

Influence of Composite Insertion Techniques (Bulk-fill and Incremental Nanofilled Composites) on Adaptability to the Pulpal Floor and Interfacial Gap Formation

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ABSTRACT

Introduction: Dental composites are the most commonly used as well as preferred among all the conventional restorative materials as far as esthetics is concerned. One of the major drawbacks of composite resin is their polymerisation shrinkage and stresses. Hence, the requirement of adequate knowledge of the material aspects and trained operator skills in composite insertion techniques are very much essential. The Aim of this study was to compare bulk fill composite (SDR) with an incremental nanofilled composite (3M ESPE Z350XT) for adaptability at pulpal floor and subsequent interfacial gap formation between increments.

Materials and methods: Twenty freshly extracted human maxillary premolars were selected for the study. Class 1 cavity was prepared to depth of 3 mm on each tooth. All samples were divided into 4 groups of 5 teeth each and restored with different restorative materials. Group I: SDR (Dentsply, DeTrey, Konstanz, Germany) –3mm, group II: Packable Nanohybrid composite Z350 XT (3M, Latin America) –3 consecutive increments of 1 mm each, group III: Nanohybrid flowable composite Z350 XT (1mm) + SDR (2mm bulk fill), group IV: Nanohybrid flowable composite Z350 XT (1mm) + Packable Nanohybrid composite Z350 XT 2mm (1 mm + 1 mm) incremental build up. Samples of each group were etched using 3M ESPE Scotch bond multi-purpose etchant for 20 seconds following which the specimens were washed with distilled water for 15–20 seconds and further blot dried for 20 seconds after which Adper Single Bond adhesive (3M ESPE, St.Paul, MN, USA) was applied. Restorations were done according to the respective groups and then light-cured (Bluephase C8 Ivoclar Vivadent, Amherst, New York) for 20 seconds. All Samples were subjected to a thermocycling regimen of 2500 thermal cycles by alternating immersion in water at $+5 \pm 8^\circ\text{C}$ and $+55 \pm 8^\circ\text{C}$ with a dwell time of 2 minutes and transfer time of 5 seconds in each bath and placed in Rhodamine B dye for 24 hours. After 24 hours samples were taken out and washed with distilled water, sectioned buccolingually with diamond disk. The samples were then subjected to Stereomicroscopic evaluation at 4 \times magnification for dye

penetration visualization and Scanning electron microscopic analysis for interfacial gap formation.

Statistical analysis: Statistical analysis was performed using Kruskal–Wallis Test and Mann–Whitney Test.

Results: Among all the groups tested, SDR demonstrated better adaptability to the pulpal floor and least interfacial gap formation compared to incremental nanofilled composite Z350 XT.

Conclusion: Bulk-fill composites performed better than incremental nanofilled composites, demonstrating better adaptability at the pulpal floor with least interfacial gap formation.

Keywords: Microleakage, Polymerisation shrinkage, Polymerisation stress, Smart dentin replacement.

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INTRODUCTION

Dental composite is a highly cross-linked polymeric material reinforced by a dispersion of amorphous silica, glass, crystalline or organic resin filler particles, and bonded to the matrix by a coupling agent.

The factors responsible for the increased longevity of a restoration depends on the restorative materials used, the operator skill and experience, age of the patient, the type and position of teeth in the dental arch, the restorative design, the size and number of restorations, and restored surfaces.

Traditionally, amalgam was the material of choice for classes I and II restorations.¹ The increased demand for esthetics among the people, especially in the posterior teeth, had led to the development of tooth colored restorations, such as composites which overtook amalgam.²

Composites gained popularity over amalgam because of the following reasons: Esthetics, advances in composites as posterior restorative materials, need for less invasive and less extensive cavity preparation, and toxic nature of mercury in amalgam. However, the biggest drawback of composites is polymerization shrinkage and stresses as it depends on certain factors, such as the configuration

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factor, composition of resin-based composites, incremental placement techniques, and curing modes. Therefore, countering the polymerization shrinkage stress is one of the most challenging aspect for a clinician.

