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Evaluation of the Effect of Tooth Surface Wetting and Bond Strength of Composite-an *In vitro* Study

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Abstract

Adhesive restorations have become integral part of routine dental treatment. To achieve clinical success with such restorations, it is of clinical importance to ensure good bonding between this restoration and tooth surface. Bonding to dentin is far more challenging. Bond between dentin and dentin bonding adhesives is greatly influenced by: (1) Surface condition of dentin (moist/dry); (2) Chemical nature of dentin bonding agents. The present study has been designed: (i) to study the effect of various conditions (moist/dry) of dentin on bonding with dentin bonding agents; (ii) to compare the strength achieved by dentin, bonding agent of different systems (water/acetone based). This study was conducted to evaluate the effect of tooth surface wetting on shear bond strength of composite. Freshly extracted central incisors were taken. Cavities were prepared in middle 1/3 of teeth. Teeth were divided in groups A,B,C depending on their surface treatment (wet, semi dry, dry surface) and again in to sub groups depending on whether they are treated water based or acetone based dentin bonding agents(scotch bond, prime bond NT, clear fil SE) . All the cavities in samples were filled with composite and light cured. Composite was debonded from teeth by Instron machine. Debonded samples were scanned and micro graphed under SEM. From the observations made, statistically analyzed and duly discussed, following conclusions are drawn:

1. Optimal water content is necessary for achieving good bonding between dentin and composite.
2. Water based dentin bonding agents, show maximum shear bond strength with dentin in dry conditions.
3. Acetone based dentin bonding agents show maximum shear bond strength with dentin in wet conditions.

Overview of the results shows that moisture plays a vital role in bonding of composite with dentin. Optimal water should be present for better bonding of dentin with composite. If dentin is in dry stage, then water based dentin-bonding agents should be used as they produce best results in dry conditions and if dentin is in wet state then acetone based dentin-bonding agents should be used as they produce best results in wet conditions.

Introduction

Adhesive restorations become a very important part while doing full mouth rehabilitation case. To achieve clinical success with such restorations, it is of clinical importance to ensure good bonding between this restoration and tooth surface.

Speaking about adhesion to tooth substances, we need to distinguish the difference between enamel and dentin. Enamel is mainly composed of hydroxyapatite crystals and bond between enamel and resin has been one of the strongest bonds achieved within tooth substance.

Bonding to dentin is far more challenging as it is composed of apatite crystals embedded in collagen matrix. Lower bond strengths to dentin are the result of a number of factors:

1. Dentin contains less mineralized tooth structure and more water than does the enamel.

2. The presence of smear layer makes wetting of dentin by the adhesive more difficult. Even when good wetting occur, stress cause by polymerisation shrinkage of resin can pull the resin away from tooth structure causing microporosity1. Bonding between dentin and composite resin is not strong enough to overcome the stress of polymerization shrinkage.

3. Fluid in dentin tubules reduces the stability of composite resin to dentin bond.

It is widely accepted that bonding to dentin relies on penetration of adhesives in to the collagen fibers and encapsulation of irregular hydroxyapatite crystals at the bottom of decalcified area, which created the resin reinforced interdiffusion zone called hybrid layer [1,2].

Bond between dentin and dentin bonding adhesives is greatly influenced by:

(1) Surface condition of dentin (moist/dry) [3,4].

(2) Chemical nature of dentin bonding agents [5,6].

The present study was designed: (i) to study the effect of various conditions (moist/dry) of dentin on bonding with dentin bonding agents; (ii) to compare the strength achieved by dentin bonding agent of different systems (water/acetone based) under different conditions of dentin. Structure of samples was also studied under SEM after it was debonded from composite.

Material and Methods

Materials used for holding sample

1. Freshly extracted non carious central incisors[1]

2. Physiologic saline → was taken to store the teeth.

3. Brassdie of 15 mm × 20 mm → was prepared to hold the sample in self polymerising resin.

4. Self polymerising resin[2] Dappen Dish

5. Mixing spatula

[1] Kurary Dental, Japan
[2] 3M Dental Products

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Equipment used for preparing the cavity

1. Airotor hand piece [3]

2. 3 No. 245 bur[4] III- Etchant and different Bonding agents used

3. [35% Phosphoric acid] Etchant [7]

4. Prime bond NT

5. Scotch bond

6. Clearfil SE bond

Material and Equipment used for application of bonding agent, etchant and drying the cavity

1. Paint brush – was used to apply bonding agent on cavity in sample tooth

2. Three way syringe

3. Timer[5]

Composite used and material used for its application and curing

1. Z-100 composite[2]

2. Teflon coated spatula

3. Visible light curing unit[3]

Instruments used for testing the bond strength of composite

Instron[4]: An instron machine was used for testing the bond strength of composite to the sample tooth sample. Instron machine had different calibrations. *Cross head speed of the machine was 1140mm/minute.*

Instrument used for Micrography

1. Supper coater: Used to deposit a uniform gold coat on sample.

2. Scanning electron microscope was used to take pictures of sample after debonding.

Methodology

I. Non carious upper/lower central/lateral incisors were selected and stored in physiologic saline solution

II. Each tooth was held in 15 mm x 20 mm mold of acrylic resin

III. A cavity was prepared on middle third of labial surface of tooth to reach sound dentin structure

IV. Samples were divided in three major groups on the basis of treatment of cavity surface Diagram 1 [8].

V. Cavity in each sample was filled with composite (Z100) and cured for 40 seconds with visible light curing unit

VI. Shear bond strength of composite in each sample was measured with the help of the Instron machine.

VII. All samples were scanned under and then photographed.

One-way ANOVA and level of significance at $p<0.05$ were used for Statistical analysis (Table 1).

