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Repeatability Of Visual, Spectrophotometer And Intraoral Scanner Methods In Shade Matching: A Comparative In-Vivo Study

Research Article

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Abstract

Introduction: Visual method of shade determination is highly subjective and a cause of concern for dentists. Instrumental methods were used to determine tooth shade hoping to achieve superior esthetics. Great controversy still exist about the best method and its repeatability for shade selection.
Objective: To compare and measure repeatability of three methods of shade determination, i.e.: visual, spectrophotometer, and intraoral scanner methods by three groups with different experience level.
Materials and Methods: Fifty participantswith intact maxillary incisor teeth were selected. Thirty evaluators with different experience level (6th year students, less than 2 years' experience and prosthodontists) evaluated teeth shade.The shade of middle third of right maxillary central incisors were recorded using visual, spectrophotometric and intraoral scanners methods. Tooth color records (VITA 3D shade and L* a* b* values) were collected, the average repeatability of each evaluator and each method were tabulated and subjected to suitable statistical analysis.
Results: Instrumental methods were more repeatable than visual methods. Intraoral scanner (Trios 3) recorded better repeatability(94%) than VITA Easyshade Advance spectrophotometer (93%) but the difference was statistically non-significant. when comparing the three methods, a statistically significant proportion of agreement between both [visual and spectrophotometric method ($P < 0.01$)] and [the visual and intraoral scanner method ($P < 0.01$)] with high percentage of agreements "yes" .In the visual method, the prosthodontists records were more repeatable (84.16%)followed by dentist with less than 2 years' experience (83.8%) then thestudents (81.5%), but the difference was not statistically significant.
Conclusion: Instrumental methods for shade selection using spectrophotometer or intraoral scanner were more repeatable than the visual method. Trios3 intraoral scanner showed higher repeatability than Easy shade spectrophotometer. Visual shade repeatability was influenced by the operator's experience.

Keywords: Spectrophotometer; Intraoral Scanner; Easyshade Advance; Trios 3; Tooth Color; Shade Matching.

Introduction

Color selection of natural teeth is a Challenging step in fixed prosthodontics as many restorations failed due to improper color choice. Final shade of the restoration should match natural tooth especially in the anterior region [1]. Shade determination can be carried out by two methods: visual method with commercial shade tabs or instrumental method by using a colorimeter, digital cameras, spectrophotometer and recently by intraoral scanners [2-4].

There are three-color systems that provides the standard principles for color analysis. Munsell color system involves a number of colored chips for visual color matching, arranged in three dimensions of appearance: (V: value), (H: hue), and (C: chroma). The CIELAB color space (also famous as CIE L*a*b*) identifies color as the following three values: L* for the lightness and it corresponds to (Value) in Munsell system, a* from green (negative) to red (positive), and b* for blue (negative) to yellow (positive) [5]. It describes color properties freely from an established image. The CIELAB color space is classically used when illustrations for print

