A comparative evaluation of dentinal hypersensitivity and microleakage associated with composite restorations in cavities preconditioned with air abrasion - An *ex vivo* study

Ankit Arora, Shashi Rashmi Acharya, Vidya Saraswathi M., Padmaja Sharma[1]

Abstract

Background and Objective: Enormous advances have been made in adhesives; however, the problem of post-operative sensitivity has dragged along. Enough literature exists on the effect of air abrasion over bond strength of composites. However, not much is reported on its relation with microleakage and post operative sensitivity. Therefore, the aim of the study was to compare and evaluate dentinal hypersensitivity and microleakage associated with composite restorations in cavities preconditioned with air abrasion. **Study Design:** Fifteen patients were selected for the study who had to undergo extractions of both maxillary first premolars. On each patient, occlusally placed Class V cavities were made using rotary burs on both the premolars. On the right side premolar, restoration was done using total etch technique. On the left side premolar, restoration was done in similar way after preconditioning of the cavity with air abrasion. Sensitivity levels were recorded on a modified visual analogue scale preoperatively and post operatively at 1 week and one month time period. Following extraction, dye penetration test was done and 1 sample each from one group was subjected to Scanning Electron Microscope for evaluation of tooth restoration interface. **Results:** Clinically significant difference was there in post operative sensitivity levels after one month between the two groups. Increase in sensitivity was less in teeth restored after preconditioning with air abrasion. Dye penetration was also less in teeth restored after preconditioning with air abrasion. However, penetration at the gingival wall was more than the occlusal wall in both the groups. **Conclusion:** The study consolidates the fact that microleakage and post operative sensitivity are linked directly. It also proves that air abrasion can help in reducing the post operative sensitivity to a level; however, a larger sample size would be needed to obtain more robust results with stronger validation.

Keywords: Air abrasion, microleakage, sensitivity

Introduction

Over the past decade, the use of resin-based dental composite fillings has increased significantly and has become a well-established dental procedure for the direct restoration of anterior and posterior teeth.[1] With the development of improved adhesive and composite systems, resin-based composites have become predictably successful. Improvements in the clinical performance of resin-based composites were made by varying polymerization methods, filler content, particle size and particle composition.[2]

Departments of Conservative Dentistry and Endodontics and [1]Orthodontics and Dentofacial Orthopaedics, Manipal College of Dental Sciences, Manipal University, Manipal, Karnataka, India

Correspondence: Dr. Ankit Arora, Department of Conservative Dentistry and Endodontics, 403, Achal Apartments I, Sama, Vadodara, Gujarat- 390 008, India.
E-mail: aroraankit24@gmail.com

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Postoperative sensitivity, bond strength and microleakage

Despite the improvements in materials and techniques, postoperative sensitivity following composite restoration still remains a problem, especially in posterior teeth.[3] Closely connected with the problem of postoperative sensitivity is the fact that light-cured composites undergo polymerization shrinkage. Volumetric shrinkage of commercially available methacrylate RBC materials has been reported to be in the range of 2-5%.[4] The stresses due to polymerization shrinkage can exceed the strength of the bond with the surrounding tooth structure leading to failure of adhesive joint[5] forming a gap between the composite and tooth.[6] This increases the likelihood of mechanical failure, permitting microleakage[7] and ingress of bacteria, which may result in pulpal irritation or result in enamel microcrack propagation, enamel fracture and cuspal deflection.[4] Marginal microleakage may provoke sensitivity due to the interfacial hydrodynamic phenomenon.[8] Postoperative sensitivity may resolve within first few weeks[9] or can persist for long time and lead to failure of restoration.[10]

