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Evaluation of Microleakage of Fibre Reinforced Composite Restorations by Different Placement Techniques-An Invitro study

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Abstract:
Background: *Composite resins are widely used in restorative dentistry due to their esthetics and adhesive properties, but they are prone to polymerization shrinkage and microleakage. Microleakage can lead to clinical complications such as secondary caries, hypersensitivity, and restoration failure. To overcome these limitations, short fiber reinforced composites (SFRCs) have been developed with improved mechanical properties. These materials help reduce crack propagation and shrinkage stress. However, the effect of different placement techniques on microleakage in SFRCs remains insufficiently explored.*
Aim: *To evaluate the microleakage of short fiber reinforced composite using different composite build up techniques.*
Materials and Methods: *Thirty extracted mandibular molars were selected and divided into three groups based on composite placement techniques: horizontal layering, oblique layering, and bulk-fill. Standardized Class I cavities were prepared, bonded, and restored using short fiber reinforced composite (everX Posterior). The samples were thermocycled, coated with nail varnish, and immersed in 2% methylene blue dye. Microleakage was evaluated by sectioning the teeth and examining dye penetration under a stereomicroscope using a standardized scoring system.*
Results: *A statistical analysis between all the composite placement technique showed significant agreement(p<0.001). These results showed that horizontal layering is a reliable method for composite placement.*
Conclusion: *Short fiber reinforced composite placed in incremental horizontal layering technique showed less microleakage compared to bulk fill technique. Further in vivo research is required to strengthen these findings.*
Key Word: *Short fiber reinforced composite;Microleakage;Polymerization shrinkage ;Composite placement techniques ;Horizontal layering ;Bulk-fill technique.*

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I. Introduction

Sound interface between composite and cavity margins is challenging in the practice of restorative dentistry. Although composites are widely used tooth colored restorative materials because of their adhesive biocompatible properties and preparing the cavity designs in a less invasive and less extensive way it has got some limitations. Some of the disadvantages include postoperative sensitivity, polymerization shrinkage, potential brittleness, difficulties in repair and disposal, limited long term durability and microleakage.[1]

Microleakage is a clinically undetectable movement of bacterial fluids, molecules and the ions in micro gaps (10 to 6 micro meters) between the cavity wall and restoration. Marginal leakage is caused by forces of contraction, masticatory forces ,polymerization shrinkage ,poor adhesion ,temperature variation ,inadequate moisture control which leads to recurrent caries , discoloration ,hypersensitivity and pulp pathology . All of these hastens the marginal breakdown of restoration, that would ultimately decrease the life of restoration.

Quest to improve the desirable properties of composites led to the invention of short fiber reinforced composites. Short fiber reinforced composites (SFRCs) can be categorized as composites where fibers are oriented in planes or randomly as reinforcing components in a resin matrix. Short fiber reinforced composite enhance the mechanical properties by, preventing crack initiation and propagation and gives better transfer of stresses to matrix. They are used in highly stress bearing areas due its flexibility strength and fracture toughness. Behavior of individual fiber as a crack stopper and stress transfer from fibers to matrix provides the reinforcement effect.[2]

Random fiber orientation reduced polymerization shrinkage and marginal microleakage compared to conventional dental composite. However degree of polymerisation shrinkage and microleakage depends on various factors like composite placement techniques, curing techniques, material properties etc.

Polymerization shrinkage can be significantly reduced by the restorative techniques used by the operator.[4] In Horizontal layering technique, 2.0 mm thickness of composite is horizontally placed against the prepared cavity surface and cured. But the primary disadvantage is that there is an increase of the C-factor, which in turn increases the shrinkage stress.

In Oblique Layering Technique wedge-shaped composite increments are placed against the prepared cavity surface and cured twice, throughout the cavity walls and the occlusal surfaces. The primary advantage in this technique is that there is less C-factor, which prevents the distorted cavity walls.

Bulkfill technique primary advantage is that the bulk material avoids the formation of incremental voids but greater polymerization shrinkage and the stress generated at cavosurface margin makes it a non-viable option.

The incremental placement techniques reduces shrinkage stress by polmerising only small volume of material at a time, reducing cavity configuration factor, and minimal contact of the restorative material with the opposing cavity wall during curing. However there is limited research available on the effect of short fiber reinforced composite placement techniques on the microleakage and there is a need for utilizing these composites on high stress bearing areas.[5,6]

Hence the purpose of this study is to evaluate the microleakage of short fiber reinforced composites by horizontal layering, oblique layering and bulk fill techniques. The null hypothesis is there is no significant difference in microleakage of short fiber reinforced composites by horizontal layering, oblique layering and bulkfill technique restorative techniques.

