Original Article

Comparison of Different Base Materials on Fracture Strength of Mesio-occlusal-distal Composite Restorations

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Abstract

Objective: The aim of this study was to evaluate the influence of different base materials on fracture strength of mesio-occlusal-distal (MOD) composite restorations. **Materials and Methods:** Forty-eight extracted, intact maxillary molar teeth with standardized, deep MOD cavities were randomly assigned into four groups according to the base material placed: Control group (CO); no base material, SDR group; bulk-fill flowable composite, CGIC group; chemically curing glass ionomer cement (GIC), and RGIC group; light curing resin reinforced GIC. All the specimens were then restored with a nanocomposite (CeramX Duo/Dentsply) in combination with etch and rinse adhesive following the manufacturer's instructions. After aging fracture, strength of the specimens was tested by the application of a ramped oblique load to the buccal cusp in a universal testing machine. Mean fracture strength values for each group were calculated and compared using one-way ANOVA ($P = 0.05$). Fracture patterns of the specimens were also evaluated. **Results:** The mean loads necessary to fracture the samples were as follows: control: 819.22 ± 253.65; SDR: 694.46 ± 266. 55; CGIC: 559.15 ± 277.34; RGIC 861.87 ± 277.28: N. The control and RGIC groups showed significantly higher fracture strength than CGIC and SDR groups ($P < 0.05$). Although the mean fracture strength value of SDR group was higher than that of CGIC group, the difference between these groups was not statistically significant ($P > 0.05$). Most frequently observed fracture patterns were adhesive (58.3%) in CO, cohesive (50%) in SDR group, cohesive (83.3%) in CGIC group, and mixed (41.7%) in RGIC group. **Conclusions:** Resin-modified glass-ionomer cement as a base material or restoration of the tooth only with composite resin resulted in higher fracture strength than composite resin restoration with a conventional glass ionomer base or a flowable bulk-fill material. Fracture pattern distributions diversed according to the base material placed under composite restoration.

Keywords: Bulk-fill, composite, fracture strength, glass ionomer cement

Introduction

Posterior teeth are considered to be under high impact forces and the patients hard biting of different objects may cause fractures which is a common problem. In addition, the position and anatomic configuration of the tooth affect the posterior teeth condition.[1,2] Posterior teeth become susceptible to fracture when an important amount of the tooth structure is lost and the fragile remaining tissue needs to be supported.[2-4] Dentine tissue is crucial for a solid base under restorations. The structural strength, integrity, quality and quantity of dentine affects and maintains the remaining structure to retain and supports the restoration.[5]

Clinicians reported that Class II cavity preparations, especially if they involve both proximal surfaces, are shown to be a challenging situation.[6,7] Different treatment options are indicated for the restoration of teeth with mesio-occlusal-distal (MOD) cavities. A wide variety of restorative modalities ranging from direct fillings using amalgam or resin composite to the more complex indirect restorations, each with its own indications, advantages, problems, and challenges exist.[8] In recent years, materials with mechanical properties more similar to dentin (such as composites) have been preferred for restoring teeth.[9] Especially in large cavities, composite restorations seem to be a more secure option for posterior teeth as a relatively low cost, esthetic alternative to crowns or onlays.[10,11]

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Although composite resin restorations have the ability of bonding to tooth structure, polymerization shrinkage stress, resulting in marginal gaps and microleakage, has been a serious drawback of composites. As a result, cuspal forces cause stress and the cracking of bond leads to microleakage. To reduce the effects of this problem, incremental placement technique,[12,13] the use of low shrinking composite resins,[14,15] soft-start polymerization technique,[16,17] and placement of base materials including flowable composites polyacid-modified resin composites and glass ionomers under composites have been recommended.[18,19] Thus, today, MOD cavities which have large tooth structure loss are generally restored with composite and glass ionomer cement (GIC) as the base material under.

