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Comparative evaluation of microleakage in conventional composite and fiber reinforced composite on class II restorations in primary molars - an in-vitro study

Dr. Lisa John [1], Dr Anandaraj S[2], Dr Sageena George [3], Dr Deepak Jose [4]

[1:] *Final year Post Graduate Student, Pediatric and Preventive dentistry,P.M.S college of Dental Science and Research, Thiruvananthapuram, Kerala*

[2:] *Professor, Pediatric and preventive dentistry, P.M.S college of Dental Science and Research, Thiruvananthapuram, Kerala*

[3:] *Head of the Department and Professor, Pediatric and preventive dentistry, P.M.S college of Dental Science and Research, Thiruvananthapuram, Kerala*

[4:] *Professor, Pediatric and preventive dentistry, P.M.S college of Dental Science and Research, Thiruvananthapuram, Kerala*

Corresponding Author: Dr. Lisa John

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ABSTRACT: **Microleakage remains a major concern affecting the longevity of composite restorations, particularly in primary teeth. This study aimed to comparatively evaluate microleakage in conventional composite and fiber-reinforced composite Class II restorations in primary molars. Fifty-two extracted primary molars were randomly divided into two groups (n=26) and restored with conventional bulk-fill composite or polyethylene fiber-reinforced composite using Ribbond. Following 100 thermocycles between 5°C and 55°C, microleakage was evaluated using 1 M silver nitrate dye penetration and stereomicroscopic examination, with selected specimens further assessed using scanning electron microscopy. The mean microleakage score was significantly lower in the fiber-reinforced group (0.88 ± 0.82) compared with the conventional composite group (2.00 ± 0.98; p=0.00015). SEM demonstrated fiber bridging and crack deflection. Ribbondfiber reinforcement significantly reduced microleakage and improved marginal integrity in Class II restorations of primary molars.**

KEYWORDS:Microleakage; Fiber-reinforced composite; Ribbond; Polyethylene fiber; Composite resin; Marginal adaptation; Polymerization shrinkage; composite restoration; esthetic restoration.

I. INTRODUCTION

Dental caries, despite being largely preventable, remains one of the most prevalent chronic diseases of childhood. The goal of restorative dentistry is to eliminate carious tissue and restore the tooth with a suitable material. Composite resins, introduced in 1962 by Bowen, are widely used to meet esthetic demands for managing caries, fractures, erosion, or developmental defects[1,2]. However, contemporary composites exhibit 2–6% polymerization shrinkage and stresses of nearly 15 MPa[3], caused by the transition of loosely bound monomers into tightly packed covalent bonds during curing[4] . Their coefficient of thermal expansion also exceeds that of enamel[5] .

To reduce polymerization shrinkage, several strategies and materials have been proposed, including incremental layering, modifying curing-light protocols, using resin liners, increasing filler content, biomimetic restorations, nanofilled composites, compomers, and silorane-based resins[6–11,40] . A well-adapted tooth–restoration interface is essential for marginal seal and longevity[12], but this may be compromised by microleakage, defined as the passage of bacteria or fluids through gaps at the restoration interface, undetectable clinically[13]. Microleakage results primarily from polymerization shrinkage and thermal stresses[14] and can contribute to hypersensitivity, recurrent caries, and pulpal injury[16] . In primary teeth, composite restorations show microleakage rates of about 40% at occlusal margins and 70% at cervical margins, attributed to limited cervical enamel and reduced bonding capability[15,17] .

To enhance restoration durability, fibers were introduced to resist crack propagation under masticatory forces[18] . Ribbondfibers, developed in 1992, consist of ultra-high-molecular-weight polyethylene with an interwoven, damage-tolerant structure[19–25,33]. Their noteworthy properties include excellent adaptation to tooth structure due to high tensile strength (~3 GPa), no need for

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additional preparation, high modulus of elasticity (117 GPa), resistance to deformation, low flexural modulus, reduced cavity-wall stress, and crack-shielding behavior[26,27]. Plasma treatment enhances their wettability and adhesion to composites[28], enabling fibers to act as crack stoppers that redirect stress and create strain harmony between tooth and restoration[27].

