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Effect of Polishing Systems on Translucency Parameter of the Resin Composites after Aging

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Abstract: *The purpose of this study was to evaluate the effect of finishing/polishing systems on the translucency parameter (TP) of resin composites after accelerated artificial aging (AAA). Four composite resins (Filtek Z250, Admira, IPS Empress Direct, Clearfil Majesty Esthetic) were evaluated. Thirty samples were prepared with each resin composite and divided into three subgroups: control (Mylar strip), disc (Optidisc), and rubber (Dimanto) (n=10). The spectrophotometer was used to determine color measurements. TP was calculated the using the CIEDE 2000 formula. Data were analyzed using Generalized Lineer Model (p<0.05). The three factors (composite resin, finishing/ polishing, and AAA) had no statistically significant influence on the TP. However, composite and finishing/polishing influenced the TP. Filtek Z250 showed the lowest TP values and the IPS Empress Direct showed the highest TP values before and after AAA. Polished groups showed higher TP values than control groups before and after AAA. IPS Empress Direct with Dimanto had higher TP values than other groups (except for IPS Empress Direct with Optidisc); Filtek Z250 with finishing/polishing groups showed lower TP values than other groups. Composite type and finishing/polishing systems influenced TP values. Unfinished groups exhibited lower TP values than finished groups. There was no difference in TP values between finishing/polishing systems (Dimanto and OptiDisc).*

Keywords: *accelerated artificial aging, polishing, resin composite, spectrophotometer, translucency parameter*

1. Introduction

Due to the recent popularity of esthetic restorative materials and increasing patient demands, color matching of resin composites to natural teeth is necessary for clinicians [1]. The esthetic success of restorations is related to optical properties, such as color and translucency. Restorative materials should have optimal translucency and mimic the natural tooth structure [2]. Translucency can be defined as a property in between opacity and transparency. Translucent materials allow light to pass through them but scatter light compared to transparent materials so that objects on the other side are not clearly visible [3]. Translucent esthetic materials ensure color matching to adjacent tooth/restoration. The translucency parameter (TP) is used to evaluate the translucency of dental materials [4]. The literature recommends the CIEDE 2000 formula for improved correction between perceived color differences obtained from the CIELAB formula [5]. However, recent studies have calculated the TP using the CIELAB formula [4].

The surface layer of the resin in contact with oxygen does not undergo polymerization and requires removal. Application of finishing/polishing systems increases the esthetic appearance and longevity of dental restorations [2]. Different finishing/polishing systems are available for finishing and polishing resin composite restorations. These systems may require one or more steps. Moreover, the abrasive particles differ in composition, presentation, type, and hardness. Considering that simplified systems save time, clinicians need to be familiar with the materials they use [6]. Finishing/polishing procedures aim to adjust occlusion, create a smooth, uniform surface, and allow adequate light reflection [2]. In clinical terms, restorative materials should be resistant to factors, such as temperature change, exposure to moisture, and mechanical stresses. Clinical studies are required to validate the treatment procedures,

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but these studies are expensive and time-consuming. In vitro studies may simulate conditions that closely resemble the clinical environment [7]. However, studies involving composites subjected to accelerated artificial aging (AAA) are difficult to compare due to differences in used methods. AAA imitates the effect of prolonged exposure to environmental conditions through an accelerated weathering process that includes differences in light, temperature, and humidity and ensures that AAA in short time intervals is equivalent to long-term use under normal conditions [8].

Although there are concerns on changes in translucency of composite resins after light-curing and finishing/polishing, [9] they have not been adequately researched. To the best of our knowledge, data comparing the effects of multi-step and one-step finishing/polishing systems and AAA on the translucency of resin composites are not available in the literature. Therefore, this study aimed to evaluate the influence of polishing systems on the translucency of resin composites after accelerated artificial aging. The following null hypotheses were investigated: (1) different polishing methods do not influence translucency; (2) the effect of AAA does not influence the translucency of resin composites.

2. Materials and methods

Shade equivalent A2 of four resin composites [(Clearfill Majesty Esthetic, Kuraray, Okayama, Japan; IPS Empress Direct, Ivoclar Vivadent, Schaan, Liechtenstein; Filtek Z250, 3M-ESPE, St. Paul, MN, USA; Admira, Voco, Cuxhaven, Germany)] were used in this study (Table 1).

