Original Article

Effects of Two Soft Drinks on Shear Bond Strength and Adhesive Remnant Index of Orthodontic Metal Brackets

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Abstract

Objective: Bond failure of brackets during orthodontic treatment is a common problem; which results in treatment interference, increased treatment time and prolonged clinical time for rebonding of failed brackets. The purpose of this study was to evaluate the effects of Coca-Cola and a non-alcoholic beer on the shear bond strength and adhesive remnant index (ARI) of orthodontic metal brackets in vitro.

Materials and Methods: Eighty intact human premolars were divided into two experimental groups of Coca-Cola and non-alcoholic beer (Istak), and a control group of artificial saliva. Over a period of thirty days, the test groups were immersed in the respective soft drinks for 5 minutes, twice a day. For the remainder of the time, they were kept in artificial saliva at 37°C. The control group was stored in artificial saliva during the experiment. All samples were subjected to shearing forces using Universal Testing Machine. ARI was determined with a stereomicroscope at ×12 magnification. The data of shear bond strength were statistically analyzed by one-way ANOVA and Tukey's Post-Hoc test and the data of ARI scores were analyzed by Kruskal-Wallis test.

Results: No significant difference was observed in ARIs of the three groups ($P\leq 0.552$). The shear bond strength of Coke group was significantly lower than that of the two other groups ($P\leq 0.035$); but there was no significant difference between the shear bond strength of Istak and the control group ($P\leq 0.999$).

Conclusion: Coca-Cola decreased the shear bond strength of orthodontic brackets.

Key Words: Soft drinks; Shear strength, Adhesive; Remnant; Index

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INTRODUCTION

Bond failure of brackets during orthodontic treatment is a common problem [1]; which results in treatment procedure interference, increased treatment time and prolonged clinical time for rebonding of failed brackets.

Incidence of bracket bond failure varies from 0.5% to 17.6% [2-4].

Various factors affect bond failure including poor operator technique, enamel surface texture, salivary contamination of the prepared enamel surface, bracket properties, masticatory forces and patient's behavior [5-8]. Acidic and alcoholic foods and beverages may influence bond failure [9-12]. There are also a number of factors affecting bracket retention during orthodontic treatment [13] such as the condition of enamel surface [14].

Soft drinks are commonly used by the adolescents and this habit often continues into adulthood [1]. Soft drinks can be carbonated or noncarbonated; both types are harmful due to their high sugar content and low level of pH; which is below the critical level required for enamel demineralization (pH≤ 5.5)[10,15]. It is obvious that fermentable carbohydrates can cause caries, which would be even more severe in presence of fixed orthodontic appliances due to increased plaque accumulation [10]. Frequent consumption of soft drinks results in severe dental erosion [16]. The most important factors influencing erosion during orthodontic treatment include oral hygiene, diet and orthodontic bonding procedure [11]. Acidic soft drinks contain citric acid and phosphoric acid. Citric acid causes more enamel erosion than phosphoric acid [17]. More erosion develops under the influence of carbonated soft drinks rather than noncarbonated ones, due to the presence of carbonic acid. In developed countries, Coca-Cola is the most consumed carbonated drink (50%), followed by lemon flavored (22%) and orange flavored drinks (7%)[11]. "Dough", a yogurt-based, salty drink and non-alcoholic beer are two popular drinks in the Iranian diet [18].

Soft drink consumption during orthodontic treatment reduces bracket retention due to enamel softening around brackets [10, 11] or degradation of adhesive /composite interface [9, 12]; it may also increase the microleakage beneath the brackets and compromise the bond strength [11,15]. Microleakage around brackets may contribute to the development of white spot lesions under the brackets [19, 20]. In addition, during fixed orthodontic treatment residual adhesives around the brackets result in more plaque accumulation and increase the risk of decalcification [14]; therefore, orthodontic patients are advised against consumption of soft drinks during treatment [11].

Omid Khoda et al. compared the effects of yogurt-based drinks, 7 Up and Pepsi on the shear bond strength of orthodontic brackets [21]. However, information is lacking on the impact of non-alcoholic beer on the bond strength of orthodontic brackets. The purpose of this study was to determine the effects of two types of soft drinks, Coca-Cola and a non-alcoholic beer (Istak) on the shear bond strength and ARI of orthodontic metal brackets in vitro.

