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Changes on Transmittance Mode of Different Composite Resins

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The purpose of this study was to evaluate the transmittance of seven different composite resins. Ten specimens were prepared (10 mm diameter, 2 mm thickness) for each experimental group, as follows: G1- Charisma® A_2 (Heraeus-Kulzer); G2- Filtek™ Supreme A_2E (3M/ESPE); G3- Filtek™ Supreme A_2B (3M/ESPE); G4-Filtek™ Supreme YT (3M/ESPE); G5- Esthet-X® A_2 (Dentsply); G6- Esthet-X® YE (Dentsply); G7- Durafill® A_2 (Heraeus-Kulzer) and G8- Filtek™ Z-100 A_2 (3M/ESPE). The transmittance mode was measured using a UV-visible spectrophotometer (Cary Instruments) at 400-760 nm. The specimens were evaluated at three different times: zero hour (initial), 24 hours and 10 days after immersion in artificial saliva. The differences in transmittance were determined by two-way analysis of variance (ANOVA) and Tukey's test. The various composite resins showed significant differences in the wavelength dependence of transmittance. The mean values of transmittance increased significantly, with wavelengths increasing from 400 to 760 nm. The performance of the experimental groups was similar in terms of immersion time, considering that at time zero and after 10 days, all the groups showed similar results, which were statistically higher than the values obtained after 24 hours of immersion. The Filtek™ Supreme YT composite resin presented the highest mean transmittance values along the wavelengths at the three measured times. Esthet-X® YE and Durafill® yielded similar mean transmittance values, which were higher than those of the other groups. This study shows that the transmittance values of composite resins are directly related with the type, size and amount of inorganic filler particles.

Keywords: *dental esthetic materials, composite resin, spectrophotometer, transmittance*

1. Introduction

Restorative Dentistry plays an important role not only from the mechanical and biological viewpoints but also in the social context, where the search for esthetic anterior and posterior teeth restorations is constant.

Acid etching of dental enamel, proposed by Buonocore[1] in 1955, associated with the organic resinous matrix (Bis-GMA) developed by Bowen[2] in 1963, revolutionized the dental practice, bringing adhesive techniques to the forefront of esthetic restorative dentistry.

Despite the substantial advances in direct esthetic filling materials, particularly light-cured composite resins, these materials still possess a number of properties that interfere in their clinical performance, such as compressive strength; hardness; abrasive strength; polymerization shrinkage; homogenization; translucence and opacity; sorption and superficial staining; elasticity modulus; and coefficient of linear thermal expansion. The inadequacy of these properties can cause the negative performance of a restoration, with color instability resulting from superficial staining and internal discoloration, among other faults.[3]

Esthetic filling materials were developed with the main purpose of mimicking the optical properties of dental tissues, not only in terms of color but also in the degree of the translucence. Ideal esthetic restorative materials should have similar properties of light reflection, scattering, fluorescence and opalescence as those of natural teeth.[4]

Translucence gives esthetic restorative materials the appearance and naturalness of the natural dental element, which is constituted of different structures and tissues in varying thicknesses that make it polychromatic.[5]

According to Crisp et al.[5] (1979), reproducing the optical features of tooth naturalness in a restoration using a monochromatic material is an impossible challenge at times. Therefore, knowledge of the optical properties of esthetic filling materials is highly relevant when the aim is to make a restoration imperceptible to the human eye.

Larson[6] (1986) points out that the main obstacle to achieving better esthetics in extensive restorations of large decayed areas is that natural teeth are polychromatic, probably due to the different colors and thicknesses found in enamel and dentine, while the available restorative materials such as composite resins are monochromatic. Moreover, depending on the characteristics of the formulation, such as the type, size and amount of filler, these restorations may show different degrees of translucence.

According to the 1990 report of Lambrechts et al.[7], several factors can affect the esthetic result of restorations with composite resin in anterior teeth. Most of these factors involve the esthetic limitations of the filling material, such as translucence and opacity, which, according to several authors, can be modified by water absorption, chemical degradation and microfractures. Light-cured composite resins are more translucent than chemically-activated resins because the former are less pigmented; overall, a reduction in translucence is observed over time.

Numerous studies have been conducted to examine the properties of a variety of restorative materials in the search for a material combining excellent esthetic results and exceptional physicomechanical and biological properties. However, few studies have focused specifically on determining the optical properties of these materials, which are

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so important for the esthetic success of a restoration, possibly due to their complexity and the lack of a standard method of evaluation. This is probably due to the technical and scientific difficulties involved in the development of methodologies and in understanding the diverse physical phenomena that determine the optical and esthetic performance of restorative materials.