Air abrasion and its role in conditioning

It has been reported that airborne-particle abrasion is an alternative conditioning method of enamel and dentin surfaces in lieu of acid etching in adhesive procedures prior to the application of an adhesive system.[11] Tooth surface preparation with airborne-particle abrasion may produce higher bond strength values for restorative materials to both enamel and dentin.[12] However, the surface prepared with airborne-particle abrasion is covered by a smear layer.[13] Use of acidic conditioner prior to application of resin is necessary to remove the smear layer created by the airborne-particle abrasion to obtain good bonding, because the smear layer can prevent diffusion of the monomers into the tooth structure.[14] Roeder *et al*.[15] reported that preparation of tooth structure by airborne-particle abrasion does not alleviate the need for chemical conditioning of the tooth before bonding. Bond strength of composite to enamel and dentin is increased when treated with air abrasion, acid etching and subsequent bonding with an adhesive[15,16] but the bond strength is inadequate when adhesive is used on air abraded enamel without etching.[17]

By using air abrasion one can achieve better bond strength which can lead to reduced microleakage and less postoperative sensitivity. The above assumption holds a stand because trends have been observed. In a microleakage analysis of pit and fissure sealants it was revealed that acid etching in combination with previous air abrasion can prevent sealant leakage.[9] Other studies have also concluded that air abrasion leads to reduced microleakage[18] and improved longevity[16] of restoration.

Sufficient literature is not there for the effect of air abrasion on postoperative sensitivity. This study evaluated the postoperative sensitivity and microleakage associated with composite restorations placed following conditioning with or without air abrasion using an *ex vivo* design.

Materials and Methods

Recruitment of participants

A total of 15 patients between 15 and 30 years of age who were indicated for extraction of both maxillary left and right first premolars due to orthodontic reason were recruited. Approval from Institutional ethics committee was taken.

Inclusion criteria

Non carious tooth with healthy gingival tissues. Tooth should not have any pulpal or periapical pathology. Scheduled for extraction of maxillary premolars after a period of one month due to orthodontic reasons.

Exclusion criteria

Preprocedural sensitivity. Using desensitizing tooth paste. Taking any analgesic or anti-inflammatory drugs regularly. Airway disorders. Dust allergy or allergy to materials used in this trial. Psychological and Neurological diseases.

Allocation of teeth

With 15 patients selected, having both right and left maxillary premolars to be extracted, the total number teeth available were 30. Two groups were formulated. In each patient, left side maxillary first premolar was included under Group A and right side maxillary first premolar was included under Group B. In both the groups, occlusally placed Class V cavities (Depth - 1.5 mm, Width - 5 mm, Occluso cervical extent - 3 mm, to maintain uniformity dimensions were evaluated at 6 points) were prepared on the labial surface and restored with Filtek Z250 (3M ESPE, St Paul, MN, USA) but the method of tooth conditioning before the restoration was different.

Group A - Conventional total etch technique incorporating use of etchant (Eco-etch, Ivoclar Vivadent) followed by application of bonding agent (Adper Single bond, 3 M ESPE, Minnesota).

Group B - Preconditioning of cavity with air abrasion Microetcher ERC (Danville materials, San Ramon, CA) followed by total etch technique similar to Group A.

Preoperative records

Initially both maxillary first premolars were isolated using rubber dam, then each tooth was tested with an ice stick applied to the buccal surface for 20 seconds or until the patient sensed the stimulus. The response was recorded on a modified visual analog scale individually for each tooth along with the response time in seconds.

Preconditioning (Enamel and dentin)

In all the subjects, cavities prepared in maxillary left I premolars were air abraded with 50 micrometer aluminium oxide using Microetcher ERC (Danville materials, San Ramon, CA) at 60 psi in 3 parallel strokes for 3 seconds each. The sand trap which was used helped in maintaining a constant distance between the nozzle and cavity surface.

Restoration

Following air abrasion on left maxillary first premolar, both the cavities were etched, followed by placement of a uniform layer of bonding agent which was light cured for 30 seconds. Microhybrid light activated resin composite Z250 was inserted using an incremental placement technique. Finishing was done using Soflex discs (3 M dental products).

Follow up records

In the follow up, one week and one month postoperative records for each patient were taken in the same manner as described above. The marked scale of preoperative measurement was shown to the patient to reduce the patient's perception error.

