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SYSTEMATIC REVIEW

Comparison of tooth shade determination using two methods: visual and spectrophotometric

Comparación de la toma de color de dientes con dos métodos: visual y con espectrofotómetro

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ABSTRACT

Introduction: dental color determination is a crucial procedure in oral rehabilitation treatments, since with precision, aesthetically correct results will be achieved that fit the naturalness of the patient's teeth. Thanks to technological advances, new tools have emerged, such as spectrophotometers, intraoral scanners, among others, which have significantly improved the way of carrying out this process.
Objective: to evaluate the effectiveness of dental color determination with the visual method compared to the spectrophotometer.
Method: a descriptive and documentary study was carried out following a systematic bibliographic search of articles in the last 10 years, which were selected according to the inclusion and exclusion criteria.
Results: the study compared the effectiveness of two methods to determine the color of teeth: visual and instrumental (with a spectrophotometer). The visual method, although traditional, presents high variability due to factors such as lighting, the observer's experience and the individual perception of color. The spectrophotometer offers a more objective and reproducible measurement of color, as it is not influenced by external factors. Although both methods can achieve similar results in some cases, significant differences were generally observed in the selection of the dental shade. The spectrophotometer allows for the detection of more subtle color differences and offers greater consistency in the results.
Conclusions: dental shade measurement is more effective with a spectrophotometer, however, the authors recommend using the two methodologies together.

Keywords: Shade Measurement; Spectrophotometer; Light; Shade Guide; Vita 3D Master Guide.

RESUMEN

Introducción: la toma de color en Odontología es un procedimiento crucial en los tratamientos de rehabilitación oral, ya que con la precisión se lograrán resultados estéticamente correctos y que se ajusten a la naturalidad de los dientes del paciente. Gracias a los avances tecnológicos, han surgido nuevas herramientas, como los espectrofotómetros, escáneres intraorales, entre otros que han mejorado significativamente la forma de llevar a cabo este proceso.
Objetivo: evaluar la efectividad de la toma de color dental con el método visual en comparación con el espectrofotómetro.
Método: se realizó un estudio descriptivo y documental siguiendo una búsqueda sistemática bibliográfica de artículos en los últimos 10 años, que fueron seleccionados de acuerdo a los criterios de inclusión y exclusión.
Resultados: el estudio comparó la eficacia de dos métodos para determinar el color de los dientes: visual e instrumental (con espectrofotómetro). El método visual, aunque tradicional, presenta alta variabilidad debido a factores como la iluminación, la experiencia del observador y la percepción individual del color. El espectrofotómetro ofrece una medición más objetiva y reproducible del color, al no estar influenciado por factores externos. Si bien ambos métodos pueden llegar a resultados similares en algunos casos, en general se observaron diferencias significativas en la selección del tono dental. El espectrofotómetro permite detectar diferencias de color más sutiles y ofrece una mayor consistencia en los resultados.
Conclusiones: la toma de color dental es más efectiva con espectrofotómetro, sin embargo, los autores recomiendan utilizar las dos metodologías en conjunto.

Palabras claves: Toma de Color; Espectrofotómetro; Luz; Guía de Color; Guía Vita 3D Master.

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INTRODUCCIÓN

Shade matching is an essential procedure in dentistry, especially in cosmetic dentistry, which involves basic parameters such as shape, size, surface texture, translucency, and tooth color. Over time, shade selection has gained more attention from dentists and patients, although it remains a procedure that requires knowledge, concentration, and patience due to the difficulty of making the right choice.[1,2]

Several studies have pointed out that shade selection is crucial to achieving high dental aesthetics, and choosing the right shade is one of the most challenging aspects of cosmetic restoration. Therefore, the professional must be trained and familiar with the system used to achieve the desired results.[3,4,5,6]

This system comprises three variables that characterize the perception of light reflected by teeth: hue, value, and chroma. Hue is the predominant tone in the tooth, value is the lightness or darkness of the tone, and chroma is the intensity of the color.[4]

Color perception is a subjective skill that can vary depending on age, gender, psychological state, visual fatigue or stress, medications, visual conditions such as color blindness, diet, and environmental changes such as lighting, with the type of light source being the most critical factor.[7,8] The International Color Commission (CIE) has established three axes for color selection, with illuminance being an essential factor. The difference in shades is expressed in units for clinical analysis. To select the shade of a restorative material, it must match the shade of a natural tooth using a commercial color guide, the most widely used being the Vita 3D Master guide due to its high reliability. However, the reliability and repeatability of human eye perception of tooth color selection can be altered by the factors mentioned above, so it can be hypothesized that it may be variable and affect the results.[3,9] Although technology has developed more accurate devices for color selection, the human eye remains fundamental to the process.