The professional must always keep in mind the physical and optical features of both natural teeth and restorative materials, so that lost dental structures can be reproduced in detail.[8]

Considering the importance of esthetics in adhesive restorative dentistry, it is important to know the inherent properties responsible for determining the success of a restoration in terms of the color and translucence of filling materials, as well as the factors that interfere in their color stability and their degree of translucence. Light transmittance characteristics are particularly important optical properties to be considered for the color of composite resins.[9]

Thus, the purpose of this study was to investigate the light transmittance of composite resins with different matrices and inorganic fillers as a function of immersion time in artificial saliva, using visible light spectrophotometry. The authors hypothesized that filler particle size may further influence the light transmittance of composite resins.

2. Experimental

Five different light-cured composite resins were used in this study (Table 1). The specimens were prepared in a stainless steel mold (10 mm in length and 2 mm in thickness). The composite resins were packed in a single increment. Glass plates were placed on the top and bottom of the mold to provide flat surfaces.

A halogen light-curing unit (LCU) (Degulux, Degussa Hüls) was used, whose power density was previously measured with a curing radiometer (Model 100, Demetron Research Corp. Serial n° 129540) and then set at 650 $mW.cm^{-2}$.

The various composite resins were light-activated as recommended by each manufacturer, applying the halogen LCU at the top and bottom surfaces, where the light tip was placed in contact with the glass plate at a distance of 1.0 mm from the specimens.

All the test specimens were prepared with standard dimensions of 10.0 mm diameter and 2.0 mm thickness[10], since there is a consensus in the literature that increasing the specimen's thickness reduces its light transmittance.[11]

Light transmission through the composite resins was measured using an UV-visible Varian Cary spectrophotometer (Cary Instruments, Monrovia, California, EL 98103323), at wavelengths varying from 400 to 760 nm through direct transmission.[12,13]

Transmittance was measured immediately after preparation of the specimens, i.e., before immersion in artificial saliva at 36° (±1°C). The second measurement was taken after 24 hours in saliva, and the last measurement 10 days after immersion in artificial saliva. Before taking the readings, the specimens were washed in tap water and dried with absorbent paper towels.

The transmittance values obtained at each wavelength were recorded by a computer connected to the spectrophotometer using specific software that displays the values of transmittance in percentages.

3. Results

Figures 1, 2 and 3 show the mean transmittance values for all composite resins at 0 hours, and after 24 hours and 10 days of immersion in artificial saliva in the wavelength band of 400 to 760 nm.

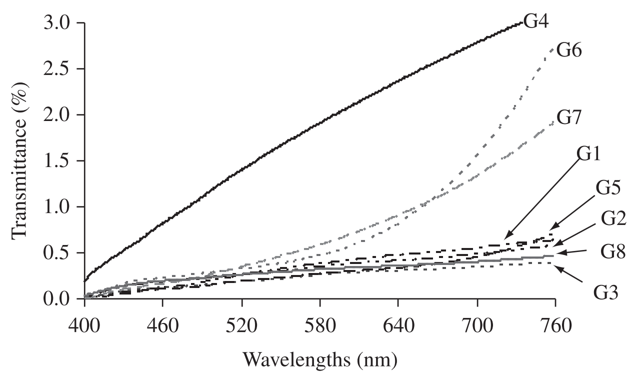

Figure 1. Mean transmittance values obtained before immersion in artificial saliva (vertical bar: 95% confidence interval for the mean population).

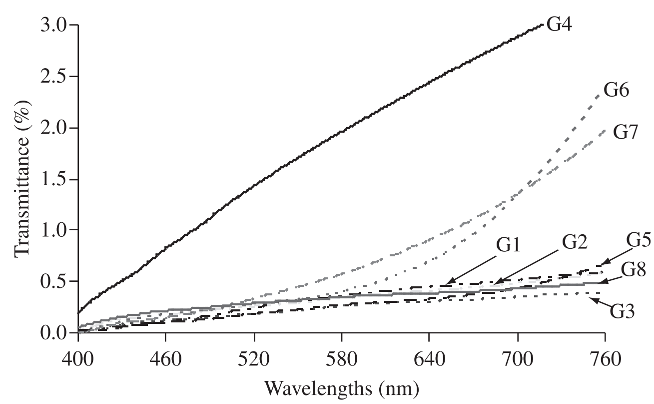

Figure 2. Mean transmittance values obtained after 24 hours of immersion in artificial saliva (vertical bar: 95% confidence interval for the mean population).

