ORIGINAL ARTICLE

The resistance of the intracanal retention thickness with flowable short fiber reinforced composite (SFRC) materials towards fracture toughness

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ABSTRACT

Introduction: Dental hard tissue problems were relatively high in Indonesia. If these problems were ignored, they would cause pulpal necrosis. The main treatment for this case was Root Canal Treatment (RCT). The selection of post-RCT treatment and suitable materials was important. One of the examples was short fiber reinforced composite (SFRC) which can be an option for intracanal retention treatment. This study aims to analyze the resistance of the intracanal retention thickness with flowable fiber reinforced composite materials toward fracture toughness. **Methods:** This research was using a correlative laboratory experimental method with a post-test group-only design. This study's samples were SFRC material inserted in 27 extracted mandibular first premolars with a length of 21 mm ± 2 mm and root canal walls width of 2 mm. All samples were given intracanal retention at a depth of 2 mm below the orifice and divided into 3 groups: intracanal retention with thickness of (A) 6 mm, (B) 5 mm, and (C) 4 mm. RCT was performed using the crown-down technique. The bonding agent was applied, and then light cured for 20 seconds. SFRC was applied according to the sample group and light cured for 20 seconds per 2 mm, followed by filling with composite resin. The sample was implanted in the dental stone 2 mm below the CEJ. The fracture toughness test was performed using UTM on the occlusal surface with a 0º tilt and crosshead of 1 mm/min. **Results:** The fracture toughness results of group A, B, and C are 735.44, 756.78, and 829 respectively. Statistical tests with one-way ANOVA showed no significant difference with p value = 0.412 ($p < 0.05$). **Conclusion:** There is no difference in resistance of the intracanal retention thickness with flowable fiber reinforced composite materials towards fracture toughness.

KEYWORDS

post-RCT treatments, intracanal retentions, SFRC, fracture toughness

INTRODUCTION

Oral health is an important thing that everyone should be aware of. However, according to the Basic Health Research (Riskesdas) in 2018, awareness level of oral health in Indonesia still needs to be improved. Nowadays, the main problems are hard and soft tissue diseases. Riskesdas stated that the level of dental hard tissue disease in Indonesian people is still high, namely 45.3% who experience dental caries.[1] Caries can become severe problems, such as pain and discomfort, and also teeth becoming easily broken due to loss of tooth tissue structure that can lead to acute and chronic infections.[2] Pulp necrosis is a condition of pulp tissue death that is usually asymptomatic. The etiology of pulp tissue death can be mechanical, chemical irritants, or bacterial microorganisms.[3] Tooth trauma is also one of the main causes of tooth fracture, which can involve damage to the tooth pulp.[4]

According to the 2020 American Association of Endodontists (AAE), root canal treatment (RCT) is the procedure for removing necrotic tissue from the root canal, followed by shaping and obturating the root canal with a filling material.[5] Post-RCT teeth will become more brittle and prone to fracture. This is because the water content in the dentine tissue decreases, causing it to become dehydrated, which causes the dentine collagen to shrink. Also, the post-RCT teeth can no longer form the secondary dentine tissue, which makes dentin support for enamel reduced.[6] As a result of these factors, post-RCT teeth become prone to fracture when they receive functional pressure or mastication.[7]

Fracture toughness is a mechanical property that describes the ability of a material to resist crack propagation and defines the level of tolerance of a material against damage.[8] The fracture toughness value depends on the physical properties and chemical composition of the components of the restorative material. In previous studies, it was shown that there is a strong correlation between the fracture toughness of the material and the fracture rate of dental restoration materials.[9] Therefore, materials with high fracture toughness values tend to be able to withstand the risk of micro fractures that may occur during the mastication process. In other words, materials that have higher fracture toughness values tend to have a better ability to resist the formation and spread of fractures.

