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Original Research Article

An In-Vitro Study to Compare the Shear Bond Strength of Orthodontic Metal Brackets on Bleached Enamel with and without Antioxidant Treatment

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Abstract

Background: Vital tooth bleaching is a safe and well accepted procedure for the treatment of surface and intrinsic staining of teeth. At times, bleaching alone may not be sufficient to achieve required esthetics, need for other procedures such as composite veneers, laminates, etc. may be required. The purpose of this in vitro study was an attempt to regain the lost bond strength, for which, the comparison of shear bond strength of composite resin to bleached enamel was carried out using various antioxidants: 10% sodium ascorbate, rosemary extracts, pedicularis extracts.

Material and Methods: The present study was conducted in the Department of Orthodontics, Chandra Dental College & Hospital Safedabad, Barabanki, Uttar Pradesh from 2017 to 2020 to compare the shear bond strength of orthodontic metal brackets on bleached enamel with and without antioxidant treatment.

Results: 100 recently extracted maxillary first premolars were divided into four groups each having 25 premolar teeth. First group was considered to be the control group and the remaining 75 teeth were bleached and considered as experimental group. Antioxidant (10% sodium ascorbate solution was applied on 25 teeth after bleaching and 25 were stored in artificial saliva for 7 days after bleaching. All the teeth were etched and bonded and then stored in deionised water at room temperature. All the 100 samples were tested for shear bond strength with the help of Instron Universal testing machine. The breaking load at which the bond failure occurred was recorded in kilograms and the bond strength was derived from it using the formula as mentioned previously. Descriptive statistics such as mean, standard deviation and range were determined. The obtained results were then subjected to statistical analysis with one way analysis of variance (ANOVA), Post hoc Tukey HSD test, Mann Whitney test, Kruskal Wallis test, Statistical 2 Sigma technique using SPSS 21 version for windows.

Conclusion: The present study concluded that the brackets bonded to recently bleached teeth have an increased chance of Bond failure. Exposed to an antioxidant prior to bonding does improve the bond strength, although further studies are needed involving the use of antioxidants. In cases where antioxidants are not applied, bonding procedure should be delayed for a week post bleaching.

Keywords: Sodium ascorbate, Orthodontic metal brackets, Antioxidant

Introduction

The basis for the addition of bracket to enamel has been enamel etching with phosphoric Acid which was first introduced by Buonocore [1] in 1955, after certain time of enamel etching has been introduced direct bonding technique as well as indirect bonding technique came up in popularization. Direct bonding technique popularized initially, thus increasing the number of orthodontic cases.

The bonding should be considered as a part of modern preventive package that should also include strict oral hygiene program fluoride supplementation and use of simple yet effective procedure in the field of dentistry [2].

After the introduction of acid etching by Buonocore in 1955, the ideology of bonding various resins to enamel has advanced rapidly in all fields of dentistry including the bonding of orthodontic brackets.

This procedure has several whip hand such as intensified ability for plaque removal by the patient decreased hyper plastic gingivitis elimination for the need of separation, absence of post-treatment band spaces, ease of application of attachments to partially erupted teeth, minimized danger of decalcification with loose bands easier detection and treatment of caries and a much more esthetic appearance for the patient. Newman *et al* [3] first applicated these techniques to direct bonding of orthodontic attachments to the tooth surface. With the increased consciousness of cosmetic dentistry within the society the advent of vital bleaching has also captured the imaginations of the public and the dental profession by offering the option of a whiter and more attractive smile. A brighter smile improves self-esteem, credence and persona, which provides an atmosphere of health to others [4].

Vital tooth bleaching is a safe and well-accepted procedure for the treatment of surface and intrinsic staining of teeth [5]. Now a day's without a prescription bleaching products are now accessible to the general public, including night gel, whitening strips, and many whitening toothpastes. At home whitening systems are effective for treating the superficial enamel layers, such as food staining, mild uniform yellow, orange or light brown discolorations, and also for mild cases of tetracycline staining, fluorosis or enamel mottling.

Haywood and Heymann *et al* [6] (1989) first reported the first patient who applied at-home bleaching system using carbamide peroxide. Since then, various whitening systems have been developed and peroxide compounds at different concentrations are currently being used to bleach enamel.

