Comparative Evaluation of Microleakage of Bulk Fill Packable Resin Composite Restorations and Bulk Fill Flowable Resin Composite Restoration in Class V Cavity Preparation - An in Vitro Study

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Abstract

Aim and Objective: Was to assess and compare the microleakage of bulk fill packable resin composite and bulk fill flowable resin composite in class V cavities along the occlusal and gingival margins using dye penetration test under stereomicroscope.

Materials and Methods: Hundred human extracted premolars were selected and randomly divided into 4 groups (n=25), as per the restorative materials for microleakage test. Group I: X-tra fil (Bulk fill packable resin composite). Group II: Power Fill (Bulk fill packable resin composite). Group III: SDR Flow Plus (Bulk fill flowable resin composite). Group IV Power Flow (Bulk fill flowable resin composite). Class V (box) cavities were prepared both on the buccal surfaces of each of the 100 teeth, a total of 100 cavities, restored, immersed in 2% methylene blue dye for 24 hours and then sectioned bucco lingually into two halves. Dye penetration score was measured along occlusal and gingival wall using a Stereomicroscope at 40X magnification. Statistical analysis was done using Chi square test for microleakage assessment. P value was set at <0.05.

Result: Intergroup comparison showed statistically no significant difference between the four groups both occlusal and gingival wall.

Conclusion: None of three resin composite materials were free from microleakage. All the four materials showed more microleakage at gingival wall compared to occlusal wall. Among all the tested groups Tetric power fill showed the least microleakage at the gingival wall.

Keyword: Microleakage, Class V, Resin composites.

INTRODUCTION

Resin composite restorative materials were introduced in dentistry in 1950 and have developed tremendously over years. The use of composite restorations have become more popular in recent decades because of their improved strength, esthetic quality, wear resistance, predictability and reduced water sorption as compared to earlier versions1.The major disadvantage of visible light cured composites is polymerization shrinkage. This shrinkage can result in gap formation between the composite material and tooth structure, particularly if the restoration margin is placed in dentin or cementum. Bacteria, fluids, molecules, or ions can pass through this gap between the resin composite and the cavity wall, a process called microleakage. Microleakage is thought to be responsible for hypersensitivity, secondary caries, pulpal pathosis, and failure of restorations2.

Polymerization shrinkage of methacrylate based dental resin composites is unavoidable, due to the fact that monomer molecules are converted into a polymer network and therefore, exchanging van der Waals spaces in covalent bond spaces2. Contraction stress is the result of polymerization shrinkage taking place under confinement caused by bonding to cavity walls. The stress magnitude is affected by the volume of each increment and cavity configuration (C-factor), which are relatively larger in bulk-fill materials applications. Therefore, the stress control has been one of the main subjects in the material development3.

Various approaches have been employed in the formulation of bulk-fill composites to reduce the stress, adjust the stress generation kinetics and improve depth of cure. Those include changes in filler content and shape, modified monomer molecular weight and structure, addition of stress relievers and polymerization modulators, increase of polymerization inhibitors, new combinations of photoinitiators, enhanced material translucency and dual-cured polymerization mechanisms4.

Bulk-fill type of composite resins has been introduced in the market with a view to simplify the procedure of introducing the material into the cavity and its polymerization5. They may be used either as dentin replacement beneath conventional resin composite or as a single filling material. Bulk-fill composite can be light cured in a single increment up to 4 mm and it makes the work quicker by reducing the number of clinical steps6. Bulk-fill composite resins can be applied in thick layers due to low shrinkage of these materials and high filler content which causes shrinkage stresses to be very low6. Nevertheless, an ideal bulk-fill composite would be one that could be placed into a preparation having a high configuration factor (C-factor) design and still exhibited very little polymerization shrinkage stress, while maintaining a high degree of cure throughout7.

In this study we compare the microleakage of two bulk fill packable resin composite restorations and two bulk fill flowable resin composite restoration in class v cavity preparation.