GIC is widely used as base material under posterior composite restorations. GICs have the ability to bond to tooth structure and its mechanism is explained as a hydrogen bonding between carboxyl group of polyacid and the calcium in the tooth structure. In addition, the micromechanical penetration of GIC into the tooth has an influence.[20]

Resin-modified GIC (RMGIC) is a hybrid combination of water-soluble polymers or polymerizable resins to conventional GIC (CGIC). RMGICs were produced in an attempt to strengthen CGICs mechanical properties and prevent high solubility.[21] Mostly, RMGICs have superior mechanical and physical properties compared to CGIC. Although RMGICs have a lot af advantages, their physical and esthetic properties are not as good as composite restorations.[22]

As another perspective, a flowable bulk-fill composite SDR (Dentsply, York, USA), which can be placed under an enamel composite to replace the missing dentin structure has been introduced in recent years. SDR bulk-fill flowable base is a single component resin composite manufactured for posterior restorations. The material is suitable to be used as base in Class I and II restorations. Handling characteristics of this composite can be categorized as "flowable" and can easily be placed as 4-mm increments. SDR bulk-fill composite's flowable feature allows the material to adapt the cavity walls and intimate the shape of the preparation. Distinctively, this bulk-fill composite needs to be overlayed with a hybrid or methacrylate-based universal posterior composite for replacement of the hard structure enamel.[23]

The aim of this *in vitro* study was to evaluate the influence of different base materials on fracture strength of MOD composite restorations. The null hypothesis was that placement of SDR base will not improve fracture strength of molars filled with resin composites.

Materials and Methods

Forty-eight extracted, intact maxillary human molar teeth were used in this study. This project was approved by the Institutional Ethics Committee. Buccolingual width of the selected teeth was similar and measured by the same instructor using a digital caliper and only a deviation of 10% was allowed.[24] Teeth were mounted vertically in acrylic blocks imitating the healthy alveolar bone and root of the teeth were covered with acryl leaving 2 mm of the cementoenamel junction (CEJ) outside.

Mesio-occlusal-distal preparations

Standardized MOD cavities were prepared using a diamond flat-ended fissure bur (Diatech, Swiss Dental Instruments, Coltrane, Switzerland) in a high-speed handpiece with water coolant. Preparations' buccolingual width at the occlusal isthmus was set to the one-third of the distance between buccal and lingual cusp tips, and the buccolingual width of the proximal box was one-third of the buccolingual width of the crown. The gingival floor of the box was 1 mm coronal to the CEJ; occlusal depth was 3.0 mm and the proximal depth was 2–3 mm. Internal angles of preparations were rounded and cavosurface margins were left at 90°. Preparation walls were parallel and the dimensions of the cavities were checked before restoring. The teeth were then randomly assigned to four groups according to base materials and restorative techniques used [Table 1].

Control group

No base material was used in this group.

Conventional glass ionomer cement group

A chemically curing GIC (Kavitan Plus, Spofa Dental, Jičín, Czech Republic) was prepared according to the manufacturer's instructions. First, Kavitan conditioner was applied to cavities. One scoop of powder to 1 drop of liquid were mixed at room temperature (20°C–25°C) and placed with a depth of 1 mm on pulpal floor and proximal dentin walls. Setting time was minimum 4 min.

Resin-modified glass ionomer cement group

A light-curing, resin-reinforced GIC (RGIC) (Riva Light Cure, SDI, Victoria, Australia) was prepared according to the manufacturer's instructions. First, Riva conditioner was applied o cavities. After one scoop of powder to 1 drop of liquid were mixed at room temperature (20°C–25°C) and placed with a depth of 1 mm on pulpal floor and proximal dentin walls, the cement was cured for 20 s using an light-emitting diodes (LED) light-curing source (Radii plus, SDI, Victoria, Australia) at an intensity of 1200 mW/cm^2.

Bulk-fill flowable composite group (SDR)

The entire cavity preparations were etched with 37% phosphoric acid (DeTREY® Conditioner 36, Dentsply; St Paul, USA) for 20 s, rinsed with air–water spray for 15 s and dried for 20 s. A bonding agent (XP Bond, Dentsply, St Paul, USA) was applied and light cured for 20 s. SDR posterior bulk-fill flowable composite (SDR, Dentsply, York, USA) was placed to the proximal cavities and occlusal cavity up to 1 mm depth over the pulpal floor which corresponds to a proximal depth of 3–4 mm and light cured using an LED light source (Radii plus, SDI Victoria, Australia) for 20 s.

