Effect of resin thickness and light-curing distance on the
diametral tensile strength of short fibre-reinforced resin composite

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Abstract. This study analyzed the effect of short fibre-reinforced resin composite (SFRC) thickness and light-curing distance on diametral tensile strength. A total of 40 disk-shaped SFRC specimens 3 and 4 mm thick and 6 mm in diameter (n = 20) were divided into two different light-curing distance groups of 2 and 4 mm (n = 10), respectively. All specimens were polymerized using a light-emitting diode (LED) curing unit at irradiance 800 mW/cm² for 20 s. Specimens were tested using a universal testing machine to determine the diametral tensile strength. Diametral tensile strengths were 43.04 ± 1.53 and 41.77 ± 1.79 MPa in the 3-mm thickness groups with 2- and 4-mm light-curing distances, respectively, compared with 42.30 ± 1.77 and 39.46 ± 1.90 MPa, respectively, in the 4-mm thickness groups. There was a significant difference in diametral tensile strength in the 4-mm thickness group with a 4-mm light-curing distance using one-way analysis of variance (ANOVA) and post-hoc Fisher’s least significant difference (LSD) tests. It is concluded that SFRC thickness and light-curing distance have an effect on diametral tensile strength.

1. Introduction
Fibre-reinforced composite is resin composite incorporating fibre as a reinforcement [1]. Fibre-reinforced composite currently is used in restorative dentistry as a dentin substitute (substructure), especially for large restorations in posterior teeth. This is due to its fracture resistance, which is equivalent to that of dentin structure [2]. A new type of short randomized fibre-reinforced resin composite (SFRC; EverXPosterior™) consists of 23% matrix and 77% inorganic particulate fillers by weight. The matrix contains bisphenol A-glycidyl methacrylate (Bis-GMA), triethylene glycol
dimethacrylate (TEGDMA), and polymethyl methacrylate (PMMA), forming a matrix called a semi-interpenetrating polymer network (semi-IPN) that provides good adhesive bonding properties between the matrix and filler [2,3]. Furthermore, this SFRC consists of inorganic particulate filler, that is, barium borosilicate glass and E-glass fibres. The average length of E-glass fibre is between 1 and 2 mm, with a diameter of 17 µm [4]. The fibre-reinforcement in SFRC improves the toughness of the polymer matrix. In addition, the fibre exceeds what is called a “critical length,” so that it can resist crack initiation and propagation [1,4].

The success of restoration depends on the mechanical properties of the material, such as general, compressive, flexural, shear, and tensile strengths [5]. These listed strengths are very important for the resin composite in accepting chewing forces and resisting fracture. A study on mechanical properties of SFRC stated that the fracture toughness of SFRC is significantly higher than that of conventional glass-filled and bulk-fill resin composites. The depth of cure (DoC) of SFRC is similar to that of the bulk-fill resin composite, specifically reaching 4.02 mm based on ISO 4049 [3].

The degree of conversion has an important role in enhancing physical and mechanical properties, color stability, and biocompatibility of resin composite restorations. Many factors affect the degree of conversion, including the shades; thickness; light-curing duration, distance and source; and cavity diameter and location [6]. One method to identify the strength of a restoration material on posterior teeth is the diametral tensile strength test. Tensile strength is the strength of a material to withstand maximum load in forms of stretch or pull before the material breaks [7].

This study analyzed the effect of SFRC thickness and light-curing distance on diametral tensile strength.

2. Methods
A total of 40 disk-shaped specimens of SFRC (EverXPosterior™; GC Corp., Tokyo, Japan; batch number, 1703293) were prepared and divided into two thickness groups: 3 mm; and 4 mm (n = 20). Stainless steel molds 6 mm in diameter with two different thicknesses (3 and 4 mm) were used to prepare the specimens. Silicone oil was smeared into the mold as a separation media, then the mold was filled with the SFRC using a plastic filling instrument. Then, the top side of the mold was covered with a mylar strip and a glass microscope slide. Specimens were pressed for 30 s with load of 1 kg [8]. The light source irradiance was measured before being used, using a radiometer (Hilux LEDMAX) to verify its irradiance. Each group was divided into two subgroups cured at different light-curing distances (2 and 4 mm; n = 10) using a plastic stopper. Then, all specimens were cured under the mylar strip using a light-emitting diode (LED) light-curing unit (Hilux LEDMAX) with an irradiance of 800 mW/cm² for 20 s [4]. After polymerization, the specimens were pushed out from the mold, then wet-stored in an incubator at 37 °C for 24 h before testing [9].

