Original Article

Evaluation of microleakage in Class II composite restorations: Bonded-base and bulk-fill techniques

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ABSTRACT

Background: This study compared microleakage of Class II cavities restored using bonded-base and bulk-fill techniques with different bases.

Materials and Methods: In this *in vitro* study, in 60 extracted human molars, standardized (4 mm × 2 mm × 8 mm) Class II cavities were prepared, such that the gingival floor was located 1 mm below the CEJ. The teeth were randomly divided into five groups and filled with: (1) Fuji II LC + x-tra fil, (2) Ionoseal + x-tra fil, (3) x-tra base + x-tra fil, (4) Grandio Flow + x-tra fil, and (5) x-tra fil only [control group]; in open-sandwich technique, the base thickness was 1 mm. The bases were coated all gingival floor. Except for the first group, where dentin conditioner was used, the Clearfil SE bond was applied before application of the bases and restorative materials as a bonding agent. After 500 thermocycles between 5°C and 55°C, the specimens were immersed in 0.5% basic fuchsine solution for 24 h. The restored teeth were sectioned, and the dye penetration in gingival floor was observed by a stereomicroscope at ×32. The data were analyzed using Kruskal–Wallis and Mann–Whitney tests in SPSS software. The significance was determined at 0.05 confidence interval.

Results: The statistical analysis revealed a significant difference in microleakage among the study groups ($P < 0.001$). The Ionoseal group followed by the control group (x-tra fil composite) had the greatest microleakage. Except for the Ionoseal group, all other groups had significantly less microleakage than the control group.

Conclusion: The use of bonded-base techniques could reduce microleakage, including those in bulk-fill composite restorations.

Key Words: Composite resin, dental leakage, flowable composite liner, resin-modified glass ionomer, bulk-fill composite resin

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INTRODUCTION

The use of tooth-colored restorative materials has increased in recent decades. Improvements in the various physical properties of composite resins have contributed to this rise in popularity. However, composite resins continue to suffer from polymerization shrinkage, which can cause stress at the interface of the material and tooth structure. If shrinkage stress exceeds bond strength, a marginal gap forms and leakage occurs at the interface.[1,2] Microleakage can contribute to marginal discoloration, recurrent caries, and pulpal irritation.[3]

When the gingival margin of a preparation is in dentin, the risk of the microleakage is increased. Many materials and methods have been proposed to improve marginal adaptation and reduce microleakage at the gingival margin. One such method is the bonded-base restorative technique. In this technique, an intermediate layer such as a glass ionomer or a low modulus resin-based material is placed between the restorative material and the dentin floor as the initial increment of the restoration.[4] Because this intermediate layer absorbs stress, it can decrease the effects of polymerization shrinkage. When glass ionomer is used as an intermediate material and is left exposed at the margin, this method is called the open-sandwich technique.[5,6]

The use of resin-modified glass ionomers (RMGIs) in the sandwich technique provides chemical bonding to dentin, micromechanical bonding to composite resin, protective effects for the pulp, and potential cariostatic activity. Some studies have reported the effect of RMGI on the reduction of polymerization shrinkage, microleakage, and secondary caries.[7-10]

Flowable composite resins can reduce microleakage because of their low viscosity, ease of adaptation with tooth structure, and low modulus of elasticity.[11-15] However, flowable composite (Grandio Flow: 6.85 Mpa) has higher elastic modulus than RMGI (Fuji II LC: 5.33 Mpa), so it is less effective in reducing the effects of restorative material shrinkage.[16] Nevertheless, one study showed no difference in microleakage of Class II restorations in flowable composite resins and RMGI when used as intermediate materials.[11]

Many *in vitro* studies[12-14] have shown reduction of microleakage when using flowable composite resins as the base, whereas other studies[17-19] have shown no improvement in marginal adaptation.

