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Original Article

Comparison of translucency and flexural strength of fiber-reinforced composite resin materials

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Abstract

Aim: The purpose of this study was to compare translucency values and flexural strength of composite resin materials reinforced with two different fibers.

Materials and Methods: In this study, two direct composites (Clearfil Majesty Esthetic and Posterior) and an indirect composite (Tescera) used with a non-fiber control group and two fiber-reinforced (EverStick glass fiber and Ribbond polyethylene fiber) composite groups. Thirty specimens were obtained from the entire composites with dimensions of 25×2×2mm^3. Translucency parameter values of the specimens were obtained using a spectrophotometer. The flexural strength (MPa) of the specimens was then determined by a three-point bending test at a rate of 1 mm/min until fracture occurred in the specimen using a universal tester. Data were analyzed by Two Way ANOVA and Tukey HSD multiple comparison test (α=0.05).

Results: Ribbond group showed similar translucency parameter values with the control group in all composite materials, but the EverStick group showed significantly lower than the control group (p <0.001). The highest mean flexural strength values were seen in the Clearfil Majesty Posterior control group, while the lowest values were seen in the Clearfil Majesty Esthetic Ribbond group. The mean flexural strength values of the control groups for each composite were found statistically significantly higher than the fiber groups.

Conclusion: The fiber addition to composite resins may affect the optical and mechanical properties of the restoration. This effect varies depending on the structural properties of composite resin and fiber. This situation should be taken into consideration in the restoration.

Keywords: Composite resin; flexural strength; translucency parameters

INTRODUCTION

Composite resins, which can be applied by direct and indirect methods, have become popular for tooth restoration because of good esthetic, mechanical properties and the capability of establishing a bond to enamel and dentin (1,2). In recent years, continuous progress has been made, providing significant improvements in terms of physical strength, optical properties, wear resistance and biocompatibility (3,4). However, composite resins have their own limitations, such as polymerization shrinkage, the gap formation, marginal discoloration and leakage. Various strategies have been used to reduce polymer shrinkage stress, including resin matrix structure changes, layering techniques, and increased placement of composite resins (5). In addition to these approaches, it is aimed to decrease the shrinkage and improve the mechanical properties by the polymerizing of composite resins with indirect methods. Indirect composites are frequently used in dental restorations with better polymerization, low shrinkage stress, high abrasion resistance, and mechanical properties (6).

Fiber-reinforcement is currently a popular approach in aesthetic dentistry to improve the mechanical properties of dental materials (7). The type of fiber that is used to restoration depends on the purpose of its usage and characteristics. In fiber-reinforced composite resin (FRC) restorations, the main function of fibers is usually to increase the stiffness and strength (8). FRC should be strong enough to support a significant load with minimal elastic distortion (9). In addition, the FRC infrastructure is semi-transparent and does not require opaque masking, which allows relatively thin layer composite resin application and excellent aesthetic appearance. Thus, they are used in adhesive bridges in anterior with their optical properties as well as their mechanical properties (10).

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Color matching between teeth and restoration is an important requirement for aesthetic restorations. Composite resins have different opacities and hues that perfectly mimic color and translucency in the dentin as much as in the enamel. Translucency is characteristic of a substance that is partially able to allow light to pass through it (11). The translucency parameter of material means the color difference between the uniform thickness of the material on a white background and the same thickness of the material on a black background. Optimal translucency is required for tooth color compatibility of composite resin restoration (12). The translucency of dental composite resins depends on the thickness of the layer, the absorption and scattering coefficients of the fillers, the properties of color pigments and opacifiers (13).

The aim of this study is to compare the translucency parameter (TP) and flexural strength (FS) of direct and indirect composite resin materials reinforced with two different fibers. The null hypotheses tested were that fiber addition on direct and indirect composite resin would not affect (1) the TP and (2) the FS values of composite resins.

MATERIALS and METHODS

Two direct composite resins [Clearfil Majesty Esthetic (CME, Kuraray Medical Inc., Okayama, Japan) and Clearfil Majesty Posterior (CMP, Kuraray Medical Inc., Okayama, Japan)] and an indirect composite resin [Tescera (T, Bisco, Inc., Schaumburg, IL, USA)] were used with a polyethylene fiber [Ribbond THM (R, Ribbond Inc., Seattle, USA)] and a glass fiber [Everstick Net (ES, Stick Tech Ltd., Turku, Finland)] in this study. The manufacturer, type and composition of materials are listed in Table 1.