MATERIALS AND METHODOLOGY

Preparation of the specimens: Class V (box) cavities were prepared on the buccal surfaces of 100 Premolar teeth, with a total of 100 cavities. The gingival cavosurface margin of the preparation was approximately 1.5 mm below the cementoenamel junction and occlusal margin was approximately 1.5 mm above the cementoenamel junction. The preparations were made with a No. 245 carbide bur (SS White) in a high speed standardized handpiece under copious water coolant. The dimension of the final cavity preparation was approximately 3.0 mm Occlusogingivally, 3.0 mm mesiodistally and 2 mm deep.

The preparations were etched with 37% phosphoric acid (Scotch bond Etchant, 3M ESPE) for 20 seconds, rinsed with water for 15 seconds and blot dried, leaving the dentin moist and shiny. An ethanol and water based adhesive system (ADPER single bond 2, 3M ESPE) was applied in two consecutive coats to the entire preparation, after 10 seconds of application gently air dried for 5 seconds and light cured for 20 seconds. Teeth were randomly divided into the four groups of 25 each corresponding to four different resin composites.

Group I: X-tra fil(Bulk fill packable resin composite), Group II: Tetric Power Fill (Bulk fill packable resin composite), Group III: SDR Plus (Bulk fill flowable resin composite) and Group IV: Tetric Power Flow(Bulk fill flowable resin composite).The specimens in each group were restored with the corresponding resin composite according to manufacturer’s instructions. The restored specimens were stored in distilled water at 370C for 12 hours. The restorations were then finished and polished with aluminium oxide disks (Sof-Lex Pop On, 3M ESPE). The teeth were coated with two layers of nail varnish leaving approximately 1.0 mm width around the restoration, to allow the contact of the tracing agent with the margin of the restoration. The specimens were thermocycled for 1000 cycles at 50C and 550C with

30 seconds of dwell time. The specimens were immediately immersed in 2% Methylene blue dye for 24 hours. The specimens sectioned through bucco lingual direction with a sectioning disc. Then the restorations were analyzed with a stereomicroscope at 40xmagnification and scored for degree of dye penetration along the occlusal and gingival walls.

MICROLEAKAGE EVALUATION

Section of each tooth were evaluated at 40X with a stereomicroscope. The dye penetration for composite/tooth interface was scored for occlusal and gingival walls on a non-parametric scale from 0 to 4 based on the Ordinal ranking system, and the degree of leakage on the enamel and dentinal/cemental margins were determined.

0	No dye penetration
1	Dye penetration short of dentino-enamel junction (DEJ)/ cemento dentinal junction (CDJ).
2	Dye penetration up to dentino-enamel junction (DEJ)/ cemento-dentinal junction (CDJ)
3	Dye penetration beyond dentino-enamel junction(DEJ)/ cemento - dentinal junction (CDJ)
4	Dye penetration till/into the axial walls

Table 1: The teeth were then divided into four groups of 25 each.

Group	Composites	Composition
I	X-tra fil Voco America, Inc., Indian Land, USA. (Bulk fill packable resin composite)	**Monomers;** Bis-GMA, UDMA, TEGDMA, **Fillers;** 86% wt% (barium-boron-alumino-silicate glass)
II	Tetric Power Fill Ivoclar Vivadent AG, Schaan Liechtenstein. (Bulk fill packable resin composite	**Monomers**; Bis-GMA, Bis-EMA, UDMA, Bis-PMA, DCP, D3MA. **Fillers**; Barium glass, Ytterbium, Trifluoride, Copolymer, Mixed Oxide (SiO2/ZrO2) (79 wt%, 53–54 vol%)
III	SDR Plus Dentsply Sirona (York, USA) (Bulk fill flowable resin composite)	**Organic Matrix Composition:** Proprietary modified urethane dimetacrylate resin, TEGDMA; polymerizable dimethacrylate resin; polymerizable trimethacrylate resin; camphorquinone photoinitiator; ethyl-4(dimethylamino)benzoate photoaccelerator; butylated hydroxy toluene; fluorescent agent, and UV stabilizer. **Inorganic Filler Particulate:** (70.5 wt%, 47.4 vol%) barium-alumino-fluoro-borosilicate glass; silanated strontium alumino-fluoro-silicate glass; surface treated fume silicas; ytterbium fluoride; synthetic inorganic iron oxide pigments, and titanium dioxide
IV	Tetric Power Flow Ivoclar Vivadent AG, Schaan, Liechtenstein (Bulk fill flowable resin composite)	**Monomers**; Bis-GMA, Bis-EMA, UDMA, CMP-1E, DCP, D3MA. **Fillers**; Barium glass, Ytterbium, Trifluoride, Copolymer, Mixed Oxide (SiO2/ZrO2) (71 wt%, 46–47 vol%)

