

Comparative Evaluation of microleakage of Bulk-fill and Posterior Composite Resins Using the Incremental Technique and a Liner in CI II Restorations

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Abstract

Background and Aim: In recent years there has been a surge in the use of tooth-colored restorations. However, the polymerization shrinkage of these materials can form gaps, resulting in microleakage. This study aimed to compare microleakage by using different materials and techniques.

Materials and Methods: In this experimental study, CI II cavities were prepared on the mesial surfaces of 60 sound human third molars. The teeth were randomly divided into five groups (n=12): Group 1 were filled with Surefil posterior composite using the oblique incremental technique. In group 2 Surefil SDR flowable composite was placed at the base of cavities followed by filling the cavity with Surefil posterior composite. Specimens in group 3 were restored only with Surefil SDR flowable composite resin in two steps, and in group 4, a layer of G-aenial Universal flow composite with 1 mm thickness was placed as the liner and the rest of the cavity filled with the Surefil posterior composite using the oblique incremental technique. Group5 benefited from snow plow technique using G-aenial Universal flow and Surefil posterior composite. Samples thermocycled and placed in 0.5% fuchsin solution for 24 hours. The teeth were evaluated under a stereomicroscope for the deepest dye penetration. Kruskal-Wallis and Mann-Whitney tests were used for analysis of data.

Results: The highest frequencies of scores 1 and zero were recorded in the group 5 which indicating the least microleakage in this group.

Conclusion: G-aenial Universal Flo composite resin with the snow plow technique resulted in a significant decrease in the microleakage.

Key Words: Composite Resins, Dental leakage, Dental Cavity Lining, Polymerization

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Introduction

In recent years there has been a surge in the use of tooth-colored restorations. One of the drawbacks of composite resins is the polymerization shrinkage or the contraction stress which could generate stress at the tooth-restoration interface, and if the

stresses exceed the bond strength, gaps would be formed which result in marginal gap and microleakage [1].

Various methods have been suggested to decrease stresses at restoration-tooth interfaces, including the use of the incremental technique, which

reduces the C-factor. Also, other techniques have been proposed to reduce stress formation during light-curing such as soft-start technique and the sandwich technique (i.e., placing a layer of glass-ionomer or resin-based materials with a low modulus of elasticity between dentin and the composite resin). These methods promote adaptation at tooth-restoration interface and also serve as stress absorbers [2-4].

On the other hand, these restorative materials are highly technique sensitive, particularly in CI II restorations, it is difficult to achieve a strong bond between the high-viscosity composite resins and cavity walls especially the gingival floor. Furthermore, the high viscosity of the posterior composite resin and their tendency to adhere (attach and stick) to the dental instrument might result in an inadequate seal, gap formation, and microleakage, especially in the cervical areas of the cavity [5].

Flowable composite resins have been proposed to use as a base or liner in CI II composite resin restorations. Their filler content was reduced by about 20-25% compared to the conventional composite resin, and as a result, the composite rigidity is reduced, resulting in better stress absorption at the interfacial areas and decreasing cuspal flexion [6]. Easier application, higher fluidity, lower modulus of elasticity, and better wetting properties of these composite resins result in a better placement and reduced number of voids at the gingival margins. Flowable composites can also serve as a stress-absorbing layer, result in lesser microleakage as it has been shown in several studies [7-10]; however, there are studies which have not demonstrated an improvement in marginal adaptation [5, 10].

Flowable composite resins can be used in another technique which referred to as the snow plow technique. In this technique, a thin layer of flowable composite is placed over the gingival and pulpal floors of the prepared cavity followed by the placement of a layer of posterior composite resin. Then both layers cure simultaneously by a light-curing device. It has been claimed that the results of this technique are better compared to separate light-curing of each layer due to a decrease in the volume and thickness of flowable composite resin; however, further studies are

necessary to evaluate different aspects of this technique [9,11,12].

Recently, resin monomers with a new chemical structure have been synthesized to decrease microleakage. These monomers have low polymerization shrinkage and therefore, less stress resulting from it.

