The Effects of Different Spectrophotometric Modes on Colour Measurement of Resin Composite and Porcelain Materials

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ABSTRACT

Objectives: To investigate the influence of a number of controlled modes on the spectrophotometric analysis of the colour of resin composite and porcelain materials. Methods: A total of 20 samples of commercially available resin composite, and 20 samples of commercially available porcelain materials in four different shades were produced (five samples for each shade). Colour was measured using a spectrophotometer (CM2600-d, Minolta Konica) set with different colour measuring modes namely, small aperture size (SAV) or large aperture size (MAV); specular component included (SCI), or excluded (SCE); 0% (UV-) or 100% UV illumination (UV+). Colour data were then compared using paired T-test. Results: Colour coordinates measured with spectrophotometric modes set as 2° observation angle, SAV, SCI, and UV- were significantly different from those measured with 10° observation angle, MAV, SCE, and UV+ respectively in most cases for both materials. Conclusion: Different spectrophotometric modes (2 or 10 degrees observation angle, SAV or MAV aperture size, 0% or 100% UV, and SCI or SCE) significantly influenced the absolute colour measurements of resin composite and porcelain samples. Clinical significance: Measuring modes should be taken into consideration when comparing the results of absolute colour measurements of resin composite and dental porcelain materials.

INTRODUCTION

Spectrophotometric measurements based on three colour parameters may be influenced by the following factors: the spectrum light of illumination; the reflected or transmitted spectrum by the object; and the spectral observation features of the human observer.[1] The spectral observation relates to the solid angle formed between a circular image and the eye of the human observer, and this is termed the angular subtense, which in turn relates to the size of circular image observed and its distance from the observer's eye. Suitable modes have been defined by Commission Internationale de l'Eclairage CIE 1931 (standard observer relating to 2°) and CIE 1964 (supplementary standard observer relating to 10°) as the available spectral observation modes; the latter is more commonly used when analysing larger samples at close observation distances.[2,3,4]

It is necessary to differentiate between the spectral observation and the viewing mode of a spectrophotometric measuring system, which refers to the angle of viewing involved in visual observation. Four illuminating and viewing modes were recommended by CIE for reflecting measurements samples: 45°/normal (or 0°), 0°/45°, diffuse/0°, and 0°/diffuse.[1,4]

The possible effects of different observation modes on the spectrophotometric colour measurements of dental materials have not been previously reported.

When evaluating colour reproducible positioning of the samples is required in each of the observation modes as the intensity of the light differs with distance from the light source according to the inverse square law. This can be accomplished by ensuring that the sample being measured is placed in contact with the aperture of the spectrophotometer, thus achieving a fixed distance for reflectance measurements.[1,3] In addition it should be appreciated that the size of the aperture might also affect the colour measurements, especially when measuring translucent samples.[6,7,8] It has been found that colour coordinates measurements of resin composites using 3 mm/3 mm illuminating/ aperture size were significantly different from those obtained using 11 mm/8 mm illuminating/ aperture size. However, colour change values on polymerization of resin composite materials were similar in both aperture sizes.[9] Moreover, colour coordinates of resin composite materials measured with 3 mm/3 mm illuminating/ aperture size were significantly lower than those measured with 11 mm/ 8 mm illuminating/ aperture size.[10]

Two different specular component modes (specular component included [SCI], and specular component excluded [SCE]) can be operated in a spectrophotometer which contains an integrating sphere mechanism. The latter comprises a sphere whose internal surface is covered with a white substance such as barium sulphate, which causes incident light to be uniformly diffused in all directions. The specular component represents the reflected light from the surface of an object in the same but opposite angle from the incident light, and it is called a specularly reflected light. While, the diffuse reflectance represents the amount of light that scattered in different directions rather than specularly reflected.[5,11]

Shiny gloss surfaces give a strong specular reflectance but weak diffuse reflectance. In contrast, a weak specular component and a strong diffuse reflectance result from rough matt surfaces.[5] Given that the surfaces of dental materials are usually neither completely shiny nor matt, including or excluding the specular component may influence the colour measurement of different dental materials.[12]

Significant differences in colour coordinates measurements of resin composite materials with SCI and SCE modes were determine.[10,12,13] Moreover, colour differences between the measurements of resin composites with SCI and SCE modes were perceptible.[12] Significant difference where found in L* colour coordinate measurements of resin composites with SCI and SCE modes. Moreover, the colour changes on aging of resin composites were also different with SCI and SCE modes.[12]