Extraction of the teeth

In each patient, both the maxillary first premolars were then extracted after one month as planned. The extractions were done as atraumatically as possible.

Dye leakage test under vaccum

14 teeth each from both the groups were subjected to this

test. The entire tooth was coated with 2 application of nail varnish, except for 1 mm around the restoration margins [Figure 1]. 2% Rhodamine B-dye was used for this test. Samples were subject to vacuum pressure of 50 mm for half an hour in a Vaccum Oven (Osworld JRIC-8) and then left undisturbed for next 24 hrs. After removal of the teeth from the dye solution, the surface adhered dye was rinsed in tap water. Teeth were then sectioned faciolingually through the center of each restoration with a diamond disc. Each section was examined at the occlusal and gingival margins using a stereomicroscope (Binocular Motic SMZ-168) at ×25 magnification. Staining along the tooth restoration interface was recorded by the same examiner, according to the following criteria:

0=No evidence of dye penetration

1=Dye penetration along the occlusal/gingival wall to less than half of the cavity depth

2=Dye penetration along the occlusal/gingival wall to more than half of the cavity depth, but not extending on to the axial wall

3=Dye penetration along the occlusal/gingival wall to the full cavity depth, but extending on to the axial wall

Depending on the scores of dye penetration the microleakage of specimens was evaluated.

SEM evaluation

One tooth each from group A and group B was sectioned facio-lingually from the center of the tooth using diamond disc. The prepared specimens were then mounted on aluminum stubs and sputter coated with ~20 nm of gold-palladium and subjected to Scanning electron microscope (JEOL JSM-6380LA) at ×1200 magnification. The tooth restoration interface was analyzed to check the adaptation of the composite material to differently treated tooth surfaces.

Statistical analysis

Frequency and percentage were used to summarize microleakage scores. The scores across occlusal and gingival walls for each group were compared initially. Following which, the scores across occlusal walls of both the Groups and Gingival walls of both the groups were compared separately.

For postoperative sensitivity, repeated measures ANOVA was used to calculate the difference between the two groups.

Results

Postoperative sensitivity

Repeated measures ANOVA was used to find the difference in sensitivity scores between the two groups at baseline, 1 week postoperative and 1 month postoperative.

Table 1 summarizes the means (in Modified VAS score) of tooth sensitivity in response to cold stimulation at three time points of two groups. Preoperatively, there was no clinically significant difference between the sensitivity levels considering the difference in clinical significance is 20 on a visual analogue scale. At one month recall, a clinically significant difference was seen in sensitivity scores of maxillary right first premolar, which were restored without preconditioning with air abrasion. As reported above, preoperatively, mean of sensitivity scores was 11 and at one month recall it was 37.6, the difference in the above values is more than 20. However, at all the recall periods, the difference in sensitivity score between the two groups was not significantly different clinically.

Figure 2 depicts the graphical representation of the postoperative sensitivity over the study period. P value for testing trend of sensitivity scores across right and left side is $P=0.188$.

Microleakage

Table 2 shows that only 1 of the 14 sections of Group A examined for occlusal wall showed leakage beyond axial wall. Whereas, 9 of the 14 sections examined for gingival wall showed complete leakage extending beyond the axial wall.

Table 3 shows that 11 of the 14 sections of Group B showed no leakage at the occlusal wall. Whereas, only 5 sections showed no leakage at the gingival wall.

The above findings clearly suggest that the leakage at the gingival walls were more than the occlusal walls in both the groups. Additional conditioning of the cavity with air abrasion did not help in reducing the leakage at the gingival margins.

Table 4 shows that only 3 of the 14 sections examined for group with air abrasion preconditioning showed leakage. Whereas, for the other group, 6 of the 14 sections showed leakage. One of which showed complete penetration of the dye beyond the axial wall.

Table 5 summarizes the dye penetration scores of the gingival wall between the two groups. It was seen that out of 14, 5 sections showed no leakage at all for the group with air abrasion preconditioning. Whereas, for the other group, only 1 section showed no leakage. Only 3 sections of former group showed complete leakage compared to 9 sections for the latter group.

