An *In-Vitro* Assessment of Operator Accuracy and Inter-Operator Agreement in Recording Shade and Shade Characteristics

Keywords

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ABSTRACT

Color assessment remains a challenging aspect of esthetic dentistry. This study aimed to evaluate inter-operator agreement and accuracy in assessing shade parameters and to investigate the effect of different clinical backgrounds of the operators under different lighting conditions. Three veneers with a single shade (VITA VM7, shade 2M2: VITA Zahnfabrik, Bad Säckingen) and different shade characteristics (lustre, translucency and opacity) were assessed by 24 operators with different backgrounds using natural and color-corrected light (Trueshade, Interempresas Media, S.L.U. - Grupo Nova Àgora, Spain). Shade assessment accuracy was only 5.5% using natural light and 9.7% using Trueshade. The majority of operators identified value and hue correctly, although chroma was mostly identified incorrectly. The most accurate assessments were recorded by technicians, and translucency was the characteristic to be least accurately recorded. Inter-operator agreement of shade was better with Trueshade compared without Trueshade, although group agreements of shade characteristics were higher without Trueshade for lustre and opacity, but not for translucency. Operators showed limited agreement and poor accuracy in assessing shade and shade characteristics and the clinical background had an effect on shade selection. Technicians were more reliable in shade assessment. Trueshade could be a promising tool to improve shade assessment outcomes.

INTRODUCTION

Color assessment and shade reproduction in dentistry remains a challenge, despite improvements in techniques and dental materials.[1-3] Inconsistencies are present between clinicians in assessing and matching the color of the same tooth and clinicians have poor ability to repeat their selected shade on different occasions[4]. This emphasizes further the problem of color communication between clinicians and technicians.[5]

A consistent method for shade matching would be of great value for production of highly esthetic indirect restorations.[5-7] Inconclusive results have been reported comparing visual and instrumental color assessment: some investigators found a significant correlation between instrumental measurements and human observations, whilst others reported no significant agreement.[5,7,8] Instrumental color measurement may be preferred compared to visual color determination as it is more rapid and is also objective,[7]

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although from a clinical point of view, the human eye is superior in its ability to differentiate subtle nuances in color between two comparable objects.[6] Furthermore natural teeth are polychromatic, translucent and have curved surfaces and consequently instrumental color assessment is not highly reliable,[5,9] thus visual color determination is most frequent in dentistry.[10] However, this method is influenced by many factors, such as individual differences in understanding and perceiving color,[11] experience of the observer,[6] lighting and the surrounding gingival color.[12]

To improve the reliability of shade-selection procedures, the Vitapan 3D-Master tooth shade system (VITA Zahnfabrik) was developed.[13] It has been documented that use of Vitapan 3D-Master shade guide improves the consistency of shade selection.[6] The shade guide is distributed in 5 primary value levels, with a secondary distribution based on chroma and hue.[16] The selection of shades is simplified by selecting the lightness level first and then selecting the chroma and finally the hue,[11] and provides a more efficient matching in shade selection process.[14]

In addition to the 'classic' three dimensions (hue, chroma and value) quantified by Mansell there are also other secondary optical properties of teeth including iridescence, translucency, opacity and surface lustre, which also have a critical role in tooth color appearance.[15] Since translucency and opacity are indicators of quantity and quality of light reflection, they are considered the most important optical properties.[16] Lustre (surface gloss) is the ratio of light reflected specularly at a material surface to the light diffusely reflected to the surface.[17] Translucency, opacity and lustre are highly important parameters to be considered in order to enhance the esthetic outcomes.[17]

Standardized illumination can be used to minimize inconsistencies with shade guide selection methods.[14,18] Although sunlight is considered as a standard against which other light sources are compared, direct sunlight is not considered a suitable source for tooth color selection as the distribution of light waves from the sun is dependent on humidity, time and pollution,[19,20] and is thus changeable in both quality and quantity.[21] The accepted measurement of natural daylight is a light with a colour temperature of 5500 degrees Kelvin, and in order to produce indirect restorations to match natural tooth structure, it is essential that the lighting source matches natural daylight and allows accurate color perception.[20] A color-corrected light device is available which is portable, handheld, and provides instant, correct, and constant daylight (5500K) at the correct proximity to the working site (Trueshade). The manufacturer of Trueshade purports that the device eliminates the problem of light source deterioration experienced when using fluorescent and other surgery light sources to allow matching of the desired shade with extreme accuracy.[22]

Many studies have investigated shade assessment differences between dental practitioners.[2,6,12] However, less is known about the assessment of shade characteristics (opacity, translucency, lustre) and the inter-rater agreement between individuals with different clinical backgrounds. In view of the limited research in this area, the purposes of this study were to evaluate inter-operator agreement and accuracy in assessing and recording shade and specific shade characteristics under natural and color-corrected light source and to assess the effect of different clinical backgrounds of the operators. We hypothesize that there is no inter-operator agreement and accuracy in assessing shade and specific shade characteristics, and that the clinical background of the operators and the lighting conditions have no effect on the shade assessment.

MATERIALS AND METHODS

STUDY DESIGN

Operators with different clinical backgrounds were asked to assess the basic shade and shade characteristics of three veneers mounted on a phantom head *(Figure 1)*. Each operator assessed the three veneers in two 'sittings': first using natural light, and then subsequently using color-corrected light. To reduce eye fatigue, the assessments were performed on two different days; additionally the veneers were presented in a different order on each occasion.

TOOTH PREPARATION

A phantom head with a full upper arch of typodont teeth was positioned on a dental chair for preparation of the upper left central incisor (tooth 21). The tooth was prepared for a porcelain veneer with a standard preparation design using a high-speed handpiece.[23] Depth grooves were prepared on the surface of the tooth using a round-ended tapered diamond bur; the labial surface was reduced by approximately 0.5mm with facial reduction in two planes. Reduction was extended interproximally to produce a finishing line labial to the contact areas. The incisal edge was reduced by 2.5mm to allow sufficient thickness for production of translucent incisal porcelain. A chamfer finish line was produced at the gingival margin *(Figure 1)*. A silicone index of the unprepared tooth was used to check the reduction depth.

LABORATORY REQUEST

Once the preparation was completed, the upper full arch was sent to the laboratory. This was duplicated and three porcelain veneers (VITA VM7, VITA Zahnfabrik, Bad Säckingen) were constructed with the same base shade (2M2) but with different degrees of lustre, translucency and opacity *(Figure 1)*. The operators and investigator were blinded to the basic shade and the degree of shade characteristics (lustre, opacity, incisal translucency) with the veneers provided for the prepared tooth identified as veneer A, B, C.