Considering the varying results obtained from different methods for Class II composite restorations, especially the introduction of new products such as bulk-fill composite resins and various materials as bases, the purpose of this study was to compare the microleakage of new base materials used in bonded-base restorations along with bulk-fill composite resin. The null hypothesis was that there is no significant difference between techniques and base materials used for placing Class II composite restorations.

MATERIALS AND METHODS

The present *in vitro* study was approved by the Research Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran (with the ethics code of 395188), 60 extracted human third molars (free from cracks, fracture, caries, abrasion, previous restoration, and structural defects) were used. The teeth were stored in 0.2% thymol, cleaned using curettes, and randomly divided into five groups, 12 samples in each group. Sample size was calculated according to a previous study by Poggio *et al*.[20] using PASS II software considering alpha = 0.05, beta = 0.2, and effect size of 0.42.

Class II box preparations were made in the mesial and distal surfaces of each tooth using a #245 bur (C21FG, Jota AG, Rüthi, Switzerland). Preparations had a buccolingual width of 4 mm, axial depth of 2 mm, and occlusogingival length of 8 mm, with gingival floors 1 mm below the CEJ. Pre-contoured clear matrices (Polyester Matrix, TDV, Santa Catarina, Brazil) were used to confine materials during placement. The thickness of the composite layers was marked on the strip to ensure uniform thickness of the composite layers. The materials used in the study, their manufacturers, and compositions are listed in Table 1.

Group 1 RMGI: The gingival floor of the preparation was conditioned for 20 s with polyacrylic acid 10% (Dentin Conditioner, GC, Tokyo, Japan) and then a 1-mm thick layer of RMGI (Fuji II LC) was placed on the gingival floor, measured by graduated periodontal probe, and light-activated for 20 s. After that, enamel margins were etched with 37% phosphoric acid (Ultra-Etch, Ultradent, South Jordan, UT, USA) for 20 s and then were rinsed and dried for 20 s. Self-etch primer was rubbed on the cavity walls for 20 s using a microbrush. Mild air pressure was applied for 10 s to remove solvent. The adhesive (Clearfil SE Bond) was applied to the entire preparation's walls. After removing the excess using a microbrush, the adhesive was light-activated for 20 s. The preparation was restored using two layers of bulk-fill composite (x-tra fil). The first and second increments were placed horizontally and had 3 and 4 mm thickness, respectively, measured by graduated periodontal probe, and then each layer was cured for 10 s. All light-curing was done using a halogen light-curing unit (Optilux 501, Kerr Demetron, Orange, CA, USA) with an intensity of 1000 mW/cm^2.

Table 1: Materials used in the study

Material	Type	Manufacturer	Composition
x-tra base	Bulk-fill flowable composite	VOCO GmbH, Cuxhaven, Germany	Bis-EMA 10-25%, aliphatic dimethacrylate 10%-25%
x-tra fil	Bulk-fill composite resin	VOCO GmbH, Cuxhaven, Germany	Bis-GMA 5%-10%, TEGDMA<2.5%
Ionoseal	Light-cured resin-modified glass ionomer liner	VOCO GmbH, Cuxhaven, Germany	Fluoroaluminosilicate glass, Bis-GMA, 1,6-hexanediylbismethacrylate 5%-10%, TEDMA 2.5%-5%
Fuji II LC	Resin-modified glass ionomer	GC Corporation, Tokyo, Japan	Liquid (24% weight): PAA, HEMA, proprietary ingredient, 2,2,4-trimethylhexamethylenedicarbonate, TEGDMA Fillers (76% weight): Fluoroaluminosilicate glass
Grandio flow	Conventional flowable composite resin	VOCO GmbH, Cuxhaven, Germany	HEDMA 5%-10%, BIS-GMA 2.5%-5%
Clearfil SE bond	Two-step self-etch adhesive	Kuraray Noritake, Japan	Self-etching primer: 2-hydroxyethyl methacrylate 20%-40%, 10-Methacryloyloxydecyl dihydrogen phosphate Hydrophilic aliphatic dimethacrylate dl-Camphorquinone Water Bond: Bisphenol A diglycidylmethacrylate 25%-45%, 2-hydroxyethyl methacrylate 20%-40%, 10-Methacryloyloxydecyl dihydrogen phosphate Hydrophobic aliphatic methacrylate Colloidal silica dl-Camphorquinone

