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Research Article

Influence of Sandwich, Snowplow and Injection Molding Modified Composite Lining Strategies on the Microleakage of Class II Proximal Box Cavities

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Abstract

Background and Aim: Packable or condensable composites are primarily indicated as a posterior restorative material due to their improved mechanical properties such as decreased wear, increased packability and depth of cure. However they have certain limitations like polymerization shrinkage and microleakage at cemento-dentinal margins. To address aforesaid shortcomings, placement of an intermediate liner below composite restorative layer has been suggested. The aim of the present study was to investigate the microleakage at the proximal box of class II preparation restored with posterior packable composite resins, different liners and lining techniques as a measure to decrease polymerization shrinkage.

Materials and Methods: Thirty seven freshly extracted, intact, non-carious human mandibular molars were selected. Standardized Class II box preparation were made with cervical margin 1 mm above the cemento-enamel junction on both proximal surfaces of each tooth.

The samples were randomly divided into five groups based on the restorative protocol. Group I (n = 5): No liner applied and restored incrementally with packable composite, Group II (n = 8): Open sandwich technique using flowable composite which was precured followed by incremental build-up of packable composite resin, Group III (n = 8): Snow plow technique where flowable composite liner and adhesive were co-cured together followed by incremental packable composite build-up, Group IV (n = 8): Injection molding technique where flowable composite liner, adhesive and the initial increment of composite co-cured simultaneously followed by packable composite build up, Group V (n = 8): Resin modified glass ionomer cement (RMGIC) placed as a liner of 1mm thickness which was precured followed by incremental build-up of packable composite resin.

The restorations were then thermocycled for 1500 cycles with temperature range of 50C to 600C +50C with a dwell time of 20 seconds for each temperature. Using modeling wax the root apices of the teeth were sealed. The surface of all the teeth were coated using 2 layers of nail varnish leaving 1mm window around cavity margin of restoration. Then the teeth were submerged in 2% methylene blue solution for 24 hours at 37oC. Later the specimens were sectioned and evaluated under stereomicroscope. The obtained data was analyzed through Kruskal-Wallis ANOVA with post-hoc Conover test.

Results: There was overall significant difference in terms of microleakage among the five groups ($p < 0.05$). Post-hoc Conover test showed that injection molding technique (Group IV) had significantly lowest mean score (0.78) than other four groups indicating that the microleakage of packable composite significantly reduced by co- curing liner, adhesive, and composite layer together. Similarly, open sandwich technique with Flowable composite liner (Groups II) with a mean score of 1.56 and Snow plow technique (Group III) with a mean score of 1.41 showed significantly less microleakage compared to control group with a mean score of 2.30. This clearly suggests that flowable composite liner reduced the microleakage but open sandwich technique with RMGIC (Group V) could not show satisfactory results with a mean score of 1.75 which is close to control group though statistically insignificant.

Conclusion: According to the results of the present study, injection molding technique performed better with least microleakage. Use of liner under packable composite improved the sealing ability in class II box preparation compared to conventional method.

Keywords: *Polymerization Shrinkage; Microleakage; Snow Plow Technique; Injection Molding Technique; Composite Resin Restoration; Packable Composite*

Introduction

Introduction of composite resin as a direct restorative material is an epoch in adhesive technology and materials [1]. Resin composites have a wide range of restorative applications from minimally invasive management of early carious lesions to the restoration of extensive caries.

The demand for resin based composites in restoration of posterior teeth is extremely increasing over the years due to their improved mechanical properties achieved by densely loaded filler content resulting in decreased wear, increased packability and depth of cure [2]. The integrity of marginal seal and ability to withstand microleakage are the sovereign factors that governs the longevity of any restoration [3]. However the major drawback of posterior resin based composites are adaptability to cavity walls due to their high viscosity. Especially when restoring a class II cavity, composite resin will not adequately adapt to tooth structure particularly at the gingival margin resulting in marginal gaps, microleakage and post-operative sensitivity [4,5].