Objective: to evaluate the effectiveness of tooth color matching using the visual method compared to the spectrophotometer.

METHOD

This is a type of qualitative research in which a systematic literature review will be conducted to obtain the most relevant information on color matching in dentistry through visual methods using the Vita 3D Master color guide and spectrophotometer instruments.

The bibliographic material was obtained from publications on official websites, specialized journals, books, degree theses, and scientific publications, among others.

To begin the search equation in the different sources mentioned, keywords were identified in English and Spanish: color matching, tooth color, spectrophotometer, visual color matching, color guide, Vita 3D Master, and colorimetry.

The information was organized systematically and grouped manually, and information management programs such as Mendele were used, as they can be organized by author, title, and source, to obtain the bibliography that was attached at the end of this research paper.

Once the information was organized, it was analyzed to obtain the most relevant and valuable data by applying critical thinking, which allowed the results to be achieved.

A descriptive and documentary study using the Google Scholar search engine found a total of 408 scientific articles on visual and instrumental color measurement, of which 44 were selected based on the inclusion and exclusion criteria described below:

Inclusion criteria

- Scientific articles on visual and instrumental color measurement.
- Scientific articles that use the Vita 3D Master guide for color matching.
- Experimental research on visual and spectrophotometer color matching.
- Articles in Spanish and English.
- Articles that reveal the effectiveness/functionality of the spectrophotometer.
- Articles published in the last 10 years (2013-2023).
- Articles that include tests carried out by dentists.

Exclusion criteria

- Articles with no scientific validity or those whose accuracy cannot be verified.
- Articles reporting a single clinical case.

Statistical analysis: the arithmetic mean of the shade match was calculated, weighted by each study's sample size, and summarized in tabular form. The shade match is the ability to select the shade that most closely matches the natural shade of the patient's teeth using visual or instrumental methods. The values can be expressed as percentages or in Delta E (ΔE) units, which quantify the color difference between the selected and reference shades. The range of human perception is between ΔE = 1 and ΔE = 3,7. A value close to 0 indicates a very close shade match, while a higher value indicates a more obvious difference in shade.

RESULTS

After conducting the corresponding search and obtaining information from various bibliographic sources on visual tooth color matching using the Vita 3D Master guide and a spectrophotometer, the following search equation is shown with the results achieved in figure 1.

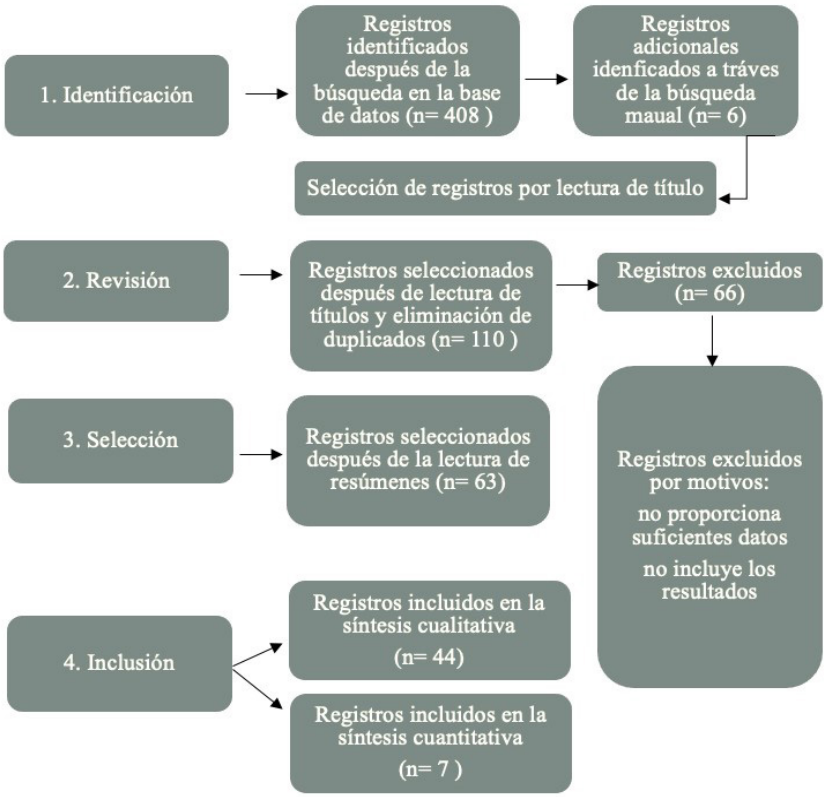

Figure 1. Search flow for results following inclusion and exclusion criteria

Four hundred-eight records were identified through database searches (PubMed, Google Scholar, Medline) and manual searches. Considering this study's inclusion and exclusion criteria, 44 articles were selected for full-text reading, seven of which were included in the qualitative analysis, and 44 were used for qualitative analysis.