MATERIALS AND METHODS

Eighty extracted non-carious human premolars of orthodontic patients were used in this study. The teeth were cleaned with fluoride-free pumice and the buccal surface was etched with 37% phosphoric acid for 30 seconds, rinsed with water for 15 seconds and air dried with oil-free compressed air until the frosty appearance of enamel appeared. A layer of Transbond XT primer (3M, Unitek, Monrovia, Ca., USA) was applied to each tooth and then light cured (Kerr, LE Demetron II, USA) for 10 seconds with an intensity of 800 mW/cm^2. Transbond XT adhesive paste was then applied to the base of the metal bracket (Standard edge wise.018, Dentaurum Germany). The bracket was centered on the crown of the tooth mesiodistally and along the long axis of the tooth, and was then pressed firmly on the tooth surface. Excess adhesive was removed with a sickle scaler and the adhesive was light cured from four sides of the bracket edge, each for 10 seconds. All samples were kept in artificial saliva at 37° C for 24 hours to allow complete polymerization of resin.

The specimens were then randomly divided into three groups:

Fig 1. A tooth mounted vertically in the acrylic block.

Fig 2. Stereomicroscopic view of two samples (×12)

-Group 1 (Coca-Cola): included 30 teeth, which were submerged in Coca-Cola for 5 minutes twice a day, with equal intervals. The procedure was repeated over a period of 30 days. After each session the solution was replenished. For the remainder of the time, samples were kept in artificial saliva at 37° C.

-Group 2 [a non-alcoholic beer, Istak (Arianoosh, Rasht, Iran)]: included 30 teeth, which were immersed in Istak following the same procedures as for group 1. Istak is a soft beverage made of malt extract, hops, sugar and carbonated water.

Coca-Cola and Istak were stored in a refrigerator.

-Group 3 (control): included 20 teeth, which were kept in artificial saliva [400 mg NaCl, 1.21 mg KCl, 780mg $NaH_2PO_42H_2O$, 5mg $Na_2S.9H_2O$, 1000mg $CO(NH_2)_2$ and 1000 ml of distilled water] during the 30 days.

Artificial saliva was refreshed daily.

After 30 days, all teeth were mounted vertically in acrylic blocks measuring 20×20×20 mm (Figure 1) so that the load could be applied to the bracket-tooth interface parallel to the buccal tooth surface.

The shear test with a crosshead speed of 0.5 mm/min was performed on the samples with the Universal Testing Machine (Z050, Zwick/Roell, Ulm, Germany). The load at bond failure was recorded using a PC connected to the testing machine. The load at failure was recorded in Newton (N) and the stress was calculated in mega Pascal (1MPa= N/mm^2) by dividing the force in Newton by the area of the bracket base. The area of the bracket base was calculated by measuring the width and length of ten bracket bases with a digital caliper accurate to 0.01mm, which was found to be 10.23 mm^2.

After debonding, each tooth was examined under a stereomicroscope at ×12 magnification and the fraction of the remained adhesive on the tooth surface was scored (Figure 2).

The possible values for the ARI were categorized as follows:

-Score 1: 0 to less than 1/6 of adhesive left on the tooth,

-Score 2: 1/6 to less than 2/6 of adhesive left on the tooth,

-Score 3: 2/6 to less than 3/6 of adhesive left on the tooth,

-Score 4: 3/6 to less than 4/6 of adhesive left on the tooth,

-Score 5: 4/6 to less than 5/6 of adhesive left on the tooth,

-Score 6: 5/6 to 6/6 of adhesive left on the tooth.

During preparation, 8 samples were lost and there were 26, 28 and 18 teeth remaining in Coca-Cola, Istak and control groups, respectively.The data of shear bond strength were statistically analyzed by one-way ANOVA and Tukey's Post-Hoc test and the data of ARI scores were analyzed by Kruskal-Wallis test.

RESULTS

In this study, the shear bond strength and ARI of orthodontic brackets in the three groups of Coca-Cola, non-alcoholic beer (Istak) and control were evaluated.

The mean shear bond strength (SBS) and standard deviation of the three groups are shown in Table 1.

The mean SBS was 19.27 ±6.53 MPa in Coca-Cola group, 25.36 ± 9.77 MPa in Istak group and 25.47 ±10.02 MPa in the control group.

One-way ANOVA showed a statistically significant difference in SBS of the three groups (P=0.022).

Tukey's Post-Hoc test was used to evaluate the significance of the difference in SBS of each group with the other groups.