Thirty specimens from each composite were obtained and divided into three groups (control group with non-fiber, polyethylene FRC group, and glass FRC group). The specimens size was determined based on the results of Tuncdemir et al.(14) aiming to obtain a power of 80%. Specimens were prepared in sizes of 25 × 2 × 2 mm^3 in a Teflon mold between two glass slides. To prepare the FRC groups, the fibers were cut 10mm length using special scissors supplied from the manufacturer and placed under adequate pressure at the center of the composite specimens. Ribbond fibers are not impregnated with resin, so they were saturated with an adhesive bonding agent (Clearfil SE Bond, Kuraray, Kurashiki, Japon) before used. CME and CMP specimens were light-activated with a visible light source (Elipar Free Light 2, 3M ESPE, Seefeld, Germany) in 4 overlapping positions of 40 seconds each. During the polymerization, the light-curing unit (LCU) device was kept in contact with the glass slide placed on the sample surface, the intensity of the LCU was set at 800 mW/cm^2 and was monitored using a power meter (Hilux Light meter, Benlioglu Dental Inc., Ankara, Turkey). Tescera specimens were subjected to pressure and light cycling for 2 minutes in a light cup (Bisco, U.S.A) in accordance with the manufacturers' instructions for polymerization. After preparation, specimens' dimensions were controlled with a caliper and polished with diamond burs. Then the specimens were stored in distilled water at 37°C for 24 hours in dark boxes.

Color was measured based on the CIELAB color scale relative to the standard illuminant D65 over a white ground (CIE L^* = 82.3, a^* = -0.1 and b^* = -0.6) and a black ground (CIE L^* = 3.4, a^* = -0.2 and b^* = -1.2) using the CIELAB (15) color notation system [L* (lightness), a* (green–red coordinate), b* (blue–yellow coordinate)]. Measurements were made via spectrophotometer (ShadePilot, Degudent; Hanau, Germany, Software V. 2.41) and CIELAB parameters (L^*, a^* and b^*) of specimens were recorded by the same observer.

Table 1. Materials used in the study

Product/Code	Manufacturer	Type	Composition	Lot No
Clearfil Majesty Esthetic /CME	Kuraray Medical, Okayama, Japan	Nanohybrid composite	Bis-GMA, Silaned barium glass, hydrophobic aromatic dimethacrylate, pre-polymerized Nano-organic filler (78 wt%)	00035A
Clearfil Majesty Posterior /CMP	Kuraray Medical, Okayama, Japan	Nanohybrid composite	Bis-GMA, hydrophobic aromatic dimethacrylate, TEGDMA, Silanated glass ceramic filler, surface treated alumina microfiller (92 wt%)	00210A
Tescera /T	Bisco, Inc., Schaumburg, IL, USA	Microhybrid indirect composite	19% ethoxylated bisphenol A dimethacryalte, Bis-GMA, glass frit, amorphous silica (60 wt%)	0300020251
Ribbond THM* /R	Ribbond, Inc. Seattle, Washington, USA	Polyethylene fiber	Plasma treated woven UHMWP, polyethylene fiber (non-impregnated)	9551
Ever Stick Net* /E	Stick Tech, Turku, Finland	Glass fiber	Electric glass, silaned fiber; Bis-GMA and PMMA	2060606-EN089
Clearfil SE Bond,	Kuraray, Kurashiki, Japon	Adhesive	Bis-GMA, DMA, MDP, 4-META hydrophilic monomer	019321A

Bis-GMA, bisphenol-A diglycidylether methacrylate, TEGDMA, triethyelene glycol dimethacrylate, UHMWP, ultra-high-molecular-weight polyethylene, PMMA, polymethylmethacrylate, 4-META (4-methacryloyloxyethyl trimellitic acid anhydride

Translucency was computed using the TP formula. (16)

$TP = [(LW^* - LB^*)2 + (aW^* - aB^*)2 + (bW^* - bB^*)2]1/2,$

Symbol "W" refers to CIELAB values for each specimen on the white backing.

Symbol "B" refers to CIELAB values for each specimen on the black backing (Figure 1).

After TP measurement, FS of each specimen was conducted according to ISO 4049 standards (International Standards Organization, 2000). Specimens were tested with a universal testing machine (Instron Corp., Canton, Mass., USA) at a crosshead speed of 1mm/min under the three-point bent testing. The data obtained in the Newton form was converted to MPA with the formula $\delta=3FL/(2BH2)$. Where;

δ = Flexural strength

F = Maximum load (in newtons)

L = Distance between the supports (20 mm)

B = Width of the specimen (2 mm)

H = Height of specimens (2 mm)

TP and FS testing data were recorded and statistical analysis was performed with SPSS 20.00 (Chicago, USA) statistical software program. The compatibility of the samples to normal distribution was examined with the Kolmogorov Smirnov test. To evaluate the effect of restorative material and fiber type on the TP and FS values of the specimens' Two-way ANOVA and Tukey HSD post hoc tests were used. Statistical significance was set at α= 0.05.

