Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

The effect of the curing time of an ultra-high intensity LED curing unit on diametral tensile strength of packable composite resin

To cite this article: A Nurlatifah *et al* 2018 *J. Phys.: Conf. Ser.* **1073** 052007

IOP Conf. Series: Journal of Physics: Conf. Series **1073** (2018) 052007 doi:10.1088/1742-6596/1073/5/052007

The effect of the curing time of an ultra-high intensity LED curing unit on diametral tensile strength of packable composite resin

A Nurlatifah, Y K Eriwati* and D J Indrani

Department of Dental Materials, Faculty of Dentistry, Universitas Indonesia, Jakarta, 10430, Indonesia

*Email: yosiarianto@gmail.com

Abstract. This study aimed to evaluate the influence of the curing time of a light emitting diode (LED) curing unit on the diametral tensile strength of packable composite resin with 1 second–3 seconds from an ultra high intensity LED (Flash Max, intensity 4000 mW/cm^2) and 20 seconds from a conventional LED (Ledmax 450, intensity 450 mW/cm^2). We used an universal testing machine and the results showed a diametral tensile strength of 31.19 ± 6.84 MPa; 42.91 ± 8.26 MPa; and 52.53 ± 7.52 MPa. The result of an independent t-test was statistically significant ($p < 0.05$). We concluded the curing time of an ultra high intensity LED curing unit influences the diametral tensile strength of packable composite resin

1. Introduction

Patients' demands for composite resins are increasing, along with their concerns about the toxicity of mercury [1]. Composite resins have several advantages, such as high aesthetic properties, a low thermal expansion coefficient, dimensional changes during low hardening, and high wear resistance [2]. Composite resins are also often used not only for anterior dentures alone but also to replace posterior dental restorations as well as amalgam [1]. Composite resin is differentiated into flowable composite resin and packable composite resin, based on its viscosity. The former has slightly more filler content than other composite resins (about 50% by volume), lower mechanical properties, and high shrinkage polymerization rates [3], whereas the latter has high filler content and matrix viscosity using various monomers. Based on the filler content, this material is superior both physically and mechanically [4,5]. Furthermore, packable composite resins can be condensed, are not attached to the dental tools, have a high viscosity as amalgam, and a low interproximal gap compared with other posterior composite resins [4]. However, the disadvantages of packable composite resin include a lower aesthetic value when applied to anterior teeth and less adaptation between one layer and another, such that the bulk-fill all at once technique is recommended for packable composite resin [1, 6].

The hardening of light activation resin requires a light curing unit (LCU) to start the polymerization process [7,8]. The increase in the use of composite resins has caused a concomitant increase in the use of the LCU. Currently, the most commonly used type of LCU is the light emitting diode (LED) curing unit with an average curing time of 20 seconds–40 seconds. Recently, an LED curing unit with a high intensity and a short curing time was developed. In 2010, an ultra high intensity LED curing unit was introduced with curing procedures of 1 second and 3 seconds, and an intensity of 4000 mW/cm^2–5000 mW/cm^2 [2]. Due to the short curing time, this LED is beneficial to both operator and patient, because it reduces the necessary working time in the clinic. However, its strength remains to be tested on packable composite resins.

The result of polymerization of composite resin is assessed based on its mechanical strength. Brittle materials—such as composite resins—are assessed by testing their diametral tensile strength. When used as posterior restoration material, packable composite resin must have greater compressive and tensile strength because it must withstand large occlusal loads. Therefore, this study observed the effect of the curing time with an ultra-high intensity LED curing unit on the diametral tensile strength of packable composite resin, by evaluating the effect of the duration of the curing time of an ultra-high intensity LED curing unit and that of an LED conventional curing unit on the diametral tensile strength of packable composite resin. This study aimed to discover whether the difference in the curing time of the LED curing unit affected the diametral tensile strength of the packable composite resin.

2. Methods

This study was a laboratory-based experimental study conducted in the Dental Materials Laboratory, Faculty of Dentistry, Universitas Indonesia between August 2014 and September 2014. Composite resin (Filtek P60 3M ESPE, USA) was used and poured into stainless steel molds (diameter 6 mm, height 3 mm). The number of specimens was determined based on the Federer formula—that is—1 group containing 9 pieces. The total number of specimens was 27 pieces (from three groups). One brand consisted of 1 comparison group and 2 treatment groups.

The tools and materials used in this study were: molds with a diameter of 6 mm and a thickness of 3 mm, plastic filling, glass preparates, a 500 mg load, plastic pots, a LCU (LED Flashmax P3 Hexagon, Denmark) with curing times of 1 second and 3 seconds, a LCU (LED Ledmax 450, Hilux, Benlioglu Dental Inc., Kulzer, India) with a curing time of 20 seconds, packable composite resin (Filtex P60 3M ESPE, USA), and a universal testing machine (Shimadzu Autograph AG 5000 E, Japan) for the diametral tensile strength test.