Table 2 shows that mean shear bond strength of subgroup A_1 is 11.518 MPa with a standard deviation of 1.9228. Mean shear bond strength of subgroup A_2 is 12.064 MPa with standard deviation of 1.19. Mean shear bond strength of subgroup A_3 is 25.10 MPa with standard deviation of 3.7108. Mean shear bond strength of subgroup B_1 is 13.378 MPa with standard deviation of 1.8175. Mean shear bond strength of subgroup B_2 is 10.226 MPa with standard deviation of 0.7162. Mean

[3]Dentsply International Inc
[4]Instron 1140 (HAL)
[5]Racer, Kadio, Japan

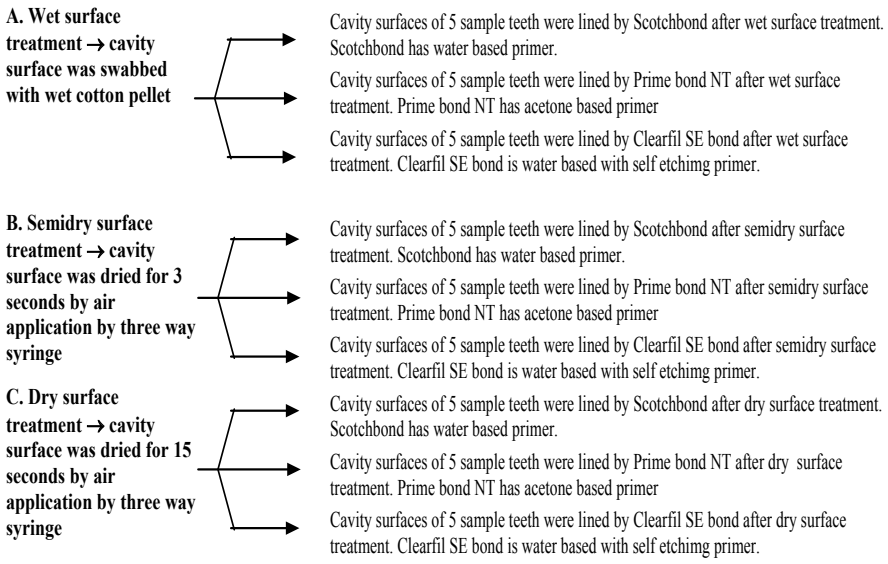

Diagram 1: Methodology.

Group A Wet Surface			Group B Semidry Surface			Group C Dry Surface		
Treated with Scotch Bond (Subgroup A1)	Treated with Prime Bond NT (Subgroup A2)	Treated with Clearfil SE Bond (Subgroup A3)	Treated with Scotch Bond (Subgroup B1)	Treated with Prime Bond NT (Subgroup B2)	Treated with Clearfil SE Bond (Subgroup B3)	Treated with Scotch Bond (Subgroup C1)	Treated with Prime Bond NT (Subgroup C2)	Treated with Clearfil SE Bond (Subgroup C3)

Table 1: Showing Groupwise Distribution of Samples.

shear bond strength of subgroup B_3 is 30.966 MPa with standard deviation of 1.0805. Mean shear bond strength of subgroup C_1 is 20.92 MPa with standard deviation of 0.9550. Mean shear bond strength of subgroup C_2 is 6.13 MPa with standard deviation of 0.7418. Mean shear bond strength of C_3 is 31.06 MPa with standard deviation 1.5962.

Table 3 shows the intergroup comparison of mean shear bond strength, standard deviation and standard error for Subgroup 1 (samples treated with Scotch Bond). It was seen that the mean shear bond strength was highest for Subgroup C_1 followed by Subgroup B_1 and then Subgroup A_1 (Diagram 2). The standard deviation was maximum in Subgroup A_1 followed by Subgroup B_1 and then Subgroup C_1. The standard error was maximum in Subgroup A_1 followed by Subgroup B_1 and then Subgroup C_1.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup C_1 and minimum in A_1 (Tables 4 and 5).

On comparing the mean shear bond strength of subgroup A_1 to subgroup B_1, the mean shear bond strength was higher in subgroup B_1 but it was not significant statistically (p=0.15, NS). However, when subgroup A_1 was compared with subgroup C_1, the mean shear bond strength for subgroup C_1 was found to be significantly higher than subgroup A_1 (p<0.001). On comparing the subgroup B_1 with subgroup C_1, once again the mean shear bond strength for subgroup C_1 was found to be significantly higher than subgroup B_1 (p<0.001).

The above analysis shows the following shear bond strength pattern for the subgroup 1 (treated with Scotch bond) in different groups (Diagram 2):

Subgroup C_1>Subgroup B_1>Subgroup A_1

Table 6 shows the intergroup comparison of mean shear bond strength, standard deviation and standard error for Subgroup 2 (samples treated with Prime Bond NT). It was seen that the mean shear bond strength was highest for Subgroup A_2 followed by Subgroup B_2 and then Subgroup C_2 (Diagram 3). The standard deviation was maximum in Subgroup A_2 followed by Subgroup C_2 and then Subgroup $B_{1\backslash 2}$. The standard error was maximum in Subgroup A_2 followed by Subgroup C_2 and then Subgroup B_2.