On the other hand, polymerization shrinkage of composites resins remains a challenge. All composite resins contract causing dimensional changes during photo- polymerization that is when monomers are converted into polymers while gaining its appropriate physical, chemical and mechanical properties [6]. *In vitro* measurements of the polymerization shrinkage associated with resin composites range from 0.2% to 2% linearly and from 1.7% to 5.7% volumetrically. This shrinkage leads to pulling of resin material from the walls of preparation resulting in shrinkage stresses at the resin-tooth interface and contributing to microleakage. To overcome these drawbacks of posterior composite resins, various techniques and modifications in material were proposed such as changes in filler size and content, use of expanded resin matrix and recent curing techniques like soft start curing, ramped curing, pulsed and delayed curing [7].

Various authors have suggested use of an elastic layer as a base or liner under posterior composite restorations which acts as an intermediate stress absorbing layer thus reducing the polymerization shrinkage. Mc Lean and Wilson introduced it as sandwich technique in 1977, where resin modified GIC or flowable composites were used as a base or liner in the prepared tooth, cured and followed by addition of composite layers. It was also referred to as the bilayered restoration [8,9]. Although pre-curing of flowable liner is beneficial, a new concept of co-curing technique came into lime light where two different light cured materials were concurrently polymerized leading to decrease in both the internal stresses in restoration and the number of clinical steps involved. Snowplow and injection molding techniques are based on co-curing concept advocated to reduce marginal leakage in class II composite restorations [10,11]. Though there are case reports describing injection molding technique, there are limited studies that evaluate the microleakage using this technique.

Hence the aim of present study was to evaluate the gingival microleakage of posterior resin composites with different modified composite lining strategies such as open sandwich technique using RMGIC and flowable composite as a liner, snow plow and injection molding technique in class II box mesio-occluso-distal (MOD) preparation using stereomicroscopy.

Methodology

Specimen collection and grouping

37 extracted intact human mandibular molars without caries, restoration, cracks or any other surface defects were collected from the Department of Oral and Maxillofacial Surgery in Panineeya Institute of Dental Sciences and Research Centre, stored in phosphate buffered saline solution for 3 days. Any calculus or soft tissue attachments were removed from the teeth using ultrasonic scaler. Each tooth was embedded below the CEJ in modeling wax block. The teeth were randomly divided into 5 groups based on the restorative technique performed (4 test groups with 8 samples each and 1 control group with 5 samples) as shown in chart 1. A box cavity was prepared on either side of proximal area of each tooth using 245 carbide bur with dimensions of 3mm buccolingual width, 1mm mesiodistal width and the gingival margin was placed 1 mm above the CEJ. Using the Williams graduated periodontal probe the measurements were controlled and standardized.

Specimen preparation

Group I (Control)

After tooth preparation, the tooth was rinsed with and dried. The metal matrix band and Tofflemire retainer was placed around the tooth and the matrix band was extended 1 mm above the cavosurface margin and 1mm below the gingival margin. Etching was done with 37%phosphoric acid (DE TREY Conditioned 36, DENTSPLY) for 30 seconds followed by rinsing for 20 seconds with air water spray and excess water was removed using gentle air press. The single step, single bottle bonding agent (Adper single bond2, 3M ESPE) was applied and agitated with the help of applicator tip followed by a mild blow of air to avoid cooling of the resin. Light curing was done with LED curing light (Bluephase N LED light curing unit, Ivoclar Vivadent) of 1200 MW/cm^2 intensity for 20 seconds. The cavity was restored in 3 horizontal increments using light cured composite resin (Filtek P60, 3M ESPE). Each increment was cured for 30 seconds. Then the matrix band was removed, and the proximal cavity was cured from the buccal and lingual surface for 30 seconds. Finishing and polishing was done using diamond points, aluminum oxide stones and abrasive discs (Shofu Composite Finishing and polishing Kit) from coarse to fine grits.

