

Comparison of two optical devices used for artificial tooth color selection

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Abstract

Background. Correct color assessment and the selection of the color of the prosthetic restoration are important aspects of prosthetic treatment, which significantly affect the success of the treatment.

Objectives. The aim of this study was to compare 2 commercial devices used for tooth color selection.

Material and methods. The color of maxillary right central incisors and right canines was assessed in a group 100 patients aged 22–40 years (25.11 ± 3.24 years), using the Easyshade[®] spectrophotometer and the ShadeStar[®] colorimeter. Two visual shade guides were used as references for the tests – VITA VITAPAN[®] Classical and VITA 3D-Master. The 2 instruments and the 2 visual shade guides were assessed in terms of agreement in tooth color selection.

Results. There were statistically significant differences between the 2 instruments in terms of agreement in tooth color selection as well as between the 2 shade guides. The VITA VITAPAN Classical shade guide was shown to be more accurate in tooth color selection than VITA 3D-Master. There was agreement between the Easyshade spectrophotometer and ShadeStar colorimeter measurements for incisors in 49% of cases with the VITA VITAPAN Classical shade guide and in 22% of cases with VITA 3D-Master. In the comparative analysis of the Easyshade and ShadeStar devices with regard to the measurements performed on canines there was 52% agreement for the VITA VITAPAN Classical shade guide and 32% agreement for VITA 3D-Master.

Conclusions. The VITA VITAPAN Classical system demonstrated superior agreement in shade selection as compared to the VITA 3D-Master system. A low degree of agreement between the optical devices used in the selection of the color of artificial teeth may indicate optical differences between devices from different manufacturers.

Keywords: tooth color, shade selection, shade guides, spectrophotometer

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Introduction

The dynamic development of dental disciplines observed in recent years has allowed dentists to meet the esthetic expectations of patients in the field of restorative dentistry.¹ The color of the teeth and their shape are the crucial features affecting their appearance.² Correct color assessment and the selection of the color of prosthetic restorations are the most important aspects of prosthetic treatment contributing to patient satisfaction.³ Generally, tooth color is assessed visually, using the color shade guide provided by the manufacturer of dental materials for tooth reconstruction.⁴ The visual method is subjective, as many factors impact color perception,⁵ for example lighting conditions, gingiva color and background colors.⁶ The effects of gender, anxiety, depression, and the use of medicaments should also be taken into consideration.⁷ For these reasons, objective methods are desirable for appropriate tooth color selection. Nowadays, an increasing number of dental offices use optical equipment and software to assess tooth color. Such aids include digital cameras, colorimeters and spectrophotometers.^{8,9} Controlled studies have shown the advantage of using such systems over the traditional visual method.¹⁰ In order to perform prosthetic work, dentists collaborate with various technicians, who may also have an influence on tooth color selection. The use of an optical instrument for assessing the color of natural teeth often gives better results than the visual method.¹⁰ As mentioned above, there are several commercial devices available for assessing color in the context of choosing the right shade of artificial teeth for prosthetic treatment.¹¹ Digital cameras are the simplest instruments used to assess tooth color. Colorimeters consist of a light source, usually a xenon lamp, photodiodes, a detector, and a converter. They use filters that simulate the color response of the human eye.¹² Spectrophotometers are the most accurate and useful of these instruments, but they are also the most expensive.⁹ They measure the amount of light reflected from an object with 1–25-nanometer bandwidths in the visible spectrum.¹³ The 2 main types of spectrophotometers are: spot measurement devices (SMDs) with a small, approx. 3–5-millimeter spot; and complete tooth measurement devices (CMDs) with a large measuring window covering the entire tooth or more than 1 tooth. Those with a limited field may be disadvantageous due to the greater loss of the reflected light, since the path of the reflected light can run outside the sensor window. Both SMDs and CMDs lose some of the incident light due to the absorption of the light beam inside the tooth; the beam passing through the tooth is beyond the range of the sensor.¹⁴ The large-scale use of these instruments is dependent on their availability, affordability, ease of use, and reliability.