This unique formulation modifies the polymerizing and cross-linking process during curing to form an optimized polymer network structure. SDR™ (Dentsply, Milford, DE, USA) is the first composite resin that has been designed with this technology. Its unique chemical structure decreases polymerization stress with an increase in its flow [12,13]. Due to its low polymerization shrinkage, this composite resin was initially marketed as a flowable composite resin that can replace lost dentin structure in a 4 mm thickness layer followed by a layer of conventional composite resin. In a study by Ilie et al. [4], placement of a final occlusal layer of bulk-fill composite resin over flowable composite resin was recommended due to the lower modulus of elasticity and strength of flowable composite resins compared to nano-hybrid and micro-hybrid composite resins.

Although several improvements have been made to the physical and mechanical properties of bulk-fill flowable composite resins in order to release stresses and improve adaptation, their use to this end has only been evaluated in a clinical study [4].

Other studies about marginal adaptation and shrinkage behavior of bulk-fill flowable composite resins have revealed that polymerization stresses of SDR were significantly less than other conventional flowable composites [14,15].

Furthermore, in vitro studies have shown that the use of fewer yet thicker layers of bulk-fill composite resins would be comparable to incremental technique with the conventional composite resins [14,16,17].

Considering the discrepancies in the results of studies on the microleakage of different techniques used for CI II composite resin restorations, further research in this respect are warranted. On the other hand, use of bulk-fill composite resins has been evaluated in a limited number of studies

Therefore, the present study was carried out to assess microleakage in CI II cavities restored with bulk-fill composite resin compared to those

restored with posterior composite resin using different methods, including the incremental technique. Also, the use of a flowable composite resin with a high filler content as a liner and snow plow technique was evaluated.

Materials and Methods

Sixty sound freshly extracted human third molar teeth were collected. Teeth were cleaned with periodontal curettes, and all the debris and tissue remnants were removed and stored in 0.1% thymol solution in glass containers until used for the study. In order to facilitate the cavity preparation, teeth were placed in a piece of foam so that their roots were retained up to 2 mm of the CEJ. C1 II cavities were prepared on the mesial surfaces of each teeth. The dimension of the cavities was approximately 6 mm in occluso-gingival length, 4 mm buccolingual width, and 1.5mm in depth. The gingival floor was positioned 1 mm apical to the CEJ. The cavities were prepared using a high-speed handpiece and the #245 burs (Jota, Switzerland), under air and water spray coolant. A new bur was utilized for every five cavities. The dimensions of the cavities were measured with a periodontal probe. One operator carried out all the cavity preparation steps. Green compound sticks were used to seal the gingival area. In order to homogenize the thickness of the layers in all the groups, the thicknesses of the each layer was marked on the preformed transparent matrix bands (TDV, Santa Catarina, Brazil). Also, to prevent penetration of light into areas other than the occlusal area during light-curing procedures, a piece of metal matrix band was placed in the axial area of the restoration. Light-curing procedures were carried out using Valo (Ultradent, South Jordan, UT, USA) light-curing unit employing the standard technique. Before light-curing, the light intensity of the light-curing unit was measured with the use of a radiometer (Demetron, Kerr), which was 600-700 W/m². The light intensity was checked after every five rounds of use.

Tooth (no.=60) were randomly divided into 5 groups (no.=12) as follows:

Group 1 (Surefil): based on the manufacturer's instructions, first, the Clearfil SE Bond primer (Kuraray, Japan) was applied with a microbrush for 20 seconds followed by the application of a

mild oil free air flow to dry it. Subsequently, the bonding was applied and spread evenly with the air pressure, and then, light-curing was carried out for 20 seconds. Afterward, cavities were restored with Surefil posterior composite resin (Dentsply Caulk, USA) using the oblique incremental technique. The first layer, the composite was placed on the gingival floor with a thickness of 1 mm and light-cured for 20 seconds. Then the rest of the cavity was filled in three 2-mm layers and each layer was separately light-cured for 20 seconds from the occlusal surface.

Group 2 (Bulk-Surefil): Bonding procedures were carried out in the same manner of group 1. However, for restoring the cavity, the Surefil SDR Flow composite resin (Dentsply Caulk, USA) with the 4 mm thickness was placed followed by light-curing for 20 seconds. Then the cavity was filled, and the occlusal surface was reconstructed with the Surefil posterior composite resin, which was light-cured for 20 seconds from the occlusal surface.