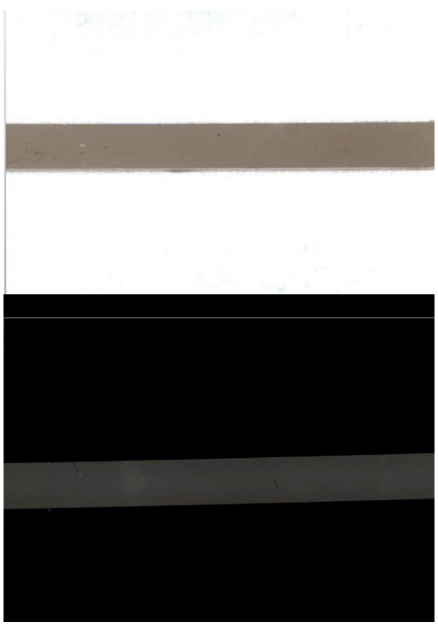

Figure 1. Specimens on white backing and black backing

RESULTS

Significant interactions were found between all groups according to the result of the two-way ANOVA test (Table 2).

Mean and standard deviations of TP and FS values for each group are given in Table 3. The highest mean TP values were obtained in the CME composite groups and the lowest was obtained in the Tescera groups. The addition of fiber to all composites reduced the mean TP value. The mean TP values of ES groups were statistically significantly lower than the R and control groups (p <0.05).

Table 2. The results of Two-way ANOVA of translucency parameter (TP) and Flexural Strength (FS) values for the groups

	Tests of between-Subjects Effects	DF	F	p
TP	Composite	2	1658.843	0.001
	Fiber	2	852.069	0.001
	Composite resin x fiber	4	77.976	0.001
FS	Composite	2	23.111	0.001
	Fiber	2	26.545	0.001
	Composite resin x fiber	4	8.811	0.001

p< 0.05 meaning significantly important differences. DF: Degrees of freedom, F: F-statistic

Table 3. Means and standard deviations (SD) of translucency parameter (TP) and Flexural Strength (FS) values for the groups

Composite	Group	TP Mean ± SD	F	FS (MPa) Mean ± SD	F
Clearfil Majesty Esthetic	Control	20.85±0.54^{a}		72,75±10,18^{a}	
	Ribbond	20.48±0.54^{a}	566.447	52,87±16,92^{b}	7.738
	EverStick	12.44±0.79^{b}		62,75±11,18^{c}	
Clearfil Majesty Posterior	Control	19.35±0.56^{a}		104,62±12,11^{d}	
	Ribbond	18.68±0.55^{a}	408.453	74,62±8,29^{a}	33.219
	EverStick	11.85±0.80^{b}		76,5±6,12^{a}	
Tescera	Control	10.03±0.53^{b}		82,87±15,02^{e}	
	Ribbond	9.69±0.64^{b}	45.816	65,37±6,39^{c}	11.475
	EverStick	7.47±0.77^{c}		70,75±8,20^{a}	

Different lower-case letters indicate that there is a statistically significant difference between the columns (p <0.05).
SD: Standard deviation, F: F-statistic

The ANOVA test to compare the FS values of the specimens showed that there were statistically significant differences were found in control groups of each composite (p <0.5). It was determined that the fiber addition to composite resin decrease the mean FS value. The highest mean FS value were obtained in the CMP composite groups and the lowest mean FS value were obtained in the CME composite groups. CMP-R group showed statistically significant higher mean FS value than the CME-R and T-R groups (p <0.05). CME-ES group showed statistically significant lower mean FS value than the CMP-ES and T-ES groups (p <0.05). Additionally, there were no significant differences seen between the CMP-R and CMP-ES group (p>0.05). But there were statistically significant differences were seen in other fiber- added composites groups (p <0.05) (Table 3).

DISCUSSION

Fibers are often used especially in the anterior region to improve the mechanical properties of composite resin restoration (17). However, in the anterior regions where the aesthetic appearance of the restoration is important, how much the fiber affects the translucency of the restoration and the effect of the fiber type on restoration durability is important and need to be investigated. This study evaluated TP and FS of direct and indirect composite resin materials reinforced with two different fibers. Translucency can be assessed by methods such as visual observation and digital devices (16,18). Measurement with digital instruments is a preferred method in researches because it is a more objective, reliable and precise method than visual assessment (19). Several digital color matching tools are available for clinical use. Spectrophotometers, colorimeters and digital color analyzers are examples of these devices (20). In this research, we used the spectrophotometer for measuring TP. This device works with an LED spectrophotometer and a connected digital camera. It may also provide translucency data calculated from the reflected light spectrum through this device (21).

