Are Digital Methods Sufficiently Successful in Colour Determination for Monolithic All-Ceramic Crowns?

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ABSTRACT

Objective: The aim of this study was to compare the visual assessment of tooth shade with the measurement using intraoral scanner (IOS) and spectrophotometer devices.

Methodology: The colour for a single unit implant supported crown was measured visually, using IOS, and spectrophotometer. The results of the digital methods were compared with the visual measurement.

Results: A complete colour match with the visual measurement was in 42.9% of cases for IOS, and in 33.3% of cases for spectrophotometry. The match in the colour value, hue, and chroma were in 61.9%, 95.2%, and 66.7% of cases, respectively, for the IOS; and in 61.9%, 61.9%, and 66.7% of cases, respectively, for the spectrophotometry. The differences between the IOS and spectrophotometry were not statistically significant.

Conclusions: The most reliable method for tooth colour selection is the visual measurement by an experienced dentist. IOS and spectrophotometer can be used as an alternative method, however in both cases they should be verified using visual measurement.

KEYWORDS

colour match; intraoral scanner; spectrophotometer; visual match

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Received: 7 March 2022
Accepted: 8 December 2022
Published online: 2 February 2023

Acta Medica (Hradec Králové) 2022; 65(3): 99–104
https://doi.org/10.14712/18059694.2022.25

INTRODUCTION

The colour of prosthodontic restoration and beautiful smile design are some of the most important factors for modern dentistry from the patient's point of view. A perfect colour match between restorations is essential to patients (1). There are many ways how to find an optimal colour match between the natural teeth and a planned fixed restoration (2). Subjective color matching provided by dentists and dental technicians had the priority in the past but still is the most frequently applied method in dentistry (3). In present time we have a selection of devices which have been developed to provide a successful color selection (4).

Human optical system is able to recognize the light wavelength from 380 nm (violet) to 780 nm (red). The cones containing photosensitive pigments are responsible for the colour vision. They are sensitive to 3 basic colours: blue (448 nm), green (528 nm), and red (567 nm). Pigments are stimulated by light, then disintegrate and create an electrical impulse which is relayed to nerves. In total there are about 6–7 million cones placed in fovea centralis. Some studies describe gender dependent sensitivity of cones (5).

Choosing tooth colour shade can be influenced by several factors, such as physical, physiological, dental, and psychological. The physical factors include, for example, metamerism and the influence of background (2). Metamerism is described as the situation when two objects are noticed different when one factor out of three (source-object-receptor = human) varies, but the other two are constant (6). Object metamerism is describing the fact that colour of the same objects varies when the light source is changed (7). Receptor metamerism depends on sensitivity of cones. The influence of background is significant, because all teeth look lighter with darker background even if the colour is the same. One of the physiological factors is age related decrease of retinal ganglion cells. Dental factors are based on facts that various teeth have naturally different colour shades, particularly, their values (canine versus central incisor) (8, 9), and older people have naturally a richer colour shade with lower hues in cervical areas (8). There are no significant differences in tooth colour between males and females (10). Psychological factors describe the sensory adaptation. Sensory adaptation has an effect on decreasing sensitivity of receptor when the stimulus is repeating. Chromatic analytical interval indicates the time for choosing the colour without doubts and is about 5 s.

Light source can influence colour match as was mentioned earlier during the discussion of metamerisms. The light quality is determined by the colour temperature which is ideally 5500 K for the colour match.

The colour of an object consists of three dimensions: value, hue, and chroma. Value is the light quantity, that the object reflects in comparison with a bright white diffuser or a black absorber. The light object reflects the most of light, it means, it has the high value. Reversely the dark object absorbs the most of light and seems to be with low value. Hue is the light wavelength. It is depended on the wavelength of the light spectrum that is reflected/transmitted by the object. An opaque object does not transmit the light, rather it creates a so-called spectral reflection curve. A transparent object (e.g., glass) transmits light and creates a so-called spectral transmission curve. Teeth are translucent objects, they reflect and transmit light at the same time. Chroma is the result of the rates of energies of various monochromatic lights represented in the certain colour or concentration of the certain hue. Rich colours do not contain a white part (e.g., spectral colors). Rich colour is created by few lights (ideally only one) – the curve is narrow and colour can be easily recognized. Non-rich colours contain a white part (it is in principle a white colour with a "touch" of colours) (11).

