Original Article

Effect of Saliva pH on Shear Bond Strength of Orthodontic Brackets

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Abstract
Objectives: The purpose of this study was to evaluate the effect of salivary pH on the shear bond strength (SBS) of orthodontic brackets to tooth surface.
Materials and Methods: Eighty intact premolars were randomly divided into four groups of 20. After bonding a bracket on each tooth, the groups one to four were stored in artificial saliva at a pH of 3.8, 4.8, 5.8, and 6.8, respectively for two months. The artificial saliva solutions were refreshed weekly. Each tooth was then embedded in an acrylic block so that the crown was exposed and its buccal surface was parallel to the direction of the force during SBS testing. All brackets were debonded using Dartec universal testing machine, and the mean values of SBS in different groups were compared using one-way analysis of variance (ANOVA).
Results: The mean SBS value in group one (pH 3.8) was significantly lower than that in other groups ($P<0.05$). The differences between other groups were not significant ($P>0.05$).
Conclusion: Decreased salivary pH due to poor oral hygiene and/or frequent consumption of acidic beverages may be responsible for orthodontic bracket bond failure.
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INTRODUCTION

Orthodontic bracket bond failure is a common problem during orthodontic treatment [1] with a reported incidence of 17.6% [2-4]. Different factors affect the bond strength in fixed orthodontic treatment [5]. The effects of acidic foods, acidic and alcoholic beverages, herbal teas and different chemical solvents on the bond strength of orthodontic brackets have been investigated by researchers [6-9]. Aside from increasing the risk of bond failure, these substances may increase the incidence of caries and periodontal problems and can lead to patient dissatisfaction [10]. Decreased pH and higher lactobacillus and Streptococcus mutans count increase the susceptibility to caries [11]. Following orthodontic bracket placement, number of microorganisms increases by 6-10% [12-14]. Plaque formation in orthodontic patients is two to three times more than in non-orthodontic adult patients with a high dental plaque score [15].

Incidence of caries and gingivitis also increases in orthodontic patients [16,17]. Drop in salivary pH due to plaque formation and bacterial activity is considered the main cause of enamel demineralization [18]. Enamel demineralization starts at a pH of 5-5.5 [19].

The effect of salivary pH on SBS of orthodontic brackets has not been studied. The present study was designed to answer the question whether bond failure of orthodontic brackets occurs more frequently in patients with decreased salivary pH.

MATERIALS AND METHODS

In this in vitro study, 80 intact premolar teeth extracted in the past six months for orthodontic reasons were used.

The teeth were examined under dental unit light to exclude the cracked ones, and washed under running water before storage in distilled water. After collecting the teeth, they were placed in 0.1% thymol solution for one week for disinfection, and then immersed in distilled water again to prevent dehydration. The buccal surfaces were cleaned by dental prophylactic brush under running water, dried, etched with 37% phosphoric acid gel for 30 seconds, rinsed for 20 seconds and dried. A white chalky surface appeared. The buccal surface of the teeth was cleaned using non-fluoridated pumice powder and prophylactic rubber cups for 15 seconds, rinsed and dried with air spray. After cleaning, the teeth were conditioned with 37% phosphoric acid gel (Fine etch Co, Chungcheongnam-do, South Korea) for 20 seconds and dried with oil- and moisture-free air spray until a frosty white appearance was achieved.

Stainless steel standard edgewise premolar brackets (Dentaurum GmbH & Co. KG, Ispringen, Germany) were used in this study. After etching, a thin adhesive resin layer (Unitek, 3M ESPE, St. Paul, MN, USA) was applied to the buccal surface of the teeth and the bracket bases were coated with composite resin (Unitek, 3M ESPE, St. Paul, MN, USA). The brackets were positioned at four-millimeter distance from the buccal cusp tip using a special gauge. After removal of excess composite with a dental explorer, adhesive was cured using light-emitting diode (LED) light curing unit (LED Curing, Morita, Kyoto, Japan) for 20 seconds (five seconds from each of the occlusal, gingival, mesial and distal directions). After bonding, the teeth were randomly divided into four groups. Each group was incubated in artificial saliva with a specific pH in similar conditions for two months. Since the normal salivary pH is 6.8 [19], and the critical pH for enamel decalcification is 5.5 [19], the pH level of solutions for groups one (control) to four was adjusted at 6.8, 5.8, 4.8, and 3.8, respectively. The solutions were refreshed weekly. Artificial saliva was prepared by dissolving 0.4g NaCl, 1.21g KCl, 0.78g NaH_2PO_4, $2H_2O$; 0.005g Na_2S, $9H_2O$ and 1g $CO(NH_2)2$ in 1000mL of deionized distilled water. Buffers were used to adjust pH. The solutions were autoclave sterilized [7]. Each tooth was embedded in self-cured acrylic block, with the crown exposed. The SBS was measured using a Dartec HC10 universal testing machine (Zwick Ltd., Herefordshire, UK) while the buccal surface was parallel to the direction of force at a crosshead speed of 0.5mm/min with a 0.5mm-thick blade.

Table 1. The shear bond strength values in the four groups

	Groups	Range	Mean	SD
1	pH = 6.8	9.65-11.74	10.7	2.24
2	pH = 5.8	8.97-11.21	10.09	2.39
3	pH = 4.8	7.92-9.95	8.94	2.17
4	pH = 3.8	5.16-7.08	6.12	2.04

The SBS was calculated by dividing the force at fracture by the base of the bracket and reported in megapascals (MPa).