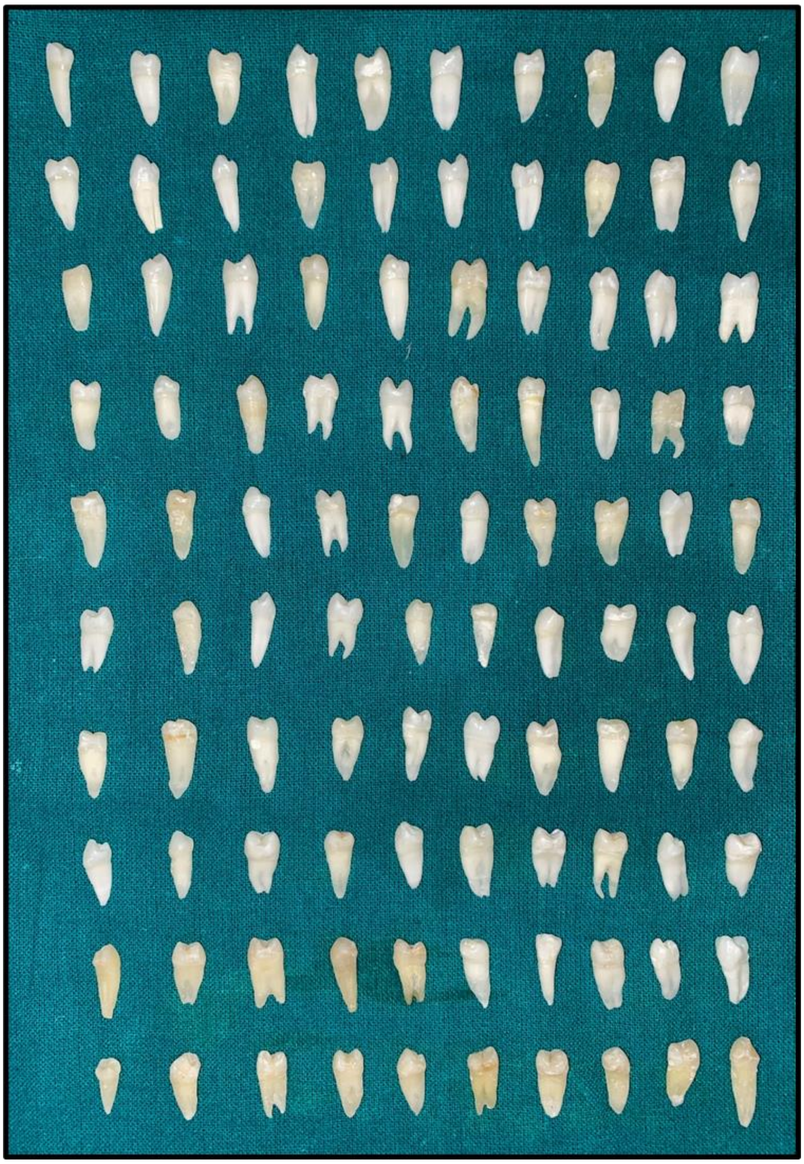
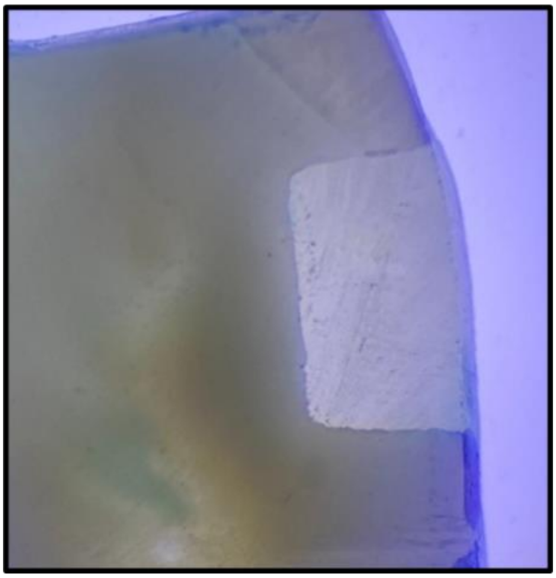
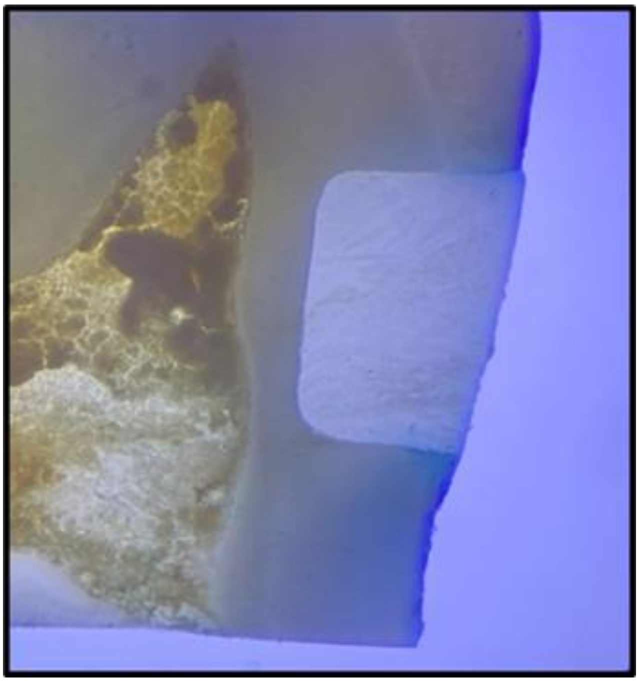