Group 3 (Bulk-fill flow): All the bonding procedures were similar to those in group 1. Then, 4 mm of cavities were filled with Surefil SDR Flow composite resin (Dentsply Caulk, USA) and light-cured for 20 seconds. Subsequently, the cavities were completely restored with the same composite resin.

Group 4 (Flow-Surefil): All the bonding procedures were carried out the same as explained in group 1. In order to restore the cavities, first, the gingival floor of each cavity was covered with a 1-mm of flowable composite resin with a high filler content (G-aenial Universal Flo, GC, USA) and light-cured for 20 seconds. Then the rest of the cavity was restored with the oblique incremental technique as explained for the group 1.

Group 5 (Snow plow): Clearfil SE Bond was used for adhesion of the restorative material the same as other groups. To restore the cavities first, a layer of flowable composite resin (G-aenial Universal SE Flo, GC, USA) with the thickness of 1.5-mm was placed on the gingival floor of the cavity and left uncured, followed by packing a layer of Surefil posterior composite resin over it and then the two layers were light-cured simultaneously (snow plow technique). The rest of the cavity was restored using the oblique incremental technique.

After restoring the cavities, the samples were finished and polished with abrasive disks (Sof-Lex, 3M ESPE, USA) and stored in distilled water at 37°C in an incubator (Behadad, Tehran, Iran) for 24 hours. Then, all specimens were thermocycled (Vafaei Industries, Iran) for 500 times at 5-50°C with 30 seconds of dwell time and a transfer time of 5 seconds according to ISO/TS 11405 specifications [18].

Microleakage Test

In order to prevent any dye penetration other than tooth-restoration interface, apices of teeth were sealed with sticky wax and teeth were covered by two layers of nail varnish except for 1 mm around the margins of the restorations. Then all the teeth were immersed in 0.5% basic fuchsin solution at 37°C for 24 hours, followed by rinsing under running water for 5 minutes. In the next step, teeth were marked at the midpoint of the restoration and mounted in acrylic resin. Teeth were sectioned longitudinally from the middle of the cavity using a sectioning device (Vafaei, Tehran, Iran). The cross section was given in mesiodistal direction and teeth were divided into two buccal and lingual parts, and each part was evaluated under a stereomicroscope (MGC-IO, Russia) at $\times 36$ magnification. The deepest dye penetration in each half was selected for scoring of the sections. Dye penetration was scored in a 4-scale classification system as follows [19]:

0: no dye penetration

1: dye penetration up to the gingival half

2: dye penetration up to the internal half of the gingival floor

3: dye penetration beyond the gingival floor, reaching the axial wall

As the data was on an ordinal scale, a Kruskal-Wallis test was used to assess differences among the different groups. Mann-Whitney U test was used as post hoc to investigate pairwise differences. Significance was predetermined at $P < 0.05$. Collected data were analyzed using SPSS.

Results

The frequencies of microleakage scores of five study groups are presented in Table 1.

Kruskal-Wallis test showed significant differences in microleakage scores between the five study groups ($P < 0.05$) (Table 1).

The following results were obtained in the two-by-two comparisons of microleakage between the study groups using Mann-Whitney test ($P < 0.05$).

The microleakage of the group 1 was not significantly different from group 2, 3, and 4 ($P = 0.118$, $P = 0.052$, and $P = 0.704$, respectively). The lowest microleakage was observed in group 5 (snow plow technique); P -values were $P = 0.041$, $P = 0.003$, $P = 0.01$, and $P = 0.015$ in comparison with group 4, 3, 2, and 1 respectively. There were no significant differences in microleakage between the Bulk-Surefil (group 2) and Bulk-fill flow (group 3) ($P = 0.665$), and Flow Surefil (group 4) ($P = 0.08$). However, results showed that there was a significant difference in microleakage between the Bulk-fill flow (group 3) and Flow Surefil (group 4) groups ($P = 0.037$).

