Original Article

Effect of Accelerated Artificial Aging on Translucency of Methacrylate and Silorane-Based Composite Resins

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Abstract

Objectives: Composite restorations must have tooth-like optical properties namely color and translucency and maintain them for a long time. This study aimed to compare the effect of accelerated artificial aging (AAA) on the translucency of three methacrylate-based composites (Filtek Z250, Filtek Z250XT and Filtek Z350XT) and one silorane-based composite resin (Filtek P90).

Materials and Methods: For this in vitro study, 56 composite discs were fabricated (n=14 for each group). Using scanning spectrophotometer, CIE L*a*b* parameters and translucency of each specimen were measured at 24 hours and after AAA for 384 hours. Data were analyzed using one-way ANOVA, Tukey's test and paired t-test at P=0.05 level of significance.

Results: The mean (±standard deviation) translucency parameter for Filtek Z250, Filtek Z250XT, Filtek Z350XT and Filtek P90 was 5.67±0.64, 4.59±0.77, 7.87±0.82 and 4.21±0.71 before AAA and 4.25±0.615, 3.53±0.73, 5.94±0.57 and 4.12±0.54 after AAA, respectively. After aging, the translucency of methacrylate-based composites decreased significantly (P<0.05). However, the translucency of Filtek P90 did not change significantly (P>0.05).

Conclusions: The AAA significantly decreased the translucency of methacrylate-based composites (Filtek Z250, Filtek Z250XT and Filtek Z350XT) but no change occurred in the translucency of Filtek P90 silorane-based composite.

Keywords: Composite Resins; Silorane Resins; Methacrylates

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INTRODUCTION

Tooth-colored composite resins are increasingly used by dental clinicians. However, despite their growing popularity, composite resins have some shortcomings compared to veneers and all-ceramic restorations namely polymerization shrinkage, secondary caries, plaque accumulation and color instability [1,2]. Recent advances in the composition of composite resins have focused on decreasing polymerization shrinkage and increasing wear resistance, esthetics, and stability in the oral environment [3]. Changing the monomer structure of composite resins led to the introduction of silorane-based composites; it has been claimed that their cationic ring opening polymerization decreases the volumetric shrinkage to 0.99% compared to 1.7 to 5.5% volumetric shrinkage of conventional methacrylate-based composites [3]. Moreover, silorane compared to the methacrylate group has less water sorption and subsequently less solubility [4]. Furthermore, nano-filled composites, manufactured by the use of nanotechnology, have optimal mechanical strength similar to that of hybrid composites [5], and at the same time, benefit from high polishability similar to microfilled composite resins [6]. Favorable optical properties [7] and high wear resistance [8] are among the other optimal characteristics of these composites.

Composite resins, as esthetic restorative materials, must have tooth-like optical properties