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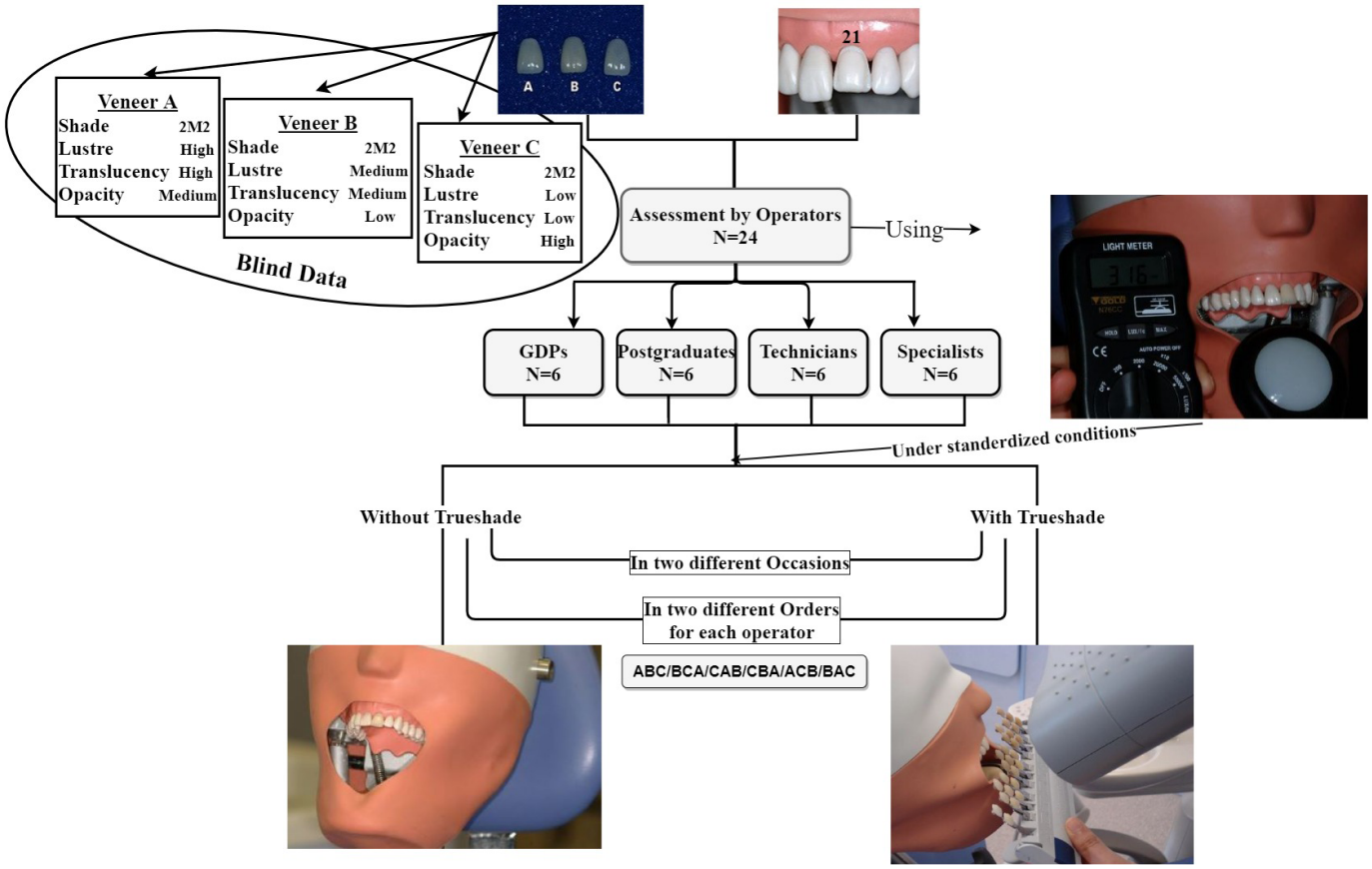

Figure 1: Flowchart showing study design (GDPs: General Dental Practitioners)

OPERATORS

Twenty-four operators with different clinical backgrounds participated in the study. The operators were restorative specialists, postgraduate dental students, general dental practitioners (GDPs) and dental technicians (n=6 in each group). Ethical approval was obtained for the study from the University of Manchester Committee on the Ethics of Research on Human Beings and consent was obtained from all participants. An Ishihara test was used to exclude color blindness of each operator.[24]

SHADE RECORDING SETTINGS

The phantom head was positioned on a dental chair held in a standardized position. The dental chair was facing a wall, being away from windows to minimize natural light, and the dental chair light was also not used. The full upper arch with the prepared tooth 21 (upper left central incisor) was mounted on the phantom head. Before assessing the shade, a calibrated light meter (Precision Gold N76CC) was positioned below the incisal level of the prepared tooth to record the light level (illuminance) of the working environment. Light recording was performed to standardize and evaluate the shade-matching environment.

Each of the three veneers was sequentially mounted on the prepared tooth using petroleum jelly. For each operator, the sequencing of veneers was randomly allocated (via blinded selection by the investigator). The operators were requested to record the basic shade of each veneer using a Vita 3D-Master shade guide (VITA Toothguide 3D-MASTER®, VITA Zahnfabrik, Bad Säckingen) and also to determine the degree of lustre, translucency and opacity of each individual veneer with and without light source.

To minimize the potential bias due to operator eye fatigue during shade assessments, each operator assessed shade parameters on two different occasions (i.e. two different days), where the first assessment was performed with natural light, while the second was performed with Trueshade (Optilume Trueshade, Interempresas Media, S.L.U. - Grupo Nova Àgora, Spain) with different order of the veneers in each occasion. For example, operator 1 was allocated with the order of CBA for the first assessment and BAC for the second.

BLINDING

Each participant was allocated an identification number and data were analyzed anonymously. Both operator and investigator were unaware of the details of construction of the veneers (A,B,C) and were blinded with respect to the basic shade, degree of lustre, degree of opacity and degree of incisal translucency, with these details only being released to the investigator by the laboratory once data collection and analysis had been completed.

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DATA COLLECTION SHEET

Each operator was given a data collection sheet, to record identification number, gender, operator clinical, graduation year, basic shade of each veneer, degree of lustre, translucency and opacity of each veneer (high, medium, low). The investigator recorded the following information: time of observation, light meter reading and natural or color-corrected light source (Trueshade).

STATISTICAL ANALYSIS

The collected data were analyzed with SPSS 20.0 software and descriptive analysis of the data was completed. Accuracy was calculated overall and for each individual subgroup (restorative specialists, postgraduates, general dental practitioners, dental technicians).

