Original Article

Estimation of the effect of acetone- or ethanol-based solvents on shear bond strength of composite resin using air- and blot-dry techniques

Deepti Jain, Sanjeev Kunhappan, Diksha Maheshwari, Manisha Goyal, Arushi Agarwal, Ankita Roy

Department of Conservative Dentistry and Endodontics, Government Dental College, Raipur, Chhattisgarh, India

Abstract

Background: An adequate amount of water is necessary to maintain the shape of collagen fibrils while excess water hampers dentin–resin bonding. Air-drying lacks control while blot-drying displaces water in a controlled manner. Solvents in adhesives affect the configuration of collagen fibrils. Thus, the present study aimed to compare the influence of air- or blot-drying methods on shear bond strength (SBS) of acetone- and ethanol-based adhesives.

Materials and Methods: Thirty-six extracted noncarious third molars with similar crown heights were selected. Teeth were decoronated and randomly divided into two groups: after acid etching, Group I was treated with acetone-based adhesives and Group II with ethanol-based adhesives. They were again subdivided into subgroups A (blot-dried) and B (air-dried) containing nine samples each. Dentin surfaces were etched and rinsed. After the respective drying method, adhesive application and composite buildup were done. SBS was measured. The data were subjected to statistical analysis.

Results: Acetone-based adhesive showed the highest SBS in both drying methods. Further, blot-dried dentin produced significantly higher SBS than air-dried dentin.

Conclusion: Solvent type and drying methods have an effect on the bond strength of total-etch adhesives to dentin. Acetone-based adhesives used with blot-drying techniques showed the best results.

Keywords: Acetone solvent; blot-dry technique; dental adhesives; ethanol solvent; shear bond strength

INTRODUCTION

With advancements of conventional etching and bonding techniques, there is an attempt to overcome the difficulties and limitations of the previous generations of dental adhesives and etchants. With better techniques and formulations, the shear bond strength (SBS) has improved for composite restorations. For better results, the use of appropriate techniques and methodology is of utmost importance. The solvents present in the adhesives are responsible for the infiltration of resin monomers into dentin surfaces. Another consideration is rinsing the tooth after etchant application; as it has an effect on the bonding of resin onto the tooth. Thus, not only the composition of the bonding agent but also, the method of moisture removal is of significance.[1]

When the total-etch technique is used, the water present on the surface of the tooth after drying will affect the dentin matrix and resin polymer bonding, as excess water may adversely affect the properties. The two techniques to dry off the etched dentin after rinsing are air-dry or blot-dry.[2] The common practice of air-drying may not be suitable, as the duration, force, and angulations of compressed air

Address for correspondence:
Dr. Sanjeev Kunhappan,
Department of Conservative Dentistry and Endodontics,
Government Dental College, Raipur - 492 001, Chhattisgarh, India.
E-mail: par_sanjeev@yahoo.co.in

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may produce collapsed collagen fibrils if used aggressively. At the same time, if appropriate removal of water is not performed, it will affect the final restoration. To prevent this, blot-drying may be used to control the amount of water removal.[3]

The solvents which have been present in commercial bonding agents are ethanol- or acetone-based.[4] These solvents cause demineralization resulting into the exposure of collagen that will interact with resins in dentin bonding agents. If adversely altered, the interlocking between collagen and bonding agents will be distorted leading to restoration which lacks bond strength.[5-7] Collagen collapsed after the use of phosphoric acid may be re-expanded by the ethanol solvents increasing the surface area available for the formation of a hybrid layer.[8] This re-expansion of collagen helps in maintaining the shape of fibrils, especially when used with wet-bonding technique. However, if excess water remains, the bonding of dentin–resin interface will be compromised.[9]

This problem of excess water can be reduced using acetone solvents. Acetone is capable of removing water effectively, as it is highly dipolar in nature[10] leading to evaporation of residual water, hence the name "water chaser."[11] It may remove excess water which can result in the collapsing of collagen fibril, thus lesser surface area is available for mechanical interlocking.[12]

Thus, the present study aimed to evaluate the effects of organic solvents (acetone or ethanol) on SBS of composite resin, applied after dentin was air- or blot-dried.