Table 1. List of materials used in present study

	Manufacturer	**Type**	**Composition**		**Lot No.**
Filtek Z250	3M Espe, St. Paul, MN, USA	Universal/ Microhybrid	BisGMA, UDMA, Bis-EMA, zirkonium/silica, 0,01-3,5 µm	%82 wt %60 vol	NF43622
Admira	VOCO GmbH Cuxhaven, Germany	Ormocer	Ormocer, BisGMA, UDMA, Aromatik ve Alifatik dimetakrilat, 0.7 µm.	%78 wt. (%56 vol. microfiller)	1914502
IPS Empress Direct (Enamel)	IvoclarVivadent, Schaan, Liechtenstein	Nanohybrid	BisGMA, UDMA, TEGDMA, Barium glass, ytterbium trifluoride, and mixed oxides silicon dioxide, copolymer 0,4 µm-100 nm	%75-79 wt %52-59 vol	Y35243
Clearfil Majesty Esthetic	Kuraray Noritake Dental Inc., Okayama, Japan	Nanohybrid	BisGMA, hydrophobic aromatic dimethacrylate, di-Camhorquinone, silanated barium glass filler, pre-polymerized organic filler, 0,37 µm-1,5 µm	%78 wt %40 vol	4H0173
Finishing/Polishing systems					
	Manufacturer	**Type**	**Composition**		**Lot No.**
OptiDisc	KerrHawe, Bioggio, Switzerland	Discs	Aluminum impregnated discs, (Coarse-Medium-Fine-Extrafine)		6778506
Dimanto	VOCO GmbH Cuxhaven, Germany	Rubber	Diaomond particles impregnated silicon rubber (One-step pre and high gloss p olishing)		1915625

Thirty disc-shaped samples were prepared for each composite (total 120 samples). A Teflon mold (8 mm diameter, 2 mm thickness) was used to prepare disc-shaped specimens of resin composites. Resin composites were placed into a hole, and a Mylar strip was placed over the top surface. Resin composites were cured using LED (3M Elipar™ Deep Cure- S LED, Saint Paul, MN, USA) for 40 s directly over the Mylar strip. Resin composite groups were randomly divided into three subgroups (n=10). Except for the Mylar strip groups, 1200 grit silicon carbide abrasive paper was used with water before application, using the polishing systems. Two polishing systems [(Optidisc, KerrHawe, Bioggio, Switzerland; Dimanto, Voco, Cuxhaven, Germany)] used are shown in Table 1. The four-step OptiDisc system includes four aluminum oxide (Al_2O_3)-embedded discs, each used for 15 s, under dry conditions. The one-step Dimanto system (rubber cup), with diamond-embedded rubber cups, was used for 60s under dry conditions. The polishing systems were applied using a handpiece at a speed of 10,000 rpm. All specimens were rinsed for 10 s and stored at 37°C for 24 h in distilled water.

2.1. Translucency parameter

The initial color measurements were obtained using a spectrophotometer (Lovibond RT Series, Tintometer® Group, Lovibond House, UK) calibrated according to the manufacturer's instructions. TP was calculated using the CIEDE 2000 formula [4]:

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L} \right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C} \right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H} \right)^2 + R_T \left(\frac{C'_B - C'_W}{K_C S_C} \right) \left(\frac{H'_B - H'_W}{K_H S_H} \right) \right]^{1/2}$$

Subscripts "B" and "W" (specified in the formula) correspond to black and white backgrounds, respectively. ($L_B' - L_W'$), ($C_B' - C_W'$), and ($H_B' - H_W'$) denote the differences in lightness, chroma, and hue on black and white backgrounds, respectively. The relationship between the variations of chroma and hue in the blue region is defined by the rotation function (RT). The weighting functions of lightness, chroma, and hue are denoted by S_L, S_C, and S_H, respectively. K_L, K_C, and K_H consist of parametric factors set 1 in this study [4].

2.2. AAA procedure

After initial measurements, all specimens were aged for 300 h and 150 kJ/m^2 in an accelerated aging chamber (Atlas ci 4000; Atlas Electronic Devices Co., Mount Prospect, Il, USA) The aging procedure was performed as stated in the previous study [8]. The aging process was as follows: 60 min in the dark with back water spray; 40 min under illumination; 20 min under illumination water spray; and 60 min under illumination. The temperature of the back panel was maintained at 38 ± 2°C in the dark and 70 ± 3°C under illumination. The dry-bulb temperature was 38 ± 2°C in the dark and 47 ± 3°C under illumination. Relative humidity was maintained at 95 ± 5 % in the dark and 50 ± 5 % under illumination. After the AAA procedure, the procedures for measuring TP were repeated.