Also, dentists can provide bleaching products including take home bleaching system as well as many in-office bleaching procedures for vital and non-vital teeth. When vital teeth are bleached, direct contact is established between the bleaching agent

and the outer enamel surface. Several studies have reported the effect of hydrogen peroxide on the structure and the strength of enamel, including morphological alterations, loss of strength, higher solubility, increased oxidation and reduced micro hardness.

Discoloured teeth can be bleached pre or post fixed orthodontic appliance treatment. Carbamide peroxide used in bleaching treatments is a biological oxidant. Carbamide peroxide actualizes the bleaching process by oxidizing the macromolecules of stains quickly and breaks them into smaller fragments, consequently diffusing them across dental surfaces. Langsten *et al* [7] (2002) reported that the bleaching systems that can be used at home normally contains carbamide peroxide diluted to a 10% solution.

Carbamide peroxide breaks down into hydrogen peroxides and urea in aqueous solution, with hydrogen peroxide being the active bleaching agent. A 35% concentration of either carbamide peroxide or hydrogen peroxide is advocated for in-office initiation of dental bleaching followed by at-home bleaching with gels containing 10%, 15%, or 20% carbamide peroxide.

Numerous studies have reported that if an in-office or an at-home bleaching system is used prior to adhesive restorations or before application of resin bonded fixed appliances, the bonding strength to tooth structures is significantly decreased [8]. Few researches revealed that bleaching with 10% carbamide peroxide does not affect orthodontic bond strength, while others report reduction of bond strength.

To get rid of the clinical problems related to post-bleaching compromised bond strength some techniques have been proposed specifically, the removal of a superficial layer of enamel, pre-treating the bleached enamel with alcohol and the use of adhesives containing organic solvents. However, the general suggestion is to reschedule any bonding procedure after the last bleaching session,

Since the reduction of composite resin bond strength to freshly bleached enamel has shown to be temporary by various authors [9]. The waiting period for bonding procedures after bleaching has been reported to differ from 24 hours to four weeks.

If the bond strength reduces on enamel treated with carbamide peroxide as a result of oxidising action, it may be reversed by application of a biocompatible and neutral antioxidant such as sodium ascorbate before application of the resin composite. Lai *et al* [10] (2002) hypothesized that compromised bonding to bleached enamel can be reversed when 10% sodium ascorbate, an antioxidant was applied for 3 hours (at last one-third of the time of the 8 hours bleaching time) to enamel after bleaching with carbamide peroxide. The sodium ascorbate neutralizes the oxidising effect of carbamide peroxide.

Vitamin C derivatives can be used as anti-oxidant agents. Ascorbic acid and its sodium salt are potent antioxidants with the capacity to quench reactive free radicals in biological systems. Studies regarding peroxide-induced oxidation and related harm in biological structures have revealed a protective effect of ascorbic acid in vitro [11].

Material and Methods

The present study was conducted in the Department of Orthodontics, Chandra Dental College & Hospital Safedabad, Barabanki, Uttar Pradesh.

Materials

- Teeth: 100 numbers (maxillary first premolars)
- Stainless steel brackets (0.22 slot MBT platinum series brackets KODEN) (Fig. 2)
- Etchant: 37% phosphoric acid gel (VIVADENT) (Fig. 4)
- Light cure composite: Transbond XT (3M Unitek) (Fig. 3)

- Light cure adhesive primer: Transbond XT(3M, Unitek) (Fig. 3)
- Light curing unit : (IVOCLAR - BLUEPHASE) (Fig. 5)
- Bleaching agent: (ZOOM - DAY WHITE) (Fig. 10)
- Antioxidant: 10% sodium ascorbate (Fig. 8)
- Artificial saliva solution : (WET MOUTH) (Fig. 9)
- Instron Universal testing machine (UNITEK 4467) (Fig. 11)
- Bracket placer, Twiser, Explorer, Mouth mirror (Fig. 1)
- MBT Guage (Fig. 1)
- Metal scale, Pencil (Fig. 1)

Methodology

Teeth selection

100 human maxillary first premolars freshly extracted for orthodontic reasons were utilised for the study. The pre molars were collected and stored in 0.5% aqueous solution of chloramine-T as per the international standards organisation protocol [12].