MATERIALS AND METHODS

The study was conducted [Figure 1] on extracted human maxillary and mandibular third molars [Figure 1a] of approximately equal size. The samples were obtained from the department of oral and maxillofacial surgery. An attempt to obtain freshly extracted teeth not stored in any medium previously was done. The teeth were cleaned of any soft-tissue tags and hard deposits. Thirty-six extracted molars were considered study samples calculated using G Power software version 3.1.9.7 (Heinrich-Heine-Universitat Dusseldorf, Dusseldorf, Germany). *A priori* analysis was done for two tails with an effect size of 0.91 keeping the confidence interval and power at 95%. The sample size obtained for the study was 36, which were divided equally into 4 groups with 9 samples in each group.

The teeth included were devoid of any carious lesion, broken or chipped off enamel and dentin, and did not have any cracks. The teeth with any developmental anomaly were excluded. They were stored in 0.1% thymol at 4°C for 14 days. They were embedded in chemically cured acrylic resin up to cementoenamel junction for better maneuver. The superficial enamel at the occlusal surface was removed using model trimmer [Figure 1b] exposing a flat dentin surface. This exposed dentin was used as a reference plane. Deep dentin was reached by cutting 2 mm from the reference place using a low-speed diamond disc [Figure 1c] under tap water. Specimens that showed any visible pulp exposures were excluded. The dentin surface was polished using 600-grit wet silicon carbide paper for 30 s to create smear layer at every side. They were then divided into two groups with two subgroups having nine samples each [Figure 1d].

Group I – Acetone-based adhesive was used (Prime and Bond, Nanotechnology dental adhesive, Dentsply Sirona) [Figure 1e].

- Group IA – Blot-dry method was used
- Group IB – Air-dry method was used.

Group II – Ethanol-based adhesive was used (Te-Econom Bond, Ivoclar Vivadent, Universal adhesive) [Figure 1f].

- Group IIA – Blot-dry method was used
- Group IIB – Air-dry method was used.

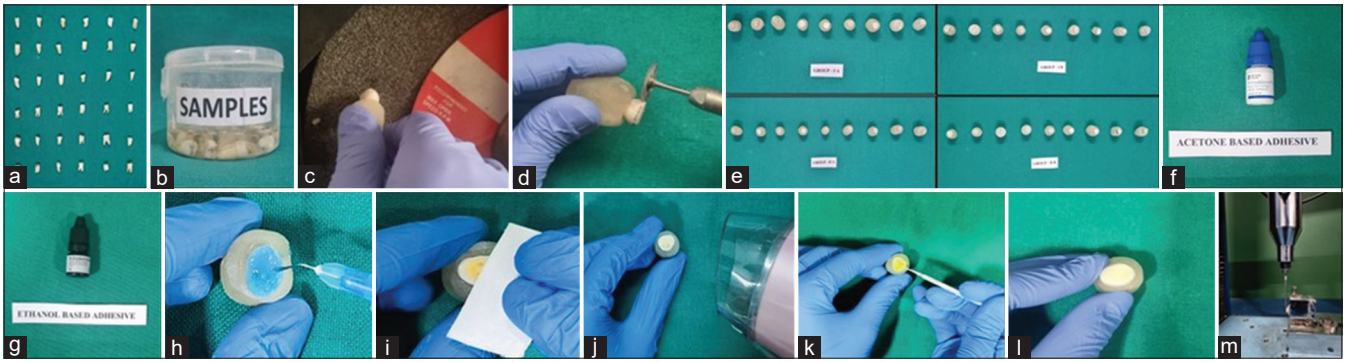


Figure 1: Figure showing various steps used in the study. (a) Extracted 3rd molars, (b) samples stored in 0.1% thymol, (c) Reference plane, (d) Deep dentine reached, (e) Samples prepared for each group, (f) Acetone-based adhesive, (g) Ethanol-based adhesive, (h) Etching, (i) Blotting paper used to dry dentin, (j) Hair dryer used to dry dentin, (k) Bonding agent application, (l) Composite build up, (m) Universal testing machine

