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COMPARATIVE EVALUATION OF MARGINAL GAP BETWEEN RESTORATION AND TOOTH INTERFACE IN CLASS I BULK FILL COMPOSITE RESTORATION DONE USING CONVENTIONAL TECHNIQUE AND DECOUPLING TECHNIQUE AT 2 MINUTES AND 5 MINUTES: AN IN VITRO SEM STUDY

Dental Science

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ABSTRACT

Aim: The study aimed to evaluate and compare the marginal gap between restoration and tooth interface in Class I bulk fill composite restoration done using conventional technique and decoupling technique at 2 minutes and 5 minutes.**Methodology:** Thirty-three freshly extracted mandibular premolars were decoronated at the cementoenamel junction. Standardized Class I cavities were prepared, entire cavity was etched and a thin layer of bonding agent was employed and light cured. The samples were randomly allocated into three groups (n=11): Group I - waiting period of 0 minutes (conventional technique); Group II - waiting period of 2 minutes; and Group III - waiting period of 5 minutes after curing the bonding agent, followed by placement of bulk fill composite restoration. The samples were then subjected to mesiodistal sectioning along the vertical plane and analysed by Scanning Electron Microscope for marginal gap at the tooth and restoration interface. Data were analysed using one-way ANOVA and by post hoc Tukey test ($p < 0.05$).**Results:** Waiting periods for 2 and 5 minutes after light curing of bonding agent followed by composite restoration placement using decoupling technique showed comparatively lesser marginal gap than waiting for 0 minute using conventional technique.**Conclusion:** As the waiting period increases marginal gap formation decreases, suggesting maturation of hybrid layer using decoupling with time technique.

KEYWORDS

Decoupling With Time, Marginal Gap, Bulk Fill Composite Restoration, Scanning Electron Microscopy, Hybrid Layer Maturation, Biomimetic Restorative Dentistry.

INTRODUCTION

The basic objective of biomimetic restorative dentistry is to reproduce the natural structure and function of the teeth using various techniques and materials that attain durable bonding of the restoration to both dentin and enamel, thereby improve its the longevity and minimize the need for retreatment.[1] It is understood by the biomimetic approach that natural tooth structure functions as unit wherein enamel, dentin, and the dentinoenamel junction work together to withstand masticatory forces and therefore restorative protocols should direct to mimic this biological coherence.[2]

Among the various protocols in biomimetic restoration, stress reduction with controlled polymerization becomes one essential principle. This protocol states that the thickness of composite resin placed initially on tooth surfaces should be less than an increment of 2 mm to reduce polymerization shrinkage.[3]However major problem surfaces when the initial composite increment of 2 mm thickness is placed and light cured too quickly over a freshly applied bonding agent while the hybrid layer is still maturing with no adequate time to attain bond strength to withstand the shrinkage developed during polymerization of the composite resin.[4]

Regardless of the technical and clinical advances in bonding over many decades, unavoidable marginal leakages persist with direct composite restorations.[5] As marginal disintegrity expose restorations to microleakage causing postoperative sensitivity, secondary caries which in turn leads to failure of the composite restoration.[6] The clinical consequences of inadequate marginal adaptation are documented in the literature and presents a significant concern for both clinicians and patients.[7]

The conception of first developing a bonded seal of the dentin surface by applying a thin coat of resin and then after a designated duration of time, placing restoration on it has been described in the literature as "decoupling with time".[8]This biomimetic protocol can effectively overcome the discrepancy amongst the different l hard tissues of the teeth involved in bonding that have been characterized as the "hierarchy of bondability".[9]It describes that, composite resin shrinks toward the most mineralized and dry walls of the preparation during polymerization and pulls away from the most moist and organic surfaces, creating differential stress distribution across the bonded interfaces.[10]

The first protocol of decoupling with time neutralizes the combined unfavourable effects of the hierarchy of bondability and polymerization dynamics. According to this protocol polymerization shrinkage stress of the maturing bond between dentin and hybrid layer should be reduced by waiting for 2 to 5 minutes and the composite is placed over the tooth surface.[11]While this waiting period, the hybrid layer matures, progressively and develop a better bond strength in a stress-free environment, which gradually makes it resistant to the shrinkage forces.[12]

Examination of marginal gaps in restorations have been conventionally carried out by various microscopic methods. Optical microscopy which is easily available comes with a major limitation such as inadequate magnification and unsatisfactory depth of resolution.[13]Scanning electron microscopy (SEM) emerges as superior alternative with high-resolution imaging and excellent depth of field, keeping all the perks of traditional electron microscopy.[14]Scanning electron microscopy (SEM) also allows investigation of specimens without the need for sample preparation.[15]

The bulk fill composite approach has emerged as a popular technique in clinical practice due to ease of application and minimized chair time. Nevertheless, concerns arise regarding the polymerization shrinkage with larger portions of composite and its effect on marginal adaptation.[16]The association between bulk fill technique and hybrid layer maturation with time has not been explored in the existing literature which creates a knowledge gap that needs research and further investigation.