It is known that fiber reinforced composite (FRC) materials have high fracture toughness values.[10,11] The properties of FRC are highly dependent on fiber diameter, fiber length, fiber orientation or direction, fiber loading, and also the adhesion or attachment between the fibers and the polymer resin matrix.[12] The development of FRC materials is urgently needed to reduce the failure rate of RCT in dentistry, especially fractures. This study aims to analyze the resistance of the intracanal retention thickness with flowable fiber reinforced composite materials toward fracture toughness.

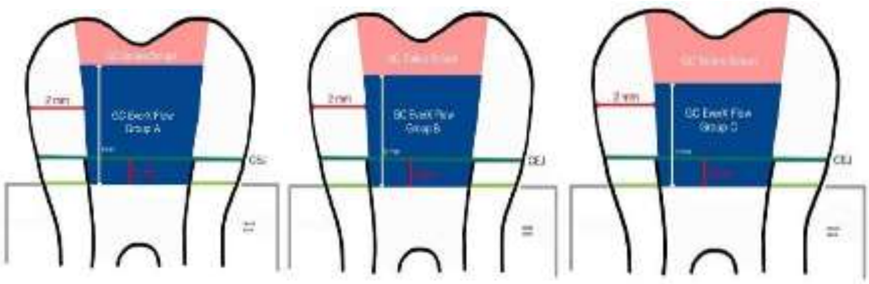
METHODS

This research was conducted using a correlative laboratory experimental method with a post-test group-only design carried out at the RSGM-P Faculty of Dentistry, Universitas Trisakti and Industrial Metrology Laboratory, Universitas Trisakti, Jakarta, Indonesia. The research sample used a flowable short fiber-reinforced resin composite (SFRC) (GC EverX Flow) inserted into the mandibular first premolar as intracanal retention.

A sample of 27 extracted mandibular first premolars with single and straight root, intact crown with no caries, without root caries, and completely closed apex teeth were cleaned and then soaked in saline water. Each sample was selected by measuring the working length using a caliper, with a length of 21 mm ± 2 mm (Figure 1).

Figure 1. Measurement with millimeter blocks.

Next, a digital radiographic photo was taken to measure the root canal walls and to ensure the length of the sample using a digital millimeter block. The length of the teeth was calculated using 2 points, namely the cusp of the premolar and the apex. The thickness of the root canal walls should be 2 mm thick from the CEJ on the outside to the root canal walls on the inside. It was then grouped into 3 groups: samples that had undergone root canal treatment and were given 2 mm intracanal retention below the orifice using SFRC flowable material with a thickness of (A) 6 mm; (B) 5 mm; (C) 4 mm (Figure 2).



Group A Group B Group C

Figure 2. The treatment scheme of the sample: Group A. Sample with 6 mm thickness of flowable SFRC intracanal retention; Group B: Sample with 5 mm thickness of flowable SFRC intracanal retention. Group C: Sample with 4 mm thickness of flowable SFRC intracanal retention

RCT was performed using the crown down technique using ProTaper (Dentsply Maillefer) up to size F3. At each file change, 2 ml of 5.25% NaOCl solution was irrigated in the root canals and then dried using three-way syringe and paper points. Then obturation was carried out using the single cone technique using gutta-percha and a sealer was applied using a root canal sealer (Dentsply AH 26). Finally, the obturation material was removed using a largo reamer #3 (Dentsply Maillefer) 2 mm below the orifice for all samples.

Bonding material (GC Solare Bond) was applied to the tooth sample and dried, then light cured for 20 seconds. Next, intracanal retention material was applied 2 mm deep under the orifice for all samples and light cured for 20 seconds per 2 mm thickness. Furthermore, the filling was carried out using a composite resin filling material (GC Solare Sculpt Composite). These thicknesses from group A, B, and C were chosen based on previous studies[13], which found that the fiber length differences between 1–2 mm could change the pattern of the fractures and greatly enhance the fracture resistance of the composite (Figure 3).