Discussion

Over the years different techniques have been introduced and used to decrease polymerization shrinkage of composite resin restorations and the microleakage that would be generated. Some of these techniques include increasing the percentage of fillers in the composite resin structure, the use of a liner (glass-ionomer or flowable composite resin) on the gingival floor of the cavity, the use of the snow plow technique in large Class II cavities [9], and introduction of bulk-fill composite resins [12,13] and flowable composite resins with a high filler content which have less polymerization shrinkage despite their lower consistency. In the present study, the oblique incremental, snow plow and bulk-fill techniques were used to restore Class II cavities with a flowable posterior composite resin with high filler content and a bulk-fill composite resin in the study groups. An identical light-curing technique was used in all the groups to eliminate the effect of light-curing method from the study.

In the present study, 500 cycles of thermocycling were applied at 5-55°C according to ISO/TS 11405 [18] protocol to simulate the oral cavity conditions. Microleakage of restorations has been evaluated in vitro using various techniques. The easiest and most commonly used technique is dye penetration [20,21]. It is believed that if dye particles could penetrate into the tooth-restoration interface, the bacteria in the oral cavity could also penetrate into the tooth-restoration gap and give rise to numerous

Table 1. Frequencies of microleakage scores in five study groups

Group	--	Score 0 N (%)	Score 1	Score 2	Score 3	Total
1)Surefil	Number	1 (8.3)	2 (16.7)	7 (58.3)	2 (16.7)	12 (100)
2)Bulk-Surefil	Number	2 (16.7)	1 (8.3)	1 (8.3)	8 (66.7)	12 (100)
3)Bulk-fill flow	Number	1 (8.3)	2 (16.7)	0 (0)	9 (75)	12 (100)
4)Flow Surefil	Number	2 (16.7)	2 (16.7)	6 (50)	2 (16.7)	12 (100)
5)Snow plow	Number	7 (58.3)	3 (25)	0 (0)	2 (16.7)	12 (100)
Total	Number	13 (21.7)	10 (16.7)	14 (23.3)	23 (38.3)	60 (100)

complications [20,22].

Considering the low significance level (0.0045) of Dunn method and its high stringency, the present study used Man-Whitney post hoc test, and the significance level was set at 0.05.

Microleakage in the Snow plow group was significantly less than other groups. Group 5 (Snow plow) and group 4 (Flow-Surefil) were used the same restorative materials. However, their restoration technique was different. The lower microleakage which observed in the Snow plow group compared to the Flow-Surefil group is similar to the results of Reddy et al. [11] and Chuang et al. [9] studies; they have shown that the snow plow technique is a proper method to decrease microleakage in restorations. Co-curing of a flowable liner and overlying composite resin together (snow plow technique) would help the uncured liner to penetrate better into the dentinal tubules and improve sealing at the margins due to the hydraulic pressure of overlying composite with the higher viscosity. Therefore, there would be less gap in the tooth-restoration interface and subsequently less microleakage with this technique compared to separately curing the flowable liner.

The results of the present study are contrary to the results that have been reported by Lotfi et al. [23] They have shown that irrespective of the type of composite resin, microleakage of the snow plow technique and incremental technique was not significantly different. The composite resins used in the current study and study as mentioned earlier were different; The flowable composite resin used

in the present study was G-aenial Universal Flo, which has better mechanical properties. In addition to its lower polymerization shrinkage due to its high filler content (69 wt%), it has a lower modulus of elasticity compared to conventional composite resins [24]. This might result in better mechanical properties to absorb mechanical stresses. These properties in association with the snow plow technique led to a significant decrease in microleakage in this group compared to other groups in the present study.

The results of the present study showed no significant differences between the Surefil (group 1) and Bulk-Surefil (groups 2) and Bulk-fill flow (group 3), and it is in agreement with several other studies [13,15,16,25-28] which have shown that marginal adaptation and microleakage of the restorations restored with the bulk-fill technique were similar to those used the incremental technique.

Also, other similar studies have shown that fewer but thicker layers of bulk-fill have similar success to the conventional incremental technique [14,17]. Despite differences between the composite resins used in various studies, the results of studies were consistent with each other. These results showed that the presence of urethane in the structure of bulk-fill composite resins alone, irrespective of the filler content and other characteristics of composite resin, can control the kinetics of polymerization and decrease polymerization shrinkage [22].