Studies in permanent teeth show that adding Ribbondfibers improves marginal seal and fracture resistance in Class I and II composite restorations. However, no such studies exist for primary teeth, which prompted us to undertake this study. [12,31]. The voids provided the rationale for evaluating the effect of Ribbondfibers on microleakage in Class II composite restorations in primary molars. This paper aim to compare the microleakage in conventional composite and fiber reinforced composite when used in a primary molar

II. METHODOLOGY

The study included 52 primary molars, free of cracks, caries or structural defects, that were exfoliated or extracted due to its physiological shedding time or for orthodontic purpose like serial extractions. The samples were stored in saline until a week prior to the commencement of study. The teeth were then immersed in 0.5% chloramine-T solution, at 4^{o}C for 1 week for disinfection. The teeth were cleaned and roots were sealed with wax.

On each tooth a class II cavity was prepared using a No 330 Carbide Bur on one proximal surface with copious water cooling. The cavity dimensions were as follows: buccolingual width - 2 mm, occlusal depth - 1.5 mm, proximal box mesiodistal width -1mm, axial wall height - 1mm.The dimensions were verified with the help of UNC Periodontal Probe. The cervical margin in the proximal box rested on the enamel.

After preparation of 5 teeth a new bur was used in order to have a uniform preparation. After etching with Etchant Gel (Prime Dental Restorite), in all the samples, a proximal wall was built up by conventional composite, (3M ESPE FILTEK Bulk Fill) after externally supporting it by matrix band thereby converting it into a class I cavity. The prepared teeth were randomly divided into two groups, group A and group B.

For group A samples, the cavity width was measured with a calibrated UNC Periodontal Probe and the needed length of ribbond was cut with the ribbond cutting scissors, measured with the metric scale, placed in a glass slab and was wet with the resin (Ribbond Wetting Resin,Ribbond,Inc). The excess resin was blot off by gently pressing resin with gloved fingers. Bonding agent was then applied on to the cavity, followed by a thin layer (0.5 mm) of viscous tacky flowable composite onto the cavity (Ribbond securing composite, Ribbond, Inc). The wet Ribbond piece was then placed onto the cavity with the help of tweezer and with the help of a small ball burnisher the Ribbond is adapted all the way through the composite in a way that the Ribbond is at least 1 mm below the cavosurface margin. Thoroughly cured the margins after the placement of finely adapted Ribbond for 20 seconds. Conventional composite was then added and cured for 40 seconds. The restoration was finished and polished with the polishing burs and discs.

For group B samples, Conventional composite was added and mass cured for 40 seconds. The restoration was finished and polished with the burs and discs. Two coats of nail varnish were applied on the samples surfaces except 1 mm around the restoration margins.

The samples underwent 100 thermal cycles between 5^{o}C and 55^{o}C with a dwell time of 30 seconds. 27. The samples were then immersed in water at 37^{o}C for 24 hours followed by 1 Molar Silver Nitrate solution for 6 hours in the dark. The samples are then rinsed in running water and immersed in developing solution 12 hours being exposed to fluorescent light.[6]

The samples were mesiodistally sectioned from the centre of the restoration with a diamond saw at a low speed with abundant coolant application. All the samples were observed under stereomicroscope with a magnification of 10x. The dye penetration score were recorded.

From both the groups the most relevant 5 sample sections were evaluated for SEM observations each. SEM Photomicrographs were obtained at 20x magnification to observe the microstructure of composite- tooth interface, ribbond-composite interface and ribbond-composite-tooth interface.It provided both observational and confirmational evidence for the study.

III. RESULTS

The collected data were compiled and analyzed using **IBM SPSS Statistics version 26.0**. The individual microleakage scores were recorded by stereomicroscopic analysis. The Shapiro–Wilk test showed that the data were not normally distributed in either group (Control: W = 0.842, p = 0.001;

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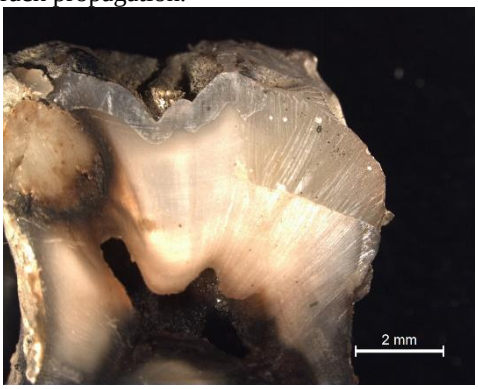
Test: W = 0.831, p = 0.001); hence, non-parametric tests were used. Descriptive analysis showed that the control group (n = 26) had a mean microleakage score of 2.00 ± 0.98, while the test group (n = 26) had a lower mean score of 0.88 ± 0.82, with scores ranging from 0–3 in both groups.

