

# The Effects of Resin-modified Glass Ionomer and Flowable Bulk-fill Base on the Fracture Resistance of Class II Restorations: Original Laboratory Experimental Study

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## ABSTRACT

**Aim:** The purpose of this study was to investigate the fracture resistance of marginal ridges restored using different techniques (amalgam, open sandwich technique, and incremental placement) and to compare these with smart dentin replacement (SDR) bulk-fill.

**Materials and methods:** Amalgam, dispersalloy; a nanohybrid resin composite (Tetric N Ceram), a resin-modified glass ionomer cement (RMGIC) base (Fuji II LC), and flowable bulk-fill composites (SureFil SDR) were used. Standardized class II (occluso-distal) OD cavities were prepared on 60 ( $n = 12$ ) extracted premolars, and five different protocols were used to restore the teeth: group 1, dispersalloy; group 2, dispersalloy with 4 mm Fuji II LC base; group 3, incrementally placed Tetric N Ceram; group 4, Tetric N Ceram with 4 mm Fuji II LC base; and group 5, Tetric N Ceram with SureFil SDR. The restorations were thermocycled then fractured using a universal testing machine, the maximum fracture load of the specimens was measured (N), and the type of fracture was recorded. Statistical analysis was carried out using one-way analysis of variance.

**Results:** Amalgam groups showed the lowest fracture resistance, with no significant difference between the based and nonbased groups. The highest fracture resistance was displayed by Tetric N Ceram with SDR base, and it was significantly higher than all the groups except the Tetric N Ceram nonbased group. The RMGIC based Tetric N Ceram displayed intermediate fracture resistance. The majority of the restorations showed mixed types of fracture except for nonbased amalgam, which mostly failed cohesively through amalgam. SDR-based composite was the only group that showed severe tooth failures.

**Conclusions:** The use of a 4 mm thick RMGIC base had no detrimental effect on the fracture resistance of class II amalgam and composite restorations.

**Clinical significance:** Bulk-fill SureFil SDR placed under a conventional resin-based composite had similar fracture resistance to incrementally placed composite but higher than amalgam and composite restorations based on RMGIC.

**Keywords:** Base material, Bulk-fill, Class II, Composite resins, RMGIC.

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## INTRODUCTION

Class II cavity preparations often have deep gingival margins, which presents several types of problems; the first is the difficulty in obtaining proper contact with the adjacent tooth and the second is the difficulties associated with bonding to dentin and cementum and polymerization shrinkage of resin-composite materials.<sup>1,2</sup> Ferrari et al. demonstrated the presence of an outer layer of 150 to 200  $\mu\text{m}$  at the border of the cervical margins; this unstructured cementum layer is located below the cemento-enamel junction (CEJ) and does not allow proper hybridization of adhesive materials.<sup>3</sup> Polymerization shrinkage of the composite resin results in forces at the tooth composite interface that leads to bond failure in the weakest margin (the gingival margin), causing postoperative sensitivity, marginal leakage, and recurrent caries. Also, the polymerization stresses could lead to cuspal deflection, enamel microcracks, and tooth fracture.<sup>4</sup>

Numerous restorative techniques and materials have been proposed to reduce polymerization shrinkage stresses, including the incremental layering technique, which is the standard of care in restorative dentistry, low elastic modulus liners, application of glass ionomer cement liners, and resin composites with lower shrinkage monomer formulations. The open sandwich technique was recommended to reduce the mass of the resin-based restorative material, to seal dentin gingival margins via chemical bonding, and to prevent the recurrence of caries with the fluoride released from the material.<sup>5,6</sup> Resin-modified glass ionomer cements (RMGICs)

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may be the material of choice for the liner because of their higher mechanical properties and low technique sensitivity compared to the conventional material, as well as their handling characteristics and light cure capability.<sup>7,8</sup> Also, RMGICs have been shown to display lower microleakage in class II cavities indicating good sealing ability at the tooth restoration interface.<sup>9,10</sup> Annual failure rates for this technique were reported to be 1.1%.<sup>11</sup>