Table 1. Materials used in this study.

Composite resin	Color	Batch number	Manufacturer	Classification	Experimental groups
Durafill VS®	A_2	010143	Heraeus-Kulzer	Microfill	G7
Charisma®	A_2	010073	Heraeus-Kulzer	Micro-hybrid	G1
Filtek™Z-100	A_2	1CF	3M/ESPE	Hybrid	G8
Filtek™Supreme	A_2E	2FM	3M/ESPE	Nanoparticles	G2
Filtek™Supreme	A_2B	4AP	3M/ESPE	Nanoparticles	G3
Filtek™Supreme	YT	1DT	3M/ESPE	Nanoparticles	G4
Esthet-X®	A_2	0120356	Caulk Dentsply	Micro-matrix with nanoparticles	G5
Esthet-X®	YE	0115263	Caulk Dentsply	Micro-matrix with nanoparticles	G6

An analysis by ANOVA showed no significant differences among the composite resins with respect to transmittance values at various wavelengths and immersion times ($p < 0.05$).

Table 2 summarizes the results of the statistical analysis, where the mean transmittance values on lines followed by the same lower-case letters and the mean values in the columns followed by the same upper-case letters indicate no statistically significant difference at a 5% level of confidence by Tukey's test.

All the experimental groups investigated here showed a similar behavior, with transmittance values increasing significantly as the wavelengths increased from 400 to 760 nm. All the experimental groups also showed similar results as a function of immersion times. At zero immersion time (before immersion in artificial saliva) and after 10 days, the transmittance values were similar and statistically higher than the values obtained after 24 hours of immersion in artificial saliva.

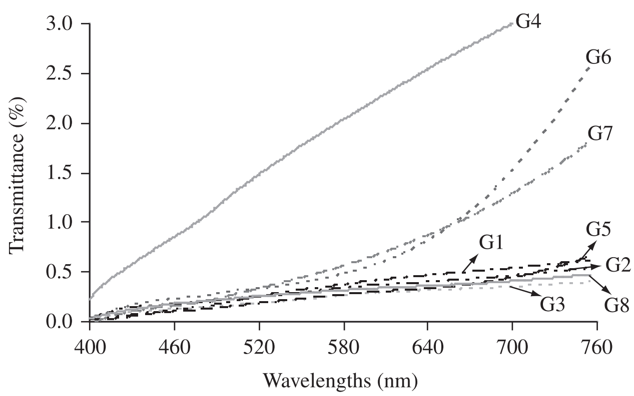

Figure 3. Mean transmittance values obtained after 10 days of immersion in artificial saliva (vertical bar: 95% confidence interval for the mean population).

The composite resin Filtek™ Supreme YT (Group 4) showed the highest mean transmittance values at wavelengths of 400 to 760 nm in the three immersion times tested here. The composite resins Esthet-X® YE and Durafill® A_2 (Groups 6 and 7) showed similar transmittance values, which were higher than the groups listed in increasing order of transmittance, as follows: Filtek™ Z-100 = Filtek™ Supreme A_2E = Charisma® A_2 > Esthet-X® A_2 = Filtek™ Supreme A_2B (G8 = G2 = G1 > G5 = G3).

4. Discussion

The search for a direct restorative material combining excellent esthetic results with superlative physicomechanical and biological properties has driven numerous researches to study and understand the various properties of different restorative materials.[1-28]

For a long time, dental professionals and patients were satisfied with restorations that showed excellent shape and contour, good marginal adaptation and "surface gloss", considering color features and other optical properties of secondary importance, possibly due to the limited knowledge of dental professionals about optical physics.

Color and translucence are the most important properties inherent to esthetic restorative materials, while shape, contour and surface texture are characteristics conferred on restorations during their preparation, which depend specifically on the artistic and manual abilities the dental professional has acquired through training.[14]

Table 2. Mean transmittance values and standard deviations (±sd) at selected wavelengths (WL) by group and immersion time in artificial saliva.

