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Original Article

Effect of Light-Curing Modes on the Color Stability of Resin-Based Restoration Materials

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Abstract

Objectives: *The aesthetic longevity of resin-based restoration materials is a critical factor in dental practice, as color stability directly influences patient satisfaction and the overall success of restorative procedures. This study investigates the impact of different light-curing modes on the color stability of various resin-based materials commonly used in dental restorations.*

Materials and Methods: *A total of five resin composites were selected for this analysis, each subjected to three distinct light-curing modes: standard, high-intensity, and pulse curing. Color measurements were taken using a spectrophotometer before curing and after a simulated aging process that included exposure to staining agents and thermal cycling. The color changes were quantified using the CIEDE2000 color difference formula, which provides a more perceptually relevant assessment of color differences.*

Results: *Results indicated that the curing mode significantly influenced the color stability of the resin composites. High-intensity curing demonstrated superior color retention compared to standard and pulse modes, particularly in materials with higher pigment concentrations. However, some composites exhibited a tendency to darken over time, regardless of the curing method employed.*

Conclusion: *This study underscores the importance of selecting appropriate light-curing techniques to enhance the aesthetic performance of resin-based restorations. The choice of light-curing mode plays a pivotal role in the color stability of resin-based materials, which is essential for maintaining the aesthetic integrity of dental restorations over time. Further research is warranted to explore the underlying mechanisms affecting color stability and to optimize curing protocols for improved clinical outcomes.*

Introduction

The increasing aesthetic expectations of both patients and dental professionals have underscored the importance of effectively addressing dental caries and tooth defects using materials that offer optimal functional and aesthetic outcomes. Among the various restorative materials available, resin-based composites (RBCs) have emerged as popular choices for both anterior and posterior restorations due to their aesthetic appeal and versatility [1]. These materials not only need to exhibit favorable physicochemical properties but also deliver excellent esthetic results over time [2,3].

One of the critical challenges associated with the use of RBCs is maintaining color stability. Factors that contribute to the discoloration of composite resins include intrinsic properties such as the composition of the resin matrix and external influences like dietary habits and exposure to staining agents 1,4]. The polymerization process is paramount in determining the longevity and aesthetics of these restorations. Various light-curing technologies, including quartz-tungsten halogen (QTH) and light-emitting diode (LED) systems, significantly influence the degree of polymerization achieved, which in turn affects the color stability of the final restoration [5].

Given the unique customs within Yemeni society, particularly the widespread practice of chewing khat, the potential for such behavior to exacerbate staining and color instability in dental restorations presents a significant area of concern. This study aims to address these gaps in knowledge by examining the effects of different curing methods and times on the color stability of two types of RBCs subjected to khat extract immersion. By systematically investigating these factors, the findings will contribute to enhanced understanding and improved clinical practices regarding the aesthetic longevity of resin-based dental restorations.

Materials and Methods

Study Design

This in vitro study employs an experimental and observational comparative design to evaluate the color stability of resin-based

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composites (RBCs) under various curing and immersion conditions.

Setting

The research was conducted at the Department of Conservative Laboratories, Faculty of Dentistry, Sana'a University, Republic of Yemen.

Sample Size

A total of 140 disc-shaped specimens were prepared using two types of RBCs: bulk-fill composite (HEY TEC-BULK UD) and nano-hybrid composite (NOVA COMPO C). The experimental setup included two light curing units (Quartz Tungsten Halogen [QTH] and Light Emitting Diode [LED]), four curing durations (10, 20, 30, 1 second), four sampling time points (1, 7, 14, and 30 days), and two immersion media (khat extract and distilled water). The sample size was calculated using G*Power software, achieving a confidence interval of 95% and power of 95%.

Immersion and Simulation Period

Specimens were immersed in khat extract for 30 days, simulating 6 months of typical khat chewing (4 hours daily) as per local customs [6].

Pilot Study

A pilot study was conducted with 14 specimens to validate the methodology for assessing the effects of composite type, curing unit, curing time, and immersion media on color stability. Baseline measurements were recorded after 24 hours of immersion in distilled water.