The most used shade guide today for choosing the colour of teeth is Vitapan 3D Master® Shade Guide (Vita, Germany). The artificial teeth are classified according to the value – groups n. 1–5 (means all teeth in the same groups have got the same value). Except for groups 1 and 5, each group consists of 3 subgroups M, L, and R according to the various hues. L means light-yellow hue, M means medium-yellow-orange hue and R means red hue. Each subgroup contains 2 (for L and R – 1.5 and 2.5) or 3 (for M – 1, 2, 3) levels of chroma (12). VITA Classical A1-D4®-shade guide is older generally and universally used guide. Shade-hue is marked by letters; A-orange-red, B-yellow, C-grey, and D-brown. There are 4 numbers matching various value and chroma in each hue, where 1 means high value and low chroma and 4 means low value and high chroma (12).

Some limitations can occur using shade guides. They are especially related to the level of opalescence and translucency. To minimize all factors influencing the visual tooth shade choosing, it is recommended to follow some regulations. Some of them are as follows: suitable light source (5500 K), suitable background (light grey), avoiding rich colours near the object (lipstick, make-up, clothing), wet tooth surface (enamel dehydration), eye to eye position (same body height or proper patient positioning), distance 30–50 cm, choosing in the morning (eye fatigue) and preferably the colour selection together with the dental technician. It is also useful to take photos of the teeth, a colour one and a grayscale one.

There are some devices helpful for this difficult task. A dental spectrophotometer measures the spectral reflectance or transmittance curve of the tooth. Light is released from light source in the spectrophotometer and then dispersed by a prism into a spectrum of different wavelengths between 380–780 nm. The spectrophotometer then measures the amount of the light reflected from the specimen for each wavelength and converts the data into numerical values of colour. Before measurement automatic calibration is needed. Intraoral scanners are based on non-contact optical acquisition technologies used by different IOS cameras to produce precise 3-dimensional renderings of soft and hard tissue. There are many principles for IOS systems – confocal microscopy with ultrafast optical scanning or laser light beams based on parallel confocal principles etc. Automatic shade matching is incorporated into the software. This technology collects actual shade values from several views, considering all angles captured by the scanner (13).

MATERIAL AND METHODS

The study was approved by the Ethics committee of the University Hospital Hradec Králové (ref. No. 201903S08P). Participation in the study was voluntary, each participant signed an informed consent. In total, 23 patients were asked for study cooperation.

The colour match for fixed single implant supported crowns during the regular treatment procedure in University Hospital Hradec Králové from October 2021 to January 2022 was determined.

The colour was selected in three different ways; the first was using Vitapan 3D Master® Shade Guide (VITA Zahnfabrik, Bad Sackingen, Germany) for visual measurement (Figure 1), second was with an IOS system (3Shape TRIOS Move +, 3Shape, Denmark) during intraoral scanning (Figure 2), and third was using spectrophotometer (Figure 3) (VITA Easyshade© Compact Advance, VITA Zahnfabrik, Bad Sackingen, Germany).

One evaluator analyzed the colour using Vitapan 3D Master® Shade Guide under given conditions: daylight in the morning with standard light source of the room, light grey background, wet tooth surface of referential tooth, and eye to eye position with distance 50 cm.

The result of the visual measurement was considered as the final colour for the crown fabrication. The material used for the restoration was monolithic zirconia oxide dental ceramic. The colour was selected according to a natural tooth in the same segment of the same jaw without any filling or restorations, not even next to gap. The selections were done in sitting patients following all recommendations for producers (the probe tip of spectrophotometer placed as flat as possible on the tooth surface) or general rules for visual match with the same light source as mentioned above. Measurement was done on the middle section of the vestibular surface of the referential tooth while it was wet. Light grey background with eye to eye position in distance 30–50 cm was used. The visual match was done during the morning hours.