Chloramine-T was used as a disinfectant to prevent from further cross infections. The criteria for tooth selection included intact buccal enamel, with no caries, enamel defects or crazing/cracks due to the pressure of the extraction forceps. The teeth had no pre-treatment with any chemicals.

Sampling

All teeth well mounted on acrylic blocks of 1 inch height. Care was taken to place the teeth in such a manner that they were debonded with a true shear force on the bracket while the debonding was carried out with an Instron machine. The teeth were randomly divided into four groups of 25 each:

Group 1: control group- the teeth were cleaned with a paste made of fine powder of pumice and deionised water applied with a rubber prophylaxis cup and a low speed conventional hand piece, rinsed for 20 seconds and dried with a mild continuous steam of oil free compressed air. A 37% phosphoric acid gel was applied with a disposable brush for 30 seconds according to the manufacturer's instruction.

The etchant was then rinse and the teeth were dried with oil free compressed air for 15 seconds [2]. The prepared etched surfaces were coated with a thin layer of unfilled resin primer. The primer used also contained the catalyst required for the polymerization reaction of resin system. The brackets were bonded to the conditioned enamel.

The mesh surfaces on the enamel side of the brackets were also covered with a thin layer of primer unfilled resin, following which the adhesive was placed on the bracket base. The brackets were then positioned on the teeth using bracket positioner and press to express the flash. After the removal of the flash with a scaler the Adhesive was cured for 40 seconds (20 seconds from the mesial and 20 seconds from the distal) and all teeth placed in artificial saliva.

Group II: following prophylaxis as in group I, 10% carbamide Peroxide Gel was applied to the enamel surfaces of the teeth for 8 hours in a day [13]. After completion of the daily bleaching procedure the specimens were thoroughly rinsed for 20 seconds and dried with a mild continuous steam of oil free compressed air. They are then Stored in artificial saliva solution. This procedure was continued for a period of one week (simulates patient using bleaching agent every night for one week). Following bleaching the brackets was bonded to the tooth in the same manner as in group 1.

Group III: following prophylaxis as in group 1 the bleaching procedure was carried out in the manner similar to that used in Group II. Following bleaching the antioxidant (10% sodium ascorbate) was dripped on the enamel surfaces of the teeth

and agitated with a sterile brush [14]. After 10 minutes the teeth were washed with distilled water and dried with oil free compressed air. Then the brackets were bonded to the tooth in the same manner as any group I and II.

Group IV: following prophylaxis as in group 1 the bleaching procedure was carried out in the similar manner as in Group II. Following bleaching the teeth was stored in artificial saliva solution at 37 degrees for 7 days to simulate the oral environment [15].

The artificial saliva solution had an electrolyte composition similar to that of human saliva. It was composed of 1 gram sodium carboxymethyl cellulose, 4.3 gram xylitol, 0.1 gram potassium chloride, 5mg calcium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate, and 100 gram distilled deionised water. The artificial saliva solution was changed twice daily during the consecutive 7 day time period. After the teeth were removed from the artificial saliva the enamel surfaces were rinsed and dried with oil free compressed air. Then the brackets were bonded to the tooth in the same manner as in the previous groups.

Determination of the shear bond strength

Experimental debonding of brackets was carried out after immersion in distilled water for 24 hours. Brackets were debonded with an Instron Universal testing machine at CIPET Lucknow that was fitted with a custom jig. The custom Jig allowed the brackets to be debonded with a true shear force (parallel to the buccal surface of the tooth) as described by Fox *et al* [16]. The Jig held the experimental or the control in the following manner:

Upper jig: Shear blade mounted on an acrylic block.

Lower jig: Teeth mounted on an acrylic block.

The Instron machine was used to apply an occlusogingival load via a shear blade, which produced a shear force at a crosshead speed of 1.0 mm/minute. The force (in kilogram) required for each bond failure was recorded digitally. The shear bond strength (SBS) was then calculated with the formula:

$$\text{SBS (in MPa)} = \frac{\text{Nominal load (kg)} \times 9.8}{\text{Bracket base area (9.25 mm}^{2)}}$$

Bracket failure interface study

Following debonding, all the teeth and the bracket bases were examined under 10 x magnifications to determine the bracket failure interface. An adhesive remnant index (ARI) score was determined according to Artun and Bergland [5]. The ARI scores were used as a comprehensive means of defining the sites of bond failure between the enamel and the adhesive; and the adhesive and the bracket base.

