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Study on the conditions of color determination in dentistry.

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Abstract

Introduction: Several variables can impact the choice of shade. Having a thorough understanding of these factors and following the proper selection technique is crucial for achieving favorable esthetic results. Aim of the study: To review the characteristics of esthetic perception of teeth in different lighting conditions, by individuals with different levels of experience in dentistry. Material and methods: Thirty volunteers, dentistry students, and general dentists were recruited. The participants were asked to determine the color of 4 mock-ups containing artificial teeth, under standardized conditions. Therefore, the samples were introduced in a custom-made box and illuminated by two different light conditions (4300 K and 5500 K), and three different colors (black, gray, and pink) were selected as background colors. Results: Our results showed a statistically significant difference between the two examined light conditions, the number of correct color determinations was significantly higher under the light with a color temperature of 5500K ($p<0.00001$). It can be seen that the gray background color proved to be statistically significantly more beneficial than the black and pink background colors. Conclusions: Among dentistry students and practitioners, environmental changes that affect shade determination have been demonstrated. Further research is still necessary regarding the perception of the esthetic expectations of dental treatments for color determination.

Keywords: tooth shade, dentist perception, color determination, lighting conditions, gray background.

Introduction

The external factors and the color of teeth are complex, interrelated phenomena. The overall perception of tooth color is influenced by lighting conditions, semitransparency, opacity, luster, light scattering, ocular perception, and color perception. In modern dentistry, tooth color can be measured using a variety of techniques, including spectrophotometry, colorimetry, visual evaluation of color samples, and computer analysis of digital photographs [1].

The success of oral rehabilitation is determined by a combination of factors such as shape, size, and color. Therefore, the accurate determination of tooth color is a very important step, and it can be determined by a visual method, using shade guides to determine the most appropriate shade. Alternatively, one of the devices that have been developed over the years to determine tooth color can be used (spectrophotometers, colorimeters, and intraoral scanners) [2].

In modern dentistry, the standard method of assessing light through visual communication with the patient, dentist, and dental technician is inadequate. Shade master, with the data being recorded on paper, is the most often used technique for visually detecting color and shade in dental care. The subjective nature of visual perception and weariness are two drawbacks of the eye analyzer, despite its sensible nature. According to a study, 75% of dentists who practice medicine have trouble doing these assessments. There is a considerable chance of inaccuracy due to the following factors: age, sex clothing, light, time of day, visual perception, etc.[1].

Colorimeters and spectrophotometers are appropriate and practical tools for analyzing and determining tooth color. The entire surface of the tooth is measured, they apply a color map or the average color of the specified region (3-5 mm). These tools are helpful for shade checking, recreation, communication with indirect restorations, and quality control of color recreation. They can also be used to analyze colors for direct and indirect restorations [2].

The authors of several articles advise combining the visual and instrumental methods of color determination whenever possible because they work well together and

produce reliable results [3,4]. Using dental photography pictures that were obtained according to protocol is an additional effective way of determining color [5]. McLaren's study demonstrates an 80% reduction in errors and color discrepancies [6].

The aim of the present study is to assess shade perception of artificial teeth in different lighting options, by individuals with different levels of experience in dentistry. The null hypothesis is that the operator's clinical experience has no correlation to determining the color shades.

Material and methods

During our experiment, dentistry students and practitioners performed shade determinations under standardized conditions. The inclusion criteria for the operators were: under 35 years old, without vision problems, and subjective perception without glasses.

Participants in the experiment were asked to determine the color of 4 dental stone mock-ups containing artificial teeth. Each mock-up contained prefabricated teeth of the anterior zone from canine to canine (Spofadent Plus, Kerr Corporation, California, USA), to facilitate the determination of their color when acting as a block (Figure 1).

