Effects of light intensity and curing time of the newest LED Curing units on the diametral tensile strength of microhybrid composite resins

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Abstract. The aim of this study was to evaluate the influence of light intensity and curing time of the latest LED curing units on the diametral tensile strength of microhybrid composite resins. Sixty-three specimens from three brands (Polofil Supra, Filtek Z250, and Solare X) were divided into two test groups and one control group. The test groups were polymerized with a Flashmax P3 LED curing unit for one or three seconds. The control group was polymerized with a Ledmax 450 curing unit with the curing time based on the resin manufacturer’s instructions. A higher light intensity and shorter curing time did not influence the diametral tensile strength of microhybrid composite resins.

1. Introduction
Composite resin is one of the most common restorative materials used by dentists. There are many types of composite resins; one characteristic that varies among them is the filler size [1]. Also, there are hybrid types combining two filler sizes, macrofill and microfill, which are expected to have better mechanical and chemical properties than nonhybrid types. The main components of a composite resin material are an organic matrix, a filler, and a coupling agent [1]. In light-cured composites, a photo initiator is another important component. The most commonly used photo initiator is camphorquinone, it has a yellow color and affects the composite resin color; therefore, only a limited concentration can be used [2]. Thus, another photo initiator was developed: 1-phenyl-1,2-propanedione (PPD) [2]. Research has shown that PPD produces the same degree of conversion as camphorquinone when activated by a light-emitting diode (LED) curing unit [3,4]. The same research also proved that an LED curing unit could activate two types of photo initiators and produce the same degree of conversion [3,4]. Because of that, many dental companies have developed LED curing units.

Another factor that affects resin polymerization is the total energy absorbed during the polymerization process. The total energy (J/cm²) is calculated based on the multiplication of the intensity of transmitted light (mW/cm²) by the curing time (seconds) [2-5]. When the first LED curing unit was made, it produced a very low light intensity, so did not result in perfect composite resin polymerization. The first generation of LED curing unit was the Lux-O-Max (AKEDA Dental, Denmark), which produced 77 mW/cm² of light intensity [6]. The new LED curing unit introduced in 2010 needs only 1–3 seconds curing time of 4000–7500 mW/cm² light intensity [7]. The wavelengths of the new and old LED curing units are the same, about 440–490 nm with a wavelength peak of 470 nm. The difference between them is in their light intensity. The increase in light intensity in the new
LED curing unit is accompanied by a decrease in curing time, so it is expected to produce the same quality of polymerization.

The polymerization of light-cured microhybrid composite resins can be proven by mechanical testing through a diametral tensile strength test, which is an appropriate test for brittle materials such as composite resins [1]. When used as a restoration, especially in a posterior tooth, composite resin will be under tensile stress—which, if applied at a maximal pressure, would fracture the restoration [8]. The aim of this study was to evaluate the effects of light intensity and curing time of the newest LED curing unit (ultrahigh intensity) on the diametral tensile strength of microhybrid composite resins.

2. Materials and Methods

This experimental laboratory study used 63 microhybrid composite resin specimens from three brands: Filtek Z250 (3M ESPE, USA), Polofil Supra (VOCO GmbH, Germany), and Solare X (GC, Japan). The specimens were prepared in a stainless steel molds of 6 mm diameter and 3mm height. Each brand was represented by 21 specimens divided into 3 groups: a control group (curing time 20 or 40 seconds according to the manufacturer’s instructions), Group I (curing time 1 second), and Group II (curing time 3 seconds). The composite resin in the control group was cured with a Ledmax 450 LED curing unit (Benlioglu Dental Inc., Turkey) with a 450-mW/cm² light intensity, while Groups I and II were cured with a Flash Max P3 LED curing unit (CMS Dental A/S, Denmark) with a 1200-mW/cm² light intensity.

The composite resin was filled incrementally. The distance from the light tip to the composite resin surface was 0 mm. The measurements of diametral tensile strength were performed with a Universal Testing Machine (Shimadzu Autograph AG 5000 E, Japan) with a 250-kgf load and a speed of 0.5 mm/min. until the specimen was broken. The value when the specimen was broken was inserted into the formula $T_s = \frac{2P}{\pi dl}$. The results were analyzed using the Shapiro-Wilk normality test. The data that were normally distributed were analyzed with a one-way ANOVA and a post-hoc Tukey test. The tests employed a significance level ($p$) of 0.05 and a confidence level ($\alpha$) of 95%.

3. Results and Discussion

3.1 Results

Table 1. Mean and standard deviation of the diametral tensile strength of microhybrid composite resin

| Brand      | Group   | Diametral tensile strength (MPa) |
|------------|---------|---------------------------------|
| Polofil Supra | control | 45.916±4.485                    |
|            | I       | 44.218±2.747                    |
|            | II      | 47.005±4.880                    |
| Filtek Z250 | control | 50.297±4.573                    |
|            | I       | 49.099±1.625                    |
|            | II      | 45.432±4.444                    |
| Solare X   | control | 37.050±2.115                    |
|            | I       | 37.852±4.257                    |
|            | II      | 35.861±1.925                    |

Group I: 1 sec. of 1200-mW/cm² light intensity; Group II: 3 sec. of 1200-mW/cm² light intensity; Control group: 20 or 40 sec. of 450-mW/cm² light intensity

The average diametral tensile strength results from the groups of composite resin specimens can be seen in Table 1. The results from the one-way ANOVA within each composite resin brand showed that there are no significant differences between the controls, Group I and Group II. The results from the one-way ANOVA comparing the brands showed that there were significant differences between
Polofil Supra and Filtex Z250 in the control group and Group I. There was also a significant difference between Polofil Supra and Solare X in the control group, Group I, and Group II.

