Research Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2016;5:2:52-62.

Comparative Evaluation of Microleakage of Class II Cavities Restored with Different Bulk Fill Composite Restorative Systems: An In Vitro Study

Pathik Patel[1*] Manish Shah[2] Neha Agrawal[3] Priti Desai[4] Khyatiben Tailor[5] Khyati Patel[6]

[1]Private Consultant, Department of Conservative Dentistry and Endodontics, Ahmedabad, Gujarat, India.
[2]Private Consultant, Department of Conservative Dentistry and Endodontics, Ahmedabad, Gujarat, India.
[3]Reader, Department of Conservative Dentistry and Endodontics, Goenka Research Institute of Dental Sciences, Ahmedabad, Gujarat, India.
[4]Professor, Department of Conservative Dentistry and Endodontics, Gurunanak Institute of Dental Science and Research, Kolkata, India.
[5]Private Consultant, Ahmedabad, Gujarat, India.
[6]Private Consultant, Department of Prosthodontics, Ahmedabad, Gujarat, India.

ABSTRACT

Aim: To evaluate the microleakage that occurs while restoring deep Cl-II cavities with different bulk fill composite restorative materials.

Materials and Methods: Forty caries free freshly extracted teeth were selected and through proper mounting and matrix application, were restored using Tetric n ceram bulk fill, Ever X posterior, SDR and Tetric N ceram nanohybrid (as control) in 4mm bulk increment. Specimens were tested for microleakage through immersion in 0.5% basic fushin dye and then sectioned and observed under Stereomicroscopeand the scores were obtained for each group.

Results: Tetric N ceram bulk fill and Ever X posterior showed the least microleakage while the Control group showed the highest. Out of all, Ever X posterior showed the least microleakage owing to its horizontal fiber distribution.

Conclusion: Overall bulk fill composites showed good bonding to the CEJ and thus can be used in deep Cl-II cavities with maximum of 4mm bulk increment. Routine composites should not be used in bulk technique.

Keywords: Microleakage, class II restoration, composite restoration.

INTRODUCTION

In the past two decades, significant improvement has taken place in restorative dentistry primarily the resin composites. They have become the material of choice for almost all kinds of restorations whether shallow or deep, minimal or extensive. Most of the commercially available dental composites are based on methacrylate chemistry, but volumetric shrinkage still remains a major drawback. The drawbacks of the shrinkage mainly include gap formation at the tooth restoration interface causing microleakage, thereby permitting the passage of micro-organisms and oral fluids resulting in post-operative sensitivity, pulpal inflammation, and secondary caries.[1, 2] Various techniques have been proposed and implemented to minimize the polymerization shrinkage in dental composites. Few of these include - use of resin liner under the restoration,[3] incremental placement of restorative material,[4] increasing the filler content in the composition, and use of ring opening monomer

Received: Nov. 21, 2015: **Accepted:** Feb. 3, 2016
***Correspondence Dr. Pathik Patel.**
Department of Conservative Dentistry and Endodontics, Ahmedabad, Gujarat, India.
Email: pathik2289music@gmail.com

pISSN 2278-0076
eISSN 2321-9270

in recent years.[5] For stress bearing posterior restorations, packable resin composites were introduced and are characterized by a high filler load along with improved handling property.[6] Despite the studies have proven them more favorable, concerns have been raised related to their ability to sufficiently wet and adapt to cavity walls especially at the cervical margins apical to cemento- enamel junction (CEJ).

Cavity liners like GICs and RMGICs have been used extensively but have shown to be variable in being able to properly seal margins and also dissolve over time in the oral environment.[7] Flowable composites have also been successfully attempted as a liner at the gingival seat area in deep Class II cavities in order to reduce microleakage owing to their less filler content and much lower viscosity and better marginal adaptation capability.[8] Recently placement of piece of fiber either glass or polyethylene beneath the packable composite have been suggested and proven successful at least in laboratory. But the clinical placement of these fiber inserts is somewhat time consuming, extremely technique sensitive and thus less feasible.

