Effect of Composite Resin Preheating and Ultrasonic Plasticization on Marginal Adaptation of Class II Restorations – SEM Study

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Abstract-
Background: Imperfect margin adaptation of class II composite resin restorations leads to clinical failure. Plasticization of bulkfill composite resins may overcome the problem.
Objective: The objective of this study was to evaluate effect of composite resin preheating and ultrasonic plasticization on marginal adaptation of class II restorations in comparison with room temperature composite resin under scanning electron microscope at 200x magnification.
Materials and methods: Box-only class II cavities were prepared on 30 extracted human maxillary premolars, with the dimensions of 3 mm buccolingual width, 2 mm mesiodistal width and 4mm occlusogingival depth. They were divided into three groups of 10 teeth each
Group I –Cavities restored with room temperature bulkfill composite resin, Group II – Cavities restored with preheated bulkfill composite resin, Group III – Cavity restored with ultrasonically plasticized bulkfill composite resin. The tooth - restoration interface was evaluated for the marginal adaptation under SEM at 200 × magnification. The micro morphological evaluation of the tooth restoration interface was carried out according to criteria by Blunck and Zaslansky.
Results: Statistical analysis done by applying Kruskal Wallis test. Group I showed higher marginal discrepancy with score 4 - severe gap of > 2µm with severe marginal irregularities, with statistically significant difference (p-value - 0.018) compared to group II and III. Group II and III demonstrated score 3 - gap visible upto 2µm with no marginal irregularities, without statistical significance.
Conclusion: Ultrasonic plasticization with good clinical handling properties may be an alternative for class II composite resin restorations.

Key words: **Preheating composite, Ultrasonic plasticization, Marginal adaptation, Scanning electron microscopy.**

Introduction

The advances in material technology are quite promising for the long term success of composite resin restorations[1]. Attempts in improving the mechanical properties in the form of high filler content have led to increased viscosity of composite resins[2]. This may affect the rheological properties which in turn may affect marginal adaptation of the material[3]. Marginal adaptation is crucial for the long term clinical outcome of adhesive restorations[4]. The possibility of marginal failure in composite resin restorations is related mainly to the quality of bond between the tooth structure and the resin, and also to stress generated within the restoration due to polymerization shrinkage[5]. The clinician's main concern, when placing direct posterior resin composite restorations, would be to counter the polymerization shrinkage stresses and consequent outcomes[6]. The main factors that determine shrinkage stress and, consequently, gap formation in composite resin restorations are polymerization shrinkage level, elastic modulus, and flow capacity of the composite resin[7]. Composite resin restorative materials undergo significant volumetric shrinkage when polymerized. As one monomer cross links with another, the molecules move closer and convert into covalent bonds forming polymer network incurring the volumetric shrinkage that ranges from 1.35% to 7.1% [8].

Several techniques have been developed to prevent and reduce these undesirable problems such as regulation of curing light intensity[9], use of flowable composite resins [10], prewarmed composite resins[10] and Sonicfill composite resin[11].

Prewarming of the composite resins have improved rheological properties and reduced film thickness[10]. Greater monomer conversion during polymerization and reduced curing time enhance the adhesion, superior marginal adaptation, reduced microleakage and increase in hardness[10]. Based on these observed improvements, prewarmed composite resin restorations have been considered to improve clinical performance of these restorations[13, 14].

Despite these improved properties there has not been a wide uptake of technique of prewarming composite resin. One of the possible reasons for this is, once composite resin is pre-heated, there is a time delay between dispensing it from a syringe or compule, placing it into a preparation, contouring it, and subsequently light polymerizing it. It is estimated that when a composite resin is heated up to 60 °C and removed from the device, the temperature reduces 50% after 2min and 90% after 5min. So this may compromise the superior property claimed by the prewarmed composite resins[12-14].

Another recent introduction of sonic fill combines the attributes of a low viscosity composite resin and a universal composite resin[11]. By activating composite resin with sonic energy, it is possible to fill the cavity and adapt the low viscosity material easily and then compact it while composite resin changes its consistency until it reaches a higher viscosity[11]. But the problem here is along with high expense it requires special equipment.

