TRANSMITTANCE CHARACTERISTICS OF DIMETHACRYLATE RESIN BASED DENTAL COMPOSITES

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Abstract

***Background**:* The transmission of light through dental composites is a major factor responsible for photo activation polymerisation and optical properties of these materials. The extent of the light transmission depends on their formulations.
***Objectives**:* The purpose of this study was to determine the transmittance of dental resin-composites and investigate the effect of material thickness and light wavelength**.**
Methods: Four photo-cured disc samples (Φ20mm) with different material thicknesses (ranging from x=0.11mm to x=1.46mm) of three different nanohybrid dental resin–composites (Regular, Flowable and Sealant) of the same shade, A3 and matrix but different filler loading were prepared. Transmittance measurements (n=3) were made using an Ocean Optics USB 4000 fibre optic Spectrometer operated by a Spectra Suite software. Data were analysed by One-way analysis of variance (ANOVA) combined with Tukey multiple test.
***Results*:** Differences were found in transmittance values as both material thickness and light wavelength increases. Transmittance (T) increase significantly ($P<0.05$) with increasing wavelength and decrease with increasing thickness. Linear regression analysis of In (T) with material thickness for light wavelength, gave R^2 values ranging from 0.81 to 0.99. Correlation of attenuation coefficient with light wavelength for the materials indicated significant correlation ($p<0.05$, $r=0.94$) with Grandio Seal but not with Grandio ($p>0.05$, $r=0.77$) and Grandio Flow ($p>0.05$, $r=0.79$).
***Conclusions*:** The significant differences in the transmittance with increasing light wavelength and material thickness of the materials may affect their clinical appearance.

Key Words: Transmittance, Dental resin-composites, Light wavelength, Dimethacrylate, Attenuation coefficient

Introduction

Visible light cured (VLC) resin-composites have become the principal type of anterior dental restorative materials. The advantages of these materials include ease of handling and aesthetic properties of translucency and colour [1,2].

Translucency is one of the many factors which influence the appearance and colour of teeth and defined as the ability of a material to allow both dispersion and passage of light such that objects cannot be seen through them clearly[3,4]. Hence, it could be described as partial opacity or a state between complete opacity and complete transparency. Translucency Parameter (TP), contrast ratio (CR) and light transmittance has been used to characterise translucency of dental resin composites[5,6].

The translucency parameter (TP) is calculated as the colour difference between a uniform thickness of a material over a black and white background and corresponds directly to common visual assessment of translucency.

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The contrast ratio (CR) is the ratio between the daylight apparent reflectance of the specimen over black and white standard backgrounds and an estimate of the opacity [5, 6].

Light transmittance is defined as the fraction of the intensity of the transmitted light through a material thickness. Its characteristics such as wavelength dependency play an important role for the colour of resin composites [6, 7]. Numerous techniques have been used to measure light transmittance of dental resin composites. They include radiometers combined with filters, a photo-conductive cell combined with an analyzing recorder[1,8,9,10], Uv-Vis Spectrophotometer [11,12], Kubelka and Munk theory[13], Goniophotometer[14], Computer-based diode technique[15].

The purpose of the present study was to determine effect of material thickness and light wavelength on transmittance and of representative dental resin-composites. In addition, investigate transmittance relationship with material thickness and light wavelength.

The research hypothesis tested was how material thickness and light wavelength influenced transmittance.

Materials and Methods

The materials used in this research study were three different nanohybrid dental resin- composites (Regular, Flowable and Sealant) of the same matrix and shade (A3) but different filler loading (Table 1).

Table 1. Materials studied

Material	Matrix Phase	Filler vol (%)	Filler wt (%)
Grandio	Bis-GMA/TEGDMA	71.4	87
Grandio Flow	Bis-GMA/TEGDMA/HEDMA	65.7	80
Grandio Seal	Bis-GMA/TEGDMA	-	70

Sample Preparation

Four photo-cured disc samples (Φ20mm) and different material thicknesses (ranging from x =0.11mm to x =1.46mm) of the dental resin–composites were prepared. The specimens were prepared by packing an uncured composite paste into Teflon moulds of inner circular space of diameter 2cm. The opened ends of the mould were covered with glass plates and the composite pastes were photo cured for 40 s at an initial temperature of 23ºC using a curing unit (Optilux 501, Kerr, U.S.A) of calibrated irradiance 500mW/cm^2. The mean specimen thickness was measured with a digital caliper to a precision of 0.01mm (Mitutoyo, Tokyo, Japan).

