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Colour Match Between Porcelain and Porcelain-Repairing Resin Composites

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Abstract - *The aim of this study was to evaluate the differences in colour between dental porcelain and porcelain-repairing resin composites. Porcelain discs were fabricated using four dentine shades in 1mm and 2mm thicknesses. Another series of discs was fabricated in 1mm and 2 mm thicknesses using three different brands of composite. Four single shades were used for the 1mm thick discs, and four single and 12 combined shades for the 2mm thick discs. The colour was measured using a spectrophotometer and colour differences ΔE* were calculated between samples. Colour differences were in the range of (ΔE*=3.5-26.9), above the accepted threshold for perceptibility (ΔE*>1) with a number above the threshold for what is considered to be clinically acceptable (ΔE*>5.5). Improvements in colour match were seen for certain shade combinations of repairing composites, in contrast to when a single shade of composite was used.*

KEY WORDS: Colour match, Porcelain, resin composite.

INTRODUCTION

Porcelain restorations remain susceptible to fracture in clinical use and clinical reports have demonstrated that porcelain fractures occur in 5 to 10% of ceramic containing restorations over a period of 10 years clinical service [1,2]. Several reasons for this have been proposed which relate to iatrogenic factors, technical errors and trauma, coupled with the inherently brittle nature of dental porcelain [1]. Porcelain fractures are considered to be the second most likely reason for failure and replacement of ceramic based indirect restorations, with approximately 18% of crown and bridge failures attributed to porcelain fractures [3]. Most ceramic fractures involving metal-ceramic restorations affect anterior restorations, and the majority of these include the labial surfaces, where there is clearly the potential to cause aesthetic problems [4].

Composite resins are considered to be the material of choice for the intraoral repair of porcelain fractures, especially when the fracture is completely within the porcelain [1, 5]. Direct application of composite resin to repair porcelain fractures has many advantages over replacement of the whole restoration, including a decrease in treatment time, reduced cost, and simplicity[1]. However, these repairs also have some disadvantages, for instance: difficulty in achieving a shade match with porcelain, discolouration, reduced resistance to wear, and poor bond strength in load-bearing areas [6, 7]. Achieving an acceptable colour match between porcelain and repairing composite can be particularly challenging[2], and the bonding between these two materials has potential for marginal leakage, which ultimately might lead to an aesthetic failure [8]. How to achieve a strong durable bond between porcelain and repairing resin composites has been widely investigated in a number of studies and the reader is directed to these articles for further details [1,5,9,10].

A number of new products and techniques have been developed to repair porcelain fractures which have raised expectations of success with this clinical procedure [11, 12]. For a satisfactory result, it is important to achieve an acceptable colour match between the repairing resin composite and surrounding sound porcelain [5]. It has been reported that the metameric effect between porcelain and repairing resin composites is influenced by the porcelain shade, resin composite brand and the illumination, and such discrepancies are worthy of further investigation [13]. In addition, differences in colour parameters between porcelain and repairing resin composites have suggested that further studies that seek to evaluate the effects of ceramic thickness and applying resin composite in combinations of shades should be performed [7].

The purpose of this study was to investigate the differences in colour between dental porcelain and resin composites when different shades, brands and thicknesses of resin composite and different shades and thicknesses of dental porcelain were used. The null hypothesis in this study was that colour differences between dental porcelain and repairing resin composite are not influenced by the shade and thickness of dental porcelain and the shade, thickness or brand of resin composite

MATERIALS AND METHODS

Four dentine shades (A1, A2, A3 and A3.5), two thicknesses (1 mm, 2 mm) and one brand of dental porcelain (Omega 900, Vita, Zahnfabrik, Bad Sackingen, Germany) were used. The porcelain discs were produced using teflon moulds (Figure 3.1) with a diameter of 8 mm and a depth of 1.1 mm and 2.1 mm. The porcelain powder (Omega 900, Vita, Zahnfabrik, Bad Sackingen, Germany)

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Table 1. *Resin composite materials used in this study.*

