Original Paper

In Vivo Evaluation of Teeth Shade Match Capabilities of a Dental Intraoral Scanner

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ABSTRACT: Intraoral scanners were introduced in order to increase patient comfort and improve dentist lab communication. Acquiring optical impressions of the prepared teeth eliminates the need for conventional impression procedures and improves patient comfort. Intraoral scanner software offers since 2017, color shade determination, by analyzing the tooth shade of the obtained 3D model. In this study we tested the accuracy of an intraoral scanner color selection capabilities compared with a dental spectrophotometer, considered as reference. Statistical differences were found between the two system tested when the results were expressed in both Vita Classical and Vita 3D Master shade tabs codification.

KEYWORDS: *Intraoral scanner, spectrophotometer, tooth color, shade tab*

Introduction

In dentistry, in order to achieve a natural and pleasant appearance of the dental prosthesis, color selection is one of most important procedures. From the patient point of view, is perhaps one of the most significant aspect of the treatment [1,2].

Thus, in order to ease this stage for the dentist, but also to obtain truthful data, a series of methods for dental color selection have been introduced over time: visual color selection, which use shade tabs organized in color standards (shade guides) that are compared with tooth surface by the clinician, and instrumental methods, based on spectrophotometric or colorimetric measurements, digital color analyzers or instruments that combine these technologies [3,4].

Although the visual methods are largely used, they are recognized as being subjective alternatives. Shade guide selection method is the most widely used for dental color assessment, but their results may vary according to numerous factors. The instrumental methods, are using the technology to overcomes those inconvenient. They are based on the computer analysis of digital images, dental spectrophotometers, and dental colorimeters. [5,6].

Shade selection is rapidly evolving toward more predictable results. The development of new shade-matching systems may help clinicians in the daily practice and provide more predictable results for shade matching. Today's shade-matching technologies have been developed in an effort to increase the success of color matching and communication between dental office and dental laboratory, the patient benefit being the increase of esthetic results efficiency.

In the last years CAD/CAM technology (Computer Aided Design/Computer Aided Manufacturing) become more present in dental offices and dental laboratories. The technique is involved today in many fields of dentistry such as: prosthodontics, restorative, orthodontics and implant dentistry. The advantages in CAD/CAM technologies consist in high quality of the materials used, with a good productivity at low costs [7,8].

Intraoral scanners were introduced in order to increase patient comfort and improve dentist-laboratory communication. Acquiring optical impressions of the prepared teeth eliminates the need for conventional impression procedures and also several steps from the restauration fabrication process. With the help of the "in office CAD/CAM systems", restorations are designed and then milled in one visit, with real benefits for the patient: eliminate multiple appointments, the need for provisional restorations, and also reduce postoperative sensitivity [9].

Intraoral scanners software offers since 2017, the color shade determination option, after an intraoral scan [10].

Objective

The objective of this study was to test the accuracy of color selection performed by intraoral scanner compared with spectrophotometer measurements. The working hypothesis was to asses if there are significant differences between the shade values obtained with the two instruments.

Materials and methods

Several 6th year students of the Faculty of Dentistry, at the University of Medicine and Pharmacy "Iuliu Haţieganu" Cluj-Napoca, Romania, were volunteered for this study. Prior including the subjects in the study, a clinical examination was performed. Inclusion criteria were considered: integrity of dental arches, integrity of buccal surfaces, for both maxillary and mandibular arches. Exclusion criteria were: lesions of the buccal surface (erosions, attrition, decay), presence of direct and indirect restorations, orthodontic appliances, severe malposition. Four subjects were selected, with an average age of 24 years old. 20 teeth from each subject, 10 maxillary and 10 mandibular were analyzed. A total of n=80 teeth were included in the study. A written informed consent was obtained from all the subjects who were willing to participate in the study.

