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CUSPAL COVERAGE WITH SHORT FIBER-REINFORCED COMPOSITE IN CLASS II MESIO-OCCLUSAL-DISTAL DIRECT RESTORATION ON FRACTURE RESISTANCE PATTERNS OF POST ENDODONTICALLY TREATED TEETH: AN IN VITRO STUDY

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Dwi Pusparani, Trimurni Abidin, Dennis: Cuspal Coverage with Short Fiber-Reinforced Composite in Class II Mesio-Occlusal-Distal Direct Restoration on Fracture Resistance Patterns of Post Endodontically Treated Teeth: an In Vitro Study -- Palarch's Journal Of Archaeology Of Egypt/Egyptology 18(1). ISSN 1567-214x

ABSTRACT

Introduction: A recently-recommended method for restoring large cavities is the biommetic approach of using short fiber-reinforced composite (SFRC) as dentin replacement material. The technique is believed to have a superior fracture resistance and a favorable aesthetic result. In addition, to ensure the success of the restoration post the endodontic treatment, coronal sealing or luting plays a crucial role. This in vitro study aims to examine the fracture resistance pattern of endodontically treated premolars in Mesio-Occlusal-Distal (MOD) direct restoration with SFRC and draw comparisons between SFRC and other composites tested, i.e. hybrid composite and polyethylene fiber reinforced ribbon.

Materials and methods: The 24 human premolars were collected and fractioned into 4 random groups. Post MOD cavity preparation, first six endodontically treated premolars in Group 1 were set up with Stress Decreasing Resin (SDR) and conventional resin composite. After using the same prep standard, the remaining groups were arranged under the following interventions, in respective order; SDR and SFRC for Group 2; SDR and polyethylene fiber reinforced ribbon (BRR) for Group 3; and GIC and conventional resin composite for Group 4; all further tested using Universal Testing Machine before being analyzed using the Kruskal-Wallis protocol.

Results: The findings indicated SDR had a better absorptive capability compared to SFRC. Conversely, SFRC acquired its strength in having a better stability of absorptive capacity in parallel with the incubation periods. Based on the Kruskal-Wallis Analysis, it was confirmed that SDR and SFRC had a strong correlation in term of absorptive capacity and its incubation period. Meanwhile, there was no significant difference of the increase of absorptive capacity between SDR and SFRC. Whilst the Vickers test verified SFRC significantly demonstrated the highest load-bearing ability. Similarly, SDR-SRFC mixture had the highest amount of thermal release among all tested composites. As the result, in term of capability, SDR-SFRC claimed the strongest resistance against fracture making other composites pale in comparison.

Conclusion: In conclusion, the supplementation of SFRC into class II MOD direct restoration with cusp coverage attested to increase the resistance to fracture of post treatment ETT which according to the findings, the group receiving treatment of SDR-based intermediate layer and direct short fiber-reinforced composite restoration gaining the benefit of having a higher resistance to fracture than the group of restoration treatment without short fiber reinforced composite.

Keywords: endodontically treated teeth (ETT), fracture resistance, mesio-occlusal-distal (MOD), short fiber-reinforced composite (SFRC).

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Introduction

Endodontically treated teeth (ETT) differ from non-restored vital teeth in structure, therefore require particular corrective treatment. ETT have a greater vulnerability risk of significantly reduced resistance to fracture mainly due to the loss of structural

integrity and dentine dehydration (Perdigao, 2016). Several factors known to cause the structure loss include extended, secondary caries and excessive removal of tooth tissue especially the dentine

during the protocol of root canal shaping (Mancebo et al, 2010). Dentine dehydration changes the structural bond of dentine collagen resulting in non-vital teeth to have an increased brittleness (Segun et al, 2008). Generally, ETT have resulted in a decrease in moisture content which is 9% lower than vital teeth with normally unimpaired pulp. A number of factors have become important key in the success of ETT restoration including the general stipulation of oral and dental health state of the patient, the preparation on pre-restored condition of the remaining tooth structure, the restorative composite or material selected, the technique employed, and later the ensuing reception of the reconstructed teeth on the material used (Segun et al, 2008).

In a retrospective overview, certain considerations however needs to be noted, as Tang et al revealed the possibility that mesio-occlusal-distal (MOD) cavity has a higher susceptibility to fracture than mesio-occlusal (MO) or disto-occlusal (DO) cavity. Reeh at al, further, reported the reduction of relative hardness of the cusp in endodontic procedure is approximately 5%, while in class I occlusal cavity is up to 20% and in MOD cavity is as high as 63%.