After 24 h of storage, the specimens were dried using tissue paper. Then each specimen was placed on the universal testing machine (UTM) and loaded at 250 kgf with a crosshead speed of 0.5 mm/min until fracture occurred [10]. The maximum load value obtained until the fracture occurred on the specimen was calculated using the diametral tensile strength formula \( \sigma_d = 2P/\pi t DT \) (1).

The result of calculation using the formula was converted into units of megapascals (MPa), multiplied by 9.8, and was considered the diametral tensile strength value of each specimen.

Statistical data tests were done using one-way analysis of variance (ANOVA) followed by post-hoc Fisher’s least significant difference (LSD) test with a significance value of \( P < 0.05 \).

3. Results
Mean diametral tensile strength values and standard deviations of SFRC with 3 and 4 mm thicknesses and light-curing distances of 2 and 4 mm are shown in Table 1 and Fig. 1.
Table 1. Mean diametral tensile strength values and standard deviations of SFRCs of various thicknesses and light-curing distances

| Depth (mm) | Curing Distance (mm) | Diametral Tensile Strength Mean ± SD (MPa) |
|------------|----------------------|------------------------------------------|
| 3          | 2                    | 43.04 ± 1.53                             |
|            | 4                    | 41.77 ± 1.79                             |
| 4          | 2                    | 42.30 ± 1.77                             |
|            | 4                    | 39.46 ± 1.90                             |

Figure 1. Diametral tensile strength of SFRCs of various thicknesses and light-curing distances

Table 1 shows the difference in values of SFRC diametral tensile strength in every group. The difference in diametral tensile strengths of 3-mm thick SFRC specimens with 2- and 4-mm light-curing distances (43.04 and 41.77 MPa, respectively) was not significant. The diametral tensile strength of the 4-mm thick SFRC specimen with a 2-mm light-curing distance also was not significant (42.30 MPa). The 4-mm thick SFRC specimen with a 4-mm light-curing distance showed a decrease in diametral tensile strength to 39.46 Mpa, which was significantly different from the strength of the 4-mm thick, 2-mm light-curing distance specimen and the 3-mm thickness group. Therefore, the diametral tensile strength value of SFRC was decreased by increasing SFRC thickness and light-curing distance.

4. Discussion
In this study, the specimen was polymerized using an LED curing unit with an irradiance of 800 mW/cm² for 20 s (total energy 16 J/cm²). The depth of polymerization had a significant influence on the light-curing distance and resin composite thickness. Light-curing distance reduces the total energy received by the resin composite. Furthermore, the specimen will not be homogeneously polymerized. With further distances, the bottom surface would receive less total energy. The light-curing distance causes an empty space filled with air on the upper surface of the resin composite. The light is due to an index bias difference between air and the resin composite surface, and refraction of light will occur resulting in the decrease in total energy received by the resin composite surface [6,11,12]. Therefore, our study showed that the further the distance, the lower the diametral tensile strength values.
Another factor that influences the depth of polymerization includes resin composite thickness [6]. In a study on the DoC of SFRC, with polymerization using an LED curing unit at a distance of 0 mm above the mylar strip, irradiance of 800 mW/cm² for 20 s (total energy 16 J/cm²), and SFRC thicknesses of 3 and 4 mm, a significant difference in DoC was found (81.0% and 78.2%) [13]. The polymerization depth of 81.0% was considered adequate to provide the hardness and strength that were acceptable for clinical application of the resin composite. In our study, a total energy of 16 J/cm², distance 2 mm, and SFRC thickness 3 mm produced a diametral tensile strength of 43.04 MPa. Diametral tensile strength with a 4-mm thick SFRC decreased to 42.30 MPa. This is because the depth of polymerization decreased to 78.2% for specimens 4 mm thick [13]. The increasing resin composite thickness caused the total energy received by the specimen to decrease due to reflection, dispersion, and distribution of light by filler particles, and to the bias index difference between matrix and filler particles [14].