Table 1. General agreement between the visual method and the spectrophotometer method for each study

Author	Objective and Method	Sample	Coincidences
Brandt[10]	Visual method matches Vita 3D Master guide, using the spectrophotometer as a reference.	107	35,5 %
Gómez Polo[11]	Visual method (Vita 3D Master) and instrumental method with spectrophotometer	1361	18,37 % (perfect balance between value, chroma, and hue)
Valenzuela Aranguiz[12]	Visual method (with Vita 3D Master guide) matches the spectrophotometer	50	18 %
Mohamed Fattouh[13]		50	72 %

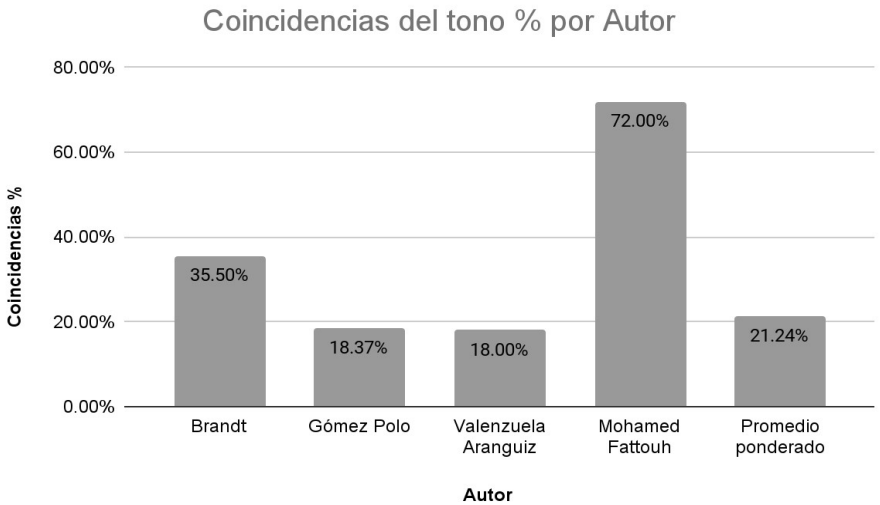

Figure 2. Tone matches between Vita 3D Master (visual) and spectrophotometer (instrumental) by author

The results obtained from the systematic search to compare visual color measurement and spectrophotometer measurement included studies by different authors that evaluated the effectiveness of each methodology. Seven studies with comparable objectives, methodology, and results expressed as percentages were selected and divided into two groups. The first group includes four studies comparing the color matches obtained with the visual method and a spectrophotometer (table 1). The second group consists of three studies in which color was measured using both techniques and the reliability of each method was evaluated separately based on the matches obtained (table 2).

Table 2. Coincidence of each visual method and spectrophotometer separately for each study

Author	Objective/Method	Sample	Coincidences
Igiel[14]	Coincidence of the visual method with Vita 3D Master guide and the instrumental method with spectrophotometer	56	43 %
			92 %
Czigola[15]	Visual method (with Vita 3D Master guide)	10	34,08 %
			26,58 %
Bahannan[16]	Instrumental method (with spectrophotometer)	204	36,3 %
			80,4 %

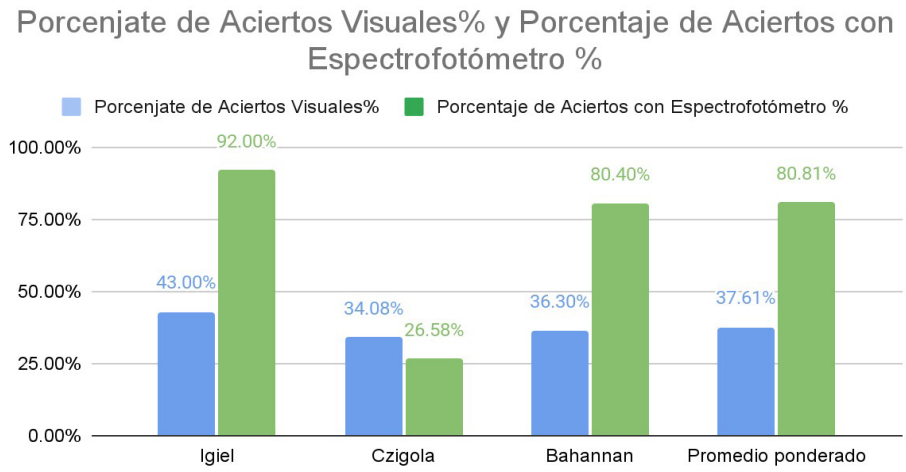

Figure 3. Shade matches for each methodology (Vita 3D Master (visual) and spectrophotometer (instrumental)) by author