Post-endodontic restorative techniques and materials used are also viewed as of the key factors in protecting against fracture (Garlapati et al, 2017). Among conventional techniques and composites commonly employed in ETT restoration are the systems using dowel (post) and core materials, onlays, and indirect crown restoration with or without cusp coverage (Ozsevik et al, 2016). With the growing popularity of dental restorations with adhesive system, consequently, the demands of endodontic treatments with minimally invasive procedure principle become higher. Restorations with adhesive treatment are widely regarded to have amendable effects in bearing any functional stress in the form of high load distribution onto the superficial area as the result of successful, completed bonding, plus, preserving the dental structure appearance to look as natural as it was (Moosavi et al, 2012). Notably, among technical modifications in restorations with resin composites to strengthen fracture resistance is by employing cusp coverage.

In accordance with the principle of minimally invasive procedure, apart from its strong point in reducing the possibilities of greater structure loss, restorations with resin based composite (RBC) prove to demonstrate its capacity in intra-coronal reinforcement, have a generally better aesthetic result, and grant time efficiency, if being compared to indirect restorations, as there is no involvement of additional laboratory works required (Moosavi et al, 2012). On the advantage of cuspal deflections and fracture resistance of stress decreasing resin (SDR) materials, Almuhaiza et al (2018) concluded that SDR with 4mm in density is reasonably sound as a liner under nanohybrid RBC restoration. Fiber strengthening materials such as polyethylene fiber or glass fiber are normally used in RBC restorations due to its effectiveness as a stress reliever and in improving dental fracture resistance against micro-crack, subsequent shrinkage, and potential creep or vulnerability to deformation (Sarabi et al, 2015).

Fiber reinforced composites are recognized for their high flexure and fatigue-tolerance strength, near-perfect dentine-like elasticity, anti-corrosiveness, biocompatibility, load-bearing capacity, fracture opposition, and commendable aesthetics (Sarabi et al, 2015). The research of Sengun et al (2008) on the effects of restoration technique with adding bondable reinforcement ribbon (BRR) on fracture resistance demonstrated that by combining BRR with conventional resin composite, the fracture resistance toughened. This result is tallied by Miao et al (2016) on their work on the effects of restoration with polyethylene fiber supplementary on fracture resistance revealing the groups with the highest fracture resistance are those receiving treatment with polyethylene fiber mixture or BRR. Short fiber reinforced composite (SFRC) belongs to a group of bulk fill resin composites with additional short glass fiber fillers composition as the form of combination between barium glass and silanated E-glass fiber which is highly recommended for its toughness and endurance against high loads.

Materials and Method

In order to fit this orthodontic-based study, the qualifications of extracted mandibular premolars collected must meet following inclusive criteria: (1) belong to mandibular premolars category; (2) appear to have no evident sign of any crown fracture and remain untouched from any restorative procedure beforehand; (3) the crowns remain intact and have no caries; (4) have a perfectly covered apex.

The nature of the study is strictly experimental with random groups design where each group is arranged of carrying six samples from 24 teeth in total which to be divided into four groups that received different treatments with details as follow; Group A: SDR + conventional RBC with 225N load post root canal treatment; Group B: SDR + short fiber reinforced (SFRC) with 225N load post root canal treatment; Group C: SDR + polyethylene fiber reinforced (BRR) with 225N load post root canal treatment; and Group D: glass ionomer cement (GIC) + conventional RBC with 225N load post root canal treatment.

Testing protocols on each sample include residual absorption ability of SDR restorative materials and SFRC based on the incubation periods (24, 48, and 72 hours, respectively); the Vickers hardness testing on SDR restorative materials, BRR, and SFRC; DSC (differential scanning calorimetry) on post endodontic restored teeth; and universal testing machine on fracture resistance of post endodontic restored teeth.

Research Procedures

Sample preparation

The 24 extracted mandibular premolars under evaluation were collected decidedly as the sample and were randomly divided into 4 groups depending on the composite base material used. Each group had 6 teeth planted into a gypsum block to ease the preparation process.