As the modulus of elasticity of a composite resin increases, the polymerization shrinkage stress at the tooth restoration interface also increases, which in turn leads to the failure of bonding, microleakage, and interfacial gap formation.³ Therefore, there is a need to reduce the polymerization shrinkage and stress associated with the conventional material used. The resulting marginal discoloration produced by a composite restoration is often misdiagnosed as recurrent caries leading to unnecessary replacement of restoration and tooth tissue loss.

The polymerization shrinkage can be reduced by the use of flowable composites and by following the incremental layering techniques which includes oblique, horizontal, vertical, three site, successive cusp buildup, bulk-fill, and centripetal buildup technique. The main disadvantage of incremental layering techniques was the difficulty in placing multiple increments and the time needed for completing the restorative procedure.

The newer bulk-fill composites are materials recommended for a one-step insertion in a 4 mm bulk. To provide a true clinical advantage for the bulk-fill composites, it requires high depth of curing along with decrease in internal stress which leads to subsequent enhanced adaptation to the tooth substrate. The rationale of the bulk-fill composite resin material would be to reduce interfacial gap formation of incremental technique and clinical steps by filling the cavity in a "single" increment leading to a reduced porosity and a uniform consistency for the restoration, further reducing the clinical time taken and cost factor of the patient.⁴

Depending on the viscosity of resin material, four types of bulk-fill resins are available in the market which includes, smart dentin replacement (SDR) (Dentsply, DeTrey, Konstanz, Germany), EverX-flow (GC Europe), QuiXfil (Dentsply, UK), Venus Bulk-Fill (Heraeus Kulzer, USA), Tetric EvoCeram BulkFill (Ivoclar Vivadent, Amherst, NY), X-tra fil (Voco, USA), SonicFill (Kerr, SybronEndo, USA), and fiber-reinforced bulk-fill composite, EQUIA Forte (GC Europe).

The aim of this study was to compare bulk-fill composite SDR with an incremental nanofilled composite (3M ESPE Z350 XT) for adaptability at pulpal floor and subsequent interfacial gap formation between increments.

MATERIALS AND METHODS

Standard Methodology was selected from previous studies and slight modifications were made according to the needs of our study.⁵⁻²² Twenty freshly extracted human maxillary premolars extracted for orthodontic reasons were selected

for the study. Teeth with developmental defects, occlusal wear facets, and microcracks were categorized as exclusion criteria.

Class I cavity was prepared to the depth of 3 mm on each tooth with a round bur of diameter 0.5 mm. The depth of class I cavity prepared was 3 mm as per manufacturer's claim that bulk-fill composites can be filled up to 4 mm.

The samples were divided into four groups of five teeth each.

All the cavities prepared were then restored to a depth of 3 mm using different materials:

- *Group I:* SDR (Dentsply, DeTrey, Konstanz, Germany) – up to 3 mm bulk-fill.
- *Group II:* Packable nanohybrid composite Z350 XT (3M, Latin America) – 3 mm incremental buildup of 1 mm each increment.
- *Group III:* Nanohybrid flowable composite Z350 XT (1 mm) + SDR (2 mm bulk-fill).
- *Group IV:* Nanohybrid flowable composite Z350 XT (1 mm) + packable nanohybrid composite Z350 XT 2 mm (1 mm + 1 mm) incremental buildup.

The teeth were subjected to etching process using 3M ESPE Scotchbond multipurpose etchant for 20 seconds followed by rinsing with distilled water for 15 to 20 seconds and further blot dried for 20 seconds. The Adper Single Bond adhesive (3M ESPE, St Paul, MN, USA) bonding agent, was applied and light cured using Bluephase C8 (Ivoclar Vivadent, Amherst, NY) for 20 seconds. Each group was filled with the desired composite resin material and light cured for 20 seconds with LED light curing unit.

Specimens were then subjected to a thermocycling regimen of 2500 thermal cycles by alternating immersion in water at $+5 \pm 8^\circ\text{C}$ and $+55 \pm 8^\circ\text{C}$ with a dwell time of 2 minutes and transfer time of 5 seconds in each bath. All specimens were placed in Rhodamine B dye for 24 hours. After 24 hours, samples were taken out and washed with distilled water, sectioned buccolingually with diamond disk. All the samples were subjected to stereomicroscopic evaluation at $4\times$ magnification for visualization of dye penetration and scanning electron microscopic (SEM) analysis for evaluating the adaptability to the pulpal floor and interfacial gap formation (Table 1).