Figure 3: Extracted Premolar Teeth used for The Study

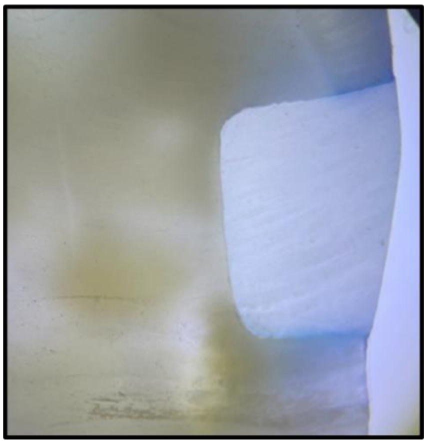


The Arrow 1 & 2 Shows no dye Penetration at Tooth Composite Interface

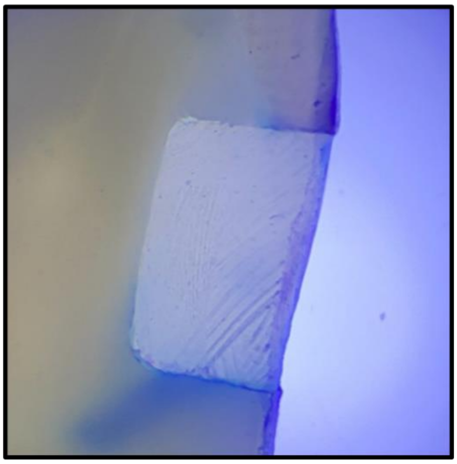
(Occlusal wall & Gingival wall Score 0)



The Arrow at interface 1 shows Dye penetration short of DEJ (Score 1) where as at interface 2 shows dye penetration beyond CDJ (Score 3)



The Arrow at interface 1 shows dye penetration up to DEJ (Score 2) where as at interface 2 shows dye penetration beyond CDJ (Score 3)