Adhesive Remnant Index

The ARI score scale ranges from 0 to 3, where

0= no adhesive left on the tooth,

1= less than half of the adhesive left on the tooth,

2=more than half of the adhesive left on the tooth, and

3= all adhesive left on the tooth, with distinct impression of the bracket mesh.

Statistical Analysis

Formula used

The results were analyzed using descriptive statistics and making comparisons among various groups. Discrete (categorical) data were summarized as in proportions and percentages (%) and quantitative data were summarized as mean ± SD. The following statistics were calculated in the present analysis

The Arithmetic Mean

The most widely used measure of Central tendency is arithmetic mean, usually referred to simply as the mean, calculated as:

$$\bar{x} = \frac{\sum x}{n}$$

The Standard deviation (σ): It is calculated by using the formula

$$\sigma = \sqrt{\frac{\sum x^2}{n} - \left(\frac{\sum x}{n}\right)^2}$$

Anova: The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the means of three or more independent (unrelated) groups. A one way ANOVA is formed as

	Source of Variation	Degrees of Freedom	Mean of Squares	F-Ratio
variance of errors →	Within Groups	n-k	$MS_w = \frac{\sum\sum (x_{ij} - \bar{x}_j)^2}{n-k}$	MS_b / MS_w
variance of factors →	Between Groups	k-1	$MS_b = \frac{\sum n_j (\bar{x}_j - \bar{x})^2}{k-1}$	
total variance disregarding factors →	Total	n-1	$MS_{tot} = \frac{\sum\sum (x_{ij} - \bar{x})^2}{n-1}$	critical F value $F_{(k-1;n-k)}$

Post hoc Tukey HSD Test: The Tukey's honestly significant difference test (Tukey's HSD) is used to test differences among sample means for significance. The Tukey's HSD tests all pairwise differences while controlling the probability of making one or more Type I errors. This is a single-step multiple comparison procedure and statistical test. It can be used to find means that are significantly different from each other after

Mann Whitney Test: The Mann-Whitney U test is used to compare differences between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed. The Mann Whitney U test, sometimes called the Mann Whitney Wilcoxon Test or the Wilcoxon Rank Sum Test, is used to test whether two samples are likely to derive from the same population (i.e., that the two populations have the same shape).

Kruskal Wallis Test: The Kruskal–Wallis test by ranks, Kruskal–Wallis H test, or one-way ANOVA on ranks is a non-parametric method for testing whether samples originate from the same distribution. It is used for comparing two or more independent samples of equal or different sample sizes.

Statistical 2Sigma Technique: Statistical 2Sigma technique was used to find significantly effective groups in comparison to others. p value < 0.05 was taken as significant level.

Figure 1: Armamentarium

Figure 2: Bracket (metal)

Figure 3: 3M transbond xt (adhesive primer & composite)

Figure 4: Etchant (37% phosphoric acid)

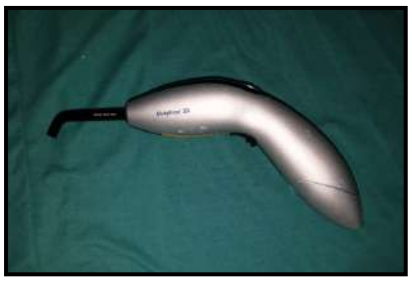

Figure 5: Light curing unit (ivoclar - blue phase)

Figure 6: Tooth mounted on acrylic block

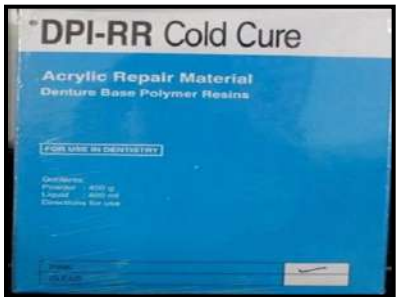

Figure 7: Cold cure (polymer resin)

Figure 8: 10% sodium ascorbate

Figure 9: Artificial saliva (WET from ICPA)