SureFil SDR posterior bulk-fill flowable composite material (SDR) (DENTSPLY, York, Pennsylvania, United States) is a flowable composite that can be placed in 4-mm bulk placement and covered with a 2-mm thick conventional resin composite material.<sup>12</sup> Although the polymerization shrinkage of SDR is 3.1 volume%, which is similar to other flowable composites, it reduces stresses

by increasing the flow and adjusting the speed of polymerization with its unique chemistry.<sup>13</sup>

Retrospective and prospective clinical studies on the clinical performance of direct posterior composites have shown that caries and fracture of teeth and restorations are the main reasons for the replacement of direct composite resin restorations.<sup>11</sup> The risk of marginal ridge fracture could be influenced by the technique or material used in the restoration of class II restorations. However, studies that directly compare these different restorative materials and techniques are limited. The purpose of this study was to investigate the fracture resistance of marginal ridges restored using the commonly used restorative techniques (amalgam restorations, open sandwich technique, and incremental placement) and to compare these with SDR bulk-fill (DENTSPLY). The null hypothesis is there is no significant difference in fracture resistance between the materials techniques tested.

## MATERIALS AND METHODS

This research is a laboratory experimental study investigating the fracture resistance of class II marginal ridges restored using different restorative techniques. It was registered and approved by the College of Dentistry Research Center in King Saud University (CDRC registration #NF 2306). A total of 60 recently extracted intact first maxillary premolar teeth were selected for the study based on their similarity in size and anatomical features. All teeth were cleaned and examined for caries, fracture lines, or anatomical abnormalities using a light microscope (SWIFT Instruments International, SA, Microscope series 80, Tokyo, Japan). The teeth buccolingual dimension and crown length at the interproximal areas were measured using a digital micrometer gauge (Mitutoyo, Kawasaki, Japan), and only teeth within less than 1 mm size range were selected. Teeth were stored in 0.05% thymol solution until the restorations were prepared. The teeth were randomly assigned to a treatment group using a random number generator (<https://www.graphpad.com/quickcalcs/randomize1.cfm>). To fit the specimens to the jig of the Instron machine, the teeth were embedded within 3 mm of the CEJ, in a plastic ring (2.5 cm in diameter) using autopolymerizing resin

(Orthoresin, DeguDent GmbH, Hanau, Germany). Class II occluso-distal cavities were prepared with buccolingual width equaling half the intercuspal distance (2.5 mm) and extending into the mesial fossa. The distal box width at the marginal ridge was 4.5 mm, and the box was extended 7 mm gingivally to a level approximately 1 mm below the CEJ. The occlusal depth was 2 mm and the width of the gingival seat was 1 mm. The cavities were prepared using bur #1156, and the burs were changed every four teeth. For standardizing, all the preparations were performed by one operator using eye loupes (×2.5), and the dimensions were confirmed using a periodontal probe and a digital micrometer with an accuracy up to 0.05 mm (Flexbar Tools, New York, United States).

The materials used in this study are shown in Table 1. The teeth were divided into five treatment groups, and the restorations were placed by two experienced operators using the following protocols:

Group 1: The 12 teeth designated as control were restored with amalgam dispersalloy (DENTSPLY). A metallic AutoMatrix (DENTSPLY De Trey) was placed, and the amalgam was mixed using Ultramat 2 [Southern Dental Industries (SDI), Bensenville, Illinois, United States] for 10 seconds, then condensed and carved to proper anatomical contour.

Group 2: In this group, RMGIC base, Fuji II LC (GC, Alsip, Illinois, United States) was mixed for 10 seconds using Ultramat 2, then a 4 mm thick base was placed at the gingival seat and light-cured for 20 seconds using Bluephase G2 (Ivoclar Vivadent, Schaan, Liechtenstein) with a light intensity of 1200 mW/cm. After hardening, the gingival seat was re-established, and amalgam was condensed and carved.

Group 3: The teeth in this group were restored with Tetric N Ceram (Ivoclar Vivadent). Ultra etch (Ultradent, South Jordan, Utah, United States) was applied for 20 seconds, washed for 20 seconds, and then gently dried using cotton pellet and gentle blotting; the dentin surface was left visibly moist. Tetric N bond was applied and gently brushed for 10 seconds, thinned with air, and then light-cured for another 10 seconds. The composite (A2) was placed in the box in three increments: the first was a 2-mm horizontal layer over the gingival floor then two oblique layers were placed on the buccal and lingual walls. The last layer filled the occlusal part of the cavity and finalized the occlusal anatomy; each layer was light-cured for 20 seconds.