The LED curing units Ledmax 450 and Flashmax P3 were measured in advance using a radiometer to determine their respective intensities before the curing process. Packable composite resin (Filtex P60 3M ESPE, USA) was used. The specimen, which was cylindrical with a diameter of 6 mm and a thickness of 3 mm, was placed on a stainless steel mold which had been previously washed and dried. The prepared resin material was placed on the mold using plastic filling and the bulk technique. Then, the surface of the resin was coated with mylar plastic to create a flat surface. The surface of the resin was covered with glass preparate and pressed it with a load of 500 grams to remove the excess material.

In treatment group I, the curing was performed for 1 second using the LED curing unit (Flash Max P3 Hexagon, Denmark). In treatment group II, the same placement/filling procedures and LCU tools were used. However, the duration of the curing time of the specimens was 3 seconds. For group III (the comparison group), the placement procedure was also the same. However, the curing process was performed using a different LED curing unit (Ledmax 450, Hilux, Benlioglu Dental Inc., Kulzer, India) for 20 seconds. The specimen and the excess was released from the mold, and the edges of the composite resin material was cleaned. Thereafter, the specimens were immersed in a plastic pot containing aquades, and stored in an incubator at 37 °C for 24 hours.

The diametral tensile strength of the composite resin was tested using a universal testing machine (Shimadzu Autograph AG 5000 E, Japan). Before the test, the specimen diameter and thickness were measured with a caliper. Each specimen was measured three times to arrive at an average value. The specimen was then placed on the machine with the load in an upright position. The specimens were loaded continuously with 250 kgf at a rate of 0.5 m/min until broken. The maximum load value was obtained just before the specimen was broken. The calculation was done by using the diametric tensile strength formula: $2P/\pi Dt$, where P is the load given, D is the specimen diameter, and t is the specimen thickness.

To analyze the result statistically, an independent t-test was used to determine whether or not the difference was statistically significant.

3. Results

The cylindrical packable composite resin specimens (Filtex P60 3M ESPE, USA) comprised group I, which was cured with an LED curing unit (Flash Max P3 Hexagon, Denmark) for 1 second, group II, which was cured with the same LED curing unit (Flash Max P3 Hexagon, Denmark) for 3 seconds, and group III (comparison group), which was cured with a different LED curing unit (Ledmax 450 Hilux, Benlioglu Dental Inc., Kulzer, India) for 20 seconds. The resulting diametral tensile strengths are shown in Table 1.

Table 1. Mean diametral tensile strength of composite resin Filtex P60 with curing times of 1 second and 3 seconds and intensity of 1200 mW/cm^2, and curing time of 20 seconds and intensity of 420 mW/cm^2

Material	Diametral tensile strength (MPa)		
	Group I 1 second (LED Flash Max P3)	Group II 3 seconds (LED Flash Max P3)	Group III 20 seconds (LED Ledmax 450)
Packable composite resin	31.1 ± 6.84	42.9 ± 8.26	52.5 ± 7.52

Table 1 show the difference between diametral tensile strength in groups I and II, which were cured with the same LED curing unit (Flashmax P3 Hexagon, Denmark) for 1 second and 3 seconds, respectively, and group III/comparator which was cured with a different LED curing unit (Ledmax 450 Hilux, Benlioglu Dental Inc, Kulzer, India) for 20 seconds.

The independent t-test analysis (table 2) revealed a significant difference between the means of the diametral tensile strengths of the specimens ($p < 0.05$) for the three groups.

Table 2. The effect of different curing times on the diametral tensile strength of packable composite resin

Specimen Group	**p-value**	**Description**
Group I–Group II	0.005*	significantly different
Group II–Group III	0.020*	significantly different
Group III–Group I	0.000*	significantly different

Information* = significant difference ($p < 0.05$)

Based on The mean value of the diametral tensile strength for group I (the group of specimens which was cured with an LED curing unit (Flash Max P3) for 1 second) and that for group II (the group of specimens which was cured with the same LED curing unit (Flash Max P3) for 3 seconds) showed a significant difference. The mean value of the diametral tensile strength for group I (the group of specimens which was cured with an LED curing unit (Flash Max P3) for 1 second) and that for group III/comparator (the group of specimens which was cured with a different LED curing unit (Ledmax 450) for 20 seconds) showed a significant difference also, as did that for Group II (the group of specimens which was cured with an LED curing unit (Flash Max P3) for 3 seconds) and that for the group III/comparator (the group of specimens which was cured with a different LED curing unit (Ledmax 450) for 20 seconds).