This test revealed that Coca-Cola had significantly lower SBS than Istak and the control group. However, there was no statistically significant difference in SBS of Istak and the control group.

The location of bond failure for each sample was evaluated with the ARI score and a summary of the data is shown in Table 2.

Table 1. Descriptive data of SBS in the three groups

	N	Mean	Std. Deviation	Std. Error
Coca-Cola	26	19.2769*	6.53765	1.28214
Control	18	25.4756	10.02367	2.36260
Istak	28	25.3675	9.77948	1.84815
Total	72	23.1951	9.18029	1.08191

Table 2. Adhesive remnant index scores in the three groups

Groups	**Adhesive remnant index score**					
	1	**2**	**3**	**4**	**5**	**6**
Coca-Cola	17 (65%)	4 (15%)	2 (7.6%)	1 (3.8%)	2 (7.6%)	0(0%)
Istak	15(53.6%)	7 (25%)	1 (3.6%)	2 (7.1%)	2 (7.1%)	1 (3.6%)
Control	11 (612%)	1 (5.5%)	1 (5.5%)	4 (22.3%)	0(0%)	1 (5.5%)

All three groups showed a similar bond failure mode (adhesive) at the enamel-adhesive interface being the most common site of bond failure in the three groups (0-1/6 of adhesive was left on the tooth surface).

Kruskal-Wallis test indicated that the distribution of ARI score was similar in the three groups (P≤ 0.552).

DISCUSSION

Bond failure of orthodontic brackets is a common problem during treatment [1]. Patients' diet and the acidity of foods and drinks can impact on shear bond strength of orthodontic brackets [9-12]. Recently, consumption of soft drinks has increased [17] in children and adolescents; these drinks have a negative impact on tooth structure [10]. The current study was conducted to evaluate the effects of two soft drinks, Coca-Cola and Istak, on the shear bond strength and adhesive remnant index of orthodontic metal brackets, in vitro.

The shear bond strength of brackets was tested using a Universal Testing Machine at a crosshead speed of 0.5 mm/min, similar to what was performed in the studies of Gillis and Redlich [22], Mascia and Chan [23] and Oncag [11].

The present study showed a significant reduction in the shear bond strength of orthodontic brackets in the Coca-Cola group compared to Istak and control groups; whereas there was no significant difference in the SBS of Istak and the control groups. Some previous studies also showed a significant reduction in SBS of brackets exposed to Coca-Cola. Oncag et al. [11] reported a decrease in the SBS of brackets in the Coca-Cola and Sprite groups in both in vitro and in vivo conditions. The study of Ulusoy et al. [1] revealed a decrease in bracket SBS following the use of Coca-Cola and Rosehip fruit tea, which was suggested to be due to their low pH. In the present study, Istak - a soft beverage made of malt extract, hops, sugar and carbonated water - was used. No SBS reduction was indicated in the Istak group. The reason might be the absence of phosphoric acid in this drink in contrast to Coca-Cola; which contains phosphoric acid.

The similarity between our study and those of Oncag [11] and Ulusoy [1] was that all three experimented on human premolars. Although there were differences in the frequency and duration of exposure to drinks, they all reported a significant reduction in SBS in the Coca-Cola group. In studies by Oncag and Ulusoy samples were immersed in soft drinks 3 times a day for 5 minutes during 90 days. In our study, the teeth were immersed in soft drinks twice a day for 5 minutes during 30 days. According to Oncag et al. demineralization around brackets was caused by the acidic soft drinks negatively affecting the bracket-enamel bonding [11]. On the other hand, softening or degradation of the adhesive/ composite resin interface impairs the interlock at the bracket-adhesive resin-enamel interfaces and may also cause bond failure [1]. It has been reported that the absorption of acids and acidic drinks may degrade the structure of Bisphenol A Glycidyl Methacrylate or bis-GMA – based composite resins [24, 9]; the resin matrix is softened and fillers leach out, decreasing the bracket bond strength [9]. According to Arikan et al, [20] the presence of microleakage at enamel-adhesive interface is critical for the appearance of white spot lesions and for the formation of caries, while microleakage at the adhesive-bracket interface is related to bond failure. Van Eygen et al, [25] in 2005 showed that even short periods of drinking soft drinks (Coca-Cola) reduces enamel microhardness. Lussi et al. [26] showed the reduced enamel microhardness to be proportional to immersion time. Hunter et al. [16] evaluated the effect of the frequency of exposure to soft drinks, twice in contrast to four times, and reported that the amount of tissue loss was not proportional to the frequency of exposure to low pH drinks.