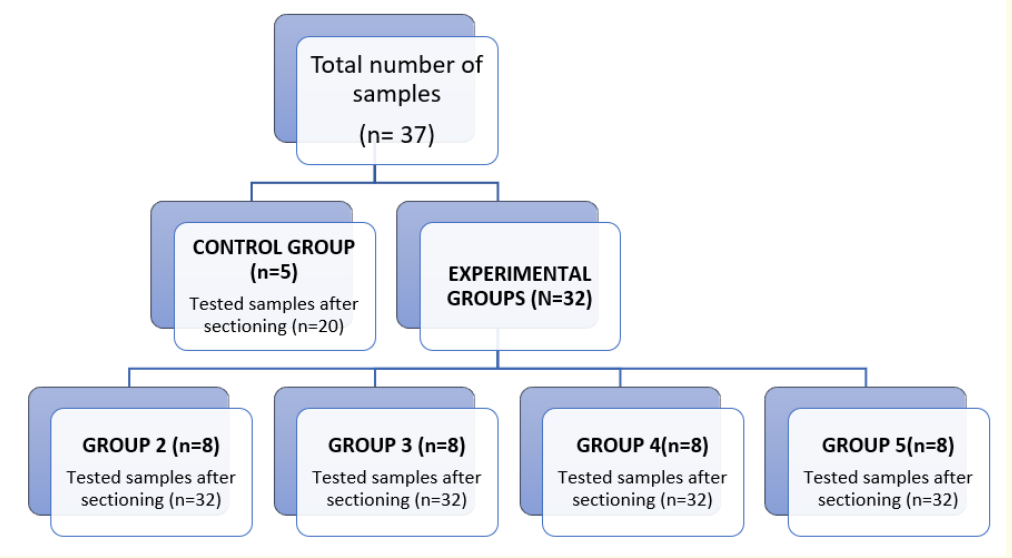


Chart 1: *Grouping of samples before and after sectioning of teeth.*

Group II (Open Sandwich technique with Flowable Composite)

After tooth preparation and matrix application, etching and bonding was done in a similar manner as Group I. Flowable Resin Composite (Esthet Xflow, DENTSPLY) was injected onto the gingival floor with thickness of approximately 1mm and it was light cured for 30 seconds. The remaining space of the cavity was filled in horizontal increments of composite resin similar to Group I.

Group III (Snow Plow Technique)

After tooth preparation and matrix application, etching and bonding was done in similar manner as Group I. Flowable resin composite was injected onto the gingival floor with thickness of approximately 1mm. However this layer was not cured or light activated. Composite resin was placed on flowable composite with the thickness of approximately 1 mm and the two layers were co-cured together for 30 seconds. The remaining space of cavity was filled in horizontal increments similar to GROUP I.

Group IV (Injection Molding Technique)

After tooth preparation and matrix application, etching was done in similar manner as Group I. The bonding agent was then applied but this layer was left uncured. Subsequent to this flowable resin composite was injected onto the gingival floor with thickness of approximately 1mm, on this light cured composite resin was placed with the thickness of approximately 1mm. The 3 layers were co-cured for 30 seconds together. The remaining space of cavity was filled in horizontal increment similar to GROUP I.

Group V (Open Sandwich with RMGIC) (N = 8)

After tooth preparation and matrix application, RMGIC (GC Gold Label-GI light cured, Universal Restoration LC-2) was placed as an intermediate layer. The RMGIC was mixed according to manufacturer's instructions and it was placed on the gingival floor with thickness of approximately 1mm and cured for 30 seconds. Then etching and bonding was done similar to group I and the remaining space of cavity was filled in horizontal increments with light cured composite resin.

Staining

The teeth were placed in isotonic saline solution in a water bath at 37^0C for 24 hours and thermocycled for 1500 cycles with temperature range of 5^0C to 60^0C + 5^0C with a dwell time of 20 seconds for each temperature. Using modeling wax the root apices of the teeth were sealed. The surface of all the teeth was coated using 2 layers of nail varnish leaving 1mm window around the cavity margin of the restoration. Then the teeth were submerged in 2% methylene blue solution for 24 hours at 37^oC.