Code	*Brand name*	*Filler amount*	*Filler size*	*Matrix Composition*	*Manufacturer*
3M	Filtek Z250	60 %	0.01-3.5μm with mean particle size of 0.6 μm	Bis-GMA, TEGDMA, UDMA, Bis-EMA	3M ESP, U.S.A
ARB	Arabisc Top	77 %	0.05-0.7μm with mean particle size of 0.37 μm	Bis-GMA, TEGDMA, UDMA,	VOCO, Germany
TET	Tetric	62 %	Mean particle size of 0.7μm	Bis-GMA, TEGDMA, UDMA,	Ivoclar Vivadent, Liechtenstein

Table 2. *Significant p-values based on univariate analysis of variance for the variables influenced the colour match between porcelain and repairing composites.*

Variables (V)	*df*	*Mean Square*	*F*	*Sig.*
Composite shade (V1)	3	369.375	1348.634	p< 0.001
Composite brand (V2)	2	398.557	1455.18	p< 0.001
Porcelain shade (V3)	3	398.007	1453.172	p< 0.001
Material thickness (V4)	1	150.002	547.676	p< 0.001
V1 × V2 interaction	6	103.3	377.159	p< 0.001
V1 × V3 interaction	9	521.818	1905.22	p< 0.001
V1 × V4 interaction	3	12.774	46.641	p< 0.001
V2 × V3 interaction	6	151.536	553.275	p< 0.001
V2 × V4 interaction	2	46.999	171.598	p< 0.001
V3 × V4 interaction	3	14.447	52.749	p< 0.001
V1 × V2 × V3 interaction	18	34.412	125.642	p< 0.001
V1 × V2 × V4 interaction	6	13.174	48.098	p< 0.001
V1 × V3 × V4 interaction	9	20.92	76.381	p< 0.001
V2 × V3 × V4 interaction	6	11.427	41.723	p< 0.001
V1 × V2 × V3 × V4 interaction	18	1.647	6.012	p< 0.001

was poured in a glass mixing pot, and modelling fluid (Vita, Zahnfabrik, Bad Sackingen, Germany) was added gradually until a suitable porcelain mixture was obtained. Then the porcelain mixture was packed into the teflon moulds with vibration. Excess moisture was removed with paper tissue to minimize porosity. The condensed specimens were placed on a firing tray and fired in a vacuum furnace at the firing temperature (900 °C) according to manufacturing instructions. Five discs were made of porcelain for each shade and thickness combination giving a total of 40 porcelain samples.

Figure 1. *Shows the teflon mould with a porcelain disc.*

Preparation of resin composite specimens

Sixteen shades were selected from three different brands of resin composite (Arabisc Top, Voco, Cuxhaven, Germany; Tetric, Ivoclar Vivadent, Schaan, Liechtenstein; and Filtek Z250, 3M ESPE, Minnesota, U.S.A [Table 1]).

The shades chosen were used either singly or in combination i.e. A1, A2, A3, A3.5, A1/A2, A1/A3, A1/A3.5, A2/A3, A2/A3.5, A3/A3.5, A3.5/A1, A3.5/A2, A3.5/A3, A3/A2, A3/A1 and A2/A1. Four single shades were selected for the 1 mm thick samples (A1, A2, A3 and A3.5). For the 2mm thick samples shades were used in combination for e.g."A1/A2" indicates combined specimen layered with A1 (enamel portion) of 1mm thick and A2 (dentine portion) of 1 mm thick. In this incremental layering technique, lighter shades were overlaid on the darker shades with the exception of A2/A1 which indicates a layered specimen in which darker shades were overlaid on the lighter shades.

Resin composite was packed into a teflon moulds (8 mm) in diameter and (2.1 mm, 1.1 mm) in thickness. Specimens were light cured from both sides each for 30 seconds with a light-curing unit of 5 mm tip diameter (Curing light XL3000, 3M ESPE, Minnesota, U.S.A). Five specimens were made for each brand, shade, and thickness combination with a total of 20 composite samples of 1 mm thickness and 90 composite samples of 2 mm thickness. All brands, shades, and thicknesses used in this study are shown in Figure 1.

Porcelain and resin composite discs were ground to ± 0.05 mm of the prescribed thicknesses (1 mm, 2 mm) and polished using 150-, 1000-, 1500-grit silicon carbide papers (Rhynowet Plus, Aveiro, Portugal) under running water. The thickness of the discs was determined using a digital thickness scale (Mitutoyo, Kanagawa, Japan).and any samples outside the required range were rejected.