Vitapan 3D Master® Shade Guide was used for primary statistical analysis, where the total colour and separate parameters of colour (value, hue, and chroma) were compared. During the secondary analysis, VITA LinearGuide 3D-Master® was used as linear colour scale for an assesment of the deviation magnitudes. The deviation to the lighter colour was denoted as negative value, whereas the darker colour was indicated with positive value.

The gathered data were analyzed in MS Excel using the methods of descriptive statistics, chi-square test, Fisher's exact test, Wilcoxon test, and One-sample proportion test. The level of statistical significance was set at $\alpha = 0.05$.

RESULTS

A total of 21 patients (11 men, 10 women) participated in the study, two of the patients rejected the study participation because of the lack of time. The study participation was 91.3% of possible patients. Fixed single implant-supported crown was planned for all of the participants. In 20 patients, the crown was in a lateral section of a jaw, one crown was in a frontal section. 12 crowns were localised in the upper jaw, nine of them in the lower jaw. Table 1 shows the localisations of the crowns, the natural teeth used for the colour measurement and the colours selected by the three compared methods.

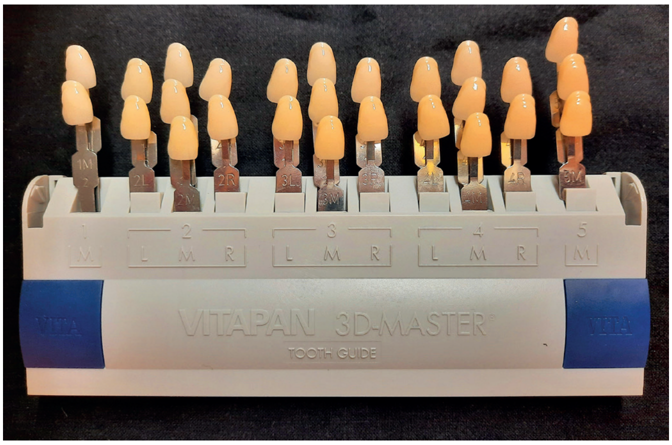

Fig. 1 Vitapan 3D Master® Shade Guide (Vita, Germany).

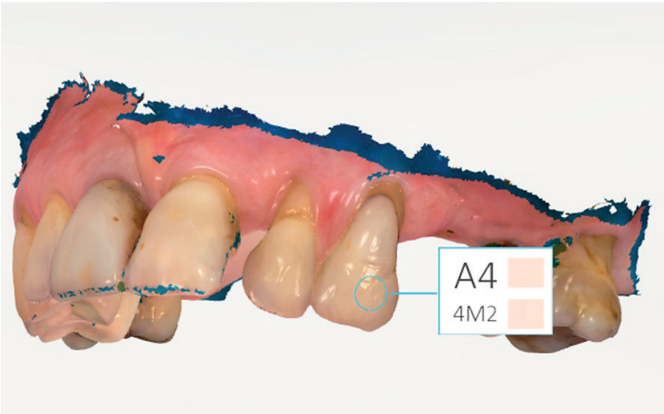

Fig. 2 Selected colour on referential tooth with IOS system 3Shape TRIOS Move + (3Shape, Denmark).

Fig. 3 Spectrophotometer VITA Easyshade© Compact Advance (VITA, Germany).

Tab. 1 Localisation of single unit crown, natural tooth matching and colours chosen with different methods.