In the study conducted by Brandt et al.[10], visual shade-taking was compared with the Vita 3D Master guide, using the EasyShade Advance 4.0 spectrophotometer as a reference to evaluate accuracy and repeatability. The accuracy of visual shade-taking by dentists was 35,5 %. The standard method for shade determination remains visual. However, there are many unavoidable sources of error, such as subjectivity, internal and external distractors, etc. On the other hand, daylight, ambient light, and contrasts do not affect measurements made with the spectrophotometer, so its accuracy and repeatability are higher than the visual method.

Color differences in clinical acceptance are 26,2 % for visual determination by the dentist, which is outside the tolerance range ($\Delta E = 6,8$). Delta E represents the magnitude of color differences but does not indicate the direction of those color differences.

In the study by Yuan et al.[17] they describe that the threshold for a clinically acceptable deviation is found in the literature as a value of $\Delta E < 6,8$. It has been found that the perception range of the human eye is between $\Delta E = 1$ and $\Delta E = 3,7$. In the study by Brandt et al., values below this limit were presented, i.e., they are clinically acceptable.

In the study by Gómez-Polo et al.[11], the human eye was compared with the EasyShade Compact spectrophotometer, and differences between the two methods were reported for shade matching. However, more excellent agreement was found in the value for hue and chroma.

Valenzuela et al.[12] evaluated visual color matching using the Vita 3D master shade guide and compared it with instrumental selection using the EasyShade Compact spectrophotometer. The results showed an 18 % match between the two methods. Therefore, there are statistically significant differences in tooth color selection using the visual method and the spectrophotometer.

Mohamed Fattouh et al.[13] reported that the shade agreement between the visual and instrumental methods is 72 %, which is significant.

Christopher Igiel et al.[18] compared intra- and inter-rater agreement between the visual and instrumental methods in their study, demonstrating that the instrumental method is more reliable. However, the eye can detect multiple or varied differences in shade or translucency found in a color tab or tooth surface.

Czigola et al.[15] found higher agreement when choosing the shade visually with the Vita 3D Master guide (34,08 %) than with a spectrophotometer (26,58 %).

Bahannan et al.[16] reported in their study that 80,4 % of participants agreed with the instrumental color measurement using

a spectrophotometer, while only 30,3 % agreed with the visual color measurement using the Vita 3D Master guide. Behind this difference lies the fact that 60 % of the time, when visual shade matching fails, it can be achieved using a spectrophotometer.

In summary, the results of these studies suggest that instrumental shade matching using a spectrophotometer is generally more reliable and repeatable than visual shade matching, although the latter may be more sensitive to small differences in shade and translucency.

DISCUSSION

Using shade guides for visual color matching is the easiest, most economical, and fastest method. The Vita 3D Master guide is the most popular choice in many studios because its system makes it easier to match shades as it is uniformly arranged, making selection rational. It also includes all the colors within the color space corresponding to tooth colors[5,19,20] and has shown the lowest error rate compared to other commercial guides, as well as fewer differences between the color of the teeth and the color chosen from the guide. Its color combination makes it more effective for matching natural shades in the clinic.[3,4] This guide has a broader spectrum of brightness and additional chroma samples than other shade guides and is also based on color value.[21,22]

The visual method is economical and readily available. Still, the visual approach is subjective, unreliable, and inaccurate, as it depends not only on the color parameters taken into account by the observer but also on certain limitations, such as lighting conditions, the color of the furniture, the environment, age, experience and skills, fatigue, and visual limitations, metamerism, which is why the result obtained may be affected. However, it has been proven that the human eye can determine minimal differences between objects due to its high sensitivity. If the rational order required by the tone guide concerning tone, chroma, and value is followed, there will be no problems with repeatability and accuracy in color matching.[3,4,5,23,24,25,26]

Studies confirm clinical experience does not influence color selection when using the Vita 3D Master guide.[27,28]

However, other authors disagree and question the reliability and consistency of visual shade selection, favoring the use of instruments such as spectrophotometers, which are more precise and accurate in their results.[3] Using shade guides alone can create a color illusion, as they are usually made with a greater thickness than a crown, giving the appearance of vitality due to how light is reflected and transmitted, creating translucency. However, when the restoration is performed, it appears more opaque because light is reflected but is less likely to be transmitted.[4,23]