Measurement of Transmittance

The transmittance measurements (n=3) were made using a standard light source and an USB4000 fibre optic Spectrometer (Ocean Optics, FL-USA) operated by Spectra Suite software (Fig.1).

The spectra suite calculates the transmittance, T using the equation below;

$$\%T_{\lambda} = \frac{S_{\lambda} - D_{\lambda}}{R_{\lambda} - D_{\lambda}}$$ Eq.1

Statistical analysis

Data were analysed by One-way analysis of variance (Anova) combined with Tukey post-hoc multiple tests at a significance level of p=0.05 and regression analysi**s**

Results

The means and the standard deviations of the transmittance for each light wavelength and material thickness group are summarised in Tables 2-4 and Figures 1-3. In Figures 1-3, the percentage direct transmittance at different material thickness of each material is plotted as a function of light wavelength.

Table 2. Transmittance measurements at different light wavelength and material thickness of Grandio.

Wavelength(nm)	Transmittance D1	Transmittance D2	Transmittance D3	Transmittance D4
500	2.90 (0.23)	1.96(0.18)	1.82(0.39)	1.24(0.48)
600	5.17 (0.17)	3.56(0.30)	3.44(0.39)	2.69(0.45)
700	5.63 (0.34)	2.66(0.16)	2.37(0.31)	1.64(0.12)
800	7.75(0.62)	3.38(0.37)	3.14(0.09)	1.93(0.12)
900	9.82(0.33)	4.57(0.40)	4.22(0.24)	2.66(0.38)

*D1=0.70mm, D2=0.97mm, D3=1.10mm, D4=1.46mm

Table 3. Transmittance measurements at different light wavelength and material thickness of Grandio Flow.

Wavelength(nm)	Transmittance D1	Transmittance D2	Transmittance D3	Transmittance D4
500	4.61(1.15)	1.99(0.32)	1.53(0.53)	0.89(0.47)
600	9.55 (1.86)	4.20(0.14)	3.16(0.14)	2.30(0.04)
700	11.20(0.13)	4.95(0.26)	2.96(0.14)	1.39(0.26)
800	15.87(0.32)	7.74(0.39)	4.65(0.25)	1.91(0.44)
900	20.25(0.25)	10.47(0.55)	6.52(0.32)	2.43(0.33)

*D1=0.63mm, D2=0.85mm, D3=1.10mm, D4=1.41mm

Table 4. Transmittance measurements at different light wavelength and material thickness of Grandio Seal.

Wavelength(nm)	Transmittance D1	Transmittance D2	Transmittance D3	Transmittance D4
500	6.75(0.59)	1.43(0.59)	1.29(0.50)	0.98(0.24)
600	10.22(0.89)	2.51(0.14)	2.00(0.27)	1.57(0.04)
700	13.99(0.16)	1.93(0.11)	1.52(0.07)	0.87(0.09)
800	19.75(0.12)	2.93(0.40)	1.29(0.06)	1.06(0.12)
900	25.26(0.45)	4.58(0.70)	1.76(0.09)	0.94(0.13)