Table 1: Brand names, main compositions, manufacturers, and batch numbers of resin cement investigated

Material	Type	Composition	Manufacturer	Application	Batch number
Kavitan plus	CGIC	Zinc oxide, aluminum oxide, calcium, itaconic acid, tartaric acid, maleic acid, water	Spofa Dental, Danaher Corporation, Markova, Czech Republic	Mixing ratio: powder/liquid=2.7:1. 1scoop of powder to 1 drop of liquid were mixed using a disposable soft paper and a plastic or non-corroding spatula, as soon as possible (max. 30-45 seconds).	1919922
Riva light cure	RMGIC	Polyacrylic acid, tartaric acid, 2-hydroxyethyl methacrylate, Dimethacrylate, acidic monomer	SDI, SDI Limited, Australia	Mixing ratio: powder/liquid ratio 3.1:1. 1 scoop of powder to 1 drop of liquid were mixed using a disposable soft paper and a plastic or non-corroding spatula and light-cured (20s).	090113
SDR	Bulk-fill flowable composite base material	urethane dimethacrylate, dimethacrylate, di-functional diluent, barium, and strontium alumino-fluoro-silicate glasses colorant	Dentsply, St Paul, USA	Increments up to 4 mm	1005001037

RMGIC – Resin-modified glass ionomer cement, CGIC – Conventional glass ionomer cement

Following the base material application procedures, the entire cavity preparations were etched with 37% phosphoric acid (DeTREY® Conditioner 36, Dentsply; St Paul, USA) for 20 s, rinsed with air–water spray for 15 s and dried for 20 s. A bonding agent (XP Bond, Dentsply, St Paul, USA) was applied and light cured for 20 s, and the cavities were restored with incremental technique, as three increments in all groups except SDR group, using a nanoceramic composite (CeramX Duo, Dentsply, St Paul, USA). Only one overlying composite layer with a thickness of 2 mm was placed on SDR group. Each composite increment was cured for 40 s using an LED light-curing source (Radii plus, SDI, Victoria, Australia).

All specimens were stored in a distilled water at 37°C for 24 h and subjected to 5000 thermal cycles at 5°C–55°C.[1] Then, the fracture strength of the specimens was tested by the application of a ramped oblique load to the buccal cusp of the maxillar molars and lingual cusp of mandibular molars in a universal testing machine (Lloyd Instruments LR 50K, AMETEK GmbH, Meerbusch, Germany) with a crosshead speed of 1 mm/min^2.

The mean fracture strength values for each group were calculated and compared using one-way ANOVA ($P = 0.05$). Tukey honestly significant difference test was used for multiple comparisons. Mode of failure (adhesive, cohesive, and mixed) was assessed using standard criteria[4,25] at a magnification of ×20 (Leica MZ 16A, Leica Microsystems, Switzerland). Fracture patterns of the specimens were also evaluated under a stereomicroscope. Categorization of fracture patterns was determined according to the location where fracture occurred and initiation of the fracture.

Results

The mean loads necessary to fracture the samples are presented in Table 2. The control and RGIC groups showed significantly higher fracture strength than CGIC and SDR groups ($P < 0.05$). Although the mean fracture strength value of SDR group was higher than that of CGIC group, the difference between these groups was not statistically significant ($P > 0.05$).

Table 2: Mean loads (Newton) necessary to fracture the samples

Groups	*n*	Mean (N)±SD
Control	12	819.22±253.65[a]
CGIC	12	559.15±277.34[b]
RGIC	12	861.87±277.28[a]
SDR	12	694.46±266.55[b]

Same superscripts in the same column indicate no significant difference ($P>0.05$). CGIC – Conventional glass ionomer cement, RGIC – Resin reinforced glass ionomer cement, SD – Standard deviation

The fracture mode distributions are presented in Table 3. Most frequently observed fracture patterns were adhesive (58.3%) in control group (CO), cohesive (83.3%) in CGIC group, mixed (41.6%) in RGIC group, and cohesive (50%) in SDR group.

In addition, the fracture modes were different between groups ($P < 0.05$). The CO had 7 adhesive fractures, whereas CGIC group had none ($P < 0.05$). RGIC and SDR groups had a similar adhesive fracture mode percentage (RGIC: 33.33%, SDR: 41.6%) ($P > 0.05$). The cohesive fracture mode percentage was very high in the CGIC group (83.3%) when it was significantly low at the CO (16.6%) [Table 3] ($P < 0.05$).