Fluorescence refers to the absorption of incident light by a substance and the subsequent spontaneous emission of light of a longer wavelength.[14] A fluorescent substance emits more visible light than is incident on it, making it appear brighter and shinier than non-fluorescent substances.[15] In dentistry, it is assumed that fluorescent materials absorb the UV component of light and emit it spontaneously in the bluish spectrum.[16]

The UV component of daylight is considered to vary with the time of the day, being lower (more red) at sunrise and sunset, and greater (more blue) at the mid of the day.[17] Thus, the UV component of daylight may vary depending on the situation. Recently, a spectrophotometer that can control the amount of UV component within the illumination has become available (Minolta spectrophotometer (CM-2600d, Konica Minolta, Japan) which has a UV filter that can adjust the amount of UV component of a pulsed xenon lamp that emits a D65 illumination which simulates the daylight. D65 illumination is generally used in comparing colour difference values between fluorescent and non-fluorescent samples because of its considerably higher spectral power distribution of UV component than any other artificial illuminations.[18,19]

Since the UV light can make the fluorescent substance to appear brighter and shinier like natural teeth, colour differences between fluorescent and non fluorescent dental materials increase under UV illumination (for instance, D65).[19,20] Thus, fluorescence of dental materials may affect the colour matching process under UV-containing light. It has been shown that the percentage of UV component included into D65 simulated xenon source significantly influenced the colour measurements of fluorescent resin composites, but did not influence the colour measurements of non-fluorescent or limited fluorescent resin composites tested.[21] On the other hand, it has been shown that UV adjustments for D65 simulated xenon source may not be important in colour measurements of resin composite materials.[22]

Therefore, it can be deduced that certain factors relating to measuring conditions including: observer curve, illuminating/ viewing aperture size, specular component and UV component may influence colour measurements of aesthetic restorative materials. Limited information was reported about the influence of these measuring conditions on the colour measurements and colour differences determination of resin composite materials, and no information was found about the influence of these measuring conditions on the colour measurements and colour differences determination on dental porcelain materials.

While visual shade-matching is most practical in a clinical environment, in a laboratory the use of spectrophotometric techniques allows for reliable and reproducible measurements of the colour of porcelain.[23,24] Spectrophotometers measure CIE-LAB values[25] to give a numeric value of 3D colour (E*) which can then be used to assess colour change (ΔE*).[26]

Determining the value of ΔE* which is clinically significant is challenging and different levels have been determined. It has been shown that the borderline ΔE* which is perceptible to all people in a colour test is 2.5.[27] A scale of perceptible colour difference has also been proposed with a ΔE* < 1 regarded as not appreciable to the human eye and a ΔE* > 2 appreciable by non-skilled persons and therefore of clinical significance.[28,29] Moreover, it has been found that 3.3 units of colour difference have been considered unacceptable by 50% of observers.[30] Similarly, 50% of observers had rejected the colour difference of 2.72 ΔE units between the samples.[31] An in vivo study has shown that the average ΔE* between teeth assessed to be a complete colour match intra-orally is 3.7 while the average ΔE* of 6.8 units has been assessed to present the clinically colour mismatch.[32] Moreover, a recent in vivo study has presented the clinically acceptable threshold to be ΔE* 5.5 units.[33] Additionally, 50:50% perceptibility threshold and 50:50% acceptability threshold of dental ceramic under simulated clinical settings were 1.2 and 2.7 respectively.[34] However, 50:50% acceptability threshold of artificial teeth under well-controlled clinical settings was 4.2.[35]

AIM OF THE STUDY:

The purpose of the study was to evaluate the differences in colour data resulting from the use of different measurement conditions when measuring the colour of resin composite and dental porcelain materials and to assess the effect of material type on the colour measurements when using these different measuring conditions.

The following null hypothesis was investigated:

There are no significant differences in determining absolute colour coordinates, or colour difference values of both resin composite and porcelain materials when using the following measuring conditions:

- 2 and 10 degrees observer curves.
- Small (SAV) and large (MAV) aperture sizes.
- 0% and 100% ultra violet (UV) component.
- Excluding (SCE) and including (SCI) the specular component.

MATERIALS AND METHODS:

STUDY DESIGN:

Four different shades (A1, A2, A3, and A3.5) were used to produce 20 samples of commercially available resin composite, and 20 samples of commercially available porcelain materials (five samples for each shade). Colour coordinates of all samples were measured using a spectrophotometer set with different measuring modes relating to the null hypotheses to be tested. Colour difference values were calculated for each shade pair (between A1/A2, A1/A3, A1/A3.5, A2/A3, A2/A3.5, and A3/A3.5). Spectrophotometric colour data obtained with different measuring conditions were then compared.