*D1=0.11mm, D2=0.28mm, D3=0.37mm, D4=0.56mm

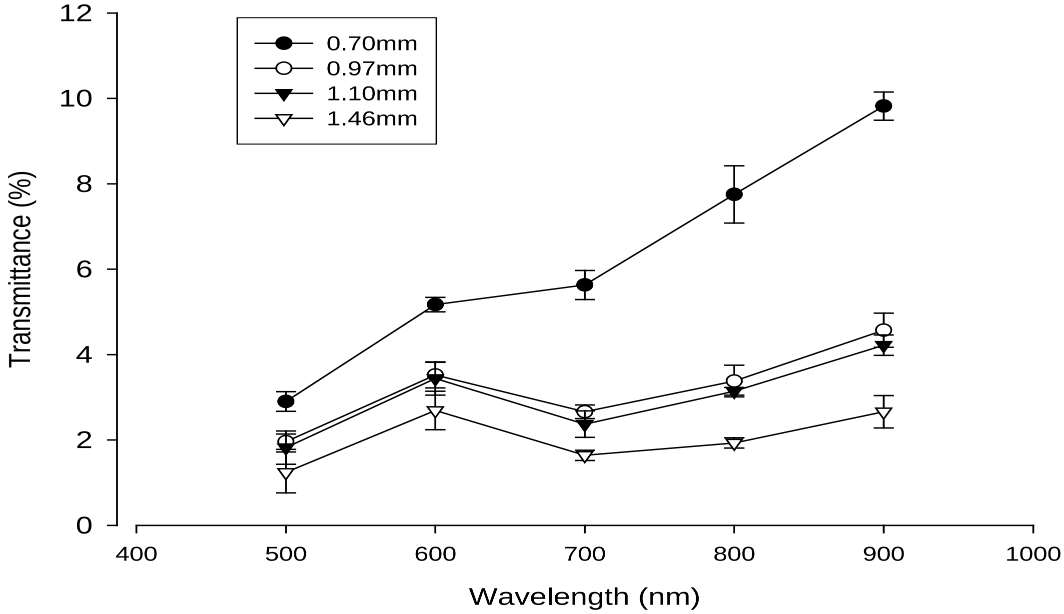

Fig. 1 Direct transmittance with light wavelength at different material thickness of Grandio

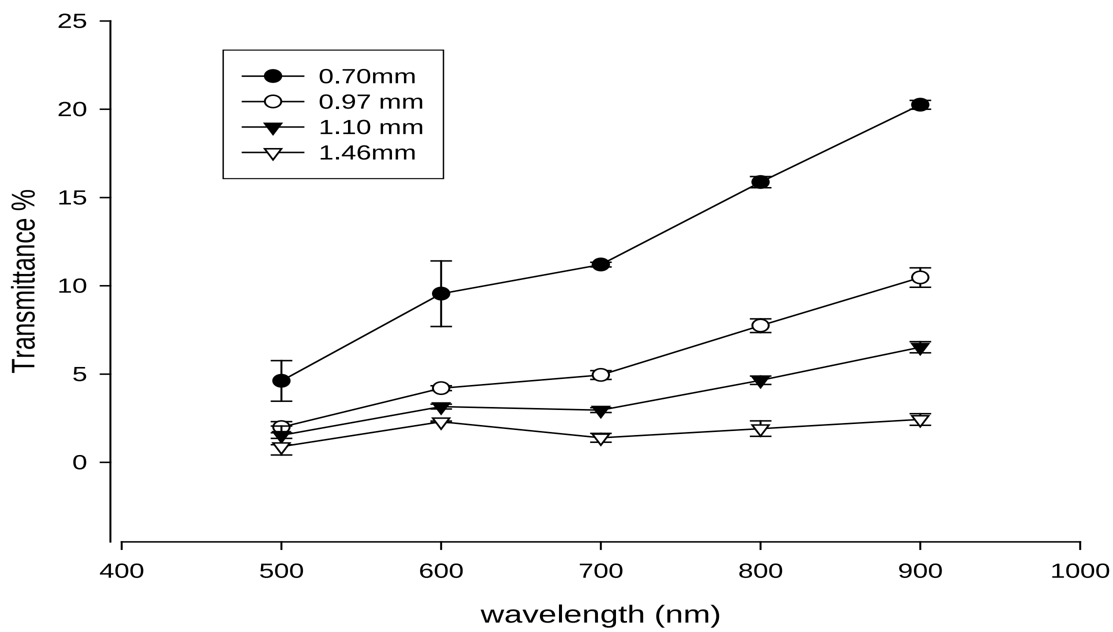

Fig. 2 Direct transmittance with light wavelength at different material thickness Grandio Flow.