The Arrow at interface 1 Shows Dye penetration beyond DEJ (Score 3) where as at interface 2 shows dye penetration till axial wall (Score 4)

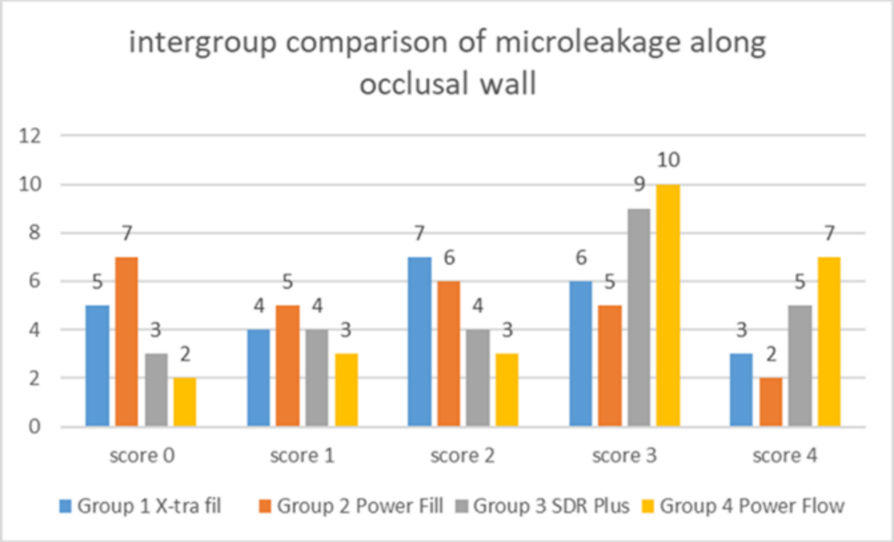
The Arrow Shows Dye penetration till/into the axial walls
(Occlusal wall & Gingival wall Score 4)

OBSERVATION AND RESULTS

The intergroup comparison of microleakage at occlusal and gingival wall of all the four study groups was done using Chi square test that showed a non significant difference between Groups I (X-tra fil), Group II (Tetric Power fill), Groups III (SDR Plus) and group IV (Tetric Power flow) (P > 0.05), but least amount of microleakage was shown by group II (Tetric Power Fill), and maximum microleakage was seen in group IV (Tetric Power Flow).(Table 2 and 3). However there was a statistically significant difference seen for the frequencies between groups when microleakage along occlusal wall and gingival wall was compared (p<0.05).(Table 4). Comparison of microleakage along occlusal wall and gingival wall between combined Packable vs Flowable composite resin, There was a statistically non significant difference seen for the frequencies between the groups (p>0.05). (Table 5 and Table 6). Thus, the results obtained from the present study showed that the least amount of microleakage was seen in Tetric Power Fill followed by X-tra Fil, SDR Plus , and the maximum was seen in Tetric Power Flow.