SAMPLE FABRICATION:

Four different dentine shades (A1, A2, A3, and A3.5) of both resin composite (Filtek Z250, 3M ESPE) and dental porcelain (Omega 900, Vita, Germany) were used to fabricated discs of 2 mm thickness and 13 mm diameter by using a mould made of polyvinyl siloxane (PVS) putty *(Figures 1a and b)*. Five samples were produced for each shade (40 samples in total).

Resin composite was packed into the silicone mould (13 mm in diameter and 2.1 mm in thickness). Specimens were light cured at five different sites from both sides each for 20 seconds using a curing light unit of 7 mm tip diameter (Curing light XL3000, 3M ESPE, USA).

The porcelain powder (Omega 900, Vita, Germany) and modelling fluid (Vita, Germany) were mixed and packed with vibration into the silicone mould. Excess moisture was removed using paper tissue to minimize porosity of the specimens. Then the condensed specimens were placed on a firing tray and fired in a vacuum furnace at a temperature of (900 °C).

Resin composite and porcelain discs were then ground to ±0.025mm of the prescribed thicknesses (2 mm) and polished using 150-, 1000-, 1500-grit silicon carbide papers (Rhynowet Plus, Portugal) with running water. The thickness of the samples was determined using a digital thickness scale (Mitutoyo, Japan).

COLOUR MEASUREMENTS:

A single spectrophotometer (Minolta CM 2600d, Konica Minolta, Japan) was used for colour measurements of all samples. This device uses a diffused illumination integrating sphere system with a d/8 mode (diffuse illumination, 8-degree viewing) *(Figure 2)*.

The spectrophotometer can operate with various modes that equate to the hypotheses to be tested namely: specular component excluded (SCE) or included (SCI); 2° or 10° observation angle; different amounts of ultra violet component; a small aperture size (SAV) permits a measuring area of 3 mm/6 mm and a large aperture size (MAV) allows an 8 mm/11 mm measuring area *(Figure 3)*; and colour measurements can be presented in different colour spaces including CIELAB colour space. Three pulsed xenon lamps provide a high resolution and dual beam mono chromatic light source; and different illuminates including D65can be selected for each light source.

Composite and porcelain samples were measured with the Minolta spectrophotometer set with the D65 light using the following modes: 2° and then 10° observation angles, SAV, 100% UV and SCE; SAV and then MAV, 2° observation angles, 100% UV and SCE; 0% and then 100% UV, 2° observation angles, SAV and SCE; SCE and then SCI, 2° observation angles, SAV and 100% UV. All colour measurements were presented according to CIELAB colour space.

Identical conditions were created for the colour measurement of each sample: the same black background, the same operator, and the same place and lighting conditions. Three measurements were taken for each sample and the means (L*, a*, and b*) were recorded as the absolute colour coordinates.

COLOUR DATA MANIPULATION AND STATISTICAL ANALYSIS:

Data was entered into a Microsoft Excel (Microsoft Corp., Redmond, USA) spreadsheet and analysed using SPSS 15 (SPSS inc., Chicago, USA).

Statistical analysis (paired t-test) was conducted on absolute colour coordinates CIELAB values at ($p<0.001$).

This was assessed by comparing the absolute colour coordinates values of all samples obtained using specific spectrophotometric mode and the corresponding colour coordinates obtained using the other mode using paired t-test.

Colour difference values were calculated for each sample using the following formula:[35]

$$\Delta E^*_{12} = ((L^*_1-L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1-b^*_2)^2)^{1/2}$$

where L*1, a*1, and b*1 express the absolute LAB values for each sample determined using one measuring mode, and L^*_2, a^*_2, and b^*_2 express absolute colour coordinates LAB values of the same sample with the other measuring modes. These colour difference values were then computed as means and 95% confidences intervals.

Moreover, colour difference values (symbol as ΔE*) between each possible paired combination of the four shades within each material were calculated using the following formula:[35]

$$\Delta E_{ab} = \sqrt{(L_a*-L_b*)^2 + (a_a*-a_b*)^2 + (b_a*-b_b*)^2}$$

Where L_a*, a_a*, and b_a* are the mean colour coordinates for one shade obtained with one measuring modes, and L_b*, a_b*, and b_b* are the mean colour coordinates of another shade obtained with the same measuring modes.

$\Delta E_{ab/1}$ and $\Delta E_{ab/2}$ were then presented in means for comparison, where $\Delta E_{ab/1}$ was the colour difference obtained with one measuring modes, and $\Delta E_{ab/2}$ was the corresponding colour difference obtained using the other measuring modes for the same shade pair. For instance, $\Delta E_{ab/1}$ was the colour difference calculated between A1 and A2 shades of porcelain with the small aperture size (SAV), and $\Delta E_{ab/2}$ was the corresponding colour difference determined between the same shade pair (A1 and A2 shades of porcelain) with the large aperture size (MAV).