Group agreement in a multi-aspect agreement space was measured as follows: supposing that every aspect represents a dimension in a space, a group G overall agreement is measured as shown in equation 1:

$$GroupOverallAgreement(G) = \sum_{g \in G} \sum_{i \in |G|} D(g_i, C_G) \quad \text{..... (1)}$$

Where *D(g,C)* is the distance function between two vectors: *g* and *C*. Every vector represents the operator's evaluations for each aspect *g <v1,v2,v3,...>* where e.g. v1 is the value of the first aspect for the group operator *g* that belongs to group *G*, which have the number of group operators denoted as $|G|$. *C* represents the centroid of the same group responses (i.e. the average of the group operator responses) represented in the same way as *C <c1,c2,c3,...>* where e.g. c1 is the average value of the first aspect of all operators in the group. One method to measure distance is using Euclidean distance, as shown in equation 2:

$$D(g, C) = \left(\sum_{j=1}^{|g|} (v_j - c_j)^2\right)^{\frac{1}{2}} \quad \text{..... (2)}$$

The overall group agreement value must be minimized to achieve higher agreement, as the closer the vectors to the centroid the less distance between their values, thus, the higher the agreement among their values. This is represented in Figure 2.

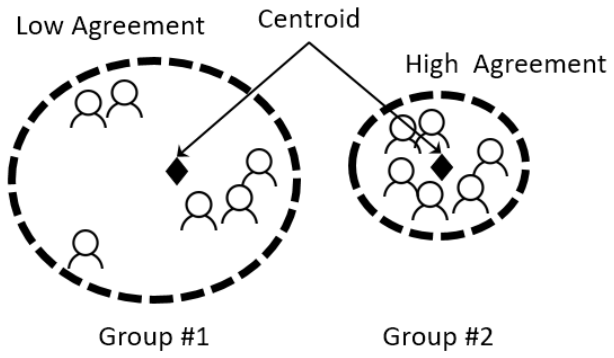

Figure 2: Illustration of agreement between operators.

An important thing to note is that although this method determines group agreements, the agreement value does not reveal any information related to the group operator evaluation accuracy; rather, it only shows whether a group is coherent (e.g. Group #2, *Figure 2*) or diversified (e.g. Group #1, *Figure 2*).

Agreement between separate group members considering the shade as a single feature was calculated. Then, the agreement was calculated taking into account the three features of shade (level, hue, and chroma), and the agreement considering the three shade characteristics (lustre, translucency and opacity). The goal of considering the three features of the shade is that the distance between members, which represents similarity between them in a multi-dimensional space, will be more representative with partial shade matching. For example, if a member chooses a shade of 2M1 in the first fold, this feature is considered a total mismatch; however, this is partially matching the shade 2M2 considering the matching value and hue, but not the chroma.

RESULTS

1. STUDY PARTICIPANTS AND LIGHT METER READINGS

A total of 24 operators (17 males, 7 females) participated in this study with an average practice experience of 10.4 years. The operators presented different clinical backgrounds and previous experience in shade assessment. The results of the color deficiency test of all operators was negative (no color deficient subjects).

The mean of light meter readings taken at each shade assessment interval was 369.94±59.65 Lux with a range of 264 to 511 Lux. The light meter readings reached a peak at around early afternoon (1-2 pm) and were at a minimum in early morning (9-10 am).

2. RANGE OF RECORDED SHADES

2.1 By All Operators

The range of shades recorded by the operators under natural (without) and color-corrected light (with Trueshade) for each individual veneer (A, B, C) is demonstrated in Figure 3. Without Trueshade, 10 shades were reported and 3M1 was the most frequently reported (32%) For veneer A, 3R1.5 was most frequently selected (25%). For both veneer B and C, shade 3M1 was recorded most frequently (33.3%) and 41.7%, respectively). 34% of the operators were able to identify the correct value and almost 67.0% of the operators recorded the hue correctly while most of the operators had difficulty in determining the correct chroma (9.7%), which is where the shades were matched incorrectly. Overall, shade 2M2 was recorded correctly 4 times (reported by technicians 3 times for veneer A and by postgraduates once for veneer C) *(Table 1*).

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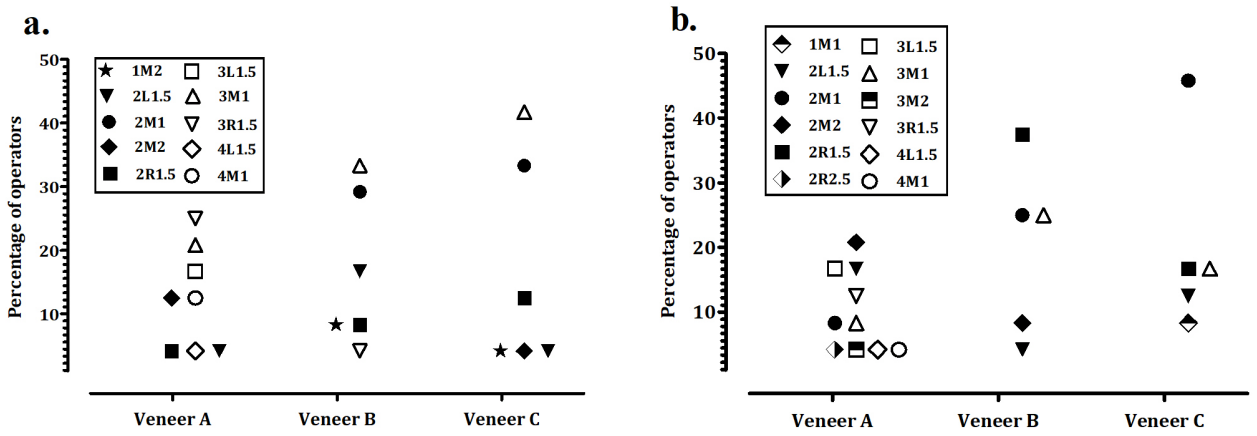

Figure 3: Range of shades recorded for veneers A, B and C without (a) and with (b) Trueshade.

With Trueshade, a total of 12 shades were selected and 2M1 was the most commonly reported shade (26.4%). The variety of selected shades was more for veneer A than veneers B and C. For veneer A, ten different shades were selected by the operators. 2M2 was the most frequent shade recorded (20.8%). For veneer B and C, five different shades were recorded. Shade 2R1.5 was selected most frequently for veneer B (37.5%) and 2M1 for veneer C (45.8%). With Trueshade, more operators were able to record the value and the chroma correctly (48.0% and 11.1%, respectively) although fewer operators recorded the hue correctly (58.3%) compared to without Trueshade. Overall, shade 2M2 was recorded correctly 7 times (reported by technicians 3 times, by specialists 2 times and once by GDP as well as by postgraduates).

2.2 By Operator Group

Figure 4 shows the shades recorded per veneer according to the operator group without Trueshade. The most frequent reported shades were 2M1 for veneer B (50.0%), 4M1 and 3M1 for veneers A and C (50.0% each), 2M1 for veneer C and 3M1 for veneer C for GDPs, postgraduates, technicians and specialists, respectively.

Figure 5 shows the range of shades recorded using Trueshade according to the operator group. The most frequent reported shades were 2M1 and 2R1.5 on veneer B and C (50.0% each) , 2M1 and 2R1.5 (50.0% each) for veneer B and C, 2M1 (83.3%) for veneers C, for GDPs, postgraduates and technicians. Specialists reported 2M2 (33.3%) for veneer A, while reporting 3M1 and 2L1.5 for veneer C (33.3% each).