It is clear from the above results that overall microleakage was less for the group in which air abrasion was used to condition the walls. Though the difference is not statistically significant considering the sample size, it is provides clinically relevant information.

Figure 3 – 5 depict the stereomicroscopic images of the dye penetration along the tooth restoration interface according to scores given to them based on the scoring criteria.

Scanning electron microscope

On tracking the tooth restoration interface along the enamel

Table 1: Means of tooth sensitivity at three time points between two groups

	N	Minimum	Maximum	Mean	Std. deviation
GpA					
Pre-op	14	2.00	39.00	11.0714	12.31300
One week	14	2.00	61.00	30.2857	18.22268
One month	14	2.00	90.00	37.6429	29.67155
GpB					
Pre-op	14	2.00	46.00	12.7143	14.60995
One week	14	2.00	61.00	25.0714	19.17316
One month	14	3.00	96.00	28.3571	25.76702

Table 2: Dye penetration scores of the group A between the occlusal and the gingival walls

Gingival (Group A)	Occlusal (Group A)			Total
	1.00	2.00	4.00	
1.00	1	0	0	1
2.00	1	1	0	2
3.00	1	1	0	2
4.00	5	3	1	9
Total	8	5	1	14

Table 3: Dye penetration scores of the group B between the occlusal and the gingival walls of the cavity

Gingival (Group B)	Occlusal (Group B)		Total
	1.00	2.00	
1.00	4	1	5
2.00	4	0	4
3.00	1	1	2
4.00	2	1	3
Total	11	3	14

Table 4: Dye penetration scores of the occlusal wall between the two groups

Occlusal (group A)	Occlusal (group B)		Total
	1.00	2.00	
1.00	6	2	8
2.00	4	1	5
4.00	1	0	1
Total	11	3	14

Table 5: Dye penetration scores of the gingival wall between the two groups

Gingival (group A)	Gingival (group B)				Total
	1.00	2.00	3.00	4.00	
1.00	0	0	0	1	1
2.00	0	0	1	1	2
3.00	1	1	0	0	2
4.00	4	3	1	1	9
Total	5	4	2	3	14

and dentin, following findings were noted:

1. There was no difference in the adaptation of composite to enamel in both the groups.
2. In the Group A tooth, gaps were found at the interface between dentin and the composite [Figure 6]. In the Group B tooth, no gaps could be found on the interface between dentin and composite [Figure 7].

Discussion

In the current study, the effect of air abrasion preconditioning was evaluated on postoperative sensitivity and microleakage consequent to placement of composite restorations in occlusally placed class V restorations.

The cavities prepared were occlusally placed class V cavities, to avoid any effects of the extraction forceps contact with the restoration during the time of extraction after one month.

Polymerization shrinkage of composites can lead to failure of adhesive unit.[3] Following placement and light irradiation, the freeradical polymerisation of methacrylate based monomers is accompanied by the closer packing of molecules leading to bulk contraction. The post-gel contraction of the resin based composites is constricted by the strength of the adhesive bond at the tooth/restoration interface and as a result polymerization shrinkage may be manifested as shrinkage stress.[4] The resultant stress may compromise the synergism between the tooth/restoration interface.[7] If the force created surpasses the bond strength, it will lead to marginal microleakage[19] which can provoke sensitivity.[20] The given explanation might be the reason for results obtained in this study.

