

Research article

Differences in compressive strength between composite resins bulk-fill with bulk-fill fiber composite resin

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Abstract: Dental and oral health problems in Indonesia are currently quite high, one of the most common dental and oral diseases is dental caries. Teeth that have been affected by caries need special attention to be treated. Considerations in selecting the filling material also need to be taken into account so that it has the ability to withstand large chewing loads and does not fracture easily. Restoration materials that are good and can restore aesthetic function are what society needs, one of these materials is composite resin. This composite resin can be applied directly into the cavity and its color can resemble natural teeth. to determine the difference in compressive strength between bulk-fill composite resin and bulk-fill fiber composite resin. The research used was laboratory experimental with a post-test only design. This research involved 2 composite resins, namely bulkfill composite resin as group I and bulkfill fiber composite resin as group II. Samples with a cylindrical tube shape have a diameter of 4 mm and a height of 6 mm, 10 samples per group, then the samples are soaked in distilled water and then placed in an incubator at a temperature of 37° for 24 hours. This was followed by each sample being tested for compressive strength using a Universal Testing Machine until it was crushed. Group I compressive strength was 223.28 Mpa and Group II was 403.9 Mpa. Data analysis used the parametric independent t-test with $p = 0.00$ where $p < 0.05$, which means the difference in compressive strength obtained was significant between bulkfill composite resin and bulkfill fiber. the compressive strength of bulkfill fiber composite resin is greater than bulkfill composite resin.

Keywords: *Composite resin, compressive strength, bulk-fill, fiber bulk-fill*

INTRODUCTION

Dental and oral health problems in Indonesia are currently quite high, one of the most common dental and oral diseases is dental caries. Teeth that have been affected by caries need special attention to be treated so that the teeth remain in the

oral cavity. Based on The Global Burden of Disease Study 2016, dental and oral health problems, especially dental caries, are a disease that affects almost half of the world's population, 3.58 billion people. According to 2018 Riskesdas data, the prevalence of caries in Indonesia is 88.8% with a prevalence of root caries of 56.6%. It can be concluded that the prevalence of caries tends to be high (above 70%) in all age groups.

One of the treatments for dental caries is to carry out restorative treatment so that masticatory function can be restored, the anatomical shape of the teeth, color, aesthetics, phonetics, and the patient's self-confidence can be maintained (Sofiani and Rovi 2020). Considerations in selecting the filling material also need to be taken into account so that it has capability to withstand large chewing loads and not easily fracture. The use of composite resin in dentistry has continued to increase significantly in recent years due to patient demand for tooth-colored restorations that have good chewing strength.

Composite resin can be used to restore the shape and function of teeth because it has good aesthetics, the material's ability to bond with the hard tissue structure of the tooth, its color resembles natural teeth, and it can be applied directly into the cavity and the resulting restoration is very satisfying. The disadvantage of composite resin is polymerization shrinkage. This can occur due to the conversion of monomers into polymers when activated by blue light which can reduce the free volume of the composite resin, resulting in a gap between the restoration material and the tooth structure (Sofiani and Rovi 2020).

Researchers in the field of dentistry continue to develop the latest innovations in improving the use of composite resin restoration materials. Bulkfill composite resin is a composite resin that was developed in 2010. This type of composite resin can be polymerized and applied in one batch (bulk technique) to a depth of 4-5 mm, because the factory modifies the composition of the initiator and reduces the amount of filler to increase polymerization (Please 2017). This is different from conventional composite resin which must be exposed to light for each resin condensation to a depth of 2 mm. Bulkfill composite resin contains modifiers such as shrinkage stress relievers which reduce the level of

polymerization shrinkage thereby reducing microleakage which can cause secondary caries (Noviyani et al. 2018).