The influence of the material type on the colour measurements using different spectrophotometric modes was evaluated using univariate analysis of variance at ($p<0.001$).

Figure 1a: PVS mould used to fabricate samples

Figure 1b: Composite disc produced using the PVS mould

Figure 2: Minolta CM 2600d spectrophotometer

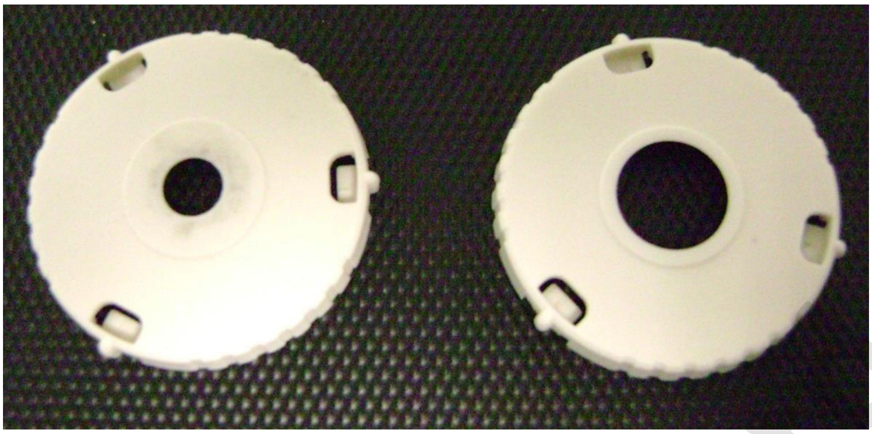

Figure 3: Small (SAV) and large (MAV) aperture sizes of Minolta CM 2600d spectrophotometer

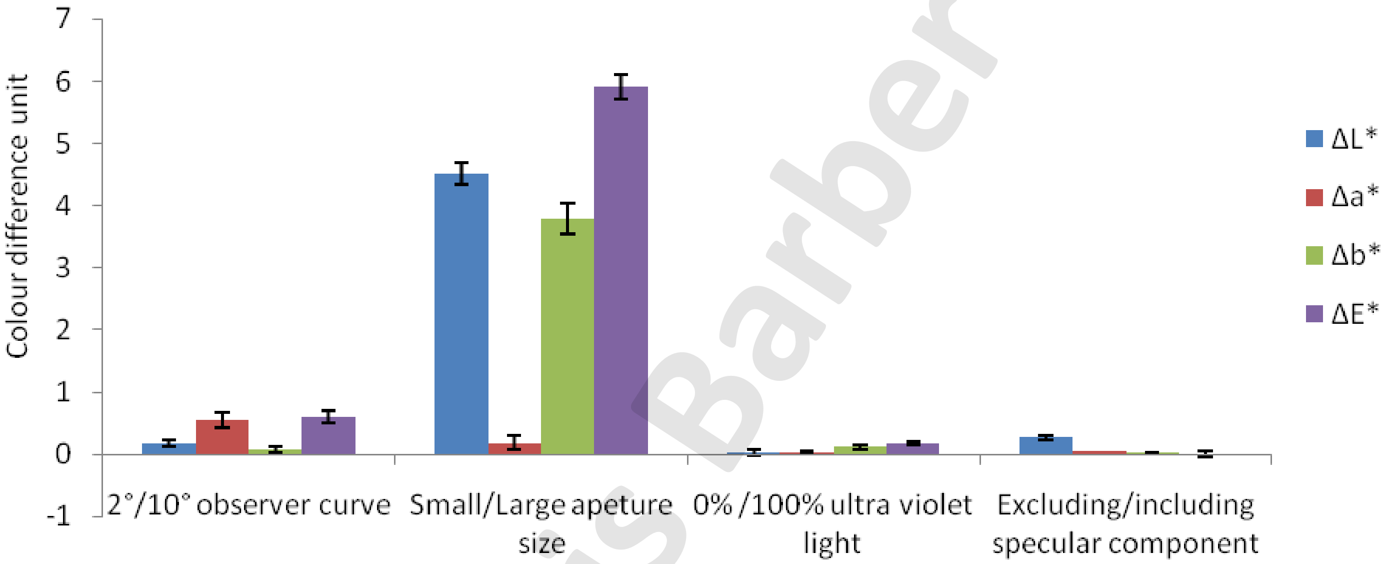

Figure 4: Differences in colour ΔE* and colour coordinates of resin composite materials measured with different measuring conditions (95% confidence intervals were illustrated)