Evaluating different composite resins, Hannig and Femerling observed that the combination of air abrasion and adhesives systems resulted in a gap-free adaptation between composites and dentin in most cases.[21] It has been proved that airborne-particle air abrasion increases the shear bond strength of composite to enamel and dentin.[12] Tensile bond strength of composite material to enamel is also increased following air abrasion and acid etching.[22] However, air abrasion alone without acid etching does not increase the bond strength.[17] Thus a combination of air abrasion and acid etching was used in anticipation of solving the problem of microleakage and postoperative sensitivity following

Figure 1: Application of nail varnish

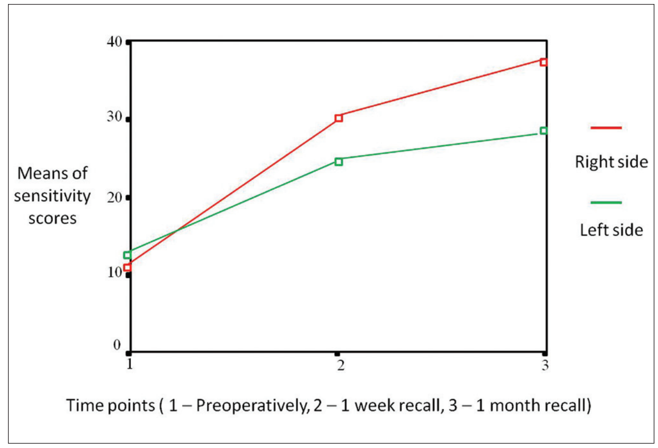

Figure 2: Graphical representation of the means of the sensitivity scores between the two groups

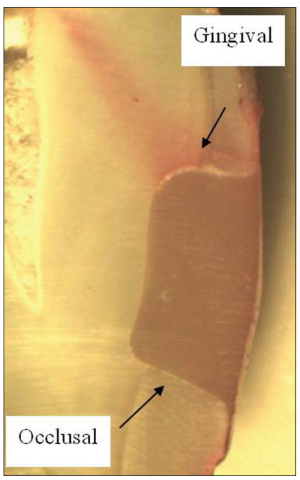

Figure 3: Score 3- for gingival wall, Score 0- for occlusal wall

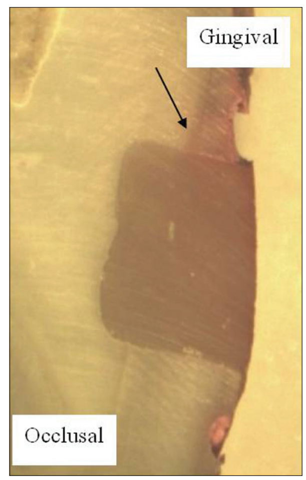

Figure 4: Score 1- for gingival wall

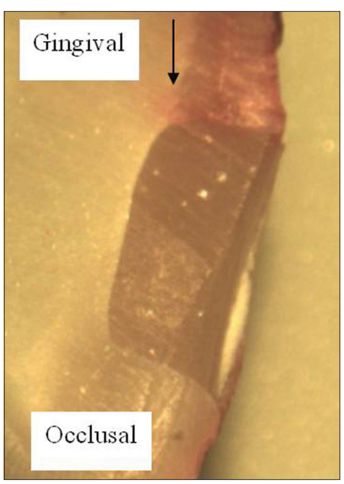

Figure 5: Score 2- for gingival wall

composite restorations. *Ex vivo* study design allowed to assess the postoperative sensitivity and microleakage associated with the restorations challenged by the oral environment for a month.

Airborne-particle abrasion produces a rough irregular surface with increased surface area,[23] thereby increasing the shear bond strength of composite to enamel and dentin.[16,12] It has also been reported that airborne-particle abrasion increases the wettability of tooth structure, provides additional mechanical retention to the adhesive system similar to etched enamel,[24] and enhances the effectiveness of the dentin adhesive system.[25] Canay *et al.*[22] analyzed the tensile bond strength of composite resin to enamel and observed that the highest tensile strength was obtained with air abrasion followed by acid etching.[26] The main advantages of higher bond strength are better retention in cavities in dentin without the aid of mechanical undercuts, and inhibition of gap formation leading to microleakage.[27] Similar conclusions can be extrapolated as an explanation to reduced microleakage seen in this study in teeth treated with air abrasion and acid etching before composite restorations. Results of the study showed that microleakage was less prevalent in teeth in which air abrasion was used for preconditioning the cavity. Also, under SEM, it was seen that margin of composite against dentin was not gap free where