Composite resin Bulkfill can be illuminated to a depth of approximately 4 mm, because the color is 15% translucent which makes it easier for light to penetrate deeper layers (Mackenzie 2009). Bulkfill composite resin is more profitable, especially for dentists and patients because the advantage of this resin is that it is easy to apply, can minimize dental treatment time and does not form empty spaces in the filling cavity as a restoration for posterior teeth, does not form voids, low polymerization shrinkage, thus reducing micro leakage occurs and can reduce shrinkage pressure because it has high elasticity (Ratih and Novitasari 2017). The disadvantage of bulkfill composite resin is that the effect resulting from shrinkage stress will be greater when the dentist uses the bulkfill technique because the entire composite resin material polymerizes at one time compared to using a layer by layer or incremental technique (Noviyani et al. 2018).

Composite resin with fiber reinforcement or also called Fiber Reinforced Composite Resin (FRC) has been widely used by practitioners in the world of dentistry. Bulkfill fiber composite resins are starting to be introduced because they have a new innovation by adding short fiber reinforcement (SFC) to it which consists of a combination of resin matrix, e-glass fiber or electrical glass and inorganic particulate filler which is resistant to water (Garoushi et al. 2011).

The fiber commonly used in dentistry is e-glass fiber because it has high flexible strength and hard properties so it is suitable for use on teeth that receive great pressure, such as posterior teeth. E-glass fiber has several functions including being chemically resistant, having good aesthetic properties, mechanical properties almost the same as dentin and biocompatible. Apart from that, e-glass fiber has limitations, namely that it is expensive (Purnamasari et al. 2019). In fiber composite resin, the addition of e-glass is expected to have a much higher fracture resistance value than composite resin without e-glass.

According to research by Panjaitan et al. 2022 reported that there was increased resistance to fracture when composite resin was combined with fiber. Purnamasari et al.'s research. 2019 states that fiber has ideal surface hardness, this can be evidence that fiber can be used for cavity fillings with a depth of 4 mm. Not

only hardness, fiber also has high fracture resistance, flexural strength and modulus with a high surface hardness value. A restorative material must be resistant to the chewing load it receives in order to survive in the oral cavity.

Considerations in choosing filling materials for anterior and posterior teeth that need to be taken into account so that the filling material has the ability to resist fractures. One of the mechanical properties required for restoration materials is good compressive strength. Compressive strength is a mechanical property that has an important role and must be possessed by restorative materials, in order to describe the strength of a material against the spread of cracks or fractures due to chewing pressure during the mastication process received by the restorative material (Sidiqa and Soerachman 2017).

METHODS

The research design used was a post test only design because there was no control over the experimental design. The treatments were divided into 2 groups, namely: bulkfill composite resin as group I and bulkfill fiber composite resin as group II. The samples in this study were bulkfill restoration materials and fiber bulkfill restorations in the form of cylindrical tubes. The number of samples used in this research was 20 samples. Based on calculations using the Hulley formula. This study used a thickness of 6 mm in diameter and a width of 4 mm.

During the curing stage, it was carried out using the continuous light-curing method for 20 seconds on each layer. Application with oblique incremental technique. This research material will be stored at 37°C for 24 hours in an incubator to condition the physiological temperature like that in the oral cavity. The procedure for using test equipment uses a Universal Testing Machine to test compressive strength in order to determine the internal resistance to loads measured in Megapascals (Mpa).

Data analysis was carried out after the end of treatment. The data was first tested for normality, using the Shapiro-Wilk normality test because the number of samples used was less than 50 samples. Then a homogeneity test is carried out to determine whether the data or sample has a homogeneous variant or not using the Levene's Test of homogeneity. If the data is normally distributed and has a

homogeneous variance then it can be analyzed statistically using two independent samples (independent t-test). The T-Test test has the condition that the difference between two groups of data must have a normal distribution. If the data is not normally distributed then a non-parametric Man Whitney U Test is carried out to determine the statistical difference in the compressive strength of bulkfill composite resin and bulkfill fiber composite resin.

RESULTS

This research used two sample groups, namely with 10 samples each in each group. Group I is bulkfill with an oblique incremental technique in the form of a cylindrical tube with a diameter of 4 mm and a height of 6 mm and group II is a fiber bulkfill with an oblique incremental technique in the form of a cylindrical tube with a diameter of 4 mm and a height of 6 mm.