**Table 1:** Restorative materials used in the study

Material/lot number	Material type	Composition	Manufacturer
Dispersalloy/000023	Amalgam	Alloy powder weight%; silver 69.5%, tin 17.7%, copper 11.8%, zinc 1.0%. Mercury 600 mg (50%)	DENTSPLY, York, Pennsylvania, United States
Fuji II LC/1811051	RMGIC	Powder: fluoroaluminosilicate glass. Liquid: polyacrylic acid (20–25%); 2-hydroxyethyl methacrylate (30–35%) HEMA; proprietary ingredient (5–15%); 2,2,3-trimethylhexa methylene dicarbonate (1–5%)	GC, Alsip, Illinois, United States
Tetric N Ceram/W27411	Nanohybrid Universal composite (low-shrinkage)	Urethane dimethacrylate, Bis-GMA ethoxylated Bis-EMA, triethyleneglycol dimethacrylate. Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide prepolymers. Additives, stabilizers, catalysts, pigments	Ivoclar Vivadent, AG, Liechtenstein
Tetric N bond/200YC9	Bonding agent	Bis-GMA, urethane dimethacrylate, dimethacrylate, hydroxyethyl methacrylate, phosphonic acid acrylate, Bis-acrylamide derivative, Bismethacrylamide dihydrogenphosphate, amino acid acrylamide, hydroxyalkyl methacrylamide. nano-fillers (SiO <sub>2</sub> ). Ethanol, water, initiators, and stabilizers	Ivoclar Vivadent, AG, Liechtenstein
SureFil® SDR posterior/1508000703	Low viscosity bulk-fill composite material	SDRTM patented urethane dimethacrylate resin, ethoxylated bisphenol A dimethacrylate, triethylene glycol dimethacrylate, butylated hydroxyl toluene, barium-alumino-fluoro-borosilicate glass, strontium alumino-fluoro-silicate glass, camphorquinone, UV stabilizer, titaniumdioxide, iron oxide pigments. (Filler load 44% volume 68% weight)	DENTSPLY De Trey, Konstanz, Germany

Group 4: This group was restored with Tetric N Ceram and Fuji II LC modified glass ionomer using the sandwich technique. The box was filled using a 4 mm layer of Fuji II LC followed by three layers of Tetric N Ceram: two oblique layers in the box and one in the occlusal isthmus.

Group 5: Tetric N Ceram and SDR posterior bulk-fill flowable composite material (DENTSPLY) were used in this group. After acid etching and the application of adhesive, a 4-mm layer of SDR was placed in the box and light-cured for 20 seconds, followed by the application of Tetric N Ceram in three layers using the method described above.

After 24 hours, the amalgam restorations were finished using amalgam finishing burs, and the composite restorations were finished using fine and ultra-fine diamond burs (ET Esthetic Trimming Diamond Kit, Brasseler, Savannah, Georgia, United States) and Soflex polishing discs (3M/ESPE). A small flat area was created in the middle of the marginal ridge of all the specimens using a straight fissure bur on a high-speed handpiece to aid in the application of the load.

The specimens were stored in distilled water at 37°C, they were subjected to 5,000 thermocycles (Thermocycler 1106/1206 SD Mechatronik, Germany) between 5 and 55°C water baths, with a dwell time of 20 seconds at each temperature, and transfer time of 10 seconds. After 2 weeks, a conical stainless-steel rod with rounded edges measuring 1.5 mm at the tip was attached to the upper member of the universal testing machine (Instron 8500, Instron Corp., Norwood, Massachusetts, United States). It was positioned in the middle of the restoration marginal ridge in a buccolingual direction and at 1 mm from the occlusal embrasure of the proximal surface. The restorations were subjected to a compressive load at a crosshead speed of 1 mm/minute until failure. The failure load was registered in Newtons (N). For failure analysis, the fractured specimens were examined using an optical microscope (stereomicroscope, Nikon SMZ 1000, Tokyo, Japan) at  $\times 50$  magnification. Failure modes were categorized as “adhesive” between the restoration and the tooth structure; “cohesive” failure of the restorative material, “cohesive” failure of the tooth structure, and “mixed” cohesive failure of the restorative material or tooth accompanied with adhesive failure at the interface with tooth structure. Severe or catastrophic tooth structure fracture, which can complicate repair, was also noted. Blinding of the operators to the materials being tested was done during the testing and fracture evaluation procedures.