Table 1: Scoring criteria for dye penetration based on graded scoring system

Score	Dye penetration
0	No dye penetration
1	Dye penetration not more than half of the occlusal or gingival wall
2	Dye penetration more than half of the occlusal or gingival wall
3	Dye penetration along the axial wall

Table 2: Kruskal–Wallis test

Variable	Group	Mean + standard deviation	p-value
Mean microleakage score	SDR bulk-fill	0.4 + 0.547	0.0031
	Z350 XT incremental	2.8 + 0.836	
	Flowable Z350 XT + SDR	1.6 + 0.547	
	Flowable Z350 XT + Z350 XT incremental	3.2 + 0.836	

Statistical Analysis

Statistical analysis was performed using Kruskal-Wallis test and Mann-Whitney test as shown in Tables 2 and 3.

The mean microleakage score was least in (group I) SDR bulk-fill and was the highest in flowable Z350 XT + incremental Z350 XT group (group IV). On Kruskal-Wallis test, a statistically significant difference in mean microleakage scores were present among all the four groups tested ($p = 0.0031$).

There was no significant difference between Z350 XT incremental group (group II) and flowable Z350 XT + SDR group (group III) ($p = 0.06$).

There was no statistically significant difference between Z350 XT + SDR group (group III) and flowable Z350 XT + Z350 XT incremental group (group IV) ($p = 0.528$).

RESULTS

The scores obtained of each sample in the groups are as follows (Table 4):

The results of this study showed that bulk-fill composites demonstrated better results than incremental filled composites.

The SEM analysis for interfacial gap formation and pulpal floor adaptability (Figs 1 to 4) demonstrated highest interfacial gap formation between the incrementally placed Z350 XT group (group II) and when SDR was used as bulk-fill (group I), the interfacial gap formation was almost nil. Group III demonstrated minimal interfacial gap formation than group IV which demonstrated moderate interfacial gap formation.

The stereomicroscopic evaluation for dye penetration revealed that SDR (group I) when used as bulk-fill had the best adaptability to pulpal floor, and incrementally filled Z350 XT group (group II) demonstrated the least adaptability to pulpal floor and maximum interfacial gap formation between the increments (Fig. 5). Whereas when the pulpal floor was lined by flowable composite, it demonstrated better adaptability to the pulpal floor even though interfacial gap formation still persisted. There was slightly more amount of dye penetration noticed in flowable Z350 XT + Z350 XT incremental group (group IV) than flowable Z350 XT + SDR group (group III).

The SEM analysis for pulpal floor adaptability revealed group I (SDR bulk-fill) having the best adaptability when compared to group II (incremental Z350 XT) having the least. Groups III and IV revealed similar adaptability, slightly inferior to group I.

Scanning Electron Microscope Analysis

Scanning electron microscopic analysis demonstrating the group filled by bulk-fill SDR composite resin up to 3 mm in single step (Fig. 1)