and maintain them for a long time. Translucency is the characteristic of allowing the passage of light while scattering it in such a way that the complete image cannot be clearly seen. Thus, translucency stands somewhere between complete opacity and transparency [9]. When composite resin is immersed in water, relatively large changes occur in its translucency; these changes should be taken into account in clinical shade matching [10]. The translucency of dental composite resins depends on their thickness and the refractive index and absorption index of resin, filler particles, pigments and opacifiers [9]. The translucency of a material is usually determined by translucency parameter (TP), which is defined as the color difference between samples of a material with uniform thickness against white and black backgrounds [9]. If a material is completely opaque, its TP would be zero. The higher the TP, the greater the translucency of a material. When a material's color has optimal translucency, the restoration will highly resemble the tooth structure and meet the esthetic requirements. Instable translucency and change in optical characteristics of composite resin depend on intrinsic factors namely the composition of resin matrix [11], filler particles [12], chemical initiator and inhibitor [13], degree of polymerization [14] and the amount of opacifier [15] as well as the extrinsic factors namely the coloring agents [12], UV light radiation [16] and thermal changes [17]. Optical properties of methacrylate-based composite resins have been the subject of numerous investigations. Lee and Lee [17] showed that the translucency of composite restorations increased after polishing. Also, TP of composite resins changed after polymerization and thermocycling. However, this change was related to the shade of composite resin. Diamantopoulou et al, [18] demonstrated that aging in water changed the color and translucency of composites. However, the magnitude of change depended on the brand and shade of composite resins and was clinically acceptable in some and unacceptable in some others. The majority of studies on the service and survival of silorane-based composite resins have focused on their mechanical properties and only limited studies have investigated their optical characteristics. Furuse et al, [19] indicated that silorane-based composites had superior color stability and translucency compared to methacrylate-based composite resins. Perez et al, [9] reported that silorane-based composites had better polymerization-dependent chromatic stability but less translucency compared to six methacrylate-based composite resins. Kaizer et al, [20] showed that the translucency of silorane-based composites and the opacity of methacrylate-based composites increased by water storage. Considering the small number of studies comparing the translucency stability of methacrylate- and silorane-based composites and their controversial results, this study aimed to compare the translucency stability of three methacrylate-based (Filtek Z250, Filtek Z250XT and Filtek Z350XT) and one silorane-based (Filtek P90) composite after accelerated artificial aging (AAA). The null hypothesis was that AAA would have no effect on the translucency of methacrylate- and silorane-based composites.

MATERIALS AND METHODS

For this in vitro experimental study, 56 discs were fabricated of four different composite resins (n=14). The characteristics of composite resins are shown in Table 1. A cylindrical mold with 8mm diameter and 2mm thickness [21] was fabricated. For the fabrication of specimens, this mold was placed on a transparent glass slab and filled with composite. A lamella was placed over the mold in order for the excess material to leak out.

The specimens were then light cured using an LED light-curing unit (Blue Phase, Ivoclar Vivadent, Schaan, Liechtenstein) with 1200 mW/cm2 intensity through the lamella for 20

Table 1: The type, manufacturer and composition of understudy composite resins

Material	Type	Manufacturer	Composition
Filtek Z250	Microhybrid methacrylate composite	3M ESPE/St. Paul, MN, USA	BISGMA, UDMA, BIS-EMA and TEGDMA 0.01-3.5µ ilica/zirconium inorganic particles 60% v
Filtek Z250XT	Nanohybrid methacrylate composite	3M ESPE/St. Paul, MN, USA	BIS-GMA, UDMA, BIS-EMA, PEGDMA and TEGDMA, 68% v silica/zirconia fillers of 3µ or less & Non-agglomerated/non-aggregated 20nm silica particles
Filtek Z350XT	Nanoparticle methacrylate composite	3M ESPE/St. Paul, MN, USA	BIS—GMA, BIS-EMA, UDMA, PEGDMA and TEGDMA; 63.3% v silica nanoparticles (20nm) and zirconia/silica clusters (0.6-10 µm)
Filtek P90	Silorane composite	3M ESPE/St. Paul, MN, USA	silorane based matrix, 55% v quartz and ytterbium trifluoride filer (0.1-2µm)

seconds and without the lamella for another 20 seconds. It should be noted that the diameter of the light guide tip was equal to the disc diameter. Fabricated specimens were polished with coarse, medium and fine aluminum oxide polishing discs (Sof-Lex Pop-on, Orange Series, 3M ESPE, St. Paul, MN, USA) to remove the resin-rich layer and smooth down the specimen surface. For this purpose, each polishing disc was used for 30 seconds with a circular motion in an interrupted fashion to avoid overheating and consequent surface changes. Specimens were immersed in distilled water for 24 hours and then CIE L*a*b* parameters were measured against both white (CIE L*=91.45, a*=-1.08 and b*=6.71) and black (CIE L*=6.81, a*=-1.26 and b*=-2.48) backgrounds using a scanning spectrophotometer (SpectroCAM, Ihara U.S Inc., CA, USA) and the CIE L*a*b* system (Commission International L' Eclairage). The aperture size of the device was 2x1.5 mm and the measuring geometry was 45°/0°. The illumination was D65 and standard observation angle was 10°. The TP was calculated for each specimen using the formula below [22]:

$$TP = [(L^*w-L^*B)2 + (a^*w-a^*B)2 + (b^*w-b^*B)2]1/2$$

Where L*w, a*w and b*w belong to the white and L*B, a*B and b*B belong to the black background and L* indicates lightness, a* indicates the green-red axis (-a: green and +a: red) and b* indicates the yellow-blue axis (-b: blue and +b: yellow) of each specimen.