The most important factor in the modification or rather reduction in shrinkage stresses is the restoration placement techniques. Incremental restoration technique has been widely accepted and clinically proven to be able to reduce polymerization shrinkage thereby attaining effective marginal seal. Bulk filling technique when used for standard composites has proved to be ineffective in obtaining an acceptable marginal seal and thus not recommended.[9] Out of many studies conducted for efficacy of incremental techniques in compensating the polymerization shrinkage, some of them proved it to be better while in other studies no significant difference was found comparing other different stratification methods. Although incremental technique may be important for adequate light penetration, its disadvantages are the possibility of trapping voids between layers owing to the formation of oxygen inhibition layer at the surface of the cured layer and the time required to place the restoration. Bulk application technique has the advantages of being simpler as it makes the treatment quicker by reducing the number of clinical steps thus making it minimally technique sensitive.[10]

A group of products with novel patented technology for polymerization shrinkage reduction have been introduced in restorative dentistry, the so-called 'bulk fill composites' like glass fiber reinforced composite everX Posterior with short fibers directed in horizontal plane, SDR bulk fill flowable composite with polymerization modulator added to the composition and Tetric N Ceram Bulk fill composite with patented Ivocerin inclusion within the core matrix. These materials are suitable for insertion in a 4 mm bulk placement due to their reduced polymerization stress and their high reactivity to light curing. Depending on the material, this layer should be covered by a layer of standard composite.[11] Class II restorations with resin composites can be placed at an acceptable standard if the gingival margin is in sound enamel, but there is much debate regarding marginal integrity that extend apical to CEJ.[12]

Need for this study was to get a clear idea regarding which of the novel bulk fill composites were to be used in clinical practice for deep Class II composite restorations that would provide the best result that is the least microleakage values. Hence, the purpose of the study was to evaluate and compare microleakage and micro gap formation in class II cavities at the gingival margin placed below CEJ, and restored with three different novel bulk fill composites. The null hypothesis of the study was that there is no significant difference in microleakage of the different evaluated bulk fill composite materials.

MATERIALS AND METHODS

Forty caries-free vital human teeth freshly extracted for periodontal or orthodontic reasons were used in this study (Fig. 1). The teeth to be prepared were mounted in a plaster block with adjacent natural teeth as abutments (Fig. 2). In each tooth two standardized Class II proximal box cavities (on mesial and on distal surfaces) were prepared with a SF 41 diamond bur at high-speed with air/water spray (Fig. 2, 3, 4). The buccolingual extension of the cavities was 3 mm; axial depth was 6mm and the gingival seat was located in dentin/cementum (1 mm below the cementum-enamel junction/CEJ). So the overall depth of the preparation from occlusal to cervical part was 6mm. All the dimensions were checked with periodontal

Fig 1: Extracted mandibular molars.

Fig 2: Mounted specimen.

Fig 3: Armamentarium.

probe (Fig. 5, 6). The prepared teeth were randomly assigned to 4 experimental groups (of 10 specimens and 20 cavities each). The bur was replaced after every five preparations. Matrix application was done using Tofflemire matrices and wedge application. Restorative procedure for all groups was as follows:

Fig 4: Class II proximal box preparation.

Fig 5: Checking depth of prepared cavity ie 6 mm.

Fig 6: Checking width of prepared cavity ie 3 mm.

The cavities were etched with 37% phosphoric acid (Fig. 10) for 30 seconds (Anabond Stedman Pharma Research (P) Limited, Tamil Nadu, India) and bonded (Fig. 11) with Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA) followed by application of light for 20 seconds.

Group 1. Tetric N Ceram Bulk fill composite

Next Tetric N Ceram bulk fill composite (Ivoclar vivadent, AG, Schaan, Liechtenstein) was filled in

4mm bulk increment, condensed with a condenser and light cured for 20 seconds.

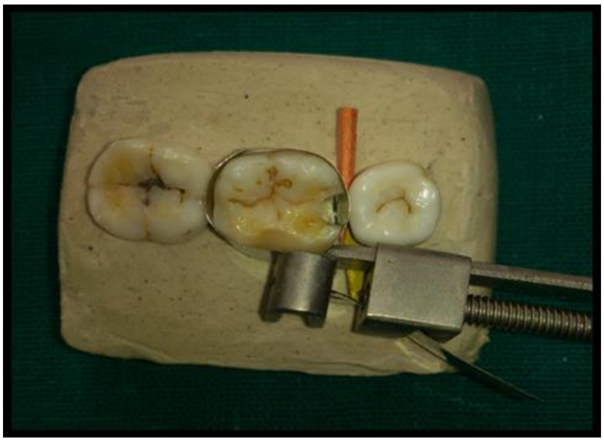


Fig 7: Matrices and Wedge application.