The fracture level distributions are presented in Table 4. Most of the fractures were under the CEJ. Fractures were subgingival at 9 specimens in the CO when only half of the specimens had a fracture subgingivally at the CGIC and SDR (6/12) group. However, at the RGIC group (12/12), all fractures were subgingival.

The fracture pattern distributions were listed as, L (from line angle), C (cuspal), C-K (cuspal and complex), and L-C (from line angle and cuspal). Most seen fracture pattern distribution was cuspal, except at the CO. Line angle fractures had the highest fracture pattern percentage at the CO [Table 5].

Discussion

Extensive cavity preparations like MOD preparations may lead to cuspal fracture if the tooth is not adequately restored.[2,5] Therefore, to ensure a good long-term prognosis, reinforcement of the cavity with the restorative material is necessary to support the remaining tooth structure and special attention has to be paid during the decision-making process of their restorative treatment options. Taha *et al*.[26] showed that the integrity of teeth are highly dependent on the proximal walls loss and fracture strength of teeth reduces relatively more than 60% of intact teeth when proximal walls are absent. Despite different cavity preparations and different location of loading, another study[27] had similar results. Previous studies have shown improved fracture resistance of teeth after using resin composites for MOD restorations.[28-30] However, shrinkage of composite materials during polymerization is a factor that adversely affected the success of direct composite restorations. Therefore, incremental composite placement is preferred for reduction of stress during the buildup and prevent gap formations at the tooth-restoration interface.[31]

Flowable liners have the ability to wet the cavity better than condensable composites as a result of their flowability and also decrease sensitivity due to fine adaptation to the preparation surfaces. In addition, good adaptation of the composite prevents voids at the interface of restoration. Furthermore, they increase fracture strength of restorations due to their stress absorbing characteristic when compared with resin composites alone.[32]

In recent years, bulk-fill flowable materials have been put on the market by manufacturers. Bulk-fill composites were developed to simplify restoration placement technique. These composites are claimed to have lower polymerization shrinkage stress compared to conventional composites and scatters light better than composites placed using the incremental technique.[25,33,34] In the present study, RMGIC group which was placed using incremental technique demonstrated higher fracture strength values than SDR placed as bulk so that the null hypothesis was rejected.

A study conducted with SDR flowable bulk-fill material had reported that polymerization stress of SDR was considerably lower than conventional flowable materials.[35] Hence, in this study, it was aimed to compare the performance of novel SDR flowable bulk-fill material with GICs which are routinely used for many years as base materials. Since their development,[36] GICs have been widely used in clinical dentistry as base or restorative material.[2] GICs have advantages and disadvantages according to their several different versions. In the present study, powder-liquid glass ionomers were used. The RMGICs show some advantages over the conventional GICs. Clearly, due to their control of the photochemical curing process by the practitioner, RMGICs allow longer working time. Therefore, the light-curing process seems to reduce sensitivity to moisture.[37]

A study conducted to evaluate the fracture toughness of dental restorative materials showed that fracture toughness of conventional GIC was lower than RMGIC and flowable resin composites had the highest fracture toughness.[38] In the present study, RMGIC demonstrated higher fracture strength than CGICs. In addition, RMGIC group showed significantly higher fracture strength than SDR group ($P < 0.05$). On the other hand, the mean fracture strength value of SDR group was not significantly different from CGIC group ($P > 0.05$).

Banditmahakun *et al*.[39] demonstrated that use of a base material with a high elastic modulus to support a ceramic inlay has an influence on fracture load. Although GIC demonstrated lower mechanical properties compared to composite resin restorations, placement of them did not affect the fracture

Table 3: Fracture mode distributions

Groups	Adhesive (%)	Cohesive (%)	Mixed (%)
Control	7 (58.3)	2 (16.6)	3 (25)
CGIC	-	10 (83.3)	2 (16.6)
RGIC	4 (33.33)	3 (25)	5 (41.6)
SDR	5 (41.6)	6 (50)	1 (8.3)

CGIC – Conventional glass ionomer cement, RGIC – Resin reinforced glass ionomer cement

Table 4: Fracture level distributions

Groups	Subgingival (%)	Supragingival (%)
Control	9 (75)	3 (25)
CGIC	6 (50)	6 (50)
RGIC	12 (100)	0
SDR	6 (50)	6 (50)

CGIC – Conventional glass ionomer cement, RGIC – Resin reinforced glass ionomer cement