The tooth sample was implanted in type II dental stone 2 mm deep below the CEJ so that it resembled the position of the teeth on the alveolar bone. Furthermore, the fracture toughness test was performed using the Universal Testing Machine (Hounsfield: 50kN, England). The pressure was applied using a fracture toughness jig on the occlusal surface with a slope of 0° along the tooth axis apically. Constant pressure was applied at a crosshead speed of 1 mm/min (American Society for Testing Materials Standard) until the tooth failed in the form of a macroscopic fracture in the intracanal retention of the SFRC material. Fractures of fillings and teeth that do not involve intracanal retention were ignored.

Figure 3. Fracture on intracanal retention with SFRC materials.

Statistical analysis was performed on the fracture toughness data. Saphiro-Wilk normality test was performed, and the p-value > 0.05 was considered as normal data distribution. Then followed by one-way ANOVA test data analysis. if the One Way ANOVA test obtained p-value < 0.05, the analysis was continued with the post hoc test with Tukey's HSD. If the p-value shows > 0.05, the conclusion was that there is no significant difference in the fracture toughness values of the sample groups A, B, and C, and the post hoc test was not carried out.

RESULTS

The statistical results showed in the Shapiro-Wilk normality test (Table 1), data is considered normally distributed if the p-value>0,05. They are then followed by One Way ANOVA data analysis (Table 3) with a p-value = 0.412. This means that there is no significant difference in the fracture toughness values of the sample groups A, B, and C.

Table 1. Shapiro-Wilk test of Normality on fracture toughness data.

Flowable SFRC	Shapiro-Wilk		
	Statistic	df	p-value
6 mm	0.200	9	0.692*
5 mm	0.200	9	0.949*
4 mm	0.200	9	0.356*

The results of the One Way ANOVA analysis (Table 2) showed that the average fracture toughness value in group A with an intracanal retention thickness of 6 mm had the lowest fracture toughness value at 735.44 N (±146.407). Group B, with an intracanal retention of 5 mm, had a fracture toughness value of 756.78 N (±153.791). While the sample in group C with intracanal retention thickness of 4 mm had the highest fracture toughness value at 829.00 N (±159.290). As can be seen in bar diagram (Figure 4). The results of the homogeneity test showed that there was no significant relationship between the sample groups (p > 0.05).

Table 2. One Way ANOVA analysis on fracture toughness data.

	n	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Min	Max
6 mm	9	735.44	146.407	48.802	622.91	847.98	548	1002
5 mm	9	756.78	153.791	51.264	638.56	874.98	502	972
4 mm	9	829.00	159.290	53.097	706.56	951.44	589	1013
Total	27	773.74	152.788	29.404	713.90	834.18	502	1013

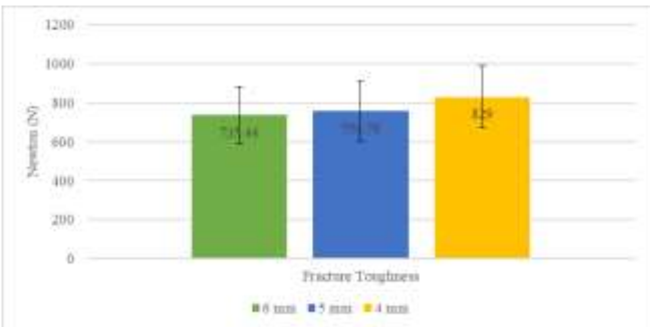


Figure 4. Fracture toughness data of group A, B, and C.

Table 3. One Way ANOVA analysis.

	Sum of Squares	df	Mean square	F	p-value
Between groups	43271.407	2	21635.704	0.921	0.412
Within groups	563679.778	24	23486.657		
Total	606951.185	26			

DISCUSSION

The test data using UTM found that the average fracture toughness value was group C > B > A. Based on the Shapiro-Wilk normality test, group A has a significance value of 0.692, group B has 0.949, and group C has 0.356. So that the significance value (p/Sig.) in this normality test can be concluded that the data is normally distributed. This conclusion is obtained from the significance value of all groups of more than 0.05. Therefore, the assumption of normality of the data is met and data analysis can be continued using the one-way ANOVA test. On the One Way ANOVA test data, it is known that the average fracture toughness value in group A is 735.44 N (±146.407), in group B is 756.78 N (±153.791), and group C is 829.00 N (±159.290). Thus, it can be known that the strongest fracture toughness value is group C with shortest intracanal retention thickness.

