Effect of Thermocycling and Type of Restorative Material on Microleakage of Class II Restorations

Vaghareddin Akhavan-Zanjani[1] Elham Moravej-Salehi[2] Azam Valian[*1]

[1]*Dept. of Operative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.*
[2]*Dept. of Operative Dentistry, School of Dentistry, Shahed University, Tehran, Iran.*

Abstract
***Objectives*:** Microleakage is a major cause of failure of dental restorations and results in development of secondary caries, tooth hypersensitivity and pulp pathosis. This study aimed to compare the microleakage of class II cavities filled with two types of composite resins and a compomer and subjected to thermocycling.
***Methods*:** In this in vitro experimental study, class II cavities with a gingival margin below the cementoenamel junction (CEJ) and beveled enamel margins were prepared in proximal surfaces of 60 molar teeth. The teeth were randomly divided into three groups of 20 and restored with Spectrum TPH3 and Esthet X composites and Dyract eXtra compomer. Each group was randomly divided into two subgroups (n=10) of control and thermocycling (1000 thermal cycles). Dye penetration in occlusal and cervical margins was scored under a stereomicroscope. Data were analyzed using the Kruskal Wallis test and Mann Whitney U test ($P<0.05$).
***Results*:** No significant difference was noted in microleakage of the three groups neither in the occlusal nor in the cervical margins in presence or absence of thermocycling ($P>0.05$). But, the microleakage in the cervical margins of compomer restorations was slightly higher than that of other groups especially after thermocycling.
***Conclusion*:** Microleakage of composite restorations was not significantly different from that of compomer restorations in the occlusal or gingival margins in presence or absence of thermocycling.
***Key Words*:** Compomers; Composite Resins; Dental Leakage
How to cite:
Akhavan-Zanjani V, Moravej-Salehi E, Valian A. Effect of Thermocycling and Type of Restorative Material on Microleakage of Class II Restorations. J Dent Sch 2016; 34(4): 202-13.

*Corresponding Author:
Valian A.
E-mail: azamvalian@yahoo.com

Received: 27.09.2016
Accepted: 27.11.2016

Introduction

Achieving an ideal seal at the tooth-restoration interface is a primary goal in restorative dentistry for biological, functional and esthetic reconstruction of teeth (1,2). Dimensional changes and inadequate adaptation of restorative materials to cavity walls can result in marginal microleakage and allow the penetration of molecules, fluids, bacteria and nutrients into the gap (2). Microleakage is the most important phenomenon resulting in development of secondary caries, tooth hypersensitivity, pulp pathosis, marginal staining and discoloration, cusp deflection, accelerated degradation and eventual failure of restorations (1,3).

Physical and chemical properties of restorative materials as well as the clinical experience and skills of the operator play an important role in occurrence of microleakage (2). In addition to exceptional esthetics, composite resins have excellent physical and mechanical properties such as high compressive, flexural and tensile strengths (3) resulting in their increased use for restoration of posterior teeth (4).

However, polymerization shrinkage of composite resins remains the most important cause of failure of composite restorations (5,6). Shrinkage stresses may compromise the bond of restorative materials to cavity walls and result in gap formation at the tooth-restoration interface and subsequent microleakage (5,6). This is especially important in gingival margins of class II composite restorations, which are located below the CEJ; because the bond to dentin below the CEJ is weaker than the bond to enamel (4,5). Moreover, composites are not capable of fluoride release, fluoride recharge, caries prevention or self-adhesion as are glass ionomers (GI) (6-8). However, studies have demonstrated that GI restorations have higher microleakage than composites (3,6,9). For this reason, polyacid modified composite resins known as compomers were introduced to dental market in 1993 as hybrid restorative materials with 20% GI and 20% resin component. Compomers offer a combination of optimal strength and esthetics of composite resins along with the fluoride release potential and adhesiveness of GIs (1,3).