Fig 8: Armamentarium.

Fig 9: Restorative materials.

Group 2. SDR Bulk fill composite

The bulk fill flowable material SDR (Dentsply DeTrey, Konstanz, Germany) was placed in a 4 mm bulk increments and light cured for 20 seconds.

Fig 10: Application of Etchant.

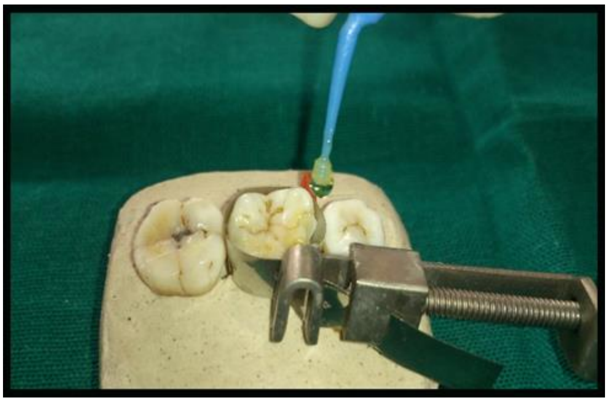


Fig 11: Application of bonding agent.

Fig 12: Bulk filling restoration.

Fig 13: Checking depth of bulk filling ie 4 mm.

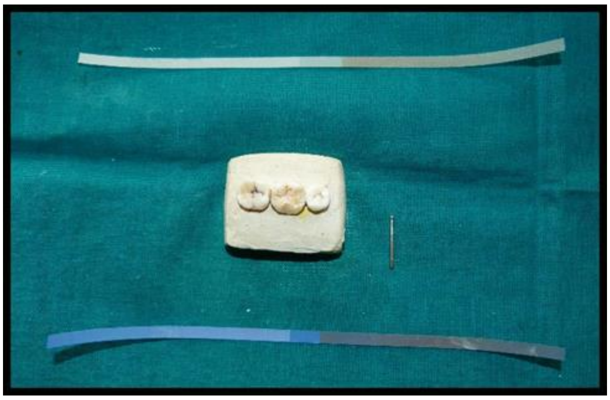


Fig 14: Finishing and polishing instruments.

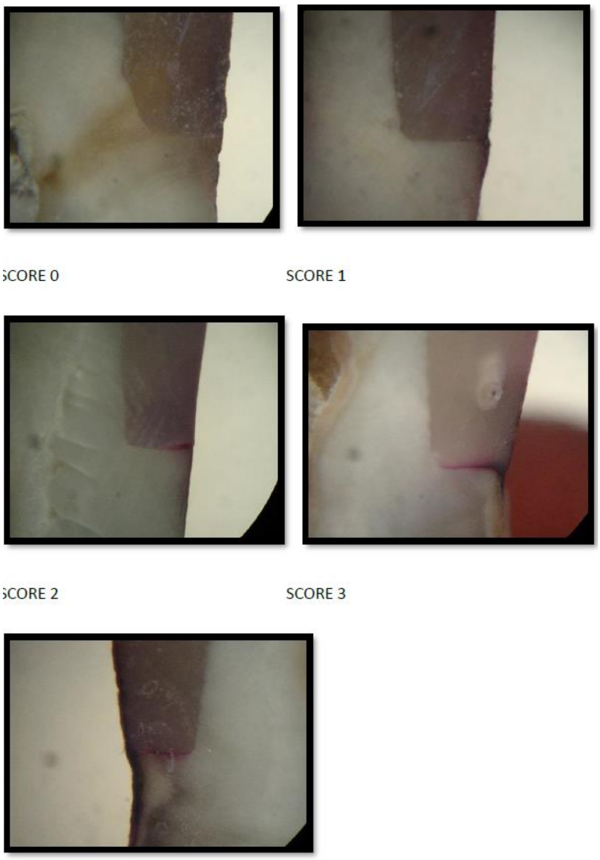


Fig 15: Scores.