All procedures were performed by single operator. The dentin was first etched [Figure 1g] using 37% phosphoric acid (Super Etch, SDI Inc., Bensenville IL, USA) for 15 s and then rinsed for 15 s. After that, a blotting paper [Figure 1h] was used to remove excess water in samples for blot-drying leaving the dentin visibly moist. In air-drying, a hair dryer was to provide compressed oil-free air with gentle stream at 45° angle horizontally from a distance of 10 cm for 5 s [Figure 1i]; the surface was still visibly moist. Respective bonding agents were applied with the applicator tip as per the manufacturer's instruction [Figure 1j] and were light-cured with BLUEDENT LED smart light-curing unit for 20 s. The surfaces were checked for appropriate application and curing of the bonding agent. A Teflon molding was done for composite application. Then, composite buildup was done at 2 mm increments [Figure 1k] and cured for 20 s after each increment. The prepared specimens were stored in distilled water at 37°C to simulate natural oral conditions for 24 h before testing SBS. Universal testing machine (ACME Engineers, India) was used to measure SBS which was expressed in MPa [Figure 1l]. A guillotine blade was used horizontally along with the couple. It glided up and down to engage the composite stub on dentin–resin interface. A speed of 0.5 mm/min was maintained.

The data were tabulated in Microsoft Excel and were subjected to the statistical test of one-way ANOVA [Table 1] and Tukey HSD [Table 2] test at a probability level of 0.05 using the Statistical Package for Social Sciences (SPSS 15.0, SPSS Inc., Chicago, IL, USA). The data were normally distributed as per Levene's test for homogeneity.

Table 1: Descriptive statistics (one-way ANOVA) of shear bond strengths of all the groups

SBS	Mean	SD	Significant
Group IA (acetone-based – blot-dried)	3.228	0.383	0.001*
Group IIB (acetone-based - air-dried)	2.557	0.622	
Group IIA (ethanol-based – blot-dried)	2.33	0.420	
Group IIB (ethanol-based - air-dried)	1.905	0.300	

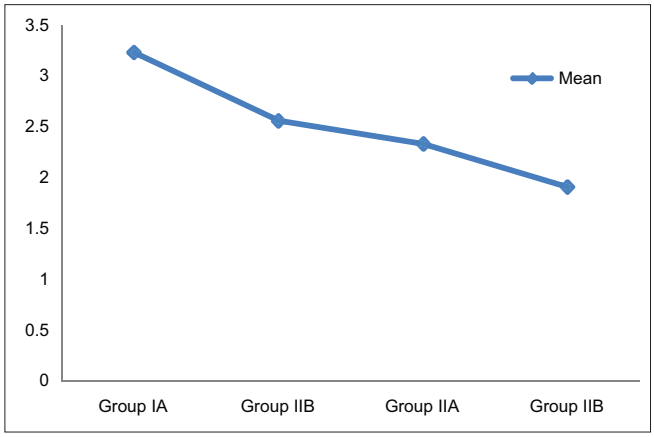
*P=0.001, HS, HS - highly signifcant p<0.05, statistically significant. SD: Standard deviation, SBS: Shear bond strength

RESULTS

The results were expressed in terms of mean difference [Table 1 and Graph 1] and intergroup comparison [Table 2] of the SBS obtained after load testing. The maximum SBS was obtained for Group IA and the minimum was obtained for Group IIB. Group I has shown better SBS as compared to Group II. The difference was statistically significant. There was a significant difference among the two groups. The blot-drying has better SBS as compared to air-drying group which was observed as the SBS of Group IA was greater than Group IB (mean difference = 0.67) and that of Group IIA was greater than Group IIB (mean difference = 0.42). The difference was statistically significant. Furthermore, there was a significant difference between Group IA and Group IIA (mean difference = 0.89) and Group IB and Group IIB (mean difference = 0.65).

DISCUSSION

The study was done to compare two different hypotheses, whether acetone-based or ethanol-based solvents will be having better SBS and whether air- or blot-drying will have better bond strength. The result showed that acetone-based solvents when used with blot-drying technique, showed the highest bond strength. The null hypothesis was rejected as there was difference in bond strength obtained.