The relationship of marginal microleakage with the type of adhesive restorative material has been extensively evaluated in vitro and in vivo. However, the reported results have been controversial due to the effect of factors such as filler content, type of monomer, light curing units and curing conditions and presence or absence of etching and bonding procedures in self-adhesive restorations (3,6-9). In absence of definite clinical findings, laboratory microleakage studies are well accepted for screening of adhesive restorative materials in terms of providing an ideal marginal seal (3). To better simulate the clinical setting and thermal challenges in the oral cavity during eating and drinking, reliable techniques such as thermocycling are used (8,10). However, only a few studies have evaluated the effect of presence and absence of thermocycling on microleakage of different restorative materials such as compomers (11,12). Therefore, this study aimed to assess the effect of three different restorative materials and thermocycling on microleakage of class II restorations.

Methods

This in vitro experimental study was conducted on 60 freshly extracted human third molars with no cracks, caries or previous restorations. The teeth were cleaned with a periodontal curette, pumice paste and a prophylaxis brush. For the purpose of disinfection, the teeth were immersed in 1% chloramine T solution for 24 hours. The teeth were then stored in saline solution at room temperature for no more than one month before use. The solution was refreshed weekly. Class II cavities were then prepared on proximal surfaces (mesial or distal) with a buccolingual width of 4mm, axial depth of 2mm (mesiodistal width of the gingival floor), pulpal floor depth of 3mm and pulpal floor mesiodistal width of 3mm using a straight diamond fissure bur (Mani Ltd., Utsunomiya, Japan) and water-cooled high-speed handpiece. The bur was changed after every five preparations. Gingival margin was prepared one millimeter below the CEJ and the enamel margins were beveled (0.5mm wide) in proximal surfaces. The internal angles were rounded and gingival margins were finished with a gingival margin trimmer. The teeth were then randomly divided into three groups of 20 and restored as follows:

Group one: Enamel and dentin were etched for 30 and 15 seconds, respectively using 37.5% phosphoric acid (Ultra Etch, Ultradent, South Jordan, UT, USA) and were then rinsed with water and air spray for 30 seconds. Excess water was eliminated using air spray in such a way that the dentin surface remained moist. Next, Prime and Bond NT bonding agent (Dentsply DeTrey, Milford, DE, USA) was used according to the manufacturer's instructions and light cured for 20 seconds using a light curing unit (Starlight Pro, Mectron, Italy) with an intensity of 600 mW/cm^2. A metal matrix band was applied using a Tofflemire matrix retainer and Spectrum TPH3 submicron hybrid composite (Dentsply DeTrey, Milford, DE, USA) was incrementally and obliquely applied in less than 2mm thicknesses from gingival towards the occlusal surface. Each layer was light cured for 40 seconds (soft start technique) using a LED light-curing unit.

Group two: Samples in this group were treated as in group one except that the cavities were restored with Esthet X hybrid composite (Dentsply DeTrey, Milford, DE, USA).

Group three: Samples in this group were treated as in group one except that the cavities were restored with Dyract eXtra compomer (Dentsply DeTrey, Milford, DE, USA).

Table 1 shows the composition of restorative materials used in our study. The metal matrix band was removed and the restorations were light cured again for 40 seconds from the buccal and lingual surfaces. The restoration surfaces were finished and polished using gold composite polishing burs (D&Z, Lemgo, Germany) and polishing discs (Sof-Lex Pop-on; 3M ESPE, St. Paul, MN, USA). The teeth were coated with two layers of nail varnish except for the restoration surface and one millimeter margin around it. The apical region was sealed with wax. The teeth were then incubated for 24 hours. Each group was randomly divided into two subgroups and coded. Subgroup one was considered as control and subgroup two samples were subjected to 1000 thermal cycles between 5 and 55°C with 30 seconds of dwell time and 15 seconds of transfer time. The specimens were then immersed in 2% methylene blue dye for 24 hours. Afterwards, the teeth were rinsed under running water for removal of excess dye for 10 minutes, dried and mesiodistally sectioned by a low speed diamond saw (IsoMet Low Speed Saw; Buehler Ltd., Lake Bluff, Illinois, USA) under water coolant. The entire procedure was performed by the same operator.