	Group A			Group B			Group C		
	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
Shear bond strength in MPa	10.32	10.31	19.0	11.22	10.6	30.6	19.5	6.02	32.0
	12.54	11.81	24.2	14.8	4.2	29.42	20.8	5.8	31.4
	9.1	13.60	28.0	13.65	9.81	31.5	20.4	7.15	29.8
	14.06	12.14	26.8	12.3	11.0	30.98	22.0	5.18	29.1
	11.57	11.90	27.5	12.92	10.52	32.33	21.0	6.5	33.0
Mean	11.518	12.064	25.10	13.378	10.226	30.966	20.82	6.13	31.06
S.D.	1.9228	1.19	3.7108	1.8175	0.7162	1.0805	0.9550	0.7418	1.5962
S.E.	0.8600	0.59	1.6595	0.8179	0.3222	0.4862	0.4298	0.3317	0.2302
n	5	5	5	5	5	5	5	5	5

Table 2: Showing mean shear bond strength with standard deviation and standard error of samples of Group A, B and C.

	A_1	B_1	C_1
Number of samples	5	5	5
Mean	11.518	13.3780	20.82
Standard deviation	1.9229	1.8175	0.9550
Standard error	0.8600	0.8179	0.4298

Table 3: Showing Intergroup Comparison of Shear Bond Strength in Subgroup 1 (Treated with Scotch Bond).

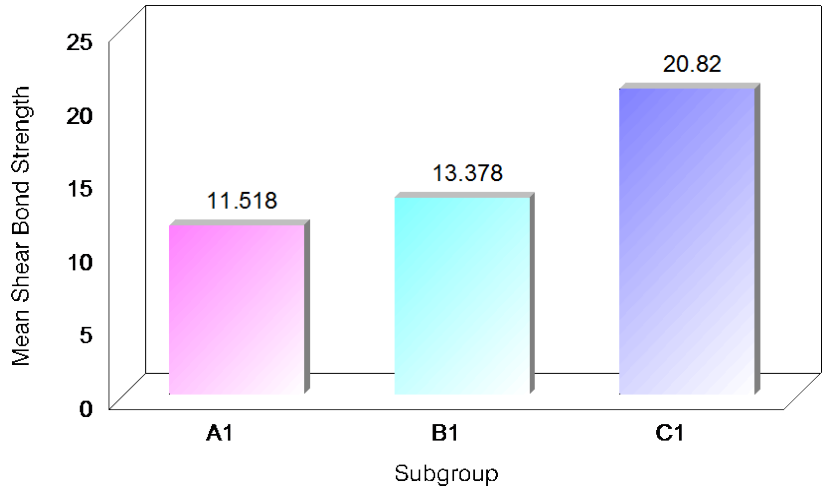

Diagram 2: Shear bond strength pattern for the subgroup 1 (treated with Scotch bond) in different groups: Subgroup C_1>Subgroup B_1>Subgroup A_1.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	242.284	121.142	45.928	<0.001
Within the groups	12	31.652	2.638		
Total	14	273.935			

Table 4: Showing Analysis of Variance of Shear Bond Strength in Subgroup 1 (Treated with Scotch Bond).

Comparison	't'	'p'
A_1 vs B_1	1.57	0.15 (NS)
A_1 vs C_1	9.69	<0.001
B_1 vs C_1	8.11	<0.001

Subgroup C_1>Subgroup B_1>Subgroup A_1

Table 5: Showing Intergroup Comparison of Shear Bond Strength in Subgroup 1 (Treated with Scotch Bond).

	A_2	B_2	C_2
Number of samples	5	5	5
Mean	11.95	10.2260	6.1300
Standard deviation	1.1729	0.7161	0.7458
Standard error	0.5245	0.3222	0.3317

Table 6: Showing Intergroup Comparison of Shear Bond Strength in Subgroup 2 (Treated with Prime Bond NT).

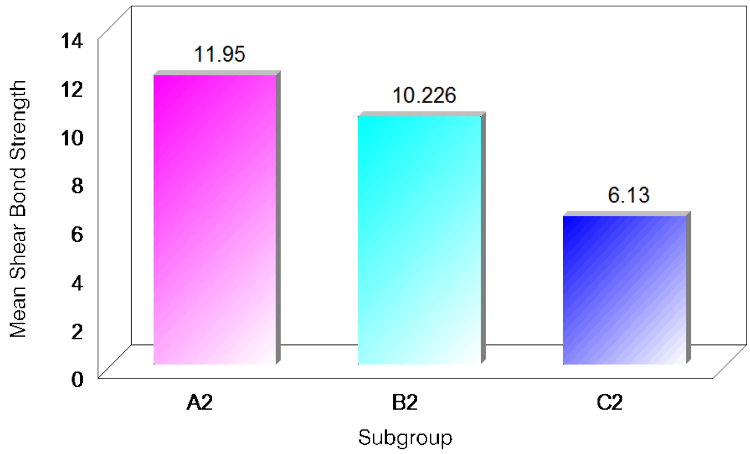

Diagram 3: Shear bond strength pattern for the subgroup 2 (treated with Prime Bond NT) in different groups: Subgroup A_2>Subgroup B_2>Subgroup C_2.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup A_2 and minimum in C_2 (Table 7).