Therefore, this in vitro study aimed to evaluate and compare the

marginal gap between restoration and tooth interface in Class I bulk fill composite restoration using the conventional technique (immediate placement) and the decoupling technique with waiting periods of 2 minutes and 5 minutes after curing the bonding agent, using SEM analysis.

Methodology

Specimen Preparation

Thirty-three recently extracted human premolar teeth free of restorations, cavities, and fractures were collected and kept in normal saline solution containing 0.5% sodium azide at 5°C for one month before use. Ethical approval was achieved from the Institutional Ethics Committee before initiating the study.

All teeth were decoronated at a level 2 mm beneath the cementoenamel junction (CEJ) using a slow-speed diamond disc and then each specimen was mounted in self-curing acrylic resin blocks to facilitate handling and standardization during cavity preparation and subsequent procedures.

Cavity Preparation

Standardized Class I cavities were prepared on the occlusal surface of each premolar using a tapered fissure diamond bur (ISO 016) with a high-speed handpiece. All the prepared cavities were confined to the following standardized dimensions: 4 mm mesiodistal length × 2 mm buccolingual width × 2 mm depth, measured using a periodontal probe. After every five preparations a brand new bur was used to ensure cutting efficiency. All internal line angles and point angles were smoothened out to reduce stress concentration. At the cavosurface margins no bevels were placed but all margins were smoothened and finished.

Placement of the Restoration

Each prepared specimen was randomly allocated to one of three experimental groups, with 11 teeth in each group. Before placement of the restoration, entire cavity was treated with 37% phosphoric acid (Scotchbond Etchant, 3M ESPE, St. Paul, MN, USA) for 15 seconds. The acid was then rinsed thoroughly with an air-water spray for 15 seconds and excess moisture was removed maintaining a moist dentin surface.

A single coat of the bonding agent (Adper Single Bond 2, 3M ESPE, St. Paul, MN, USA) was applied with a disposable micro-applicator tip, gently rubbed for 15 seconds, air-thinning was done followed by light curing with light curing unit (Elipar DeepCure-S, 3M ESPE).
for 20 seconds.

The three groups were designated as follows:

- **Group I (Conventional technique):** Bulk fill composite restoration (Filtek One Bulk Fill, 3M ESPE) was placed immediately (0-minute waiting period) after curing the bonding agent.
- **Group II (Decoupling - 2 minutes):** A waiting period of 2 minutes was observed next to curing of the bonding agent before placement of the bulk fill composite restoration.
- **Group III (Decoupling - 5 minutes):** A waiting period of 5 minutes was observed after curing the bonding agent before placement of the bulk fill composite restoration.

In all groups, the bulk fill composite resin was employed in a bulk in the entire cavity depth (2 mm) and light cured for 20 seconds. The restorations were finished and polished with fine-grit diamond finishing burs and Sof-Lex polishing discs (3M ESPE).

SEM Analysis

Prior to SEM examination, each restored tooth was sectioned mesiodistally along the vertical plane through the centre of the restoration using a double-faced diamond disc mounted on a slow-speed handpiece. The sectioned specimens were then randomly sent for microscopic evaluation.

The SEM analysis was carried out using Scanning Electron Microscope (FEI Quanta 200, FEI Company, Hillsboro, OR, USA) at an accelerating voltage of 25 kV. The specimen chamber was kept at a pressure of 4.6–6.7 torr, and images were captured at a distance of 18–20 mm. Samples were then placed on aluminium stubs for SEM examination. magnification of 350× was used to measure the marginal gap between tooth-restoration interface. Specimens were measured randomly to obliterate operator bias and all measurements were carried out by a single examiner.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS version 21.0, IBM Corp., USA) was used to analyse the data. Descriptive statistics such as minimum, maximum, mean, and standard deviation (SD) were calculated for each group. One-way analysis of variance (ANOVA) was used to evaluate the overall differences in marginal gap among the three groups at different time intervals. For intergroup pairwise comparisons, the post hoc Tukey test was applied. The statistical significance level was set at $p < 0.05$ for each analysis.

Results

Comparison of the marginal gap at different time durations

Table 1 summarizes the marginal gap measurements at different time durations. The highest mean marginal gap was observed in Group I (0 minutes) at 11.13 ± 4.70 µm, followed by Group II (2 minutes) at 5.35 ± 1.22 µm, and the lowest gap was recorded in Group III (5 minutes) at 3.19 ± 0.92 µm. The overall difference in the marginal gap among the groups was found to be statistically significant ($p < 0.001$).

Table 1. Marginal Gap formation at Different Time Durations

Time Duration	N	Mean	SD	p-value
0 minutes	11	11.13	4.70	<0.001*
2 minutes	11	5.35	1.22	
5 minutes	11	3.19	0.92	

One-way ANOVA test; * indicates a significant difference at p≤0.05

Pairwise Comparisons

Table 2 presents the pairwise comparison of marginal gap values at different time durations. The marginal gap at 0 minutes was comparatively greater than that at 2 minutes ($p < 0.001$) and significantly greater than that at 5 minutes ($p < 0.001$). However, the difference in marginal gap between 2 minutes and 5 minutes was statistically insignificant ($p = 0.198$).

