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

Fatma Dilsad Oz, Esra Ergin, Sevil Gurgan

Department of Restorative Dentistry, School of Dentistry, Hacettepe University, Sihhiye, 06100, Ankara, Turkey

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 restor

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

Access this article online			
Quick Response Code:	Website: www.ejgd.org		
	DOI: 10.4103/ejgd.ejgd_153_17		

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]

Address for correspondence: Dr. Fatma Dilsad Oz, Department of Restorative Dentistry, School of Dentistry, Hacettepe University, Sihhiye 06100, Ankara, Turkey. E-mail: dilsadoz@yahoo.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Oz FD, Ergin E, Gurgan S. Comparison of different base materials on fracture strength of mesio-occlusal-distal composite restorations. Eur J Gen Dent 2018;7:25-30.

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/cm².

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.

Material	Туре	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

	Table 1: Brand names	, main compositions	, manufacturers.	, and batch numbers	of resin cem	ent investigated
--	----------------------	---------------------	------------------	---------------------	--------------	------------------

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/min².

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

Groups	п	Mean (N) \pm SD
Control	12	819.22±253.65ª
CGIC	12	559.15±277.34 ^b
RGIC	12	861.87±277.28 ^a
SDR	12	694.46±266.55b

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

groups was not statistically significant (P > 0.05).

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

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				
Subgingival (%)	Supragingival (%)			
9 (75)	3 (25)			
6 (50)	6 (50)			
12 (100)	0			
6 (50)	6 (50)			
	e level distributions Subgingival (%) 9 (75) 6 (50) 12 (100) 6 (50)			

CGIC – Conventional glass ionomer cement,

RGIC - Resin reinforced glass ionomer cement

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 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, RGIC – Conventional 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.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Kivanç BH, Alaçam T, Görgül G. Fracture resistance of premolars with one remaining cavity wall restored using different techniques. Dent Mater J 2010;29:262-7.
- Nam SH, Chang HS, Min KS, Lee Y, Cho HW, Bae JM, et al. Effect of the number of residual walls on fracture resistances, failure patterns, and photoelasticity of simulated premolars restored with or without fiber-reinforced composite posts. J Endod 2010;36:297-301.
- Meng QF, Chen YM, Guang HB, Yip KH, Smales RJ. Effect of a ferrule and increased clinical crown length on the *in vitro* fracture resistance of premolars restored using two dowel-and-core systems. Oper Dent 2007;32:595-601.
- Soares PV, Santos-Filho PC, Martins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part I: Fracture resistance and fracture mode. J Prosthet Dent 2008;99:30-7.
- Unlu N, Cobankara FK, Ozer F. Effect of elapsed time following bleaching on the shear bond strength of composite resin to enamel. J Biomed Mater Res B Appl Biomater 2008;84:363-8.
- Krämer N, Reinelt C, Frankenberger R. Ten-year clinical performance of posterior resin composite restorations. J Adhes Dent 2015;17:433-41.
- Pallesen U, van Dijken JW. A randomized controlled 30 years follow up of three conventional resin composites in class II restorations. Dent Mater 2015;31:1232-44.
- Christensen GJ. Longevity of posterior tooth dental restorations. J Am Dent Assoc 2005;136:201-3.
- 9. Eskitaşcioğlu G, Belli S, Kalkan M. Evaluation of two post core systems using two different methods (fracture strength test and a finite elemental stress analysis). J Endod 2002;28:629-33.
- Mondelli RF, Ishikiriama SK, de Oliveira Filho O, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. J Appl Oral Sci 2009;17:161-5.

- Plotino G, Buono L, Grande NM, Lamorgese V, Somma F. Fracture resistance of endodontically treated molars restored with extensive composite resin restorations. J Prosthet Dent 2008;99:225-32.
- Ghavamnasiri M, Moosavi H, Tahvildarnejad N. Effect of centripetal and incremental methods in class II composite resin restorations on gingival microleakage. J Contemp Dent Pract 2007;8:113-20.
- Idriss S, Abduljabbar T, Habib C, Omar R. Factors associated with microleakage in class II resin composite restorations. Oper Dent 2007;32:60-6.
- Palin WM, Fleming GJ, Nathwani H, Burke FJ, Randall RC. *In vitro* cuspal deflection and microleakage of maxillary premolars restored with novel low-shrink dental composites. Dent Mater 2005;21:324-35.
- Yamazaki PC, Bedran-Russo AK, Pereira PN, Wsift EJ Jr. Microleakage evaluation of a new low-shrinkage composite restorative material. Oper Dent 2006;31:670-6.
- Hofmann N, Denner W, Hugo B, Klaiber B. The influence of plasma arc vs. halogen standard or soft-start irradiation on polymerization shrinkage kinetics of polymer matrix composites. J Dent 2003;31:383-93.
- Chan DC, Browning WD, Frazier KB, Brackett MG. Clinical evaluation of the soft-start (pulse-delay) polymerization technique in class I and II composite restorations. Oper Dent 2008;33:265-71.
- Alomari QD, Reinhardt JW, Boyer DB. Effect of liners on cusp deflection and gap formation in composite restorations. Oper Dent 2001;26:406-11.
- Cho E, Chikawa H, Kishikawa R, Inai N, Otsuki M, Foxton RM, *et al.* Influence of elasticity on gap formation in a lining technique with flowable composite. Dent Mater J 2006;25:538-44.
- Leinfelder K. Characteristics of a new glass ionomer material. Inside Dent 2006;1:42-4.
- Hill EE. Dental cements for definitive luting: A review and practical clinical considerations. Dent Clin North Am 2007;51:643-58, vi.
- Khoroushi M, Keshani F. A review of glass-ionomers: From conventional glass-ionomer to bioactive glass-ionomer. Dent Res J (Isfahan) 2013;10:411-20.
- Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: An in vitro assessment of their mechanical performance. Oper Dent 2013;38:618-25.
- Taha NA, Palamara JE, Messer HH. Cuspal deflection, strain and microleakage of endodontically treated premolar teeth restored with direct resin composites. J Dent 2009;37:724-30.
- Soares CJ, Soares PV, de Freitas Santos-Filho PC, Castro CG, Magalhaes D, Versluis A, *et al.* The influence of cavity design and glass fiber posts on biomechanical behavior of endodontically treated premolars. J Endod 2008;34:1015-9.
- Taha NA, Palamara JE, Messer HH. Fracture strength and fracture patterns of root filled teeth restored with direct resin restorations. J Dent 2011;39:527-35.
- Soares PV, Santos-Filho PCF, Queiroz EC, Araújo TC, Campos RE, Araújo CA, *et al.* Fracture resistance and stress distribution in endodontically treated maxillary premolars restored with composite resin. J Prosthodont 2008;17:114-9.
- Eakle WS. Increased fracture resistance of teeth: Comparison of five bonded composite resin systems. Quintessence Int 1986;17:17-20.
- 29. Gelb MN, Barouch E, Simonsen RJ. Resistance to cusp fracture in