After the initial color readings, AAA process was carried out based on ASTM Standards G154-00A. In this standard system, light and steam were used to induce aging of non-metallic materials [23]. Therefore, Specimens were then subjected to light and thermal cycles using the weathering tester (QUV, Q-Panel, USA) for 384 hours. Each cycle included 4 hours of UVB radiation at 50°C simulating eight months of clinical service [24]. After aging, TP of specimens was calculated again using the above-mentioned formula and the data were analyzed using SPSS version 16 software, one-way ANOVA, Tukey's post hoc test, and paired t-test. Level of significance was set at $\alpha=0.05$.

RESULTS

Based on the Kolmogorov-Smirnov test, data regarding the TP before aging (TP1), after aging (TP2) and the difference between the two (ΔTP) had normal distribution ($P>0.05$). The mean and standard deviation of TP1, TP2 and ΔTP for understudy composites are shown in Table 2.

The mean (±standard deviation) of TP for Filtek Z250, Filtek Z250XT, Filtek Z350XT and Filtek P90 was 5.67±0.64, 4.59±0.77, 7.87±0.82 and 4.21±0.71 before AAA and 4.25±0.615,

Table 2: The mean and standard deviation of TP1, TP2 and ΔTP of the understudy composites

Material	TP1	TP2	ΔTP
Z250	5.67±0.64	4.25±0.61	-1.41±0.95
Z250XT	4.59±0.77	3.53±0.73	-1.06±0.61
Z350XT	7.87±0.82	5.94±0.57	-1.83±0.63
P90	4.21±0.71	4.12 ±0.54	-0.09±0.81

3.53±0.73, 5.94±0.57 and 4.12±0.54 after AAA, respectively. After aging, the translucency of methacrylate-based composites decreased significantly ($P<0.05$). However, the translucency of Filtek P90 did not change significantly ($P>0.05$).

One-way ANOVA revealed that the mean TP1 of composites was significantly different ($P<0.001$). The results of post-hoc Tukey's test for pairwise comparisons of the mean TP1 of composites are shown in Table 3. On the other hand, the results of one-way ANOVA for TP2 were significantly different ($P<0.001$). The results of post-hoc Tukey's test for pairwise comparisons of TP2 of composites are presented in Table 3. Also, ΔTPs of composites were significantly different ($P<0.001$). The results of post-hoc Tukey's test for ΔTPs are shown in Table 3.

Figure 1 shows the mean TP1, TP2, and ΔTP as well as the results of paired t-test for each composite. Table 4 summarizes the mean and standard deviation of L, a and b color parameters against a black background.

Table 3: The results of post-hoc Tukey's test for pairwise comparisons of the mean TP1, TP2 and ΔTP of composites

Material	TP1 P-value	TP2 P-value	ΔTP P-value
Z250/ Z250XT	0.002	0.17	0.62
Z250/Z350XT	<0.001	<0.001	0.46
Z250/P90	<0.001	0.941	<0.001
Z250XT/Z350XT	<0.001	<0.001	0.47
Z250XT/P90	0.518	0,069	0.007
Z350XT/P90	<0.001	<0.001	<0.001

DISCUSSION

At present, dental composite resins are extensively used for esthetic restorations. Since the enamel has innate translucency, an important success criterion for composite restorations is to maintain a long-lasting translucency similar to that of natural teeth.