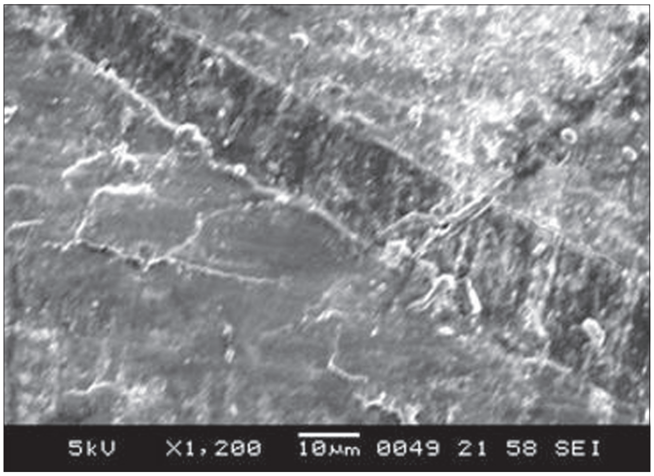

Figure 6: Gap at the interface of composite and dentin

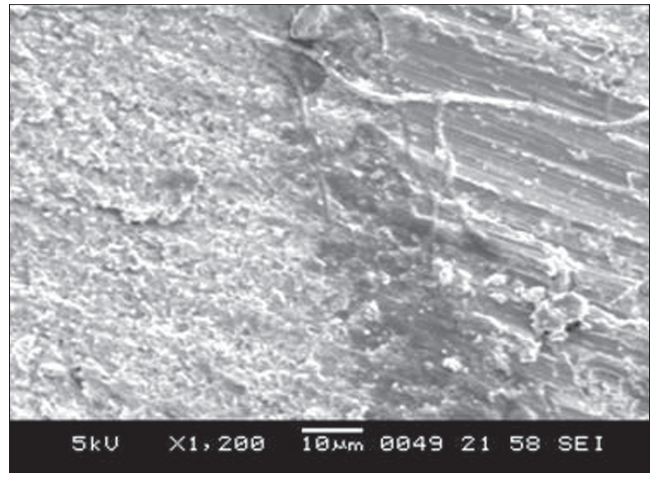

Figure 7: Intimate adaptation seen at the interface of composite and dentin

air abrasion was not used; however, this cannot be concluded from this study with conviction because of the insufficient sample size. It is also said that round margins obtained due to air abrasion help in reducing polymerization stress and marginal microleakage,[28] however, extrapolation of these findings into results of this study cannot be validated with conviction since the initial cavity preparation was done using rotary burs in the present study.

In this study, initially, cavity preparation for both the groups was done using traditional high speed rotary instrument because this technique is simple, relatively clean and quick.[28] It has been observed that preparations with air abrasions do not present precise and clearly identifiable outlines.[29] Thus, in the present study, an attempt was made to combine the advantages of both high speed cutting and air abrasion.

Microleakage was seen to be more along gingival wall as compared to the occlusal wall in both the groups in this study. In the present study, since the cavities were occlusally placed, even the gingival margins were in enamel. Thus the difference in microleakage values cannot be attributed to morphological and structural differences of substrate (Dentin/ cementum) as has been reported in earlier studies.[30] The reason can be attributed to the role of occlusal stresses in normal function and parafunction in generating stresses in the cervical region leading to deterioration of the margin and microleakage,[31] also that the thickness of enamel at the gingival margin was less as seen on stereomicroscope. Other than the oral environment related factors, several differences between the physical properties of teeth and restorative materials including polymerization shrinkage, the coefficient of thermal expansion, and modulus of elasticity can contribute to microleakage.[32,33] However, in the present study other factors were constant since the materials used in both the groups were same only the methodology was different.