Since the fracture data were normally distributed and the variances were homogeneous, one-way analysis of variance (ANOVA) was used to determine the differences between the groups, followed by multiple comparisons and the statistical significance was set at  $p < 0.05$ .

## RESULTS

### Fracture Resistance

One-way ANOVA detected a difference between the groups ( $p < 0.001$ ) (Table 2). The amalgam groups showed the lowest fracture resistance; although the force required to fracture the based amalgam group was slightly higher than the nonbased, the difference was statistically insignificant. The highest fracture resistance was displayed by the Tetric N Ceram with SDR base, and it was significantly higher than all the groups except the Tetric N Ceram nonbased group. Tetric N Ceram based with resin modified displayed an intermediate level in marginal ridge fracture resistance (Table 3).

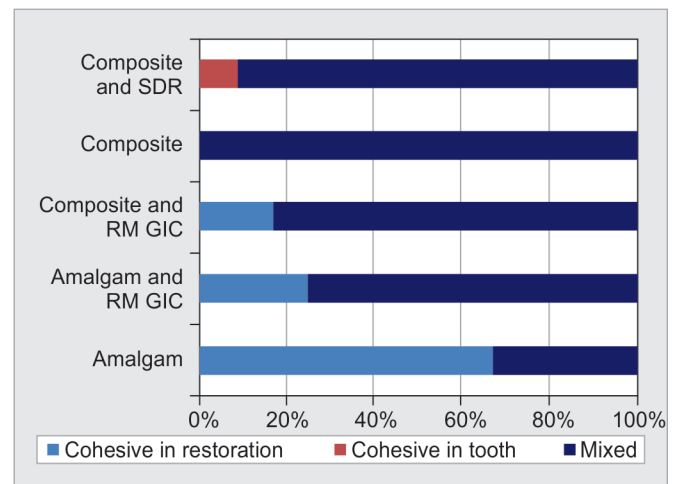
**Table 2:** Fracture resistance of class II restorations showing the results of Scheffe multiple comparisons

Group	Mean	Standard deviation
Amalgam	636 <sup>a</sup>	163
Amal+R M GIC	727 <sup>a</sup>	155
Tetric N+RMGIC	1099 <sup>b</sup>	162
Tetric N Ceram	1193 <sup>b,c</sup>	235
Tetric N+SDR	1364 <sup>c</sup>	139

\*Different superscript letters indicate statistical differences between groups

**Table 3:** Homogeneous subsets of mean fracture resistance

Group	Subset for $\alpha = 0.05$		
	1	2	3
Amalgam	636		
Amal+ GIC	727		
Comp+ GIC		1099	
Composite		1193	1193
Comp+ SDR			1364
Sig.	0.913	0.595	0.404