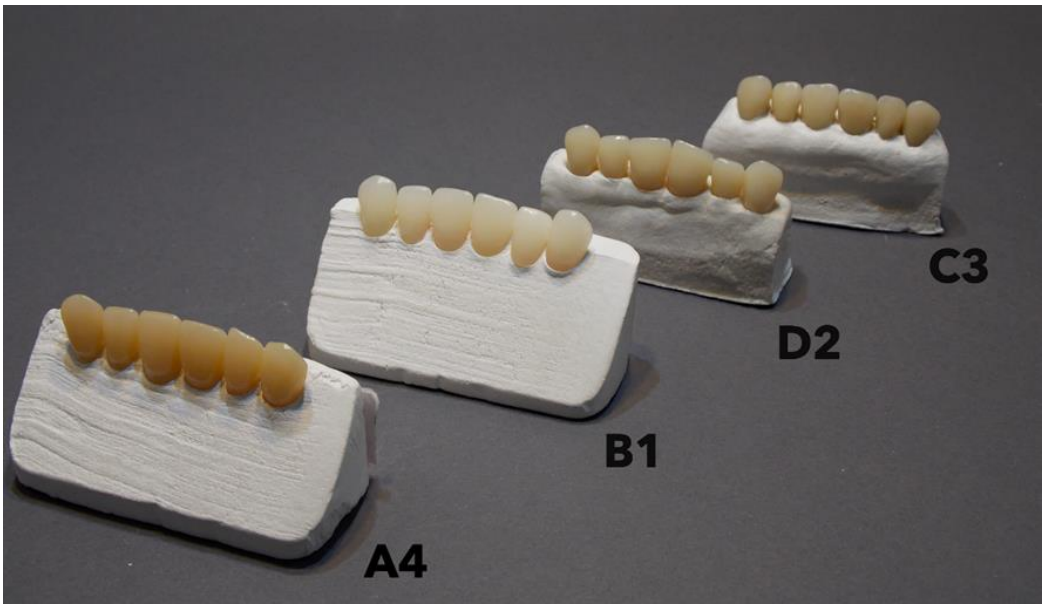

Figure 1. The mock-ups used for shade determination

The standardized conditions were provided by the experimental box (40 cm height, 40 cm width, and 40cm length) prepared for an earlier study by one of our students. The box was made of transparent plastic and four spot burners (Lexman) with white and yellow light bulbs installed were located in the upper section of it. The built-in potentiometer can be used to adjust the yellow light, allowing many lights with different color temperatures to be set. Alternatively, it is possible to utilize only yellow or white light. Since the walls of the box are transparent, it was covered with a white sheet to block out the outside light (Figure 2).

Figure 2. The custom-made box

The background colors to be tested can be created using the colored cardboard sheets placed in the experimental box. By changing the cardboard sheets, we can examine the effect of different background colors on the accuracy of color determination under the same conditions.

A total of 30 subjects participated in the experiment, divided into 3 groups, each of 10 individuals. The first group was represented by 3rd-year dentistry students, the second group by graduating dentistry students, and the third by general dentists. Based on the results of a questionnaire from our previous research (part of the main author's thesis), black, gray, and pink were selected as background colors. Therefore, the samples were introduced in a custom-made box and illuminated by two different light conditions (4300 K and 5500 K). Each evaluator had 15 seconds available for each color determination. The allocation of time was restricted due to the proposition that extending the duration results in a higher frequency of mistakes. During each background change, the participants rested their eyes by looking at a blue surface for 1 minute.

Statistical analysis was made using chi-square tests and t-tests (SPSS software), and the level of significance was set at 0.05.

Results

The investigation involved a total of 30 participants, with 56.6% identifying as females and 43.3% identifying as males.

A total of 720 color determinations were conducted during the course of the experiment. After taking into consideration the potential impact of lighting conditions, background colors, and the experimenters' experience, it was observed that the participants accurately identified the color of the models in 327 cases, corresponding to a correct determination rate of 45.4%.