Sectioning and measuring of microleakage

The teeth were removed from dye solution after 24 hours subsequently washed in running water and dried for 5 minutes. All specimens were sectioned longitudinally in mesiodistal direction into buccal and lingual half of the tooth, using a water-cooled; slow-speed diamond saw ISO 524 (Top Dent, Swiss Made). After sectioning, the surfaces to be evaluated per specimen were increased to four times (i.e. mesial box preparation and distal box preparation of buccal portion and lingual portion of tooth) as shown in Figure 1. The lengths of dye penetration in millimetres were examined using stereomicroscope (Hamilton, BioVision 320) with magnification of 16X.

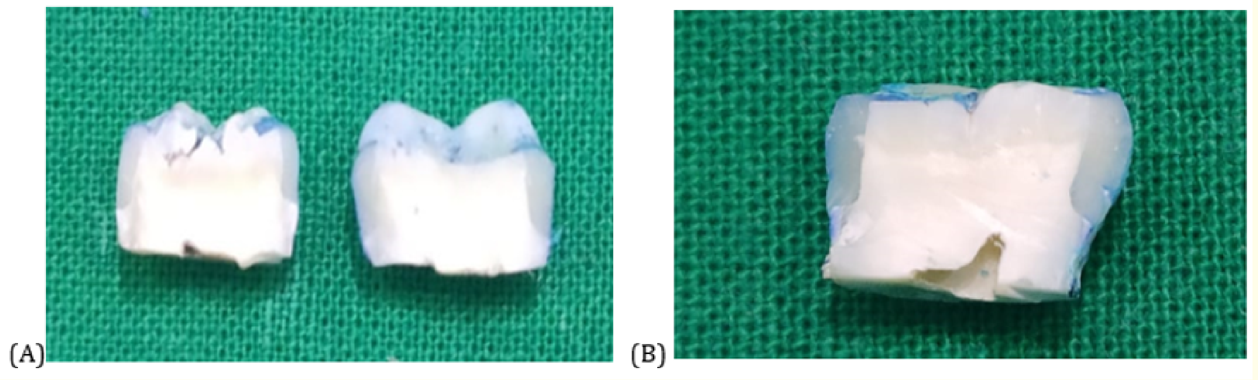


Figure 1: *(A and B) Sectioned specimen showing buccal and lingual halves.*

The degree of microleakage at gingival margins was scored according to Leevaloj C, Cochran MA., *et al.* [12].

Score 0 – No dye penetration (Figure 2)

Score 1 - Dye penetration up to ½ gingival floor (Figure 3)

Score 2 - Dye penetration beyond ½ gingival floor (Figure 4)

Score 3 - Dye penetration all along the gingival seat up to ½ axial wall (Figure 5)

Score 4 - Dye penetration in whole of axial wall (Figure 6).