Intraoral scan

For each subject, both arches were scanned using an intraoral scanner, Cerec Omnicam, (Sirona, Bensheim, Germany) using Cerec SW 4.5.2 software. The scanner was calibrated for color selection prior each scan. Shade detection function was activated. Color 3D Models were obtained and color determination was performed from the cervical, middle and incisal third of each tooth included in the study.

Starting with 2017, Cerec software 4.5 came with several new functions. One of the new features available with the new version of the software is Shade Detection, which allows color detection of dental structures. It manages to detect dental color, and the results are expressed in color codes corresponding to Vitapan Classical (VC) and Vitapan 3D Masters (V3DM) shade tabs, Vita, Germany (Fig.1,2,3).

Fig.1. Clinical aspect of the maxillary arch

Fig.2. Scanned 3D model

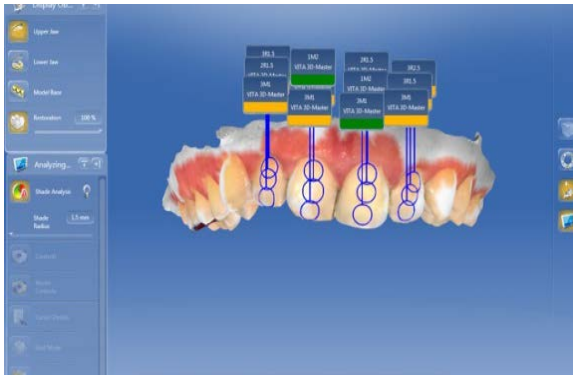

Fig.3. Color determination from the 3D model

Fig.4. Vita EasyShade measurements-Tooth Area mode

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Spectrophotometer measurements

Dental spectrophotometer Vita EasyShade Advanced (Vita, Germany) was used for performing clinical measurements and it was considered as a reference.

The spectrophotometer is a spot measurement device, it's hand piece ends in a 5mm fiber optic tip, containing 19-1mm diameter fiber optic fibers.

Prior to each measurement the device was calibrated.

EasyShade was used in Tooth area mode in order to measure color parameters in incisal, middle and cervical third of each tooth included in the study.

The results were recorded in Vitapan Classical and Vitapan 3D Master codification (Fig.4).

A database was created with the data obtained for each tooth, both from the intraoral scanner and spectrophotometer measurements. The statistical analysis was performed using the SPSS 25.0 package software for Windows.

Results

In order to facilitate the statistical analysis, a numerical value was assigned for each shade tab codification. Thus, The Vita Classical Shade tab and the Vita 3D Master Shade tab were arranged on a value scale basis [11], Table 1,2.

Table 1. Vita Classical Shade tab arrangement and codification

B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3,5	B4	C3	A4	C4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Table 2. Vita 3D Master Shade tab numerical codification

0M1			2M1			3M1			4M1		5M1
0M2	1M1	2L1.5	2M2	2R1.5	3L1.5	3M2	3R1.5	4L1.5	4M2	4R1.5	5M2
0M3	1M2	2L2.5	2M3	2R2.5	3L2.5	3M3	3R2.5	4L2.5	4M3	4R2.5	5M3
1			6			13			20		27
2	4	7	8	9	14	15	16	21	22	23	28
3	5	10	11	12	17	18	19	24	25	26	29

For each tooth included in the study, color measurements data were recorded in the incisal, middle and cervical third with the intraoral scanner, and spectrophotometer.

The results were presented in VC and V3DM shade tab codification. A comparison of obtained data was realized. From a total number of determinations (480) for both color systems (VC and V3DM), 73 (15%) were similar for the two detection methods (Vita EasyShade and CEREC software).

If we consider only VC shade tab, similar results were obtained in 17.5% of measurements, and for V3DM in 12.9%.

The measurements correlations by tooth areas are presented in Table 3.