The results of the present study showed no significant differences in microleakage between

Surefil (group 1) and Flow Surefil (group 4) groups, which is in agreement with the result of a systematic review by Boruziniat et al. [29] They selected 18 in vitro and clinical studies that the effect of the flowable composite as a liner on microleakage of composite restoration was evaluated. They concluded that application of flowable composite as a liner in composite restorations cannot reduce microleakage or improve clinical performance [29].

It has been pointed out that the flowable composite resins might be able to improve the marginal seal due to their low elastic modulus and stress buffering capacity [6,30,31]. Castaneda et al. [32] showed that flowable composite continues to generate contraction stress for at least 2 minutes after light curing. The residual stress from polymerization shrinkage masks the favorable effect of low elastic modulus in the flowable composite. If the remaining stress from polymerization shrinkage has not been eliminated, there would be no differences in term of microleakage between restoration groups with or without flowable composite as the liner [32].

The results of this study are contrary to the finding of Lotfi et al. [23] they reported that due to a relatively small percentage of fillers in flowable composite resins, they have high polymerization shrinkage, which consequently increases the microleakage of the restoration. In the present study, a flowable composite resin (G-aenial Universal Flo) with high filler content (50 vol%, 69 wt%) was used, therefore, stresses generated by polymerization shrinkage was decreased due to the reduction of the number of monomers available for participating in the polymerization reaction [24]. Also, this composite resin has a high flow rate despite its higher filler content compared to SDR composite resin, resulting in its better adaptation with cavity margins, which will in turn decrease microleakage. A study by Garoushi et al. [33] indicated that the type of flowable composite resin used as the base in the restoration affects the amount of microleakage. In their study, restorations with the ever X Posterior composite resin (ever X posterior composite resin, GC, USA) as the base showed significantly less microleakage than repairs that used conventional flowable composite resin (Tetric Evo Flow, Ivoclar

Vivadent, Liechtenstein) as the base. However, microleakage of restorations with the ever X Posterior composite resin as the base was not significantly different from restorations filled with Tetric N-Ceram using the conventional incremental technique. Therefore, by improving the mechanical properties of the flowable composite resins, for instance improving their elastic modulus, many characteristics of the restorations could be enhanced.

The elastic moduli of different flowable composites vary between 6.5 and 12.5 GP. The filler content and degree of conversion of the composite may influence the elastic modulus [34]. The deviation in the results of various studies might be explained by the differences in elastic modulus of the different flowable composite which used as the liner [35].

Based on the results of the present study, there was no significant difference in the amount of microleakage between the Bulk-fill flow (group 3) and Bulk-Surefil (group 2) groups, indicating that only the gingival layer affects microleakage. This result is contrary to the results reported by Poggio et al. [13], who reported more microleakage in restorations consisted of a 4-mm layer of SDR (SDR/Denstply Caulk, mildford, DE, USA) composite resin at the base followed by reconstruction of the cavity with posterior composite resin compared to the group that the whole cavity was filled with the bulk-fill composite (sonicfill/Kerr, Orange, CA, USA). The differences between the present study and the study by Poggio et al. [13] were in the study design, procedural steps, and utilized materials. The bulk-fill group cavities in the study by Poggio et al. [13] were restored with Sonicfil composite resin (Sonicfill/Kerr, west Collins, Orange, CA, USA), and the difference between the two study groups in their study might be attributed to the composite resin type rather than the restorative technique. However, in the present study, the composite resin used in the 4-mm layer of the base was the same in the Bulk-fill flow and Bulk-Surefil groups and only the composite resins used for the occlusal reconstruction were different. Therefore, the results of the present study are more reliable than those of Poggio et al. [13]

Analysis of the collected data in the present study

showed significantly higher microleakage in the Bulk-fill flow (group 3) compared to Flow-Surefil (group 4) groups. Conversely, previous studies have shown that polymerization stress of SDR composite resin is less than other flowable composite resins [14,15]. This might be because of the type of the flowable composite resin (G-aenial Universal Flo) used in the present study which characteristics have already been discussed. Similar to Rengo et al. [25] findings, no differences in microleakage between bulk-fill and conventional flowable restorations (G-aenial composite resin) was found regardless of restorative techniques.