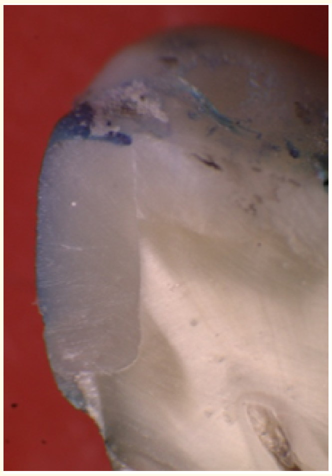


Figure 2

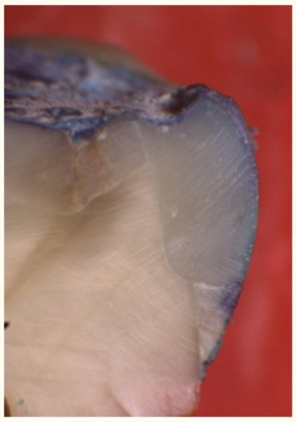


Figure 3

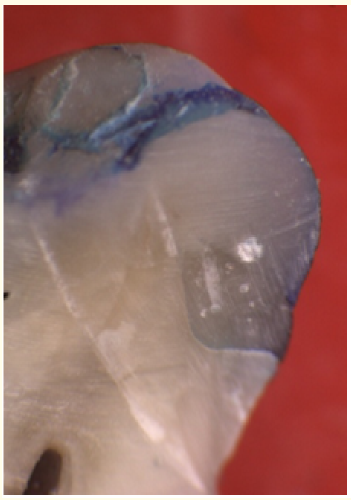


Figure 4

Figure 5

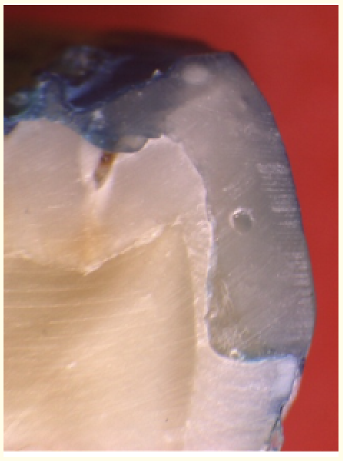


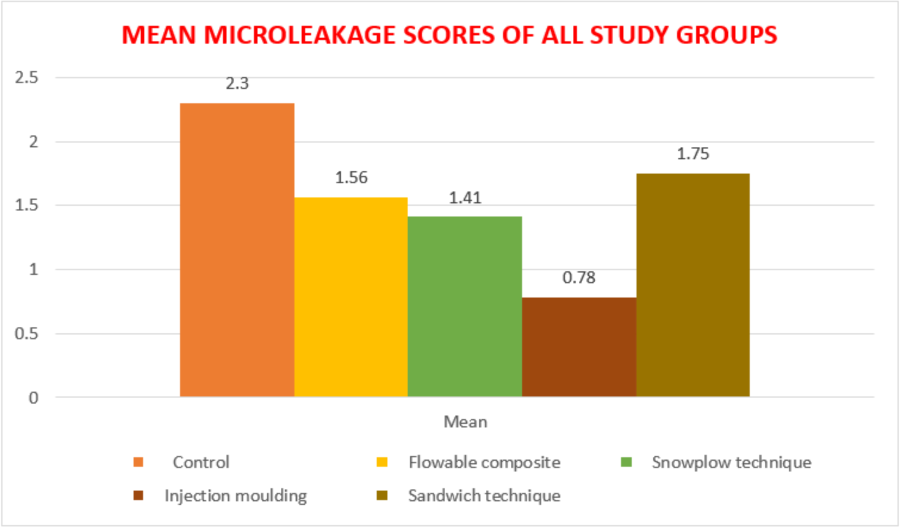
Figure 6

Statistical analysis

The data obtained was statistically analysed using Med Calc Version 14. A p-value of <0.05 was considered statistically significant. Comparison of dye penetration scores was done using Kruskal Wallis ANOVA with post-hoc Conover test as presented in Table 1 and Graph 1.

Group	Mean	SD	P-value	
Control group (n = 20)	2.30	.92	<0.001; Sig	1>2,3
Open Sandwich technique with Flowable composite liner (n = 32)	1.56	.98		
Snow Plow technique (n = 32)	1.41	.98		
Injection Molding technique (n = 32)	0.78	1.04		1,2,3,5>4
Open Sandwich technique with RMGIC liner (n = 32)	1.75	.88		

Table 1: *Kruskal Wallis ANOVA with post-hoc Conover test.*



Graph 1: *Graphical representation of mean microleakage values of all the groups of study.*

The data showed that there was an overall significant difference in terms of microleakage among the five groups ($p < 0.05$). Post-hoc Conover test for all the experimental groups showed less mean scores than the control group. Open sandwich technique with RMGIC (Groups V) could not show satisfactory results with a mean score (1.75) which is close to control group though statistically insignificant. Similarly, open sandwich technique with Flowable composite liner (Groups II) with a mean score (1.56) and snow plow technique (Group III) with a mean score (1.41) showed significantly less microleakage compared to control group with a mean score(2.30). This clearly depicts that flowable composite liner reduced the microleakage. Injection molding technique (Group IV) had significantly lowest mean score (0.78) than other four groups indicating that the microleakage of packable composites was significantly reduced by co- curing the liner, adhesive, and composite layer together by forming a monoblock.