3. DEGREE OF LUSTRE, TRANSLUCENCY AND OPACITY

3.1 By All Operators

For each individual veneer, different degrees of shade characteristics were recorded *(Figure 6*). Without Trueshade, lustre was most frequently selected as medium for all veneers (i.e. for veneer A: 58.3%, B: 54.2%, and C: 41.7%). Translucency was commonly recorded as low for veneer A (70.8 %), high for B (66.7%) and medium for C (58.3%). Opacity was frequently selected as medium for veneers A, B and C.

Assessment of shade characteristics with Trueshade showed similar results as without, except for lustre for veneer A, where low and medium values were reported equally (50% each). Furthermore, opacity was reported as high value most frequently on veneer A.

3.2 By Operator Group

Table 2 shows the different degrees of lustre, translucency and opacity recorded by each group of operators without and with Trueshade. Results reported with and without Trueshade for lustre showed high correlation at low value and inverse relation at high value for all veneers, translucency showed high correlation at all values (high, low, medium) for all veneers and opacity showed high correlation at high value for all veneers.

4. OPERATOR ACCURACY IN ASSESSING SHADE AND SHADE CHARACTERISTICS

Table 1 and Figure 7 show the results of shade and shade characteristics for all groups. The overall accuracy in assessing shade and characteristics in this study without Trueshade was higher than with Trueshade (i.e. 20.8% and 17.7% respectively). However, the percentage of operators who recorded the shade correctly (i.e. 2M2) was 5.5% without Trueshade compared to 9.7% with Trueshade. The overall accuracy in assessing shade characteristics without Trueshade was 26.0% compared to 20.4% with Trueshade. The percentages of correct assessments of specific shade characteristics without Trueshade were: 27.8%, 15.2% and 34.7% for lustre, translucency and opacity respectively, compared to 22.2%, 19.4% and 19.4% with Trueshade. Of the shade characteristics, translucency had the lowest correct assessments by operators with and without Trueshade and was the only characteristic that showed improvement using Trueshade.

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Table 1. Number of correct shade and characteristic assessments reported by all operators and each operator group (without (W/O) Trueshade and with Trueshade).

Parameters			All operators (n=24)		GDPs (n=6)		Postgraduates (n=6)		Technicians (n=6)		Specialists (n=6)	
			W/O	With	W/O	With	W/O	With	W/O	With	W/O	With
Shade Details	Value	A	5	12	1	2	0	2	3	5	1	3
		B	13	18	4	5	2	5	5	4	2	4
		C	13	18	4	6	3	4	4	5	2	3
	Total		31	48	9	13	5	11	12	14	5	10
	Hue	A	11	11	1	3	3	0	6	5	1	3
		B	17	14	5	2	4	3	3	5	5	4
		C	20	17	3	3	5	5	6	6	6	3
	Total		48	42	9	8	12	8	15	16	12	10
	Chroma	A	3	6	0	2	0	0	3	2	0	2
		B	2	2	0	0	1	1	0	1	1	0
		C	2	0	1	0	1	0	0	0	0	0
	Total		7	8	1	2	2	1	3	3	1	2
Shade (2M2)		A	3	5	0	1	0	0	3	2	0	2
		B	**0**	2	0	0	0	1	0	1	0	0
		C	**1**	0	0	0	1	0	0	0	0	0
Total			4	7	0	1	1	1	3	3	0	2
Lustre	high	A	1	0	1	0	0	0	0	0	0	0
	medium	B	13	13	3	3	2	3	4	4	4	3
	low	C	6	3	0	0	2	2	1	1	3	0
Total			20	16	4	3	4	5	5	5	7	3
Translucency	high	A	0	2	0	1	0	1	0	0	0	0
	medium	B	6	8	2	2	1	3	3	1	0	2
	low	C	5	4	2	0	2	3	1	1	0	0
Total			11	14	4	3	3	7	4	2	0	2
Opacity	medium	A	11	7	3	1	3	1	1	2	4	3
	low	B	8	2	1	2	3	0	3	0	1	0
	high	C	4	5	2	1	1	2	0	0	1	2
Total			25	14	6	4	7	3	4	2	6	5

GDPs: General dental practitioner

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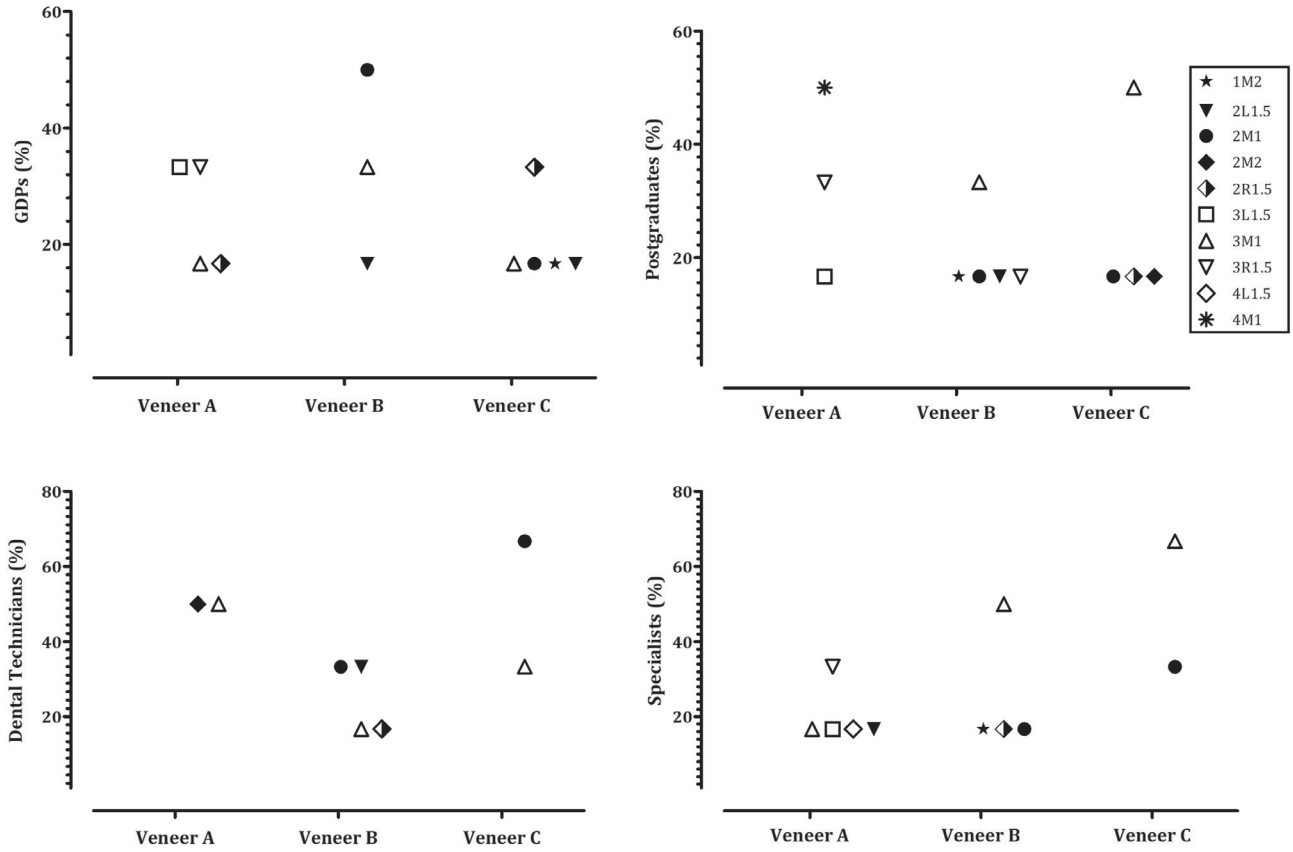