Group 2: First, the preparations were etched, primed, and bonded as described for Group 1 and then a 1-mm thickness of resin-reinforced glass ionomer (Ionoseal) was applied to the gingival floor and was light-activated for 20 s. The restorations were completed by placing x-tra fil bulk-fill composite. The first and second increments were 3 and 4 mm thick, respectively, and each layer was cured for 10 s.

Group 3: All etching, priming, and bonding steps were accomplished as in the previous groups. For restoration, a 1-mm layer of a composite resin base (x-tra base) was inserted into the gingival floor and was cured for 20 s. The restoration was completed using x-tra fil composite in the same manner as described before.

Group 4: All etching, priming, and bonding steps were accomplished as in the previous groups. A 1-mm layer of flowable composite resin (Grandio Flow) was placed on the gingival floor and light-cured for 20 s. The restoration was completed using two increments of x-tra fil composite, as described before.

Group 5 (Control) (x-tra fil): All etching, priming, and bonding steps were accomplished as in the previous groups. The preparation was restored using x-tra fil composite resin in two layers as in the previous groups.

The restored specimens were finished and polished using a series of abrasive discs (Sof-Lex, 3M Oral Care, St. Paul, MN, USA) and were stored for 24 h at 37°C with 100% relative humidity in an incubator (BehdadIncub, Behdad, Tehran, Iran). Then, they were subjected to thermocycling procedures consisting of 500 cycles[21] (Mp Based, KARA 1000, Tehran, Iran) between 5°C and 55°C with a dwell time of 30 s in each bath and a transfer time of 10 s.

A dye penetration method was used to evaluate the microleakage. All the root apices were sealed with wax and to prevent dye penetration; two layers of nail varnish were applied to all surfaces, up to 1 mm from the restoration margins. The teeth were immersed in 0.5% basic fuchsine solution for 24 h. Specimens were then mounted in acrylic resin to be placed in the cutting device and the middle increment of the restoration was marked for sectioning. The specimens were sectioned half in the mesiodistal plan using two-sided diamond disks and gingival floor was observed under a stereomicroscope with a magnification of ×32 (MGC-10N9116734). The highest dye penetration rate in each half was selected to score the microleakage. Dye penetration was scored according to a four-point scale (ISO/TS 11405: 2003), including:

- 0 = No dye penetration

- 1 = Dye penetration to the middle of the gingival floor
- 2 = Dye penetration over half of the gingival floor without reaching the axial wall
- 3 = Dye penetration over the gingival floor and reaching the axial wall.

Two different operators performed the scoring and measured the highest dye penetration. The data were statistically analyzed using SPSS software version 20. The differences were considered statistically significant for *P* < 0.05. Kruskal–Wallis test was used to detect significant differences and Mann–Whitney test for comparisons between the independent groups.

RESULTS

Microleakage mean and median scores of the five groups are presented in Table 2. The greatest dye penetration occurred in the Ionoseal group and in the control group and was not significantly different. Dye penetration in each of the other three groups was significantly less than the control and Ionoseal groups (*P* < 0.02). Except for the Ionoseal group, all other groups had significantly less microleakage than the control group (*P* < 0.02), but no significant dye penetration was observed among groups (*P* > 0.05) Table 3.