On the other hand, the spectrophotometer will measure shades independently of light, whether during the day, at night, or under natural or artificial light.[21,24,26,29]

Kim-Pusateri et al.[30], in their study to evaluate the reliability and accuracy of various spectrophotometers for color measurements, found high reliability and similarity among them, with the Vita EasyShade at 96 %. However, they mentioned that the most accurate results are obtained by following the manufacturer's instructions, which indicate repeating the measurement until the same color is obtained twice in a row, which allows for more predictable results. In addition, accuracy is also determined by the size of the measuring probe, which is 5 mm in diameter and allows for a larger area of the tooth to be covered. However, it only works in the anterior sector, as its size prevents it from being used in the posterior region.[29] The position and angle of the probe are decisive for the reliability of the instrumental reading. Therefore, it should be noted that when using the instrument on surfaces larger than 5 mm in diameter, it fades the rest of the object so that the light from the target is reflected into the instrument.[18]

Other authors add that it should be calibrated before each use to avoid possible errors and incorrect positioning, as anatomical differences, surface texture, and tooth shine can influence the result since spectrophotometers are manufactured to measure color on flat surfaces, and teeth are mostly convex in shape, which can affect the result due to losses. For this reason, they recommend using an individualized positioning template for each tooth, thus maintaining the same position before each color measurement.[10,29,31]

The shade guide plays a vital role when choosing the visual color. It should not be done with just any guide, as several brands are made with different materials. The material used to make it must be real; otherwise, the color will vary between various manufacturers, and, in turn, the optical properties will also vary.[32]

When color measurements are carried out with a spectrophotometer, not only numerical data is obtained but also a spectral reflectance graph for each color, making it accurate and versatile.[24,26]

Özat et al.[3] evaluated the repeatability and reliability of the human eye in visually selecting shade and concluded that visual color matching is the most reliable and acceptable method.

Other studies recommend using instrumental methods in combination with the conventional visual technique for shade matching, as they complement each other and allow for more predictable results. When used separately, they found more disadvantages in both cases.[3,21,29,33] Gehrke et al.[34] confirm that the spectrophotometer's reproducibility is more excellent than conventional visual color selection and recommend it as a reliable addition to color matching.

CONCLUSIONS

Based on all the scientific evidence analyzed, 15 authors validate the hypothesis of this study, which states that tooth color matching using the visual method is significantly less effective than using a spectrophotometer. Spectrophotometers are automated instruments that are easy to use and unaffected by external factors. However, the device must comply with the necessary parameters to function correctly. In addition, it should be noted that variations in shade and translucency may occur during color measurement, which only the human eye can detect due to its high sensitivity. Therefore, the authors recommend using both methodologies together.

Tooth color selection should be taught with color science at the undergraduate and graduate levels. It should be practiced to gain the experience needed to achieve increasingly better results.

There is no single, absolute method for selecting color, as each clinical case is a challenge that must be evaluated individually. Success in determining color using color guides depends on the type of light used to illuminate the area. There are significant differences when exposed to different kinds of light. Distractions in the environment should be avoided, and the light to which patients will be exposed in their daily routine should be determined before selecting the color.

In line with this research's objectives, we synthesized the information obtained from different bibliographic sources on visual and spectrophotometric color matching, compared each methodology to evaluate its effectiveness, and discussed the results. In addition, the parameters that must be taken into account to perform the procedure correctly in each case were mentioned. According to the results presented, there is more excellent agreement when performing color measurement with a spectrophotometer. With this, we could fully meet this study's objectives.

FINANCING

None.

CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTION

Conceptualization: Mezzalira Betancourt AG, Saldaña JA.
Data curation: Mezzalira Betancourt AG, Saldaña JA.
Formal analysis: Mezzalira Betancourt AG, Saldaña JA.
Research: Mezzalira Betancourt AG, Saldaña JA.
Methodology: Mezzalira Betancourt AG, Saldaña JA.
Project management: Mezzalira Betancourt AG, Saldaña JA.
Resources: Mezzalira Betancourt AG, Saldaña JA.
Software: Mezzalira Betancourt AG, Saldaña JA.
Supervision: Mezzalira Betancourt AG, Saldaña JA.
Validation: Mezzalira Betancourt AG, Saldaña JA.
Visualization: Mezzalira Betancourt AG, Saldaña JA.
Writing – original draft: Mezzalira Betancourt AG, Saldaña JA.
Writing – review and editing: Mezzalira Betancourt AG, Saldaña JA.

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