Discussion

To meet the current esthetic demands composite restorations have become a popular alternative to the traditional amalgam restorations. The newer generations of composites are superior to amalgam in terms of esthetics, physical properties, ability to bond to tooth structure thereby warranting their use as a posterior restorative material. However they have certain drawbacks like polymerization shrinkage, microleakage and poor adaptation to the cavity walls. Micro-leakage is more so often in class II cavities that may lead to post-operative sensitivity and secondary caries [12]. To overcome these problems composites with higher viscosity were introduced known as the packable or condensable composites which led to lesser voids and better marginal adaptation.

The different methods to evaluate microleakage are air pressure, bacterial assessment, radioisotope studies, scanning electron microscopy, chemical identifiers, electrochemical studies and dye penetration. In the current study, the dye penetration or staining technique was employed which is a semi-quantitative method and it is simple and relatively economical [13,14]. The advantages of this technique include precision in evaluation of marginal seal and its ability to reveal an existing micro gap. In addition, it gives data on linear penetration and direct reading of the penetrated marker by microscope [6].

Injection molding is a novel advanced technique of restoring a class II preparation advocated by Dr David J Clark, to reduce the polymerization shrinkage of packable composites. In this method during restoration of class II proximal box, a layer of bonding agent or adhesive has to be coated on the gingival seat which is not cured, followed by placement of a flowable composite liner and initial increment of packable composite over the liner where all three layers are co- cured simultaneously. The resin flowable paste mass is polymerized together in a single light cure [15]. The goal of this technique is to reduce the volume of flowable liner to 10 - 20% and 80 - 90% of volume filled by paste composite, as greater thickness of flowable liner contributes to high rates of marginal ridge fracture and complete filling dislodgement [11].

The least microleakage for injection molding technique in the present study, can be attributed to the low viscosity resins, both adhesive and flowable composite, act as temporary wetting agents and the heavier resin displaces the lesser ones thus improving the marginal seal. All three layers co-cured together results in a monolithic mass to improve cavity adaptation and reduce the potential for internal gap formation.

The study by Majety KK., *et al.* have shown similar results with less microleakage, when thin lining of flowable composite resin was used (about 1 mm thickness) in comparison with 2 mm thickness as wear rate of flowable resin composite is higher than that of packable composites [8].

This method recommends the use of conservative or minimally invasive cavity design and translucent matrices such as anatomic matrix (Bioclear) for injection molding technique. These matrices make it possible to perform 3 point curing from buccal, lingual and occlusal sides of the proximal box. As the present study is *in vitro*, such matrices were not used but clinically this technique can show surplus benefit.

Injection molding technique shows many advantages as compared to conventional method of composite placement. In conventional method, the excessive flowable composite as a liner results in significantly more polymerization shrinkage than the paste composite and there is a fuse between the flowable and the paste composite. Air-thinning the resin drives it past the margins, leaving a gingival margin that is not light-cured, may be prone to dissolution and an eventual void, which can be minimized in injection molding technique.

Snow plow technique showed less microleakage compared to control group and sandwich technique. The co-curing of flowable liner and overlying composite together would help to improve the penetration of uncured liner due to hydraulic pressure of overlying heavier viscosity composite, reducing voids and also C-factor which can reduce marginal microleakage [2,10,12]. The results of Tabatabaei SH., *et al.* showed that the amount of microleakage in snowplow method was less compared to conventional method [2]. A study done by Reddy SN., *et al.* showed that applying an ultrathin flowable composite lining with co-curing technique improved the marginal sealing which can be explained as when overlying packable composite undergoes polymerization shrinkage the adjacent flowable composite stretches or elongates and increase the flexibility of the bonded assembly acting as a stress breaker [16].