The samples were evaluated under a stereomicroscope (SMZ800; Nikon, Tokyo, Japan) at ×25 magnification. One observer, blinded to the group allocation of samples, scored the degree of microleakage. Depth of dye penetration at the cervical and occlusal margins was scored from 0 to 3. The scoring scales for marginal microleakage are shown in Figure 1:

Occlusal margin:

Score 0 = No dye penetration
Score 1 = Dye penetration into the enamel
Score 2 = Dye penetration into the dentin, not including the pulpal wall
Score 3 = Dye penetration into the dentine including the pulpal wall
Cervical margin:
Score 0 = No dye penetration
Score 1 = Dye penetration into ½ of the cervical wall
Score 2 = Dye penetration into the entire length of cervical wall
Score 3 = Dye penetration into the cervical and axial walls

The results were analyzed using SPSS version 18. Considering the fact that microleakage was an ordinal variable, the Kruskal Wallis test was used for assessment of differences among groups and the post hoc Mann Whitney U test was applied for pairwise comparisons. Level of significance was set at $P<0.05$ (α) and ß was estimated lower ($P<α$).

Table 1- Composition of materials used

Material	Classification	Composition
Prime & Bond NT	Bonding agent	Di- and trimethacrylate resins, PENTA, functionalized amorphous silica, stabilizers, photoinitiators, cetyl amine hydrochloride, acetone
Spectrum TPH3	Nanohybrid composite	Monomer: Bis-GMA; BisEMA Filler: Barium aluminum borosilicate glass, fluoroaluminium borosilicate glass, silica (0.02 - 1 mm)
Esthet X	Microhybrid composite	Monomer: Bis-GMA, Bis-EMA, TEGDMA Filler: Silanized fluoroaluminium borosilicate glass, silanized barium (1 mm) and colloidal silica (0.04 mm)
Dyract Extra	Compomer	Monomer: Bis-GMA, UDMA, carboxylic acid modified dimethacrylate (TCB), trimethylolpropane trimethacrylate (TMPTMA), TEGDMA Filler: Strontium aluminosodium fluorophosphor silicate glass

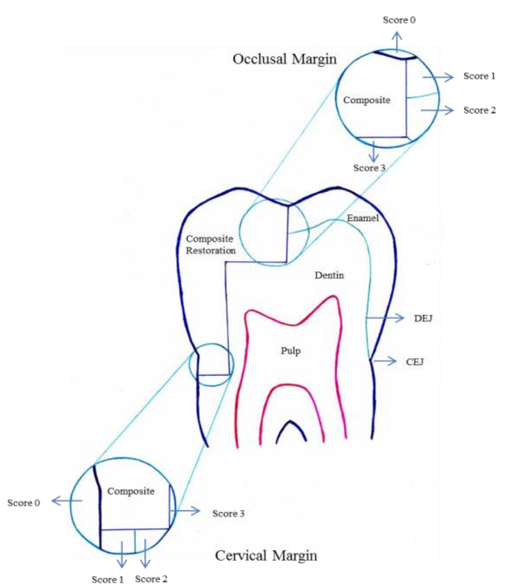

Figure 1- Schematic view of the scoring scale for microleakage in mesiodistal sections

Results

Figures 2 and 3 show the relative frequency of microleakage at the occlusal and cervical margins in the study groups. No microleakage was observed in the occlusal margins of 100% of the Spectrum TPH3 and Esthet X restorations in presence and absence of thermocycling. Maximum microleakage was noted in the cervical margin of Dyract eXtra restorations following thermocycling. Overall, microleakage in the cervical margins was greater than that in the occlusal margins. Also, microleakage in compomer restorations was greater than that in the two composite restorations.