DISCUSSION

Microleakage is an inherent defect of dental restorations. If restoration's margins are not completely sealed, fluids, bacteria, and debris can enter the cavity preparation. Leaky margins result in the development of caries, pulpal irritation with tooth sensitivity, and staining on the margins. Microleakage refers to microscopic openings between the margins of the resin filling and tooth structure.[20,22] Several methods have been designed and used for this purpose. In this study, as in many previous studies, dye penetration was used to evaluate microleakage. This is a simple technique that does not require complex procedures or advanced equipment.[23,24]

The statistical analysis revealed significant differences in microleakage between some treatment groups. The control group, in which x-tra fil composite resin was used without a base, had the highest microleakage scores. Among the four types of bases used in the experimental groups, Fuji II LC had the least microleakage and Ionoseal had the greatest. All

Table 2: Distribution of microleakage scores in the study groups

Groups	Mean	Median	Microleakage scores				
			0	1	2	3	Total
x-tra fil (control)	2.5	2.5[a]	0	0	6	6	12
Ionoseal	2.67	3.0[a]	0	0	4	8	12
Fuji II LC	1.08	1.0[b]	0	11	1	0	12
x-tra base	1.67	1.5[b]	3	3	1	5	12
Grandio Flow	1.67	2.0[b]	2	3	4	3	12

a,b, Different superscripts indicate statistically significant differences

Table 3: *P* value of compared microleakage of studied groups according to Mann-Whitney test

Group 1-Group 2	Significance
x-tra fil (control) - Ionoseal	0.064
x-tra fil (control) - Fuji II LC*	0.000
x-tra fil (control) - x-tra base	0.068
x-tra fil (control) - Grandio Flow*	0.048
Fuji II LC - Ionoseal*	0.000
Fuji II LC - x-tra base	0.076
Fuji II LC - Grandio Flow	0.100
Ionoseal - x-tra base*	0.020
Ionoseal - Grandio Flow*	0.014
x-tra base - Grandio Flow	0.898

Mean values with the same letter *in each category showed they were significantly different (*P*>0.05)

except the Ionoseal group were significantly different from the control.

X-tra fil is a bulk-fill composite with low polymerization shrinkage (1.7%). According to its manufacturer, the physical properties of this material are due to the combination of multihybrid filler technology with the initiator system required for photopolymerization. Although the material is claimed to have low shrinkage stress, when no base was used, microleakage was relatively high.

It would appear that modification of the resin-based composite (RBC) restoration protocol of some conventional RBCs or bulk-fill resin restoratives may significantly improve bond integrity.[25]

The reason for the higher microleakage of Ionoseal, despite the presence of glass ionomer chemistry, could be a higher resin content. Its elastic modulus is greater than that of RMGI and it can therefore absorb less stress from the polymerization of composite resin in bonded base restorations.[8]

Compared with previous studies, few studies were found to be similar in terms of materials and methods, but their results were consistent with those of the present study. For example, Zajkani *et al.* compared

microleakage in two composite resin restoration techniques (open-sandwich and bonding technique) and reported that the least microleakage was observed in the open-sandwich restorations, including RMGI. RMGIs have a lower elastic modulus than highly filled composite resins.[26] This results in less stress during setting, which can reduce the likelihood of microleakage.[27]

In addition, the reduction of composite volume in the sandwich technique can reduce polymerization shrinkage and microleakage of composite restorations.[28]

Kim assessed the microleakage of Class II composite resin restorations in a nonbased group (control) and three groups with flowable, compomer, and RMGI bases. They reported that the use of RMGI as a base was effective in reducing microleakage. In contrast, compomer and flowable composite bases did not reduce microleakage.[8]

There was a significant difference between Ionoseal group and flowable and x-tra base groups, which may be due to the high percentage of filler in the flowable and x-tra base. The higher filler content could result in less polymerization shrinkage of these materials and therefore less leakage.[29]