After debonding, the enamel surfaces were examined under a stereomicroscope (Carl Zeiss AG, Oberkochen, Germany) at ×10 magnification to evaluate the amount of remaining adhesive. The adhesive remnant on the surface was scored using adhesive remnant index (ARI) of Oliver [20]. This index is scored based on the percentage of adhesive remained on the surface. The scores are: one, 100%; two, more than 90%; three, between 10-90%; four, less than 10%; and five, 0%.

Statistical analysis

Descriptive statistics including the mean and standard deviation (SD) of SBS values were calculated by means of statistical package for social sciences (SPSS) (SPSS for windows, release 10.0.0, Chicago, IL, USA). The Kolmogorov – Simonov test showed normal distribution of data. The ANOVA and Tukey's post hoc test were used for multiple comparisons of SBS between the groups. To evaluate differences in ARI scores, the Kruskal–Wallis test was applied. $P<0.05$ was considered significant for all statistical tests.

RESULTS

The obtained SBS values are shown in Table 1. The highest SBS (10.7 ± 2.24 MPa) belonged to group four (pH of 6.8) and the lowest (6.12 ± 2.04 MPa) to group one (pH of 3.8). There were no significant differences in SBS values among groups one, two and three (10.7 ± 2.24, 10.09 ± 2.39 and 8.94 ± 2.17 MPa, respectively) ($P>0.05$), but group four (6.12 ± 2.04 MPa) showed significantly lower value compared to others ($P < 0.05$) (Table 2).

Descriptive statistics for ARI scores are shown in Table 3. The Kruskal Wallis test revealed significant differences among groups in ARI scores. Bond failure was mostly at the adhesive-enamel interface (scores four and five) in groups one and two, and at the adhesive-bracket interface in groups three and four (scores one and two).

DISCUSSION

In this study, the highest mean value of SBS belonged to group four (pH of 6.8), but this value was not significantly different from that of groups three (pH of 5.8) and two (pH of 4.8).

Having a higher mean SBS value might be related to higher level of pH. Oncag and coworkers in 2005 reported that acidic beverages, by decalcifying the enamel surrounding the brackets, have negative effects on the bond strength at the bracket-enamel interface [7].

Lee and coworkers in 1996 evaluated the effect of liquids, simulating foods and drinks, on SBS of brackets. In their study, extracted intact premolars with bonded brackets were stored in buffered lactic acid with a pH of four, and corn oil for 12 weeks. Their results showed that 50% ethanol and lactic acid with a pH of four caused the lowest SBS [21].

Table 2. Comparison of shear bond strength among groups

	1		2		3		4	
	P-value	Sig	P-value	Sig	P-value	Sig	P-value	Sig
1	-	-	0.824	NS	0.067	NS	<0.001	*
2	0.824	NS	-	-	0.359	NS	<0.001	*
3	0.067	NS	0.359	NS	-	-	0.001	*
4	<0.001	*	<0.001	*	0.001	*	-	-

Ns: Not significant

*: P-value < 0.05

Ulusoy and coworkers in 2009 studied the effects of different kinds of tea on SBS of orthodontic brackets. In their study, 90 intact premolars were assigned to six groups. Four of them were immersed in four different kinds of tea including: black tea, green tea, tea with lime flavor and fruit tea. Two other groups were subjected to a carbonated beverage (Coca Cola), and distilled water as controls. The results showed a direct correlation between the pH of beverages and the SBS of orthodontic brackets [6].

Statistical tests revealed significant differences among groups in terms of ARI scores. The ARI scores showed that in an acidic environment, bond failures were mostly at the bracket-adhesive interface. Softened adhesive compromises the bracket–adhesive interlocking. Acids and acidic beverages may damage bisphenol A glycidyl methacrylate in the composite structure [8,22].

When the resin matrix softens, fillers may become dislodged, decreasing the SBS [8]. Oral hygiene, nutrition, and bonding technique are the most effective factors determining the degree of erosion. Reduction of pH below 5.5 creates a favorable environment for enamel erosion [7]. Steffen stated that the cariogenic activity of bacteria in the oral cavity is accelerated in presence of acidic beverages [23].

In the current study, group one (pH of 3.8) showed the least SBS value, which was significantly different from that of other groups. This study suggests that acidic oral environment, due to poor oral hygiene, malnutrition, and frequent use of acidic beverages, may be the reason of increased incidence of bond failure in these orthodontic patients.

Although Oncag and coworkers showed that only extremely acidic oral environment (pH=2-3) may reduce the SBS [7], in-vitro environment may be different from in-vivo, and also other factors may play roles in reducing the SBS. We can prevent bond failure and its consequences by encouraging patients to maintain good oral hygiene and limit the use of acidic beverages such as Cola.

CONCLUSION

The results of this study showed that:

1- The SBS values of groups two (pH of 4.8) and three (pH of 5.8) were not significantly different from that of group four (pH of 6.8) (control).

2- The SBS value of group one (pH of 3.8) was significantly lower than that of three other groups.

3- This study strongly recommends maintaining good oral hygiene and limiting the use of acidic beverages.

Table 3. Distribution of Adhesive Remnant Index (ARI) scores

Groups	pH	ARI scores					Chi- square	Degree of freedom	Asymptotic p value
		1	2	3	4	5			
1	6.8	-	2	2	9	7	40.949	3	<0.001*
2	5.8	-	1	2	10	7			
3	4.8	5	8	4	2	1			
4	3.8	8	7	3	2	-			

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