By simulating this concept, with the use of ultrasonic tips for generating ultrasonic vibrations it is possible to alter the consistency of high viscosity material to a consistency that can be compacted and made to adapt to cavity walls.

Ultrasonic equipment is an essential equipment for a dental clinic for various applications. The tips used for retreatment of endodontics with modification can be used for composite adaptation.

Both viscosity of the composite resin material and insertion technique may influence final film thickness and the overall restoration quality. Improved flow properties of highly filled composite resin materials may be achieved by ultrasonic insertion of the restoration[15]. The use of vibration may reduce film thickness via a thixotropic effect, thus enhancing wetting properties of composite resin materials and allowing better marginal adaptation of the restoration[15].

No data on the adhesive properties of this novel technique are yet available, except for the preheated composite resin adaptation and mechanical properties of material after heating.

The null hypothesis states that there will be no difference in the marginal adaptation in class II cavity placed by pre warming of composite material and ultrasonic plasticization of composite material and room temperature composite material.

Accordingly, this in vitro study was designed to evaluate the marginal adaptation of this ultrasonic plasticization composite resin material in comparison to the conventional composite resin and prewarmed composite resin groups.

Materials and methods:

Ethics: A total of 30 freshly extracted human maxillary premolars with intact crown structure were collected from the Department of Oral and Maxillofacial Surgery. Ethical committee clearance was obtained for the use of natural teeth in the study. (No: VDC/IEC/2018/25).

Study design:

Inclusion criteria: Intact human maxillary premolar teeth extracted for orthodontic reasons free of carious lesions and of similar dimensions were included in the study.

Exclusion criteria: Carious teeth, teeth with previous restoration and previous endodontic treatment and those with preexisting fractures or cracks were excluded from the study.

In order to simulate clinical teeth alignment, the premolars were mounted on a plaster mould, with a canine tooth on the mesial side and a second premolar on the distal side with good contact.

Box-only class II cavities were prepared on distal side of each tooth, with the dimensions of 4 mm buccolingual width, 2 mm mesiodistal width, 4mm occlusogingival depth. A SF 31 diamond bur (Mani Inc., Japan) was used to prepare the cavity. All the preparation procedures were carried out under copious water spray using a high speed hand piece.

The cavities were selectively-etched with 37% phosphoric acid gel for 30 seconds on enamel and 15 seconds on dentin, rinsed with water for 10 seconds, and blot dried for 2 seconds. Thick coat of Tetric N Bond (Ivoclar Vivadent products, Delhi, India) was applied onto the cavity surface, gently air dried, and light cured for 20 seconds, using a LED curing light of intensity 1,000 mW/cm2 (Wood pecker, Guilin, China). A Sectional matrix and retainer was placed around the tooth (RebornEndo, Vision group SHREE GUJARAT TRADERS, India). The wooden wedges were inserted inter proximally in order to tightly seal the cervical margins.

Then the teeth were randomly divided into three groups of 10 each using computer generated randomization: -

Group I –Cavity restored with conventional room temperature composite resin

Group II – Cavity restored with prewarmed composite resin

Group III – Cavity restored with ultrasonically plasticized composite resin.

GROUP I: The cavity was restored with room temperature bulkfill packable nanohybrid composite (Tetric N Ceram, Ivoclar Vivadent products, Delhi) (LOT no:X20834) , in one increment and was light cured for 20 seconds using the same LED light source with intensity 1000mW/ cm^2 according to the manufacturer’s instructions.

GROUP II: The cavities were restored with bulkfill packable universal nanohybrid composite material in one increment which was prewarmed (Delta Co., India). The cling wrap was placed around the open end of the composite tube and inserted for 5 minutes in composite warmer at 60°C (**Figure 1**). The prewarmed composite resin (LOT no:X20834) was inserted into cavity and was light cured for 20 seconds using the same LED light source. The light curing procedures were performed according to the manufacturer's instructions.