On comparing the mean shear bond strength of subgroup A_2 to subgroup B_2, the mean shear bond strength was significantly higher in subgroup A_2 ($p<0.01$). When subgroup A_2 was compared with subgroup C_2, once again the mean shear bond strength for subgroup A_2 was found to be significantly higher than subgroup C_2 ($p<0.01$). On comparing the subgroup B_2 with subgroup C_2, the mean shear bond strength for subgroup B_2 was found to be significantly higher than subgroup C_2 ($p<0.001$) (Table 8).

The above analysis shows the following shear bond strength pattern for the subgroup 2 (treated with Prime Bond NT) in different groups (Diagram 3):

Subgroup A_2>Subgroup B_2>Subgroup C_2

Table 9 shows the intergroup comparison of mean shear bond strength, standard deviation and standard error for Subgroup 3 (samples treated with Clearfil SE Bond). It was seen that the mean shear bond strength was highest for Subgroup C_3 followed by Subgroup B_3 and then Subgroup A_3 (Diagram 4). The standard deviation was maximum in Subgroup A_3 followed by Subgroup C_3 and then Subgroup B_3. The standard error was maximum in Subgroup A_3 followed by Subgroup C_3 and then Subgroup B_3.

It was observed in SEM of debonded samples that subgroups A_3, B_3, C_3 show cohesive failure in composite. Micrograph of A_3, B_3, C_3 show presence of some composite in debonded area. None of the sample in A_1, B_1, C_1 and A_2, B_2, C_2 show times of cohesive failure. They show adhesive failure. There is no sign of composite in debonded area.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup C_3 and minimum in A_3 (Table 10).

On comparing the mean shear bond strength of subgroup A_3 to subgroup B_3, the mean shear bond strength was significantly higher in subgroup B_3 ($p<0.01$). When subgroup A_3 was compared with subgroup C_3, the mean shear bond strength for subgroup C_3 was found to be significantly higher than subgroup A_3 ($p<0.01$). On comparing the subgroup B_3 with subgroup C_3, the mean shear bond strength for subgroup B_3 was found to be higher than subgroup C_3 but it was not significant statistically ($p=0.91$, NS) (Tables 11-13).

The above analysis shows the following shear bond strength pattern

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	89.370	44.685	54.968	<0.001
Within the groups	12	9.755	0.813		
Total	14	99.125			

Table 7: Showing Analysis of Variance of Shear Bond Strength in Subgroup 2 (Treated with Prime Bond NT).

Comparison	't'	'p'
A_2 vs B_2	2.81	<0.01
A_2 vs C_2	9.38	<0.01
B_2 vs C_2	8.88	0.001

Table 8: Showing Intergroup Comparison of Shear Bond Strength in Subgroup 2 (Treated with Prime Bond NT).

	A_3	B_3	C_3
Number of samples	5	5	5
Mean	25.10	30.97	31.06
Standard deviation	3.7107	1.0800	1.5662
Standard error	1.6595	0.4862	0.7002

Table 9: Intergroup Comparison of Shear Bond Strength in Subgroup 3 (Treated with Clearfil SE Bond).

for the subgroup 3 (treated with Clearfil SE Bond) in different groups (Diagram 4):

Subgroup C_3>Subgroup B_3>Subgroup A_3

Table 14 shows the comparison between mean shear bond strength, standard deviation and standard error for Group A. It was seen that the mean shear bond strength was highest for Subgroup A_3 followed by Subgroup A_2 and then Subgroup A_1. The standard deviation was also maximum in Subgroup A_3 followed by Subgroup A_1 and then Subgroup A_2. The standard error was maximum in Subgroup A_3 followed by Subgroup A_1 and then Subgroup A_2.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup A_3 and minimum in A_1.

On comparing the mean shear bond strength of subgroup A_1 to subgroup A_2, the differences were found to be statistically non-significant. However, when subgroup A_1 was compared with subgroup A_3, the mean shear bond strength for subgroup A_3 was found to be significantly higher than subgroup A_1 ($p<0.001$). On comparing the subgroup A_2 with subgroup A_3, once again the mean shear bond strength for subgroup A_3 was found to be significantly higher than subgroup A_2 ($p<0.001$) (Tables 15 and 16).

The above analysis shows the following shear bond strength pattern for the three subgroups of Group A:

Subgroup A_3>Subgroup A_2>Subgroup A_1

Table 15 shows the comparison between mean shear bond strength, standard deviation and standard error for Group B. It was seen that the mean shear bond strength was highest for Subgroup B_3 followed by Subgroup B_1 and then Subgroup B_2. The standard deviation was maximum in Subgroup B_1 followed by Subgroup B_3 and then Subgroup B_2. The standard error was maximum in Subgroup B_1 followed by Subgroup B_3 and then Subgroup B_2.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup B_3 and minimum in B_2.

On comparing the mean shear bond strength of subgroup B_1 to subgroup B_2, the mean shear bond strength was significantly higher in subgroup B_1 at 99% level of confidence ($p<0.01$). However, when subgroup B_1 was compared with subgroup B_3, the mean shear bond strength for subgroup B_3 was found to be significantly higher than subgroup B_1 ($p<0.001$). On comparing the subgroup B_2 with subgroup B_3, once again the mean shear bond strength for subgroup B_3 was found to be significantly higher than subgroup B_2 ($p<0.001$) (Tables 17-19).

The above analysis shows the following shear bond strength pattern for the three subgroups of Group B:

Subgroup B_3>Subgroup B_1>Subgroup B_2

Table 20 shows the comparison between mean shear bond strength, standard deviation and standard error for Group C. It was seen that the mean shear bond strength was highest for Subgroup C_3 followed by Subgroup C_1 and then Subgroup C_2. The standard deviation was maximum in Subgroup C_3 followed by Subgroup C_1 and then Subgroup C_2. The standard error was maximum in Subgroup C_3 followed by Subgroup C_1 and then Subgroup C_2.