Figure 10: Bleaching agent (zoom – day white 10% carbamide peroxide)

Figure 11: Universal testing machine (instron)

Figure 12: Shear bond testing

Figure 13: Loading of the sample for shear bond testing

Results

Table 1: Intergroup Comparison of Force among the Study Groups

Group	Force in Kg				ANOVA Test	
	Mean	SD	Min.	Max.	F-value	p-value
Group - I	9.18	1.38	7.14	11.14	4.56	0.005
Group - II	7.79	1.28	5.97	9.87		
Group - III	9.04	1.49	6.92	11.02		
Group - IV	9.05	1.32	6.93	11.24		

The mean force (in kg), standard deviations and the range for each group tested are shown in table 1 and in graph 1. It shows that the highest mean force was produced in group I (9.18±1.38 kg) while lowest in group II (7.79±1.28 kg). According to ANOVA test, significant difference was found in mean force among the four groups (p=0.005).

Table 2: Bi-group Comparison of Force among the Group Pairs

Comparison Groups		Force in Kg		p-value!
		Mean Diff.	SE	
Group - I	Group - II	1.395	0.434	0.010

Group - I	Group - III	0.138	0.434	0.989
Group - I	Group - IV	0.135	0.434	0.989
Group - II	Group - III	-1.257	0.434	0.025
Group - II	Group - IV	-1.260	0.434	0.024
Group - III	Group - IV	-0.003	0.434	1.000

Calculated using Post hoc Tukey Test

The bi-comparisons among the group pairs revealed that the significant differences in force were found between the pairs Group I vs Group II (p=0.010, diff=1.395), Group II vs Group III (p=0.025, diff=1.257) and Group II vs Group IV (p=0.024, diff=1.260).

Table 3: Quality Control Analysis of Force for the Study Groups

Group	Force in Kg		
	Force	CL	CU
Group – I	9.18	8.1	9.4
Group - II	7.79	8.1	9.4
Group - III	9.04	8.1	9.4
Group - IV	9.05	8.1	9.4

The mean strength force was maximum in Group I and minimum for group II. The Statistical 2 Sigma analysis shows that the forces of group I, II & IV were found to be equivalent and of average intensity while the mean force of group II was inferior than others as the means of group I, II & IV are lying between the upper and lower 95% confidence lines (CU & CL), while the mean of group II is lying below the lower 95% confidence line (CL). So the groups can be arranged in decreasing order of force as: Group I= Group III= Group IV> Group II.

Table 4: Intergroup Comparison of Shear Bond Strength among the Study Groups

Group	Shear Bond Strength (Mpa)				ANOVA Test	
	Mean	SD	Min.	Max.	F-value	p-value
Group - I	9.73	1.46	7.57	11.81	4.83	0.004
Group - II	8.25	1.36	6.32	10.45		
Group - III	9.65	1.51	7.33	11.68		
Group - IV	9.59	1.40	7.34	11.91		

The mean shear bond strength (in MPa), standard deviations and the range for each group tested are shown in table 4 and in graph 4. It shows that the highest mean shear bond strength was produced in group I (9.73±1.46MPa) while lowest in group II (8.25±1.36MPa). According to ANOVA test, significant difference was found in mean shear bond strength among the four groups (p=0.004).

Table 5: Bi-group Comparison of Shear Bond Strength among the Group Pairs

Comparison Groups		Shear Bond Strength (Mpa)		
		Mean Diff.	SE	p-value!
Group - I	Group - II	1.478	0.454	0.009
Group - I	Group - III	0.075	0.454	0.998
Group - I	Group - IV	0.143	0.454	0.989
Group - II	Group - III	-1.404	0.454	0.014
Group - II	Group - IV	-1.335	0.454	0.022
Group - III	Group - IV	0.069	0.454	0.999

Calculated using Post hoc Tukey Test

The bi-comparisons for shear bond strength among the group pairs revealed that the significant differences were found between the pairs Group I vs Group II (p=0.009, diff=1.478), Group II vs Group III (p=0.014, diff=1.404) and Group II vs Group IV (p=0.022, diff=1.335).