GROUP III: The cavities were filled with bulkfill packable universal nanohybrid composite material in one increment and ultrasonic plasticization of material was done by placing Cricdental ultrasonic tip (RT No – 2) (Cricdental, Mumbai, India) (P5 Newtron, Satelec Aceton, France) over the composite resin material (LOT no:X20834) for 2 minutes at a power level of 6-9, moving the tip in buccolingual direction and then compacted with suitable instrument (**Figure 2**). Composite resin was light cured for 20 seconds using the same LED light source according to the manufacturer's instructions.

FINISHING AND POLISHING PROCEDURE: Then the specimens were polished with Super-Snap Mini-Kit finishing & polishing discs.

The restorations were evaluated under dental operating microscope (Labomed) at 1x magnification.

THERMOCYCLING PROCEDURE:

After specimens were stored in distilled water at 37°C for 7 days, teeth were subjected to artificial thermal aging according to the ISO (The International Organization for Standardization, ISO 11405 standard) recommendations. Thermocycles were performed using a dwell time of 30 seconds in each bath and a transfer time of 15 seconds between baths for 500 cycles between 5°C and 55°C.

SCANNING ELECTRON MICROSCOPE EVALUATION: The samples were then processed for SEM evaluation to examine the tooth - restoration interface for adaptation of composite restorative material to the tooth margins at 200 × magnification. The entire interface was evaluated and SEM images were captured accordingly. The collected SEM photographs were renamed/decoded by another colleague not involved in the study, in order to keep the principal investigator blinded. The micro morphological evaluation of the tooth restoration interface was done according to the criteria[16] (Blunck and Zaslansky; 2011) mentioned as below:

Scoring criteria

MQ1 Perfect margin (hardly visible)

MQ2 Margin visible, no gap irregularities;

MQ3 Margin irregularities (like bulbs, minor swelling) but no gaps.

MQ4 "Hairline" crack: sharp and clear discontinuation (gap width <2μm) at the margin without any irregularities.

MQ5 "Hairline" crack (gap width <2 μm) +minor margin irregularities or gap width <5 μm without any irregularities

MQ6 Gap formation (gap width <5 μm) + heavy margin irregularities

MQ7 Gap formation (gap width >5 μm)

Final Scoring criteria

Score 1: MQ1 + **MQ2** (Margin not or hardly visible, no or slight marginal irregularities; no gap)

Score 2: MQ3 (No gap but severe marginal irregularities)

Score 3: MQ4 (Gap visible (hairline crack up to 2 μm wide), no marginal irregularities

Score 4: **MQ5** + **MQ6** + **MQ7** (Severe gap more than 2 μm wide), slight and severe marginal irregularities)

No Gap: Score 1 & 2 = MQ1 + MQ2 + MQ3; Gap: Score 3 & 4 = MQ4 + MQ5 + MQ6 + MQ7.

Results:

The resultant data were statistically analysed by applying Kruskal Wallis test, using the SPSS (version 20.0) software.

The p-value of **0.018,** obtained through statistical analysis suggests that there is statistically significant difference between the study groups in terms of marginal adaptation.

Table I - Kruskal Wallis test representing p-value

	Median	Standard deviation	F value	P value
Group I	4.0000	0.42164	8.045	0.018
Group II	3.0000	1.05409		
Group III	3.0000	1.07497		

Table II: Comparison of marginal quality between two individual groups was done using Independent Mann Whitney U test.

		Mean	Standard deviation	F value	P value
1	Group I	3.8000	0.42164	.089	.047
	Group II	3.0000	1.05409		
2	Group I	3.8000	0.42164	.009	.005
	Group III	2.6000	1.07497		
3	Group II	3.0000	1.05409	.436	.386
	Group III	2.6000	1.07497		

The mentioned results (Table I Table II) had shown, room temperature bulkfill composite resins (group I) represented higher gap, followed by preheated composite resins (group II) and ultrasonically plasticized composite resins (group III), there is statistical significant difference between group I and group II($p=0.047<0.05$), and group I and group III ($p=0.005\leq0.05$) but, there is no statistical significant difference in the gap between group II and group III ($p=0.386>0.05$).