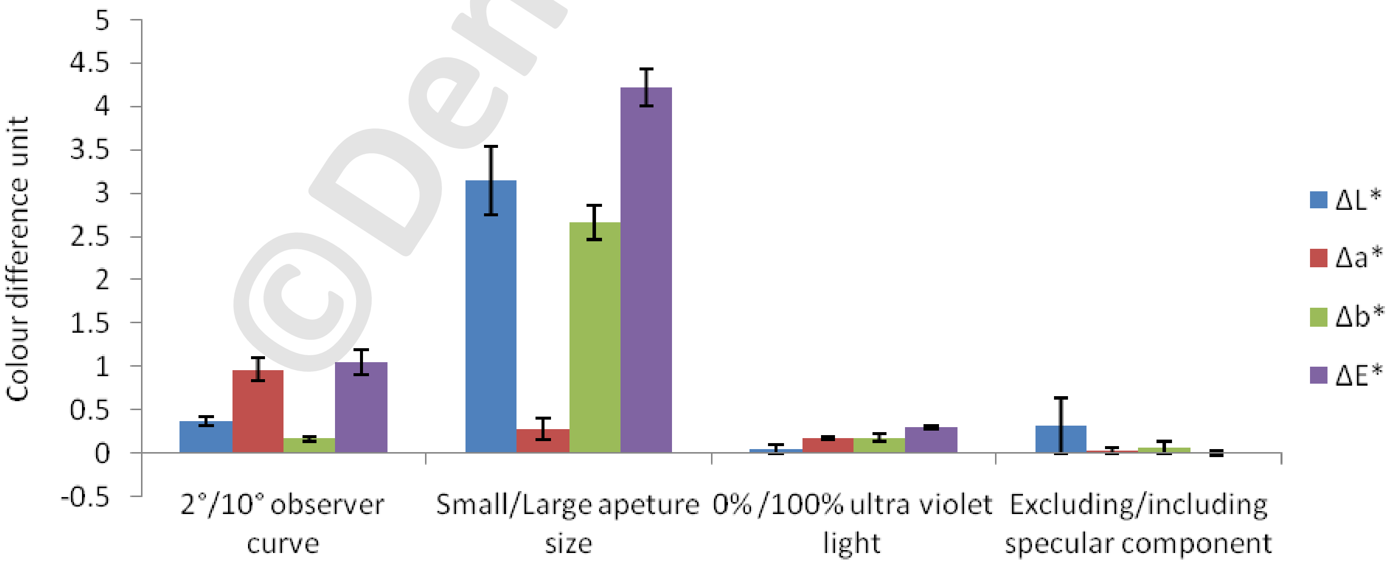

Figure 5: Differences in colour ΔE* and colour coordinates of porcelain materials measured with different measuring conditions (95% confidence intervals were illustrated)

RESULTS:

DIFFERENCES FOR ABSOLUTE COLOUR COORDINATES.

Observation angle:

The colour coordinates measured with 2 degrees observer curve and those measured with 10 degrees observer curve were significantly different for both resin composite and porcelain materials ($p \leq 0.001$). The results based on paired t-test are illustrated in Table 1 and Figure 4 for resin composite and in Table 1 and Figure 5 for porcelain material. The colour difference values calculated between these mentioned colour coordinates were ΔE*= 0.6 (0.48-0.71 at 95% confidence interval) for resin composite and ΔE*=1.05 (0.91-1.19 at 95% confidence interval) for the porcelain material.

Aperture size:

The colour coordinates measured with small aperture size and those measured with large aperture size were significantly different for both resin composite and porcelain materials ($p \leq 0.001$). The results based on a paired t-test were illustrated in Table 2 and Figure 4 for resin composite and in Table 2 and Figure 5 for porcelain material. The colour difference values calculated between these mentioned colour coordinates were ΔE*=5.91 (5.71-6.11 at 95% Confidence Interval) for resin composite and ΔE*=4.22 (4-4.43 at 95% Confidence Interval) for porcelain material.

Ultra Violet Light:

The (a* and b*) colour coordinates measured with 0% UV and those measured with 100% UV were significantly different for both resin composite and porcelain materials ($p \leq 0.001$), while the L* coordinate was not significantly different in both materials. The results based on paired t-test along with the results of absolute colour difference values calculated between these colour coordinates are shown in Table 3 and Figure 4 for resin composite and in Table 3 and Figure 5 for the porcelain material. The colour difference values calculated between these mentioned colour coordinates were ΔE*=0.18 (0.14-0.2 at 95% confidence interval) for resin composite and ΔE*=0.3 (0.26-0.32 at 95% confidence interval) for the porcelain material.