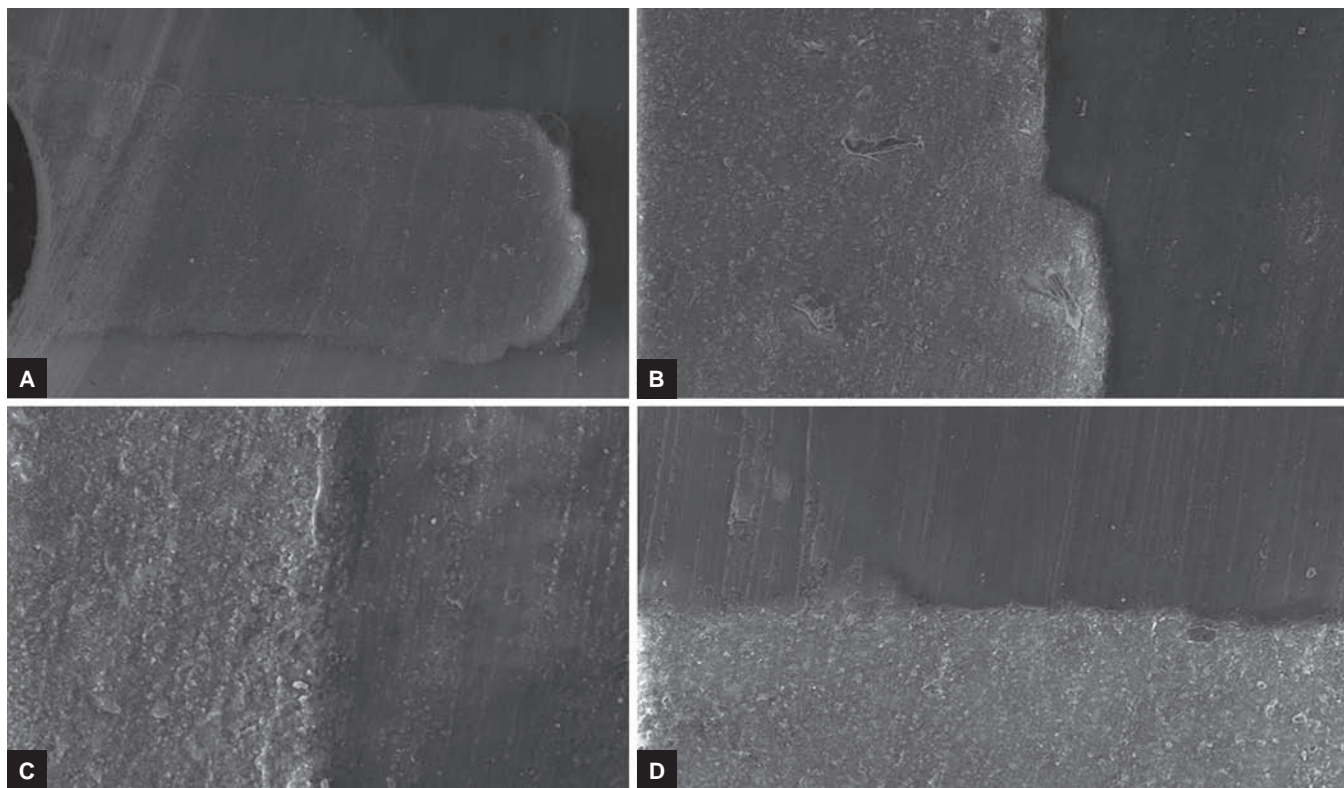
Scanning electron microscopic analysis demonstrating the group filled up to 3 mm with 1 mm each incremental technique with packable nanofilled Z350 XT composite resin (Fig. 2).