4. Discussion

The group of specimens which was cured by an LED curing unit (Flash Max P3 Hexagon, USA) for 1 second, the group of specimens which was cured by an LED curing unit (Flash Max P3 Hexagon, Denmark) for 3 seconds and the group of specimens/comparator cured by an LED curing unit (Ledmax 450 Hilux, Benlioglu Dental Inc., Kulzer, India) delivered diametral tensile strength values of 31.1 ± 6.84 MPa; 42.9 ± 8,264 MPa; and 52.5 ± 7.52 Mpa, respectively. Statistically the diametral tensile strength values of these groups were significantly different ($p < 0.05$).

When measured by the radiometer, the intensity of the LED curing unit (Flash Max P3) was lower than that described in the information contained in the packaging and the product manual. According to the product packaging, the intensity of the LCU Flash Max P3 tool delivers 4000 mW/cm^2, but when we measured it using a large radiometer, the intensity was 1200 mW/cm^2 only, which affected the total energy of the emitted rays.

The total light energy is the multiplication of the intensity with the length of time. Many studies have confirmed the greater the total light energy on the composite, the more complete the polymerization that occurs [9]. According to Booksman to achieve the optimum degree of polymerization of composite resins, the energy required ranges from 17 J/cm^2 to 20 J/cm^2 [10]. The magnitude of the light intensity (mW/cm^2), the duration of the curing time, and the distance between the light tip and the surface of the composite resin all influence the total light energy emitted. According to Niepraschk et al. and Dall'Igna et al. the degree of resin polymerization has a close relationship with the duration of light curing time rather than with the intensity of the emitted light [11].

When viewing the intensity and the duration of the curing time of each group in this study, the total energy received by group I specimens—cured by LED (Flash Max P3) with an intensity of 1200 mW/cm^2 and a curing time of 1 second—was 1.2 J/cm^2. The total energy received by group II specimens—cured by LED (Flash Max P3) with an intensity of 1200 mW/cm^2 and a curing time of 3 seconds—was 3.6 J/cm^2, while the energy received by group III—cured by LED (Ledmax 450) with an intensity of 420 mW/cm^2 and a curing time of 20 seconds—was 8.4 J/cm^2. This study clearly demonstrated—based on the amount of the total light energy—the group of specimens that received a high amount of total light energy would have a high diametral tensile strength as well, while the group receiving low total light energy would have a lower diametral tensile strength (Table 1). This is supported by the assertion that low total light energy will result in a low conversion degree of composite resin and low mechanical composite resin properties [12].

Group III which was cured by LED Ledmax 450 for 20 s had the highest composite resin tensile strength compared to groups I and II which were cured with LED Flash Max P3 for 1 seconds and 3 seconds. The curing time of the composite resin in this group was longer, so that the molecules could be activated and start the polymerization process, and the heat generated could initiate the propagation process (chain extension), thereby increasing the LCU polymerization and depth of cure levels and heightening the conversion degree of the composite [7,8,13,14]

Judging by the specimen forms after the curing process, the base shape of group I specimens was still slightly soft. In group II and group III/comparator, the specimen base forms were harder. This shows the duration of the curing time was associated with the depth of cure, thereby reaching the base of the composite resin during the polymerization process.

The research undertaken by Rahman et al. investigating the depth of the composite resin curing (Filtek P60) that was cured using the LED curing unit (Flash Max P3) found that it incrementally produced a thorough polymerization compared to other composite resins (for posterior teeth) [9]. Razooki et al. used composite resin (Filtex P60) with an incremental curing process (1.5 mm) using C5 bluephase LED (Ivoclar, Vivadent AG FL-9494 Schann/Liechteinsein, Austria), an intensity of 400 mW/cm^2, and a curing time of 40 seconds, and obtained a diametric tensile strength value of 55.8 ± 8.47 MPa [15]. In this study, we used the bulk/simultaneous technique with a thickness of 3 mm; the possibility, therefore, exists the composite resin was not fully cured after 1 second of curing time by the LED curing unit (Flash Max P3) and this resulted in imperfect polymerization. The diametral tensile strength of the composite resin (Filtex P60) which was incrementally cured in Razooki's study did not differ greatly from that of our bulk/simultaneous method; in our study it was 52.5 ± 7.52 MPa. According to Gharma, the depth of cure is the thickness of the resin that is converted from monomer to polymer under a light cure [11]. Several factors—such as the type of composite resin, its color, thickness, radiation distance, and particle size, and the distribution of the filler—all influence the depth of cure [16].