2.3. Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows (Version 23.0. Armonk, NY: USA) package program. The data were checked for normal distribution (Kolmogorov-Smirnov test for skewness and kurtosis). General linear model was used for TP of interaction between the factors (group × composite × AAA). Bonferroni correction was used to compare the main effects. Tukey's test was used for multiple comparisons. The significance level of difference was set at $p<0.05$.

3. Results and discussions

Interaction factors are shown in Table 2 for TP. The analyzed factors (resin composite, finishing/ polishing, and AAA) had no statistically significant influence on TP. However, resin composite and finishing/polishing systems influenced TP. TP values are shown in Table 3. The lowest TP values were found with Filtek Z250 and the highest TP values with IPS Empress Direct before and after AAA. Compared to polishing systems, the lowest TP values were found in control groups before and after AAA. There were no differences within Optidisc and Dimanto groups before and after AAA. IPS

Empress Direct with Dimanto had higher TP values than other groups (except IPS Empress Direct with Optidisc). Filtek Z250 exhibited lower TP values than other resin composites.

Table 2. Interactions among the factors for TP

	Type III		
	Wald Chi-Square	**df**	**Sig.**
(Intercept)	23042.985	1	<0.001
Group	37.359	2	<0.001
Composite	333.908	3	<0.001
AAA	3.762	1	0.052
Group * Composite	33.882	6	<0.001
Group *AAA	0.022	2	0.989
Composite * AAA	0.648	3	0.885
Group * Composite *AAA	0.079	6	1

Table 3. Means and standard deviations for TP values

		Composites				
Groups	Time	Filtek Z250	IPS Empress	Admira	Clearfil M	Total
Control	t1	5.32 ± 0.48	6.58 ± 0.94	6.32 ± 0.90	7.18 ± 0.62	6.35±1.00
	t2	5.17 ± 1.29	6.45 ± 0.86	6.25 ± 0.51	6.90 ± 0.24	6.20±1.02
	Total	5.25 ± 0.95[a]	6.52 ± 0.88[bef]	6.28 ± 0.71[e]	7.04 ± 0.48[cb]	6.27±1.00[A]
Optidisc	t1	5.37 ± 0.53	7.70 ± 0.64	6.94 ± 0.58	7.21±0.45	6.81±1.03
	t2	5.22 ± 0.63	7.57 ± 0.75	6.81 ± 0.37	6.96±0.45	6.64±1.03
	Total	5.30 ± 0.57[a]	7.64 ± 0.68[cd]	6.87 ± 0.47[bef]	7.08±0.46[cb]	6.72±1.03[B]
Dimanto	t1	5.48 ± 1.09	8.16 ± 0.59	7.14 ± 0.73	7.24 ± 0.69	7.00±1.24
	t2	5.29 ± 0.78	7.95 ± 0.59	7.09 ± 0.76	6.94 ± 0.68	6.82±1.19
	Total	5.38 ± 0.93[a]	8.05 ± 0.59[d]	7.11 ± 0.73[cf]	7.09 ± 0.68[cb]	6.91±1.21[B]
Total	t1	5.39 ± 0.73	7.48 ± 0.98	6.80 ± 0.80	7.21 ± 0.57	6.72±1.12[X]
	t2	5.23 ± 0.91	7.33 ± 0.96	6.72 ± 0.65	6.93 ± 0.47	6.55±1.10[X]
	Total	5.31 ± 0.82[A]	7.40 ± 0.97[B]	6.76 ± 0.73[C]	7.07 ± 0.54[D]	6.64±1.11

t1: before AAA; t2: after AAA
There is no difference between the same letter (A-B; between the groups) in the column. There is no difference between the same letter (A-D; between the composites) in the row. There is no difference between the same letter (a-f; interaction composite*group) in the column. There is no difference between the same letter (X-Y; AAA) in the column (AAA).