Table 3: Mann-Whitney test

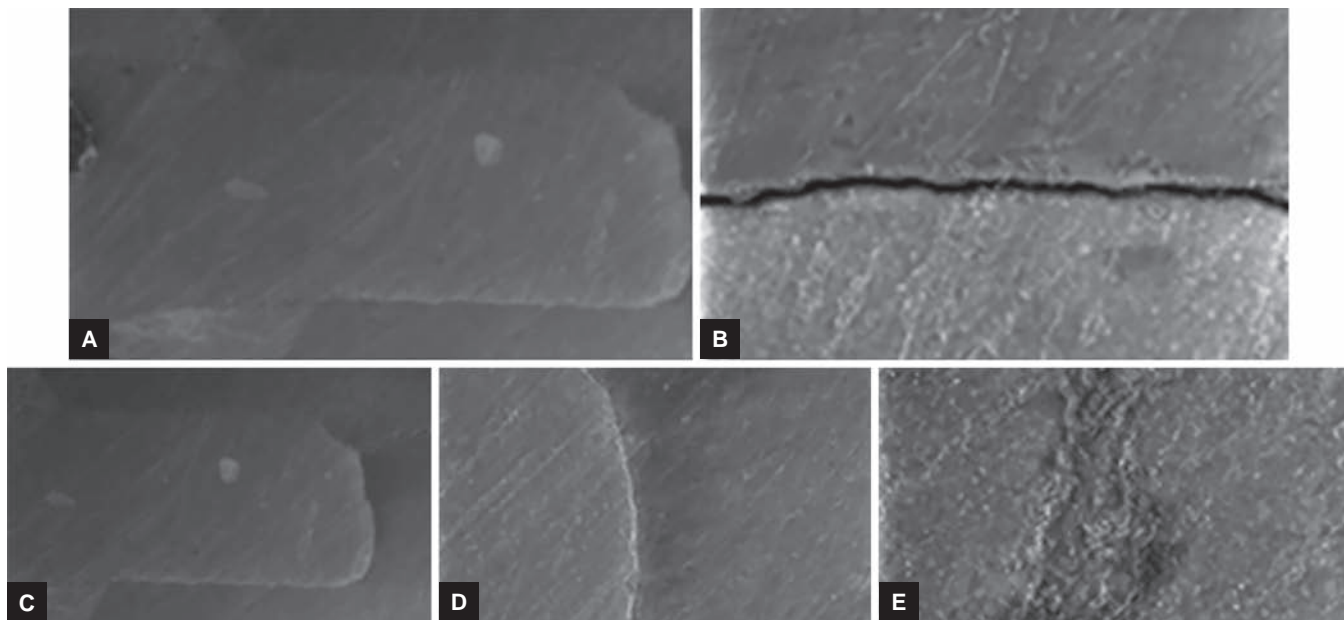
Variable	Group	Mean + standard deviation	Z	p-value
Mean microleakage score	SDR bulk-fill	0.4 + 0.547	-2.506	0.012
	Z350 XT incremental	2.8 + 0.836		
	SDR bulk-fill	0.4 + 0.547	-2.088	0.036
	Flowable Z350 XT + SDR	1.6 + 0.547		
	SDR bulk-fill	0.4 + 0.547	-2.5067	0.012
	Flowable Z350 XT + Z350 XT incremental	3.2 + 0.836		
	Z350 XT incremental	2.8 + 0.836	1.88	0.06
	Flowable Z350 XT + SDR	1.6 + 0.547		
	Z350 XT incremental	2.8 + 0.836	-0.628	0.528
	Flowable Z350 XT + Z350 XT incremental	3.2 + 0.836		
	Flowable Z350 XT + SDR	1.6 + 0.547	-2.193	0.028
	Flowable Z350 XT + Z350 XT incremental	3.2 + 0.836		

Table 4: The scores obtained of each sample

Group	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
I	1	0	1	0	0
II	2	3	4	3	2
III	1	2	1	2	2
IV	2	3	3	4	4



Figs 1A to D: Group I – SDR bulk-fill (up to 3 mm)



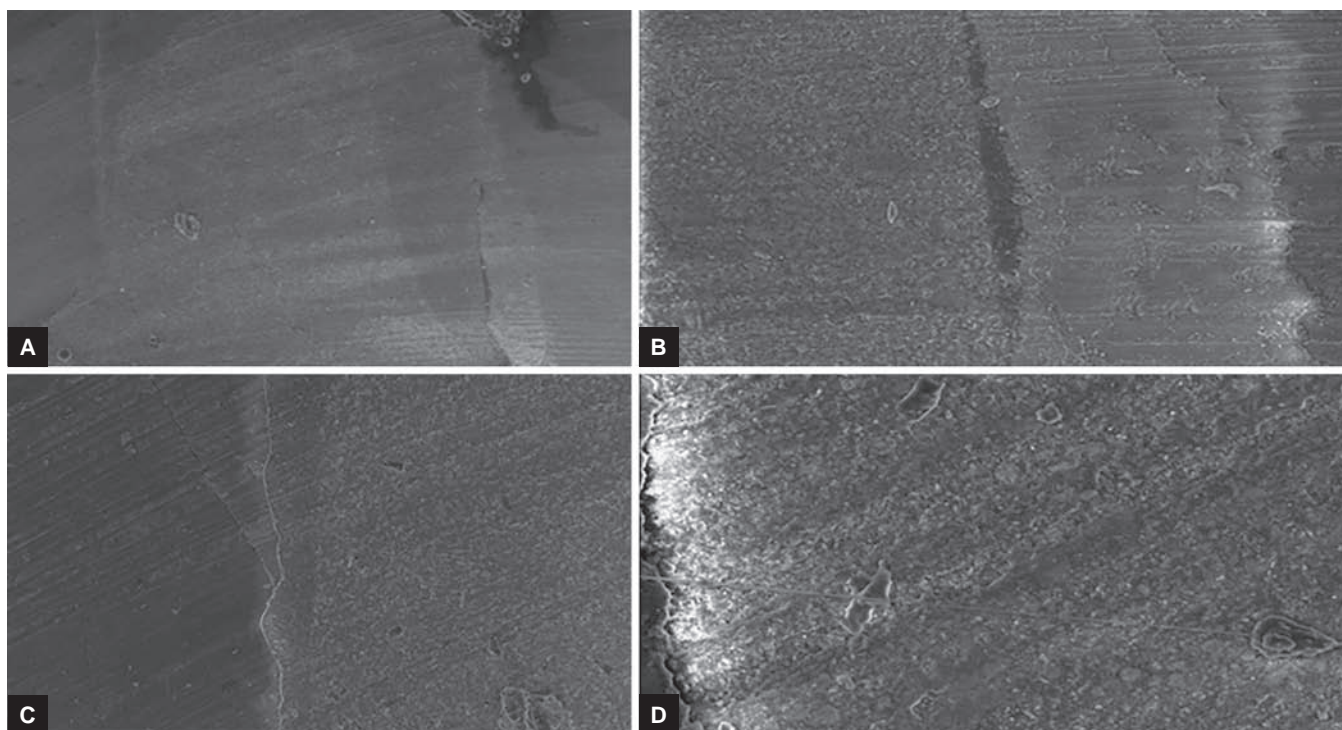
Figs 2A to E: Group II – Z350 XT incremental (1 mm + 1 mm + 1 mm)