Group 3. EverX Posterior Fiber reinforced composite

Fiber reinforced composite everX Posterior (GC, India) was filled in a 4 mm bulk increments, condensed with a condensor and light cured for 20 seconds.

Group 4. Control group

The cavities were then filled with nanohybrid composite Tetric N Ceram (Ivoclar Vivadent AG, Schaan, Liechtenstein) without giving a flowable lining, in 4mm bulk increment.

An occlusal layer of CeramX Mono (Dentsply DeTrey, Konstanz, Germany) was filled for the remaining 2mm preparation space to build the final anatomy and as a hard enamel like structure and light cured for 20 seconds.

Table 1: Experimental groups of the study

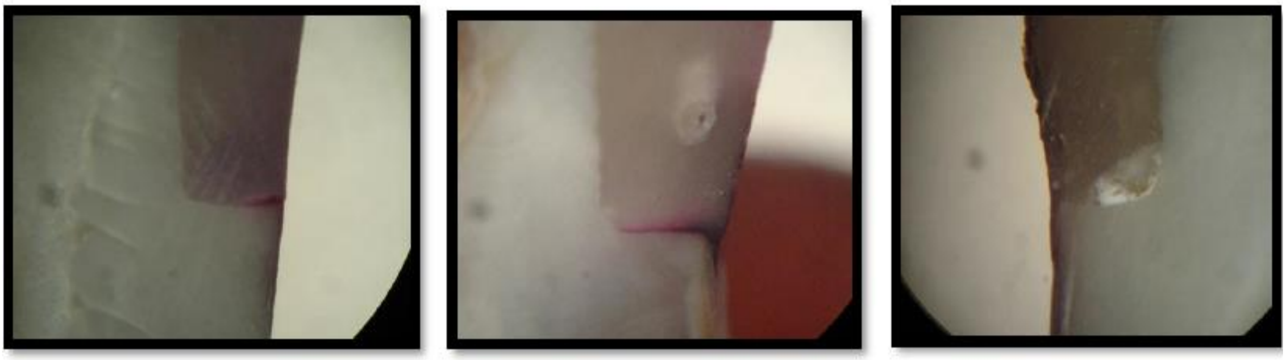
Group	1st increment (4mm)	2nd increment (2mm)
Group 1	Tetric N Ceram Bulk fill	CeramX Mono
Group 2	SDR Bulk fill	CeramX Mono
Group 3	everX Posterior	CeramX Mono
Group 4 - Control	Tetric N Ceram	CeramX Mono

To standardize the protocol, all the bulk fill materials, even standard composite, were inserted using the same technique. Each layer or increment was cured for 20 seconds in continuous intensity mode at a light intensity 1200 mW/cm2 (LED light, Unicorn Denmart, New Delhi, India). All teeth were coated with two layers of nail varnish up to 1 mm from the restorations margins, while the apical part was sealed with wax. The restored teeth were then subjected to artificial aging by thermocycling. All specimens were immersed alternately in water baths at 5 ± 2°C and 55 ± 2°C for 1000 cycles, with a dwell time of 20 seconds in each bath and a transfer time of 10 seconds. After thermocycling, the specimens were first cut bucco-lingually to obtain separate mesial and distal sections. Then they were immersed in a 0.5% basic fuchsin dye solution and incubated at 37°C for 24 hours such a way that the restoration surface remain immersed in the dye solution while the sectioned surface with the pulp cavity would not have intimate contact with the solution. The teeth were subsequently rinsed for 10 minutes under running water to remove extra external dye, dried and sectioned mesiodistally through the center of the restorations with a low-speed water-cooled diamond cutter.

I. MICROLEAKAGE ANALYSIS

All specimens were examined at 4X magnification in a stereomicroscope (Labomed,

Group 2 SDR (Fig. 17)



Group 3 everX Posterior (Fig. 18)

Group 4 Tetric N Ceram Nano hybrid composite (Fig. 19)

