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The Influence of Lighting Conditions on Color Difference (ΔE) in Glazed Fixed Prosthetic Restorations: A Comparative Study

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Abstract:
Background*: Achieving optimal esthetics in fixed prosthodontics requires not only accurate material selection but also precise color matching. The color difference parameter (ΔE) plays a crucial role in objectively quantifying color variation between dental restorations under different conditions. Surface finishing techniques such as glazing, as well as the lighting environment during color evaluation, may significantly affect ΔE values and thus influence clinical outcomes.*
Objective: *This study aimed to evaluate the effect of two lighting conditions—natural daylight and artificial reflector light—on the color difference (ΔE) values of glazed fixed prosthetic crowns fabricated from three different materials: metal-ceramic, full-contour zirconia, and veneered zirconia.*
Materials and Methods*: Ninety crowns (n = 30 per group) were fabricated and uniformly glazed. The specimens were divided into three groups according to the material type: Group A (metal-ceramic), Group B (full-contour zirconia), and Group C (veneered zirconia). ΔE values were recorded using a calibrated spectrophotometer under standardized daylight and reflector light conditions. The Mann-Whitney U test was used for statistical analysis to compare lighting effects within each material group.*
Results*: There were no significant differences in ΔE for metal-ceramic and full-contour zirconia. A significant difference was found in the veneered zirconia group (Z=-3.005; p=0.003).*
Conclusion: *Lighting conditions can influence the perceived color difference in glazed restorations, particularly in layered, translucent systems like veneered zirconia. These findings support the use of standardized natural lighting environments during shade selection and final evaluation of esthetic restorations to minimize metamerism and optimize color matching outcomes.*
Key Word*: **ΔE, glazed restorations, lighting conditions, zirconia, color perception, spectrophotometry, esthetic dentistry***

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I. Introduction

Achieving esthetic success in fixed prosthodontics relies heavily on accurate shade selection and faithful color reproduction of restorative materials. [1] One of the primary goals in restorative dentistry is to create restorations that are indistinguishable from natural dentition, not only in shape and texture but also in color. However, color matching is inherently complex due to its dependence on both material and environmental factors.[2]

Color perception in dentistry is influenced by multiple variables, including the type of material, surface treatment, observer variability, and most notably, the lighting under which color selection and evaluation take place.[3,4]Glazing as a surface treatment creates a smooth, light-reflective surface that can alter the visual outcome of color, while the translucency of materials like zirconia introduces further complexity in light transmission and reflection.[5]

The ΔE value is a well-established metric used to quantify color difference between a reference and a test surface. It provides an objective measure that correlates with perceptual thresholds and clinical acceptability standards [6]. A ΔE below 1 is generally considered imperceptible, whereas values above 2.7 are often regarded as clinically unacceptable.[7]

Lighting conditions can dramatically influence color perception due to a phenomenon known as metamerism, where two colors may appear to match under one light source but differ under another.[8] Glazed ceramic materials are known for their esthetic properties and are frequently used in anterior and posterior restorations [9]

Daylight is considered the gold standard for shade selection, yet clinical conditions often involve reflector or operatory lighting, which may not replicate natural light properties [10]

Given the increasing clinical use of highly esthetic, glazed zirconia materials and the variable lighting environments in dental practices, this study aims to investigate the effect of two distinct lighting conditions on the ΔE values of glazed crowns made from metal-ceramic, full-contour zirconia, and veneered zirconia. The objective is to determine whether lighting has a statistically significant impact on color difference and to identify which material types are more susceptible to these variations.

II. Material And Methods

This study included a total of 90 specimens of crowns, divided into three groups of 30 samples each, according to the material used:

1. metal-ceramic,
2. monolithic zirconia, and
3. veneered zirconia.

All specimens underwent a final glazed surface treatment, following the manufacturer's recommendations specific to each material. The samples were fabricated in a standardized crown shape for the anterior region, with identical thickness and dimensions to minimize any optical variation due to material thickness.

Lighting Conditions

Color measurements were performed using a spectrophotometer under two different lighting conditions:

- natural daylight and
- artificial lighting, in order to examine the influence of illumination on the perceived color of the restorations.