Studies have indicated that physicochemical reactions such as visible light radiation, UV radiation, temperature and heat can cause intrinsic color change in composites over time [25]. Artificial aging methods have been vastly used to assess the effects of mentioned factors on optical and mechanical properties of composite resins [26,27]. In AAA, restorative materials are exposed to UV radiation, moisture and sudden thermal changes for a long duration of time. In this method, some changes occur in the organic matrix leading to color change in long-term [28] and change in the translucency of composites [16]. In this study, the effect of AAA on the translucency stability of three methacrylate-based and one silorane-based composite was evaluated. The photo-aging process used in this study mainly affects the resin matrix of the composites and the composites used in this study were not exposed to any coloring agents. Thus, the resultant color changes in the understudy specimens are solely attributed to the internal physical and chemical changes in the composites. Thickness [29] and shade [30] of composites and the light curing protocol [31] can also affect their translucency. Thus, in this study, all specimens were fabricated of A2 shade of composite resin and a mold was used to ensure their equal thickness. The same light curing protocol was used for all specimens. Moreover, since polishing can affect the translucency of composites [32] and also in order to simulate the clinical setting, the specimens were polished using a hand-piece and polishing discs in an orderly fashion. Furthermore, the optical properties of specimens were assessed using a spectrophotometer.

Table 4: The mean and standard deviation of a, b and L color parameters before and after AAA against a black background

Material	L_1	L_2	ΔL	a_1	a_2	Δa	b_1	b_2	Δb
Z250	49.17±0.54	56.54±1.57	7.37±1.35	-1.72±0.48	-2.04±0.17	-0.33±0.16	1.42±0.17	-0.89±1.20	-2.31±1.20
Z250XT	56.97±0.40	61.3±1.51	4.32±1.54	-1.31±0.72	-1.04±0.10	0.27±0.14	3.57±0.26	8.51±1.71	4.94±1.75
Z350XT	50.89±0.38	52.87±0.67	1.98±0.84	-2±0.22	-2.11±0.10	-0.11±0.22	-0.64±0.44	9.34±0.64	9.98±0.75
P90	53.44±0.78	51.54±0.65	-1.9±0.95	-1.68±0.16	-0.62±0.12	1.06±0.22	6.55±0.53	13.98±0.60	7.44±0.98

The results showed that at baseline, the translucency of P90 silorane-based composite was significantly different from that of Z250 and Z350XT composites. Also, all methacrylate-based composites had significant differences with one another in this respect. Moreover, after AAA the translucency of all composites decreased but this reduction only in methacrylate-based composites was statistically significant. After AAA, only the TP of Z350XT was significantly different from that of the remaining three composites.

Studies have shown that composites with organic matrix containing Bis-GMA have less difference in refractive index with zirconium fillers [11] because the refractive index of Bis-GMA, UDMA and TEGDEMA is 1.55, 1.48 and 1.46, respectively and the refractive index of fillers containing zirconium and strontium is approximately 1.55 [33].

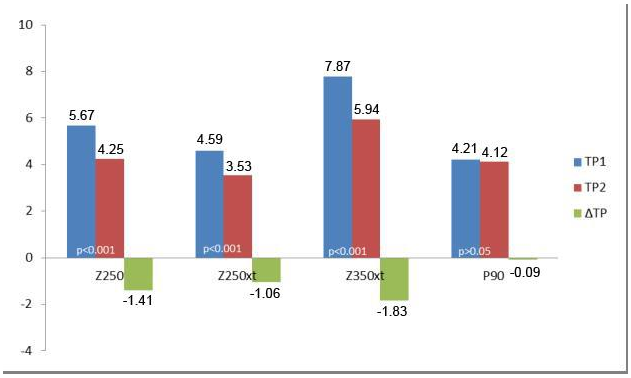

Fig. 1: The results of paired t-test for each composite

Thus, in general, composites containing Bis-GMA and the mentioned conventional fillers have higher translucency. Methacrylate-based composites used in our study were Z250XT, Z350XT and Z250 and all contained Bis-GMA and zirconium fillers. Their baseline translucency was higher than that of P90. However, the translucency of Z250XT was not significantly different from that of P90. This finding may be attributed to the higher filler content of Z250XT than Z350XT and Z250; because it has been demonstrated that increasing the filler content decreases the translucency of composites [34].