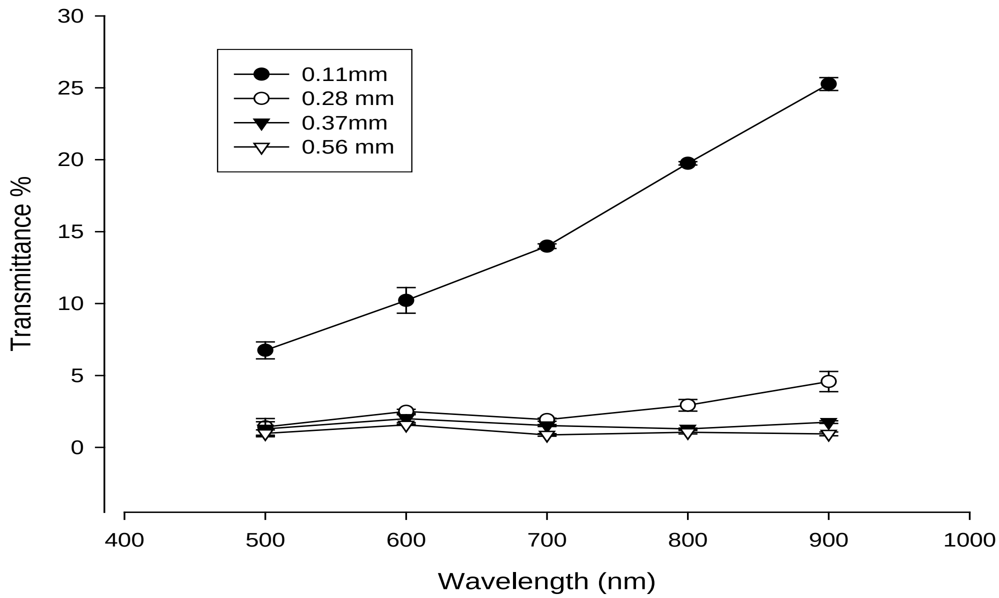

Fig. 3 Direct transmittance with light wavelength at different material thickness of Grandio Seal.

There were significant differences ($p<0.05$) in the direct transmittance variations with light wavelength and material thickness among the materials. Figures 4-6, indicates the natural log of direct transmittance (InT) of each material plotted as a function of material thickness for a range of wavelength from 500-900nm and yielded straight lines with negative slope. The slope is a measure of the attenuation coefficient and values with wavelength for each material are indicated in Table 8. Fig. 7 indicates the variation of the attenuation coefficient with light wavelength. Analysis of linear regression carried out on the In(T) variations with material thickness, gave r^2 values ranging from 0.81 to 0.99. Correlation of attenuation coefficient with light wavelength for the materials indicated significant correlation ($p<0.05$, r =0.94) with Grandio Seal but not with Grandio ($p>0.05$, r=0.77) and Grandio Flow ($p>0.05$, r =0.79).

Table 5. Natural log of direct transmittance measurements at different light wavelength and material thickness of Grandio

Wavelength	ln(T) D1	ln(T) D2	ln(T) D3	ln(T) D4
500	1.06(0.08)	0.67(0.09)	0.56(0.21)	0.16(0.38)
600	1.64(0.03)	1.27(0.08)	1.23(0.09)	0.98(0.16)
700	1.73(0.06)	0.98(0.06)	0.91(0.09)	0.50(0.08)
800	2.05(0.08)	1.21(0.11)	1.14(0.03)	0.66(0.59)
900	2.28(0.03)	1.52(0.09)	1.44(0.56)	0.97(0.15)

*D1=0.70mm, D2=0.97mm, D3=1.10mm, D4=1.46mm

Table 6. Natural log of direct transmittance measurements at different light wavelength and material thickness of Grandio Flow

Wavelength	ln(T) D1	ln(T) D2	ln(T) D3	ln(T) D4
500	1.51(0.24)	0.68(0.17)	0.38(0.34)	0.10(0.28)
600	2.15(0.03)	1.43(0.03)	1.14(0.13)	0.83(0.02)
700	2.53(0.03)	1.60(0.05)	1.09(0.05)	0.32(0.19)
800	2.76(0.02)	2.05(0.05)	1.54(0.05)	0.63(0.24)
900	3.01(0.01)	2.35(0.05)	1.87(0.05)	0.88(0.14)

*D1=0.63mm, D2=0.85mm, D3=1.10mm, D4=1.41mm

Table 7. Natural log of direct transmittance measurements at different light wavelength and material thickness of Grandio Seal.