The Mann–Whitney U test demonstrated a significant difference in microleakage between the two groups. The control group showed a higher mean rank (35.19) compared with the test group (17.81), with a U value of 538.0 and p = 0.00015. Since p < 0.05, the difference was statistically significant, indicating that the test group exhibited significantly lower microleakage than the control group.

The frequency distribution of microleakage scores also demonstrated a clear difference between the groups. In the control group, 7.7% showed no dye penetration, 23.1% showed penetration to the outer one-third, 30.8% to two-thirds, and 38.5% through the entire cavity wall. In comparison, the test group showed 34.6% with no dye penetration, 50.0% limited to the outer one-third, 11.5% extending to two-thirds, and only 3.8% extending through the entire cavity wall. The Chi-square test showed a statistically significant difference in the distribution of microleakage (χ^2 = 14.92, p = 0.0019).

SEM evaluation of four specimens (two from each group) revealed distinct differences in fracture morphology. Ribbond-reinforced specimens demonstrated irregular fracture surfaces with fiber bridging, crack deflection, branching, partial fiber pull-out, and localized crack propagation, suggesting greater energy dissipation and resistance to crack progression. In contrast, non-reinforced specimens showed smooth and relatively uniform fracture surfaces with wide, continuous and linear cracks, characteristic of brittle fracture. Overall, SEM findings supported the ability of Ribbondfiber reinforcement to modify fracture behavior and restrict crack propagation.



IV. DISCUSSION

The present study demonstrated that fiber-reinforced composite restorations showed significantly lower microleakage than conventional composite restorations in Class II cavities of primary molars. The mean microleakage score was 2.00 ± 0.98 in the control group compared with 0.88 ± 0.82 in the test group. The Mann–Whitney U test confirmed a statistically significant difference between the groups (U = 538.0, p = 0.00015). This finding suggests that incorporation of polyethylene fibers within the composite restoration contributed to improved marginal sealing. The lower microleakage observed in the fiber-reinforced group may be attributed to the ability of the fibers to distribute stresses within the restoration and reduce stress concentration at the tooth–restoration interface. These findings are consistent with Belli et al. (2006) and Garoushi et al. (2013), who reported improved stress distribution and marginal adaptation following fiber reinforcement.

The categorical distribution of dye penetration further supported these findings. The fiber-reinforced group demonstrated a greater proportion of specimens with no dye penetration (34.6%**)** and penetration restricted to the outer one-third of the cavity wall (50.0%), whereas the conventional composite group showed higher proportions of penetration extending to two-thirds (30.8%) and the entire cavity wall (38.5%). The difference was statistically significant (χ^2 = 14.92, p = 0.0019). The marked reduction in severe dye penetration in the test group indicates better marginal integrity. This may be related to the reinforcing effect of the polyethylene fibers, which can act as a stress-absorbing component and help maintain the integrity of the bonded interface during polymerization and subsequent thermal stresses.

The findings are in agreement with previous investigations demonstrating that fiber inserts can reduce polymerization stress and marginal gap formation. Belli et al. reported improved marginal adaptation with fiber reinforcement, while Garoushi et al. demonstrated enhanced structural performance of fiber-reinforced composites. The present findings also support the concept proposed by Van Ende et al., that stress-absorbing intermediate layers can reduce the effects of polymerization contraction. However, the literature is not entirely consistent.

Sadeghi reported no significant difference in microleakage between fiber-reinforced and conventional composites. Such discrepancies may be related to differences in cavity configuration, fiber position, restorative materials, bonding protocols, and experimental methodology. Therefore, the favorableoutcome observed in the present study may depend not only on the presence of fibers but also on their appropriate placement and impregnation within the composite.