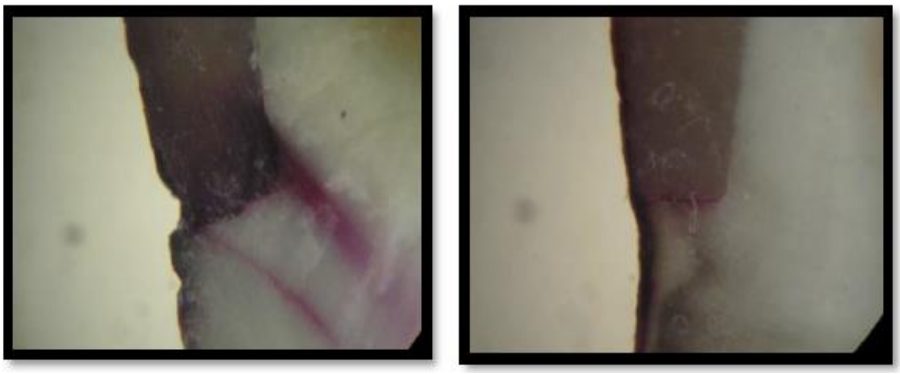


Fig 16: Group 1 Tetric N Ceram bulk Fill

USA) and standardized digital images in 2X zoom were obtained. Dye penetration was measured from the gingival margin.

The cervical marginal microleakage was recorded based on the following criteria (Fig. 15) (18):

Score 0 = no dye penetration,
Score 1 = dye penetration limited to cementum,
Score 2 = dye penetration beyond the dentin-cementum junction but limited to 2/3rds of the cervical wall length,
Score 3 = dye penetration beyond 2/3rds of the cervical wall length but not to the pulpal wall,
Score 4 = dye penetration to the pulpal wall.

The scores obtained were thus subjected to statistical analysis.

RESULTS

Table 1 shows the percentage of the scores in each of the groups while Table 2 shows the mean value of the scores for all the groups and Table 3 shows the Kruskal Wallis statistical analysis for the p value. Mann Whitney comparison between each of the restored groups and also between the control group and the restored groups is shown in Table 4.

The results demonstrated no statistical difference between Group 1 and Group 3 with almost equal number of score 0 in both groups (Fig. 16, 18). Score 0 was more in number in Group 3 than Group 1. Also no statistical significance was found between Group 2 and Group 4 with maximum mean score to be 3 (Fig. 17, 19). Group 3 showed significant statistical difference with Group 2 and Group 4. Same result was seen for Group 1 with Group 2 and Group 4.

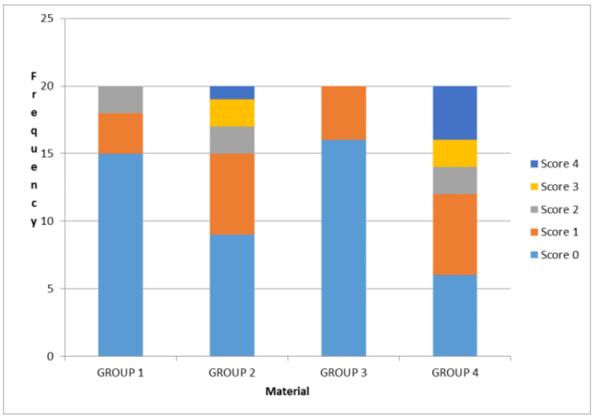
The highest mean scores were obtained for Group 4 i.e. the control group and thus showed the highest microleakage (Fig. 19). The lowest microleakage scores were obtained for Group 3 and next for Group 1 thus both showed least microleakage at the gingival margins.

SCORE 4

Table 2. Frequency distribution of microleakage scores (percentages) of cemento-dentinal margins among the different groups tested.

	Score 0	Score 1	Score 2	Score 3	Score 4
Group 1	15 (75%)	03 (15%)	02 (10%)	00	00
Group 2	09 (45%)	06 (30%)	02 (10%)	02 (10%)	01 (5%)
Group 3	16 (80%)	04 (20%)	00	00	00
Group 4	06 (30%)	06 (30%)	02 (10%)	02 (10%)	04 (20%)

Table 2 shows highest percentage of score 0 is for Group 3, followed by Group 1 and lowest for Group 4. Group 3 and Group 1 has 0 percentage of scores 3 and 4, whilst maximum number of score 4 is for Group 4.



Graph 1. Distribution of microleakage scores of the different groups.

Figure shows the graph of material vs frequency of different scores of microleakage. Light blue bar suggest score 0, orange suggest score 1, grey suggest score 2, yellow suggests score 3 and dark blue suggests score 4.