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have to be changed from red green blue (RGB) to CMYK color models [6]. The CIELCH is the third color space, the C* identifies chroma and h° means hue angle for angular assessment. CIELCH color system isrelated to physical samples established on Munsell color scale [7]. CIE L*a*b* represents-according to Pecho et al. [8] - the most accurate tool for color evaluation in dentistry. The most popular method of shade determination is visual comparison usingshade guide as Shofu Vintage shade guide, Ivoclar-Vivadent Chromascop, Dentsply Portrait IPN shade guide, Vitapan Classical, and VITA 3D-Master,however this method is highly subjective and depends on multiple variables as age of the dentist and his color perception, illumination,background, optical illusion,intensity of light source and angle of incidence [9].VITA 3D-master shade guide is the most commonly used visual method, considering the three parameters of color: hue, chroma, and valueIt gives standardized and superior color selection [10]. In a study carried by Pohlen et al. [11], VITA 3D-master shade guide system recorded best shade matching results with more standard color difference than other shade guides. VITA3D-master shade guide has more ordered color distribution and higher color match than other shade tabs. Electronic method significantly decreases subjective errors of the visual shade guides. Electronic devices that are used to determine teeth shade are ShadeScan (digital camera with colorimeter, Cynovad, Canada), VITAEasyshade (spectrophotometer, Vident, Brea, CA, USA), ShadeVision (digital camera with colorimeter, X-Rite America, Inc., Grand Rapids, Michigan, USA) and Spectroshade (spectrophotometer, MHT Optic Research AG, Niederhasli, Switzerland) [4]. VITA Easyshade Advance 4.0 (VITA Zahnfabrik, Bad Säckingen, Germany) is a contact spectrophotometer, its probe is held at 90° on labial surface of the selected tooth [12]. It has a standardized built-in illumination that isn't affected by surrounding illumination , making its readings unaffected by surrounding moreover, it measures the light energy returned from the tooth at 25 nm intervals across the visible spectrum [13]. Trios 3 Intraoral scanner (3Shape, Copenhagen, Denmark) had been used to record colored images and distinguish between soft and hard tissue structures [2] where, the light is projected to the teeth and then reflected to internal sensor and managed by the scanner software to generate an image from the scanned parts [14], shade matching is carried by LED light, high-definition camera , computer software and it is based on VITA shade guide [15]. The evaluator's experience may play an important role in shade matching, Della Bona et al. [16] reported significant relationship between visual and the instrumental methodswhen the dentists were experienced. Others support this idea in researches carried out in different circumstances [9, 17-19], but Kröger et al. [20] stated that experience had minimal role and of no practical importance in shade selection between different groups with variable experiences. Other researches [21-23] supported this conclusion, arguing that when using the VITA 3D-master shade guide, dentist's experience was not an effectiveelement in the selection of teeth shade.

The aim of this in vivo study was to compare the color matching of maxillarycentral incisor using visual method (VITA 3D-master shade guide) and instrumental methods using VITA Easyshade and Trios 3. The null hypothesis was that there would not be a significant difference between the shade matching methods as well as the three groups of evaluators.

Materials And Methods

Sample size was calculated according to previous published studies [11, 16, 24], fifty participants representing 80% power to detect a difference between means and $\alpha = 0.05$,to be able to detect significant differencesin results, sample size was calculated using power analysis software (G*Power). This study was performed in Fixed Prosthodontics Department clinics of Faculty of Dentistry, Umm Alqura University, Makkah, Saudi Arabia. The Research Ethics Committee of Umm Alqura University approved the study protocol (Approval number: HAPO-02-K-012-2021-04-660). A written informed consent describing the treatment plan, photos' publishing, and collection of results was signed by each participant.

Participants' selection

Shade matching procedures were performed on50 participants , Inclusion criteria were: Age range from 20 to 35 years with intact maxillary incisor teeth with no history of endodontic treatment , any conservative or prosthetic restorations and with healthy periodontal tissue, The exclusion criteria are 1) having teeth that have been bleachedbefore 2) usage of medication 3) Presence of a systemic disease 4) a history of taking antibiotics during childhood or fever disease.

Evaluators' classification

Evaluators of tooth shadewereclassified into three groups according to their experience level. The first group (10 evaluators) involved 6th year dental students from Faculty of Dentistry, Umm Alqura University, the second group (10 evaluators) involved dentist with less than two years (<2) of experience and the third group involved 10 prosthodontists. All evaluators were checked for any color vision impairments using the Ishihara color vision test [25]. Evaluators with any kind of visual deficiency were excluded from the study. They were trained on the proper usage of the VITA3D-master shade guide , VITA Easy shade and Trios 3 according to the shade guide's and machine's instruction manuals.

Shade matching procedures

The tooth selected for shade matching was the maxillary right central incisor. After cleaning and polishing the teeth, shade recordings were done for middle third of maxillary right central incisor using three different methods: 1- Visual evaluation using VITA 3D-master shade guide, 2- Spectrophotometric evaluation using VITA Easyshade Advance, 3- intraoral scanner evaluation using Trios 3 intraoral scanner. Matching procedureswas done between 11:00 AM and 1.00 PM [26] with dental chair directed toward North and facing sunlight. Each participant sit in upright position at the same level from the evaluator's eyes,40 cm. away from the evaluator, with elimination of all bright colors as (lipstick, tinted eye glasses).In between every measurement, each evaluator re-adapted his eye by looking at a blue paper for five seconds to prevent eye fatigue [27].