Discussion:

Several adverse effects in resin-based composite restorations are frequently connected to polymerization shrinkage stress[17]. The incremental (or layering) technique has been the most common insertion method for resin composite to reduce the effects of polymerization shrinkage and polymerization stresses.

When using more viscous compositions, such as high-filler content densified or hybrid resin composite materials, it is of concern as these may not adapt fully or entirely to the cavity preparation[18].

The preheated composite method[19] and sonic (or ultrasonic) vibration[20] have been introduced to improve the convenience of manipulation and increase the adaptability of dental composites to a cavity without changing the composite formulation.

According to the Kruskal Wallis test, bulkfill room temperature composite resin represented higher surface defects with a median value of 4.0000, followed by bulkfill preheated composite resin and bulkfill ultrasonically plasticized composite resin with a median value of 3.0000.

Group I>Group II=Group III

The null hypothesis is rejected since difference in the marginal adaptation in class II cavity placed by pre warming of composite material and ultrasonic plasticization of composite material and room temperature composite material.

Based on SEM results, it can be inferred that none of the groups could provide 100% perfect margins at the CEJ, regardless of the restorative technique used. But, there is a statistically significant difference in the quality of the margins among the room temperature and experimental groups. But no significant difference was evidenced in terms of the quality of the margins among the prewarmed and ultrasonically plasticized composite resin groups.

In the present study, none of the placement techniques completely eliminated marginal discrepancies. In previous research, composite resin type and placement (4-mm bulk/2-mm increments) on internal marginal adaptation of Class I preparations were evaluated, using dye penetration method and digital camera. No significant differences in gap-free margins were found between placement methods within a given product per location at enamel and dentin interface[21]. This could be attributed to the fact that when placed and polymerized in bulk, shrinkage stresses at the enamel and dentine interfaces were less. It results due to unpolymerised composite resin deep in the restoration deform and absorb resulting stress development from the strain of composite curing at superficial layer. However, 20% of the sample revealed gap formation[21].

In another study, the authors concluded that completely gap-free margins were not obtained with either bulkfill or conventional composite resins. Bulk-fill composite resin materials showed similar marginal adaptation in SEM analysis at 200x magnification than standard composite resin[22]. It was reported that despite decreasing total amount of composite resin, the dimensional change within materials and internal stress generated within conventional composite resins continued to deform the restoration interface and created stress on the tooth-composite resin structure[22].

A systematic review done by Boaro et al. in October 2019, demonstrated that bulk-fill material showed similar or better performance compared to traditional composite resins in terms of polymerization stress, cuspal deflection, marginal gap, degree of conversion, flexural strength, and fracture strength. However, the clinical performance of more than three years was not favourable[23].

The results of preheated group in the study are in accordance with the results in a previous study, conducted in the mesial and distal surfaces premolar teeth. Two different composite resins were used at two different temperatures. Marginal gap at proximal and gingival margins was measured under a scanning electron microscope at ×2000 magnification in µm[4]. It was proved that preheating resulted in a decrease in marginal gaps in both composite resins compared to room temperature restorations with a statistically significant difference in enamel margins[4]. The effect of composite resin type on marginal adaptation was the same.

Since composite resin is a viscoelastic material, an increase in temperature decreases its viscosity. It increases its liquidity, which is due to the thermal vibration of the resin monomers and an increase in their separation. Under these conditions, if the resin's film thickness decreases and if it is placed in the cavity rapidly, it is easily adapted with the cavity walls. Therefore, a decrease in the marginal gaps after preheating the composite resin can be justified [4, 24,25].

Similarly, a study was conducted to examine the change in resin film thickness of a variety of commercially available conventional composite resins. Room temperature composite resins, when preheated prior to light polymerization, demonstrated a significant decrease in film thickness when heated to 54°C or 60°C[10]. Regardless of preheating temperature, conventional composite resins provided a film thickness greater than room temperature flowable composite resins[10]. With heating, sufficient energy was given to overcome hydrogen bonding and chain entanglement to allow the freedom of molecules to move in a less hindered sheering pattern with respect to one another.