Table 2: Shows intergroup comparison of microleakage along occlusal wall

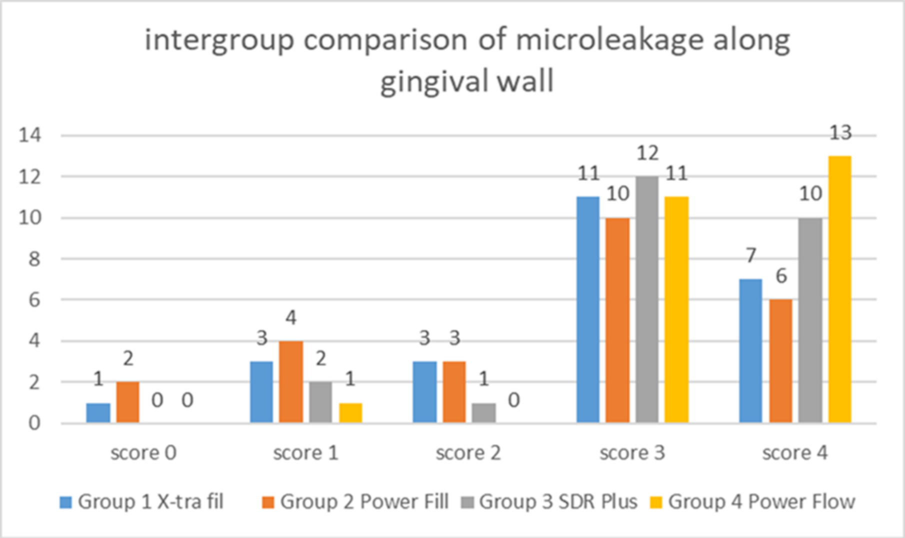
Groups	Occlusal wall dye penetration						Chi sq Value	p value of Chi sq test
	0	1	2	3	4	Total		
Group I X-tra fil	5	4	7	6	3	25(100)	9.711	0.469
Group II Tetric Power Fill	7	5	6	5	2	25(100)		
Group III SDR Plus	3	4	4	9	5	25(100)		
Group IV Tetric Power Flow	2	3	3	10	7	25(100)		



There was a statistically non significant difference seen for the frequencies between the groups (p>0.05)

Table 3 : Shows intergroup comparison of microleakage along gingival wall

Groups	**Gingival wall dye penetration**						**Chi sq Value**	**p value of Chi sq test**
	0	1	2	3	4	Total		
Group I X-tra fil	1	3	3	11	7	25(100)	13.039	0.366
Group II Tetric Power Fill	2	4	3	10	6	25(100)		
Group III SDR Plus	0	2	1	12	10	25(100)		
Group IV Tetric Power Flow	0	1	0	11	13	25(100)		



There was a statistically non significant difference seen for the frequencies between the groups (p>0.05)

DISCUSSION

Resin composites are widely used for restoring cervical lesions. They are esthetic, mercury free and bond to tooth structure with the use of bonding systems59. The longevity of resin based composite depends on the interfacial bonding between resin and cavity walls, which should prevent the marginal microleakage that causes staining at the margins of restorations, recurrent caries, hyper sensitivity and pulp pathology66.

Microleakage is an important property that has been used in assessing the success of any restorative material used in restoring tooth. Improvements in resin composites have increased their usefulness as restorative materials; however, polymerization shrinkage continues to remain one of the primary deficiencies of composite restorations. Polymerization shrinkage causes contraction stress within the restoration that leads to microleakage, as well as stress within the surrounding tooth structure2.

The coefficient of linear thermal expansion of resin composites is three or four times that of tooth structure. In addition to the differences in thermal expansion coefficients, the shrinkage of composites during curing induces stresses at the tooth/restorative interface and generally results in gap formation. Therefore, polymerization shrinkage and the thermal expansion coefficient of these restorative materials have been suggested as major causes of microleakage67,68,69.

Other Possible reasons for microleakage at the tooth restoration margin are cavity configuration (C-factor), dentinal tubule orientation to the cervical wall (CEJ), organic content of dentine substrate and movement of dentinal tubular fluids, incomplete alteration or removal of smear layer by acidic primers (self-etch system) for adequate demineralization and hybrid layer formation, inefficient infiltration/ penetration of primer components into the demineralized collagen fibrils, physical characteristics of the restorative material, (filler loading, volumetric expansion, and modulus of elasticity), inadequate margin adaptation of restorative material, polymerization source photo initiator incompatibilities, and finishing and polishing effects2.

It is generally believed that the conventional composite materials should be polymerized in increments not thicker than 2mm. During the polymerization of a thicker increment, the material can pass through the gel point at different times at different depths. When the superficial material layers are already in post gel phase, the deeper layers have not yet reached the gel point. The superficial part of the material becomes firm, and the deeper part is still liquid. Application of large increments of material triggers a shrinkage stress rise, and therefore the reduction of this phenomenon is a particular challenge70,71.