The manufacturer stated that SFRC can be restored to 4 mm using the bulk technique and irradiance of 700 can be restored to 1200 mW/cm² using LED-light control units (LCU) with a curing time of 20 s (total energy of 14-24 J/cm²) [4,15]. A resin composite will layer the upper surface of SFRC with a thickness of 1 to 2 mm, so the light-curing distance will be 2 mm. This study used an irradiance of 800 mW/cm² and 20 s of curing time (total energy 16 J/cm²) to produce a 77% depth of polymerization [16]. In this study, the same total energy, 4-mm SFRC thickness, and 2 mm distance would cause a lower diametral tensile strength value than would occur with a 3-mm SFRC thickness. To achieve 80% depth of polymerization, the total energy must be increased so that the diametral tensile strength with a 4 mm thickness may increase to equal the 81% depth of polymerization attained with a 3-mm SFRC thickness.

5. Conclusion
In conclusion, the resin composite thickness and light-curing distance had a significant effect on diametral tensile strength of SFRC. This strength decreases as the SFRC thickness and light-curing distance increase.

References
[1] Vallittu P K 2013 Fibre-reinforced composites (FRCs) as dental materials. In: Woodhead Publishing Series in Biomaterials. (Finland: Woodhead Publishing Limited) pp. 352–64
[2] Garoushi S, Säilynoja E, Vallittu P K and Lassila L 2013 Physical properties and depth of cure of a new short fibre reinforced composite Dent. Mater. 9 835–41
[3] Tsujimoto A and Takamizawa T 2016 Mechanical properties, volumetric shrinkage and depth of cure of a new short fibre-reinforced resin composite Dent. Mater. J. 35 418–24
[4] GC Asia Dental EverX Posterior [Internet]; 2016. www.dibateb.com. Available at: http://sea.gcasiadental.com/everx-posterior.html. [Last accessed 18 April 2017]
[5] Powers J M and Wataha J C 2013 Dental Materials Properties and Manipulation. 10th ed. (St. Louis: Mosby Elsevier) pp 17-18, 42-43, 224
[6] AlShaafi M M 2017 Factors affecting polymerization of resin-based composites: A literature review Saudi Dent. J. 29 48–58
[7] Anusavice K J and C Shen H R 2012 Phillips’ Science of Dental Materials. 12th ed. (St. Louis: Elsevier) pp 58 277
[8] Nagi S, Moharam L and Zaazou M 2015 Effect of resin thickness, and curing time on the micro-hardness of bulk-fill resin composites J. Clin. Exp. Dent. 7 600–4
[9] Della Bona A, Benetti P, Borba M and Cecchetti D 2008 Flexural and diametral tensile strength of composite resins Braz. Oral. Res. 22 84–9
[10] Sood A, Ramarao S and Carounanidy U 2015 Influence of different crosshead speeds on diametral tensile strength of a methacrylate based resin composite: An in-vitro study J Conserv Dent. 18 214–8
[11] Dunne S M and Millar B J 2008 Effect of distance from curing light tip to restoration surface on depth of cure of composite resin Prim. Dent Care. 15 147–52
[12] Malik A H and Baban L M 2014 The effect of light curing tip distance on the curing depth of bulk fill resin based composites J. Bagh. Collage Dent. 26 46–53
[13] Andjani A N 2016 (Jakarta: Universitas Indonesia) Effect of resin thickness on the depth of cure of fibre-reinforced resin composite as substructure. Undergraduate Thesis
[14] Malhotra N AND Mala K 2010 Light-Curing Considerations for Resin-Based Composite Materials: A review Part II Compend Contin Educ. Dent. 31 584–8, 590-1
[15] Pamphlet everx posterior [Internet]; 2016. www.dibateb.com. Available at: http://www.dibateb.com/wp-content/uploads/2016/01/FAQ-everx-posterior.pdf. [Last accessed 10 september 2017]
[16] Sharfina L. 2016 (Jakarta: Universitas Indonesia) Effect of light-curing distance on the depth of cure of fibre-reinforced composites as substructure Undergraduate Thesis