Since 'F' is significant, hence shear bond strength differs significantly in subgroups. It is maximum in Subgroup C_3 and minimum in C_2.

Table 20 Comparison of Shear Bond Strength among the three subgroups of Group C.

On comparing the mean shear bond strength of subgroup C_1 to subgroup C_2, the mean shear bond strength was significantly higher in subgroup C_1 ($p<0.001$). However, when subgroup C_1 was compared with subgroup C_3, the mean shear bond strength for subgroup C_3 was found to be significantly higher than subgroup C_1 ($p<0.001$). On comparing the subgroup C_2 with subgroup C_3, once again the mean shear bond strength for subgroup C_3 was found to be significantly higher than subgroup C_2 ($p<0.001$).

The above analysis shows the following shear bond strength pattern for the three subgroups of Group C:

Subgroup C_3>Subgroup C_1>Subgroup C_2

Debonded samples were studied under SEM. It was observed in SEM of debonded samples that a few samples in subgroups A_3, B_3, C_3 show cohesive failure in composite. Micrograph of A_3, B_3, C_3 show presence of some composite in debonded area.

None of the sample in A_1, B_1 C_1 and A_2, B_2, C_2 show signs of cohesive failure. They show adhesive failure. There is no sign of composite in debonded area.

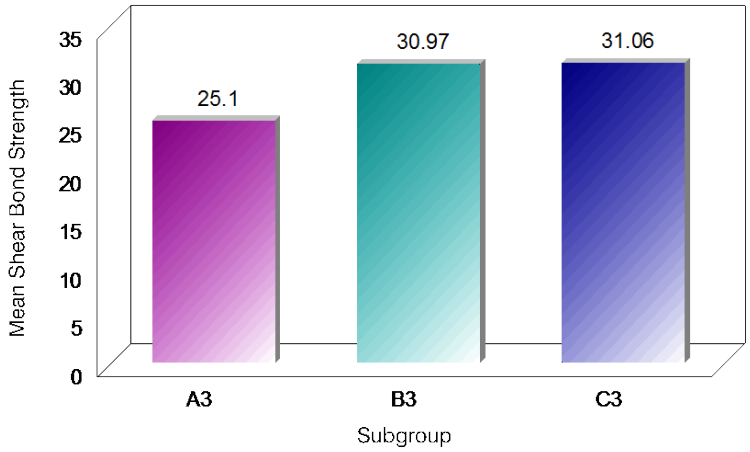

Diagram 4: shear bond strength pattern for the subgroup 3 (treated with Clearfil SE Bond) in different groups: Subgroup C_3>Subgroup B_3>Subgroup A_3.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	116.567	58.284	10.00	<0.001
Within the groups	12	69.942	5.828		
Total	14	186.509			

Table 10: Showing Analysis of Variance of Shear Bond Strength in Subgroup 3 (Treated with Clearfil SE Bond).

Comparison	't'	'p'
A_3 vs B_3	3.39	<0.01
A_3 vs C_3	3.30	<0.01
B_3 vs C_3	0.10	0.91 (NS)

Table 11: Showing Intergroup Comparison of Shear Bond Strength in Subgroup 3 (Treated with Clearfil SE Bond).

	A_1	A_2	A_3
Number of samples	5	5	5
Mean	11.518	12.064	25.10
Standard deviation	1.9228	1.19	3.7108
Standard error	0.8600	0.53	1.6595

Table 12: Showing Comparison of Shear Bond Strength in Group A.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	593.687	296.843	47.159	<0.001
Within the groups	12	75.535	6.295		
Total	14	669.222			

Table 13: Showing Analysis of Variance of Shear Bond Strength in Group A.

Comparison	't'	'p'
A_1 vs A_2	0.48	NS
A_1 vs A_3	7.27	<0.001
A_2 vs A_3	7.51	<0.001

Table 14: Showing Comparison of Shear Bond Strength among the three subgroups of Group A.

	B_1	B_2	B_3
Number of samples	5	5	5
Mean	13.378	10.2260	30.9660
Standard deviation	1.8175	0.7161	1.0805
Standard error	0.8179	0.3222	0.4862

Table 15: Showing Comparison of Shear Bond Strength in Group B.

Discussion

Adhesive restorations have become the inseparable part of dentistry. For, success of these restorations bonding between restoration and tooth surface is of utmost importance. Bonding with dentin is far more complex process. The dynamic variable nature of dentin poses significant challenges to bonding between adhesive restoration and dentin.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	1249.034	624.517	375.952	<0.001
Within the groups	12	19.934	1.667		
Total	14	1268.968			

Table 16: Showing Analysis of Variance of Shear Bond Strength in Group B.

Comparison	't'	'p'
B_1 vs B_2	3.61	<0.01
B_1 vs B_3	18.60	<0.001
B_2 vs B_3	35.78	<0.001

Table 17: Showing Comparison of Shear Bond Strength among the three subgroups of Group B.

	C_1	C_2	C_3
Number of samples	5	5	5
Mean	20.82	6.13	31.06
Standard deviation	0.9550	0.7418	1.5962
Standard error	0.4298	0.3317	0.7002

Table 18: Showing Comparison of Shear Bond Strength in Group C.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F	'p'
Between the groups	2	1570.264	785.132	587.351	<0.001
Within the groups	12	16.041	1.337		
Total	14	1586.305			

Table 19: Analysis of Variance of Shear Bond Strength in Group C.