Root canal treatment modeling

Following the opening of access cavity for the decoronated teeth, the proceeding step was determining the working length using K-file size 10 or 15. The preparation of root canal was carried out using the ProTaper NEXT system, rotary file instruments with sizing ranges from 17/04 to 25/06, which is continued by the irrigation using NaOCl 2.5% as the disinfectant after each time switching the file. The prepared teeth then were filled with a gutta-percha substance using warm vertical compaction technique.

Access preparation

The outline form was shaped by utilizing a diamond bur which typically designed for class II MOD cavities on mandibular premolars with cusp coverage with following details; a 2.5mm in buccal width, an 11.5mm in lingual length, a 4mm in depth, a 2mm reduced buccal cusp, and a 1.5 mm lingual (Garlapati *et al*, 2017).

Sample restoration

The obturated premolars were directly taken under restorative treatment based on the sample grouping, the results of access cavity preparation, the acid etching, the teeth bonding and the period of being applied and hardened with a special light, of which all the groups receiving the same handling; 15 seconds for acid etching, 20 seconds for bonding, and 20 seconds for polymerization. Afterwards, the finishing steps followed which includes polishing the restored teeth with fine bur or silicon dental bur. A 2mm SFRC was put as an intermediate layer on the top of SDR and a 2mm conventional composite as the cuspal icing. The function of bondable reinforcement ribbon (BRR) was to coat bulk fill SDR and cover the cavity walls.

Thermocycling

The sample of restored premolars were next set into a breaker glass filled with iced water for 30 seconds at 5°C and within a 5-second intermission then moved into the water bath of 55°C and let stand for 30 seconds. It is necessary to repeat these steps for 200 times to simulate the natural state of human oral condition (Kemaloglu et al, 2015). Thermocycling enables the process of hydration of the filling material to absorb water.

Sample planting on an acrylic mold

The restored premolars were implanted with the inclination of 90° on a 1mm self-curing acrylic cylinder at the bottom of cement-enamel junction (CEJ) to imitate the precise position on alveolar bones.

Fracture resistance testing

The procedure was conducted in the Basic Mechanical laboratory of Mechanical Engineering Faculty of UNSYIAH to investigate the load-bearing capacity of the sample. The sample of restored teeth were put on the testing instrument by placing the stressing point on the occlusal surface in contact with the cusps and in ordination with the axial length of the teeth. Sample premolars were then compressed at the velocity of 0.5mm/minutes to assume fracture possibility under the mastication load of 225N using Universal Testing Machine.

Absorptive capacity testing of the materials

According to Pareara (2018), the absorptive capacity testing is considered in analyzing the conversion capacity, microhardness or composite polymerization shrinkage loads. In addition, this is the common indicator to estimate the load-bearing levels of polymerization in order to anticipate any maintenance possibly needed to preserve the wellbeing of the physical features of a composite. The sample composites tested were SFRC and SDR.

Material hardness testing (Vickers)

The sample of restored premolars were processed and hardened through polymerization employing SDR, SFRC, and BRR and later tested by using Vickers hardness test to observe the degree of hardness of each restorative material.

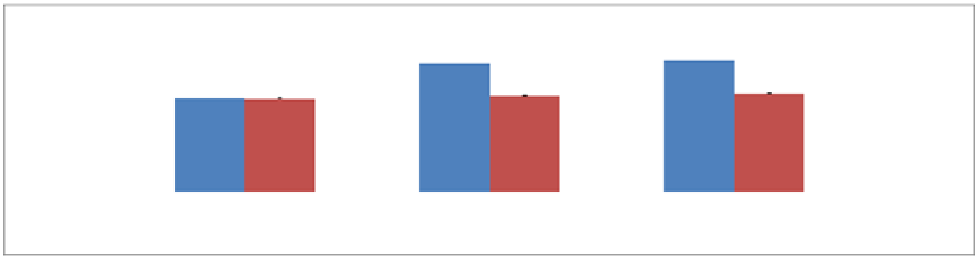
Differential Scanning Calorimetry (DSC)

This procedure required six sample teeth in each group to be first soaked on a water bath for 15 minutes and put under vibration for another 15 minutes. This is to be repeated for 5 times on each sample group. In the final part of this procedure, all samples were tested using DSC to examine which of the composites with the highest amount of heat release.