Controversial reports have been published in literature regarding the beneficial effects of prewarmed composite resins[26]. The systematic review published in June 2020 by Larissa Coelho et al. has reported improved mechanical and physical properties with a caution that clinical studies are lacking to confirm the same[26].

To overcome unwanted properties, another technique was evaluated in the present study, i.e., ultrasonic plasticization. The statistical analysis of the results demonstrated better marginal adaptation in ultrasonically plasticized technique compared to room temperature and preheated composite resin groups. The statistical significance was observed with room temperature composites with a p-value of 0.005.

The results of the ultrasonically plasticized composite resin group in the study are in accordance with the results in a previous study, where ultrasound was used with high viscosity composite resin. Authors concluded that when ultrasound was used in combination with the high-viscosity material under investigation, film thickness could be significantly reduced and was comparable to the film dimensions obtained with a low-viscosity composite resin material[15]. The reason is that the use of vibration energy utilizing the thixotropic effect may cause changes in the filler/matrix distribution[15].

Similarly, another study showed that the indirect application that is application of ultrasonic vibrations buccally or proximally at equatorial height showed better marginal quality at the axial walls and reduced marginal deterioration after thermal and mechanical stress in unbevelled cavities with incremental layering technique[27].

Relevant film thinning was observed with ultrasound energy even at room temperature, this is advantageous over preheated resin, as there is no drop in temperature while handling, allowing the material to properly adapt to the cavity walls. However the increase in temperature is around ±10˚C.

The limitations of this study are there is no literature available regarding the amount of heat production and the rate of polymerization that occurred with the use of ultrasonics. Studies with more sample size might have a different effect on the results.

Conclusion:

None of the groups could provide 100% perfect margins, regardless of the type of restorative technique used. There is statistically significant difference in marginal adaptation between room temperature composite resin group to that of the preheated composite resin group and ultrasonically plasticized composite resin group.

Clinical Significance of the Study:

Techniques like preheating and ultrasonics might result in a decrease in the viscosity of composite resins and improve the flow, leading to better marginal adaptation and clinical success.

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Table and Figures legends

Figure no I - Preheating composite resin in warmer

Figure no II-Ultrasonic plasticization of composite resin

Table I - Kruskal Wallis test representing p-value

Table II - Comparison of marginal quality between two individual groups was done using Independent Mann Whitney U test.

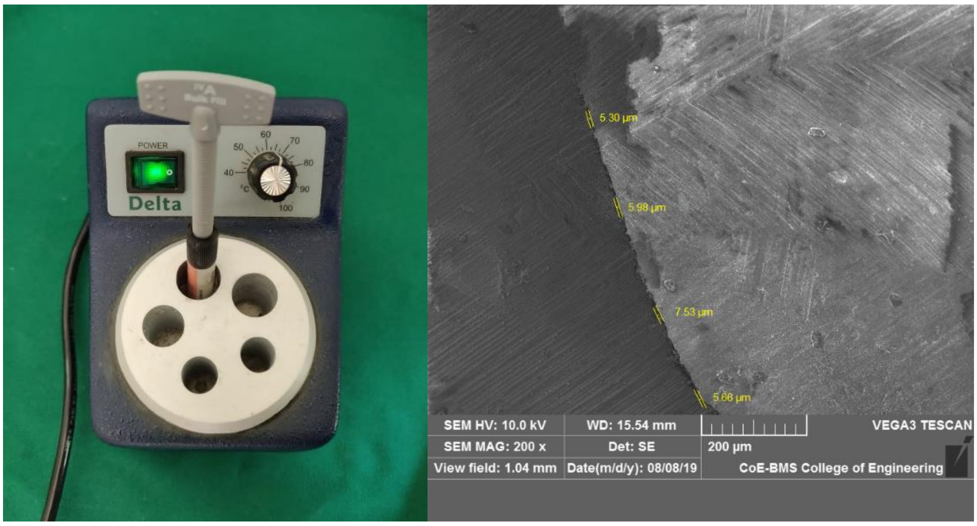

Figure I: a- Composite warmer, b- SEM image from preheated group

Figure II: a- Ultrasonic plasticization, b- SEM image from ultrasonically plasticized group.