Table 6: Quality Control Analysis of Shear Bond Strength for the Study Groups

Group	Shear Bond Strength		
	Shear Bond Strength (Mpa)	CL	CU
Group – I	9.73	8.6	10.0
Group – II	8.25	8.6	10.0
Group – III	9.65	8.6	10.0
Group – IV	9.59	8.6	10.0

The mean shear bond strength was maximum in Group I and minimum for group II. The Statistical 2Sigma analysis shows that the bond strengths of group I, II&IV were found to be equivalent and of average intensity while the mean force of group II was inferior than others as the means of group I, II & IV are lying between the upper and lower 95% confidence lines (CU & CL), while the mean of group II is lying below the lower 95% confidence line (CL). So the groups can be arranged in decreasing order of bond strength as : Group I= Group III= Group IV> Group II.

Table 7: Intergroup Comparison of ARI Score among the Study Groups

Group	**ARI Score**				**Kruskal Wallis Test**	
	Mean	**SD**	**Min.**	**Max.**	**chi sq**	**p-value**
Group - I	2.60	0.82	0.00	3.00	21.65	<0.001
Group - II	1.30	0.86	0.00	3.00		
Group - III	2.35	0.93	0.00	3.00		
Group - IV	2.40	0.99	0.00	3.00		

The mean ARI, standard deviations and the range for each group tested are shown in table 7 and in graph 7. It shows that the highest mean ARI score was found in group I (2.60±0.82) while lowest in group II (1.30±0.86). According to Kruskal Wallis test, significant difference was found in mean ARI score among the four groups (p<0.001).

Table 8: Bi-group Comparison of ARI Scores among the Group Pairs

Comparison Groups		**ARI Score**			
		Mean Diff.	**SE**	**U-value***	**p-value**
Group - I	Group - II	1.300	0.286	59.0	**<0.001**
Group - I	Group - III	0.250	0.286	169.0	0.414
Group - I	Group - IV	0.200	0.286	179.0	0.583
Group - II	Group - III	-1.050	0.286	84.5	**0.001**
Group - II	Group - IV	-1.100	0.286	80.0	**0.001**
Group - III	Group - IV	-0.050	0.286	190.5	0.799

* Using Mann Whitney Test

The bi-comparisons for ARI score among the group pairs revealed that the significant differences were found between the pairs Group I vs Group II ($p<0.001$, diff=1.300), Group II vs Group III ($p=0.001$, diff=1.050) and Group II vs Group IV ($p=0.001$, diff=1.100)

Table 9: Quality Control Analysis of ARI Score For the Study Groups

Group	ARI Score		
	ARI Score	CL	CU
Group – I	2.60	1.7	2.6
Group – II	1.30	1.7	2.6
Group – III	2.35	1.7	2.6
Group – IV	2.40	1.7	2.6

The mean ARI score was maximum in Group I and minimum for group II. The Statistical 2Sigma analysis shows that the ARI scores of group I, II&IV were found to be equivalent and of average intensity while the mean score of group II was inferior than others as the means of group I, II & IV are lying between the upper and lower 95% confidence lines (CU & CL), while the mean of group II is lying below the lower 95% confidence line (CL). So the groups can be arranged in decreasing order of ARI score as: Group I= Group III= Group IV> Group II.

Discussion

Shear bond strength (SBS) is the main factor, which has to be concerned in the evolution of bonding materials. The bond strength of the orthodontic bracket must be able to withstand the forces applied during the orthodontic treatment.

In the present study, 100 extracted maxillary first premolars were divided into four groups of 25 each. The premolars were collected and stored in 0.5% aqueous solution of chloramine-T as per the international standards organisation protocol [12]. Later they were mounted on an acrylic block. First group was control and the remaining 75 teeth were bleached. Antioxidant was applied on 25 teeth (Group II) after bleaching and another 25 teeth were stored in artificial saliva for 7 days after bleaching (Group IV). All the teeth were bonded and stored in deionised water at room temperature. All the samples were tested with Instron Universal testing machine.