3.2 Discussion

Based on the measurements, the difference in curing time (along with the increase in light intensity) did not produce a significant difference in the microhybrid composite resin diametral tensile strength, as seen in Table 1. The resin polymerization results depended on the total energy absorbed during the polymerization process [2-5]. Based on this formula, if the curing time was decreased, light intensity must have increased to have the same total energy released. If the measurements had been done based on theory, the control group, which had 20 seconds of curing time (for the Filtex Z250 and Solare X group) with a light intensity of 450 mW/cm² (Ledmax 450LED curing unit), absorbed a total energy of 9 J/cm². Group I (Filtek Z250 and Solare X), which had a curing time of 1 second with a light intensity of 1200 mW/cm² (Flashmax P3LED curing unit), absorbed a total energy of 1.2 J/cm². Group II (Filtex Z250 and Solare X specimens), which had 3 seconds of curing time with a light intensity of 1200 mW/cm², absorbed a total energy of 3.6 J/cm².

For the microhybrid composite resin control group (Polofil Supra), the curing time was 40 seconds with a light intensity of 450 mW/cm² (Ledmax 450LED curing unit), the total energy absorbed was 18 J/cm². The total energy absorbed for the Group I Polofil Supra microhybrid composite resin, with 1 second of curing time and a light intensity of 1200 mW/cm², was 1.2 J/cm². Group II, with 3 seconds of curing time and a light intensity of 1200 mW/cm², absorbed a total energy of 3.6 J/cm². Theoretically, the same degree of conversion will result in the same mechanical properties of the composite resin if it receives the same total energy from any kind of curing unit [9]. Also, other studies have shown that the greater the total energy, the greater the composite resin’s Knoop hardness value [10]. The results of this study contradict those of a previous study [10] which shows difference in the total absorbed energy. However, that difference did not affect the diametral tensile strength in this study; the strength is likely affected by the differences in the tip size of the LED curing units. The Flashmax P3, with a light intensity of 1200 mW/cm², had an 8-mm-diameter tip, and the Ledmax 450, with a light intensity of 450 mW/cm², had a tip diameter of 10.5 mm.

The tip of the LED curing unit can affect the depth of the curing and the Knoop hardness [11]. That study states that for composite resins, an 8-mm tip can produce a greater depth of cure and a higher Knoop hardness than a 10-mm tip. This is because polymerization with a 10-mm tip needs additional curing time—about 10 seconds—to achieve the same depth of cure as an 8-mm tip [11]. With an 8-mm tip and a higher light intensity, the beam from the Flashmax P3 LED curing unit is sharper and more focused, so the polymerization can achieve the same diametral tensile strength as with the Ledmax 450. In terms of the color and the initiator, the three composite resins was used in this study have the same color (shade A2) and use the same photo initiator (camphorquinone). Thus, the difference in the diametral tensile strength can also be affected by the differences in the organic matrix and the composition of the inorganic filler. The three composite resins studied have a UDMA monomer as the organic matrix component. Besides UDMA, Polofil Supra composite resin also contains bis-GMA, TEGDMA, and HEMA. Filtex Z250 composite resin contains bis-EMA and UDMA. Solare X composite resin contains only UDMA as an organic matrix. Because the organic matrices contained in the composite resins are not so different, the average diametral tensile strengths of the three composite resins are not significantly different when compared, especially Polofil Supra and Filtex Z250. The statistically significant difference was found only in Group I (curing time 1 second) and the control group, not in Group II (curing time 3 seconds).

The difference found between Group I and the control group exists because they have the same component in their organic matrix (UDMA). Filtex Z250 has a bis-EMA monomer that is similar to the bis-GMA monomer in Polofil Supra [12]. The filler size in both is similar, as is the percentage of inorganic filler. Polofil Supra has a filler percentage of about 76.5 wt%, and Filtex Z250 has a filler percentage of about 78 wt%. The diametral tensile strength measurement of Group I showed that the tensile strength of Polofil Supra is lower than that of Filtex Z250; this is because there are many
TEGDMA components in Polofil Supra. Composites with more TEGDMA than UDMA or bis-GMA have lower diametral tensile strengths than composites with more UDMA [13]. If TEGDMA is replaced by UDMA and bis-EMA, the degree of cure in polymer matrix can increase, so the wear resistance can also increase [14].

A significant difference was also seen between Polofil Supra and Solare X and between Filtex Z250 and Solare X. Previous studies stated that the smaller the filler size, the better the mechanical properties of the composite resin [15,16]. However, the filler sizes in the three composite resins used in this study were nearly the same. Therefore, the differences in the diametral tensile strength in this study may have been affected by the prepolymerized filler in Solare X composite resin. The filler loading in the three composite resins was nearly the same, about 77wt%. However, if the total filler loading in Solare X is 77wt%, and it already includes prepolymerized filler, the total percentage of inorganic filler is lower than 77wt% (lower than the other two brands). This accords with a previous study stating that a lower percentage of inorganic composite resin filler leads to poor mechanical properties of the composite resin [17]. Other studies have also found that composite resins containing a prepolymerized filler have worse mechanical properties than universal hybrid resins, because the composite resins have a lower percentage of inorganic filler [18].

4. Conclusion
Based on the results, it can be concluded that the higher light intensity and shorter curing time of the newest generation of LED curing units did not influence the diametral tensile strength of microhybrid composite resins. Polymerized resins using the latest LED curing units produced the same diametral tensile strength as microhybrid composite resins that were polymerized using older LED curing units.

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