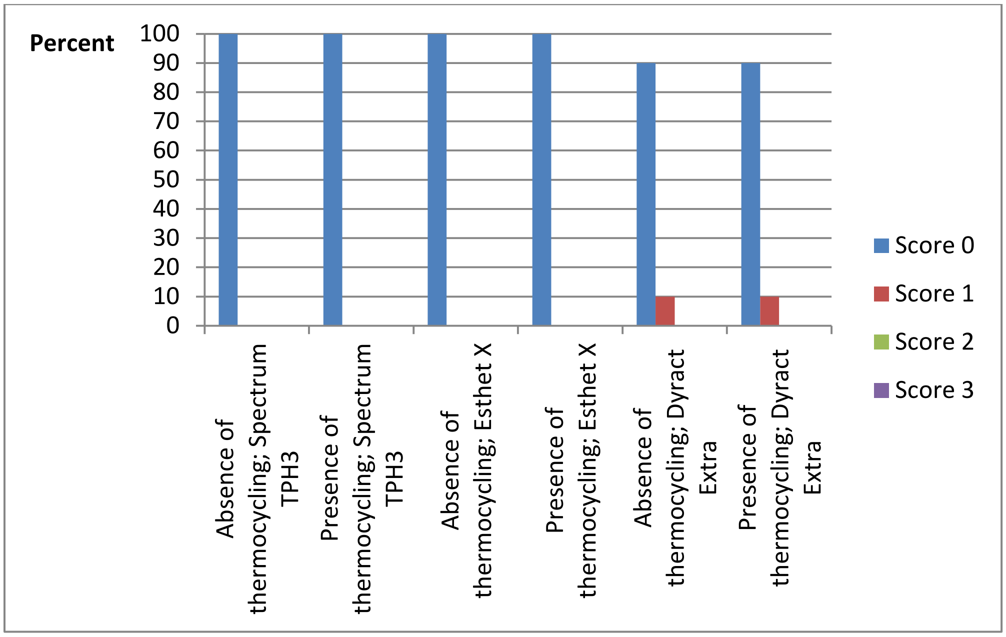

Figure 2- Distribution of microleakage scores (based on percentage) in occlusal margin of restorations

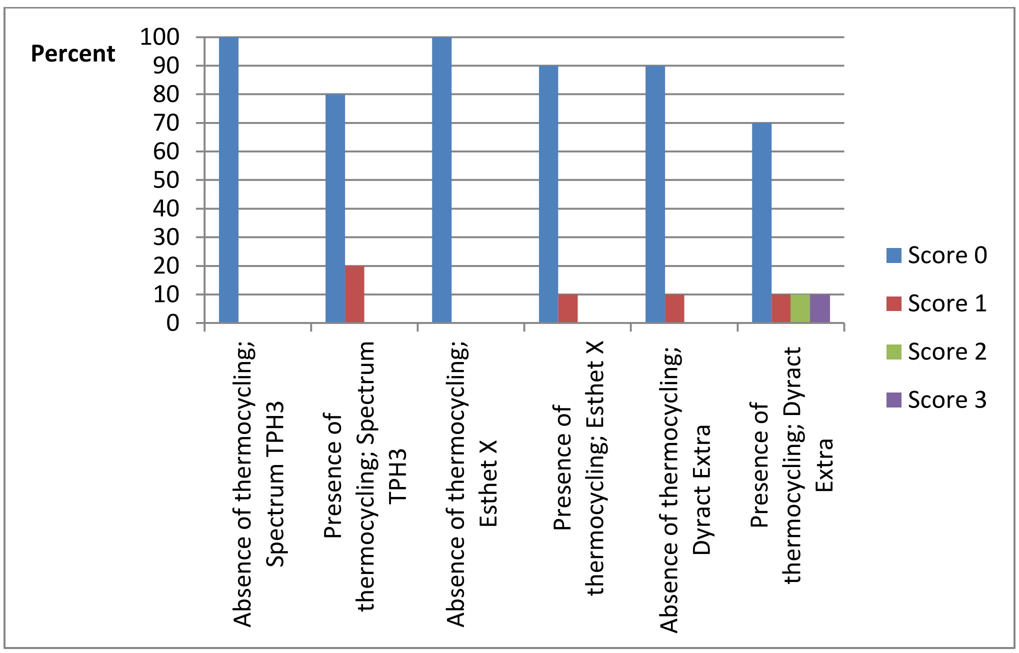

Figure 3- Distribution of microleakage scores (based on percentage) in cervical margin of restorations

Comparison of microleakage at the occlusal and cervical margins of the control and thermocycled samples revealed no significant difference in any of the Spectrum TPH3, Esthet X or Dyract eXtra groups (*P*>0.05, Table 2).

The Kruskal Wallis test showed that after thermocycling, microleakage was not significantly different in the occlusal (*P*=0.461) or the cervical (*P*=0.368) margins of Spectrum TPH3, Esthet X and Dyract eXtra groups.