Wavelength	ln(T) D1	ln(T) D2	ln(T) D3	ln(T) D4
500	1.90(0.08)	0.60(0.04)	0.40(0.23)	-0.01(0.02)
600	2.30(0.04)	0.90(0.06)	0.70(0.14)	0.40(0.04)
700	2.60(0.01)	0.60(0.05)	0.20(0.25)	-0.10(0.11)
800	3.00(0.01)	1.10(0.14)	0.20(0.03)	0.03(0.15)
900	3.20(0.02)	1.50(0.60)	0.60(0.03)	-0.10(0.13)

D1=0.11mm, D2=0.28mm, D3=0.37mm, D4=0.56mm

Table 8. Attenuation coefficient of the dental resin-composites

Wavelength	Attenuation coefficient Grandio	Attenuation coefficient Grandio Flow	Attenuation coefficient Grandio Seal
500	1.17	1.95	4.27
600	0.84	1.61	4.01
700	1.55	2.73	6.08
800	1.75	2.66	6.51
900	1.66	2.66	7.20

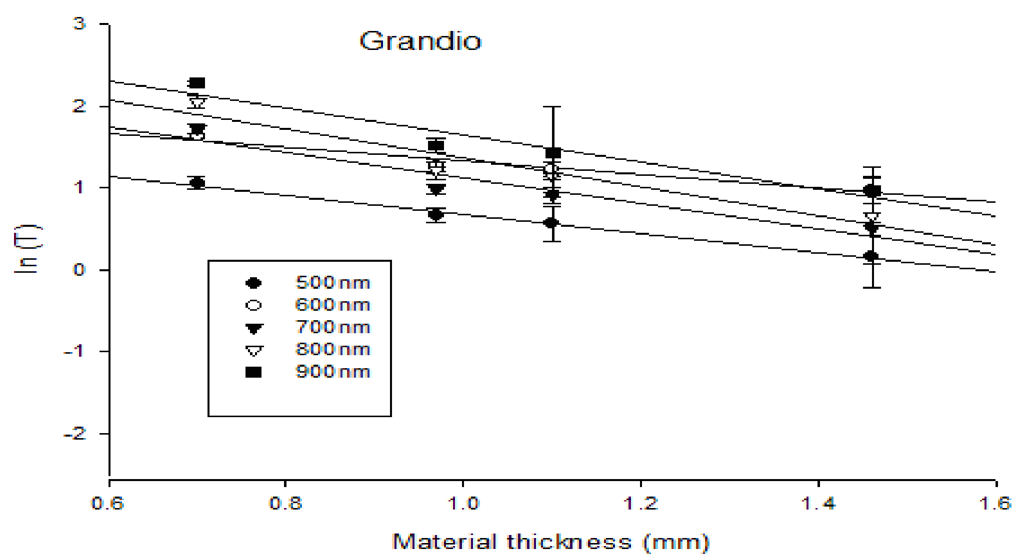

Fig. 4 Natural log of direct transmittance (InT) with material thickness at different light wavelength of Grandio.

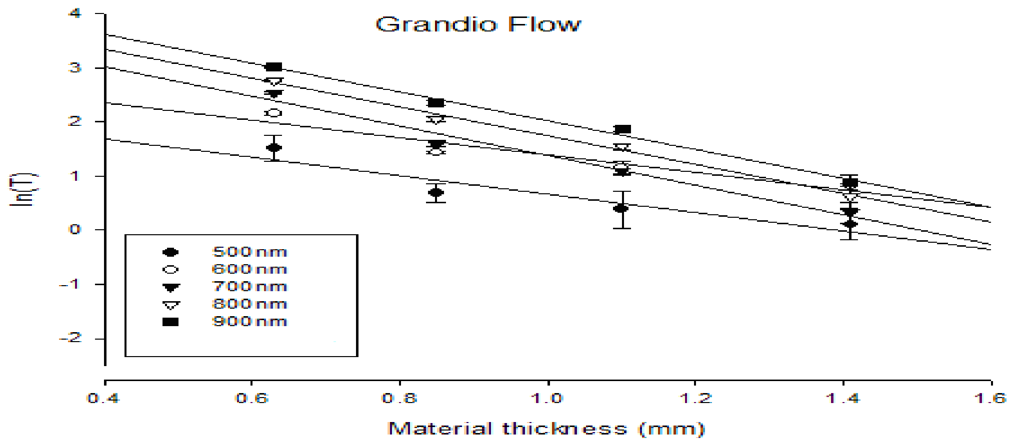

Fig. 5 Natural log of direct transmittance (InT) with material thickness at different light wavelength of Grandio Flow.