Single implant-supported crown	Natural tooth matching	IOS	Spectrophotometer	Human eye-resulting colour used
46	47	2M2	2M2	3M2
46	44	2M3	3L2.5	4L1.5
24	34	4M2	3M3	4M2
14	15	4M3	2R2.5	4M2
36	35	3M1	3M2	3M2
36	35	3M3	3M3	3M3
46	45	4M2	3M3	3M2
46	45	4M2	3L1.5	3M2
26	25	3M1	3M2	3M2
36	35	3M3	3M3	3M3
24	34	3M2	3M3	3M2
25	24	2M2	2M2	2M2
46	44	3M2	3M3	3M2
26	21	2M1	1M2	3M2
22	21	3M2	3M2	3M2
26	25	2M2	2M2	2M2
16	11	2M2	2M1	3M2
45	44	2M2	2M2	3M2
14	42	3M1	2L1.5	2M2
36	34	2M3	2M3	2M2
46	44	3M2	1M1	3M2

Figure 4 shows the correspondence of the colours selected by IOS and spectrophotometer with the visual measurement in the overall colour and in all parameters of colour separately. The differences between IOS and spectrophotometer were not statistically significant (Fisher's exact test-p = 0.1588, p = 0.1637, p = 0.381, p = 1 for total colour, value, hue, and chroma, respectively.

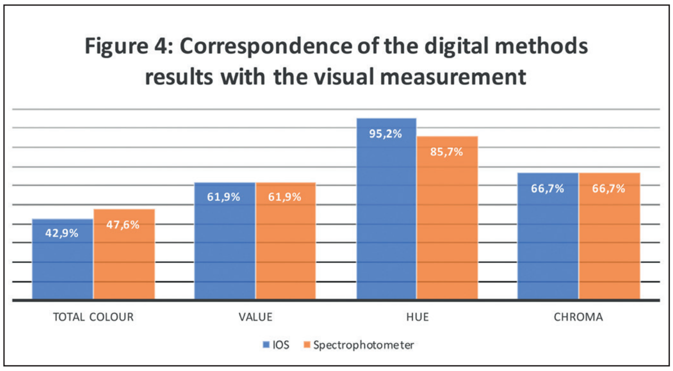

Fig. 4 Correspondence of the digital methods results with the visual measurement.

Figure 5 shows the grades of the colour deviation of both digital methods from the visual measurement. The median value and quartiles were 0 (−5, 1.5) and 0 (−7, 0) for IOS and spectrophotometer, respectively. The differences between both digital methods from the visual measurement were not statistically significant (Wilcoxon test, IOS: p = 0.433 and spectrophotometer: p = 0.0505).

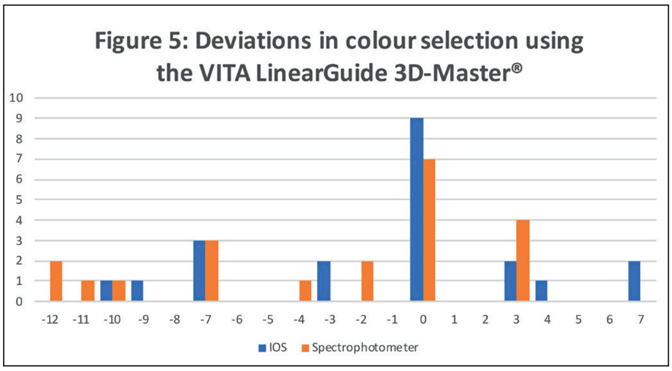

Fig. 5 Deviations in colour selection using the VITA LinearGuide 3D-Master®.

For IOS the negative deviation was found in 33.3% of cases (n = 7), no deviation in 42.9% (n = 9), and positive deviation in 23.8% (n = 5). For spectrophotometer the negative deviation was found in 47.6% of cases (n = 10), no deviation in 33.3% (n = 7), and positive deviation in 19.1% (n = 4).

The trend to positive or negative colour deviation was not statistically significant for both methods (one-sample proportion test, IOS: p = 0.7744 and spectrophotometer: p = 0.18).

DISCUSSION

The colour selection for new fabricated restorations is one of the most important tasks for dentists. Although the

VITA Classical®shade guide is generally and universally used, the Vitapan 3D Master® Shade Guide was used for this study. The reason for this decision was that several recent studies considered VITA Classical A1-D4®shade guide the least consistent with the examined tooth (14). The Vitapan 3D Master® Shade Guide achieved more consistent results in repetitive shade selection (15). VITA Linearguide 3D-Master has arrangement similar to the VITA Classical A1-D4®shade guide but using all colour aspects as Vitapan 3D Master® Shade Guide and is more synoptical for beginners. Some studies revealed significant advantage for colour match using VITA Linearguide 3D-Master compared to Vitapan 3D Master® Shade Guide (16). To maximize shadow matching it is also recommended to use digital photography, however, the results were worse compared to the visual measurement and IOS color match (12).