The recommended alternative to layered techniques, the bulk-fill techniques, has taken up this challenge. The single increment application and polymerization method (the bulk-fill technique) proposed by the manufacturers of these composites did not compromise marginal adaptation of restorations. Bulk-fill composite materials evaluated in the present study seem to meet satisfactorily the requirements of this type of materials in terms of marginal adaptation. Bulk-fill composites are more translucent than other restorations, which allow the light to get to much deeper layers. The content of photo initiators of polymerization and stress inhibitors determines the optimal marginal seal of these composites72.

The current study examined the microleakage of different composite resins placed in class V cavities using a dye penetration test. In the present study, non carious Class V restorations were chosen for evaluation, because that the preparation of Class V cavities is minimal and their restoration is relatively easy, thereby reducing technique-sensitivity and operator-related variability. Secondly, Class V cavities have margins located both partly in enamel and partly in dentin. Moreover, class V cavities have high configuration factor (C-Factor). C-Factor is the ratio of bonded to the unbounded surface area. Class V restorations has high C-Factor (5) which is the reason for the internal bond disruption as well as microfissures around the restoration and cavity walls1,73.

To evaluate microleakage, methylene blue dye was used in this study. The diameter of dye molecules is 0.80nm that is less than the diameter of dentinal tubules (1-4μm) (Bayne and Thompson, 1998)51.

Thermocycling was done in this study because it is a widely used method in dental research, particularly when testing the performance of adhesive material. It aims at thermally stressing the adhesive joint at the tooth / restoration interface by subjecting the restored teeth to extreme temperatures encountered intraorally. This process may highlight the mismatch in thermal expansion between the restoration and tooth structure, resulting in different volumetric changes during temperature changes and causing fatigue of the adhesive joint with subsequent microleakage74. In this study Adper single bond II was used as a bonding agent for all the groups which may have influenced the marginal gap formation.

In this present study, There was a statistically non significant difference seen for the frequencies between the groups (p>0.05). But Tetric Power Fill (group II) showed least amount of microleakage scores followed by X-tra fil (Group I) , SDR Plus (group III) and the maximum was seen in Tetric Power flow (groupIV). The possible reason that Tetric Power Fill showed lower microleakage was that Tetric Power Fill was optimized by including a (β-allyl sulfone) addition fragmentation chain transfer (AFCT) reagent. AFCT reagent pushes an uncontrolled radical chain growth polymerization reaction toward a step growth-like polymerization reaction4.

During standard polymerization, excited photo initiators create radicals which attack the double bonds of monomers resulting in methacrylate addition. It can lead to materials with an uncontrolled and inhomogeneous network architecture4.

In Tetric Power Fill, the radicals can potentially attack either a methacrylate double bond of a monomer resulting in methacrylate addition or the double bond of a β-allyl sulfone resulting in chain transfer. In the case of chain transfer, the growing radical chain is terminated by forming an intermediate radical that undergoes fragmentation and forms a sulfonyl radical and a new double bond. Essentially successive shorter chain formation is favoured over standard radical long-chain growth, leading to a delayed gel point and a more homogenous network4,10.

Gorsche et al. showed that the addition of an AFCT reagent to monomer formulations improved the double-bond conversion and resulted in a more homogenous polymer network76. AFCT reagents therefore allow for a certain amount of control over the radical polymerization process. It is suggested that resultant materials should have reduced shrinkage stress, increased conversion and greater toughness77. Hee Young Park et al. showed allyl sulfide addition-fragmentation chain transfer reduces the final stress in ternary thiol-ene-methacrylate polymerizations by as much as 75% at high allyl sulfide concentrations75.

Other possible reason that Tetric Power Fill showed lower shrinkage than the conventional resin composite. This could be explained due to its pre-polymerized filler particles (shrinkage stress reliever) functionalized with silane, that seems to have relatively low elastic modulus (~10 GPa), causing it to act like a microscopic spring, attenuating the forces of shrinkage stress11,78.

Due to its low elastic modulus (10 GPa), the shrinkage stress reliever within Tetric PowerFill acts like a spring (expanding slightly as the forces between the fillers grow during polymerization) amongst the standard glass fillers which have a higher elastic modulus of 71 GPa. As a result, these Isofillers are capable of accommodating the tensile stresses that occur during polymerization11,78.