The Results

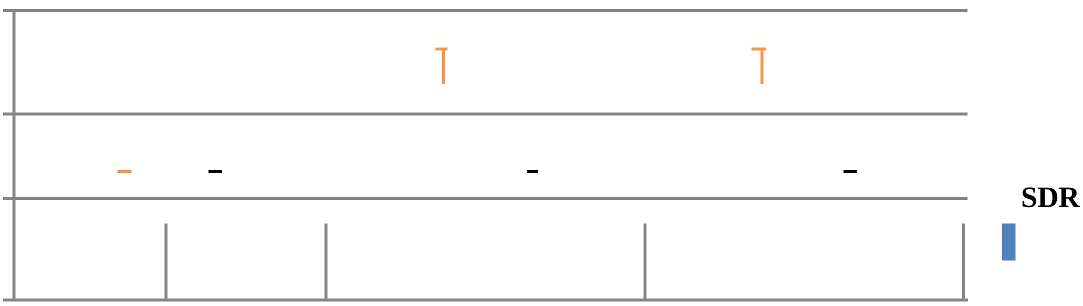
Residual absorption testing

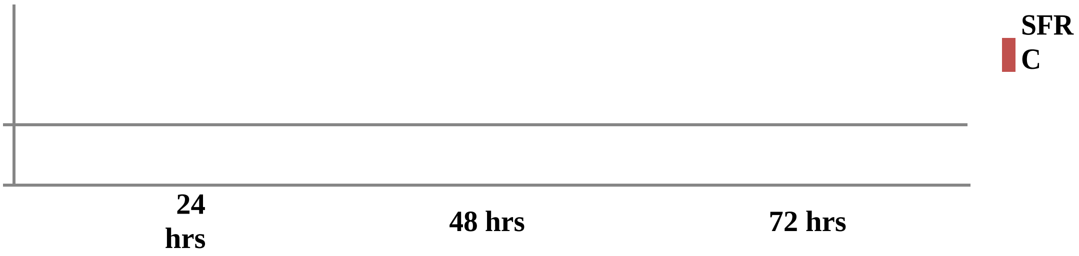
The sample group of SDR and SFRC was put into 14 ml sample tubes with the arrangement of SFRC 0.25g/5ml and SDR 0.25g/5ml, and dissolved in ethanol 90% and put under vibration for 15 minutes. Output solution from both composites was transferred into petri dishes with putting on the labels of the tested material and each was incubated for 24, 48, and 72 hours respectively.



level (mm) Absorptive capacity

Degree of absorption





Journal Master

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Figure 1. Degree of absorption of the tested materials (SDR and SFRC). SDR composite asserted to have a better absorptive capacity level than SFRC in term of incubation periods (24, 48, and 72 hours, respectively). Both composites exhibited the increase of absorptive levels the greater the incubation periods, nevertheless, the raise of SFRC was much steadier than that of SDR.

Table 1. The Kruskal-Wallis Analysis of Absorptive Capacity Level of SDR and SFRC

		Descriptive Statistics				**Kruskal-Wallis**	
Variable Analysis	N	Min	Max	Mean	SDV	Absorption vs Incubation Periods	Absorption vs Tested Materials
Absorption	12	6.10	10.00	7.07	1.33		
Incubation Periods	12	1.00	3.00	2.00	0.85	$p<0.05$ (0.04) r=0.69	$p>0.05$ (0.127) r= -0.46
Tested Materials	12	1.00	2.00	1.50	0.52		

Table 1. The degree of absorption of both SDR and SFRC increased along with the incubation periods ($p<0.05$) indicating a strong correlation (r=0.69), while the increase of the absorptive capacity between these composites had no significant difference ($p>0.05$) and indicated a weak correlation for both composites (r=-0.46) as presented in the table.

Material Hardness Testing (Vickers)