Colour measurements

The colours of porcelain and resin composite specimens were measured using a spectrophotometer (Vita Easy shade, Vita, Zahnfabrik, Bad Säckingen, Germany). The colours were measured three times by one operator, against the same black background, in the same place and under the same lighting conditions, and then the means of the three readings were taken.

The means of colour coordinate L*, a*, and b* values of the five porcelain specimens within each shade group were determined, and were employed as the reference values (target) for determination of colour differences with resin composite materials. The colour difference ΔE* between porcelain and repairing resin composites were calculated using the following equation [14]:

$$\Delta E^*_{12} = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}\ .$$

Statistical analysis

The data were entered into SPSS (PASW 17.0, Chicago, USA). The influence of the shade and thickness of both porcelain and repairing resin composite and the brand of resin composite on the difference in colour were analysed using four-way univariate analysis of variance (ANOVA). The colour difference between porcelain and repairing resin composite was considered statistically significant at $p \le 0.05$. Colour difference ΔE* values were calculated between each individual shade of Omega 900 porcelain and different shades of the three brands of repairing resin composite for each thickness and presented as a mean ± standard deviation. These colour difference (ΔE*) values could then be compared with previously suggested values that relate to likely perceptibility and acceptability in clinical conditions.

RESULTS

The differences in colour between porcelain and repairing resin composites were significantly influenced by the following variables: shade and brand of repairing resin composite ($p<0.001$), the shade of porcelain ($p<0.001$), thickness of both porcelain and composite materials ($p<0.001$), and all interactions between these variables ($p<0.001$). The results based on univariate analysis of variance are listed in Table 2.

Samples of 2 mm thickness

The colour difference values between porcelain and resin composites of different shades and brands are illustrated in Figures 2, 3, 4 and 5 for A1, A2, A3 and A3.5 porcelain shades respectively.

Samples of 1mm thickness:

The colour difference values porcelain and resin composites of different shades and brands are illustrated in Table 3 for all porcelain shades.

DISCUSSION

The null hypothesis of the present study was rejected because the shade and thickness of both dental porcelain and repairing resin composites, together with the brand of resin composite significantly affected the colour matching between porcelain and repairing resin composite materials ($p<0.001$). The colour differences were in the range of ΔE*=3.5-26.9 for all brands, shades, and thickness combinations of porcelain and repairing resin composites, which are all >1ΔE* unit which has been proposed as a perceptibility threshold for colour differences [14].

Colour coordinates L* a* and b* of resin composites and colour differences between porcelain and repairing resin composites can vary significantly by the brand of resin composite even when the same shade pairs are used [11,15,16]. The same findings were observed in the present study as the brand of resin composite affected the colour difference between porcelain and repairing resin composite in both thicknesses used. It has been shown that the size and volume fraction of filler materials may influence the light scattering and absorption properties, which in turn