Visual shade selection

The VITA 3D-Master shade guide (VITA Zahnfabrik, Bad Säckingen, Germany) was used for the visual shade selection method

(Figure 1). It uses the accepted color perception concepts of hue, value and chroma where the first number represent value (lightness) then the letter represents hue and final number denotes chroma. For every participant, the suitable shade was selected based on the matching tab.

Spectrophotometer shade selection

A Clinical Spectrophotometer (VITA Easyshade Advance, VITA Zahnfabrik, BadSäckingen, Germany) was used (Figure 2). The manufacturer's instructions were followed for shade recordings wherethe Instrument probe tip was positioned on the middle third of the upper right central incisor. The "Tooth single"program was chosen for recording the shade and the L* a* b* values of the tooth.

Intraoral Scanner shade selection

An intraoral scanner (Trios 3, 3Shape, Copenhagen, Denmark) was used to scan maxillary right incisor from the incisal, vestibular and palatal aspects,when the arch image was showed on the screen, the "shade icon" wasapplied to the labial third of the toothto determine theshade.

VITA Easyshade Advance and Trios 3 were calibrated before scanning each tooth.The 3D-Master reference recorded by the three methods was transformed into L*, a* and b* values using the table assumed by Alshiddi et al. [17].

Data collection and statistical analysis

Collected data from the three methods were recorded. The average repeatability and standard deviation (SD) of each evaluator and each method were tabulated in Microsoft Excel sheet, each dimension was considered individually. For the statistical analysis, Statistical Package for the Social Sciences (SPSS version 22.0, IBM Corporation, New York, USA) was used to analyze the repeatability of each method. To analyze the repeatability of each shade recording method, Analysis of variance (ANOVA) test was carried out. Also, ANOVA test was used to evaluate the statistical significance difference of the evaluator groups and to evaluate which group of evaluator fulfilled a higher repeatability.Agreement coefficient was tested between visual and spectrophotometric methods using Cohen's Kappa test. Agreement between visual and spectrophotometric methods as well as between visual and intraoral scanner methods was tested using z-test for proportions. In all tests, ($P < 0.05$) was considered to be statistically significant.

Results

Tooth color records (VITA 3D shade and L* a* b* values) were collected by the mean visual, spectrophotometer and intraoral

Figure 1. Visual shade selection using VITA 3D-Master shade guide.

Figure 2. Spectrophotometric shade selection using VITA Easyshade Advance.

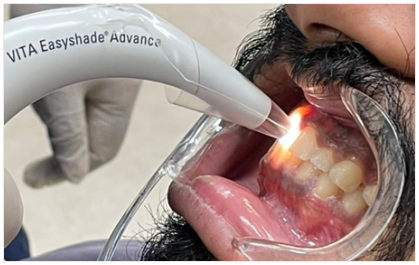

Figure 3. Repeatability of different shade matching methods.

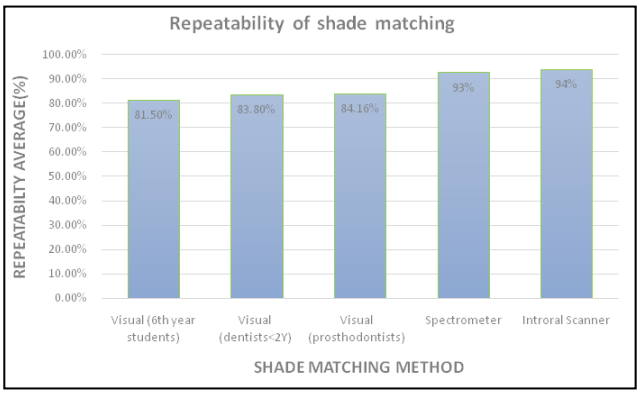

Table 1. Results of shade selection for all participants.