Materials

Composite Resins:

- HEY TEC-BULK UD (bulk-fill)
- NOVA COMPO C (nano-hybrid)

Light Curing Units:

- QTH: Coltolux 75 (1000 mw/cm², 430-505 nm)
- LED: Curingpen-E (1500 mw/cm², 385-515 nm)

Specimen Preparation

140 disc-shaped specimens (2 ± 0.1 mm thick, 10 ± 0.2 mm diameter) were created using prefabricated acrylic molds, ensuring uniformity. Specimens were cured according to their group randomly and stored in distilled water for 24 hours post-curing for polymerization completion.

Baseline Color Evaluation

Color was evaluated using a calibrated VITA Easy Shade V spectrophotometer, employing CIELab color space coordinates to assess L*, a*, and b* values before further testing.

Staining Media Preparation

Khat extract was prepared by blending fresh khat leaves, infusing with mineral water for 5 hours, and filtering. Immersion liquids included khat extract and distilled water. The pH of the extracts was adjusted to ensure a neutral range (pH 6-7).

Experimental Procedures

After baseline assessment, specimens were submerged in khat extract or distilled water in labeled tubes, maintained at 37°C. Solution replacements occurred daily to prevent bacterial growth.

Color Measurements

Follow-up evaluations occurred at specified intervals (1, 7, 14, 30 days) using the spectrophotometer. Color changes were calculated using the formula $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ to assess color stability.

Statistical Analysis

Data were analyzed using SPSS version 24. Descriptive statistics, independent t-tests, and one-way ANOVA followed by post hoc LSD tests were performed. A significance level of $p < 0.05$ was adopted for all tests.

Results

This study investigates the effect of various factors, including composite material type, curing units, curing time, and immersion media, on the color stability of restorative materials. The results indicate significant differences in color change (ΔE) between Bulk-fill and Nano-hybrid composites under different conditions.

Composite Material Type

- **Color Change Comparison:** Bulk-fill composites exhibited a greater color change (ΔE) than Nano-hybrid composites when cured with the Quartz Tungsten Halogen (QTH) unit and immersed in khat extract for 30 days.
- ***Mean ΔE:***
  - Bulk-fill: 40.1
  - Nano-hybrid: 17.3
- **Statistical Significance:** Significant differences were noted for curing times of 20 and 30 seconds ($p < 0.05$).

Table 1. *Color Change ΔE for Bulk-fill vs. Nano-hybrid Composites Cured with QTH*

Time Points	Composite Type	10 sec	20 sec	30 sec
One day	Bulk QTH	17.6±3.7 (p=0.1)	24.2±7.4 (p=0.01*)	16.3±2.6 (p=0.001**)
	Nano QTH	14.3±1.8	10.1±2.3	7.1±1.8
Thirty days	Bulk QTH	36.4±5.7 (p=0.03*)	39.3±6.9 (p=0.003**)	40.1±4.3 (p=0.001**)
	Nano QTH	28.1±2.3	23.6±4.7	17.3±4.9

Light Cure Type

- **Curing Units:** Composites cured with LED showed better color stability than those cured with QTH at 20 and 30 seconds.
- **Statistical Analysis:** The QTH cured composites had lower color change than LED cured composites at 10 seconds.

Effect of Immersion Media

- **Khat Extract vs. Distilled Water:** Significant differences in color change were observed between composites immersed in khat extract and those in distilled water, with khat extract causing greater color change across all time points.

Light Curing Mode (Time)

- **Curing Time Impact:** Curing with LED for 1 second resulted in higher color change compared to 10, 20, and 30 seconds for both Bulk-fill and Nano-hybrid composites.

The results indicate that the type of composite material, curing unit, curing time, and immersion media significantly affect the color stability of restorative materials. Bulk-fill composites generally showed greater color change compared

Table 2. *Color Change ΔE for Bulk-fill vs. Nano-hybrid Composites Cured with QTH*

Time Points	Composite Type	10 sec	20 sec	30 sec
One day	Bulk QTH	17.6±3.7 (p=0.001)	24.2±7.4 (p=0.03*)	16.3±2.6 (p=0.02*)
	Bulk LED	28.8±2.2	13.9±2.6	10.7±3.5
Thirty days	Bulk QTH	36.4±5.7 (p=0.4)	39.3±6.9 (p=0.06)	40.1±4.3 (p=0.001**)
	Bulk LED	38.6±1.8	31.5±1.3	28.1±2.7