Postoperative sensitivity was seen to be less prevalent in teeth which were preconditioned with air abrasion. Over a period of one month, a clinically significant increase was seen in sensitivity levels on application of cold stimulus in the other group. This could be attributed to the increased microleakage, considering that cavity depth was standardized, materials used were same for both the groups, preoperative sensitivity levels were not significantly different.

Since the study required a follow up of one month, only those subjects could be selected who were scheduled for extraction of both right and left maxillary first premolars for orthodontic reasons after a period of one month. This led to limited sample size.

One month recall period is justified by the fact that patients who present with postoperative sensitivity within first month of placement of restoration are more likely to have failed restorations within the first five years of them being placed.[3] It has been reported that most postoperative sensitivity usually disappears within 30 days after restoration,[34] however, Murray *et al*.[35] concluded that because the reparative processes commence after approximately 28 days,[36] reduction in sensitivity caused by bacterial microleakage is reduced after 57 days of restoration placement. But before this time, the sensitivity generally leads to apprehension among the patients. As seen through the results of the present study that use of air abrasion in preconditioning the cavity before composite restoration can lead to reduction in postoperative sensitivity, hence lead to lesser complaints by patients.

Moreover, treatment of persistent postoperative sensitivity may consequently require replacement of filling, which in turn increases cost of treatment, chair side time and excessive use of trained man power time.

Polymerization shrinkage forms a gap under the restoration, it is then filled with dentinal fluid within the first 24-36 hrs.[37] When that particular tooth is subjected to either hot or cold stimulus, as in this study ice stick was used, fluid contraction and expansion in that gap occurs, which causes fluid movement within the dentinal tubules and therefore leads to postoperative sensitivity.[38]

2% Rhodamine B dye was used because it presents a greater diffusion on the human tooth than methylene blue dye.[39] Also, the molecules of Rhodamine B dye are small and nanometric and are optimal to stimulate enzymes and toxins of leakage resulting from bacterial metabolism.[40] Dye leakage was conducted under vacuum pressure because studies have reported that vacuum pressure decreases the volume of entrapped air and allows complete dye penetration.[41]

In *in vivo* studies, inconsistency arises due to interoperator variability, as skills, competence, and experience of the operators may vary.[37] And since the sample size was limited as well, primary investigator was the only operator.

Al-Omari and others[42] showed that short-term (2-30 days) postoperative sensitivity was affected by lesion depth. Also, as concluded by Auschill *et al*., only cavity depth was significantly associated with the appearance of postoperative sensitivity.[43] Thus, in the present study, utmost care was taken to standardize the depth of the cavity. The depth was evaluated at 6 points on the floor of the cavity using periodontal probe.

50 μm alumina particle were used as it is well-known that surface roughness increases with the abrasive particle diameter[44] and there appears to be an increase in bond strength when surfaces are abraded with larger diameter particles.[45] Baiping *et al*.[46] concluded that enamel surface air abraded with 50 μm particles is more receptive to the placement of the composite resin than that air abraded with 27 μm aluminum oxide particles. However, many studies showed no difference in microleakage (or bond strength) due to abrasive particle size effects.[47]

Class V restorations were chosen for this study because microleakage results in marginal discoloration,[48] and marginal discoloration was cited as reason for almost one-third of replacements for class V restorations.[49]

An ideal restorative material would provide high bond strength and eliminate microleakage, but the relationship between bond strength and microleakage is not clearly understood. Logically, bond strength and microleakage should have an inverse relationship, and it has been proved as well,[50,51] but the literature also hints on a poor correlation between these parameters.[51-53]

Conclusion

Clinically significant difference was there in postoperative sensitivity levels after one month between the two groups. Increase in sensitivity was less in teeth restored after preconditioning with air abrasion. Dye penetration was also less in teeth restored after preconditioning with air abrasion. However, penetration at the gingival wall was more than the occlusal wall in both the groups.

The study consolidates the fact that microleakage and postoperative sensitivity are linked directly. It also proves that air abrasion can help in reducing the postoperative sensitivity to a level; however, a larger sample size would be needed to obtain more robust results with stronger validation.

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