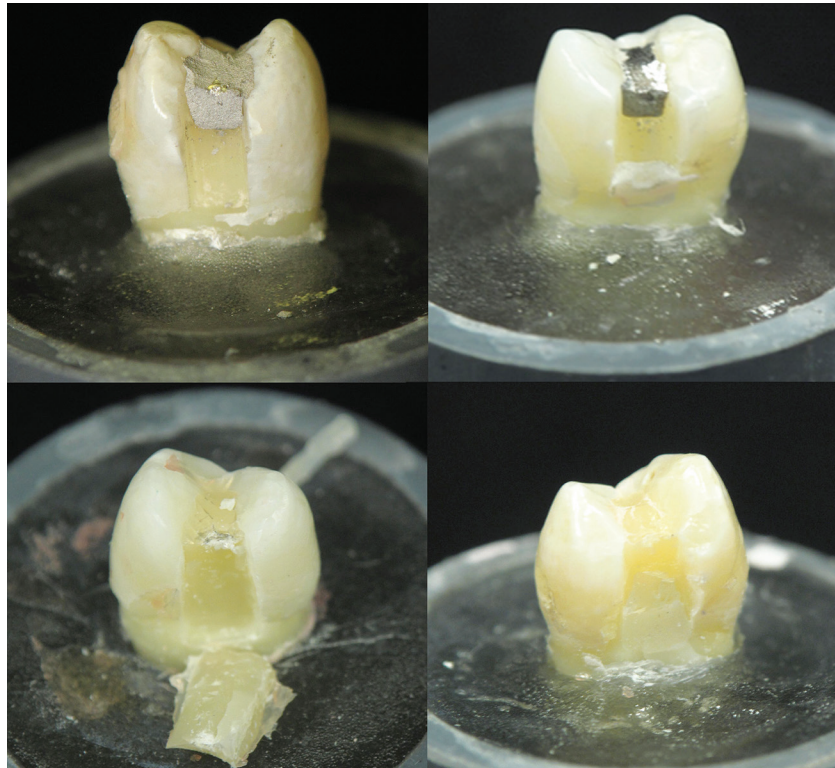
**Fig. 1:** The distribution of the failure modes for all groups

### Modes of Fractures in Class II Restorations

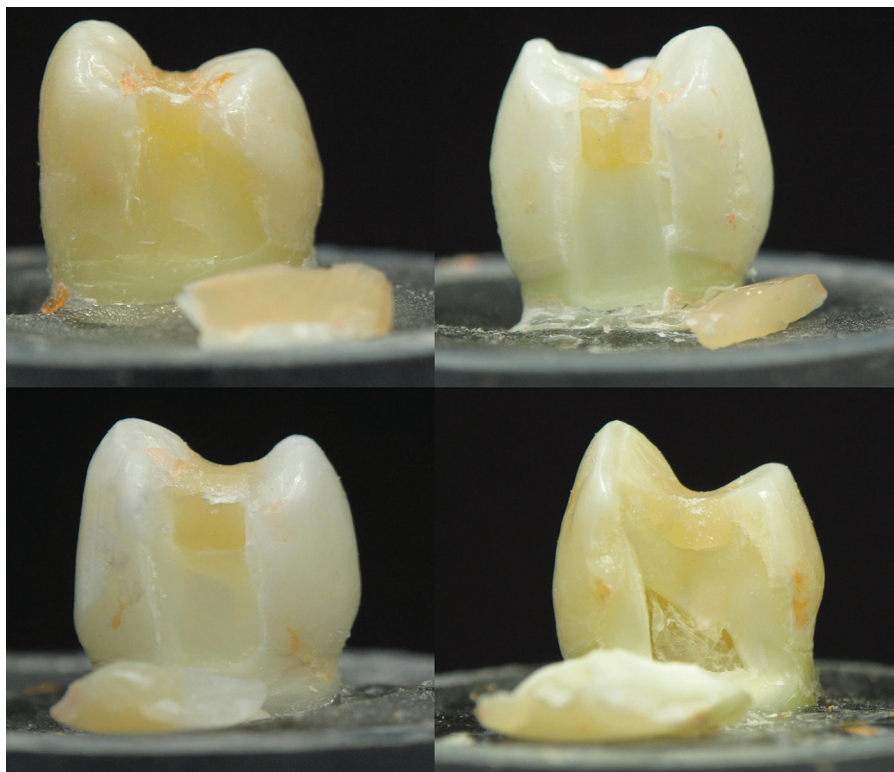
The modes of fracture for all the groups are shown in Figure 1. The majority of amalgam restorations failed cohesively through the marginal ridge and the box, with few displaying mixed fractures that start cohesively at the marginal ridge, and then failure occurred adhesively along the axial wall. When RMGIC base was used with amalgam, most of the restorations had mixed failures, and the majority of the RMGIC remained attached to the tooth, and only 58% of the bases were damaged (Figs 2A and 2B).

Composite restorations mostly failed in the mixed-mode; initial fracture occurred within the composite at the marginal ridge, with some adhesive failures in the axial wall and cohesive enamel failures buccally and lingually (Figs 2C and 2D). Pure adhesive fracture between tooth and restoration was rarely seen, however, severe fractures of the tooth were seen in two samples (Figs 3A and 3B).