Table 2. Pairwise Comparison of Marginal Gap at Different Time Durations

Pairwise Comparison	Mean Difference	p-value
0 minutes vs 2 minutes	5.79	<0.001*
0 minutes vs 5 minutes	7.94	<0.001*
2 minutes vs 5 minutes	2.15	0.198

The results distinctly presented a decreasing pattern of marginal gap with increasing waiting time. The sequence of marginal gap formation i.e. Highest to lowest was 0 minutes > 2 minutes > 5 minutes.

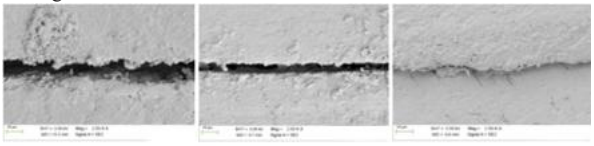

Image: SEM image for 0minute duration

Image: SEM image for 2 minute duration

Image: SEM image for 5 minute duration

DISCUSSION

The present in vitro study compared and evaluated the concept of the decoupling technique with different waiting periods on marginal gap in Class I bulk fill composite restorations. The results depicted that increase in the waiting time between curing the bonding agent and placement of the composite restoration remarkably reduced the marginal gap at the tooth-restoration interface, strongly approving the principles of biomimetic restorative dentistry.

The basic process underlying the results explains the dynamics of polymerization of composite resin and the hybrid layer maturation. When composite resin undergoes polymerizes, it tends to shrink, creating stresses at the bonded surfaces.[17]These stresses are directed towards the centre of the mass.[18]In freshly bonded dentin, the hybrid layer presents most vulnerable interface, as it is composed of a complex network of resin within the demineralized collagen matrix and requires time to achieve maturity.[19]

The comparatively lower marginal gap values noted in Group II and Group III compared to Group I can be contributed to the waiting period for the maturation of the hybrid layer. Immediately after curing of the bonding agent, the hybrid layer initiates to mature, and the dentin bond develops better strength.[20] By allowing a stress-free waiting before subjecting the bond to the polymerization stresses of the curing composite, the hybrid layer attains better structural integrity and resistance to debonding.[21]

David Starr Alleman et al. (2021) confirmed these findings by showing that, when immediate dentin sealing is performed, hybrid layer matures with time and attains better bond strength, leading to greater marginal adaptation of composite restoration.[22]The biomimetic protocols focused on respecting the biological time for the hybrid layer to mature which is essential for achieving better marginal seal.

Khamis A. Hassan et al. (2022) also supported the current findings by reporting that, the hybrid layer initiates maturation immediately after applying the bonding agent and the dentin bond begins to develop; however, at least 5 minutes are required for the bond to strengthen the hybrid layer and the dentin to reach better potential in a stress-free environment without being subjected to polymerization shrinkage forces.[23]This finding aligns with our result that Group III (5 minutes) demonstrated the least marginal gap.

Conversely, Somani et al. (2020) reported that the bulk fill restorative technique demonstrated the increased microleakage due to high polymerization shrinkage resulting from the bulk of composite material and reduced effectiveness of polymerization at deeper portions.[24]However, the present study demonstrates that this limitation of the bulk fill technique can be effectively mitigated by incorporating a waiting period after curing the bonding agent, thereby allowing the hybrid layer to achieve sufficient maturity to resist the shrinkage stresses generated by the bulk-placed composite.

Neppelenbroek (2015) emphasized that achieving optimal marginal adaptation in direct and indirect restorations remains one of the most significant clinical challenges in contemporary restorative dentistry.[3]The decoupling technique, as evaluated in the present study, offers a simple, cost-effective, and clinically practical strategy for improving marginal adaptation without requiring additional materials or complex procedural modifications.

The present study has certain limitations. First, as it is an in vitro study, the results may not be directly applicable to clinical conditions where factors such as salivary contamination, moisture control, operator variability, and occlusal loading are present. Second, sample size of 11 specimens per group is inadequate for observing significant differences limiting the statistical power.

Future studies should focus on larger sample sizes, varying materials, and clinical set up to validate these findings.

CONCLUSION

considering the limitations of the study, it can be concluded that,

1. The decoupling technique with a waiting period after the bonding agent curing and before placement of the restoration, notably reduced the marginal gap at the tooth-restoration interface in comparison with the conventional technique which uses immediate placement of the composite restoration.

2. The mean marginal gap decreased progressively with increasing waiting time, following the sequence: 0 minutes (11.13 μm) > 2 minutes (5.35 μm) > 5 minutes (3.19 μm).

3. The decoupling technique is a simple, practical, and effective biomimetic protocol that can be easily inculcated clinically to improve the marginal integrity of bulk fill composite restorations.

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