Figure 1. Samples of bulk fill composite resin and bulk fill fiber composite resin

Table 1. Results of compressive strength tests for bulkfill and resin composite resins bulk fill fiber

No.	Group I	Group II
1	237,8	396,9
2	236,3	437,1
3	228	396,5
4	230,4	387,8
5	193	402
6	236,7	391,2
7	211,2	402,6
8	199,3	414,6
9	233,9	414,6
10	226,2	395,7
Mean	223,28	403,90

Note: Group I: Cylindrical tube bulkfill composite restoration samples. Group II: Cylindrical tube bulkfill fiber composite restoration samples.

Table 1 shows the average compressive strength values sequentially, namely group I is lower and group II is higher. An illustration of the difference in the average compressive strength values of these two groups can be seen in the picture above.

Table 2. Data Normality test

Group Results	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BULKFILL	,271	10	,036	,825	10	,059
BULKFILL FIBER	,235	10	,124	,871	10	,104

In this study, the normality test data used the Shapiro-Wilk test because the number of samples was 20 (≤ 50) and the results obtained were $p = 0.059$ in group I in group II and $p = 0.104$. The data shows that $p > 0.05$ so it can be seen that the data obtained is normally distributed.

Table 3. Homogeneity test

Results				
Levene Statistic		df1	df2	Sig.
0,363		1	18	0,554

Based on the results of the homogeneity test using the Levene's test method on the sample, the p value = 0.554. The data shows $p > 0.05$ so it can be concluded that the data obtained has the same variety (homogeneous).

Table 4. Result of t-test two free sample

	Group	N	Mean	Std. Deviation	Std. Error Mean
results	BULKFILL	10	223,28	16,305	5,156
	BULKFILL FIBER	10	403,90	14,636	4,628

Table 5. Independent Samples test

Levene's Test for Equality of Variances					t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	0,363	0,554	-26,068	18	0,000	-180,620	6,929	-195,177	-166,063
Equal variances not assumed			-26,068	17,794	0,000	-180,620	6,929	-195,189	-166,051

Based on the results of the t test, the data from the two independent samples obtained $p = 0.000$. The T-Test test results are said to have a difference if the Sig. (2-tailed) < than 0.05. So based on the results of the T-Test there is a significant difference because Sig. (2-tailed) < 0.05, namely 0.000, so it can be concluded that there is a significant difference in average compressive strength between bulkfill composite resin and bulkfill fiber composite resin. Bulkfill fiber composite resin shows that its compressive strength is higher and is followed by bulkfill composite resin which is lower.

DISCUSSION

Based on the results of research that has been carried out, it can be concluded that there is a significant difference in compressive strength. The compressive strength of bulkfill fiber composite resin is greater than that of bulkfill composite resin. Results Tests showed that the average compressive strength of group I bulkfill composite resin was 223.28 Mpa and group II bulkfill fiber composite resin was 403.90 Mpa. The average value has a difference of 180.62 Mpa. Group II shows higher compressive strength and is followed by group I which has lower compressive strength values.

In group I, bulkfill composite resins are classified into materials with low viscosity and high viscosity. Composite resins with high viscosity contain a greater number of filler particles compared to composite resins with low viscosity. Bulkfill composite resins generally show a reduction in the amount of filler and an increase in filler size to achieve polymerization depth (Dionysopoulos 2016). Bulkfill composite resin has four main components and additional components. The four main components include an organic polymer matrix, inorganic filler particles, coupling agent and photoinitiator, while additional components are inhibitors, pigments and optical modifiers. Some of the resin matrices used are a combination of several monomers such as BIS-GMA, UDMA, TEGMA, BIS-EMA, AFM (Harahap 2017).