If the filler size is smaller than the visible wavelength, the filler will not be able to scatter or absorb light; as the result, human eye will not be able to detect fillers. Thus, nanofiller composites have higher translucency and esthetics [35]. In this study, Z350XT had the highest translucency among the understudy composites before and after aging and this difference was statistically significant. Vichi et al, [36] reported that composites with larger filler particles showed greater changes in color and opacity. Nonetheless, in our study, changes in the translucency of Z350XT with the smallest filler particles were similar to those of Z250 and Z250XT. According to the manufacturer, the majority of Z350XT clusters are produced by the loose attachment of nanoparticles without sintering, providing a wide range of cluster sizes (6 to 10μ). The voids between fillers may be responsible for the reduction in color stability [37] or translucency of these composites after

aging.

Susceptibility to water sorption is another factor that may change the translucency of composites and indicates the sensitivity of composites to hydrolytic degradation [38]. It has been documented that composite resins containing Bis-GMA have greater water sorption while composites containing TEGDMA have higher solubility in an aqueous environment [39]. In our study, all three methacrylate-based composites contained Bis-GMA and TEGDMA and showed significant changes in their translucency after aging. Also, it has been confirmed that the lower the degree of polymerization of composite resin, the greater its water sorption and water solubility [40]. Degree of polymerization depends on light irradiance, duration of exposure to light and other factors such as the composition of the material [41], its shade [42] and translucency [43]. Studies have demonstrated that silorane-based composites have less polymerization depth than methacrylate-based composites [44]. However, due to hydrophobicity, silorane-based composites in aqueous environment show favorable chemical stability and low water sorption, solubility and diffusion coefficient [3,4]. Thus, these composites are expected to have more stable translucency; which is in accord with our findings. Kaizer et al, [20] observed that after 24 hours and 30 and 120 days of water storage, the translucency of silorane-based composites increased compared to the baseline value. They believed that since the quality of bond between the epoxy silorane matrix and quartz particles in silorane-based composites has reported to be questionable in the previous studies [16], micro-cracks and micro-voids at the matrix-filler interface may allow the penetration of water and this water sorption may affect the refractive index of matrix and filler and consequently increase the translucency of these composites.

Yu and Lee [45] reported that the L, a and b values measured against a black background compared to white had stronger association with TP. Thus, in our study, a, b and L were analyzed against a black background. They also showed that when color parameters increased against a black background, the TP values decreased. Moreover, changes in b and L played a more important role in changing the translucency. In our study, the TP of all methacrylate-based composites decreased by AAA. However, only in Z250XT the value of all color parameters increased against a black background. In Z250 composite, the a and b parameters decreased while the L parameter increased. In Z350XT, the value of a did not change significantly while L and b increased. In P90, with no significant change in TP, the L parameter decreased while the remaining parameters increased. Thus, it may be concluded that the inverse correlation between the color parameters and TP, which was reported by Yu and Lee [45] may not be always true for all different materials. This finding has been confirmed by a previous study as well [20]. However, similar to other in vitro studies, precise simulation of oral conditions is difficult if not impossible and this fact was the most important limitation of our study. Future studies are required to scrutinize the correlation of TP with a, b and L parameters.

CONCLUSION

Based on the results, the baseline (primary) translucency of Z350XT, Z250XT and Z250 methacrylate-based composites and the P90 silorane-based composite resin was significantly different and the primary translucency of Z350XT nanofilled composite was higher than that of others. After AAA, the translucency of all methacrylate-based composites significantly decreased but no significant change occurred in the translucency of P90 silorane-based composite. Comparison of the translucency of each composite before and after AAA revealed that Z350XT nanofilled composite had the highest translucency while the translucency of

other composite resins was not significantly different.

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