive index and dispersion of fused silica [4]. Optical properties of some biological tissues and dental materials were investigated on some researches and the refractive indices were determined to be $n = 1.652$ and 1.546 for enamel and dentin, respectively [5–7]. Refractive index values of optical liquid and glycerol solutions are similar and ~ $n = 1.55$ [2]. Therefore, these solutions can be used as an optical connection material for dental research and clinical studies to increase the transition of light when passing from one medium into another.

Luting cement materials are marked in various types with different physical characteristics and colors. Sorption, solubility and discoloration of luting cements in different solutions have been evaluated in many clinical or laboratory studies [8–13]. However, there isn't any research about the effects of refractive index solutions on the color of different luting cements. The purpose of this study is to determine the effects of refractive index solutions on the color of different luting cements at different periods. That the application of refractive index solutions would affect the color of different luting cements was the hypothesis for this study.

Materials and methods

Two different refractive index materials; a phthalate ester solution (Cargille Optical Gel Code 081160, Cedar Grove, NJ) (OL), a glycerol solution (Iron Kimya, Izmir, Türkiye) (GL) and three different luting cements at universal shade; a glass ionomer cement (Meron, Voco, Coxhaven, Germany) (GIC),

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a resin-modified glass ionomer cement (RelyX Luting Plus Cement, 3M ESPE, St. Paul, MN) (RMGIC) and a resin cement (RelyX-Unicem, 3M ESPE) (RC) were used in this study.

Fourteen disc-shaped specimens were prepared for each cement material (11 × 0.2 mm) according to the manufacturer's instructions. All specimens were divided into two groups and a phthalate ester; glycerol refractive index solutions were applied to the specimens at different periods. Cement specimens first color measurements were performed before applying and repeated at 5, 15 and 60 min and after 24 h periods. All measurements were done with a digital spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Säckingen, Germany) by positioning the specimens on a white background mold. The spectrophotometer recorded the measurements at CIE L*a*b* coordinates and they were transferred to a personal computer. Color differences (ΔE*) between before and after applying the refractive index materials were calculated with the use of $\Delta E^\star = [(L_1^\star - L_0^\star)^2 + (a_1^\star - a_0^\star)^2 + (b_1^\star - b_0^\star)^2]^{1/2}$ formula. ΔE value of 3.3 or greater is considered to be visually imperceptible as well as clinically acceptable [7,14].

Color differences data were analyzed by multiple variance analyses (ANOVA) (SPSS16.0.1; SPSS Inc, Chicago, IL), followed by a multiple comparison's test performed using a Tukey HSD test ($\alpha = 0.05$).

Results

The mean values and standard deviations (SD) of color changes and differences between groups are presented in Table I. Multiple variance analysis revealed that periods and periods–cement interaction were statistically significant ($p \leq 0.05$).

When ΔE values were evaluated, OL applied GIC and RMGC groups were high from the clinical visually imperceptible level (ΔE ≥ 3.3) at 60 min. Color differences were lower than the clinical visually imperceptible level for the other OL applied groups (ΔE < 3.3).

When the GL was used as a refractive index solution, determined color differences at 60 min of GIC, 15 and 60 min of RMGIC were high from the clinical visually imperceptible level (ΔE ≥ 3.3). Color differences were lower than the clinical visually imperceptible level for the other GL applied groups (ΔE < 3.3). The lowest ΔE value was consistently observed in GL applied GIC at 5 min (ΔE = 2.05 ± 0.33) and the highest ΔE was observed in the GL applied RES at 15 min (ΔE = 3.82 ± 0.76).

Table I. Mean and SD of color changes and differences between groups.