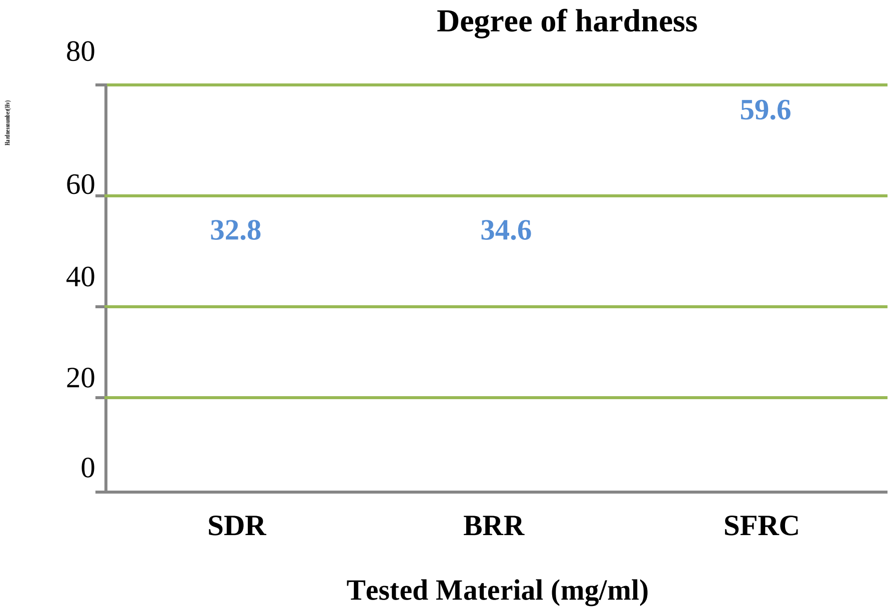


Figure 2. Vickers testing on the hardness of SDR, BRR (bondable reinforcement ribbon), and SFRC. SFRC was noted to have the highest number of hardness of all tested materials including SDR and BRR.

In Figure 2, it showed that SFRC possessed a greater load-bearing capacity up to 59.6

Hv (47%) compared to BRR 34.6 Hv (27%) and SDR 32.8 Hv (26%) based on the Vickers with

the load weight of 6 kg.

<u>Differential Scanning Calorimetry (DSC) Testing</u>

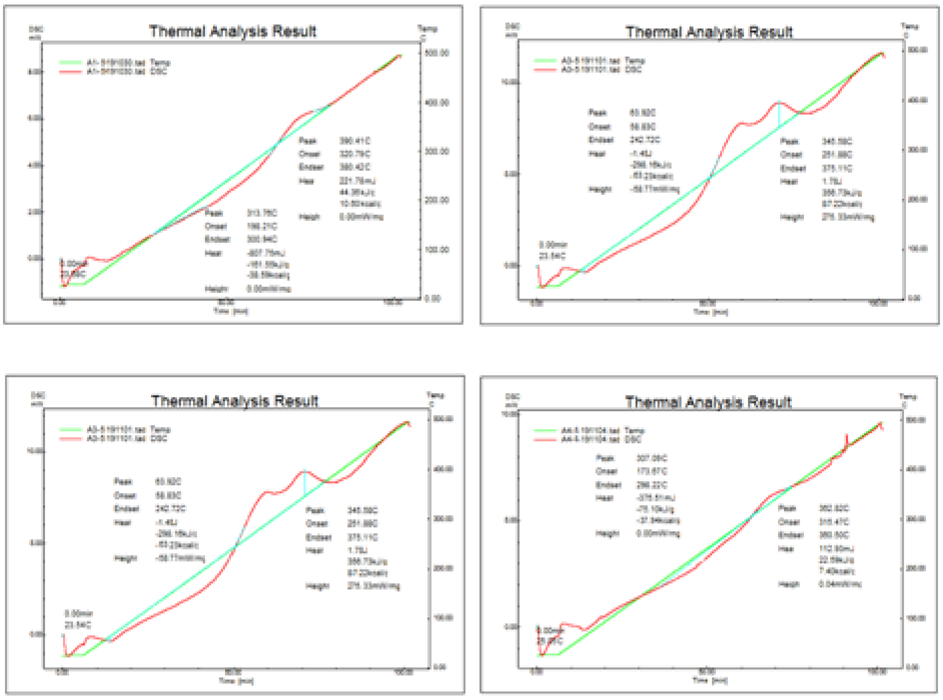


Figure 3. Differential Scanning Calorimetry (DSC) Testing Results: (a) SDR + packable RBC; (b) SDR + BRR; (c) SDR + SFRC; and (d) GIC + packable RBC.