Time	Wavelength	G1	G2	G3	G4	G5	G6	G7	G8
Initial	460	$0,13^{B}_{b}$	$0,20^{A}_{d}$	$0,13^{A}_{b}$	$0,82^{A}_{a}$	$0,12^{B}_{d}$	$0,24^{B}_{e}$	$0,18^{B}_{c}$	$0,20^{B}_{f}$
		0,012	0,011	0,008	0,087	0,007	0,012	0,015	0,007
	520	$0,27^{D}_{b}$	$0,28^{B}_{b}$	$0,20^{B}_{a}$	$1,40^{B}_{a}$	$0,20^{C}_{b}$	$0,34^{D}_{c}$	$0,36^{D}_{c}$	$0,27^{F}_{d}$
		0,017	0,012	0,008	0,148	0,012	0,019	0,035	0,006
	580	$0,39^{F}_{d}$	$0,36^{C}_{c}$	$0,27^{C}_{a}$	$1,91^{C}_{a}$	$0,29^{D}_{b}$	$0,48^{F}_{e}$	$0,60^{E}_{f}$	$0,32^{G}_{g}$
		0,026	0,014	0,008	0,207	0,016	0,035	0,065	0,006
	640	$0,49^{H}_{d}$	$0,43^{D}_{c}$	$0,32^{E}_{a}$	$2,37^{D}_{b}$	$0,35^{E}_{b}$	$0,83^{H}_{e}$	$0,92^{F}f$	$0,36^{I}_{g}$
		0,036	0,018	0,009	0,272	0,017	0,090	0,110	0,008
24 hours	460	$0,12^{A}_{b}$	$0,19^{A}_{d}$	$0,13^{A}_{b}$	$0,82^{A}_{a}$	$0,11^{A}_{d}$	$0,19^{A}_{e}$	$0,16^{A}_{c}$	$0,21^{C}_{f}$
		0,009	0,012	0,009	0,052	0,007	0,067	0,015	0,009
	520	$0,26^{C}_{b}$	$0,27^{B}_{b}$	$0,20^{B}_{a}$	$1,43^{B}_{a}$	$0,19^{C}_{b}$	$0,29^{C}_{c}$	$0,34^{C}_{c}$	$0,29^{E}_{d}$
		0,014	0,014	0,010	0,082	0,010	0,072	0,031	0,010
	580	$0,37^{E}_{d}$	$0,35^{C}_{c}$	$0,27^{C}_{a}$	$1,96^{C}_{a}$	$0,28^{D}_{b}$	$0,42^{E}_{e}$	$0,59^{E}_{f}$	$0,35^{H}_{g}$
		0,018	0,017	0,012	0,113	0,012	0,077	0,063	0,012
	640	$0,46^{G}_{d}$	$0,42^{D}_{c}$	$0,32^{E}_{a}$	$2,44^{D}_{b}$	$0,34^{E}_{b}$	$0,71^{G}_{e}$	$0,92^{F}_{f}$	$0,39^{J}_{g}$
		0,025	0,022	0,013	0,142	0,013	0,104	0,110	0,014
10 days	460	$0,13^{AB}_{b}$	$0,19^{A}_{d}$	$0,14^{A}_{b}$	$0,85^{A}_{a}$	$0,11^{AB}_{d}$	$0,24^{B}_{e}$	$0,17^{AB}_{c}$	$0,18^{A}_{f}$
		0,009	0,010	0,009	0,096	0,005	0,016	0,016	0,008
	520	$0,27^{D}_{b}$	$0,26^{B}_{b}$	$0,20^{B}_{a}$	$1,48^{B}_{a}$	$0,20^{C}_{b}$	$0,35^{D}_{c}$	$0,34^{CD}_{c}$	$0,26^{D}_{d}$
		0,016	0,013	0,010	0,146	0,010	0,023	0,039	0,007
	580	$0,39^{F}_{d}$	$0,35^{C}_{c}$	$0,28^{D}_{a}$	$2,04^{C}_{a}$	$0,29^{D}_{b}$	$0,49^{F}_{e}$	$0,57^{E}_{f}$	$0,32^{G}_{g}$
		0,023	0,015	0,011	0,196	0,014	0,047	0,076	0,008
	640	$0,48^{H}_{d}$	$0,41^{D}_{c}$	$0,33^{F}_{a}$	$2,55^{D}_{b}$	$0,35^{E}_{b}$	$0,83^{H}_{e}$	$0,88^{F}_{f}$	$0,36^{I}_{g}$
		0,033	0,019	0,012	0,257	0,014	0,132	0,128	0,009

Masotti et al.[13] (2008) define translucence as the partial passage of light through a certain structure. However, it should be noted that translucence is not synonymous with transparency. The term translucence, which is the quality of translucent bodies, is often used erroneously, for the fraction of radiant energy transmitted by the system, or even the amount of light transmitted through the material or body, should be understood as transmittance. Thus, the correct term to describe the amount of light that crosses a body or surface is transmittance and not translucence. The amount of light absorbed and reflected by the material must therefore be considered, since it is not simply the passage of light, but depends on the wavelength of the emitted light.