When comparing group II (Tetric Power Fill) and group IV (Tetric Power Flow) the result was statistically non significant (p>0.05). But Tetric Power Fill showed less microleakage then Tetric Power Flow. Due to the higher monomer and lower filler content, the amount of shrinkage in the flowable composites exceeds that of the sculptable composite10.

When comparing group III (SDR Plus) and group IV (Tetric power Flow), SDR Plus (group III) showed less microleakage than group IV. The possible reason could be: larger size of the SDR resin compared to conventional resin systems (molecular weight of 849 g/mol for SDR resin compared to 513 g/mol for Bis-GMA). The SDR technology comprises the unique combination of such a large molecular structure with a chemical moiety called a “Polymerization Modulator” chemically embedded in the center of the polymerizable resin backbone of the SDR resin monomer. The high molecular weight and the conformational flexibility around the centered modulator impart optimized flexibility and network structure to SDR resin and it produce lower stress build up during polymerization9,79.

The microleakage scores of bulk fill SDR were in accordance with other similar studies conducted by Sahadev C K et al.80 and MirosBaw OrBowski et al72.

When comparing group I and group II (packable resin composite) with group III and group IV (flowable resin composite), the result showed statistically non significant difference (p>0.05). But packable resin composite (group I and group II) showed less microleakage than flowable resin composite (group III and group IV).

The possible reason could be: When the contents of the fillers increase, the contents of monomers decrease, resulting in a reduction of the total level of polymerization shrinkage and shrinkage stress and an increase in the flexural modulus of the material81.

Similar to our results, Jin-Young Kim et al. reported that high-viscosity conventional composites showed lower Volemetric Contraction than low-viscosity conventional composites8.

Similar to our results, Alagarsamy Venkatesh et al. reported that Filler volume fraction is inversely proportional to volumetric shrinkage. As the volume of filler content increases, the volume of resin matrix decreases and hence volumetric shrinkage reduces proportionately. The Monomer molecules which are held together by VanderWaals forces with the intermolecular distance of 0.3 nm - 0.4 nm are replaced by covalent bonds after their polymerization where the intermolecular distance is reduced to 0.15 nm. This reduction in the distance between the molecules leads to volumetric polymerization shrinkage82.

The present study also showed that microleakage at gingival margin in each of the groups was significantly more compared to the occlusal restoration. The possible reason could be: a) marginal seal at gingival margin restoration is less than occlusal which is due to better and stronger enamel band in occlusal because the enamel has an inorganic and hemogenous structure, b) the absence of dentinal fluid in its structure has betterment infiltration of monomer in micro tags after etching and resulted in better micromechanical bond. But dentin is a dynamic substrate that contains a significant proportion of the water and organic matter that damages bonding system by the current adhesive process40. This was in accordance with previous studies done by Anil kumar S et al74 and Kumar Gupta et al21.

De Munck et al83 and Manhart et al84 showed that the Microleakage in Class V restorations in the occlusal margin was significantly different with gingival margin and the microleakage at gingival margin was higher than the occlusal in all studies.

STUDY LIMITATIONS AND SCOPE FOR FURTHER STUDY

The present study was done under in vitro conditions and used natural extracted teeth for restoration, and thermocycling was used as part of test protocol.

In vitro studies are very important for an early assessment of the dental material. However, only a clinical study takes into account, all the potential variables that vary from patient to patient. Some of the variables include masticatory forces, types of food, oral temperature, and humidity variations and presence of salivary enzymes and bacterial by-products.

Many new restorative materials are evolving rapidly, each with better properties and promising results for better performance. Therefore, further studies are required to establish the factual clinical worth of these materials to validate their in vitro established results.

CONCLUSION

Within the limitations of the study,

1. None of four resin composite materials tested were free from microleakage.
2. All the four materials showed more microleakage at gingival wall compared to occlusal wall.
3. Tetric Power Fill showed the least microleakage at both occlusal and gingival walls.

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