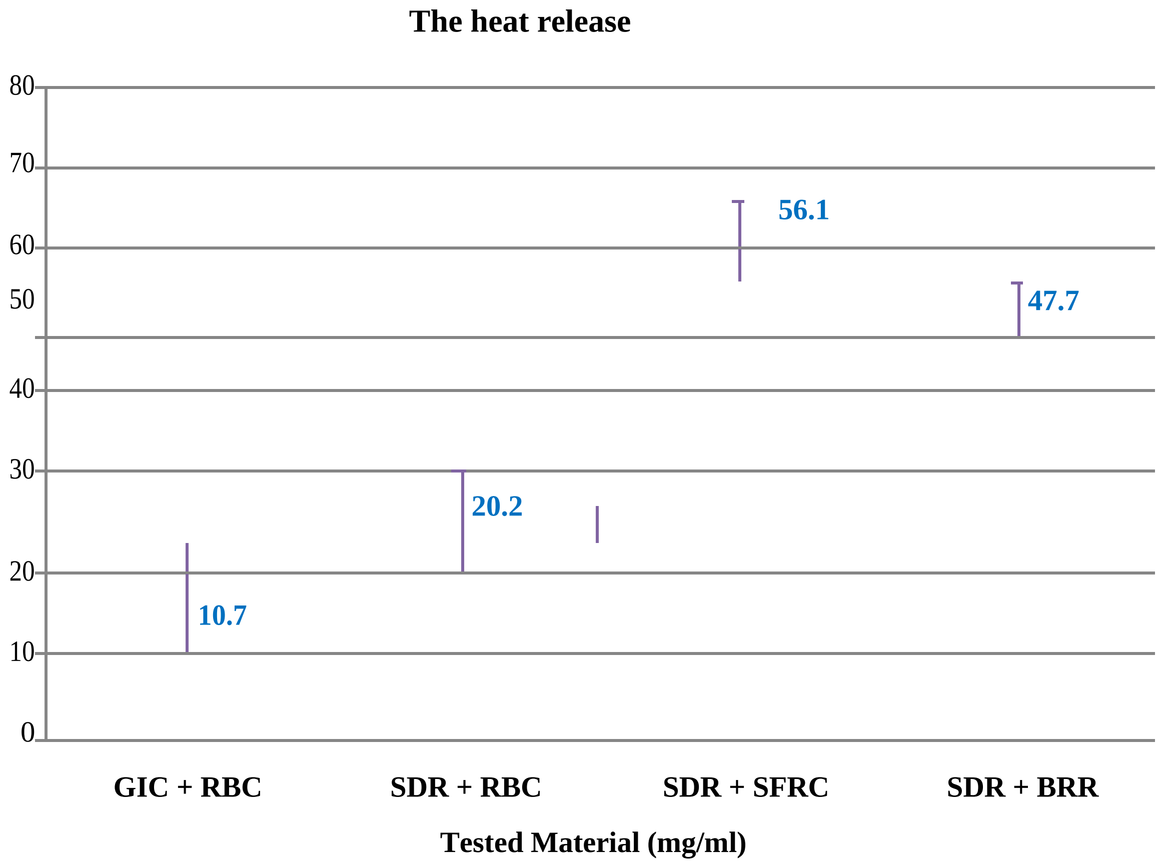
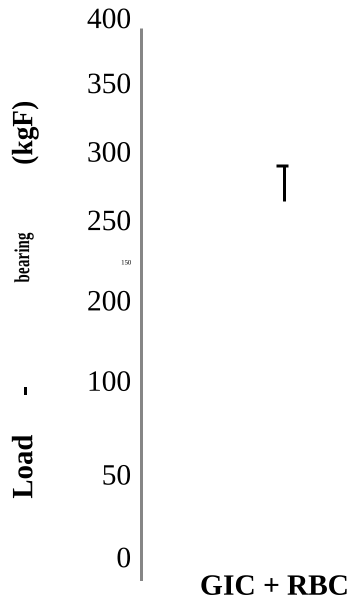
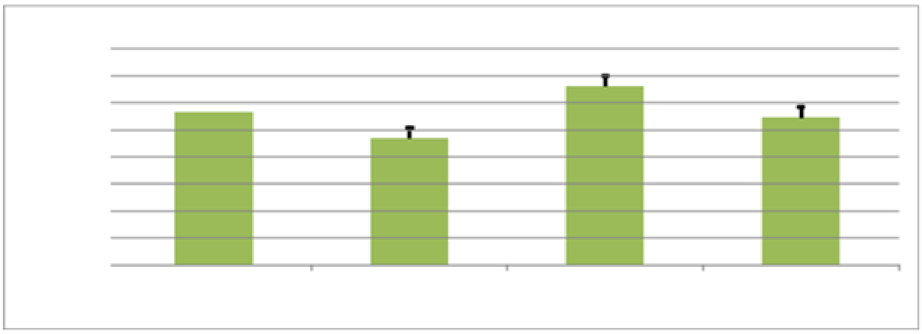


Figure 4. According to the results from DSC (Differential Scanning Calorimetry), SDR + SFRC had the highest amount of thermal release among all tested composites. Primary bars (heat release); error bars (standard deviation).