**Fig. 2A to D:** Representative failure types. (A) Amalgam restoration after the fracture showing cohesive fracture in amalgam and adhesive failure with dentin walls. (B) Fuji II LC/amalgam sandwich restoration after the fracture showing intact base. (C) Tetric N Ceram specimen cohesively fractured, showing resin material covering the axial wall of the preparation. (D) Fuji II LC/Tetric N Ceram restoration showing fractured composite leaving some intact base



**Fig. 3A to D:** Representative failure types showing cohesive failure in the tooth structure. (A) Tetric N Ceram specimen cohesively fractured with the lingual enamel. (B) Fuji II LC/Tetric N Ceram restoration showing adhesively fractured composite with cohesive enamel chipping. (C) Tetric N Ceram/SDR mixed fracture involving composite, bulk-fill material, and facial enamel. (D) Tetric N Ceram/SDR specimen showing severe fracture of restoration and tooth

Composite with RMGIC base showed mixed modes of failure with cohesive fractures through composite, base as well as tooth structure, mainly enamel at the buccal and lingual walls. RMGIC base generally remained attached to the composite and all fractured together with it, only one sample separated from the composite.

Composite and SDR also showed mixed modes of fractures involving cohesive failures in the composite as well as the tooth structure mainly enamel (Fig. 3C). This is the only group that showed severe tooth failures in three of the teeth (Fig. 3D). Adhesive failure at the tooth/restoration interface was not frequently seen. In all but one of the samples, the SDR base broke with the composite and remained attached to it.

## DISCUSSION

The two most common causes of failure of resin-based composites (RBCs) are bulk fracture and secondary caries, and the restoration of some posterior teeth with composite restorations is clinically challenging.<sup>14</sup> Class II restorations have always provided a restorative dilemma, presenting dentistry with serious complication possibilities; the first is the failure of gingival bonding, and the second is related to the process of polymerization and depth of cure of composite materials. The range of materials and techniques to counteract these complications could have serious implications on the performance of restoration in the oral cavity.<sup>15</sup> The current study investigated the marginal ridge fracture resistance of teeth restored using amalgam restorations, open sandwich technique with Fuji II LC, incrementally placed Tetric N Ceram, and compared them with Tetric N Ceram/SDR bulk-fill flowable composite restorations. The null hypothesis that there is no significant difference in fracture resistance between the materials and techniques tested was rejected.

The two amalgam groups had the lowest fracture resistance of all the restorative techniques. Amalgam is a brittle material, and although it is strong under compressive load, it is quite weak under tension. Clinical studies have confirmed that fracture, either in tooth or restoration is a common cause of failure for amalgam restorations.<sup>16</sup> The use of RMGIC had no significant effect on the fracture resistance; however, the type of fracture changed from predominantly cohesive in the amalgam to mostly mixed type of fracture when the RMGIC base was used. Furthermore, more than half of the bases were lost or damaged. This might be due to the use of a very thick base; it is possible that if the base thickness was limited to 2 mm, the result might have been different. Studies have shown that the thickness and the elastic modulus of the base affect the amalgam strength; the thinner the base and the higher the elastic modulus, the stronger the amalgam.<sup>17,18</sup> However, if the remaining amalgam thickness is maintained at 3 mm, amalgam restorations will not be significantly weakened.<sup>19</sup> A previous study by Güray Efes et al. showed that a 1-mm-thick layer of glass-ionomer liners slightly increased the fracture resistance of open-sandwich class II amalgam restorations; however, in their study, the resistance of the tooth to fracture was tested and not the marginal ridge of the restoration.<sup>20</sup>