Based on the chi-square test, a significant difference exists between the two light conditions under investigation in relation to the number of accurate color determinations. The difference results from the fact that the light with a color temperature of 5500K resulted in a significantly greater number of correct color determinations ($p<0.00001$).

The statistical analysis conducted using the Chi-square test revealed a significant difference in the effectiveness of the gray background compared to the black and pink background colors. The statistical analysis reveals that there is a substantial difference in the number of accurate color determinations between gray and black background colors ($p=0.006$), as well

as between gray and pink background colors (p=0.0009). Nevertheless, the statistical analysis reveals that there is no significant difference in the impact of black and pink backgrounds on color recognition (p=0.577).

Regarding the accuracy rate of shade determinations, the experiment observed three distinct groups of participants, each exhibiting varying levels of performance. Specifically, group 3 achieved correct shade determinations in 52% of cases, group 2 in 45% of cases, and group 1 in 39% of cases. The observed discrepancy exhibited statistical significance just in the comparison between the first and third groups (p=0.004). Group 3 achieved 38% of accurate shade determinations, whereas Group 2 achieved 33%, and the first group achieved 29%.

In addition to the influence of lighting conditions and background colors on color recognition and the subjective experience of the individual doing the color identification task, the following outcomes were achieved for the tested models. Out of the four mock-ups that were evaluated, the A4 color mock-up demonstrated the highest accuracy in color determinations, with a total of 145 correct determinations. Stated in terms of percentage, the participants exhibited accurate identification of the shade of the A4 model in 80.5% of instances. The accuracy rate for accurately determining the color of the B1 mockup was 62.2%. According to the C3 model, the accuracy rate for color determinations is 24.4%. The D2 mockup had the lowest rate of accurate color determinations, as participants correctly identified the color of the mockup in only 14.4% of instances. Figure 3 displays the distribution of accurate color determinations among the three distinct groups of participants. There is a statistically significant difference in the number of correct color determinations observed between the different shades of the mockups, with a p-value less than 0.05.

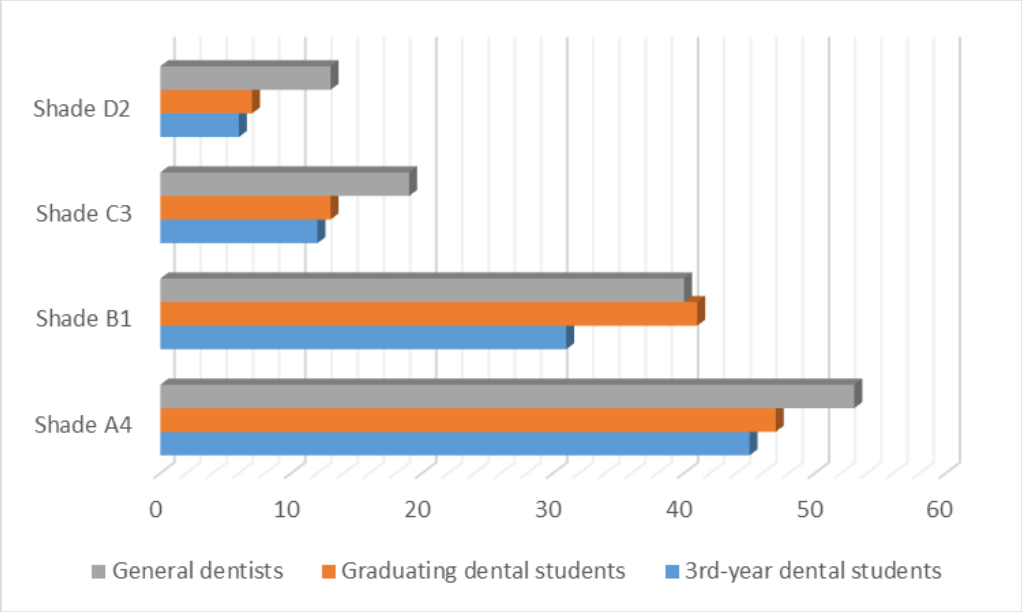

Figure 3. Distribution of the numbers of accurate color determinations by the shade of the mockup

Discussions

The determination of tooth color is a crucial step in the development of esthetic prosthetic work, as the suitability of the color greatly impacts the functional and formal perfection of the prosthesis. In the field of dentistry, the prioritization of restoring functionality is commonly emphasized by practitioners. However, it is noteworthy that a significant proportion of patients choose to prioritize the restoration of esthetic appearance. Hence, it is imperative that we make diligent efforts to ascertain the precise shade of tooth color.