The results of the present study are consistent with the Garoushi et al [33] study. Complete simulation of the oral cavity conditions requires imitation of thermal conditions and occlusal forces that restorations are subjected to. Several studies have shown that occlusal forces result in debonding of the restoration, which increases microleakage [33,36]. Therefore, it is suggested that microleakage of the similar study groups should be evaluated after application of cyclic loading comparable to masticatory forces.

Conclusion

Based on the results of the present study, use of G-aenial Universal Flo with the snow plow technique results in a significant decrease in microleakage of CI II restorations. Improved properties of this type of composite resin along with the technical advantages of the snow plow technique can be used in the clinic to increase the quality of posterior tooth-colored restorations.

References

1. Burke FJ, Shortall AC. Successful restoration of load-bearing cavities in posterior teeth with direct-replacement resin-based composite. *Dent Update*. 2001 Oct;28(8):388-94.
2. van Dijken JW, Pallesen U. Clinical performance of a hybrid resin composite with and without an intermediate layer of flowable resin composite: a 7-year evaluation. *Dent Mater*. 2011 Feb; 27(2): 150-6.
3. van Dijken JW, Pallesen U. Four-year clinical evaluation of Class II nano-hybrid resin composite restorations bonded with a one-step self-etch and a two-step etch-and-rinse adhesive. *J Dent*. 2011 Jan; 39(1):16-25.
4. van Dijken JW, Pallesen U. A randomized controlled three year evaluation of "bulk-filled" posterior resin restorations based on stress decreasing resin technology. *Dent Mater*. 2014 Sep;30(9):e245-51.
5. Jain P, Belcher M. Microleakage of Class II resin-based composite restorations with flowable composite in the proximalbox. *Am J Dent*. 2000 Oct;13(5):235-8.
6. Korkmaz Y, Ozel E, Attar N. Effect of flowable composite lining on microleakage and internal voids in Class II composite restorations. *J Adhes Dent*. 2007 Apr;9(2):189-94.
7. Kubo S, Yokota H, Yokota H, Hayashi Y. Effect of low-viscosity resin-based composite on the microleakage of cervical restorations. *Am J Dent*. 2003 Aug;16(4):244-8.
8. Kubo S, Yokota H, Hayashi Y. Microleakage of cervical cavities restored with flowable composites. *Am J Dent*. 2004 Feb;17(1):33-7.
9. Chuang SF, Jin YT, Liu JK, Chang CH, Shieh DB. Influence of flowable composite lining thickness on Class II composite restorations. *Oper Dent*. 2004 May-Jun;29(3):301-8.
10. Ernst CP, Cortain G, Spohn M, Rippin G, Willershausen B. Marginal integrity of different resin-based composites for posterior teeth: an in vitro dye-penetration study on eight resin-composite and compomer-/adhesive combinations with a particular look at the additional use of flow-composites. *Dent Mater*. 2002 Jun;18(4):351-8.
11. Reddy SN, Jayashankar DN, Nainan M, Shivanna V. The effect of flowable composite lining thickness with various curing techniques on microleakage in class II composite restorations: an in vitro study. *J Contemp Dent Pract*. 2013 Jan 1; 14(1):56-60.
12. Burgess J, Cakir D. Comparative properties of low-shrinkage composite resins. *Compend Contin Educ Dent*. 2010 May;31 Spec No 2:10-5.
13. 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.
14. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on

the SDR™ technology. *Dent Mater.* 2011 Apr; 27 (4):348-55.

15. Roggendorf MJ, Krämer N, Appelt A, Naumann M, Frankenberger R. Marginal quality of flowable 4-mm base vs. conventionally layered resin composite. *J Dent.* 2011 Oct;39(10):643-7.

16. 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 Jun;40(6):500-5.