Figure 4: Range of shades recorded for veneers without Trueshade according to operator category: A. General dental practitioner (GDPs), B. Postgraduates, C. Specialists in restorative dentistry, D. Dental technicians.

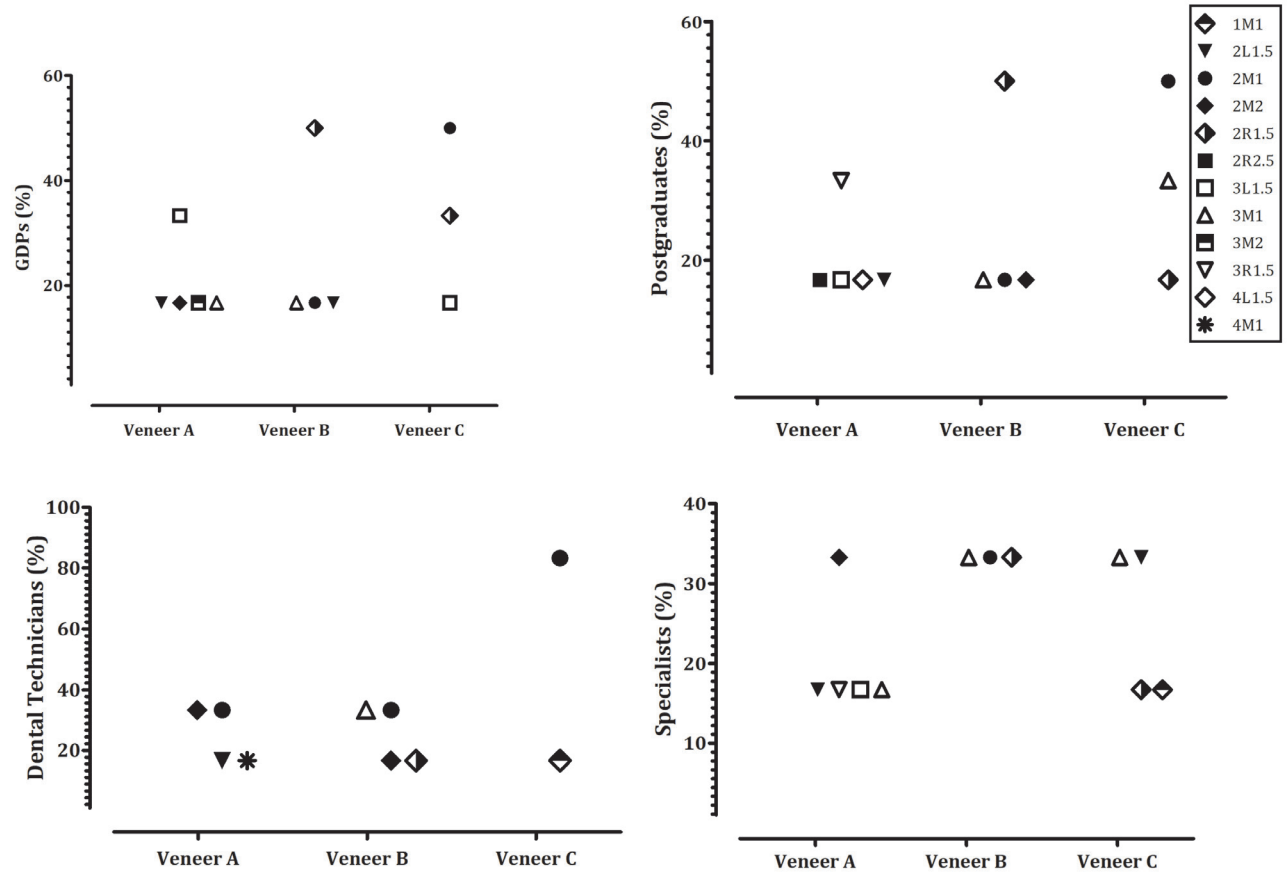

Figure 5: Range of shades recorded for veneers with Trueshade according to operator category: A. General dental practitioner (GDPs), B. Postgraduates, C. Specialists in restorative dentistry, D. Dental technicians.

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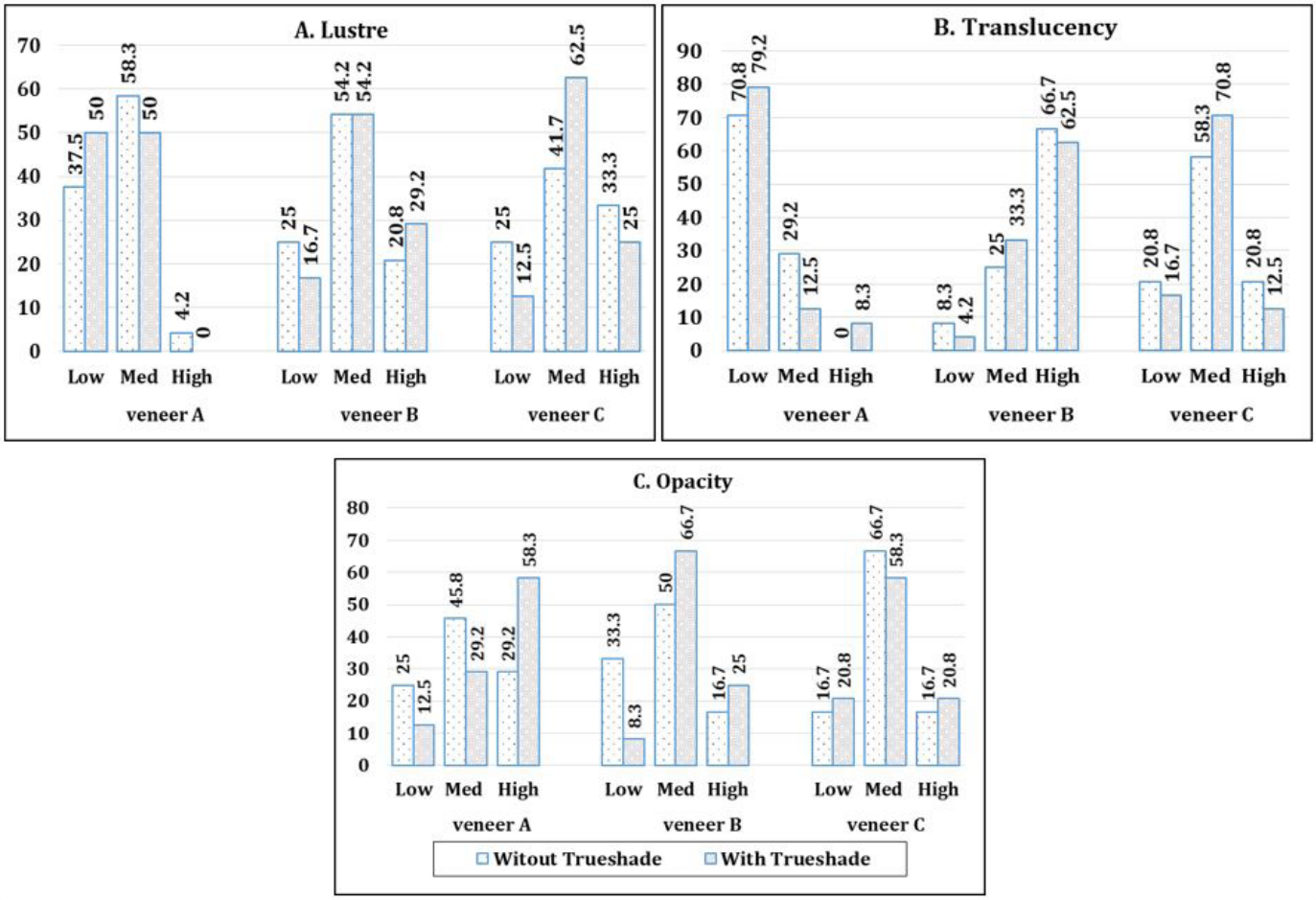