Table 3. Mean values of the restored groups

Group	N	Mean	Std. Deviation	Minimum	Maximum
1	20	0.35	0.671	0	2
2	2	1.00	1.214	0	4

	0				
3	20	0.20	0.410	0	1
4	20	1.60	1.536	0	4

Table 3 shows Group 1 and 3 having mean values less than 0.5 while other groups having mean value 1 and above.

Table 4. Kruskal-Wallis Test

	Group	N	Mean Rank	p value
DATA	1	20	32.88	0.001
	2	20	45.48	
	3	20	30.00	
	4	20	53.65	

Table 4 show the Kruskal Wallis non-parametric test for all the restored groups with the mean rank value of Group 3 being the lowest which brings the p value highly statistically significant.

Table 5. Mann Whitney comparison between each of the restored groups

GROUP	N	Mean Rank	Sum of Ranks	p value
1	20	17.28	345.50	0.047
2	20	23.73	474.50	
1	20	21.20	424.00	0.603
3	20	19.80	396.00	
1	20	15.40	308.00	0.003
4	20	25.60	512.00	
2	20	24.50	490.00	0.012
3	20	16.50	330.00	
2	20	18.25	365.00	0.204
4	20	22.75	455.00	
3	20	14.70	294.00	0.001
4	20	26.30	526.00	

Table 5 shows the presence or absence of statistical significance between each of the restored groups.

Comparison of Group 1 and 3 is not statistically significant, also the comparison of Group 2 and Group 4 is statistically insignificant. Comparison between Group 1 and Group 2 and between Group 2 and 3 is statistically significant whereas comparison between Group 1 and Group 4 and Group 3 and Group 4 is highly statistically significant.

DISCUSSION

The results of the study showed that there is significant difference between microleakage of different evaluated bulk fill composites and thus the null hypothesis was rejected. Stresses that are generated due to polymerization shrinkage of composites have the potential to cause an adhesive failure or microcracking of restorative material and/or enamel. Deformation would take place if the adhesion remains unhampered following contraction stress. Weak adhesion would result in gap formation. Extensive studies in the past decade have proven that the technique of restorative material placement is an important factor in the modification of the shrinkage stresses and the magnitude of the stress is mediated by curing rate, stiffness of the composite, its stress relieving capacity as well as the constraint applied by the bonding to the cavity preparation. The internal stresses will be minimized if the polymerization of composite occurs in an unconstrained condition.[13] However, when the polymerization process is taking place, the volumetric contraction of the composite along with the effective bonding to the dentin results in undue stress transfer thus leading to inward deformation of the cavity walls.[14] Thus a technique that uses smaller increments to fill the entire cavity would lead to less stress generation over larger area of cavity walls and thus incremental technique is normally considered the most appropriate placement technique.[13] This technique not only alleviates stress but also decreases the C-factor.[30]

Previous works of many researchers have led to a hypothesis that elastic modulus of composite has more to do with stress than the shrinkage alone. Keeping this property in mind, it can easily be concluded that flowable composites, either conventional or bulk fill, with lesser filler load or greater proportion of diluent monomers are effective in reducing overall stress even though they produce higher volumetric shrinkage than the packable composites.[13] However, significant stress relief cannot be guaranteed when flowable composites with elastic modulus of approximately 5 GPa and higher are used. Also more the volumetric shrinkage, more is the tooth deformation and ultimately the stress on the cavity walls would be greater for both conventional as well as bulk fill flowable composites.[14]

Incremental filling technique combined with the elastic buffer effect of flowable materials has demonstrated interesting dentine marginal adaptation in class II cavities. But already large number of studies have been performed for the latter technique in the last decade and has proven it to be the best technique for reducing polymerization shrinkage. The only disadvantage that lies with the technique is the increased number of clinical steps and thus many factors come into play including isolation, patient co-operation as well as operator's skill to handle the placement of flowable composite lining at the gingival floor with blood, saliva or gingival crevicular fluid posing challenges.[15]