Table 3. Correlations between the two measurement systems used For Vita Classical and Vita 3D master shade tabs

	VC	**V3DM**
Cervical	21.5%	20%
Middle	22%	19%
Incisal	10%	8%

Non-parametric Wilcoxon test was used in order to determine the statistically differences between the two color selection methods in the cervical, middle and incisal tooth areas, using the two shade tabs codification.

P value were lower than 0.05, showing a significant difference between the spectrophotometer and intraoral scan measurements in all situations, except VC shade tab cervical third. (Table 4).

Table 4. The obtained p values

	Cervical 1/3	**Middle 1/3**	**Incisal 1/3**
Vita 3D Master	p=0.000005	p=4.086137e-09	p=1.845901e-11
Vita Classical	p=0.479161	p=0.000121	p=1.092175e-07

Discussions

This study aimed to verify the accuracy of shade matching with the help of the CEREC 4.5.2 software using as control a Vita EasyShade dental spectrophotometer.

There are no studies in the literature that compare exactly these two objective instrumental methods of color determination. One reason for this may be that the color analysis option with CEREC software has been introduced relatively recent.

The subjective methods of dental color selection are dependent on many factors. In 1998 Horn et al. concluded in an in vitro study that the spectrophotometer is a more reliable and predictable method than visual analysis [12].

They have a reproducibility of 80%, over the subjective analysis that did not exceed 65%. Polo et al. reports the same findings in 2002, the spectrophotometers having a higher degree of accuracy and reproducibility than human analysis [13].

A systematic review of the literature was conducted by Chen et al. in 2012 in order to compare the two methods for color selection, subjective and objective, in terms of accuracy and precision. The objective method performed the most precise with a high accuracy [1].

According to the results of a study by Igiel et al. in 2017, Vita EasyShade Advance offers more accurate result in choosing color against the subjective method that use shade tabs [14].

Posavec et al. have shown that Vita EasyShade Advance offers reproducibility and is independent of environmental lighting [15].

As mentioned above, a large number of authors have demonstrated the superiority of the spectrophotometer in color selection as compared with subjective methods. The purpose of our study was to verify the correlation between two objective methods: the CAD software CEREC SW 4.5.2 from Cerec intraoral scanner and Vita EasyShade Advance spectrophotometer.

In our study, the correlation between the shade selection result with Vita EasyShade and CEREC 4.5 software, for both shade guides was 15%. The results obtained for Vitapan Classical shade tab have shown a slightly higher degree of correlation comparing with those obtained for Vita 3D-Master (17.5%vs.12.9%).

The explication of this difference between the two shade tabs is given by the better shade distribution in the color space, for V3DM comparing with VC [2,6].

At tooth areas analysis, the cervical and middle thirds showed the highest correlations, whereas lower values were obtained for the incision third. Vita EasyShade is a spot measuring device. The lower incisal correlation rate is explained by the spectrophotometer measuring strategy. During a measurement, the light emitted by the measuring tip is reflected by the tooth surface back in the spectrophotometer. Measuring color in a translucent incisal edge can produce a false result because of the amount of grey shade perceived by the spectrophotometer.

Following statistical analysis using the Wilcoxon test, statistically significant differences ($p<0.05$) were observed between the two color determination methods studied for both VC and V3DM. The null hypothesis was rejected, there are statistically significant differences in color selection between the two devices.

The "Shade Detection" feature recently introduced by CEREC wants to simplify the entire clinical process with an improvement in time and cost efficiency, creating a better patient experience, requiring a single scan. The results of this study have shown, that the Shade Detection require improvements.

Further studies should be done in order to investigate the correlation in shade measurements of intraoral scanners with colorimeters, visual shade selection and the computer analysis of digital images.

Conclusions

Within the limitation of this study, the digital intraoral scanner may not be used as an accurate method of shade selection, considering significant differences in shade tab codification with the spectrophotometer. The scanner's capability in shade selection should be further evaluated.

Author contribution

Carina Culic, Mihai Varvara and Smaranda Buduru equally contributed to the manuscript.

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