Graph 1: Graph showing mean shear bond strength obtained

Table 2: *Post hoc* Tukey comparing the mean shear bond strengths of all four groups

		Multiple comparisons (Tukey HSD)				
(I) Group	(J) Group	Mean difference (I–J)	SE	Significant	95% CI	
					Lower bound	Upper bound
Group IA	Group IB	0.67111	0.21095	0.016*	0.0996	1.2426
	Group IIA	0.89889	0.21095	0.001*	0.3274	1.4704
	Group IIB	1.32333	0.21095	0.001*	0.7518	1.8949
Group IB	Group IIA	0.22778	0.21095	0.704	−0.3438	0.7993
	Group IIB	0.65222	0.21095	0.020*	0.0807	1.2238
Group IIA	Group IIB	0.42444	0.21095	0.205	−0.1471	0.9960

*P=0.001, HS, HS - highly signifcant p<0.05, statistically significant. SE: Standard error, HSD: Honestly significant difference, CI: Confidence interval

The formation of hybrid layer requires ionization of acidic monomer to cause demineralization of dentinal fibrils. It was noted that solvents tend to form an azeotropic mixture allowing the perfusion of monomers into dentin and thus helping in the formation of resin tags.[13] It suggests the necessity of water in the solvents. However, the presence of excess water will dilute the concentration of adhesive and may remain in the openings of tubules affecting the resin–dentin interface.[14] Furthermore, lack of water will lead to shrunken collagen fibrils causing incomplete dentin–resin bonding, making the restoration fracture prone as there will be an incomplete polymerization reaction and the unpolymerized monomer molecule will weaken the dentin surface by continuous demineralization.[15,16]

The properties of solvents are based on their vapor pressure and boiling temperature. Acetone-based adhesives have a high vapor pressure, high volatility, and low boiling temperature as compared to ethanol-based adhesives. Acetone tends to get evaporated completely by air-drying method as compared to ethanol.[17] However, in the present study, air-drying was done to the extent that visibly moist dentin was still seen which is referred to as "wet-bonding technique." The acetone being the water chaser must have removed more water as compared to ethanol resulting in better SBS. Acetone is less viscous as compared to ethanol resulting in more penetration into dentinal tubules. When dentin is excessively air-dried, acetone will not be able to expand the collagen fibrils, and the hydrogen bonding required at the dentinal interface will suffer.[18] This could be the reason why the result of blot-drying technique was better than that of the air-drying technique in the present study.

The acetone used in the present study had nanoparticles in it. It is possible that the nanoparticles may have filled the gap in the hybrid layer if present leading to effective bonding. Similar results were obtained in the study done by Usha *et al*.[19] Ethanol-based solvents contain water as cosolvents. They cause demineralized collagen fibrils to maintain their shape to form an effective hybrid layer.[20,21] These solvents tend to have effective bonding when air-drying method is employed,[22] however, the present study had the opposite effect where blot-drying was found to be more effective. It was evident that both the solvents have more vapor pressures than water and thus they evaporate faster. When this happens, the concentration of monomers in the bonding agent is increased, further reducing the vapor pressure of the solvents. It makes evaporation of remaining solvents on the surface difficult. When the residual solvent is present, areas of incomplete polymerization will cause voids in the dentin–resin interface causing low final bond strength.[23,24]

Another relevant finding of the study is that SBS in the blot-drying group was superior to that in the air-drying group. This was in agreement with the study done by Umino *et al*. where they suggested that prolonged drying will result in the removal of water more than required and hence decreased bond strength.[25] Da Silva *et al*. also showed that wet dentin produces better bonding than dry dentin.[26] Although in the present study, air-drying was used for 5 s from a distance of 10 cm but controlling the airflow is difficult. The air-drying method is unable to effectively remove the excess water. The blot-drying method is better suited for this, as the removal of water is uniform and more controlled in manner. This could be the possible explanation of the results obtained as blot-drying method will have better control in removing the water.[27] This was in contrast to the results of Pereira *et al*. where the bonding was seen to be more effective when air-drying was applied for 30 s.[28] Another study advocated 3 s of air-drying over blot-drying produces improved results.[29]

The result of the study has paved the way to effectively use the most common solvents to achieve a stronger bond in the composite restoration. The study did not employ microscopic analysis which could exactly explain the type of bonding being achieved. The effect of storage to assess long-term effect was done, thus further study can be opted for evaluating the effectiveness in the long run using advanced technology.

CONCLUSION

Within the limitation of the present study, it can be suggested that the blot-drying method provides better strength to both acetone- and ethanol-based solvents. Acetone-based solvents can be better to use in clinical conditions where moisture control could be a problem.

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Conflicts of interest
There are no conflicts of interest.

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