Participant number	Shade	Visual by Group 1 (student)	Visual by Gp 2 (<2Y)	Visual by Gp3(Prosthodontist)	Spectrophotometer (Easyshade)	Intraoral Scanner (Trios 3)	Agreement between mean Visual method, Spectrophoto-meter	Agreement between mean Visual method, Intraoral scanner
					L* b* a*	L* b* a*		
1	2M3	3M2	2M3	2M3	84.3 3.5 33.4	83.5 3.1 29.5	Yes	No
2	4M2	4M2	4M2	4M2	68 3.1 25	67.3 2.7 27	Yes	No
3	3M2	2M3	3M2	3M2	78.6 -1.7 12.7	78 -1.7 12.5	Yes	Yes
4	2L2.5	2L2.5	2L2.5	2L2.5	81.7 -1.4 18	80.3 -1.5 16.3	Yes	Yes
5	2M2	2M2	2M2	2M2	68.4 2.8 25.6	67.3 2.7 27.1	Yes	Yes
6	1M2	1M1	1M2	1M2	78.7 -1.7 9.7	79 -2.2 11.1	Yes	Yes
7	3M2	2M3	3M2	3M2	80.7 -2.1 14.6	80.7 0.9 13.6	No	No
8	2L2.5	2R2.5	2L1.5	1L2.5	82.6 -0.9 18.4	83 -0.7 18	Yes	Yes
9	3M2	2M3	2M3	3M2	79.4 -1.3 12.5	82.3 -0.8 11.7	No	No
10	4L1.5	4L1.5	4L1.5	3M3	71.7 4.7 30.7	71.2 3.2 30.7	Yes	Yes
11	1M2	1M2	1M2	1M2	87.9 -2.7 16.3	86.2 -2.2 16	Yes	Yes
12	3M2	2M3	3M2	3M2	78.9 -1.7 14.4	78.2 -1.3 14.1	Yes	Yes
13	2M3	2M3	2M3	2M3	84.5 3.5 33.4	83.4 3.1 29.5	Yes	No
14	3M2	3M2	2M3	3M2	81.5 -1.9 15.9	81.3 -1.3 15.3	No	Yes
15	2M2	2M2	2M3	2M2	81.4 -1.8 14.9	81.3 -2 11.1	No	No
16	1M2	1M2	1M2	1M2	86.3 -2.3 17.3	86 -2.4 17.7	Yes	Yes
17	2M2	2M2	2M2	2M2	83 -3 11	82.7 -2.2 13.1	Yes	No
18	3L1.5	3M2	3L1.5	3L1.5	70 -1.4 11.7	76.6 -2.7 13.2	No	Yes
19	3M2	2M3	3M2	3M2	77.8 -1.6 12.8	78.2 -1.7 12	Yes	Yes
20	2L2.5	2M3	2L2.5	2L2.5	83.1 -1.8 25.4	82.8 -1.8 22.1	Yes	No
21	3L1.5	3L1.5	3L1.5	3L1.5	72.1 -1.4 13.3	72.7 -1.5 13.7	Yes	Yes
22	3M2	2M3	2M3	3M2	36.9 -3.1 10.7	83.2 -2.7 13.1	No	Yes
23	1M2	1M2	1M2	1M2	84 -2.4 15.3	84.2 -0.95 15.8	Yes	Yes
24	3M2	3M2	3M2	3M2	73.3 -1.7 12.3	74 -3.2 12.5	Yes	Yes
25	4L1.5	2M3	4L1.5	4L1.5	66.9 -0.7 21	73.3 -0.8 19.7	Yes	Yes
26	1M2	1M2	1M2	1M2	83 -2.3 14	82.8 -0.8 14	Yes	Yes
27	1M1	1M1	1M1	1M1	80.7 -2 9.8	80.2 -2.2 10.1	Yes	Yes
28	3M1	3M1	1M3	3M1	79.6 -1.7 16	80.2 2.3 15.2	Yes	No
29	2L2.5	2L2.5	2M3	2L2.5	84.3 -2.3 17.7	84.2 -2.2 15.4	Yes	No
30	1M2	1M2	2M1	1M2	85.4 -1.8 15.5	84.9 -1.6 13.3	No	No
31	1M2	1M2	1M2	1M2	85.9 -1.4 15.5	86.2 -1.3 15.3	Yes	Yes
32	1M2	1M2	1M2	1M2	84.5 -1.9 13	84.2 -1.4 11.4	Yes	Yes
33	1M1	1M1	2M1	1M1	77.6 -1.2 +14.2	78.2 -1.7 13.3	No	Yes
34	1M2	1M2	1M2	1M2	84.4 -2.4 12.7	84.3 -2.2 12.3	Yes	Yes
35	1M1	1M1	2M1	1M1	83.6 -2.4 15.5	83.3 -0.7 15.1	No	Yes
36	4L1.5	3M3	3M3	4L1.5	64 2.8 18.7	66.6 -2.7 17.3	No	No
37	4L1.5	4L1.5	4L1.5	4L1.5	79 -1.8 16.5	78.6 1.3 16.3	Yes	Yes
38	1M1	1M2	1M2	1M1	83.7 -2.3 16.4	81.3 -3.1 11.1	No	No
39	4L1.5	2M3	2M3	4L1.5	81.2 -0.5 12.7	81 -2.2 11.2	No	No
40	3M3	2R2.5	2R2.5	3M3	77.1 1.8 32.4	77.4 1.9 29.1	No	No
41	3M1	3M1	3M1	3M1	77.9 -0.7 16.8	77 -0.9 16.3	Yes	Yes
42	2M3	2M3	2M3	2M3	78.9 -0.8 21.3	78.5 -1 19.1	Yes	Yes
43	1M1	1M1	1M1	1M1	83 -2.4 12.3	81.9 2.2 14.1	Yes	Yes
44	3R2.5	3R2.5	3M3	3R2.5	78.8 -0.5 18.4	78.4 -0.6 17.1	Yes	Yes
45	4L1.5	4L1.5	4L1.5	4L1.5	80.2 -2 15.3	80 -0.8 15	Yes	Yes
46	3L1.5	3L1.5	3L1.5	3L1.5	70.1 1.5 12.9	71.5 1.3 11.1	No	No
47	3M3	3M3	3M3	3M3	74 -2.1 11.6	77.2 -3.2 13.3	Yes	Yes
48	3M1	2M3	3M1	3M1	85.2 -2.9 13.6	85.3 -2.2 15.1	Yes	Yes
49	1M2	1M2	1M2	1M2	82.2 -2.2 14.3	83.3 -2.5 14.9	Yes	Yes
50	3L1.5	2M2	3L1.5	3L1.5	70.4 1.5 11.7	70.3 1.4 12.3	Yes	Yes