The SEM findings provided additional evidence for the reinforcing effect of Ribbond**.** Fiber-reinforced specimens demonstrated irregular and complex fracture surfaces with crack deflection, branching, fiber bridging, and partial fiber pull-out. The cracks were relatively narrow and discontinuous, indicating restricted crack propagation and greater energy dissipation. In contrast, conventional composite specimens showed smoother fracture surfaces with wider, continuous and relatively linear cracks, characteristic of predominantly brittle failure. The observed fiber bridging and crack deflection suggest that the polyethylene fibers acted as barriers to crack propagation and facilitated stress redistribution within the composite matrix. These observations are consistent with the mechanisms described by Belli et al. and Garoushi et al. for fiber-reinforced composite systems.

Evaluation of the composite–tooth and fiber–composite interfaces further helped explain the improved performance of the test group. Effective impregnation of Ribbond with the wetting resin is essential for establishing intimate integration between the fibers and surrounding composite matrix. Proper resin impregnation allows efficient transfer of stresses from the composite to the fibers and enhances the reinforcing effect. The combined findings from stereomicroscopic and SEM evaluation therefore suggest that Ribbond reinforcement may improve both marginal integrity and resistance to fracture propagation. The reduction in microleakage observed in the present study may consequently represent the combined effect of improved stress distribution, reduced crack propagation, and greater structural continuity within the restoration.

From a clinical perspective, these findings indicate that fiber-reinforced composite may be a useful conservative alternative for selected Class II restorations inprimary molars when sufficient tooth structure remains and adequate moisture control can be achieved. Unlike full-coverage restorations, placement of a fiber-reinforced composite does not require extensive additional tooth reduction and provides an esthetic restorative option. However, this approach should not be considered a replacement for full-coverage restorations in extensively damaged primary molars, where stainless steel or other preformed crowns may remain more appropriate. The potential advantage of fiber reinforcement is particularly relevant where preservation of sound tooth structure and esthetics are important considerations.

The present study has certain limitations that should be considered when interpreting the findings. As anin-vitro investigation, it could not completely reproduce the complex oral environment, including continuous occlusal loading, saliva, bacterial activity, and prolonged thermal and mechanical aging. SEM evaluation was also limited to four specimens and therefore provides supportive rather than definitive evidence. Nevertheless, the significant reduction in microleakage demonstrated by stereomicroscopic analysis, together with the favorable fracture characteristics observed on SEM, supports the potential of Ribbondfiber reinforcement to improve the marginal integrity and fracture behavior of Class II composite restorations in primary molars. Further clinical studies with larger sample sizes and long-term follow-up are required to determine whether these laboratory advantages translate into improved clinical longevity

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V. CONCLUSION

The present study has certain limitations that should be considered while interpreting the findings. As an in vitro study, it could not completely replicate the complex oral environment, including the effects of saliva, thermal fluctuations, masticatory forces, oral microbiota, and patient-related factors that may influence restorative performance and longevity. Additionally, the placement and handling of Ribbondfibers under laboratory conditions may differ from clinical practice, where access, moisture control, and operator variability can affect the outcome. The relatively short evaluation period, without long-term aging or fatigue loading, also limits the ability to predict the clinical durability of the restorations. Within these limitations, the present study

demonstrated that incorporation of polyethylene fiber reinforcement significantly reduced microleakage in Class II composite restorations of primary molars compared with conventional composite. The improved marginal seal may be attributed to better stress distribution and inhibition of crack propagation at the tooth–restoration interface, thereby enhancing the structural integrity of the restoration. These findings suggest that fiber-reinforced composites have the potential to provide a favorable balance between function, marginal integrity, and esthetics in the restoration of primary molars. Further long-term clinical studies are warranted to validate these findings and determine the performance and longevity of fiber-reinforced composites under actual oral conditions.