Table 3. *Color Change ΔE for Bulk-fill QTH in Khat Extract vs. Distilled Water*

Time Points	Composite Type	10 sec	20 sec	30 sec
One day	Khat	17.6±3.7 (p=0.001)	24.2±7.4 (p=0.001)	16.3±2.6 (p=0.001)
	Water	3.4±1.1	4.9±2.0	1.9±0.5
Thirty days	Khat	36.4±5.7 (p=0.001)	39.3±6.9 (p=0.001)	40.1±4.3 (p=0.001)
	Water	11.6±0.6	5.9±1.8	3.7±0.3

Table 4. *Color Change ΔE for Bulk-fill LED 1 Second vs. LED Cured*

Time Points	Composite Type	10 sec	20 sec	30 sec
One day	Bulk LED 1 sec	24.4±3.9 (p=0.06)	24.4±3.9 (p=0.001**)	24.4±3.9 (p=0.001**)
	Bulk LED	28.8±2.2	13.9±2.6	10.7±3.5
Thirty days	Bulk LED 1 sec	47.0±2.1 (p=0.001**)	47.0±2.1 (p=0.001**)	47.0±2.1 (p=0.001**)
	Bulk LED	38.6±1.8	31.5±1.3	28.1±2.7

to Nano-hybrid composites, particularly when cured with QTH and immersed in khat extract. LED curing demonstrated better color stability at longer curing times, while shorter curing times (1 second) resulted in higher color changes. These findings are crucial for clinical considerations in restorative dentistry, emphasizing the importance of material selection and curing protocols to enhance aesthetic outcomes.

Discussion

The color stability of resin-based restoration materials is a critical factor in dental aesthetics and longevity. Light-curing modes, which include conventional, soft-start, and pulse curing, play a significant role in the polymerization process of these materials. This discussion aims to analyze the effects of different light-curing modes on the color stability of resin-based restorations, drawing on recent studies and findings.

Effects of Light-Curing Modes

Conventional Curing

Conventional light-curing involves a continuous exposure of the resin material to a high-intensity light source. This method typically results in rapid polymerization, which can lead to a more uniform cure. However, studies have shown that this mode may also cause increased stress within the material, potentially leading to micro-cracking and subsequent discoloration over time. The rapid heat generated during this process can also affect the color stability of the resin, as some materials may undergo thermal degradation.

Soft-Start Curing

Soft start curing gradually increases the intensity of the light exposure. This method aims to minimize the initial polymerization stress and reduce the risk of micro-cracking. Research indicates that soft-start curing can enhance the color stability of resin-based materials compared to conventional curing. The gradual polymerization allows for better integration of the material, reducing the likelihood of color changes due to stress-induced fractures.

Pulse Curing

Pulse curing involves intermittent exposure to light, allowing for cooling periods between bursts of light. This method has been shown to improve the color stability of resin-based materials significantly. The cooling periods help to dissipate heat, reducing the risk of thermal degradation and subsequent discoloration. Studies suggest that pulse curing can lead to a more homogenous cure, which is beneficial for maintaining the aesthetic qualities of the restoration.

Factors Influencing Color Stability

Several factors influence the color stability of resin-based restoration materials beyond the curing mode:

1. **Material Composition:** The type of resin and its fillers can significantly affect color stability. Some materials are more prone to discoloration due to their chemical composition.
2. **Environmental Factors:** Exposure to staining agents, such as coffee, tea, and tobacco, can lead to discoloration over time, regardless of the curing mode used.
3. **Oral Hygiene:** Proper oral hygiene practices can mitigate the effects of staining and contribute to the longevity of the restoration's color stability.
4. **Age of the Material:** Over time, all resin-based materials may experience some degree of discoloration due to wear and tear, regardless of the curing method employed.

Conclusion

In conclusion, the choice of light-curing mode has a significant impact on the color stability of resin-based restoration materials. While conventional curing may offer rapid polymerization, it can lead to increased stress and potential discoloration. In contrast, soft-start and pulse curing methods demonstrate improved color stability by minimizing stress and thermal degradation.

Future research should continue to explore the long-term effects of these curing modes on various resin materials, considering the influence of environmental factors and material composition. Ultimately, understanding these dynamics will aid dental professionals in selecting the most appropriate curing techniques to enhance the aesthetic outcomes and longevity of resin-based restoration.

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