Figure 6: Lustre, translucency and opacity recorded for veneers with and without Trueshade.

Table 2. Recorded characteristics without (W/O) and with Trueshade, according to operator group.

Categories (n=6)		Lustre (%)						Translucency (%)						Opacity (%)					
		W/O Trueshade			With Trueshade			W/O Trueshade			With Trueshade			W/O Trueshade			With Trueshade		
		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
GDPs	A	33.3	50	16.7	33.3	66.7	0	50	50	0	66.7	16.7	16.7	0	50	50	16.7	16.7	66.7
	B	33.3	50	16.7	16.7	50	33.3	16.7	33.3	50	0	33.3	66.7	16.7	50	33.3	33.3	50	16.7
	C	0	66.7	33.3	0	83.3	16.7	33.3	33.3	33.3	0	66.7	33.3	16.7	50	33.3	50	33.3	16.7
Postgraduates	A	33.3	66.7	0	66.7	33.3	0	83.3	16.7	0	66.7	16.7	16.7	0	50	50	16.7	16.7	66.7
	B	50	33.3	16.7	50	50	0	0	16.7	83.3	0	50	50	50	33.3	16.7	0	83.3	16.7
	C	33.3	0	66.7	33.3	50	16.7	33.3	50	16.7	50	50	0	16.7	66.7	16.7	0	66.7	33.3
Technicians	A	50	50	0	33.3	66.7	0	83.3	16.7	0	100	0	0	83.3	16.7	0	16.7	33.3	50
	B	16.7	66.7	16.7	0	66.7	33.3	0	50	50	16.7	16.7	66.7	50	50	0	0	83.3	16.7
	C	16.7	66.7	16.7	16.7	33.3	50	16.7	50	33.3	16.7	83.3	0	0	100	0	0	100	0
Specialists	A	33.3	66.7	0	66.7	33.3	0	66.7	33.3	0	83.3	16.7	0	16.7	66.7	16.7	0	50	50
	B	0	66.7	33.3	0	50	50	16.7	0	83.3	0	33.3	66.7	16.7	66.7	16.7	0	50	50
	C	50	33.3	16.7	0	83.3	16.7	0	100	0	0	83.3	16.7	33.3	50	16.7	33.3	33.3	33.3

GDPs: General dental practitioners

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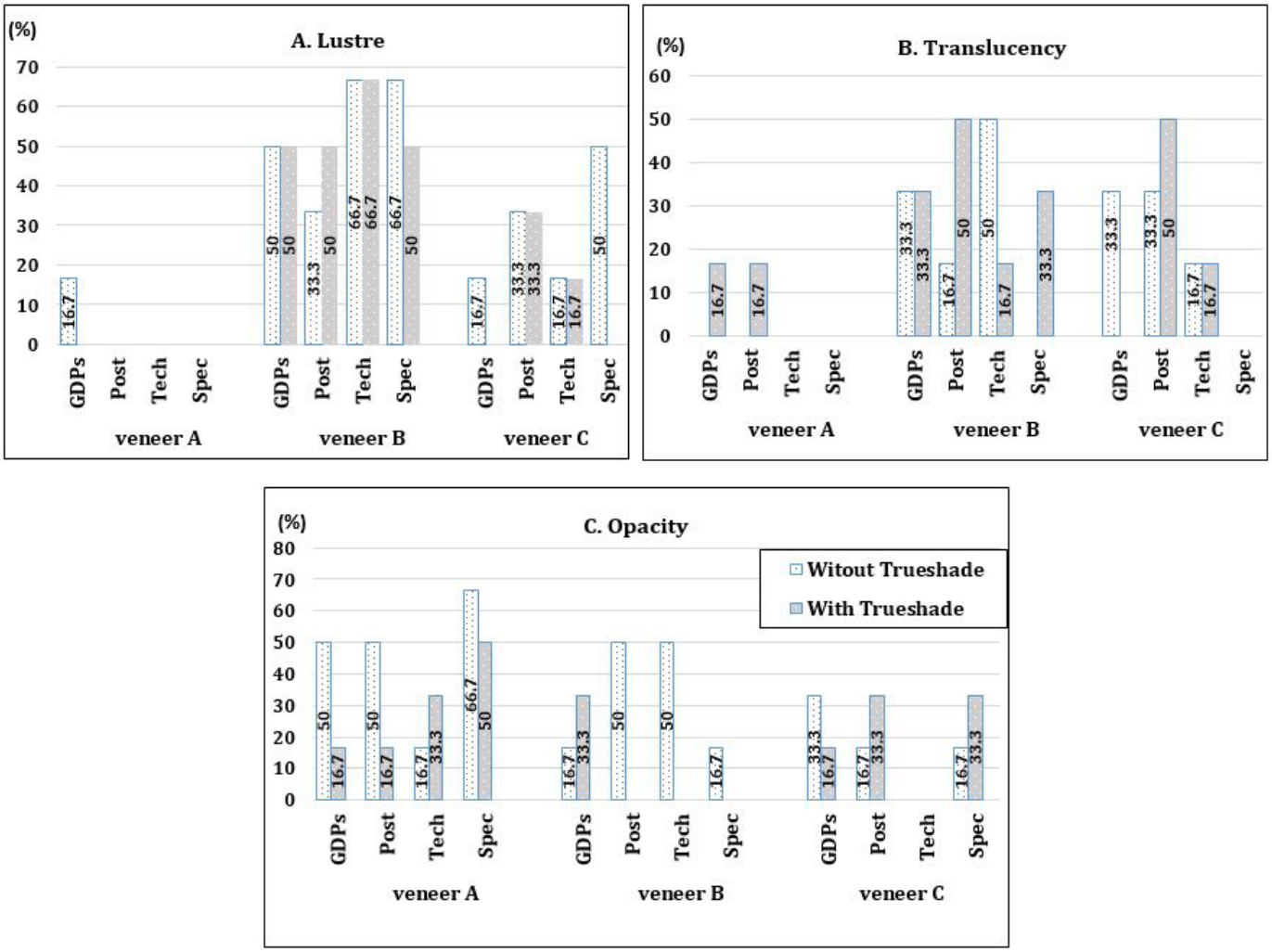