Comparison	't'	'p'
C_1 vs C_2	27.16	<0.001
C_1 vs C_3	12.31	<0.001
C_2 vs C_3	31.67	<0.001

Table 20: Comparison of Shear Bond Strength among the three subgroups of Group C.

The purpose of this study was to evaluate the effect of various conditions (moist/ dry) of dentin on bonding with dentin bonding agent and to compare the strength achieved by dentin bonding agent of various systems (acetone/water) under different conditions of dentin (moist/dry). Structure of dentin was also studied under SEM after it was debonded from composite.

Several factors complicate the process of bonding of adhesive resins to dentin. Brannstrom in 1993 showed dentinal fluid under positive pressure from pulp may affect diffusion of monomers in to etched dentin. Structural variability of dentin must also be considered. Intertubular dentin which is ideal for formation of Hybrid layer occupies 96% of dentin surface at DEJ and only 12% near pulp [4,9]. Thickness and tenacity of smear layer attachment to underlying dentin surface also affects bonding. Role of moisture is of utmost importance in dentin bonding with adhesive resins [5].

The central incisors were selected for the study as the use of composite restorations is largely done for esthetically purposes. So it will be relevant to study the behavior of dentin-bonding under various conditions (wet, semi-dry, dry) in central incisors which bear utmost esthetic value.

Teeth were held in resin mold of 15 mm x 20 mm [as specified for Instron machine]. A cavity was prepared in middle third of labial surface of tooth for the ease of testing shear bond strength with Instron machine.

No. 245 bur was used to prepare the cavity and was penetrated till 1/3rd to 1/2 of the length of the bur head. This will place the cavity margins within 0.2 mm of dentin and the chances of pulp exposure were minimized.

Now the samples were divided in three groups. Cavities in group A samples were treated by wet surface treatment before applying dentin bonding agent by swabbing the cavity with wet cotton pellet. It was done to observe the effect of bonding of dentin with dentin bonding agent in wet conditions.

Cavities in Group B samples were treated by semi-dried surface treatment before applying dentin bonding agent by drying the cavity for 3 seconds. It was done to observe the effect of bonding of dentin with dentin bonding agent in semi-dried conditions.

Similarly, cavities in Group C samples were treated by dry surface treatment by drying the cavities by 15 minutes to observe the effect of bonding of dentin with dentin bonding agent in dried condition. Cavities in Group C were dried for 15 seconds because when several teeth were dried and time for complete drying of the teeth was observed then the mean time of the drying of the teeth was found to be 15 seconds.

Now Groups A, B and C were further subdivided into subgroups A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2 and C_3.

In subgroups A_1, B_1, C_1 Scotch bond was used to line the cavity surface as it has water-based primer so it could be observed that in what conditions of dentin, dentin-bonding agents with water based primers show maximum shear bond strength 2, 3, 4.

In Subgroups A_2, B_2, C_2 Prime-bond NT was used to line the cavity surface as it is acetone based. So it could be observed that in

what conditions of dentin acetone-based dentin-bonding agents show maximum shear bond strength.

In Subgroups A_3 A_3, B_3, C_3 Clearfil-SE was used to line the cavity surface. Clearfil-SE is also water based but has self-etching primer. Clearfil-SE is placed in sixth generation of dentin-bonding agents. So it can be observed what effect does self-etching primer containing dentin-bonding agent has on shear bond strength with dentin under various conditions.

The choice of dentin-bonding agents served the purpose of the study as it was aimed to observe the effect of various conditions (wet, dry and semi-dry) of dentin on bonding with dentin-bonding agents and comparisons of strengths achieved by various dentin-bonding agents of different systems (water/acetone based) under different conditions of dentin.

After treating the samples by wet, semi-dry or dry surface treatments cavity was filled with Z-100 composite and was light cured. Shear bond strength of all samples were tested using Instron machine.

As shown in Table 5, mean shear bond strength of C_1 was highest followed by B_1 and A_1. It can be explained by the study of Iwami et al. proved that when the water on the dentin surface is less before application of dentin bonding agent, collagen fibers in dentin surface might shrink [8]. Shrinkage of collagen fibers inhibits the infiltration of resin monomers in to dentin and optimal amount of water is necessary to inhibit the shrinkage of collagen fibers. In contrast, excessive water on dentin surface prevents infiltration of resin monomers into the dentin because the concentration of resin monomer in dentin bonding agent decreases. Therefore, optimal water on dentin surface is necessary for the formation of adequate bond strength between resin composite and dentin.

Scotch-bond has water based primer. In wet conditions, it actually over wets the dentin that in turn prevents the infiltration of resin monomers in dentin because the concentration of resin monomers in primer decreases.

In dry condition, Scotch-bond wets the dentin and prevents the shrinkage of collagen fibers, thus helping in better infiltration of resin monomers in dentin.

Table 8 shows that mean shear bond strength of A_2 was highest followed by B_2 and then C_2. It can be explained by the study of Kanca et al. [10,11], which showed that acetone containing dentin bonding agents work well in wet conditions. Acetone present in primer apparently acts as water chasers. Acetone spreads the primer over water coated dentin surface in carried the resin monomer present in primer in to dentin. In addition acetone containing primer on contact with wet dentin surface raise the boiling point of acetone and lower the boiling point of water such that this may enhance removing water in the collagen matrix which in turn exchanges for acetone and finally for the adhesive resins.