Figure 4 indicated the degree of heat release of the four tested composites which characteristically relying on the respective composing components. The highest amount of heat release was of SDR + SFRC mixture, the second highest was of SDR + packable RBC, and the lowest was of GIC + packable RBC.

Fracture resistance testing





SDR + RBC SDR + SFRC SDR + BRR Tested Material (mg/ml)

Resistance to fracture

Figure 5. The degree of resistance to fracture of the tested restorative materials. SDR-SFRC was acknowledged to be the highest of all tested composites in the qualification based on fracture resistance capacity. Primary bars (fracture resistance); error bars (standard deviation).

According to Figure 5, SDR + SFRC proved to have a greater stability in fracture resistance than any other composites. Based on the load-bearing testing, the descriptive mean of all four tested restorative composites is the implementation of 2mm SDR, and SFRC fared better in the resistance quality against fracture than other modified resin composites, including GIC + packable RBC, SDR + BRR, and SDR + packable RBC in the in vitro study of cuspal coverage in class II MOD direct restoration of ETT.

Discussion

The conceptual purpose of this study is to provide a systematic review by examining the characteristics of direct class II MOD restoration with cusp coverage on certain mixture composites including SDR–packable RBC, SDR–SFRC, SDR–BRR, and GIC– packable RBC based from their recuperative resistance to fracture post endodontic treatment. A series of designated testing setups employed in this study aim to help configure and compare the beneficial strengths of each material on their endurance buildups in protecting restored teeth against fracture post endodontic treatment tried through the implementations of material absorption testing, the Vickers hardness testing, differential scanning calorimetry, and universal testing machine on fracture resistance. testing machine on fracture resistance.

Residual absorption testing on SDR–SFRC

Residual absorption testing is technically required to characterize conversion capacity, microhardness, and polymerization shrinkage stress of the composite which according to Pareara (2018) functions to cipher the degree of polymerization stress to further estimate any possibility also variability of alteration or even fault that might occur to the composite.

Residual absorption testing (Figure 1 and Table 1) showed the degree of absorption of SDR and SFRC increasing following the progressive variables of the incubation period (24, 48, and 72 hours, respectively)

($p<0.05$) which suggested significant correlation ($r=0.69$), indicating each material tested (SDR and SFRC) has similar strength in absorption degree on adhesive medium, confirming in a positive measure that incubation periods affect the absorption degree of both SDR and SFRC materials. Even though SFRC seemed to have a slightly better outcome in term of stability than SDR, it was considered not much noticeable and relatively weak. This establishes the point that any occurrence with raising degree of absorption is affected mainly by the thermocycling process instead of the material compositions. The reasonable supporting ground for this is because each produced material must be qualified for the foreseeability on its period of validity during which it proves to be able to substantially bond and successfully adapt with the remaining structure. Both, as any materials given, are naturally expected to have a certain limit of cogency span. Any ISO 11405 certified fit and proper test using a 500 thermal cycle within the range of 5° and 55°C is generally conceived as the most compatible for the simulation of short-term ageing capacity of restorative dental materials (Ghavani, 2018).

Vickers hardness testing on SDR and BRR

Vickers testing is needed to measure the degree of hardness of materials. The principle of calculating the hardness number is determined by the load over the surface area of the indentation. The typical test is applicable to vast and various kinds of material, thus, making one comparable to another in term of hardness.

Based on the Vickers result, SFRC exceled in both hardness and strength compared to either SDR or BRR (Figure 4). This is likely due to its material composition which is made from the combination of resin matrix, short E-glass fiber, and inorganic particulate fillers. Short E-glass fiber is implemented during the filling of the cavity using resin composite to create firm interaction between RBC and the filled cavity (Garoushi, 2015). In addition, the resin matrix used was a mixture of Bis-GMA (Bisphenol A-glycidyl methacrylate), TEGDMA (Triethylene glycol dimethacrylate), and linear PMMA (Polymethylmetacrylate) that blended and formed a polymer matrix known as semi-interpenetrating (semi-IPN) polymer structure that serves as a sustainable and solid bind to improve the toughness of the composite (Garoushi, 2015). Fiber reinforced resin composite exhibits the advantage of controlling loads-related shrinkage during fiber-oriented polymerization process, therefore preventing from any marginal micro-leakage, making it easily superior compared to any type of conventional resin materials (Garoushi, 2008). This SFRC material insofar is the only known composite whose outcome structurally closest to or almost as perfectly natural as dentine.