Table 5: Fracture pattern distributions and percentages

Groups	C (cuspal) (%)	L (from line angle) (%)	L-C (from line angle and cuspal) (%)	C-K (cuspal and complex) (%)
Control	2 (16.6)	7 (58.3)	1 (8.3)	2 (16.6)
CGIC	10 (83.3)	-	-	2 (16.6)
RGIC	4 (33.33)	4 (33.33)	1 (8.3)	3 (25)
SDR	6 (50)	5 (41.6)	-	1 (8.3)

C (cuspal) – Only one cusp fracture is present; the restoration is not included to the fracture, L (from line angle) – Two cusp fracture is present; the restoration is not included to the fracture, L-C (from line angle and cuspal) – Two cusp fracture involved and the restoration is included to the fracture, C-K (cuspal and complex) – Three cusps fracture involved and the restoration is included to the fracture. CGIC – Conventional glass ionomer cement, RGIC – Resin reinforced glass ionomer cement strength negatively.[28] Besides, some authors reported that GIC improved fracture strength of the restored teeth to levels not significantly different from the intact tooth.[40,41] Davidson[42] claimed that it could be attributed to the ability of GIC to act as absorber for stress encountered during polymerization. Similar to the present study, Taha *et al*.[26] demonstrated that fracture strength was not significantly greater in GIC groups than in the group restored with resin composite alone. In the present study, SDR bulk-fill material was used to fill the cavity up to 4 mm according to manufacturer's recommendations. The material showed low mechanical behavior compared to control and RMGIC groups. On the other hand, the results of a study confirmed that the curing of bulk-fill resin composites was efficient at 4 mm depth and showed acceptable results.[43]

Hormati and Fuller[44] demonstrated that increasing the thickness of the base material resulted in a decrease in fracture strength of restorations. Their results clearly showed that the base material thicknesses played a crucial role. The present study also revealed similar results, as the group without base material showed highest fracture strength.

The method of occlusal loading during the fracture test is another important factor. In this *in vitro* study, oblique forces were applied to the buccal and lingual cusps. Some studies reported that when oblique loading was applied fractures typically occurred at the restoration-tooth interface,[41,45] but clinically, in addition to axial forces, lateral forces, and fatigue loading, should also be considered.[1]

Repair of restoration is a valuable and accepted method to improve the quality of restorations and longevity of a tooth and the evidence about this issue seems to be in favor of repair over replacement.[46] Repairability of a material is important since replacements show worse clinical results than repair. Besides, the possibility for repair also depends on the location and size of the defect, and therefore, whether it is accessible for repair or not.[47] For this reason, fracture levels and fracture patterns were also considered to be very important and evaluated in detail in the current study.

The SDR group mostly had cuspal fracture patterns (%50) which were compatible with the minimally invasive approach, but on contrary, subgingival fracture level distributions (%50) were high in this group. Most frequently observed fracture pattern at the SDR group was cohesive (50%) and complex fracture patterns that (%8.3) occurred rarely at this group. The SDR group exhibited isolated fracture of the restoration, whereas the RCIS group showed serious fractures with the root involvement. RGIC group showed subgingival fractures (%100), whereas with CGIC fracture patterns were 50% subgingival and 50% supragingival. Most of the fracture patterns in the CGIC group were repairable (Cuspal: %83.3). However, with the subgingival fracture levels (%100) and higher complex fractures than other groups (%25), RGIC groups' fracture types could not be considered as repairable.

The clinical significance of these findings should consider that this study was carried out under *in vitro* conditions. Long-term thermal, chemical, and physical effects of oral conditions should ideally mimic with more relevant test methods. A clinical study showed that the presence of a GIC base did not affect the survival of resin-composite restorations.[48] Further clinical investigations are recommended to verify *in vitro* test results.

Conclusions

Within the limits of the current study, it can be concluded that the use of an RMGIC as a base material or restoration of the tooth only with composite resin resulted in higher fracture strength than composite resin restoration with a conventional glass ionomer base or a flowable bulk-fill material. Further *in vitro* and *in vivo* studies are necessary to confirm the results of this study.

Clinical relevance

Despite higher fracture strength values of resin-modified GIC, clinicians might prefer conventional glass ionomer base materials and dentin replacement flowable bulk-fill materials since their fracture patterns are repairable.

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Conflicts of interest

There are no conflicts of interest.

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