Table 2- Comparison of microleakage in presence and absence of thermocycling

Location of microleakage	Restorative material	Absence or presence of thermocycling	Mean score	Sum of scores	*P*-value
Occlusal	Spectrum TPH3	Absence	0	0	1.000
		Presence	0	0	
	Esthet X	Absence	0	0	1.000
		Presence	0	0	
	Dyract eXtra	Absence	0.1	1	1.000
		Presence	0.1	1	
Cervical	Spectrum TPH3	Absence	0	0	0.234
		Presence	0.2	2	
	Esthet X	Absence	0	0	0.317
		Presence	0.1	1	
	Dyract eXtra	Absence	0.1	1	0.146
		Presence	0.6	6	

Discussion

Study of the marginal microleakage of materials is one method for assessment of the efficacy of adhesive restorative materials because obtaining and maintaining an optimal seal at the tooth-restoration interface plays an important role in clinical success and longevity of restorations (13). Use of organic dyes is among the oldest and most common methods for in vitro assessment of microleakage. Dye penetration values reported in vitro are often higher than the values obtained in vivo (14). In the dye penetration method, different dyes or tracers such as fuchsin, silver nitrate and methylene blue are used. Methylene blue is the most commonly used tracer due to easy detectability under visible light, water solubility and the ability to diffuse freely (8). However, some researchers believe that the small size of methylene blue molecules may result in overestimation of dye penetration and microleakage (15). But, use of methylene blue in optimal concentrations is believed to be suitable for assessing and scoring microleakage. Therefore, in the current study, similar to many previous investigations, methylene blue was used for this purpose (8,16).

It should be noted that although in vitro study of microleakage cannot completely simulate the oral cavity conditions, it enables the comparison of microleakage following the application of different materials and techniques (17). Also, according to the available standards, by assessment of marginal microleakage following thermocycling in water baths between 5 and 55°C, oral environmental conditions can be better simulated and thus, the results may be generalized to the clinical setting with higher certainty (18,19). Moreover, assessment of the effects of such thermal changes is critical for durability of bond due to different coefficients of thermal expansion of dental polymers from that of tooth structure (20). For this reason, the current study evaluated the effect of presence or absence of thermocycling on microleakage of different restorative materials at the occlusal (enamel) and cervical (dentin or cementum) margins. In our study, similar to that of Wagner *et al*, (21) in 2008 and Rehka and Varma (7) in 2012 samples were subjected to 1000 thermal cycles in water baths between 5 and 55°C. However, it should be noted that the effects of thermocycling may be variable in different studies depending on the factors such as the temperature of water baths, number of cycles, dwelling time in each bath and transfer time (22,23). Moreover, design of the prepared cavity (variable dimensions and depths), restorative materials used and many other factors may be responsible for the variability and controversy in the results of similar studies (22,23).

Class II cavities have an adequate design for evaluation of microleakage because the mesiodistal width of these cavities allows for simultaneous study of microleakage at both cervical and occlusal margins (24). Some previous studies have reported higher cervical compared to occlusal microleakage especially in restorations with gingival margins below the CEJ (16,21). In our study, microleakage in the occlusal margins especially in thermocycled samples was less than that in cervical margins but not significantly. Such a difference in microleakage of cervical and occlusal margins may be due to the higher mineral content of enamel compared to that of dentin and cementum. Following acid etching, greater microporosities are formed in the enamel, resulting in better penetration of adhesive and subsequent formation of a strong micromechanical bond to resin (13). In the study by Wagner *et al*, (21) the difference in microleakage of cervical compared to occlusal margin of Esthet X restorations bonded with Prime and Bond NT was greater than that in our study. Since the thermocycling protocol was the same in both studies, such a difference in results may be due to the more apical placement of cervical margin and doubled dwell time in each bath in their study compared to ours.

Moreover, studies have shown that presence of an enamel bevel along the facial and lingual margins of vertical walls of class II cavities restored with composite resin minimizes the microleakage in the gingival and cervical margins. The enamel bevel in our study similar to other investigations may also be responsible for minimal microleakage in the occlusal and gingival margins of cavities restored with different resin materials (25,26).