In research conducted by Vidyanara et al. 2021 states that bulkfill composite resin is reinforced by AUDMA and AFM monomers. AUDMA (Aromatic Dimethacrylate) monomer will reduce the number of reactive resin groups, reduce

volumetric shrinkage and matrix stiffness when polymerizing. AFM monomers (Addition Fragmentation Monomers) will also reduce stress to maintain its physical properties. This type of composite resin has a low viscosity so it has good sealing ability and is considered to reduce polymerization shrinkage.

Factors that influence the quality of bulkfill composite resin polymerization are light intensity, exposure time, light wavelength, composite resin thickness, distance between the tip of the light curing unit and the restoration surface, the color of the composite resin and the composition of the composite resin material itself. Another factor that plays a role in influencing the quality of bulkfill composite resin is the thickness of the composite resin material. Cavity restoration with a deep thickness will result in the spread of light curing energy or rays diverging towards the surface of the bulkfill composite resin.

This results in decreased polymerization of the bulkfill composite resin. According to research conducted by Ratih and Novitasari in 2017, the application of packable composite resin for clinical use must be layered in deep cavities to produce an optimal restoration. Apart from that, layered applications also need to be done restoration with bulkfill composite resin because research also shows that bulkfill composite resin shows lower compressive strength with a depth of 4 mm. Although application in layers is very time consuming and the possibility of contamination between layers or the formation of air bubbles between layers can increase, if done carefully it can increase the success of packable bulkfill resin composite restorations.

The results of this research are in line with research conducted by Noviyani et al. 2018 states that polymerization of bulkfill composite resin up to a layer thickness of 4 mm due to increasing the degree of polymerization of bulkfill composite resin is carried out by modifying the filler. Increasing the size of the bulkfill composite resin filler will reduce the spread of light between the filler and the matrix so that light penetration can be deeper. Another component contained in bulkfill composite resin is the polymerization booster (ivocerin), a substitute for the photoinitiator camphorquinone.

This initiator has a wider absorption wavelength ratio than camphorquinone, so bulkfill composite resin can be applied to a depth of 4 mm. However, bulkfill

composite resin with a thickness of 6 mm makes the polymerization process imperfect and the value affects the compressive strength which decreases. Cavity restoration with deep thickness will result in the spread of light curing energy or rays diverging towards the surface of the composite resin. This causes a decrease in the polymerization of the bulkfill composite resin. Therefore, the compressive strength value of bulkfill composite resin is lower than that of bulkfill fiber composite resin.

This happens because group II, namely bulkfill fiber composite resin, according to research conducted by Garoushi in 2018, bulkfill fiber composite resin increases compressive strength because there are fiber components embedded in a polymer resin matrix which has the function of reinforcing, while the matrix functions to channel the pressure between fiber and protect the fiber from mechanical and environmental damage. The increase in material properties can also be caused by the fiber's ability to stop crack propagation. In addition, this bulkfill fiber composite resin consists of short glass containing a combination of randomly distributed e-glass fiber resin matrix and inorganic particulate filler.

Based on the chemical composition, glass fiber is grouped into several types such as fiber type (alkaly), E (electrical), C (chemical) and S (strength) with differences in mechanical and chemical properties. The e-glass fiber type is the main type that uses plastic reinforcement and consists of potassium amino borosilicate which has tensile strength, elastic modulus and good density so as to obtain high compressive strength results. The diameter of the short e-glass fiber filler measures 17 μm and the length is 1.3-2 mm. The resin matrix consists of BisGMA, TEGDMA and PMMA which form semi-IPN during material polymerization which can improve the bonding properties and compressive strength of the composite resin. Semi-IPN has the ability to reactivate the surface structure of the bulkfill fiber composite resin so that the restoration material has a long-lasting bond and can repair the restoration if damage occurs.

According to research by Donova et al. (2016) stated that masticatory forces can cause the formation and propagation of cracks. However, this is different from bulkfill fiber composite resin restorations which can overcome this because this

restoration material contains fiber on a millimeter scale so the resulting compressive strength is much better.