Table 2. Coefficient of agreement between Visual and Spectrophotometric methods.

	Spectrophotometer		Total	Kappa coefficient
	Did not agree	Agreed		
Visual method Did not agree	0	8	8	0.213
Visual method Agreed	8	34	42	
Total	8	42	50	

Table 3. Overall agreement between Visual and Spectrophotometer methods.

Agreement	Frequency (%)	P value of z test
No	14(28%)	0.001**
Yes	36(72%)	
Total	50 (100%)	

**p < 0.05

Table 4. Overall agreement between Visual and Intraoral scanner methods.

Agreement	Frequency (%)	P value of z test
No	16(32%)	0.001**
Yes	34(68%)	
Total	50 (100%)	

**p < 0.05

scanner methods (Table 1). Assessment of the repeatability of shade matching using spectrophotometer and the intraoral scanner method was done and compared to the visual method. Repeatability was evaluated by recognizing repeated measures from the same participant . As shown in Figure 3,The visual method carried by the sixth year dental students recorded the lowest repeatability in shade matching with matching observations of 81.5% and (SD=11.48%), followed by visual method by dentist with less than two years' experience (83.8%- SD=7.02%) then visual method by prosthodontist (84.16%- SD=5.31%) then, spectrophotometer (93%- SD=4.02%), while the intraoral scanner gave the highest repeatability with 94% and SD= 4.6%.

There is statistical significant difference between Visual, spectrophotometer methods as well as between Visual, intraoral scanner methods (P = 0.003, P = 0.002 respectively). There is no statistical significant differences between spectrophotometer and intraoral scanner methods (P = 0.64).

The coefficient of agreement (using Kappa coefficient) was used to compare of shades recorded by visual and spectrophotometric systems, Results showed that (Kappa coefficient = 0.214) indicating a fair agreement between the shades as done by these two methods [Table 2]. Z test for proportions was used to compare agreement between the visual and spectrophotometric method. Results showed high proportion of agreement "yes" and there was a statistically significant difference [Z score was –4.1 and P value was 0.00245 (P < 0.01)] (Table 3).Z test for proportions was used to compare the agreement between visual and intraoral scanner methods,results were statistically significant with high proportion of agreement "yes" [the Zscore was −2.9and P = 0.00651(P < 0.01).](Table 4).The repeatability of visual shade matching as influenced by evaluator's experience was shown in (Figure 3), ANOVA test showed that the differences between the three groups were not statistically significant (P = 0.526).