Transmittance is one of the various factors that determine the optical characteristics of a material. It is an important feature of restorative materials, since the tooth allows the partial passage of light through its tissues, and may also present different degrees of translucency, depending on the anatomical region. Therefore, the presence of different degrees of translucency in composite resins is a determining factor for the quality of esthetic reproductions of lost portions of teeth.[13]

Finely honed sensitivity and professional skills are required to perfectly mimic the transmittance of lost dental tissues, since these tissues have different indices of transmittance. Enamel has a higher transmittance than dentine, which in turn differs considerably from that of cementum, since these tissues have different compositions, and mineral and organic components of different amounts and qualities.[12]

Visible light spectrophotometry has also been reported as an efficient method to verify the transmittance of different materials or structures. Transmittance can be measured through direct transmission, by interposing the specimen between a light source and a detector that checks the amount of light that crosses the sample at a given wavelength.[12]

This study evaluated direct transmittance using a visible light spectrophotometer to record the transmittance of specimens at wavelengths ranging from 400 to 700 nm, which corresponds to the light spectrum visible to the human eye, according to the methodology described by Brodbelt et al.[12] (1980) and Masotti et al.[13] (2007).

Several factors such as filler and polymeric matrix, refractive index, type of monomer and filler, and filler content[13,15,16] can influence the light transmittance and opacity of composite resins. These properties must be thoroughly evaluated in order to ensure the esthetic longevity of a restoration in terms of color stability.

Color stability is a determining factor for the good esthetic performance of restorative materials, i.e., their ability to resist color changes caused by either intrinsic or extrinsic factors. This stability determines the longevity of a restoration, since color changes may impair its esthetic appearance. According to Luce and Campbell's[10] 1998 report, the two-phase composition of composite resins, the type of staining agent and the duration of the contact between the staining agent and the material determine the degree of staining.

The color of composite resins can change in response to extrinsic factors, such as absorption of staining agents, liquid sorption, etc. The higher the water absorption of resins the greater the intensity of staining. Changes resulting from intrinsic factors include discoloration of the material itself by alteration of the matrix interface, matrix or fillers and oxidation of the structure of remaining unreacted methacrylate groups.[17,18]

Another factor that may reduce the material's transmittance is its thickness. An increase in the specimen's thickness causes its opacity to increase and the material's transmittance to decrease.[8,11,19-21] This fact was considered when standardizing the thickness of the specimens in all the experimental groups evaluated in this study.

The mean immersion time strongly affects the staining and therefore the transmittance of composite resins, and the stronger the staining the higher the material's opacity.[10]

The results obtained in this study are congruent with those of Brodbelt et al.[12] (1980), who reported that the opacity of all their specimens, regardless of the immersion time, diminished as the wavelength increased, indicating that transmittance depends on the wavelength. Transmittance is always higher at longer wavelengths[9,11,13,22]

Comparisons of the immersion time factor of composite resins have shown contradictory results. In 2002, Nakamura et al.[23] found that transmittance was not modified over time. In contrast, Lambrechts[7] (1990) and Luce and Campbell[10] (1988) reported that transmittance diminished gradually over time, with the longest immersion times leading to the lowest transmittances.

This contradiction led us to reexamine the influence of this variable. The findings of this study revealed a transmittance behavior unlike that of earlier reports, indicating the same transmittances at time zero (before immersion) and at 10 days. Moreover, these transmittances were higher than that measured after 24 hours immersion in artificial saliva. This apparent discrepancy is likely explained by the higher water sorption during the first 24 hours of immersion in saliva. The materials analyzed in all the experimental groups displayed this discrepant behavior. Buchalla et al.[18] reported that the greatest color change of composite resins occurs over time, mainly in the first 24 hours.

The transmittance of composite resin restorations depends on the chemical composition of each resin and on the amount and quality of the inorganic filler particles. The composition of the composite resin influences the material's direct transmittance, but this direct transmittance is not directly correlated with the shade of the composite resin.[13]

According to Bowen[2], the transmittance of a composite resin changes according to its ability to transmit light to its components, as well as the number and size of internal bubbles, the refractive index of the components of the organic matrix, and the particle size. Rayleigh's equation indicates that particle size exerts a strong influence, since transmittance has been found to decrease as the radius (dimensions) increases.[13]

Eldiwany et al.[24] (1995) suggested that materials with a high inorganic filler content display the highest color stability.