Similar to the current study, Erdilek *et al*. (25) demonstrated that in absence of thermocycling, microleakage in the occlusal and cervical margins of class II spectrum TPH composite restorations bonded with Prime and Bond NT was minimal and not significantly different. However, simultaneous thermocycling and mechanical loading increased the microleakage especially at the cervical margin with a statistically significant difference. Difference in results may be attributed to the higher number of thermal cycles and simultaneous application of thermal cycles and mechanical load in their study compared to ours.

In our study, no significant difference was noted in microleakage of different restorative materials in absence or presence of thermocycling. Spectrum TPH3 used in our study is a hybrid composite with submicron and nanometer-scale highly dispersed silicon dioxide particles (27). Presence of such tiny particles not only improves the physical and mechanical properties but also decreases the polymerization shrinkage of composite resin (28). Moreover, Esthet X is a microhybrid composite with silica nanofillers (0.04μm) (27). Also, presence of Bis-EMA monomer in the formulation of these composites decreases their volumetric shrinkage (28,29). Therefore, decreased polymerization shrinkage eventually results in lower microleakage (11). Thus, it appears that physical and chemical properties of restorative resin materials such as the size of filler particles and type of monomer can affect the microleakage even under thermocycling conditions (2).

Dyract eXtra compomer was used in our study because it can be used for restoring all cavity classes. Due to fluoride release, it has antibacterial activity and is recommended for use in patients with poor oral hygiene (30). However, studies on microleakage especially under thermocycling conditions to simulate the oral environment are scarce (12). Application of etching and bonding for compomer restorations is optional. Previous studies have reported that if etching and bonding are performed prior to the application of compomers, the microleakage will be significantly less compared to when etching and bonding are not performed (1,31).

The morphology of dentin is complex due to the formation of smear layer. The smear layer serves as a barrier and decreases the permeability of dentin. Also, it prevents the penetration of resin into the underlying dentin substrate. Phosphoric acid removes the smear layer, opens the dentinal tubules and allows for deeper penetration of resin matrix. Application of adhesive on the prepared cavity improves the retention of restoration due to the formation of a hybrid layer and is the most important factor that guarantees the optimal bond of dentin to resin restorations (7). Therefore, based on the results of the current study, it appears that etching and bonding the cavity prior to the application of compomer decreases microleakage and yields a microleakage value similar to that of composite restorations. This finding is similar to the results of Rodrigues *et al* (32). In our study, microleakage of compomer restorations especially at the cervical margin of thermocycled samples was slightly higher than that of composite restorations. This can be due to the difference in physical and chemical properties of compomers such as the resin content, lower filler content, water sorption and polymerization shrinkage, which result in higher microleakage (6,33).

In our study, similar to studies by Hassan and Ibraheem (11) and Aguiar *et al*, (34) presence or absence of thermocycling had no significant effect on marginal sealability of restorative materials in the cervical margins. Rigsby et al, (35) also reported no statistically significant difference in microleakage of composite restorations that received thermal and mechanical cycles alone. Moreover, Bedran-de-Castro *et al*. (36) stated that absence or presence of thermocycling and application of mechanical load alone or along with thermocycling did not cause a significant difference in microleakage; although a slight increase in microleakage of these restorations was noted when thermocycling was combined with mechanical load application. In our study, microleakage was higher in thermocycled samples compared to the control group especially in compomer restorations; although this increase was not statistically significant. However, another study reported that thermocycling along with mechanical load application with equal number of cycles as in a previous study by Bedran-de-Castro *et al*. (36) can increase microleakage (23). Therefore, despite the presence of controversial results, it appears that advances in physical and chemical properties of adhesive restorative materials as well as enhanced knowledge and expertise of clinicians in application of these materials have resulted in lower microleakage.

Future studies are required to assess the microleakage and nanoleakage of different restorative materials with cariostatic properties such as giomer and nano-ionomer under higher number of thermal cycles along with mechanical load application using scanning electron microscopy.

Conclusion

Within the limitations of this study, no significant difference was noted in microleakage of class II composite and compomer restorations at the occlusal and cervical margins in presence or absence of thermocycling.

Acknowledgement

The authors would like to thank the vice-chancellor of Shahid Beheshti University of Medical Sciences for supporting this research.