II. Material And Methods

This in-vitro comparative study was carried in the Department of Conservative Dentistry and Endodontics, at Anil Neerukonda Institute Of Dental Sciences, Visakhapatnam, Andhra Pradesh.

Study Design: Cross- sectional Invitro original research

Study Location: Department of Conservative Dentistry and Endodontics, at Anil Neerukonda Institute Of Dental Sciences, Visakhapatnam, Andhra Pradesh

Study Duration: July 2025 to October 2025

Sample size: 30 mandibular molar teeth.

Subjects & selection method: 30 mandibular extracted teeth.

Inclusion criteria:
1. Teeth free from caries
2. Teeth free from cracks
3. Mandibular molars

Exclusion criteria:
1. Presence of fractures
2. Endodontically treated teeth

Procedure methodology:

Thirty freshly extracted (n=10 for each group) mandibular molars were collected. Samples were kept in distilled water during the period between extraction and onset of experiment. Teeth were cleaned using ultrasonic scaler.No.245 carbide bur (SS White) and were used to prepare 30 standardized class 1 cavities on each tooth with a high-speed handpiece (NSK). The final preparation dimensions include depth of the cavity penetration is 0.5 mm into the dentin. Etchant (37% phosphoric acid-prime dental etching gel) was applied to the cavity and washed off with water followed by air drying. Bonding agent (3M ESPE, Adper, single bond adhesive) was applied and light curing (woodpecker) was done for 20 seconds.

Teeth were randomly distributed into 3 groups of 10 each based on composite placement techniques. Group 1: horizontal layering, Group 2: oblique layering, Group 3: bulk fill technique. All the samples were restored with short fiber reinforced composite EVER X posterior (GC).

Restorations were finished using diamond burs and soft flex discs(Shofu) followed by storing the samples in chloramine beta hemihydrate solution(disinfectant) for a day followed by thermocycling procedure was done in water baths for 500 cycles for 15 seconds. Apart from 2 mm around the restoration samples were issued with 2 layers of nail paint. Samples were soaked in 2%methylene blue for 24 hours and sectioning was done using diamond disk. Sectioned samples were analyzed under a steriomicroscope(ZEISS) at 12 x magnification to score for the degree of dye penetration.

Samples were evaluated for degree of dye penetration by scoring criteria given by santhosh. et al which includes:
score 0 (no penetration)
score1(penetration to 1/3the depth of cavity)
score 2 (penetration greater than 1/ 3 but not 2/3 the depth of cavity)
score 3(penetration greater than 2/3the depth of cavity)
score 4 (penetration to the floor of the cavity and involvement of dentinal tubules).

FIG 1: Armamentarium of the study

FIG 2: Cavity Preparation

FIG 3: Acid etching

Fig 4: Bonding agent application

Fig 5: Curing of bonding agent

Statistical analysis

Data were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS version 21.0, IBM Corporation, New York, USA).

For all the statistical tests, $P < 0.05$ was considered to be statistically significant.

III. Results

Table 1:

14ANOVA VAR00002							
Sum of Squares				df	Mean Square	F	Sig.
Between Groups	(Combined)		11.267	2	5.633	8.403	.001
	Linear Term	Contrast	11.250	1	11.250	16.782	.000
		Deviation	.017	1	.017	.025	.876
Within Groups			18.100	27	.670		
Total			29.367	29			

Table 2:

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	1.8000	.91894	.29059	1.1426	2.4574	.00	3.00
2.00	10	2.6000	.84327	.26667	1.9968	3.2032	1.00	4.00
3.00	10	3.3000	.67495	.21344	2.8172	3.7828	2.00	4.00
Total	30	2.5667	1.00630	.18372	2.1909	2.9424	.00	4.00

Table 3:

Dependent Variable: VAR00002 LSD

(I) VAR00001	(J) VAR00001	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.80000*	.36616	.038	-1.5513	-.0487
	3.00	-1.50000*	.36616	.000	-2.2513	-.7487
2.00	1.00	.80000*	.36616	.038	.0487	1.5513
	3.00	-.70000	.36616	.067	-1.4513	.0513
3.00	1.00	1.50000*	.36616	.000	.7487	2.2513
	2.00	.70000	.36616	.067	-.0513	1.4513

Table 4:

*. The mean difference is significant at the 0.05 level.