The current study found significant differences between polishing systems on TP. Therefore, the null (first) hypothesis was rejected. AAA did not influence TP. Therefore, the null (second) hypothesis was accepted. In the current study, resin composites were not colored to any agents. Translucency is influenced by various factors; the thickness of composites, [10] pigments and other chemical ingredients of the material [11] and light-curing protocol [12]. This study used composite samples of A2 tons and equal thickness. The same light-curing device was used for the polymerization of samples. Due to the shortcomings of the CIELAB formula in the literature, we used the CIEDE 2000 formula [4] to calculate TP values. The optical characteristics of teeth depend on the region, between the teeth, and factors, such as the choice of material. Ideally, the color and translucency of restorative materials should mimic natural teeth in esthetic restorations [8]. The ability of a material to allow passage of light is an indicator of translucency, and higher TP values show higher translucency [2]. Salas et al. [4] reported the translucency perceptibility and acceptability thresholds of composite resins according to the CIEDE

2000 formula as 50%:50% TPT (perceptibility) 0.62 and TAT (acceptability) 2.62, respectively. Our study results showed that changes in TP values of the materials were clinically acceptable. TP values of resin composites decreased after AAA. However, this decrease was not significant, probably due to increased reflectance of higher ΔL values [2]. TP differences in samples can be attributed to composite resin contents and the effect of polishing systems. Lee and Lee [13] reported that the translucency of resin composites increased after polishing. In the current study, control groups showed significantly lower TP values than finished/polished groups. These findings contradict the results of a study by Elsayad [2]. A previous study showed that the multi-step system increased TP values; however, the one-step system decreased TP values, with significant TP change [14]. Our study showed no difference in TP values between finishing/polishing systems. Different application and aging protocols used in studies may affect results. Moreover, applied polishing systems can be crucial to material translucency and light scattering from the surface because they increase surface gloss, resulting in higher TP values than control groups.

A previos study show that nanohybrid composite resins have high translucency due to particle sizes smaller than the wavelength of light, resulting in minimal scattering of photons [15]. In current study, IPS Empress Direct groups showed higher TP values than other groups, probably due to the differentiation of light scattering resulting from nano-sized filler particle of the IPS Empress Direct composite is used in the anterior region. In this context, its translucency is expected to be high. Ceram-X Duo and Admira are ormocer-based composite resins. Cengiz et al. [16] stated that TP values were low due to ormocer content. However, our study showed the lowest TP values for Filtek Z250. Optical properties of resin composites are affected by resin matrix composition, pigment, and other added substances, which result in light reflection at different wavelengths [17]. Naeimi Akbar et al.[18] stated that translucency values of resins increase with a decrease in filler particle size and volume. In our study, Filtek Z250 had higher filler volume and particle size than other materials that may have played a role in low TP values. Howard et al. [19] reported that the differences in refractive index between filler and matrix decrease with an increase in the C=C conversion degree of monomers so that the resin scatters more light and shows more translucency. Material composition differences can be attributed to variations in TP values. Reports show that the translucency values of the materials are affected by many factors, [4] such as the composition of the applied resin matrix, [4] resin matrix content, [20] distribution of filler, [21] number of particles per volume, different chemical structures, added substances,[8] and types of polymerization initiator/inhibitor [21]. In resin composites, light absorption is enabled by the organic matrix, while diffusion is due to the size and distribution of inorganic fillers and the difference between the refractive index of the organic matrix and inorganic filler contens [14, 22]. Azzopardi et al.[20] stated that resin matrix and filler particles could influence on the translucency of experimental composite resins. Furthermore, the translucency of resins depends on absorption and scattering, although scattering occurs due to the refractive index mismatch between the organic matrix and filler particle and the size and dispersion of inorganic filler [22].

This study subjected composite resin samples to polishing systems after 300 h AAA and found differences in TP values. Within the methodological limitations, to mimic the effects of aging on materials that may occur in the oral environment in a short time to estimate the clinical performance of resin composites. The oral environment can influence the longevity on translucency in resin composites. Further studies using different aging or finishing/polishing methods are necessary to complement the currently obtained results. This study may contribute to improved techniques for preserving the translucency of resin composites.

4. Conclusions

AAA did not influence TP values. Composite and finishing/polishing systems influenced TP values. Unfinished (control) groups exhibited lower TP values than finished groups. There was no difference in TP values between multi-step and one-step groups. The highest TP values were noted with IPS Empress Direct (nanohybrid) and the lowest TP values with Fitek Z250 (microhybrid) before and after AAA.

Clinicians should be aware that the polishing systems they use may affect the translucency values of resin composites.

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