These results could be caused by the nature of the SFRC material, which is a resin matrix combined with e-glass fiber and inorganic particulate fillers.[14] The fiber functions as a reinforcement embedded in a polymer resin matrix to transmit the pressure received by the tooth to the surrounding tissue and protects the tooth from mechanical and environmental damage in the form of fracture.[15] Basically, the matrix of the resin composites has much lower modulus than the fiber which makes the matrix easily strains more. Fibers that are incorporated into the matrix form a stress transfer and have the ability to stop the crack propagation through the material. This is the reason why fibers could enhance the physical properties of a material.[13] In previous studies stated that flowable SFRC as intracanal retention can improve the integrity of the restoration and enable efficient stress distribution that is able to withstand fractures in composite restorations.[10] In this study, flowable SFRC as intracanal retention was tested with 3 groups of thickness and does not show significant results. These results are consistent with the results of a previous study regarding the effect of fiber post length on fracture resistance conducted by Adanir and Belli[16], where they also found no significant relationship between fiber post length and fracture resistance.

Resin materials have several drawbacks, one of which is experiencing shrinkage during the polymerization process (polymerization shrinkage). Polymerization is a chemical reaction process when the resin monomer molecules bind and form chain bonds which are called polymers.[17] Polymerization shrinkage can cause microleakage, which causes teeth to fracture easily.[3] During the polymerization process, the chains of triethylene glycol dimethacrylate (TEGDMA) can experience higher shrinkage which caused by the higher conversion of double bonds in highly flowable restorative materials such as SFRC.[18] In the previous research conducted by Agwu and Ozoegwu[19], cited from Tezvergil et al. that SFRC is anisotropic, which makes SFRC material with different mechanical and thermal properties in all directions. This causes shrinkage in SFRC materials to also occur in all directions with varying shrinkage levels. In addition, shrinkage will occur greater in fibers perpendicular to the direction of polymerization because the bond between the fiber and the matrix is broader in the direction of the fiber orientation that is lead to a lower fracture toughness value with more intracanal retention length. According to a study conducted by Gupta et al. [20] that cited from Giachetti, the degree of polymerization shrinkage stress becomes smaller when the thickness of the composite resin material is thinner. When the thickness of the material is thinner, the volume of SFRC material involved is less, which causes the stress that is formed to be smaller.[20,21] This explains the relation between intracanal retention length and fracture toughness value, and the reason why group C with shorter intracanal retention thickness have a higher fracture toughness value. The more length of intracanal retention of SFRC, the higher shrinkage polymerization will occur, causing fracture toughness value to decrease.

According to research conducted by Sakaguchi et al., Ping et al.[22] stated the stress given to the polymerization process would cause vacancies in the interfacial bonds or voids in the bond volume between fibers that would lead to material failures. Polymerization on a larger surface area or volume will result in a larger particle interfacial bond vacancy.[19] The void at the fiber particle interface is caused by a decrease in wetting in the matrix, which ends in a reduction of mechanical properties and failure of the composite system. Besides that, other factors can affect the results of the study, one of which is the cavity configuration factor or c-factor. The c-factor is the surface ratio of the bonded and unbound restoration areas to the cavity walls. The more surface area of the bonded resin, the value of the c-factor will increase, resulting in an increase in polymerization shrinkage.[6] The discussion could suggest exploring other mechanical properties of SFRC material such as diametral tensile strength, or developing the studies with another bonding technique.

CONCLUSION

This study showed no resistance of the intracanal retention thickness with flowable fiber reinforced composite materials toward fracture toughness. However, in the research that has been done, SFRC material as intracanal retention with a thickness of 4 mm shows the highest fracture toughness value.

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Data Availability Statement: http://repository.trisakti.ac.id/usaktiana/index.php/home/ detail/detail_koleksi/ 0/SKR/pembimbing/ 0000000000000111341/widyastuti#menu

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