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Fig 1 - Cavity preparation

Fig 2 – Ribbond Incorporation

Fig 3 – Ribbond securing composite

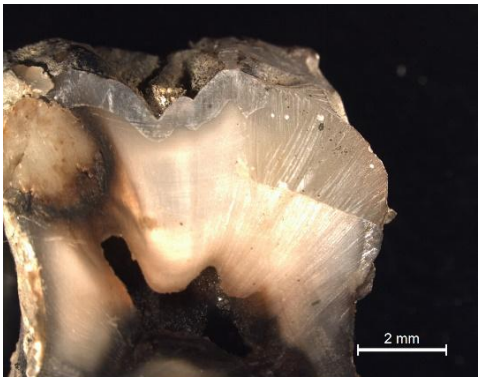

Fig 4 – Stereomicroscopic view of test group composite

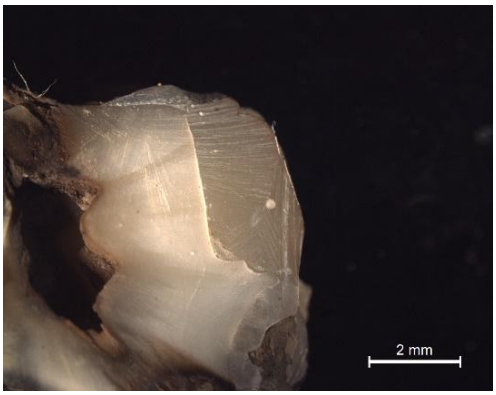

Fig 5 – Steremicroscopic view of control group composite

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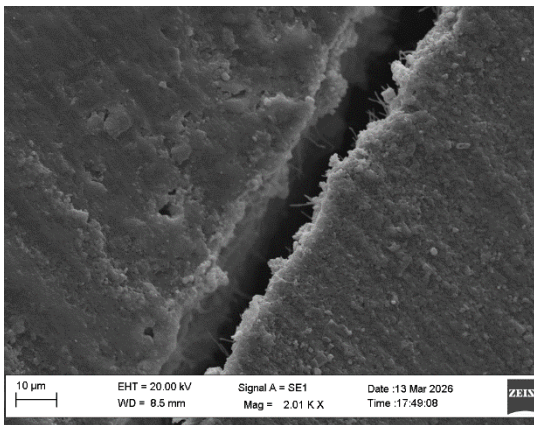

Fig – 6 Scanning electron microscopic view of control group

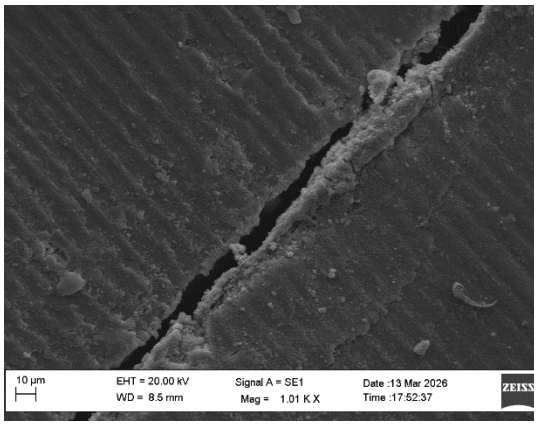

Fig – 7 - Scanning electron microscopic view of control group

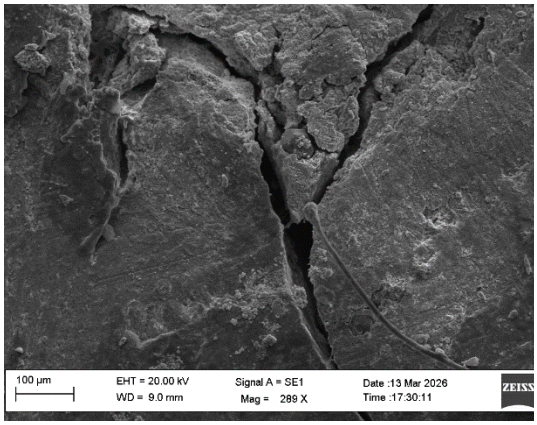

Fig 8 - Scanning electron microscopic view of test group

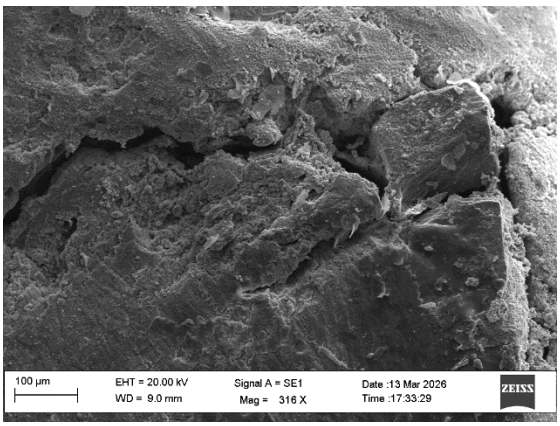

Fig 9 - Scanning electron microscopic view of test group