Discussion

The science of color is acombination of science and art.Visual matching using a shade guide is the most commonused method to record the teeth shade. It depends on the evaluator's visual perception. This method is easy and economicalthat compares teeth shade with a standard shade guide [28]. However, itdepends on many psychological and physiological factors and can vary according to surrounding environment [16, 17, 29]. An alternative method of shade recording is using instrumental color measurements as colorimeters, digital cameras, spectrophotometers and intraoral scanners [30]. As the teeth color are greatly influenced by the patient's age so, participant's age in this study was between 20 and 35 years [31].

Shade matching was taken in the middle third of the tooth because the incisal third usually shows some translucent areas or white spots, this may give a mixed colors that are difficult to be recorded by spectrophotometers [32] Also, the cervical third shade may change due to contrast of the gingiva.VITAEasyshadeintraoral spectrophotometer was used in this study, its probe is positioned on the tooth giving precise measurement in the form of L* a* b* values. Trios 3 intraoral scanner has confocal microscopy with 20 microns accuracy; it uses photo-imaging technique to scan the

tooth [33]. There is great controversy regarding the repeatability of visual and instrumental methods. The null hypothesis that the tested methods for shade recording would have similar repeatability and that no alteration would be between their deviation records was rejected. The null hypothesis was rejected as shade matching using spectrophotometer or intraoral scanner was more repeatable than visual method, this was previously confirmed in other studies [4, 11, 12, 34-38]. Instrumental methods gave more accurate results and facilitating communication between dental professionals [39, [40]. Some studies showed that visual matching is more reliable than instrumental one [41, 42], Bahannan [21] reported that VITA Easy shade gave 80.4% of correct shade matches while visual shade guide records 36.3% of shade matches. Moreover, shade matching by Easyshade was more repeatable than the VITA classical shade guide was. Jarad et al. [43] investigated computer-based shade determination and found that it improves the dentist's capability to match the shade in a tough situation when it is difficult to assess a single tab to match the tooth, matching was 61.1% with computer while it was 41% in conventional method. Some studies recommended using both visual and instrumental methods to integrate each other achieving superior results [44, 45] but, the high price of these machines limits its spread in clinical practice [46].Our result wasreflected on the percentage of agreement of shade selection between the visual and bothinstrumental methods (Tables 3 and 4). The percentage of agreement between visual and spectrophotometric method was 72%, between visual and intraoral scanner method was 68%, whichare statistically significant. Gómez-Polo et al. [47] showed a significant differences between visual method and spectrophotometricone, they found a high " value" agreement when compared to "chroma andhue". No significant differences in repeatability was found between VITA Easyshade spectrophotometer and Trios 3 intraoral scanner. Previous studies proved the same result where Easy shade accuracy where comparable to trios even in clinical situations [48, 49].

Yilmaz et al.[28] proved that no significant difference between instrumental and visual matching when carried out by an expert dentist. Theoretically, dentist's experience should affect shade determination because dental practice and repetition will allows reproducible and more accurate results over time. Many studies support this hypothesis [9, 16, 18, 50]. However, other researches disprove it [20-23]. Our results also disagree with this rule, despite there is increase in repeatability percent from sixth year dental students to dentists with less than two years' experience to experienced prosthodontists, these differences were small with no statistically significant.

Study limitations

No time limit for each shade-matching session, which may lead to eye fatigue in visual method. No typical scanning technique has been recommended for shade matching using intraoral scanners, where factors as distance, scan angle and light source may affect results.

Conclusion and Clinical Significance

Within the limitations of this clinical study, the following conclusions were drawn:

1. Instrumental methods for shade selection using spectrophotometer or intraoral scannerwere more repeatable than the visual method.
2. Trios3 intraoral scanner showed higher repeatability than Easy shade spectrophotometer, but the difference was statistically non-significant
3. Visual shade repeatability was influenced by the operator's experience but with no statistical significance difference between studied groups.

Further studies on larger sample size with the use of digital cameras available in the market for shade selection are recommended, also measuring color difference (E) between different methods of shade selection is important.

Declaration of patient consent

All participants have given their written consent for their photos and other data to be published in the journal without identifying their names.

Conflict of interest

No conflicts of interest and No funding was received for the research that could have influenced its results.

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