Majority of the Class II carious lesions extend upto or beyond the CEJ and into deeper dentin along the proximal pulpal wall. Therefore, the cervical margins of restorations will be placed at dentine or cementum surfaces, which may lead to a weaker marginal seal than at the enamel surface.[16] Microleakage has also been associated with the oral environment (including occlusal forces and temperature variation) and several differences between the physical properties of teeth and restorative materials (including polymerization shrinkage, coefficient of thermal expansion, and modulus of elasticity).[17]

Thermocycling has been proved to be the most influential factor in enhancing the process of microleakage in the previous studies. Effects of the wide range of cycle numbers, temperatures and exposure times were revealed from a previous research for *in vitro* thermocycling regimens. The conditions used in the present study (1000 cycles of 5 ± 2°C to 55 ± 2°C with 20s dwell time) were based on the recent studies on Class II and Class V restorations.[18]

Tetric N-Ceram Bulk Fill is the efficient four millimeters posterior composite of the nano-optimized Tetric N-Collection. The patented light activator Ivocerin is responsible for ensuring the complete cure of the filling. This group showed lesser microleakage values (Fig. 16) compared to Group 2 and Group 4 and statistical insignificant difference when compared to Group 3 which showed the least values (Table 4). Comparatively less voids were observed in the magnification for this group as compared to SDR. Still presence of voids in some specimens does create some doubt for its efficiency in long run under constant oral environmental changes.

SDR, developed by Dentsply, is the first posterior composite for dentin replacement combining the handling properties of a flowable composite with minimal shrinkage stress. As a result, it can be placed in increments of up to 4mm. It is based on 'Stress Decreasing Resin' technology. This means that a substance described as a 'polymerization modulator' is chemically embedded in the backbone of the polymerizable resin. The polymerization modulator synergistically interacts with the camphoroquinone photo-initiator to result in a slower elasticity modulus development, allowing for stress reduction without a decrease in the rate of polymerization or degree of conversion. There was prevalence of score 3 (Fig. 17) in this group with maximum score 1 showing microleakage in atleast half of the specimens (Table 1) (Graph1). Group 2 showed statistical significance with both Group 1 and 3 except the Group 4 which was the control group, to which it showed insignificant difference (Table 4). Most of the specimens of SDR group showed presence of voids in the stereomicroscopic images (Fig. 17), few of them detectable even by naked eye at varied depths of the restoration. The reason for voids may be because of the low viscosity of the flowable composite.

EverX Posterior consists of a combination of a resin matrix, horizontally orientated E-glass fibers and inorganic particulate fillers. The resin matrix contains bis-GMA, TEGDMA and PMMA, forming a matrix referred to as a semi-interpenetrating polymer network (semi-IPN), which provides good bonding properties and improves the toughness of the polymer matrix.[19]

Pertaining to the addition of fibers within the composite system, it has been theorized that a stress-free shock absorbing complex is created at the fiber-resin interface. Also, fibers replace some part of the composite, resulting in a slight but significant overall reduction in volumetric contraction of the composite and thereby decreasing the shrinkage stress.[18] Manufacturers of everX Posterior claim that its shrinkage characteristics are different to other composites. During the placement, the fibers orientate into a horizontal plane within the cavity (Fig. 18). Due to the strong adhesion between the resin and the silanated fibers, the direction of the fibers minimizes shrinkage in the horizontal plane after placement though vertical shrinkage does take place.[20] But overall the percentage of shrinkage is reduced which is proven in this study as Group 3 gave the best results out of all considering the number of 0 dye penetration score it had (Table 1) (Fig. 18). Also, important thing to note is that there were no voids present in any of the tested specimens of Group 3 suggesting homogeneity of the restoration (Fig. 18). Such a restoration would be more resistant to flexure and thus fracture under occlusal loading thereby serving for a longer time from clinical point of view alongwith the main advantage of minimum or no postoperative sensitivity and chances of recurrent caries.

The main concern regarding a bulk technique is whether the composite cures enough in the deeper portions and, at this moment, there are few studies evaluating the degree of conversion and polymerization kinetics of bulk-fill composites. One of them revealed that Surefil SDR, Tetric EvoCeram Bulk Fill and Venus Bulk Fill exhibited adequate curing at the deepest portion of a 4-mm increment. In general, the claims of the manufacturers about the depth of polymerization of bulk-fill composites can be considered reliable.[21, 22]

The proposed mechanism of reducing shrinkage even though filled in bulk have been proven correct with EverX posterior (Group 3) and Tetric N Ceram bulk fill composites (Group 1) and proven incorrect for SDR (Group 2). Control group (Group 4) showed the highest microleakage values that was expected as the nanohybrid conventional composite is not designed to work when placed in bulk especially concerning the depth of cure parameter and absence of any stress modifiers. In the present study, it was placed in bulk as the comparison had to be made between the different bulk fill materials and not the techniques. However the following study was performed in vitro so in the scenario of in vivo study, the result may or may not be the same.