Conflict of interest:"None Declared"

References:

1. Demir T, Tirali RE. Effects of different light sources on microleakage of cervical compomer restorations in primary teeth. Int J Clin Dent Sci. 2013;4:26-30.
2. Yadav G, Rehani U, Rana V. A Comparative Evaluation of Marginal Leakage of Different Restorative Materials in Deciduous Molars: An in vitro Study. Int J Clin Pediatr Dent. 2012 May;5(2):101-7.
3. Mali P, Deshpande S, Singh A. Microleakage of restorative materials: an in vitro study. J Indian Soc Pedod Prev Dent. 2006 Mar;24(1):15-8.
4. Sadeghi, M. Influence of flowable materials on microleakage of nanofilled and hybrid Class II composite restorations with LED and QTH LCUs. Indian J Dent Res. 2009 Apr-Jun;20(2):159-63.
5. 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 Sep;18(5):e793-8.

6. Xie H, Zhang F, Wu Y, Chen C, Liu W. Dentine bond strength and microleakage of flowable composite, compomer and glass ionomer cement. Aust Dent J. 2008 Dec;53(4):325-31.
7. Rekha CV, Varma B. Comparative evaluation of tensile bond strength and microleakage of conventional glass ionomer cement, resin modified glass ionomer cement and compomer: An in vitro study. Contemp Clin Dent. 2012 Nov;3(3):282-7.
8. Singla A, Garg S, Jindal SK, Suma Sogi HP, Sharma D. In vitro evaluation of marginal leakage using invasive and noninvasive technique of light cure glass ionomer and flowable polyacid modified composite resin used as pit and fissure sealant. Indian J Dent Res. 2011 Mar-Apr;22(2):205-9.
9. Divya KT, Satish G, Srinivasa TS, Reddy V, Umashankar K, Rao BM. Comparative evaluation of sealing ability of four different restorative materials used as coronal sealants: an in vitro study. J Int Oral Health. 2014 Jul;6(4):12-7.
10. Crim GA, Swartz ML, Phillips RW. Comparison of four thermocycling techniques. J Prosthet Dent. 1985 Jan;53(1):50-3.
11. Hassan LA, Ibraheem AF. The effect of thermocycling on microleakage analysis of bulk filled base composite in comparison to incrementally placed nanohybrid composite in class II MOD restorations (An in vitro study). JBCD. 2013 Sep; 25(3):28-34.
12. Hakimeh S, Vaidyanathan J, Houpt ML, Vaidyanathan TK, Von Hahen S. Microleakage of compomer class V restorations: effect of load cycling, thermal cycling, and cavity shape differences. J Prosthet Dent. 2000 Feb;83(2):194-203.
13. Sawani S, Arora V, Jaiswal S, Nikhil V. Comparative evaluation of microleakage in Class II restorations using open vs. closed centripetal build-up techniques with different lining materials. J Conserv Dent. 2014 Jul;17(4):344-8.
14. Fabianelli A, Sgarr A, Goracci C, Cantoro A, Pollington S, Ferrari M. Microleakage in class II restorations: open vs closed centripetal build-up technique. Oper Dent. 2010 May-Jun;35(3):308-13.
15. Abd El Halim S, Zaki D. Comparative evaluation of microleakage among three different glass ionomer types. Oper Dent. 2011 Jan-Feb;36(1):36-42.