IOS digital systems have benefited from their speed and ability to facilitate communications with patients as well as dentists and dental technicians (17), but to fulfill the rule of chromatic analytical interval, the visual match timing is similar to digital systems. Previous studies have found that the examiner's experience may have greatly impacted the tooth colour determination (5). Moreover, visual tooth shade determination can be learned (18). These facts may result in a higher success rate of the visual match compared to the digital methods. Thus, a not-experienced young dentist can be more familiar with digital devices. Gender can also play a role in consideration of the differences between the methods. Men are likely to rely more on the digital methods, as they suffer from colour perception deficiencies more frequently (8%) than women (0.5%) (5).

Some clinical studies declare that the instrumental methods for colour shade matching were more reliable than the visual methods (19). Studies also have shown different results of spectrophotometers and IOS systems (20). IOS systems are a good alternative for tooth shade selection (17). The colour match with IOS was superior to visual colour match but using A1–D4 values (21).

The spectrophotometer reported higher accuracy, reliability and repeatability in shade selection followed by photocolorimetric method. Knowledge and practice in the shade selection protocol are necessary for proper shade matching (15). The colour determination with IOS was more repeatable than when using visual systems (22). In this study, both digital methods are considered as an alternative method, especially for value and chroma. They showed a high correspondence in hue, but the value and chroma should be always verified by the visual measurement. That result is in accordance with another study confirming the fact, that the best matching shade was selected using the visual method. IOS can be used as an alternative method of shade selection, but it is recommended to verify the measurements using the visual method (14).

Different factors can affect the accuracy and precision of the tooth shade selection methods and devices (23). The light source as well as having a neutral background in visual methods are most important. For IOS, the most important factor is the way of reading the information about the colour match. IOS can measure the attributes of colour in very small areas, so for one particular tooth we can have many different colour matches. A small area means the average colour for every 3–5 mm on the tooth surface so the device provides a so called "colour map" (24). All-ceramic crowns fabricated as monolithic are preferred for lateral segment, which needs to simplify that information into one shade. That is the reason why it is more difficult to find proper colour. In case of veneered all-ceramic crowns, where the colour map can be respected by dental technician, this single colour is not necessary. It can cause that, the colour match was not perfect with IOS device. Spectrophotometer results could be influenced by difficult positioning of the device tip to a flat surface. Vestibular surface of the teeth is always convex.

The colour match can be also influenced by different crown material especially for monolithic crowns. Some hybrid ceramic has better color match for frontal teeth (VITA Enamic Translucent), other ones for lateral teeth (VITA Enamic HT) (25).

The limitation of this study was quite small number of the participating patients. Further research is needed to confirm the results using higher number of participants. Visual measurement of colour shade for prosthodontic restorations is the widespread method used by dental practitioners. The colour determination by only one experienced prosthodontist for visual measurement is an advantage, less experienced dentist can have different results.

CONCLUSION

The colour determination for implant-supported crowns can be realized by all methods used in this study. The congruence of both digital methods with the visual assesment was relatively low, even though the differences were not statistically significant. IOS and spetrophotometer can be used as an initial method, but the colour assesment should be verified visually according to authors´ recommendation and literature search.

DISCLOSURE

The authors declare no conflicts of interest related with this article. The authors are not in any relationships with the producers of the devices and materials used in this study.

ACKNOWLEDGEMENTS

The authors would like to thank RNDr. Eva Čermáková (Computer Technology Center, Charles University, Faculty of Medicine in Hradec Králové, Czech Republic) for statistical analysis and all participants for patience during the colour selection.

The study was supported by the Charles University's COOPERATIO Program, Research Area DENTAL MEDICINE.

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