17. Campodonico CE, Tantbirojn D, Olin PS, Versluis A. Cuspal deflection and depth of cure in resin-based composite restorations filled by using bulk, incremental and transtooth-illumination techniques. *J Am Dent Assoc.* 2011 Oct;142(10):1176-82.

18. de Almeida JB, Platt JA, Oshida Y, Moore BK, Cochran MA, Eckert GJ. Three different methods to evaluate microleakage of packable composites in Class II restorations. *Oper Dent.* 2003 Jul-Aug; 28(4):453-60.

19. 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 Jan-Feb;30(1):29-33.

20. Cehreli ZC, Gungor HC. Quantitative microleakage evaluation of fissure sealants applied with or without a bonding agent: results after four-year water storage in vitro. *J Adhes Dent.* 2008 Oct;10(5):379-84.

21. Raskin A, D'Hoore W, Gonthier S, Degrange M, Déjou J. Reliability of in vitro microleakage tests: a literature review. *J Adhes Dent.* 2001 Winter;3(4):295-308.

22. Lotfi N, Esmaeili B, Ahmadizenouz G, Bijani A, Khadem H. Gingival microleakage in class II composite restorations using different flowable composites as liner: an in vitro evaluation. *Caspian J Dent Res.* 2015;4(1):10-6.

23. Jang JH, Park SH, Hwang IN. Polymerization Shrinkage and Depth of Cure of Bulk-Fill Resin Composites and Highly Filled Flowable Resin. *Oper Dent.* 2015 Mar-Apr;40(2):172-80.

24. Rengo C, Spagnuolo G, Ametrano G, Goracci C, Nappo A, Rengo S, et al. Marginal leakage of bulk fill composites in Class II restorations: A micro CT and digital microscope analysis. *Inter J Adhes Adhes.* 2015 July;60(1):123-9.

25. Heintze SD, Monreal D, Peschke A. Marginal Quality of Class II Composite Restorations Placed in Bulk Compared to an Incremental Technique: Evaluation with SEM and Stereomicroscope. *J Adhes Dent.* 2015 Apr;17(2):147-54.

26. Furness A, Tadros MY, Looney SW, Rueggeberg FA. Effect of bulk/incremental fill on internal gap formation of bulk-fill composites. *J Dent.* 2014 Apr;42(4):439-49.

27. Abdul Kader M, 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;4(2):153-5.

28. Boruziniat A, Gharaee S, Sarraf Shirazi A, Majidinia S, Vatanpour M. Evaluation of the efficacy of flowable composite as lining material on microleakage of composite resin restorations: A systematic review and meta-analysis. *Quintessence Int.* 2016 Feb;47(2):93-101.

29. Basavanna R, Garg A, Kapur R. Evaluation of gingival microleakage of class II resin composite restorations with fiber inserts: An in vitro study. *J Conserv Dent.* 2012 Apr;15(2):166-9.

30. Anatavara S, Sitthiseripratip K, Senawongse P. Stress relieving behaviour of flowable composite liners: A finite element analysis. *Dent Mater J.* 2016;35(3):369-78.

31. Castañeda-Espinosa JC, Pereira RA, Cavalcanti AP, Mondelli RF. Transmission of composite polymerization contraction force through a flowable composite and a resin-modified glass ionomer cement. *J Appl Oral Sci.* 2007 Dec; 15(6):495-500.

32. Garoushi S, Säilynoja E, Vallittu PK, Lassila L. Physical properties and depth of cure of a new short fiber reinforced composite. *Dent Mater.* 2013 Aug;29(8):835-41.

33. Cadenaro M, Marchesi G, Antonioli F, Davidson C, De Stefano Dorigo E, Breschi L. Flowability of composites is no guarantee for contraction stress reduction. *Dent Mater.* 2009 May;25(5):649-54.

34. Braga RR, Ferracane JL. Alternatives in polymerization contraction stress management. *Crit Rev Oral Biol Med.* 2004 Jun 4;15(3):176-84.

35. Campos PE, Barceleiro Mde O, Sampaio-Filho HR, Martins LR. Evaluation of the cervical integrity during occlusal loading of class2 restorations. *Oper Dent.* 2008 Jan-Feb;33(1):59-64.