The complete polymerization process affects the mechanical properties of the composite resin, including its diametral tensile strength. Polymerization is related closely to the degree of conversion—that is, the percentage of a double chain of carbon transformed into a single chain to form a resin polymer—or, in this case, the percentage of the methacrylate group formed in the composite resin [7,8]. According to Caselli et al. there is a positive correlation between the degree of conversion of a monomer (degree of conversion) and its composite mechanical properties, such as fracture resistance, and degree of surface conversion [17]. Many factors—including monomer composition, light intensity, and filler content in the resin matrix, the transmission of light through the material, and the magnitude of the activator/initiator and the inhibitor—influence the degree of conversion of composite resin [17]. Many studies have shown the degree of conversion depends more on the total light energy to which the composite resin is exposed than on the light curing method, such as soft start, pulse delay, or ramp cure [11].

Although the advantage of the LED curing unit (Flash Max P3) lies in having a very high intensity of 4000 mW/cm^2–5000 mW/cm^2, with a curing time of 1 second–3 seconds, there is not much research showing the success of the tool in the complete polymerization of composite resins, particularly on packable resins [9]. In addition to the diametral tensile strength test, the hardness of the packable composite resin exposed to LED curing units (Flash Max P3 Hexagon, Denmark) in bulk needs further investigation. Similarly, high intensity LED curing units (>1000 mW/cm^2) need to be retested using a radiometer to determine the accuracy of the intensity.

5. Conclusion

There is a significant difference in the diametral tensile strengths of the composite resins which were cured with an LED curing unit of ultra-high intensity for 1 second and for 3 seconds and which was cured by the conventional LED curing unit for 20 seconds.

6. References

[1] Joseph CC and Blaine CN 2003 *Clinical Update*. **25**
[2] Craig RG and Powers JM 2012 *Restorative Dental Materials*.13th Ed. (St Louis: Mosby) pp 228, 229,232,234,242,247
[3] Sensi LG, Strass HE and Webley W 2007 Direct composite resins *Inside Dentistry*. **3** 76
[4] Kilaru KR, Hinduja D, Kisyooe KH, Kumar S and Rao RN 2012 Comparative evaluation of compressive strength, vickers hardness and modulus of elasticity of hybrid and packable (condensable) posterior composites - an in-vitro study *AED*. **4** 9–16
[5] Kelsey, WP, Latta, MA, Shaddy, RS and Stainslav, CM 2000 Physical properties of three packable resin-composite restorative materials *Oper. Dent*. **25** 331–5
[6] García AH, Lozano MA, Vila JC, Escribano AB and Galve PF 2006 Composite resins. A review of the materials and clinical indications *Med. Oral. Patol. Oral. Cir. Bucal*. **11** E215–20
[7] Anusavice KJ 2003 *Phillip's Science of Dental Materials*. 11 ed. (St. Louis: Elsevier Science) pp 88, 201, 202, 217
[8] D Ariani, E Herda and Y K Eriwati 2017 Effects of light intensity and curing time of the newest LED Curing units on the diametral tensile strength of microhybrid composite resins *J. Phys.: Conf. Ser.* **884** 012106
[9] Majeed MA, Al-Shamma AM and Abd-Awn BH 2012 The laboratory dental cutting rates in comparison with the clinical dental cutting rates and the cutting rates on a new suggested training block *J. Bagh. College. Dentistry.* **24** 15–21
[10] Boksman L and Santos GC 2012 Principles of light-curing *Inside Dentistry.* **8** 94-97
[11] Chowdhary V, Shah N, Sharma A and Mandlik J 2014 *International Journal of Dental and Health Sciences* **1** 493–9

[12] Correr AB, Mario ACS, Lourenco CS, Rubens NT, Luis FJS and Simonides C 2005 effect of the increase of energy density on knoop hardness of dental compositelight cured by conventional QTH, LED and xenon plasma are *Braz. Dent. J.* **16**
[13] Namoto R, McCabe JF, Nitta K and Hirano S 2009 Relative efficiency of radiation sources for photopolymerization *Odontology*. **97** 109–114
[14] Olivera M, Morais A, Franca FA and Arrais CA 2009 Comparison between halogen light and led curing units: the degree of conversion of one nanofilled resin composite Revista Saude **3** 1–4
[15] Al Shekhil AA and Isra'a A 2009 *JIMD.* **2** 1–4
[16] Flury S, Hayoz S, Peutzfeldt A, Hüsler J, Lussi A 2012 Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? *Dent. Mater.* **28** 521–8
[17] Casselli DS, Worschech CC, Paulillo LA and Dias CT 2006 Diametral tensile strength of composite resins submitted to different activation techniques *Braz. Oral. Res.* **20** 214-8