Figure 7: Percentage of correct recordings for lustre, translucency, and opacity of veneers according to operator category: GDPs - general dental practitioner; Post - postgraduates; Spec - specialists, Tech - dental technicians.

The percentages of correct assessments of shade and its characteristics without Trueshade according to operator group were 18.1%, 22.2%, 19.4% and 20.8% for specialists, technicians, GDPs, and postgraduates respectively, compared to 16.7%, 16.7%, 15.3% and 22.2% with Trueshade. Trueshade only showed a marked difference in shade assessment accuracy for translucency for postgraduates. Specialists showed the highest percentage of correct assessments in lustre and opacity; however, performed poorly on translucency. *(Figure 7)*

Lustre and translucency was recorded correctly most commonly for veneer B without and with Trueshade (i.e. 65.0%, 81.3% for lustre, 54.5%, 57.1% for translucency). Opacity was recorded correctly most commonly for veneer A with and without Trueshade (44.0%, 50.0% respectively).

5. INTER-OPERATOR AGREEMENT FOR ASSESSING SHADE AND SHADE CHARACTERISTICS

Measuring the shade agreement between all operators with and without Trueshade showed that there was higher agreement using Trueshade (0.4878) compared to without Trueshade (0.5094). The technicians were an outlier in this case, as they agreed more without Trueshade; nevertheless, they had the best agreement average among all other groups.

Detailed agreements on a feature-level are reported in Table 3. Numbers reveal interesting observations: 1) shade agreements are driven by the value and chroma agreements with Trueshade over the various groups, 2) the overall agreements of all features are not necessarily significant when considering the shade as a single feature; however, for shade features, overall agreements are significant, and 3) only value was agreed upon by all groups indicating that it was easier to identify with Trueshade. The lowest numbers in bold show the highest agreements.

Luster and opacity shade characteristics showed higher agreement without Trueshade while translucency showed higher agreement with Trueshade. Without Trueshade there was a significant difference between the technician group in comparison to other groups in terms of luster and opacity evaluations. While most groups tended to choose low-medium rating for luster and translucency, GDPs and postgraduates tended to choose medium-high ratings for opacity. On the other hand, with Trueshade, postgraduates were the only group that rated luster and translucency as low-medium,

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Table 3. Inter-operator agreement (homogeneity within group) of shade and characteristics with and without (W/O) Trueshade. Numbers in bold represent the highest agreement for each group on each parameter.

Parameter		Technique	Agreement between all operators	Agreement within subgroups			
				GDPs	Postgraduates	Technicians	Specialists
Shade		W/O Trueshade	0.5094	0.5845	0.5492	**0.4100**	0.4938
		With Trueshade	**0.4878**	**0.5395**	**0.4963**	0.4585	**0.4568**
Shade details	**Value**	W/O Trueshade	0.5139	0.5926	0.5926	0.5556	0.5556
		With Trueshade	**0.4351**	**0.4815**	**0.4815**	**0.4444**	**0.4444**
	Hue	W/O Trueshade	**0.243**	**0.2222**	**0.2222**	**0.25**	**0.25**
		With Trueshade	0.2986	0.3611	0.3611	0.3333	0.3333
	Chroma	W/O Trueshade	0.2639	0.2778	0.2778	0.2222	0.2222
		With Trueshade	**0.2222**	**0.2593**	**0.2593**	0.2222	0.2222
Lustre		W/O Trueshade	**0.4514**	0.5	0.4444	**0.4167**	**0.4444**
		With Trueshade	0.4553	0.5	**0.2778**	0.5555	0.5
Translucency		W/O Trueshade	0.4792	**0.4722**	0.4722	0.4722	0.5
		With Trueshade	**0.4778**	0.5533	**0.4116**	**0.3889**	0.5
Opacity		W/O Trueshade	**0.4792**	0.6389	**0.5028**	**0.2778**	**0.4722**
		With Trueshade	0.6042	**0.5**	0.6667	0.5833	0.6667
Overall Shade and shade characteristics average		W/O Trueshade	**0.4798**	0.5489	0.4922	**0.3942**	**0.4776**
		With Trueshade	0.5063	**0.5232**	**0.4631**	0.4966	0.5309
Detailed Shade and shade characteristics average		W/O Trueshade	**0.4051**	0.4568	0.4187	**0.3333**	**0.4074**
		With Trueshade	0.4155	**0.4425**	**0.4097**	0.3580	0.4444

while other groups rated these features as medium-high. This indicates that postgraduates were, on average, the only group which rated all features on all veneer types consistently.

The agreement between groups varied based on the veneer shade characteristics. Most groups had significantly higher agreement on veneer A without Trueshade compared to with Trueshade. In contrast, for veneer B, most groups had higher agreement with Trueshade compared to without Trueshade. For veneer C, agreements were equally split where two groups had significantly higher agreements with Trueshade, while the other two groups had insignificantly higher agreements without Trueshade. Additionally, an interesting observation is that the agreement values were lower when comparing cases with Trueshade to the cases without Trueshade (a 3.10% difference for the specialists group and 1.00% difference for the technicians group) *(Table 4)*.

Table 4 shows that that considering all shade details compared to the shade as a single feature, results were inconsistent for GDPs and specialists and higher agreement was achieved without Trueshade compared to with Trueshade. Agreements of the postgraduates and technicians were in harmony with those reported using the whole shade as a feature: the technicians achieved higher agreement without Trueshade, while GDPs achieved higher agreements with Trueshade.

DISCUSSION

Shade assessment has been shown previously to be inconsistent among different clinicians,[6] but the assessment (agreement and accuracy) of shade and shade characteristics (lustre, translucency and opacity) by operators with different clinical backgrounds using visual color determination under different lighting conditions has not been studied before. The present study shows that under standardized working conditions, the

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Table 4. Inter-operator agreement (homogeneity within group) of shade and characteristics, with and without (W/O) Trueshade, by veneer type.