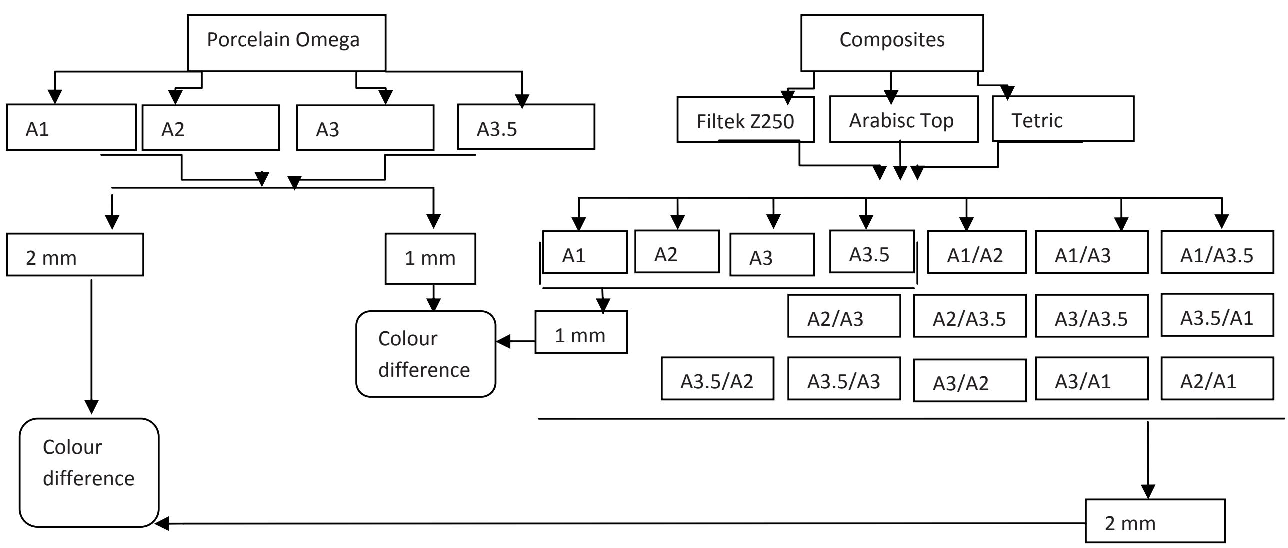

Figure 2. *Study design flow diagram.*

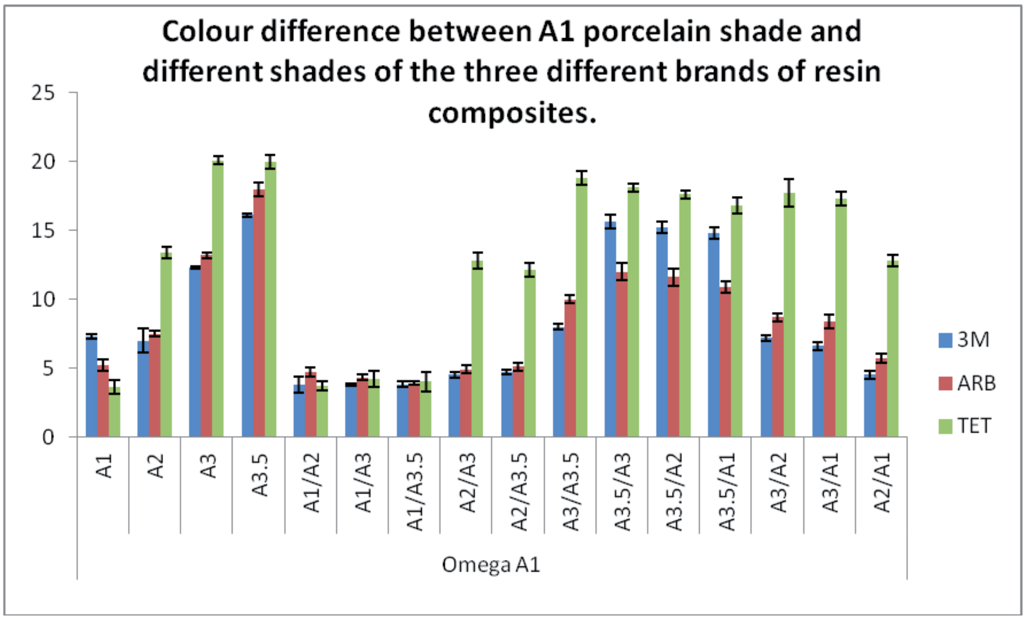

Figure 3. *Colour differences (ΔE* values) between A1 shade of porcelain and different shades of the three brands of repairing resin composites for 2 mm thick samples.*