16. Phanombualert J, Chimtim P, Heebthamai T, Weera-Archakul W. Microleakage of Self-Etch Adhesive System in Class V Cavities Prepared by Using Er: YAG Laser with Different Pulse Modes. Photomed Laser Surg. 2015 Sep;33(9):467-72.
17. Friedl KH, Schmalz G, Hiller KA, Markl A. Marginal adaptation of class V restorations with and without 'soft start polymerization'. Oper Dent. 2000 Jan-Feb;25(1):26-32.
18. Jawaed NU, Abidi SY, Qazi FU, Ahmed S. An in-vitro evaluation of microleakage at the cervical margin between two different class II restorative techniques using dye penetration method. J Coll Physicians Surg Pak. 2016 Sep;26(9):748-52.
19. Kader MA, Altheeb A, Al-Asmry AA, Luqman M. Microleakage evaluation of class II composite restoration with incremental and bulk fill technique. J Dent Res Rev. 2015;2(4):153-7.
20. Santini A, Ivanovic V, Tan CL, Ibbetson R. Effect of prolonged thermal cycling on microleakage around Class V cavities restored with glass-ceramic inserts with different coefficients of thermal expansion. An in vitro study. Prim Dent Care. 2006 Oct;13(4):147-53.
21. Wagner WC, Aksu MN, Neme AL, Linger JB, Pink FE, Walker S. Effect of pre-heating resin composite on restoration microleakage. Oper Dent. 2008 Jan-Feb;33(1):72-8.
22. Morresi AL, D'Amario M, Capogreco M, Gatto R, Marzo G, D'Arcangelo C, et al. Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. J Mech Behav Biomed Mater. 2014 Jan;29:295-308.
23. Consani S, Sinhoreti MAC, Correr-Sobrinho L, Leite RSB, Bortoletto KJ. An alternative method for thermal cycling test: effect on the marginal microleakage and bond strength of dental polymer bonded to dentin. Mat Res. 2012 Sep;15(6):1045-9.
24. Demarco FF, Ramos OL, Mota CS, Formolo E, Justino LM. Influence of different restorative techniques on microleakage in class II cavities with gingival wall in cementum. Oper Dent. 2001 May-Jun;26(3):253-9.
25. Erdilek D, Dörter C, Koray F, Kunzelmann KH, Efes BG, Gomec Y. Effect of thermo-mechanical load cycling on microleakage in class II Ormocer restorations. Eur J Dent. 2009 Jul;3(3):200-5.
26. Bishara SE, Ajlouni R, Laffoon JF, Warren JJ. Comparison of shear bond strength of two self-etch primer/adhesive systems. Angle Orthod. 2006 Jan;76(1):123-6.

27. Oliveira GUD, Mondelli RFL, Charantola Rodrigues M, Franco EB, Ishikiriama SK, Wang, L. Impact of filler size and distribution on roughness and wear of composite resin after simulated toothbrushing. J Appl Oral Sci. 2012 Sep-Oct;20(5):510-6.
28. Willershausen B, Callaway A, Ernst CP, Stender E. The influence of oral bacteria on the surface of resin-based dental restorative materials – an in vitro study. Int Dent J. 1999 Aug;49(4):231-9.
29. Yamamoto T, Hanabusa M, Momoi Y, Sakaguchi RL Sakaguchi RL, Powers JM. Polymerization stress of dental resin composite continues to develop 12 hours after irradiation. J Esthet Restor Dent. 2015 Jan-Feb;27(1):44-54.
30. Lennon ÁM, Wiegand A, Buchalla W, Attin T. Approximal caries development in surfaces in contact with fluoride-releasing and non-fluoride-releasing restorative materials: an in situ study. Eur J Oral Sci. 2007 Dec;115(6):497-501.
31. Kugel G, Perry RD, Hoang E, Hoang T, Ferrari M. Dyract compomer: comparison of total etch vs. no etch technique. Gen Dent. 1998 Nov-Dec;46:604-6.
32. Rodrigues JA, De Magalhães CS, Serra MC, Rodrigues Júnior AL. In vitro microleakage of glass-ionomer composite resin hybrid materials. Oper Dent. 1999 Mar-Apr;24(2):89-95.
33. Ajami B, Makarem A, Niknejad E. Microleakage of Class V Compomer and Light-Cured Glass Ionomer Restorations inYoung Premolar Teeth. J Mashhad Dent Sch. 2007;31(Special Issue):25-8.
34. Aguiar FH, Dos Santos AJ, França FM, Paulillo LA, Lovadino JR. A quantitative method of measuring the microleakage of thermocycled or non-thermocycled posterior tooth restorations. Oper Dent. 2003 Nov-Dec;28(6):793-9.
35. Rigsby DF, Retief DH, Bidez MW, Russell CM. Effect of axial load and temperature cycling on microleakage of resin restorations. Am J Dent. 1992 Jun;5(3):155-9.
36. Bedran-de-Castro AKB, Cardoso PEC, Ambrosano GMB, Pimenta LAF. Thermal and mechanical load cycling on microleakage and shear bond strength to dentin. Oper Dent. 2004 Jan-Feb;29(1):42-8.