Watts and Cash[25] (1994) demonstrated that the material's composition is a determining factor of its optical properties. Filler composition, content, shape and size are some of the factors responsible for the optical dispersion of a material[16], and for the light transmittance characteristics of composite resins.[9]

Waikai et al.[26] (1973) showed that increasing the size of inorganic particles increased the transmittance of these materials. In 1986, Larson[6] reported that microparticle resins are more translucent than hybrid composite resins, and that reducing the average size of filler particles increases the transmittance of these resins.

The size and volume fraction of fillers in composite resins should be controlled for the best color reproduction, considering the refractive indices of filler and resin matrix.[27] The incorporation of small filler particles significantly reduces the light transmittance through composite resins.[9]

According to Sampath and Ramachandra[22] (2008), the inclusion of glass-fibers in experimental composite resin reduces the amount of light transmittance through the structure. In 2008, Lee[4] showed that increasing the amount of filler caused an almost linear decrease in transmittance.

According to Dietschi et al.[14] (1994), the high susceptibility of microfill materials to staining can be attributed to their high filler content and water absorption. These authors showed that the best results were achieved with the group that received surface finishing and polishing. This finding can likely be attributed to the removal of the surface layer of resin rich in organic matter and therefore susceptible to staining. The lowest staining was generally correlated with the lowest water absorption, low organic matrix content, and satisfactory brightness after finishing and polishing. They concluded that the staining susceptibility of composite resin depends on its composition and surface properties.

Luce and Campbell[10] suggested that microfill composite resin staining depends on the type of organic matrix, particle size, percentage of inorganic filler, degree of polymerization, interval of time between finishing and burnishing, water absorption, the staining agent, and the duration of contact between the staining agent and the resinous material.

However, Mitra et al.[28] (2003) claimed that resinous nanoparticle and nanoagglomerate composites provide better transmittance and polishing than microfill resins, while displaying the same physical properties and wear resistance as several hybrid and microhybrid composites.

In the present study, the Filtek™ Supreme YT nanocomposite resin (Group 4) showed the highest transmittance. This is likely due to its composition, which consists of primary silica particles (non-agglomerated) with a mean size of 75 nm, and silica agglomerations with 75 nm particles, forming nanoagglomerations of 0.6 to 1.4 nm. This composition differs from that of traditional color composite resins of the same brand (primary silica particles – non-agglomerated) with an average size of 20 nm and agglomerations of zirconium and silica with average particle sizes ranging from 5 to 20 nm, which form agglomerations of 0.6 to 1.4 nm. Our findings are congruent with the results reported by Masotti et al.[13] (2007). According to Santos et al.[11] (2008), nanocomposites show a higher gain in transmittance at a fixed thickness than hybrid resins, which is attributed to the filler particle size of nanocomposites.

The Esthet-X® YE and Durafill® composite resins (Groups 6 and 7) fell within an intermediate and stable range at the 3 different immersion times evaluated, showing higher transmittance values than all the other groups, whose values were similar. The other groups showed transmittance values as a function of immersion time, in the following increasing order of transmittance: Filtek™ Z-100 = Filtek™ Supreme A_2E = Charisma® A_2 > Esthet-X® A_2 = Filtek™ Supreme A_2B (G8 = G2 = G1 > G5 = G3).

In the present study, the greatest differences in transmittance values among the composite resins were due to their different amounts of organic filler, type of inorganic filler particles, and especially the amount of particles; the most important variable to evaluate is this amount in volume. These findings are congruent with the results obtained by Masotti et al.[13] (2007), who reported that the composition of the materials affected the direct transmittance percentages, and with Arikawa et al.[9] (2007), who stated that filler particles, as well as particle size and filler content, significantly affected the light transmittance characteristics and color of composite resins.

The properties of the material's composition may strongly influence the transmittance of incident light, although their effect is still somewhat uncertain.

It is important to emphasize that the information available to date can be analyzed from a practical point of view, although it should be analyzed carefully when applying it to clinical dentistry. The results obtained in this study confirmed the initially formulated hypothesis, i.e., that the composition of the material does in fact influence its transmittance.

5. Conclusions

The composite resins Filtek™ Supreme YT, Exthet-X® YE and Durafill® A_2 showed higher direct transmittance than the other composite resins evaluated here. The composition of the composite resins influenced the direct transmittance of the material. The transmittances of composites resins are directly related to the type, size and amount of inorganic filler particles.

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