In contrast, a study done by Yazici., *et al.* [17] showed high microleakage in snow plow method compared to conventional method due to polymerization shrinkage of overlying composite which caused contraction forces and dislodges the bond of uncured flowable composite liner from cavity walls [10,12]. The delay in exposing the adhesive to curing light until the insertion of resin composite, may lead to dentin over etching that leads to deeper demineralization of both intertubular and peritubular dentin [18]. Hence further clinical research is required to confirm to the results of the present study.

Open Sandwich or bonded- base technique where RMGIC or any flexible liner like flowable composite is placed as an initial increment in the proximal box, if the gingival margin is in close proximity or apical to or below the CEJ. There is considerable *in vitro* evidence that bonded base technique results in a reduction of marginal leakage.

In the present study open sandwich technique with flowable composite as liner showed statistically less microleakage when compared to open sandwich technique with RMGIC as liner. This result is in agreement with the studies of Gowda VB., *et al.* [12], KRK Raju., *et al.* [19], JH Payne [20], Al Azzawi HJ., *et al.* [21]. The result could be due to low filler content in flowable composite that enhanced flow, reduced elastic modulus, provides good adaptation to the prepared tooth structure, forms an elastic stress absorbing layer. Flowable composite resin also acts as flexible intermediate layer reducing the C- factor and helps in relieving polymerization shrinkage of the composite resin overlying it [12,21,22]. RMGIC showed more microleakage and this could be due to the particle size and viscosity which is more comparable to flowable composite. RMGIC is a two- component system, hence there are more chances of porosities [12].

RMGIC may be sensitive to dehydration leading to severe loss of water resulting in considerable changes at the tooth restoration interface and bond failure [2,12]. Studies done by Hotta M., *et al.* [23], Peliz MI., *et al.* [24] have reported that using RMGIC liner failed to reduce gap formation and marginal sealing showing similar results as the present study. In contrast, studies done by Kasraei., *et al.* [9], Chuang., *et al.* [25], Dietrich., *et al.* [26] had demonstrated that RMGIC improved the marginal seal and adaptation of direct class II restorations with a sandwich technique. Andersson-Wenckert and others [27] indicated that a noticeable distortion of RMGIC occurred after few years.

Though snowplow and injection molding techniques showed less microleakage than conventional method in the present study, clinically the excess flow of flowable composite may lead to higher percentages of marginal overhangs specially in beveled Class II restorations. Use of proper matrix and wedges should be indispensable in this scenario. In the technique advocated by Dr David J Clark, preheating of paste composite was emphasized which highly improves flow, reducing viscosity and internal gap formation. But preheating of composite resins may cause detrimental effects on the restoration margin as it increases the polymerization shrinkage of the composite resin. In addition, Sabatini., *et al*. found that preheated composite resins did not significantly reduce gap formation at the gingival margin of class II restorations. Once composite is pre-heated, there is a time delay between dispensing it from a syringe or campule, placing it into a preparation, contouring it and subsequently light polymerizing it. It has been estimated that when a composite material is removed from the heating device, the temperature reduces 50% after 2 min and 90% after 5 min [28]. Hence in the present study preheating of composite was not done.

In view of the fact that there is limited literature on the use of Injection molding and snow plow technique further *in vitro* and *in vivo* studies are needed to determine its clinical validity.

Conclusion

Within the limitations of study, none of the groups had totally prevented microleakage at the gingival margin of class II proximal box cavities. In open sandwich technique, a thin layer of flowable composite liner up to 1mm showed better gingival marginal adaptation when compared to RMGIC. Microleakage of packable composite was significantly reduced by co-curing techniques (Injection molding and snow plow technique) when compared to open sandwich technique and the conventional method. Hence, these modified composite lining methods can hold promise in restoring class II preparations to improve adaptation to cavity walls, reducing polymerization shrinkage and microleakage thus enhancing the longevity of resin based restorations.

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