Specular Component:

The colour coordinates measured including the specular component (SCI) and those measured excluding the specular component (SCE) were significantly different. The results, based on paired t-test, along with the results of absolute colour difference values calculated between these colour coordinates, are shown in Table 4 and Figure 4 for resin composite and in Table 4 and Figure 5 for porcelain material for both resin composite and porcelain material. The colour difference values were ΔE*=0.28 (0.25-0.3 at 95% confidence interval) for resin composite and ΔE*=0.33 (0.3-0.36 at 95% confidence interval) for porcelain material.

Colour difference values ΔE*:

Colour difference ΔE* values calculated between each of the two shades with 2° observer curve, SAV, 0% UV and SCI were around those calculated between the same shades with 10° observer curve, MAV, 100% UV and SCE. The mean colour difference ΔE values for all different measuring conditions used in this study are presented in Table 5 for resin composite and Table 6 for porcelain materials.

Material effect:

The material type was found to have a significant influence on the following colour data: ΔL*, Δa*, Δb* and ΔE* values using 2 and 10 degrees observer curve; ΔL*, Δb* and ΔE* values with SAV and MAV aperture sizes; Δa* values with 0% and 100% UV component; and ΔL*, Δa*, Δb* and ΔE* values with SCI and SCE geometries. Results based on Univariate analysis of variance (ANOVA) are illustrated in Table 7 for both resin composite and porcelain materials.

Table 1. Significance p-values based on paired t-test for the differences in colour coordinates measured with 2 and 10 degrees observer curves

	Composite				Porcelain			
	Mean	95% confidence interval		Significance	Mean	95% confidence interval		Significance
		Lower	Upper			Lower	Upper	
L*	0.18	0.15	0.22	P< 0.001	0.37	0.32	0.42	P< 0.001
a*	-0.55	-0.67	-0.43	P< 0.001	-0.97	-1.1	-0.84	P< 0.001
b*	-0.08	-0.12	-0.04	p≤ 0.001	0.17	0.13	0.2	P< 0.001

Table 2. Significance p-values based on paired t-test for the differences in colour coordinates measured with SAV and MAV aperture sizes

	Composite				Porcelain			
	Mean	95% Confidence Interval		Significance	Mean	95% Confidence Interval		Significance
		Lower	Upper			Lower	Upper	
L*	-4.52	-4.68	-4.35	p< 0.001	-3.15	-3.54	-2.76	p< 0.001
a*	-0.19	-0.29	-0.08	p≤ 0.001	-0.28	-0.41	-0.16	p< 0.001
b*	-3.79	-4.02	-3.55	p< 0.001	-2.66	-2.87	-2.46	p< 0.001

Table 3. Significance p-values based on paired t-test for the differences in colour coordinates measured with 0% and 100% UV component

	Composite				Porcelain			
	Mean	95% Confidence Interval		Significance	Mean	95% Confidence Interval		Significance
		Lower	Upper			Lower	Upper	
L*	0.03	-0.02	0.08	0.24	-0.05	-0.1	0	0.052
a*	0.03	0.02	0.05	p≤ 0.001	0.18	0.15	0.2	p< 0.001
b*	0.12	0.08	0.16	p< 0.001	0.18	0.13	0.23	p< 0.001

Table 4. Significance p-values based on paired T-test for the differences in colour coordinates measured with including (SCI) and excluding (SCE) the specular component

	Composite				Porcelain			
	Mean	95% Confidence Interval		Significance	Mean	95% Confidence Interval		Significance
		Lower	Upper			Lower	Upper	
L*	0.27	0.24	0.3	p< 0.001	0.32	0.29	0.35	p< 0.001
a*	-0.06	-0.07	-0.06	p< 0.001	-0.03	-0.04	-0.03	p< 0.001
b*	-0.01	-0.01	0	p< 0.05	-0.07	-0.08	-0.06	p< 0.001

Table 5. Colour difference ΔE values calculated between different shades pairs of resin composite materials for all different measuring conditions

Composite	2° curve	10° curve	SAV	MAV	0% UV	100% UV	SCI	SCE
A1/A2	2.49	2.48	2.49	2.76	2.19	2.17	2.32	2.32
A1/A3	4.25	4.31	4.25	4.83	6.47	6.39	6.51	6.52
A1/A3.5	6.85	6.83	6.85	8.03	3.60	3.65	3.78	3.82
A2/A3	2.08	2.11	2.08	2.65	4.35	4.30	4.27	4.28
A2/A3.5	4.50	4.50	4.50	5.38	1.87	1.91	1.90	1.94
A3/A3.5	3.15	3.04	3.15	3.52	3.30	3.20	3.25	3.22