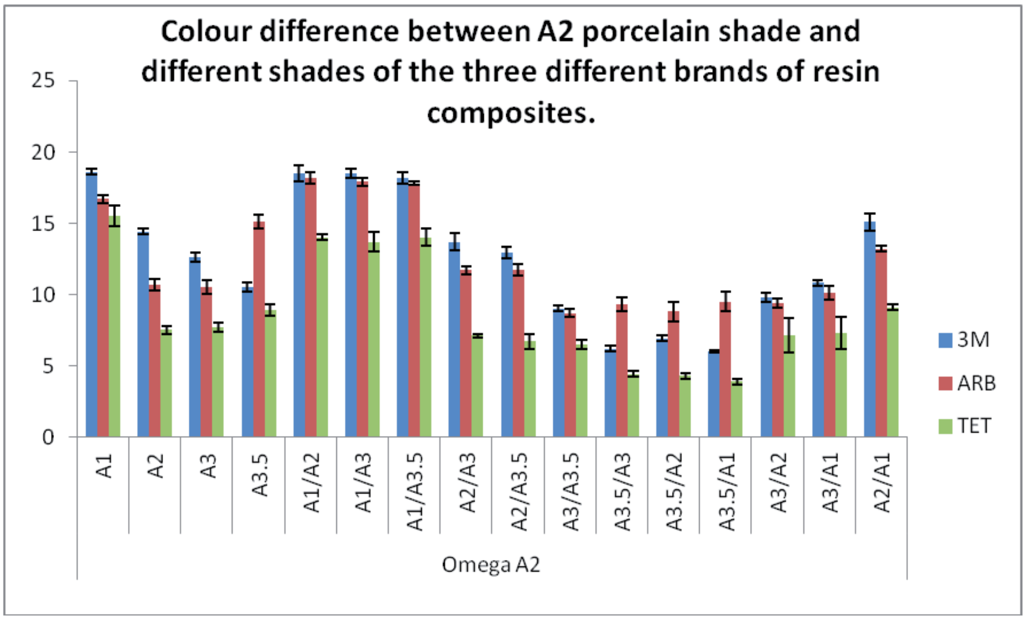

Figure 4. *Colour differences (ΔE* values) between A2 shade of porcelain and different shades of the three brands of repairing resin composites for 2 mm thick samples.*

determines the translucency and opalescence of resin composite materials [17]. The composites used in this study differ in these characteristics (Table 1), and could have affected the colour match between porcelain and repairing composites that we report here. However, there is no obvious trend that suggests that more filler or smaller filler particles will give a better colour match, for example Filtek Z250 composite and Tetric resin composite have almost the same filler size and volume still showed colour differences for all shades of porcelain. Thus, in addition to filler size and amount, other factors possibly related to the organic matrix may have influenced the colour difference between porcelain and resin composites. It has been reported that the organic matrix composition of resin composites has a significant effect on the translucency of filler-containing composite materials [18]. The organic matrix of all the three brands of repairing composites used in this study consisted of Bis-GMA, TEGDMA, and UDMA, except the Filtek Z250 composite, which contained Bis-EMA in addition to these compounds. Therefore, the composition of the organic matrix of the different resin composites might have influenced the colour match between porcelain and repairing composites.

The colour match between porcelain and repairing resin composite was also influenced by the shade used of both materials. The colour difference ΔE* values between porcelain and repairing resin composite of the same shade was significantly high. This may be traced back to the differences in composition and structure between these two materials. In an attempt to investigate whether a decrease in the colour difference between porcelain and resin

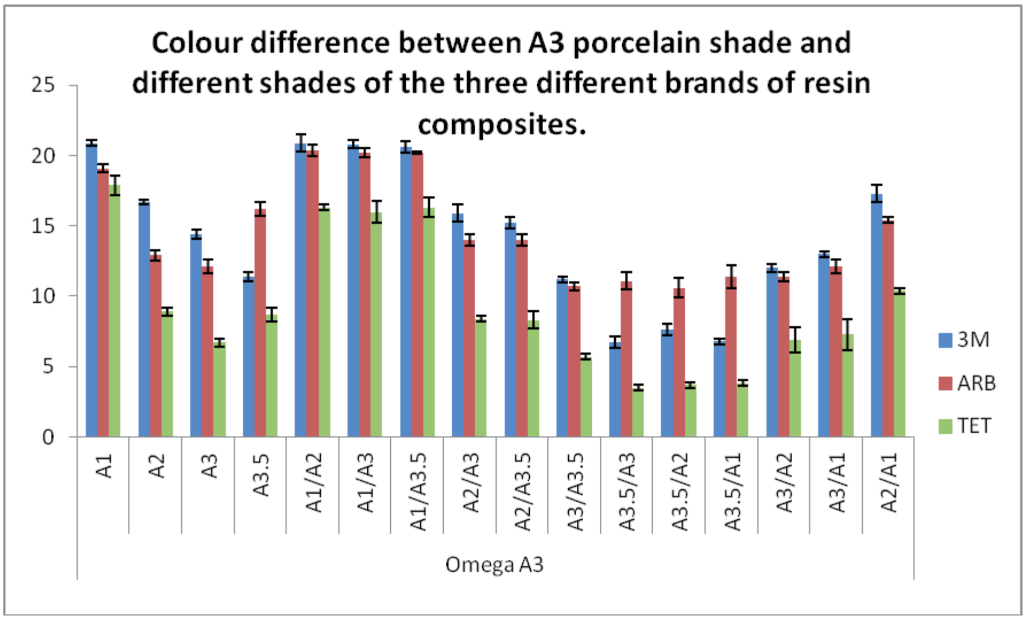

Figure 5. *Colour differences (ΔE* values) between A3 shade of porcelain and different shades of the three brands of repairing resin composites for 2 mm thick samples.*