The debonding was then carried out with the shear blade mounted on an acrylic block which delivered the occluso-gingival shear load to the bracket [17]. The shear blade was selected for debonding because the wire loop is not as rigid as the blade to deliver the occlusal gingival load. As recommended by Fox *et al* [16] the wire loop method might have better clinical resemblance and lower dispersion yet they could only be used in a shear pull testing circumstances. In debonding procedures where the bracket is heaved with the use of a wire, the loop hardness adaptation and frictional resistance may complicate the results [18]. Further there is ability to withstand the repetitive load application procedures and consumption of some of the energy given to the system pushes for the use of shear blade method slightly ahead.

The direction of the debonding force with the shear blade was made parallel to the bracket base for all the specimens as it has been pointed out that changes in the direction of the debonding force would influence the actual forces. The breaking load at which the bond failure occurred was recorded in kilograms and the bond strength was derived from it using the formula as mentioned previously.

After debonding was carried out the multiple comparisons of collected data results were analysed with one way analysis of variance, Post hoc Tukey test, Mann Whitney test, Kruskal Wallis test and statistical 2 sigma technique. The descriptive statistics obtained revealed that the mean shear Bond strength of group 1 (control 9.18 ± 1.38kg or 9.73±1.46 MPa) was the highest and mean shear Bond strength of Group II (bleached 7.79 ±1.28Kg or 8.25 ±1.36 MPa) being the lowest. According to ANOVA Test significant difference was found in mean force among the four group (p= 0.005)

When evaluating the mean Shear Bond strengths of all the groups by ANOVA test, a significant difference between all the groups was found.

Group II was bleached with 10% carbamide peroxide for one week prior to bonding, and had mean shear Bond strength of 8.25 MPa compared to the control mean of 9.73 MPa. This is in agreement with findings of Miles *et al* [19] who found that the bleached group (10% carbamide peroxide) had significantly lower mean Bond strength. Turkun and Kaya *et al* [14] (2004) investigated the effect of different concentrations of carbamide peroxide on the shear Bond strength of resin composite to bleached bovine enamel and demonstrated a significant decrease in shear Bond strength caused by 10, 16 and 20 percent carbamide peroxide. That study also showed the reduction in the tensile Bond strength of brackets post bleaching in contrast to a control group.

Bishara *et al* [20] bleached A group of teeth for one week (change to the bleaching agent every 8 hours) and determined shear Bond strength using an instron testing machine. They found no statistical difference between the bleached group (mean shear bond strength of 10.2) and control (mean shear bond strength of 12.3) but interestingly did recommend postponing enamel bleaching until after orthodontic treatment. Bishara *et al* [20] did however use a cross head speed of 0.5mm/min compared to our study that used a crosshead speed of 1 mm per minute. The potential for higher shear Bond strength also exist with faster crosshead speed.

Uysal *et al* [21] found no significant differences between bleached and unbleached group when using 35% hydrogen peroxide. In their study the bleached group was etched with 37% of phosphoric acid gel for 60 seconds prior to the bonding. The bleaching agent was only left in place for a total of 7 minutes with two 3 second exposures to a light source. Once the bleaching agent was rinsed the bonding area was again etched with 37% phosphoric acid gel for 30 seconds. Uysal *et al* [21] used Universal testing machine with a cross head speed of 0.5mm/min. The present study left the bleaching agent on the tooth surface for a longer time period (eight hours) than the study by Uysal *et al* [21]. Perhaps this explains the conflicting results seen in the present study.

It has been suggested that the weak bonding surfaces are related to the enamel surface morphology with varying degrees of surface roughness and structural changes by laws of Prismatic formation. (Cavalli *et al* [22] in 2004). In another study by Titley *et al* [23] in 1992, SEM examinations of interfaces between resin and bleached enamel displayed a granular and Porous aspect with a Bubbly appearance. It has been suggested that these might be due to gaseous bubbling, possibly the result of oxidation of peroxide trapped in the subsurface layer of the enamel. This suggestion is corroborated by the study of Turkun and Kaya [14].

Ascorbic acid and its salts are well known antioxidants that can reduce various oxidative compounds especially free radicals. The sodium ascorbate should be applied for at least one third of the bleaching time (3 hours) for 10% carbamide peroxide

according to Lai *et al* [10]. Kaya and Turken *et al* [14] found 10 minutes of antioxidant treatment to be effective. This time period was used for antioxidant treatment in the present study as it is a beneficial time for clinical situation. The antioxidant was agitated continuously for its enhanced effect on the bleached enamel.