Cement	Period	OL ΔE (SD)	GL ΔE (SD)
GIC	5 min	2.27 (± 0.74)^{aA}	2.05 (± 0.33)^{aA}
	15 min	3.26 (± 1)^{bc}	2.25 (± 0.45)^{a}
	60 min	*3.5 (± 0.89)*^{c}	2.53 (± 0.76)^{ab}
	24 h	2.89 (± 1.1)^{abB}	2.84 (± 0.65)^{abcB}
RMGIC	5 min	2.55 (± 0.61)^{abC}	3.05 (± 0.66)^{abcdC}
	15 min	2.61 (± 0.72)^{abc}	3.82 (± 0.76)^{d}
	60 min	*3.44 (± 0.53)*^{cdD}	*3.45 (± 0.26)*^{cdD}
	24 h	2.09 (± 0.68)^{aE}	2.43 (± 0.79)^{abE}
RES	5 min	2.64 (± 0.93)^{abcF}	2.8 (± 0.76)^{abcF}
	15 min	2.56 (± 0.94)^{abG}	2.61 (± 0.68)^{abcG}
	60 min	3.01 (± 0.73)^{abcH}	2.67 (± 0.55)^{abcH}
	24 h	2.35 (± 0.61)^{abI}	2.26 (± 0.92)^{aI}

Italics indicate ΔE values of equal or greater than clinically acceptable level (ΔE ≥ 3.3).
Values having the same letters (lowercase: within time periods; uppercase: within refractive index material) were not significantly different for Tukey test ($p > 0.05$).

Discussion

On the basis of these data, the hypotheses set as the premises of this study should be accepted. The present study showed that both refractive index solutions affect the color of luting cements, but there was no statically significant difference between their mean color change value and these values were smaller than a clinical visually imperceptible level (ΔE < 3.3). Extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of contamination from exogenous sources [13]. Chemical compositions, viscosity of solutions and environments temperature are the most effective factors for absorption of refractive index solutions by the cement specimens [15]. Despite the chemical compositions and viscosity properties of solutions not being the same, similar color change values should be caused because of their colorless feature and short application time.

RMGIC represented higher color change compared with GIC and RC, but there was no statically significant difference between their mean color change value ($p > 0.05$). It was an expected result that the refractive index solutions would affect the color co-ordinate of the luting cements, because it affected the transmittance of light passing through cement. However, sorption and solubility of luting cements in refractive index solutions might be the major factor for the color change. In a previous study [15], the solubility, sorption and dimensional change of eight luting cements in two different solutions (50% ethanol:water and distilled water) were examined and the resin-modified glass ionomer cement exhibited significantly higher sorption compared to the resin-based luting cements, both in water and ethanol:water. The water sorption mainly depends on the hydrophilic compositions such as hydroxyethyl methacrylate (HEMA) or resin molecules that contain hydrophilic moieties clearly increased water sorption value, as observed in resin-modified glass ionomers [16–18]. Sorption and solubility of resin cement are usually dependent on the type of resin matrix, filler composition and nature of filler particles [15,16,19,20]. In another study [21], it was indicated that water diffuses through the resin and reacts with the filler at the filler–matrix interface and coupling the matrix and filler particle significantly reduced the water uptake. The mixing method (mixing on a paper pad vs auto-mixing of paste–paste cement) is an important factor to obtain an homogeny cement structure and will generate different amounts of air voids within luting cements [22]. These voids will be incorporated into the material and lead to numerous oxygen-inhibition zones of unpolymerized materials, which then affect the solubility of the set cement [20–22]. In this study, a large number of air voids was observed in the RMGIC specimens and this may be another reason in explaining its higher color change values when compared to other cements.

In the present study, color change value were increased from 5 min to 60 min and decreased from 60 min to 24 h and there were statically significant difference between 5–60 min and 60 min–24 h periods ($p \leq 0.05$). In a previous study [13], percentage change in volume of the RMGIC and RC in water or ethanol:water was examined and highest values were determined at the first hour. In another study, water sorption of RMGIC and GIC cements were compared and it was seen that the maximum water sorption value were determined likewise at the first hour [23]. In the present study, the highest color change values were determined at 60 min for all of the luting cements, similar to with previous studies.

In this study, the effects of two different refractive index solutions on the color of different luting cements were examined. Their other physical, chemical or mechanical effects on the luting cements or other dental materials will be investigated. Also, color differences were measured at short applying periods so their long-term effects can be investigated. These are factors which may be considered in future research.

Conclusions

Within the limitations of this study, the following conclusions can be drawn.

(1) Refractive index solutions affected the color of luting cements.
(2) Type of the luting cement, matrix and the filler characters, polymerization degree, mixing method and many other factors may be decisive factors on the discoloration of luting cements.
(3) When the refractive index solutions are used in dental research, especially for discoloring materials, researchers must pay attention and keep the contact time as short as possible.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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