The significance and relevance of the subject matter are substantiated by the existence of a plethora of research conducted

over time, which have examined the optimal conditions and influential factors involved in determining tooth color. Drawing upon the existing literature and the findings of our research, we attempted to identify the optimal parameters for shade determination [3,5,7].

The findings of our study align with the existing literature, which indicates that the visual method with color keys remains the predominant approach for color determination, even in contemporary practice [7]. The likely cause of this phenomenon can be attributed to the elevated cost of colorimeters and the absence of complete precision in their measurements. Furthermore, the predominant technique taught at academic institutions for color matching is the visual method. Hence, it is unsurprising that the subjective visual shade identification approach continues to be extensively employed in dental practices in Europe and the United States [8]. The process of visual shade selection presents a number of drawbacks, including subjectivity and susceptibility to various influencing factors. However, empirical evidence suggests that dentists possess the ability to accurately choose clinically acceptable hues by utilizing shade guides [9].

Therefore, we opted for a color scheme consisting of black, gray, and pink, with the latter representing the contextual ambiance of the mouth cavity. Based on the findings of our study, it was determined that the gray background exhibited a statistically significant advantage over the black ($p=0.006$) and pink ($p=0.0009$) background colors. The results gained align with other studies in the literature, which also indicate that gray is the preferred background color for color determination [10,11,12].

Numerous articles in the academic literature examine, among other things, whether color-matching expertise and experience influence the precision of the process. The outcomes, nevertheless, are inconsistent. According to the findings of a number of researchers, clinical experience has no appreciable impact on the precision of color-matching [13,14]. Several investigations, however, indicate the opposite [15,16,17]. The study by Juliana A. Medeiros et al. involved one hundred individuals, including dentists, dentistry students, dental auxiliaries, dental technicians, and laypeople, and reached the conclusion, based on their findings, that the discernment of the observer has an impact on the precision of tooth color determination. In contrast to other cohorts of observers, dentists, and dental technicians demonstrated a more pronounced capacity to discern subtle variations in hue, as evidenced by their findings [17].

Based on the results of this study, experience does have an effect on the accuracy of shade identification. In the experimental phase of the present research, the group of dentists performed significantly better than the group of third-year students in terms of the number of correct color determinations ($p=0.004$). However, it should also be mentioned that the difference between the dentists and sixth-year students, as well as between the sixth-year students and third-year students, is not significant in this regard. Our results can probably be explained by the fact that the third-year students did not even have the theoretical foundations of color definition, as this knowledge is acquired in a later year of university. Although the sixth-year students had a theoretical foundation, their practical experience was limited due to the restrictions imposed during the pandemic. The group of dentists had both theoretical knowledge and practical experience and as Siddhesh et al. point out, both knowledge and experience improve the ability to determine color [16].

According to the meta-analysis conducted by Siddhesh et al., it was shown that the clinician's ability to estimate tooth shade can be enhanced by factors such as clinical experience, understanding of dental shade determination, and training in the shade determination methodology [16].

Conclusions

Despite the limitations of the present study, we consider that the 5500 K color temperature light proved to be the most appropriate for color determination. Acromatic background colors have been shown to be beneficial in terms of color definition, and grey has been highlighted in this study. The clinical experience of the observer also affects the

accuracy of color determination. Thus, the null hypothesis was rejected.

Conflict of interest: None to declare.

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