class II prepared and restored premolars. J Prosthet Dent 1986;55:184-5.

- Jagadish S, Yogesh BG. Fracture resistance of teeth with class 2 silver amalgam, posterior composite, and glass cermet restorations. Oper Dent 1990;15:42-7.
- Krejci I, Sparr D, Lutz F. Three-layer light hardening procedure with traditional composites for black class II restorations. Quintessenz 1987;38:1217-29.
- Chuang SF, Jin YT, Liu JK, Chang CH, Shieh DB. Influence of flowable composite lining thickness on class II composite restorations. Oper Dent 2004;29:301-8.
- Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Investig 2014;18:1991-2000.
- Kim RJ, Kim YJ, Choi NS, Lee IB. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. J Dent 2015;43:430-9.
- Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR™ technology. Dent Mater 2011;27:348-55.
- Mohammadi N, Kahnamoii MA, Yeganeh PK, Navimipour EJ. Effect of fiber post and cusp coverage on fracture resistance of endodontically treated maxillary premolars directly restored with composite resin. J Endod 2009;35:1428-32.
- Wilson AD. Resin-modified glass-ionomer cements. Int J Prosthodont 1990;3:425-9.
- Ilie N, Hickel R, Valceanu AS, Huth KC. Fracture toughness of dental restorative materials. Clin Oral Investig 2012;16:489-98.
- Banditmahakun S, Kuphausuk W, Kanchanavasita W, Kuphasuk C. The effect of base materials with different elastic moduli on the fracture loads of machinable ceramic inlays. Oper Dent 2006;31:180-7.
- Hernandez R, Bader S, Boston D, Trope M. Resistance to fracture of endodontically treated premolars restored with new generation dentine bonding systems. Int Endod J 1994;27:281-4.
- Wendt SL Jr., Harris BM, Hunt TE. Resistance to cusp fracture in endodontically treated teeth. Dent Mater 1987;3:232-5.
- Davidson CL. Glass-ionomer bases under posterior composites. J Esthet Dent 1994;6:223-4.
- Li X, Pongprueksa P, Van Meerbeek B, De Munck J. Curing profile of bulk-fill resin-based composites. J Dent 2015;43:664-72.
- Hormati AA, Fuller JL. The fracture strength of amalgam overlying base materials. J Prosthet Dent 1980;43:52-7.
- Ausiello P, De Gee AJ, Rengo S, Davidson CL. Fracture resistance of endodontically-treated premolars adhesively restored. Am J Dent 1997;10:237-41.
- Hickel R, Brüshaver K, Ilie N. Repair of restorations Criteria for decision making and clinical recommendations. Dent Mater 2013;29:28-50.
- 47. Sharif MO, Fedorowicz Z, Tickle M, Brunton PA. Repair or replacement of restorations: Do we accept built in obsolescence or do we improve the evidence? Br Dent J 2010;209:171-4.
- 48. van de Sande FH, Rodolpho PA, Basso GR, Patias R, da Rosa QF, Demarco FF, *et al.* 18-year survival of posterior composite resin restorations with and without glass ionomer cement as base. Dent Mater 2015;31:669-75.

"Quick Response Code" link for full text articles

The journal issue has a unique new feature for reaching to the journal's website without typing a single letter. Each article on its first page has a "Quick Response Code". Using any mobile or other hand-held device with camera and GPRS/other internet source, one can reach to the full text of that particular article on the journal's website. Start a QR-code reading software (see list of free applications from http://tinyurl.com/yzlh2tc) and point the camera to the QR-code printed in the journal. It will automatically take you to the HTML full text of that article. One can also use a desktop or laptop with web camera for similar functionality. See http:// tinyurl.com/2bw7fn3 or http://tinyurl.com/3ysr3me for the free applications.