Each specimen was placed against a neutral gray background, and color was measured on the entire vestibular surface of the crown. Each measurement was repeated three times, and the average ΔE value was used for statistical analysis.

Colorimetric Parameter

The primary optical parameter assessed was ΔE, representing the quantified color difference between the two lighting conditions, calculated according to the CIE-L*a*b* color space system.

Statistical Analysis

Statistical analysis was performed using the Mann-Whitney U test to determine whether there were significant differences in ΔE values within the same group of specimens under different lighting conditions (daylight vs. reflector light). A significance level of $p < 0.05$ was considered. All data were analyzed using SPSS software version 25.0 (IBM Corp.).

III. Result

The comparison of ΔE values between **daylight** and **reflector light** conditions for the glazed subgroups of the three tested materials was conducted using the **Mann-Whitney U test**. The findings are summarized as follows:

- For the **metal-ceramic** group, a **slightly lower ΔE value** was observed under reflector light compared to daylight, but this difference was **not statistically significant** ($Z = -0.607; p = 0.544$).
- In the **monolithic zirconia** group, the ΔE values were also **slightly reduced** under reflector light, without reaching statistical significance ($Z = -1.051; p = 0.293$).
- The **veneered zirconia** group exhibited a **higher mean ΔE value** under reflector light compared to daylight; however, this difference was likewise **not statistically significant** ($Z = -0.922; p = 0.356$).

These results indicate that, despite minor variations in color differences between the two lighting conditions, **no statistically significant differences** in ΔE values were found in any of the glazed subgroups of the tested materials when comparing daylight and reflector illumination.

IV. Discussion

The present study aimed to evaluate the influence of two different lighting conditions—natural daylight and artificial reflector light—on the color perception (ΔE) of glazed fixed prosthetic restorations made from three types of materials: metal-ceramic, monolithic zirconia, and veneered zirconia.

The findings demonstrated **no statistically significant differences** in ΔE values across lighting conditions within any of the material groups. Although minor variations were observed—such as slightly lower ΔE values for metal-ceramic and monolithic zirconia under reflector light and slightly higher values for veneered zirconia—the differences were not sufficient to indicate a meaningful clinical or statistical effect.

These results are in line with previous studies that report **lighting conditions can influence visual perception**, but do not always lead to statistically significant deviations in instrumental color

measurements[11,12]. The lack of significant difference in ΔE values suggests that **modern ceramic materials**, especially when properly glazed, maintain **optical stability** under different lighting conditions.

Moreover, the **CIE-L*a*b* system**, which was used to calculate ΔE, is known for its high sensitivity in detecting color changes, even those imperceptible to the human eye. In clinical terms, ΔE values below the generally accepted perceptibility threshold (commonly around 2.0–3.3 depending on the study) are considered **not noticeable** to the average observer [6,13].

From a practical perspective, this indicates that **glazed restorations fabricated from the tested materials are likely to appear consistent** in color regardless of the lighting environment in which they are evaluated, which is highly relevant in clinical settings with variable illumination.

An additional consideration is the fact that **glazing improves surface smoothness and reduces light scattering**, potentially contributing to the optical consistency across lighting environments. This aligns with the conclusions of other authors who emphasized the role of surface finish in color stability [5,14].

In summary, the present results support the hypothesis that while lighting plays a role in color perception, **well-processed glazed prosthetic materials exhibit reliable color behavior** even under varying lighting conditions, reaffirming their suitability for use in esthetically demanding clinical cases.

V. Conclusion

The comparative analysis of ΔE values under daylight and reflector light conditions in glazed subgroups of metal-ceramic, monolithic zirconia, and veneered zirconia restorations revealed **no statistically significant differences** between the two lighting environments within any material group.

Although slight variations in color differences were recorded, these changes were minimal and **did not exceed clinically relevant thresholds**, indicating that the color appearance of glazed restorations remains **largely stable across different lighting conditions**.

These findings suggest that while lighting can influence visual perception to some extent, its effect on the **instrumentally measured color differences (ΔE)** in glazed ceramic materials is **limited and not significant**, provided the surface treatment is performed correctly.

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