The null hypothesis tested was that there is no difference in the chosen tooth color between the 2 color-matching devices. The aim of the present study was to verify whether the use of the optical equipment provided

by different manufacturers for tooth color selection will give reproducible and acceptable results.

Material and methods

Study population and ethical considerations

A total of 100 participants (22 males and 78 females) were recruited to this study. The age of the patients ranged from 22 to 40 years (25.11 ± 3.24 years). Each participant was provided with a full explanation of the study aim and the procedures to be followed. Informed written consent was obtained from the participants before they were enrolled for the study. The study was approved by the Ethics Committee of Poznan University of Medical Sciences, Poland (No. 459/14).

Inclusion and exclusion criteria

The inclusion and exclusion criteria are presented in Table 1. The inclusion criteria required a vital tooth, and maxillary right central incisors and right canines with no cracks, fillings and/or discolorations. The exclusion criteria were as follows: a non-vital tooth; and a tooth with discolorations, fillings, and after root canal treatment or whitening procedures.

Data collection

The color of maxillary right central incisors and right canines was assessed in a group of 100 patients with the use of the Easyshade[®] V spectrophotometer (VITA Zahnfabrik, Bad Säckingen, Germany) and the ShadeStar[®] colorimeter (DeguDent, Hanau, Germany) by the same dental specialist in prosthodontics. Two shade guides were used for the tests – VITA VITAPAN[®] Classical and VITA 3D-Master (VITA Zahnfabrik). Differences in tooth color

Table 1. Inclusion and exclusion criteria

Criteria	Details
Inclusion criteria	a vital tooth
	maxillary right central incisors and right canines
	no cracks
	no fillings
Exclusion criteria	no discoloration
	a non-vital tooth
	a tooth with discolorations
	a tooth with fillings
	a tooth after root canal treatment
	a tooth after whitening procedures

selection with the use of the abovementioned devices were assessed.

The subject teeth were cleaned with gauze, and the device was properly cleaned and disinfected before use. Protective coating was applied to the tip of the probe to avoid damage to the optical system and to prevent the tip from slipping off the tooth being examined. After activating the Easyshade spectrophotometer and allowing the lamp to reach the operating temperature, an automatic calibration process was carried out. The tip of the probe was placed in the spectrophotometer calibration block at an angle of 90°. After proper calibration, the operating mode of the device was selected for the measurement of a single tooth. The tip of the probe was placed perpendicular and close to the tooth surface, 2 mm below the gingival margin and at least 2 mm above the incisal edge of the tooth, to prevent incorrect measurements. The measurement lasted about 2 s. Care was taken not to move the measuring tip during the color test. The probe was pulled away from the tooth after a beep from the instrument, when the result appeared on the Easyshade monitor. The measurement was made at least 3 times on each of the examined teeth and repeated until 2 identical results appeared in succession before the color was recorded.

The same procedure was carried out using the ShadeStar colorimeter.

Statistical analysis

The statistical analysis was performed with Statistica, v. 12.0 (StatSoft Polska, Kraków, Poland), and the MedCalc® statistical software, v. 19.1.7 (MedCalc Software, Ostend, Belgium; <https://www.medcalc.org>). The values are presented as number and percentage distribution (n (%)). Cohen's kappa coefficient was used to measure differences between the devices. The comparative analyses of the percentage of consistent assessment were performed using the paired difference test. The results were deemed statistically significant at $p < 0.05$.

Table 2. Compatibility of the Easyshade spectrophotometer and ShadeStar colorimeter measurements according to the VITA VITAPAN Classical and VITA 3D-Master shade guides ($N = 100$)

Teeth	VITAPAN Classical (%)	κ	3D-Master (%)	κ	p -value
Incisors	49	0.47	22	0.28	0.0001*
Canines	52	0.50	32	0.38	0.0064*

κ – Cohen's kappa coefficient; * statistically significant.