DSC (differential scanning calorimetry)

DSC is a thermal-based analyzing technique to measure the amount of heat as energy absorbed by or discharged from a sample as a function of time or temperature. When a sample produces thermal transition, DSC will calculate the amount of transitional energy emission at certain temperature using calorimetry (Gill et al, 2018).

In Figure 3, it revealed that each of the materials tested using DSC had different characteristics in releasing heat capacity. The demand for stability of heat release is necessary to act as defensive response when being fused together with the host material (Gandia, 2019). The amount of heat release depends on the degree of absorption and the intensity level of the material by which correlated with the physical attributes of the material itself (Scapino, 2017).

However, unprecedented thermal pressure of the materials might occur internally and at subsequent stage, this can be translated as a highly potential defect because it will negatively impact especially the superficial structure of the composites and the tooth. This phenomenon is called polymerization shrinkage which unfortunately could impend to all resin-based restorative materials (Kleverlaan et al, 2005: 1150-1157).

Fracture resistance testing

Resistance to fracture, apparently, is the most crucial quality and the most credible qualification of the dental restoration result. Ultimate components known to greatly impact the fracture resistance of a final restored structure are the porous surface of the teeth and the characteristics of the restorative composite applied. Both factors will eventually determine the capacity in preventing crack propagation while the polymerization process takes place (Moosavi et al, 2012). SFRC is a resin-based composite containing E-glass fiber, inorganic particulate, and semi-IPN polymer matrix of Bis-GMA, TEGDMA, and PMMA. E-glass fiber composition in RBC possesses superior value as an excellent buildup to fracture resistance owing to its exceptional performance in transmitting loads from the matrix to the fiber. In case there is imminent possibility of shrinkage during the polymerization, the fiber-filled composite with its high quality random-oriented feature will absorb any loads potential to cause shrinkage during the polymerization by raising its capability in bearing the loads distributed on the matrix, resulting in polymerization shrinkage to less likely happen (Garlapati et al, 2017).

The testing confirmed that apart from the thermocycling process along with the material unit and its composition, other significant factor to crucially affect the intensity level of a composite is its density. In accordance with other previous similar studies, resistance to fracture relies on a number of factors including the density of the restorative composite (Ertuk et al, 2018). This hypothesis is strengthened using the base from the result on SDR–SFRC that demonstrated higher intensity level than any other composite mixtures (Figure 5). A 4mm SDR has a high degree of convention which increases the possibility risk of shrinkage to also likely happen (Denstply, 2011). The result of this study corresponds to Eapen et al (2017) which specifically observed the fracture resistance of endodontically treated class II MOD premolars and discovered the following order; SFRC to polyethylene fiber to the composite without fiber; according to the degree of resistance to fracture from the highest to the lowest.

Conclusion

This study confirmed the nature of correlativity among the methods employed by describing the capacity of each technique in its characteristic degree of fracture resistance of the post treatment ETT with a special note on SDR–SFRC for its certain aspects of prominence which include the growth of its degree of absorption which is directly proportional with the increase of the amount of time of its incubation period ($p<0.05$), and its unadulterated polymerization result with zero residual matter. The thermocycling process also assisted to raise the degree of absorption of both composite ingredients which in consequence, impacting the amount of thermal release. The supplementation of SFRC into class II MOD direct restoration with cusp coverage attested to increase the resistance to fracture of post treatment ETT ($p<0.05$) which according to the findings, the group receiving treatment of SDR-based intermediate layer and direct short fiber-reinforced composite restoration gaining the benefit of having a higher resistance to fracture than the group of restoration treatment without short fiber reinforced composite.

The sample group with the highest resistance to fracture was the one receiving SFRC supplementation with a considerably significant degree of superiority compared to the sample group without short fiber reinforced composite and even to the one with polyethylene fiber reinforced (BRR). The findings of the study also confirmed that apart from the thermocycling process along with the material unit and its composition, other significant factor to crucially affect the intensity level of a composite is its density.

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