Table 6. Colour difference ΔE values calculated between different shades pairs of porcelain materials for all different measuring conditions

Composite	2° curve	10° curve	SAV	MAV	0% UV	100% UV	SCI	SCE
A1/A2	7.82	7.79	7.82	8.97	7.76	7.91	7.82	7.77
A1/A3	8.05	8.03	8.05	9.24	7.99	8.09	7.99	7.95
A1/A3.5	11.93	12.03	11.93	14.05	11.79	11.88	11.93	11.92
A2/A3	0.90	0.89	0.90	1.00	0.84	0.82	0.82	0.84
A2/A3.5	6.22	6.27	6.22	6.69	6.19	6.08	6.19	6.28
A3/A3.5	5.70	5.75	5.70	6.19	5.69	5.67	5.74	5.80

Table 7. Significance p-values based on ANOVA test of the influence of the material type (resin composite and porcelain) on the differences in colour data for all used colour measuring conditions

		Material effect			
		0 /10 degrees	SAV/MAV	0 UV/100 UV	SCE/SCI
Colour data	ΔL*	$p < 0.001$	$p < 0.001$	0.118	$p < 0.05$
	Δa*	$p < 0.001$	0.217	$p < 0.05$	$p < 0.001$
	Δb*	$p < 0.001$	$p < 0.001$	0.546	$p < 0.001$
	ΔE*	$p < 0.001$	$p < 0.001$	0.113	$p < 0.001$

DISCUSSION:

Since identifying a colour by an observer is a combined physical and psychological phenomenon, different viewing conditions or modes are likely to result in different amount of changes in colour and colour coordinates.[13] This was confirmed by the findings of this study, and the colour coordinates (L*, a*, and b*) of composite and porcelain materials measured with 2 degrees observation mode were significantly different from those measured with 10 degrees observation mode ($p \leq 0.001$).

Measurements of absolute colour coordinates is most significantly influenced by changing the measurement modes, and different degrees of discrepancies might be expected to happen even under controlled conditions.[36,37] Therefore, absolute colour coordinates L*, a* and b* measurements could be considered to be of little practical importance. On the other hand, assessment of the colour difference ΔE* values calculated between different shades using a single specific measuring mode followed by corresponding colour difference values obtained with other specific measuring modes may be of greater practical use. The values of colour differences ΔE calculated between each possible shade pair with 2 degrees observer curve were around those values calculated with 10 degrees observer curve for both composite and porcelain materials *(Table 5 and Table 6)*.

It has been revealed that standard CIE 2 degrees observation mode is advised for fields of angular subtense between 1 and 4 degrees, while the supplementary standard CIE 10 degrees observation mode is recommended for fields of angular subtense more than 4 degrees, and therefore it is more common for larger objects at close observation distances.[4] In this study, the surface square of the discs used (13 mm in diameter) is around the surface square of the labial surfaces of most human teeth, which are considered as small objects. However, the observation angle was not found to significantly influence the measurements of colour difference ΔE* values calculated between different shades groups. Moreover, even with the measurements of colour coordinates, the colour difference values calculated between colour coordinated obtained with 2 degrees observation mode and those obtained with 10 degrees observation mode were 0.6 for resin composite material which is below 1 ΔE* unit and 1.05 for porcelain material which is just above that perceptibility threshold.

For absolute measurements of colour coordinates (L*, a*, and b*) obtained using the Minolta spectrophotometer set with the small aperture size was significantly different from those obtained using the same spectrophotometer with the large aperture size for both composite and porcelain materials ($p \leq 0.001$). Moreover, the colour difference values calculated between absolute colour coordinates obtained with small aperture size and those obtained with large aperture size was 5.91 and 4.22 for composite and porcelain materials respectively, which are highly above the perceptibility threshold (ΔE*> 1 unit) with the first value above the clinically acceptable threshold as well (ΔE*> 4.2 units). However, the colour difference ΔE* values calculated between each two different shades when using the small aperture size were close to those made with the large aperture size for both composite and porcelain materials *(Table 5 and Table 6)*.

Colour of aesthetic dental materials is identified by the paths of light within the material and absorption along these paths. Therefore, the limited size of the opening cause some of the illuminating light to be scattered through the object beyond the edge of the opening, which is called an edge-loss effect, which increased when using smaller opening sizes or when measuring translucent samples.[7,8,28] In our study, the opening size was found to influence the absolute colour coordinates measurements significantly, especially with measuring such translucent resin composite and porcelain samples, which reflects the different ranges of edge-loss effects with each aperture size.