Prime-bond NT is acetone based. In wet conditions acetone spreads the dentin bonding agent over water coated dentin surface in carrying resin monomer in dentin.

In dry condition acetone in Prime bond dentin over dries the dentin as acetone is water chaser. So, it causes shrinkage of collagen fibers in dentin and thus minimizes the infiltration of resin monomer in dentin which in turn causes weak bond between dentin and composite.

Table 11 shows that mean shear bond of C_3 was highest followed by B_3 and A_3. It can be explained, as in case of Table 5, as Clearfil-SE is also water-based dentin bonding agent.

High mean shear bond strength [12-14] of A_3, B_3, C_3 as compared to A_1, B_1, C_1 and A_2, B_2, C_2 can be explained by the fact that Clearfil-SE is sixth generation dentin bonding agent whereas Scotch-bond is placed in fourth generation and Prime-bond NT is placed in fifth generation.

These results were in confirmation of earlier studies which prove that optimal amount of water is necessary for dentin for good bonding with composite. Over wetting or over drying both decreases the strength of bond between dentin and composite.

It could be observed from the study that out of subgroups A_1, B_1, C_1, subgroup C_1 showed maximum shear bond strength followed by B_1 and A_1 as Scotch-bond has water based primer and worked best in dry conditions. Of subgroups A_2, B_2, C_2 mean shear bond strength of A_2 was highest followed by B_2 and C_2 as Prime-bond NT is acetone based bonding agent and worked best in wet conditions. Of subgroups A_3, B_3, C_3 mean shear bond strength of C_3 was highest followed by B_3 B_3 and A_3 as Clearfil SE is water-based bonding agent and worked best in dry conditions.

So the water-based dentin-bonding agents work well in dry conditions and acetone based dentin-bonding agents work well in wet conditions.

All the bonded samples were scanned under SEM. A few samples of subgroups A_3, B_3, C_3 showed cohesive failure in composite (Figures 7-9). This shows that the fracture occurred within the composite which

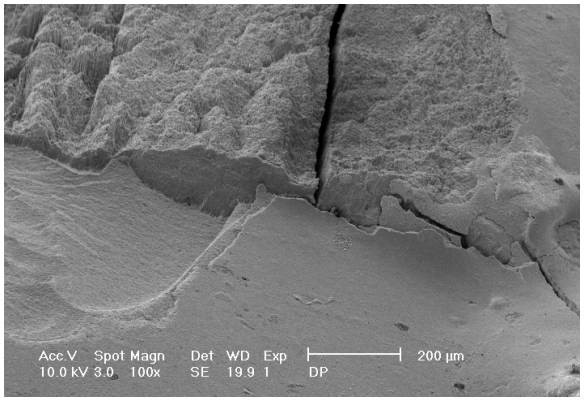

Figure 1: SEM micrograph of subgroup A_1 after debonding.

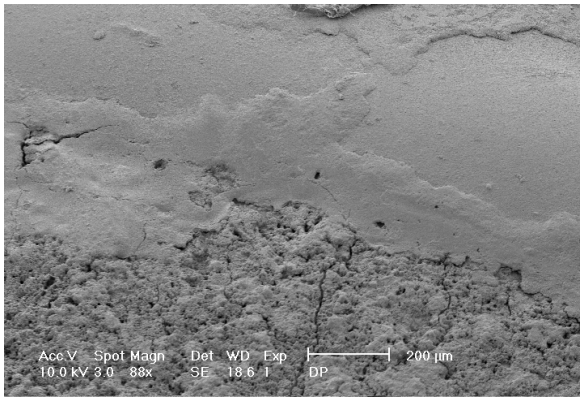

Figure 2: SEM micrograph of subgroup B_1 after debonding.

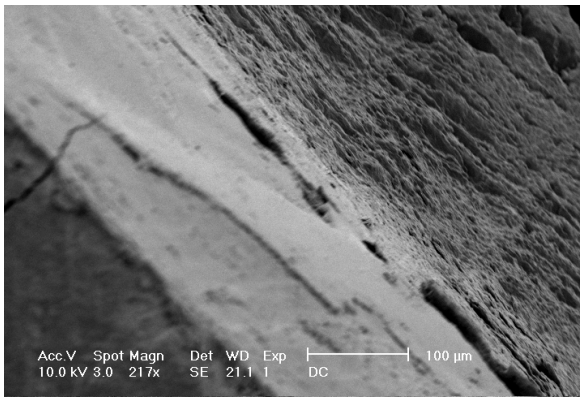

Figure 3: SEM micrograph of subgroup C_1 after debonding.

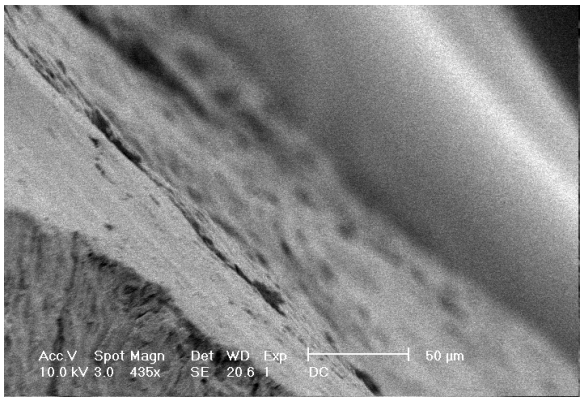

Figure 6: SEM micrograph of subgroup C_2 after debonding.