Groups		P value
Group 1	Group 2	0.38
Group 2	Group 3	0.67
Group 3	Group 1	0.00

This study evaluated microleakage on each of the tooth-restoration surface walls for thirty Class I restored teeth using a microscope with 12x magnification. The penetration depth of the 2% methylene blue was measured and scored based on a scale proposed by Santosh et al., score 0 (no penetration); score 1 (penetration to 1/3 the depth of the cavity); score 2 (penetration >1/3 but 2/3 the depth of the cavity); and score 4 (penetration to the cavity floor and involvement of dentine tubules). The data collected was entered in a excel sheet and IBM SPSS version 24, and were used for analysis. Descriptive statistics was used for frequency distribution of study variables. One way ANOVA TEST was used for evaluation for Inter group comparison. Mean value for microleakage obtained for Group 1 horizontal layering technique for ten samples was 1.80+0.91 which was lowest among the groups followed by group 2 oblique layering technique which was 2.6+0.8. Mean value scores obtained for bulk fill technique was 3.3+0.67 which showed highest microleakage among the groups. The p value obtained was 0.001 which was stastically significant. Post hoc multiple comparsion test revealed stastically significant difference between group 1horizontal layering technique and group 3 bulkfill technique .(p value<0.05). The difference was not significant even between group 2 oblique layering and group 3 bulkfill technique. The results concluded that horizontal incremental placement of short fiber reinforced showed less microleakage followed by oblique layering technique and highest microleakage scores was seen with bulkfill technique.

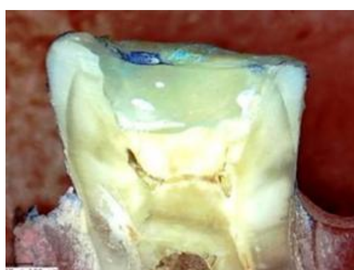

FIG 6

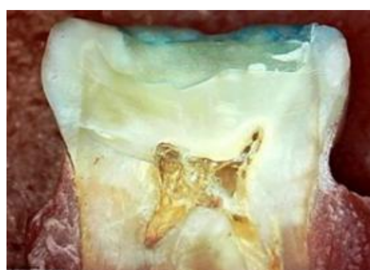

FIG 7

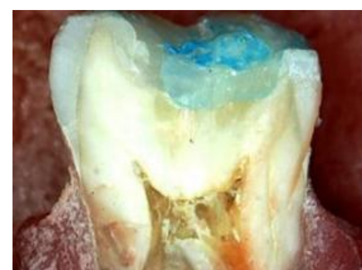

FIG 8

Steriomicroscopic views : Fig 6: Horizontal layering technique; Fig 7: Oblique layering technique; and Fig 8: Bulk fill technique

IV.DISCUSSION

Multiple critical factors are involved to perform a successful composite restoration. One of these is the contact tightness between the composite resin surface and the tooth surface. The volume of the composite resin will shrink when monomers polymerize as a result, stress is produced in the resin composite's surface adhesion to the tooth surface. In the region where polymerization contraction stress is highest, the resin composite adhesion to the tooth surface can create a gap that causes adhesion failure and microleakage .[13]

Some factors that influence the polymerization contraction stress of composite resins are the cavity configuration factor, the material factor, the thermal expansion coefficient, the modulus of elasticity, hygroscopic expansion, and polymerization contraction.[14]

Two main causes for the failure of large restorations in molar tooth are bulk fracture and secondary caries. A review of clinical cases of composite restorations in posterior teeth were due to restoration issues, such as material choice or placement technique. A number of studies have proposed methods to make large posterior restorations last longer and to support the structure of the teeth that remains.

One of these attempts employed short fiber-reinforced resin based composite (SFRC) for substitute of dentin. SFRCs include short or nano fibers and inorganic filler particles as reinforcing components in a resin matrix. The short fibers enhance the mechanical properties by functioning principally as crack blocker, preventing crack initiation and propagation.

In clinical dentistry, several fibers are used for reinforcement like carbon fiber, E glass fibers,hydroxyapatite..etc. Ever-X Posterior (GC, Tokyo, Japan) is a short fiber reinforced composite with a fiber length of 1,300–2,000 µm fiber diameter of 17 µm, aspect ratio 76–118 , E-Glass fiber filler type and 74.2% filler volume.[15]

Short fiber-reinforced composite (FRC) (everX Posterior) has properties are similar to those of composite base or dentine-replacing materials. The resin matrix contains crosslinked bis-GMA, TEGDMA and linear PMMA forming a polymer matrix called semiinterpenetrating polymer network (semi-IPN),which provides good bonding and increases the toughness.[15]

Random fiber orientation matrix by the semi-IPN matrix had a significant role in mechanical properties. According to Krenchel, short random orientated in 3D fiber provides strengthening factor of 0.2, whereas in 2D orientation gives 0.38, and unidirectional fibers gives factor of 1.[16]

The short fiber composite resin has also proved to control the polymerization shrinkage stress by fiber orientation and, thus, marginal microleakage was reduced compared with conventional PFC resins.[17] Reinforcing effect of the fiber fillers is based not only on stress transfer from polymer matrix to fibers, but also behavior of individual fiber as a crack stopper. In the posterior region, forces range from 8 to 880N during normal mastication, but greater loads have been described in bruxism, and teeth in this region may be exposed to extremely high forces when accidentally biting on a hard object or in trauma. Such extreme forces might lead to cracking and/or fracture of the enamel, but crack propagation continues toward the dentine where it is completely absorbed.[18]