Other *in vitro* studies have shown a decrease in microleakage for flowable composite resins as bases.[13,15] However, flowable composite (Grandio Flow: 6.85 Mpa) has higher elastic modulus than RMGI (Fuji II LC: 5.33 Mpa), so it is less effective in reducing the effects of restorative material shrinkage.[16] Thickness of the flowable layer might have some effect. For example, Hernandes *et al.* compared microleakage in Class II composite restorations by varying restorative techniques and thickness of two flowable composite resins. No significant differences were observed between materials. However, the lower thicknesses of the flowable composite resulted in less leakage.[30]

In another study, Toledano *et al.* examined the microleakage of Class V composite resin restorations filled with RMGI and compomer. They reported that microleakage in the three groups was not significantly different.[31] In addition, the results of the study by Sadeghi *et al.* suggested that the use of flowable liners, regardless of the type of material (composite resin or compomer), effectively reduced the microleakage in the gingival margin of Class II composite resin restorations.[15] However, according to the results of Moorthy *et al.*, flowable composites used as bases

did not result in less cervical microleakage in Class II restorations than an incrementally placed highly filled composite.[32] Furthermore, Politi *et al.* claimed that the conventional resin base composite materials had significantly lower microleakage scores compared with their bulk-fill resin counterpart materials.[25]

According to the results of this study, despite the introduction of bulk-fill composite resins with low polymerization shrinkage, the use of a base under the Class II composite restorations is recommended. The base can be either RMGI or flowable composite resin. Furthermore, microleakage of these materials should be investigated under more challenging conditions, such as artificial aging, use of hydrolytic enzymes, or exposure to an oral environment.

CONCLUSION

According to the results of this study, despite the introduction of bulk-fill composite resins with low polymerization shrinkage, the use of a base under the Class II composite restorations is recommended. The base can be either RMGI or flowable composite resin.

Limitations
In this study, mechanical loading was not performed, which is one of the limitations, since different results could have been obtained if the restorations had received occlusal loads. Another limitation of this study was the evaluation of specimens only under a stereomicroscope.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

REFERENCES

1. Alani AH, Toh CG. Detection of microleakage around dental restorations: A review. Oper Dent 1997;22:173-85.

2. Burke FJ, Shortall AC. Successful restoration of load-bearing cavities in posterior teeth with direct-replacement resin-based composite. Dent Update 2001;28:388-98.

3. Loguercio AD, Alessandra R, Mazzocco KC, Dias AL, Busato AL, Singer Jda M, *et al*. Microleakage in class II composite resin restorations: Total bonding and open sandwich technique. J Adhes Dent 2002;4:137-44.

4. Dietrich T, Lösche AC, Lösche GM, Roulet JF. Marginal adaptation of direct composite and sandwich restorations in Class II cavities with cervical margins in dentine. J Dent 1999;27:119-28.

5. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 1987;66:1636-9.

6. Fourie J, Smit CF. Cervical microleakage in Class II open-sandwich restorations: An *in vitro* study. SADJ 2011;66:320-4.

7. Dhingra V, Taneja S, Kumar M, Kumari M. Influence of fiber inserts, type of composite, and gingival margin location on the microleakage in Class II resin composite restorations. Oper Dent 2014;39:E9-15.

8. Kim KO. Microleakage at the cervical margin of Class II composite restorations with different intermediate layer treatments. J Korean Acad Conserv Dent 2003;28:467-74.

9. Karaman E, Ozgunaltay G. Polymerization shrinkage of different types of composite resins and microleakage with and without liner in class II cavities. Oper Dent 2014;39:325-31.

10. Tolidis K, Nobecourt A, Randall RC. Effect of a resin-modified glass ionomer liner on volumetric polymerization shrinkage of various composites. Dent Mater 1998;14:417-23.

11. Majety KK, Pujar M. *In vitro* evaluation of microleakage of class II packable composite resin restorations using flowable composite and resin modified glass ionomers as intermediate layers. J Conserv Dent 2011;14:414-7.

12. Attar N, Turgut MD, Güngör HC. The effect of flowable resin composites as gingival increments on the microleakage of posterior resin composites. Oper Dent 2004;29:162-7.