CONCLUSION

Thus, within the limitations of the study, it can be concluded that bulk filling technique ensures adequate marginal adaptation in enamel but not adequate in dentin and cementum. All the restored groups showed microleakage, out of which everX Posterior showed the least microleakage and good homogeneity of the restoration, followed by Tetric N Ceram bulk fill composite that equally showed good marginal adaptation as the fiber reinforced composite though it did have presence of voids in some of the specimens, and the highest microleakage was observed in SDR composite with maximum number of voids thus proving to be the weakest material of amongst other two in marginal adaptation and homogeneity. Conventional composites when filled in bulk showed the worst results and thus should be avoided to be filled in bulk.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Watts DC, Hindi A. Intrinsic soft start polymerization shrinkage — kinetic in an acrylic based resin composite. Dent Mater 1999;15:39-45.
2. Going RE. Microleakage around dental restorations: A summarizing review. J Am Dent Assoc 1972;84:1349-57.
3. Sadeghi M, Lynch CD. The effect of flowable materials on the microleakage of class II composite restorations that extend apical to cemento enamel junction. Oper Dent 2009;34:306-11.

4. Ymazaki PC, Bedran-Russo AK, Pereira PN, Swift EJ. Microleakage evaluation of new low shrinkage composite restorative material. Oper Dent 2006;31:670-6.

5. Weinmann W, Thalackar C, Guggenberger E. Siloranes in dental composites. Dent Mater 2005;21:68-74.

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

7. Holtan JR, Nystrom GP, Douglas WH, Phelps RA. Microleakage and marginal placement of a glass-ionomer liner. Quintessence Int 1990;21:117-22.

8. Versluis A, Douglas WH, Cross M, Sakaguchi RL. Does an incremental filling technique reduce polymerization shrinkage stresses? J Dent Res 1996;75:871–8.

9. Coli P, Brannstrom M. The marginal adaptation of four different bonding agents in Class II composite resin restorations applied in bulk or in two increments. Quintessence Int 1993;24:583–91.

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

11. Claudio P, Marco C, Andrea S, Jenia M, Marco C. 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;18:793–8.

12. Sufyan G, Eija S, Vallittu PK, Lassilaa L. Physical properties and depth of cure of a new short fiber reinforced composite. Dent Mater 2013;29:835–41.

13. El-Damanhoury H, Platt J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Oper Dent 2014;39:374-82.

14. Juloski J, Carrabba M, Aragoneses JM. Microleakage of Class II restorations and microtensile bond strength to dentin of low-shrinkage composites. Am J Dent 2013;26:271-7.

15. Kubo S, Yokota H, Sata Y, Hayashi Y. Microleakage of self-etching primers after thermal and flexural load cycling. Am J Dent 2001;14:163-9.

16. Retief DH, Mandras RS, Russell CM. Shear bond strength required to prevent microleakage of the dentine /restoration interface. Am J Dent 1994;7:44-6.

17. Litonjua LA, Andreana S, Bush PJ, Tobias TS, Cohen RE. Noncarious cervical lesions and abfractions: a re-evaluation. J Am Dent Assoc 2003;134:845-50.

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

19. Geis-Gerstorfer J. In vitro corrosion measurements of dental alloys. J Dent 1994;22:247-51.

20. Wahab FK, Shaini FJ, Morgano SM. The effect of thermocycling on microleakage of several commercially available composite Class V restorations *in vitro*. J Prosthet Dent 2003;90:168-74.

21. Finan L, Palin WM, Moskwa N, McGinley EL, Fleming GJ. The influence of irradiation potential on the degree of conversion and mechanical properties of two bulk-fill flowable RBC base materials. Dent Mater 2013;29: 906–12.

22. Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater 2014;30:149–54.