Table 3. Differences between incisors and canines in terms of compatibility of the Easyshade spectrophotometer and ShadeStar colorimeter measurements according to the VITA VITAPAN Classical and VITA 3D-Master shade guides

Variable	VITAPAN Classical			3D-Master		
	incisors	canines	p -value	incisors	canines	p -value
Agreement in tooth color selection between the Easyshade and ShadeStar devices	49	52	0.3193	22	32	0.1111

Data presented as percentage (%).

Results

The comparative analyses of the compliance of the Easyshade spectrophotometer and ShadeStar colorimeter measurements for VITA VITAPAN Classical and VITA 3D-Master showed that the agreement of the Easyshade spectrophotometer measurements with those performed with the ShadeStar colorimeter for maxillary right central incisors according to the VITA VITAPAN Classical key was 49%, while according to the VITA 3D-Master key, it was 22%. The agreement of the Easyshade spectrophotometer measurements with those made with the ShadeStar colorimeter for maxillary right canines according to the VITA VITAPAN Classical key was 52%, whereas according to the VITA 3D-Master key, the compliance was 32% (Table 2).

The comparative analyses of the compatibility of the Easyshade and ShadeStar devices for maxillary right central incisors showed a statistically significant difference between the VITA VITAPAN Classical and VITA 3D-Master dyes ($p = 0.0001$), and likewise for maxillary right canines ($p = 0.0064$) (Table 2).

Cohen's kappa coefficient showed a moderate agreement for the VITA VITAPAN classical shade guide for incisors ($\kappa = 0.47$) and a moderate agreement for VITA VITAPAN Classical shade guide for canines ($\kappa = 0.50$). The comparative analyses of the compatibility of the Easyshade spectrophotometer and ShadeStar colorimeter measurements according to the VITA 3D-Master shade guide showed a fair agreement for incisors ($\kappa = 0.28$) and a fair agreement for canines ($\kappa = 0.38$) with respect to Cohen's kappa coefficient (Table 2).

The comparative analyses of the compatibility of the Easyshade spectrophotometer and ShadeStar colorimeter measurements according to VITA VITAPAN Classical as well as VITA 3D-Master showed no statistically significant differences between incisors and canines ($p = 0.3193$ and $p = 0.1111$, respectively) (Table 3).

Discussion

Spot measurement devices were selected for this research because of the positive evaluation of the instruments by many authors.^{8,15} Kim-Pusateri et al. studied the reliability and repeatability of tooth color measurements with the use of 4 spectrophotometric devices; the results showed high accuracy in the tooth color measurements made with the Easyshade spectrophotometer.⁸ Llana et al.

compared SMD and CMD, noting the high reproducibility of the results in the selection of the color of artificial teeth as measured by the Easyshade device.¹⁵ The sensor diameter of the Easyshade spectrophotometer is 5 mm, and this device operates with 2 VITA shade guides – VITAPAN Classical and 3D-Master. ShadeStar is a colorimeter with a sensor diameter of 3 mm, which operates with 4 shade guides – VITA VITAPAN Classical, VITA 3D-Master, Ceram[®] X-Mono, and Ceram X-Duo. Due to the compatibility of both devices with the same color shade guides (VITAPAN Classical and 3D-Master), it was decided to subject these to a comparative analysis.

In this study, the consistency of measurements between the Easyshade spectrophotometer and the ShadeStar colorimeter while testing the 100 incisors was 49% for VITAPAN Classical and 22% for 3D-Master. By comparison, in the analysis of the Easyshade and ShadeStar measurements made on canines there was 52% agreement for VITAPAN Classical and 32% agreement for 3D-Master. It indicates that the results are not completely satisfactory. The lower compatibility obtained with the 3D-Master shade guide was probably due to the greater number of color shade tabs. Similar observations were made by Sarafianou et al.¹⁶ They examined the consistency of measurements from 2 spectrophotometric devices – Easyshade and SpectroShade[®]. The authors reported a low degree of compatibility for both spectrophotometers, thus suggesting the lack of compatibility of devices from different manufacturers.¹⁶ Such low compatibility between devices can lead to problems in communication with dental technicians, who may check the color of the prosthetic work with a different device than the one used by the dentist when choosing the color of the teeth.