SEM analysis demonstrating the group filled with a flowable nanofilled Z350 XT followed by incremental 2 mm SDR bulk-fill single step (Fig. 3).

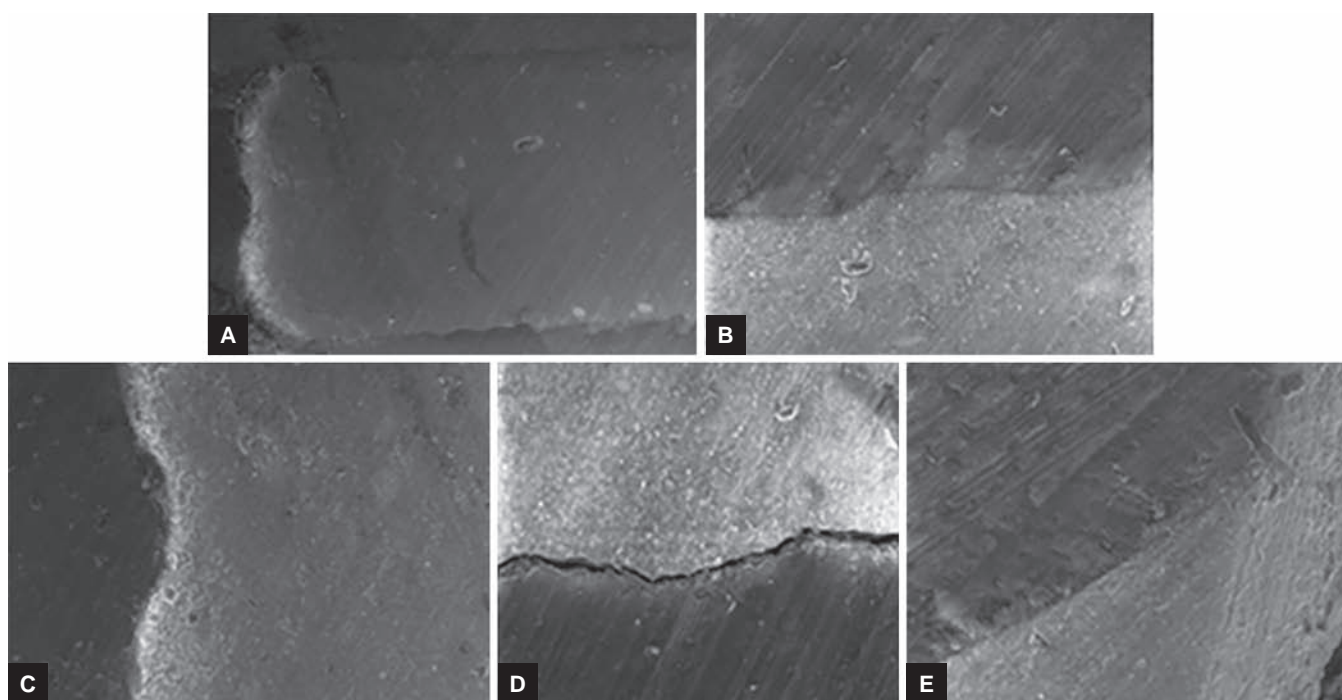
SEM analysis demonstrating the group filled with flowable nanofilled Z350 XT composite resin followed by 2 mm incremental packable composite resin (1 mm + 1 mm) (Fig. 4).