13. 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.

14. Olmez A, Oztas N, Bodur H. The effect of flowable resin composite on microleakage and internal voids in class II composite restorations. Oper Dent 2004;29:713-9.

15. Sadeghi M. The effect of fluid composite as gingival layer on microleakage of Class II composite restorations. DRJ 2008;4:40-7.

16. Ruiz JL, Mitra S. Using cavity liners with direct posterior composite restorations. Compend Contin Educ Dent 2006;27:347-51.

17. Jain P, Belcher M. Microleakage of Class II resin-based composite restorations with flowable composite in the proximal box. Am J Dent 2000;13:235-8.

18. Poggio C, Chiesa M, Scribante A, Mekler J, Colombo M. Microleakage in Class II composite restorations with margins below the CEJ: *In vitro* evaluation of different restorative techniques. Med Oral Patol Oral Cir Bucal 2013;18:e793-8.

19. Malmström HS, Schlueter M, Roach T, Moss ME. Effect of thickness of flowable resins on marginal leakage in class II composite restorations. Oper Dent 2002;27:373-80.

20. Poggio C, Chiesa M, Scribante A, Mekler J, Colombo M. Microleakage in Class II composite restorations with margins below the CEJ: *In vitro* evaluation of different restorative techniques. Med Oral Patol Oral Cir Bucal 2013;18:201-10.

21. García Marí L, Climent Gil A, LLena Puy C. *In vitro* evaluation of microleakage in Class II composite restorations: High-viscosity bulk-fill vs conventional composites. Dent Mater J 2019;38:721-7.

22. Raskin A, D'Hoore W, Gonthier S, Degrange M, Déjou J. Reliability of *in vitro* microleakage tests: A literature review. J Adhes Dent 2001;3:295-308.

23. Agrawal VS, Parekh VV, Shah NC. Comparative evaluation of microleakage of silorane-based composite and nanohybrid composite with or without polyethylene fiber inserts in class II restorations: An *in vitro* study. Oper Dent 2012;37:E1-7.

24. Asselin ME, Fortin D, Sitbon Y, Rompré PH. Marginal microleakage of a sealant applied to permanent enamel: Evaluation of 3 application protocols. Pediatr Dent 2008;30:29-33.

25. Politi I, Mc Hugh LE, Alfodeh RS, Fleming GJ. Modification of the restoration protocol for resin-based composite (RBC) restoratives (conventional and bulk fill) on cuspal movement and microleakage score in molar teeth. Dent Mater 2018;34:1271-7.

26. Zajkani E, Joolaie M, Faghihzadeh S. Comparative evaluation of microleakage in class II cavities restored with a low shrink silorane resin composite and a methacrylate based composite using two different techniques (total bonding and open sandwich). J Zanjan Univ Med Sci Health Serv 2014;22:91-100.

27. Aboushala A, Kugel G, Hurley E. Class II composite resin restorations using glass-ionomer liners: Microleakage studies. J Clin Pediatr Dent 1996;21:67-70.

28. Gladys S, Van Meerbeek B, Braem M, Lambrechts P, Vanherle G. Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass-ionomer and resin composite restorative materials. J Dent Res 1997;76:883-94.

29. Kakaboura AI, Eliades GC, Palaghias G. Laboratory evaluation of three visible light-cured resinous liners. J Dent 1996;24:223-31.

30. Hernandes NM, Catelan A, Soares GP, Ambrosano GM, Lima DA, Marchi GM, *et al*. Influence of flowable composite and restorative technique on microleakage of class II restorations. J Investig Clin Dent 2014;5:283-8.

31. Toledano M, Osorio E, Osorio R, García-Godoy F. Microleakage of Class V resin-modified glass ionomer and compomer restorations. J Prosthet Dent 1999;81:610-5.

32. Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR, Fleming GJ. Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. J Dent 2012;40:500-5.