		Shade and characteristics average		Shade details and characteristics average	
Veneer	**Groups**	**W/O Trueshade**	**With Trueshade**	**W/O Trueshade**	**With Trueshade**
Veneer A	**GDPs**	0.5291	0.6092	0.6395	0.8567
	Postgraduates	0.3928	0.5701	0.6700	0.7996
	Technicians	0.3518	0.4685	0.6303	0.8499
	Specialists	0.4715	0.4179	0.6085	0.7855
Veneer B	**GDPs**	0.6175	0.5374	0.7729	0.8420
	Postgraduates	0.5996	0.4289	0.8747	0.6985
	Technicians	0.4628	0.4872	0.7433	0.8339
	Specialists	0.5287	0.4559	0.7833	0.7503
Veneer C	**GDPs**	0.6070	0.4718	0.8310	0.7426
	Postgraduates	0.6552	0.4897	0.8142	0.6693
	Technicians	0.4155	0.4197	0.4909	0.5054
	Specialists	0.4812	0.4966	0.4233	0.9599

results of shade and shade characteristics assessment by operators from different clinical backgrounds under different lighting conditions were mostly inconsistent with minimal accuracy. Various shades were selected for a single basic shade with and without Trueshade (artificial light source) with minimal accuracy. Consequently, the hypothesis that there was no inter-operator variation in accuracy in assessing shade and specific shade characteristics was rejected. In addition, the hypothesis that the clinical background of the operators has no effect on shade assessment was also rejected.

Trueshade improved the shade assessment accuracy and agreement between operators overall. The use of Trueshade produced better results when assessing the basic shade and the translucency but no improvement was found when Trueshade was used for assessment of opacity and lustre. This signifies that Trueshade might produce better results for assessment of certain shade characteristics. The hypothesis that lighting conditions has no effect on shade assessment was rejected.

The total number of selected shades with and without Trueshade was 10 and 12 and the varieties of selected shades were more for veneer A than B and C. This could be related to the high level of translucency and lustre for veneer A, however veneer A shade was reported accurately on three occasions compared to none for veneer B and once for C. Although the aim of this study was to identify the level of agreement in shade and shade characters assessment, it was also possible to determine where in the color space the shade was incorrectly recorded. The shade for all the veneers was 2M2; generally, most operators recorded the value and the hue correctly, but chroma was mostly matched incorrectly by operators, with better results using Trueshade.

Dental technicians recorded the lowest range for a single basic shade and the highest correct shade assessments, which suggests that technicians are more reliable in shade assessment: this emphasizes the advantage of availability of dental technicians in dental practice. These results are in line with a previous study, where technicians showed better results in shade selection.[25] Although postgraduates were slightly more reliable in overall shade parameter assessment than GDPs and specialists, most variations in shades recorded were by postgraduates, highlighting the benefit of further consultation on shade selection by those under training. This result confirms that more training and education positively affects shade selection ability, as proved by previous study.[1] The remaining operators (specialists and GDPs) presented a similar range of shades with very minimal accuracy in shade selection, where the clinical background and experience doesn't improve the shade selection quality. This result is contrary with a previous study where prosthodontists showed superior results compared to GDPs6, but is in line with other studies reporting that clinical experience and background has no significant effect on shade matching accuracy and consistency.[25,26]

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Lustre, opacity and translucency assessment was very challenging with high variation. The feedback from most of the operators was that assessment shade characteristics was very difficult and assessment of opacity was the most difficult exercise and this could explain the wide range of variations and very subjective measures when assessment of opacity was performed. However, upon analysis, the correct assessment of opacity was highest compared to the other characteristics. Most of the outcomes of translucency assessment were incorrect, making this characteristic the most difficult to judge: GDPs recorded the widest range of translucency. Individual operator accuracy in shade characteristic assessment was not improved using Trueshade.

Agreement between all the operators in shade assessment with Trueshade was better than without, reflecting that Trueshade did improve the inter-operator agreement. These results are in line with a previous investigation which reported that correcting light devices improved the shade matching ability of dental students.[22] However, studies have also reported that color matching under different light sources is inconsistent and color perception tends to be different among different groups.[6,19] Technicians showed the highest shade agreement, which may reflect better understanding of color compared to other groups. Furthermore, this signifies the advantage of having the technicians present in the dental practice.[25]

The environment and the lighting conditions were standardized within reasonable and controllable limits in this study. The Vita 3D-Master shade guide offers a more efficient performance in shade selection,[14] accordingly 3D-Master shade guide was used in this study. However; in this investigation using 3D-Master did not result in a good accuracy or inter-operator agreement. This inconsistency may result from uncontrolled factors such as aging, fatigue, light conditions, and some of the operators found it complex to assess with 3-D shade guide,[12] preferring the Vita Classic shade guide with which they were more familiar.

The main limitation of the present and the above-mentioned *in-vitro* studies is that the distribution of gender was not equal, and a similar number of males and females from different clinical backgrounds may have reduced bias. However, the gender distribution was representative of the working population from which volunteers were recruited. Although Trueshade is a device that provides instant, correct daylight, some operators found it heavy to hold and assess the shade simultaneously while others had difficulty focusing through the lens, although a few operators found it easier to assess the shade with Trueshade due to the magnification through the lens, which provided a clearer field of vision. Direct comparison of this investigation with previously reported studies was difficult due to differences in methodologies, operators, and the tested parameters. Despite these limitations of the present study, it has provided valuable information on the challenges faced by practitioners in shade selection, considering shade characteristics, clinical backgrounds, and different lighting conditions that altogether resulted in high variations in shade selection. Furthermore, these outcomes highlight the importance of using both visual and instrumental color matching methods, where they complement each other and lead to more predictable esthetic outcomes.

In this study, poor accuracy in assessing a single base shade was demonstrated; further work is required to allow for investigation of the ability of operators to discriminate between multiple shades. Similarly, further work to assess the consistency/reliability of operators to select the same shade over multiple episodes would be informative. According to the outcome of the present study under standardized working conditions, the results of shade and shade characteristics assessments were variable with minimal accuracy without Trueshade and relatively better with. This signifies that multiple additional factors are affecting the accuracy of color perception.

CONCLUSIONS

Within the limitations of this study the following conclusions may be drawn:

1. Under standardized working conditions, shade and shade character (lustre, translucency and opacity) assessment shows low agreement between operators from different clinical backgrounds under different lighting conditions with minimal accuracy.
2. Clinical experience/expertise alone is not sufficient to increase proficiency in color matching. Technicians were more reliable in shade selection and should be involved more efficiently in shade selection.
3. Trueshade might be a promising tool to produce better results for assessment of certain shade characteristics (assessing basic shade and translucency). This may warrant more training to implement this device efficiently in shade selection.
4. Color-related education of existing and future clinicians would be beneficial with consequently better understanding of color science and shade assessment.

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