The repeatability of colorimeter measurements may also be low due to the aging of the filters and the metamorphism of the tested objects.¹⁷ Reports regarding the assessment of the accuracy and repeatability of the color measurements performed with the use of a spectrophotometer are contradictory.^{1,8,16,18,19} In vitro studies indicate greater accuracy of spectrophotometric devices.^{8,19} In a few studies, the accuracy of spectrophotometers under clinical conditions was evaluated.^{20–22} However, conducting in vivo tests is more difficult; for example, failing to keep the measuring tip of the device stationary inside the patient's mouth may lead to lower measurement precision.^{8,12} Weyhrauch et al. claimed that the Easyshade spectrophotometer is characterized by high repeatability of measurements, and therefore specialists can use it independently of each other without affecting the quality of tooth color analysis.²³ Measurements with the use of these devices were also carried out under laboratory conditions. Agreement between 3 spectrophotometric devices – Easyshade, SpectroShade and ShadeVision[®] – was checked in the conditions simulating the clinical situation.¹² The measurements were made in 2 different settings – standardized and traditional, in accordance

with the manufacturer's recommendations. The Easyshade spectrophotometer had the highest repeatability under standardized conditions, corresponding to 100% for VITAPAN Classical and 3D-Master colors. While performing measurements as recommended by the manufacturer, i.e., under conditions that simulate those of the dental office, repeatability decreased to 48.2% for the VITAPAN Classical shade guide and to 55.3% for the 3D-Master shade guide.¹² In our study, measurements with the devices were repeated 3 times for each tooth. In the event of the devices showing a variation in color, the measurement was repeated until 2 identical color results were obtained in succession. This approach improves the precision of devices and increases the likelihood of choosing the most acceptable color.^{19,24} In vitro studies have shown that there is a significant difference between the subjective assessment made by the dentist and instrumental tooth color selection in favor of colorimeters.²⁵ Only a few researchers have shown considerable agreement between the visual method and instrumental methods in assessing tooth color under clinical conditions.^{26,27}

Li and Wang suggest that the accuracy of selection is not guaranteed, either by subjective or objective methods, although better results are obtained when using a colorimeter.²⁸ Our research showed poor agreement in the results obtained with the spectrophotometric and colorimetric devices, and statistically significant differences for incisors and canines when using the VITAPAN Classical and 3D-Master shade guides. Judeh and Al-Wahadni reported that spectrophotometers needed improvement, but the combination of measurements by means of these devices with visual assessment produced favorable results.²⁹ Lasserre et al.³⁰ and Śmielecka and Dorocka-Bobkowska⁵ came to similar conclusions, reporting that the highest agreement between visual and computer-assisted selection was achieved when a lamp was used to optimize lighting conditions during the choice of color by the dentist.

Limitations

A limitation of this study is the loss of some colorimetric data due to the reflection or refraction of the beam of light generated in the direction of the tested object; as the teeth are not perfectly flat and opaque, some of the reflected light is not 'captured' by the instrument sensor. Additionally, in the study, the measurements were made in the central part of the tooth; the tests should be extended to the cervical and incisal zones of the tooth, since it is known the teeth are not of a uniform color.

Conclusions

Within the limitations of this study, we concluded that the VITA VITAPAN Classical system demonstrated

superior agreement in shade selection as compared to the VITA 3D-Master system. A low degree of agreement between the optical devices used in the selection of the color of artificial teeth may indicate optical differences between devices from different manufacturers.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Poznan University of Medical Sciences, Poland (No. 459/14). Informed written consent was obtained from the participants before they were enrolled for the study.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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