Ascorbic acid and its salts are well known antioxidants and are capable of reducing a variety of oxidative compounds especially free radicals. In contrast to our study C Turkmen et. al [24] concluded that treatment of bleached enamel with 10% sodium ascorbate before bonding was not effective in restoring the reduced shear bond strength of adhesive resin to enamel. These results concur with those of tabatabai *et al* who had shown that the reduced bond strength of composite resin to bleached enamel was not effectively reversed by 10% SA treatment for 5 or 10 minutes.

Group III was bleached with 10% carbamide peroxide for one week and then 10% sodium ascorbate was applied on the enamel surface for 10 minutes prior to bonding. Group III had increased mean shear Bond strength of 9.65 MPa as compared to Group II at 8.25 MPa. This finding is in agreement with Lai *et al* [10] and his use of antioxidant to increase compromised Bond strength after bleaching. With this increase in Bond strength there was no statistically significant difference between Group III and the control group.

Lai *et al* [10] said that the incorporation process of peroxide ions in the apatite lattice might also be reversed by an antioxidant. They also suggested that sodium ascorbate allows free radical polymerization of the adhesive resin to proceed without premature termination by restoring the altered redox potential of the oxidized bonding substrate and hence reverses the compromised bonding. Future investigation will include finding and appropriate concentration and time exposure for sodium ascorbate with different concentrations of the bleaching agent.

The bleached group that was immersed in artificial saliva for one week (Group IV) had a mean Bond strength measurement of 9.59 MPa and is not statistically significant when compared to the control. Previous investigations have demonstrated that immersion of the samples in artificial saliva, distilled water or even saline results in the complete reversal of the reduced enamel bonds [25,26]. The results of the present study are in agreement with those findings assuming that the immersion process is removing the residual oxygen from the bleaching material. Human saliva is supposed to have a similar action after bleaching in the oral environment. The delay period after bleaching required to return the bonding strength to a pre-bleached level is still debated but the commonly suggested delay period is 7 days before a bonding [9]. The present study confirmed that a period of 7 days after bleaching is sufficient to obtain adequate Bond strength.

When comparing all the groups to Reynold [25] Bond strength range of 5.9 to 7.8 MPa to be clinically successful, all the groups I, II, III and IV fall within or above this range. These findings suggest that even though teeth may be bleached with 10% carbamide peroxide they still have clinically acceptable Bond strength.

The ARI score between the bleached group and the other groups were significantly different. ARI score in the present study showed that in the bleached group (Group II), failure was mostly at the resin/enamel interface (ARI score of 1 was the most commonly occurring frequency). The finding is in agreement with that found by Torneek *et al* [27] and Uysal *et al* [21].

This clinical investigation shows that bonding orthodontic brackets to recently bleached enamel does reduce the bond

strength. An antioxidant such as sodium ascorbate (Vitamin C) could somehow be incorporated into a gel and used to reverse the compromised bonding caused by bleaching agents. If no antioxidant is used it is recommended that bonding should not be performed immediately after bleaching. There should be a one week period between bleaching and bonding.

Future studies could further investigate the use of antioxidant such as sodium ascorbate or other remineralizing or desensitizing agent to be used to reverse the compromised bonding seen with bleached enamel. Investigation into antioxidant concentration and exposure time is needed with different concentrations of the bleaching agent.

Conclusion

The present study was conducted with the following objectives:

1. To determine if enamel bleaching affect the bond strength of orthodontic brackets;
2. To determine if an antioxidant such as sodium ascorbate can reverse the compromised bonding;
3. To determine if delaying the bonding procedure after bleaching had any difference from that of antioxidant treatment.

Decreased Bond strength was found on bleached enamel in the present study. Statistically significant differences were found between the bond strength of a bleached and unbleached teeth. The antioxidant sodium ascorbate did reverse the compromised Bond strength. A week of artificial saliva immersion also tended to recover the decreased Bond strength.

Thus the present study concluded that the brackets bonded to recently bleached teeth have an increased chance of Bond failure. Exposed to an antioxidant prior to bonding does improve the bond strength, although further studies are needed involving the use of antioxidants. In cases where antioxidants are not applied, bonding procedure should be delayed for a week post bleaching.

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