With the exception of the group restored with composite/SDR combination, the RBC groups showed similar fracture resistance. The use of RMGIC base material did not show a significant effect on the fracture resistance of the Tetric N Ceram composite material. The base material was damaged in all the samples, and it detached together as one unit, which indicates a very strong bond between the RBC and RMGIC. The use of low elastic modulus RMGIC in the

open sandwich technique is one of the methods used to provide a stress-buffering effect for the restoration and tooth during polymerization. Castañeda-Espinosa et al. found that the RMGIC liner was able to absorb part of the polymerization contraction force of Z-250, and the authors concluded its use as an intermediate layer under composite resin restorations could be recommended in situations where the composite resin polymerization contraction force is neither controllable nor predictable.<sup>21</sup> Also, an intermediary layer of RMGIC was found to reduce marginal leakage in class II composite restorations, indicating better sealing at the tooth-restoration interface.<sup>9,22</sup> RMGICs might be the most appropriate liner material for use with RBC restorations because of their handling characteristics and their high strength compared to the conventional material.<sup>20</sup> Van de Sande et al. reported that the 18-year survival of posterior composite resin restorations was not detrimentally affected by the use of a glass ionomer cement base.<sup>23</sup> However, the beneficial effect of RM GIC/RBC sandwich-type restoration has been disputed by many authors; Opdam et al.'s systematic review and meta-analysis on the longevity of posterior composite restorations questioned the advantage of this technique.<sup>24</sup> Furthermore, van Dijken stated that the elastic wall concept obtained with the intermediary poly-acid modified resin composite layer could not be shown to be superior in the long term clinical evaluation.<sup>25</sup>

The incremental placement technique is the standard of care for composite restorations; the primary reason for the recommended 2 mm increment thickness is related to the limited light penetration and compromised resin conversion beyond that depth. Placing and light-curing composites in increments are also believed to reduce polymerization stresses by decreasing the total volumetric shrinkage.<sup>15</sup> However, several authors questioned the validity of the reduction of polymerization shrinkage claim. Yu et al. indicated that polymerization stresses varied considerably between conventional and bulk filled materials depending on product composition, especially filler volume fraction, cavity depth, and the degree of conversion of the RBCs.<sup>26</sup> Other studies also concluded that bulk-fill resin composites and incrementally inserted resin composites had a similar volume of polymerization shrinkage and gap formation.<sup>27,28</sup> Conversely, some studies found that bulk-fill resin composites develop lower shrinkage forces than conventional counterparts.<sup>29</sup>

In the current study, the use of a 4-mm base of the low viscosity bulk-fill material SDR showed the highest fracture resistance, although it was not statistically higher than the incrementally placed conventional Tetric N Ceram composite; this is in agreement with previous reports.<sup>30</sup> Catastrophic cohesive tooth fractures were only seen in samples in this group, indicating a possibly different fracture mechanism. A high frequency of the unfavorable type of tooth fracture was also reported with SDR restoration in previous research.<sup>31</sup> A polymerization modulator capable of interacting with the camphorquinone photo-initiator was included within the composition of SDR to control the polymerization kinetics, which will result in a slower elasticity modulus development.<sup>32</sup> Given the lower filler content and elastic modulus of SDR compared to the conventional RBC, the ability of the base material to resist deformation due to loading might be impaired.<sup>33</sup> Furthermore, the possibility of stress transfer to the surrounding tooth structure is very high, which might explain the occurrence of such fractures.

The methodology used for this *in vitro* experiment is a limitation of this study as it does not accurately duplicate conditions in the oral cavity, in which fatigue failures are the main mode of fracture of restorations. The fracture resistance of restorations is affected

by many factors, including material composition, the geometry of the preparation, tooth size and structural integrity, and bonding quality. In addition, the type and direction of the applied force are major factors that can affect the outcomes. In a laboratory setting, many experiment design factors can have a profound effect on the results. The static load test used in this study does not resemble the loads the marginal ridge of the tooth is subjected to in the clinical situation; however, our results can shed some light on fracture behavior of class II posterior composite resin restorations. Cyclic loading and clinical studies should be undertaken to provide more clinically relevant information.

## CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that the use of a 4-mm thick RMGIC base had no detrimental effect on the fracture resistance of class II amalgam and composite restorations. Bulk-fill flowable SureFil SDR placed in a 4-mm increment under a conventional RBC had similar fracture resistance to incrementally placed conventional RBC but higher than amalgam and composite restorations based with RMGIC.

## CLINICAL SIGNIFICANCE

The use of RMGIC base had no detrimental effect on the fracture resistance of class II amalgam and conventional RBC restorations. Composite restorations with bulk-fill SureFil SDR base had similar fracture resistance to incrementally placed composite but higher than amalgam and composite restorations based with RMGIC.

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