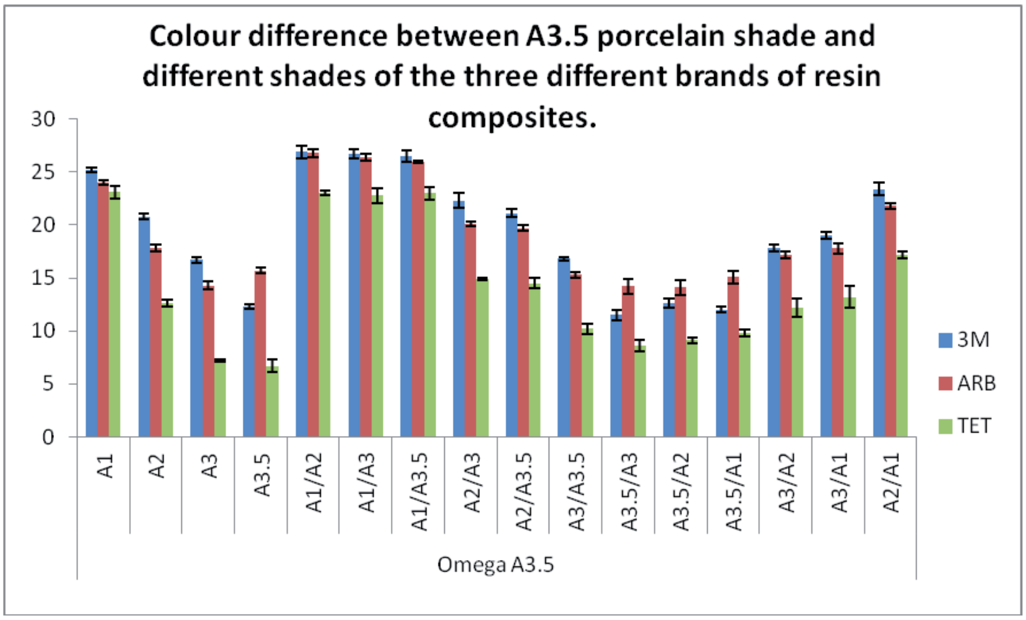

Figure 6. *Colour differences (ΔE* values) with the standard deviations between A3.5 shade of porcelain and different shades of the three brands of repairing resin composites for 2 mm thick samples.*

Table 3. *Color differences (ΔE* values) with the standard deviations between each individual shade of porcelain and different shades of the three brands of repairing resin composites for 1mm thick samples.*

Repairing Composite		*Omega/A1*		*Omega/A2*		*Omega/A3*		*Omega/A3.5*	
		*ΔE**	*SD*	*ΔE**	*SD*	*ΔE**	*SD*	*ΔE**	*SD*
3M ESPE	A1	9	0.6	15.5	0.3	19	0.3	21.6	0.3
	A2	7.7	0.2	11.8	0.5	15.2	0.5	17.8	0.5
	A3	9.4	0.2	9.6	0.3	12.8	0.3	14.5	0.2
	A3.5	13.9	0.3	6.9	0.4	8.2	0.6	8.2	0.4
ARB Top	A1	9	0.3	15.2	0.3	18.6	0.3	21.1	0.3
	A2	9.6	0.9	11.4	0.9	14.7	0.9	16.4	0.5
	A3	11	0.4	9.5	0.4	12.5	0.4	13.3	0.3
	A3.5	18	1.2	14.9	1.6	17.3	1.6	14.9	1.4
TET	A1	4.1	0.9	11	0.7	14.4	0.7	18.2	0.4
	A2	11.6	0.2	8.1	0.5	10.5	0.6	11.5	0.5
	A3	15	0.2	6.9	0.1	6.8	0.3	7.3	0.2
	A3.5	16.8	0.5	10.2	0.6	11.6	0.6	8.8	0.4

composites could be achieved by combining composite shades, the layering technique of resin composite was used in 2 mm thick samples. Some improvements in the colour match between specimens after layering were seen in comparison with single shade samples. For example the colour difference obtained with the A2 porcelain shade was ΔE*= 7.5 with A2 shades of Tetric, while the A3.5/A1 shade showed a smaller colour difference ΔE*=3.9.