In this study, no statistically significant TP values difference was observed between the polyethylene fiber (R) and control groups in all composites. According to manufacturers' instruction, the polyethylene matrix structure and content of the R fiber gives it a transparent appearance. The similarity in TP values between the R group and the control group can be explained by this translucent structure of R fiber. Therefore, the first null hypothesis that fiber addition on direct and indirect composite resin would not affect the TP of restoration was partially rejected. Similar to results of this study, a previous study (22) demonstrated no significant differences in total color change and TP values between the control groups and polyethylene fiber-reinforced groups for different composite resins. However, the mean TP values in the glass fiber (ES) groups in this study were significantly lower than the control and other groups for each composite. Color, optical properties and degree of polymerization affect the TP value of the material. The low TP value of ES groups may be explained by the fact that these fibers affect the light distribution and polymerization degree of the composite during polymerization with the glass structure (23).

Direct composites used in this study showed higher TP values than indirect composites. (p<0.001) This difference may be due to the matrix compositions and the polymerization techniques of the composites. Azzopardi et al. (23) and Perez et al. (24) showed that the organic matrix and filler particles could affect the opacity of the composite resins and that there was a linear correlation between the organic resin matrix and the translucency. Similarly, according to Lee (13), as the number of filler increases, transparency decreases and there is an inverse correlation between translucency and filler content. Polymerization techniques can also affect the color and translucency of the composite resins. It has been reported in different studies that different polymerization techniques may affect the color stability and optical properties of the composite resin (25,26). Based on these investigations, different matrix composition, and different polymerization techniques may be effective on different TP values between direct and indirect composite resins in this study.

As well as optical properties, the matrix structure, filler content and filler type of the composite resins effects their mechanical properties such as wear resistance, strength and modulus. FS had been widely used to define the mechanical properties of restorative materials (27, 28). Bi-axial flexure strength tests and three-point flexure tests are often used for this purpose. Chung et al. suggested the ISO three-point bending test, which is a more reliable method for polymer-based restoratives because of the low repeatability of the biaxial test, for evaluating FS value (29). The three-point bending test is based on the ISO specification no 4049/2000 (30). Although some studies recommended the alternative flexural test designs, the three-point bending test is still an important choice for evaluation of the composite resins flexural strength due to the lower coefficient of variation, the lower standard deviation, and the less complex stress (29,31).

In this study, CMP group showed the highest FS values in comparison between control groups. CMP is a highly loaded nanofill composite which is recommended for use in the posterior teeth. CMP's high filler volume (%92) and matrix content may explain high FS values. Although the average FS value of the CMP-R group was lower than the CMP-E, the difference was not significant as in other composites. In the study, the fibers were placed in the middle of the composite resin specimens. The thickness of high-filled CMP composite specimens may have reduced the effect of the fiber type. Therefore, although the addition of fiber reduces the FS values of the CMP samples, there may be no significant difference between the R and ES groups. The degree of polymerization of composite resin is also one of the factors affecting the FS value. It has been reported in the literature that composite resins polymerized by indirect methods show a higher degree of polymerization. In this study, despite the lower filler content (60% wt), Tescera specimens showing higher mean FS value than CME specimens (78% wt). This result may explain with a higher polymerization degree of Tescera indirect composite specimens.

Bae et al. (32) observed that the use of fiber in composite restoration increased the FS value. However, in this study the mean FS value of FRC groups in all composites was lower than the control groups. Therefore, the second null hypothesis for this study that fiber addition on direct and indirect composite resin would increase the FS of the restoration was rejected. This situation may be caused by fibers placed in the middle of the composite in this study. Fuji et al. (33) placed fibers in three different positions (top, middle, and bottom) in FRC in their study and noticed that placing fibers at the bottom of restoration provides the best effects. The fiber type and thickness also affect the FS value of restoration. The higher mean FS value in ES groups in the present study may be explained by the fact that the glass fiber is more compact and rigid than the polyethylene fiber. Sadeghi (34) advised that fiber content should be less than 60% for optimum results. Using too much fiber results in a decreased amount of resin matrix and decreased FS (35). In this study, the decrease in average TP value with the use of fiber may be related to the fiber-composite resin matrix ratio.

CONCLUSION

Within the limitations, the addition of fiber to composite resins may affect the optical and mechanical properties of the restoration. This effect varies depending on the structural properties of composite resin and fiber. This situation should be taken into consideration in the restoration; polyethylene fiber may be preferred especially in cases in aesthetic anterior restorations.

Conflict of interest : The authors declare that they have no competing interest.

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Ethical approval: Since this study was an in-vitro material study, it was stated that there was no need for ethics committee approval by the clinical research ethics committee.

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