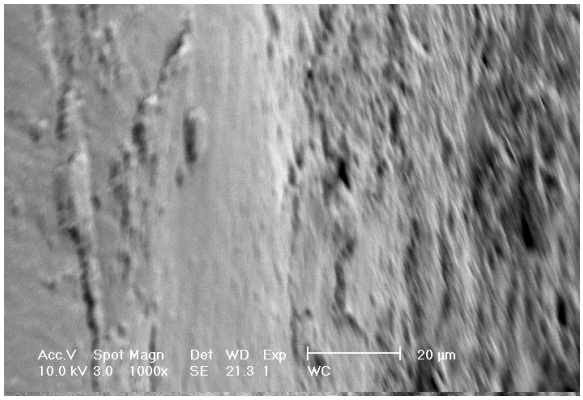

Figure 4: SEM micrograph of subgroup A_2 after debonding.

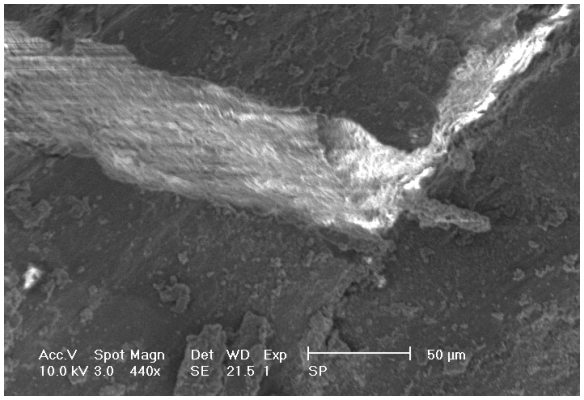

Figure 7: SEM micrograph of subgroup A3 after debonding.

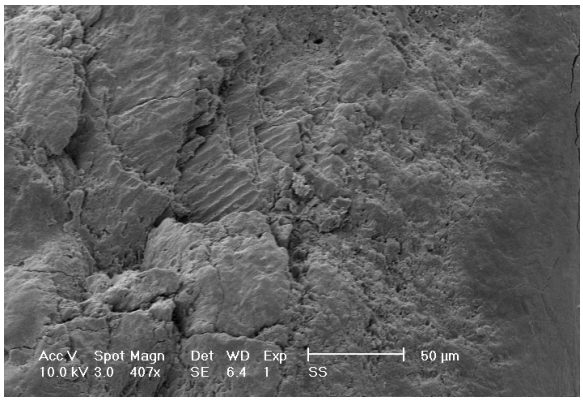

Figure 5: SEM micrograph of subgroup B_2 after debonding.

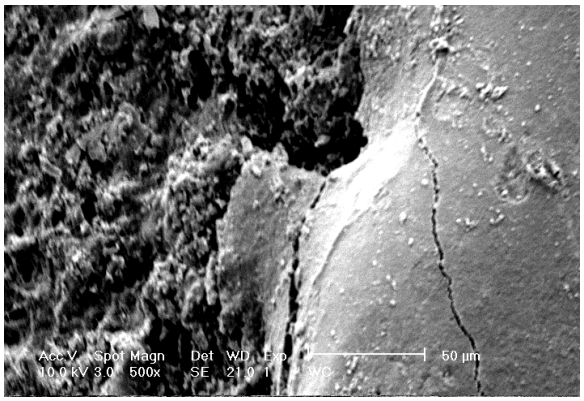

Figure 8: SEM micrograph of subgroup B_3 after debonding.

proves good bonding between dentin and composite. None of the sample showed cohesive failure in composite in subgroups A_1, B_1, C_1 (Figure 1-3) and A_2, B_2, C_2 (Figures 4-6) which show adhesive failures.

This can be explained as the greater strength of the bond formed in sixth generation dentin bonding agent as compared to fourth and fifth generation dentin bonding agents.

Overview of the results shows that moisture plays a vital role in bonding of composite with dentin. Optimal water should be present for better bonding of dentin with composite. If dentin is in dry stage, then water based dentin-bonding agents should be used as they produce best results in dry conditions and if dentin is in wet state then acetone based dentin-bonding agents should be used as they produce best results in wet condition.

Conclusion

From the observations made, statistically analyzed and duly discussed, following conclusions are drawn:

1 Optimal water content is necessary for achieving good bonding between dentin and composite.

2 Water based dentin bonding agents, show maximum shear bond strength with dentin in dry conditions.

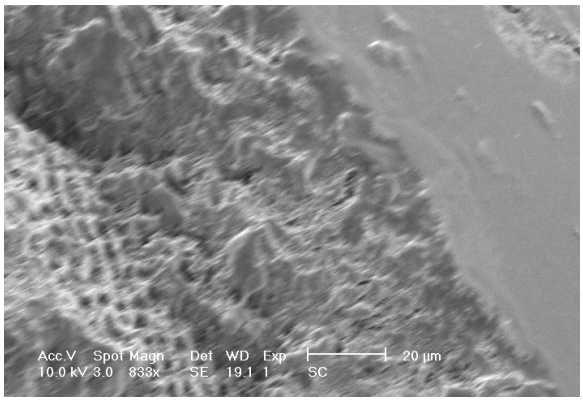

Figure 9: SEM micrograph of subgroup C_3 after debonding.

3 Acetone based dentin bonding agents show maximum shear bond strength with dentin in wet conditions.

Acknowledgement

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