Hence posterior teeth where more forces are concentrated are used in the study. SFRC had been extensively studied for its superior mechanical properties, which include a higher fracture resistance, fatigue limits and flexural strength.[19]

Ever X Posterior was choosen because Tsujimoto et al. in his study concluded EverX Posterior exhibited the lowest volumetric shrinkage compared to other bulk fill composites. [20]

From this study, microleakage in the groups 1,2 and 3 was found to be significantly different statistically (Table 2). This was possibly caused by the Class I cavity form that has the highest C-factors. The application technique did not reduce the C-factor. It caused contraction stress to be formed that affects the larger volume of the composite resin and the polymerization effect is reduced in deep cavities. However, when composite resin elasticity returned to normal, polymerization stress contraction still occurred. The polymerization stress contraction, which occurs at that time, is greater than the resin bond and can cause microleakage. From the data gathered in this study, incremental technique by horizontal layering and oblique layering technique showed less microleakage than bulkfill technique. Until now, no literature has directly explained the effects of placement techniques for short fiber reinforced composite resin. It was assumed that the use of incremental placement of composite for restoration application techniques decreased the shear force on the material particles that decreased the material viscoelasticity, to enable better flow.

Incremental application techniques are generally used for composite resin applications to reduce the polymerization contraction in conditions with high C-factors. The procedure is carried out by applying 2 mm of composite resin into the cavity. Deliperi stated that with this technique, the stress contraction in one incremental layer can be compensated for by the next layer, so that polymerization contraction occurs in the last layer.

A possible cause of the discrepancies between the two studies is the lighting direction: from the facial or the lingual. It can be concluded that C-factors have an important role in composite resin application techniques. In cavities with higher C factors, it is difficult to overcome microleakage even though the application technique being used is incremental.

In this study, microleakage compared between Bulkfill and oblique layering, and incremental horizontal and oblique techniques are not significantly different (see Table 2). Stereomicroscope is a simple and effective method that enables to view of objects by enhanced visibility from the illumination option.36 All groups show microleakage. Mean value for microleakage obtained for Group 1 horizontal layering technique for ten samples was 1.80+0.91 which was lowest among the groups followed by group 2 oblique layering technique which was 2.6+0.8. Mean value scores obtained for bulk fill technique was 3.3+0.67 which showed highest microleakage scores among the groups. The p value obtained was 0.001 which was stastically significant. Post hoc multiple comparsion test has shown stastically significant difference between group 1 horizontal layering technique and group 3 bulkfill technique.(p value<0.05).

The results concluded that horizontal incremental placement of short fiber reinforced showed less microleakage followed by oblique layering technique and highest microleakage scores was seen with bulkfill technique.

In this study, from the percentages, the horizontal layering technique group showed lower microleakage than the Oblique layering and Bulkfill groups .As well as this, the level of polymerization effectiveness in the floor of cavity in bulk-fill technique is reduced.

Loguercio et al. reported that the incremental technique is proven to elevate bond strength because the incremental technique gives maximal and uniform polymerization in every incremental layer .

An in vivo study by Lopes et al. compared gap formation in oblique incremental techniques to bulk-fill in class II restoration. They showed that oblique incremental techniques give better result.

A recent study reported a high level of water sorption and volumetric changes in everX Posterior when compared to a broad range of materials. When short fibers are exposed during the finalizing process of the restoration, through cracks in the composite, the transport of saliva and water along the interface is much higher than diffusion through the resin matrix because of the capillary effect of the fiber.

It is suggested that further studies, to evaluate the effect of various composite resin application techniques on microleakage in class I restorations, should use three dimensional observations. Further research in vivo is needed for determining the longeivity of restorations done utising short fiber reinforced composites. Research should also extend on restoring other classes of restorations including complex cavities in vivo to determine marginal leakage and longeivity of restoration.

V.CONCLUSION

The following conclusions can be drawn from the current study:
Overall in the present study, there is a definitive correlation between composite placement technique and microleakage of short fiber reinforced composite.
1. Regarding the Mean percentage of microleakage evaluation by dye penetration method for short fiber reinforced composite horizontal layering technique has less microleakage followed by oblique layering technique followed by bulkfill technique respectively.
2. Between horizontal layering and bulkfill technique there is stastically significant difference.
3. Horizontal layering and oblique incremental build up did not show any significant difference in microleakage.
4. Statistically no significant difference was seen between oblique layering and bulkfill technique.
To Conclude short fiber reinforced composite placed in incremental horizontal layering technique showed less microleakage compared to bulk fill technique. Further in vivo research is required to strengthen these findings.

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