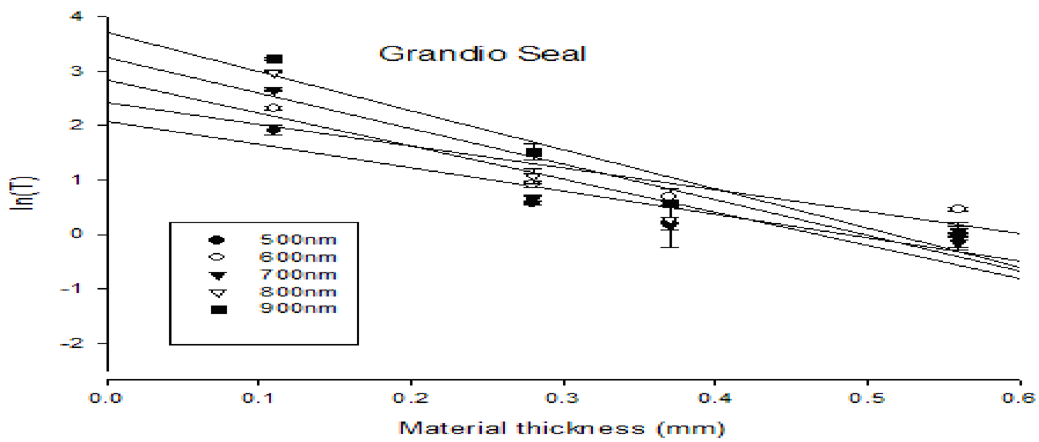

Fig. 6 Natural log of direct transmittance (InT) with material thickness at different light wavelength of Grandio Seal.

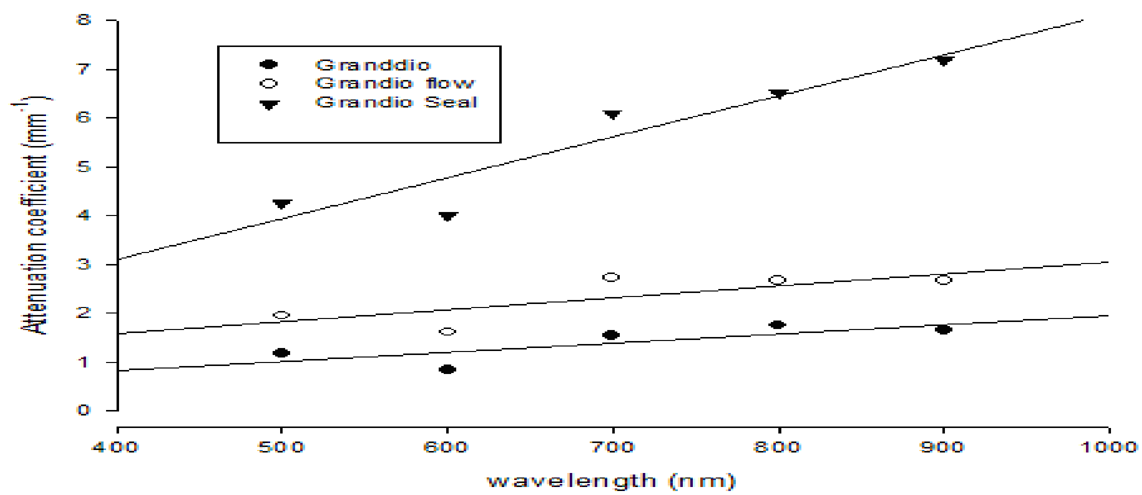

Fig. 7 Attenuation Coefficient with light wavelength of the dental resin composites

Discussion

The success of esthetic dental restorations requires that there should be no visible difference between the restorative material and the natural teeth. This is achieved by matching the optical properties of the restoration and the natural tooth. The matching of the optical properties involves manipulative techniques such as the layering technique [15]. However, the polymerisation of dental resin composites results in significant changes in the optical properties including transmittance between the uncured and cured material[11-13]. The increase in light transmittance in the cured material may be explained as due to two processes namely vitrification and photobleaching [12].