This indicates that using different shades of resin composite in combination can to some extent compensate for the colour differences resulting from the composition and structure of porcelain and resin composite materials. It has also been demonstrated that, in addition to the improvement in colour match shown in the study reported here, layering of resin composite can be used to produce a more natural appearance to teeth restored with light -polymerized materials [19].

Two layering techniques of repairing composite materials of 2 mm thickness were used in this study: lighter shades overlaid darker shades; and darker shades overlaid lighter shades. There is no obvious trend that suggests that one layering technique will give a better colour match than another. For example, the colour difference was ΔE*=3.8 with the A1/A3 shade of Filtek Z250 and ΔE*=6.6 with the A3/A1 shade for A1 porcelain shade; on the other hand, the colour difference was ΔE*=18.5 with the A1/A3 shade of Filtek Z250 and ΔE*=10.8 with the A3/A1 shade for A2 porcelain shade.

It has been shown previously that the thickness of porcelain materials results in significant changes to the colour coordinates of porcelain restorations [20, 21, 22, 23]. These findings were also observed in the current study as the colour differences between porcelain and repairing composite were also significantly influenced by the thickness of both materials. For instance, the colour difference between Arabisc composite and porcelain of A1 shade was ΔE*=9 in case of 1 mm thick samples, whereas, it was ΔE*=5.2 for 2 mm thick samples. Therefore, the thickness of porcelain to be repaired should be taken into consideration to achieve a satisfactory colour match.

Core materials employed in all-ceramic restorations come in varying degrees of translucency and opacity dependent upon the particular ceramic used, the composition and thickness of the core influences the overall colour of the ceramic restoration [24]. Additionally, Seghi reported that same shades of different brands of dental porcelains result in different colours [25]. In the present study, as only one type of porcelain was used, it would be important to investigate different brands and systems of dental ceramic.

Although all the colour differences values between the various porcelain and repairing resin composite samples could be deemed perceptible (ΔE* > 1 unit), some these colour differences may have been considered to be clinically acceptable when applying the proposed clinically acceptable threshold of >ΔE* 5.5 [26]. For 2 mm thick samples, the following colour combinations were below this 'clinically acceptable' threshold value: A1/A2, A1/A3, A1/A3.5, A2/A3, A2/A3.5 and A2/A1 shades of Filtek Z250 composite; A1, A1/A2, A1/A3, A1/A3.5, A2/A3 and A2/A3.5 shades of Arabisc composite; and A1, A1/A2, A1/A3, A1/A3.5 shades of Tetric with the A1 shade of porcelain; A3.5/A3, A3.5/A2 and A3.5/A1 shades of Tetric with A2 shade of porcelain; A3/A3.5, A3.5/A2 and A3.5/A1 shades of Tetric with the A3 shade of porcelain. For 1 mm thick samples, all colour differences between porcelain and repairing resin composite were above the ΔE* 5.5 threshold with the exception of the colour difference between Tetric and porcelain of A1 shade which was below this value.

CONCLUSION

Differences in colour between porcelain and repairing resin composites were significantly affected by the shade and thickness of porcelain together with brand, shade, and thickness of repairing resin composites. Differences in colour between porcelain and repairing resin composite materials were found especially when the using single composite shades. Reductions in colour difference were seen when certain combinations of different shades of repairing composites were employed. Tetric resin composite produced lower colour difference values with most shades and thicknesses of Omega 900 porcelain than the other composite brands used.

MANUFACTURERS' DETAILS

- Omega 900, Vita, Germany.
- Modelling fluid, Vita, Germany.
- Arabisc Top, Voco, Germany.
- Tetric, Ivoclar Vivadent, Liechtenstein.
- Filtek Z250, 3M ESPE, U.S.A.
- Curing light XL3000, 3M ESPE, U.S.A.
- Grit silicon carbide papers, Rhynowet Plus, Portugal.
- Digital thickness scale, Mitutoyo, Japan.
- Vita Easy shade spectrophotometer, Vita, Zahnfabrik, Bad Säckingen, Germany

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