DISCUSSION

Composite material has seen revolutionary changes in its material composition and properties since it was introduced by Bowen in the year 1962. However, polymerization stress and shrinkage still persist. To overcome the after effects of stress and polymerization shrinkage, bulk-fill composites were introduced in the year 2009 as a novel modality.



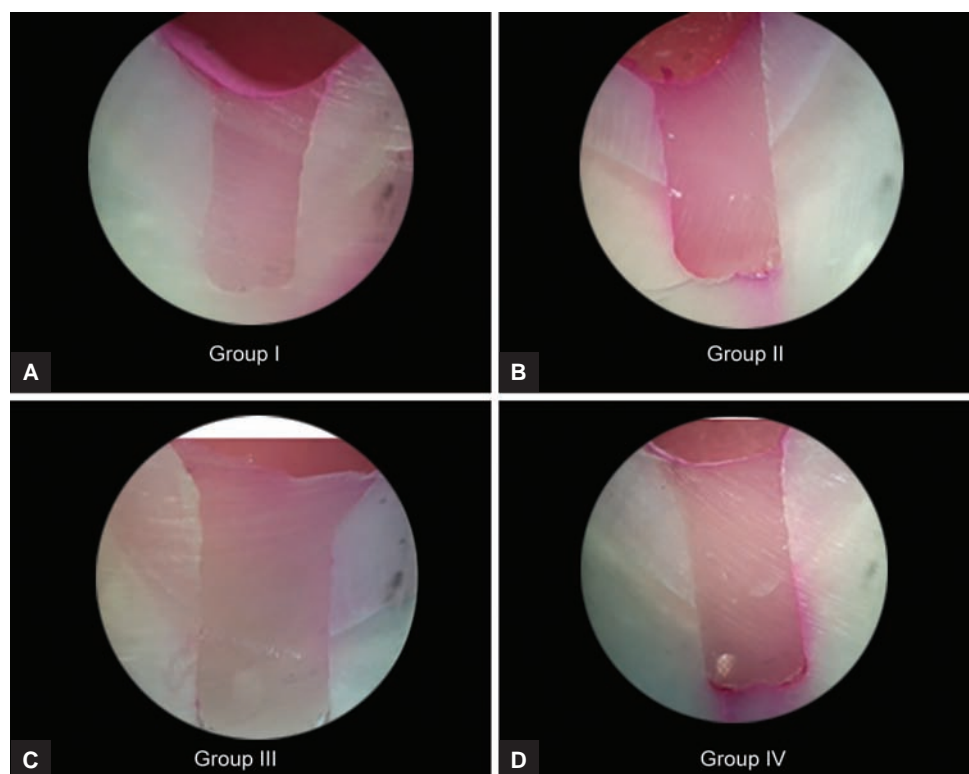
Figs 3A to D: Group III – Flowable composite Z350 XT (1 mm) + SDR bulk-fill 2 mm



Figs 4A to E: Group IV – Flowable composite Z350 XT (1 mm) + Z350 XT incremental (1 mm + 1 mm)

The main advantages of bulk-fill material were the lower filler loading, lower viscosity, and the high flowability. Also, the material has a self leveling property that helps to adapt well to cavity walls. The material can be easily placed up to 4 mm increments and light cured. According to Chaung et al, SDR shows 60 percent less polymerization shrinkage and 30 percent decreased operating procedure

time as it has a self leveling consistency for optimum adaptation to the cavity walls.²³ A study was conducted by Van Ende et al which stated that SDR had satisfactory bond strength regardless of the filling technique used.²⁴ The result of this study corroborates with the study conducted by Orłowski et al which showed that there was no dye penetration when restored with SDR.²⁵