Bulkfill fiber composite resin has a compressive strength mechanism measuring millimeters, this is because the fiber has the ability to prevent crack propagation, resist the initiation of cracks and propagation of cracks so that a gap is formed and reduces the stress intensity at the tip of the crack. This causes pressure and cracks not to easily hit this restoration. Fiber composite resin is claimed to have different shrinkage characteristics than other composite resins. When applied the fiber will be oriented in the horizontal plane of the cavity. This occurs because of the strong adhesion between the resin and fiber so that shrinkage will be minimal in the horizontal plane even though shrinkage will still occur in the vertical plane (Vidyanara et al. 2021).

The adhesion (silanization) process between the fiber composite resin and the matrix resin occurs well because of the high silica oxide content of the fiber. This silanization is assisted by silane (coupling agent) which is a functional molecule that is able to unite the matrix with the fiber. The silanization process between the fiber and the matrix cannot be separated from the volume. It is important to know the volume between fiber and silane as a coupling agent because it can affect the compressive strength of the composite resin (Widyastuti and Fahrini 2021). However, adding too much silane will cause the compressive strength of the fiber composite resin to decrease (Rosyida et al. 2015).

Abouelleil et al. (2015) stated that the addition of fiber can improve material properties because stress is transferred from the matrix to the fiber and fiber also plays a role in stopping crack propagation. Apart from adding fiber, fiber length and diameter play an important role in improving the properties of the composite. Fibers added to a composite can improve material properties if the fiber has a length that exceeds a certain minimum length. The minimum fiber length is when the fiber reaches its compressive strength and the matrix reaches its maximum shear strength. In this study, fiber length and diameter were measured using a stereomicroscope and SEM and obtained a fiber diameter of 16 mm and an average length of between 1 and 2 mm.

The results of this study are also in line with the results of research conducted by Patel et al. (2016) who also stated that the presence of fibers in composite resin is theorized as stress-free shock absorption that will occur between the fiber-resin surfaces. Fiber also replaces some parts of the composite as a whole or significantly reduces volumetric contraction thereby reducing shrinkage stress. Manufacturers of (EverX, GC) claim that its shrinkage characteristics are different from other composites. When laying, the fibers are oriented in a horizontal plane in the cavity. Due to the strong bond between the resin and the fiber, the direction of the fiber reduces shrinkage in the horizontal plane even though shrinkage occurs in the vertical plane. These results can be evidence that bulkfill fiber composite resin can be used to fill cavities with a depth of 4 mm. Not only in terms of compressive strength, bulk-fill fiber composite resin also has the same high fracture resistance, flexural strength and modulus.

From the research results, it can be seen that each group has several compressive strength test results which have very different values from other samples in the group. This is caused by calculating the compressive strength of the sample from the Universal Testing Machine which is connected to a computer, so that in the computer system the value is limited to 6000 Mpa. So several values differ greatly from the samples in the group. Apart from that, the condition of the oral cavity can be related to the presence of water and chemicals in the oral cavity which can reduce the compressive strength of a restoration material, but in this study no treatment was carried out in this regard.

The results of this study are under the author's hypothesis and statistically there is a significant difference in compressive strength between bulkfill composite resin and bulkfill fiber composite resin because the composite resin restoration material for posterior teeth in the oral cavity during mastication can experience compressive and tensile forces in the horizontal direction simultaneously. If the composite resin does not have the strength to withstand the pressure of chewing, the composite resin will break or crack.

CONCLUSIONS AND SUGGESTIONS

Based on the results of the research and discussion above, it can be concluded that there is a significant difference in compressive strength between the compressive strength values of bulkfill fiber composite resin and bulkfill composite resin, where bulkfill fiber composite resin has a higher compressive strength than bulkfill composite resin. Further research needs to be carried out on other mechanical property tests on bulkfill composite resins and bulkfill fiber composite resins and further research needs to be carried out on compressive strength tests on bulkfill composite resins and bulkfill fiber composite resins accompanied by special treatments such as immersion in saliva.

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