The present research study aims to investigate the influence of material thickness and light wavelength on direct transmittance of different dental resin-composites (regular, flowable and sealant) of the same shade and filler type (Table 1) after polymerisation. The direct transmittance was used to characterize the translucency of the materials and was measured using an USB 4000 fibre optic spectrometer operated by Spectra Suite software and a standard light source.

The results of the transmittance values for all the materials irrespective of the type of material indicated a significant increase with light wavelength from 500nm to 900nm for each material thickness (Figs.1-3). However, the light transmittance values decrease with increasing material thicknesses. Possible explanations to the variation of light transmittance with light wavelength could be due to the changes in the refractive indices of the polymeric matrix as a result of polymerization and scattering of light by the filler particles and other additives in the resin-composites. This scattering of light decreases with increasing light wavelength resulting in a reduction in the transmittance with decreasing wavelength and in accordance to the Rayleigh scattering equation of light (eqn. 2) which effectively analyses the light transmittance for a composite structure such as dental resin-composites[9,11];

$$T = \exp - 2.303d\left[3V_p r^3 \frac{\left(\frac{n_p}{n_m} - 1\right)}{4\lambda^4}\right] \quad (2)$$

where d is the material thickness of the sample, Vp is the volume fraction of the particles, r is the particle radius, n_p is the refractive index of the particles, n_m is the refractive indices of the polymeric matrix and λ is the light wavelength.

The results of the transmittance with light wavelength are consistent with those of other researchers [12, 19, 20].

The direct transmittances decrease exponentially with increase in material thickness (Figs. 1-3). This variation in transmittance with thickness could be explained as a result of increases in absorption by the polymeric matrix and other additives and scattering of light by the fillers and appreciable light reflectance at the outer surface of the materials and according to Rayleigh scattering equation [11, 13].
and Lambert's law equation of light[15] (eqn 3);

$$T = \frac{I}{I_o} = \exp(-\mu d) \quad (3)$$

where *T* is the transmittance, μ is the coefficient of attenuation, *d* is the material thickness, *Io* is the incident light intensity, and *I* is the transmitted light intensity.

On application of the napery an log, eqn (3) becomes [15];

$$\ln(T) = a - \mu d \quad (4)$$

where *a* accounts for experimental unknowns including the reflectance at the surface of the materials [9]. Equation (4) is confirmed by Figures 4-6.

The results seem to be consistent with other studies which found decreases in light transmittance with sample thickness of materials [14, 19,20].

On application of regression analysis of naperian log of direct transmittance (lnT) versus material thickness, the slopes and intercepts of the graphs (Figs.4-6), are determined (Table 8) .The slopes represents the optical attenuation coefficient of the materials which describes how the intensity of light decreases by a given thickness of a material medium, i.e. characteristic of the material and the light wavelength[17].

There was significant correlation of the attenuation coefficient with light wavelength for the Grandio Seal but not with Grandio and Grandio Flow. The optical attenuation coefficient determination has been suggested as a precise method in the measurement of both low and high radio-opacity than the equivalent aluminium thickness method[18]. The intercept is measure of the reflectance at the surface of the material and an additional factor to be considered responsible for the decrease of light transmission through the materials [9].

The clinical significance of the present study relates to the optical aesthetics of dental resin composites with regards to shade matching and suggests that clinicians must take into consideration the significant changes in the transmittance (translucency) with material thickness and light wavelength as well as the surface reflectance for successful shade selection.

Conclusions

The conclusions of the research study are summarised as follows: The transmittance was significantly influenced by material thickness and by light wavelength. The variation with material thickness and light wavelength was in accordance with the Lambert's law as well the Rayleigh scattering equation. The dependency of direct transmittance of the cured dental resin-composites on material thickness and light wavelength may result in significant changes in colour and clinical appearance of the visible light cured resin-composites.

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