Figs 5A to D: Stereomicroscopic evaluation demonstrating the dye penetration in different groups

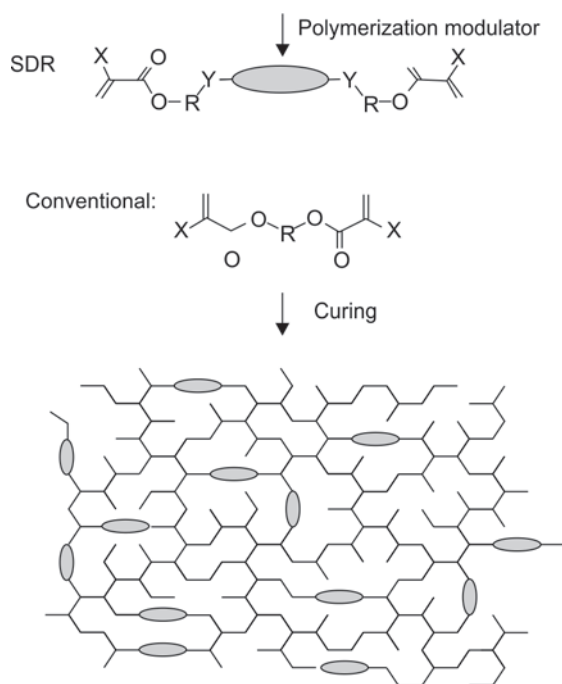


Fig. 6: Chemistry of SDR technology

A polymerization modulator was chemically embedded in the polymerizable resin backbone as stated by the manufacturer (Fig. 6).

Duarte and Dinelli et al found no significant marginal leakage improvement when restored with incremental placement and bulk placement techniques even in class V preparations.²⁶ Based on scientific evidence gathered to date, the polymerization modulator synergistically

interacts with the camphorquinone photoinitiator so as to result in slower modulus development, allowing for stress reduction without a reduction in the polymerization rate or conversion.²⁷ Essentially, the entire radical photopolymerization process is mediated by the polymerization modulator specially built into the SDR resin which allows more linear/branching chain propagation without much cross-linking and hence, slower modulus development.²⁸

This modulating effect allows extended polymerization without a sudden increase in cross-link density. The extended “curing phase” maximized the overall degree of conversion and also reduced the polymerization shrinkage stress.

As packable resin composites have a higher filler loading that lead to a concern for marginal integrity and adaptability when compared to flowable composites. The flowable composite when used as a liner acts as a stress absorbing layer between the hybrid resin composite and the tooth structure and has an ability to sufficiently wet as well as adapt to the cavity walls when used under a packable composite. The advantage of using flowable composite as a liner is attributed by its low modulus of elasticity, which absorbs stress when restorative resin shrinks. The reasons for interfacial gap formation are the difference in coefficient of thermal expansion and elastic modulus between the resin and the tooth structure which may result in stress.

In this study, due to low viscosity and lower filler loading, the bulk-fill composites were able to adopt properly to the margins and reduce the marginal micro-

leakage. Also, the inherent quality of low polymerization shrinkage of SDR bulk-fill had contributed toward better performance of material.

Limitations of the Study

The small sample size is one of the limitation of this study. The statistical analysis of the groups studied would have been affected by the small sample size.

CONCLUSION

Within the limitations of the study, it can be concluded that:

- Bulk-fill composites performed better than incremental composites, demonstrating better adaptability at the pulpal floor, and least interfacial gap formation.
- Interfacial gap formation was the least in SDR bulk-fill group (group I) followed by groups lined by flowable composites (groups III and IV). The highest interfacial gap formation was noticed in incremental Z350 XT group (group II).
- Pulpal floor adaptability: Group I demonstrated the best adaptability followed by groups III and IV having moderate adaptability. Group II demonstrated the least adaptability.

Further studies using larger sample size is recommended for assessing the long-term performance of the material used.

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