Another type of edge-loss effect is caused by the shadow from the edge of the opening within the translucent objects, this shadow, in turn; affects the intensity of the observation.[1] However, this type of edge-loss caused by edge shadow could not be avoided in the current study since a spectrophotometer using an opening to position the sample was used.

Colour coordinates (a* and b*) of composite and porcelain materials measured under D65 illumination with 0% UV was significantly different from those measured under the same illumination with 100% UV ($p \leq 0.001$), while the measurement of L* coordinate was not significantly different for both materials as well. Therefore, the change in a* and b* coordinates rather than L* coordinate are the responsible for the material to appear brighter, in that the UV light is absorbed and emitted as a bluish light.[16]

The colour difference values calculated between colour coordinates obtained under D65 with full UV light and those obtained with no UV light was (ΔE*= 0.18 and 0.3) for resin composite and porcelain materials respectively, which are quite below the perceptible threshold. Moreover, colour difference ΔE* values calculated between different shades with 0% UV were approximately similar to those calculated with 100% UV for both materials *(Table 5 and Table 6)*. This shows that the UV component has little impact on the colour matching process under D65 lighting conditions (daylight). However, it is recommended for absolute colour measurement to be determined with UV-included condition as these measurements are closer to the true colour.[22]

The UV light emitted from D65 illumination can be considered as a proper source for the assessment of fluorescence of dental aesthetic materials, which should match the natural teeth in terms of colour and fluorescence.[21] In this study, D65 illumination was used which is simulated the daylight, and the fluorescence was of little effect on colour measurements under normal viewing conditions. Other situations such as under black lighting or in dance clubs, the UV light may have a great influence and it might be crucial for the restorative materials to show the same fluorescence of the natural teeth.[42] Therefore, more studies on the effect of UV light under different illuminating conditions should be performed.

Colour coordinates (L*, a*, and b*) measured when including the specular component (SCI) was significantly different from those measured when excluding the specular component (SCE) for both composite and porcelain materials. However, the colour difference ΔE* values calculated between colour coordinates measured with SCI and SCI were (ΔE*=0.28 and 0.33) for resin composite and porcelain materials respectively, which are not perceptible. Therefore, including or excluding the specular component in colour measurements is considered of little impact. And this was confirmed by the very small differences found between colour difference ΔE values calculated between each shade pairs with SCI and those calculated with SCE for both composite and porcelain materials *(Table 5 and Table 6*).

The specular component might be presented as a function of the surface condition along with the incidence angle and the refractive angle of the object and the geometrical shadowing function.[43] However, the specular component is not found to be a significant factor in colour matching process of both composite and porcelain materials. That might be reflected the matt surfaces of the samples used in this study, which are only polished with different abrasive papers. In clinical context, composite restorations are covered with a thin layer of non-filled resin adhesives, and the porcelain restorations are covered with glaze porcelain, that may result in more glossy surfaces of these materials. Therefore, further studies are recommended on the effect of including or excluding the specular component on colour measurements of composite and porcelain samples simulated to those applied in clinical conditions.

Since the specular component is not a significant factor in colour difference ΔE* determination, it is preferable to use SCE mode for colour measurements of dental materials depending on the accepted theory in colour science that the SCE mode approximates the view of the human eye.

The material type had a significant influence on changes of absolute colour coordinates measurements and colour differences determinations under most measuring conditions used in this study *(Table 7*). That might be explained by different factors. Differences were found between composite and porcelain in the amount of emitted light after the absorption of UV component, and therefore, difference in the fluorescence between these two materials. Different amounts of specular components reflected from each material which can be attributed to several factors including different surface roughness, varied compositions, and different optical properties of these two materials. Differences found in surface conditions of both materials which can affect the translucency and therefore affect the degree of edge loss which, in turn, affect the overall colour measurements of these materials. It has been stated that with a well glazed surface, the samples became more translucent and the hue of colour shifted toward yellow-orange.[44]

CONCLUSION

Different measuring conditions (2 or 10 degrees observer curve, small or large aperture size, 0% or 100% ultra violet light, and including or excluding of specular component) significantly influenced the absolute colour coordinates measurements of resin composite and porcelain samples. Therefore, measuring conditions should be considered when evaluating the absolute colour coordinates of resin composite and porcelain materials.

The colour difference values ΔE* calculated between different shades of resin composite and porcelain materials were approximately the same for different measuring conditions. Therefore, analysing colour difference values of resin composite and dental porcelain materials can be accomplished whatever the measuring mode used.

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