Owen et al. [27] dipped the samples in drinks for 24 hours for a total of 14 days and observed enamel surface modifications; which appeared as irregularities in enamel morphology visualized under light and scanning electron microscopes. Steffen [28] evaluated the effects of soft drinks on etched and sealed enamel. Samples were immersed in drinks for 72 hours. Scanning electron microscopy revealed enamel damage in all specimens. This study showed that light cured sealants provided low protection for enamel. Even short duration of exposure to soft drinks has adverse effects on the structure and microhardness of enamel. The results of Navarro [15] and Omid Khoda [21] were different from those of Oncag [11], Ulusoy [1] and ours. Navarro did not indicate a significant difference in SBS and ARI of Coca-Cola, Schweppes lemon and control groups. This difference, at least in part, may be due to the use of bovine teeth instead of human teeth. Another reason may be the fact that their specimens were not thermocycled; thermocycling has been proven by some researchers to reduce bond strength between 20-70% [29, 30]. Although the samples in the present study and Ulusoy's were not thermocycled, SBS reduction in the Coca-Cola group was reported to be significant; therefore, thermocycling might not be a critical factor in SBS change. Omid Khoda et al. [21] evaluated and compared the effects of acidic soft drinks with a phosphoric acid base such as Pepsi, with a citric acid base like 7Up, and lactic acid base like carbonated and noncarbonated yoghurt drinks on the shear bond strength of orthodontic brackets. They revealed minimal difference in SBS between groups in their study. Such different findings may be attributed to the type of composite used in the mentioned studies. The composite used in Oncag's [11], Ulusoy's [1] and our studies were Transbond XT (light cure), but in Omid Khoda's [21] study, Unite (self cure) was used; thus, it may be concluded that Unite composite is more resistant to acid than Transbond XT [31]. The mean shear bond strength in our study was much higher than that of previous studies and it was also higher than the suggested clinically acceptable bond level by Reynolds and Von Fraunhofer [32]; which might probably be due to the lower frequency and duration of exposure to soft drinks compared to other studies or in-vitro condition of the study. According to Littlewood et al, [33] bond failure can occur within the bracket, at the bracket-adhesive interface, within the adhesive or at the tooth surface-adhesive interface. In our study, ARI was utilized to determine the extent of residual adhesive on the enamel surface following bracket debonding. There was no significant difference in ARI among the three groups (Coca-Cola, Istak and control). In fact, in all three groups, a high fraction of samples had less than 1/6 of the adhesive remained on their surfaces. There was no significant correlation between the SBS and ARI in any of the three groups. Although the SBS of the Coca-Cola group was less than that of the two other groups, the dominant mode of ARI in all three groups was similar. Navarro et al. [15] expressed an absence of correlation between ARI and SBS in tested groups. Ulusoy et al, [1] in evaluation of the effects of herbal teas reported a significant difference in ARI of Coca-Cola group (positive control) with that of other groups. Samples of Coca-Cola group produced the most consistent separation at the enamel-adhesive interface, leaving the enamel surface intact (ARI score 0). For all other groups, the majority of bond failures were ARI score 1 that is at the enamel-adhesive interface. ARI score 1 means that more adhesive materials are adhered to the bracket base and less adhesive materials remain on the tooth surface. It was surprising that although both Coca-Cola and Rosehip fruit tea reduced SBS, the mode of bond failure in Coca-Cola and Rosehip fruit tea groups was different. ARI scores were 0 and 1 in Coca-Cola and Rosehip fruit tea groups, respectively. Therefore, the absence of correlation between the SBS and ARI in Ulusoy's study was consistent with the present study.

Presence of low residual adhesive on tooth surface reduces the clean up time, is less troublesome for patients and less harmful to structural integrity of the enamel. The present study was designed to simulate oral environment as closely as possible; however, there were still differences left, including varying oral temperature due to diet and absence of bacterial plaque. Oncag et al. [11] evaluated the effects of acidic soft drinks on SBS both in vivo and in vitro and observed that there was no significant difference in SBS of brackets of the same group in vivo and in vitro. Although the difference was not significant, more extensive enamel defects were observed in the in vivo groups compared to the in vitro groups under the scanning electron microscopy. The reason for this difference was bacterial function in the oral cavity [11]. Steffen [28] stated that bacteria of the oral cavity accelerate enamel erosion following exposure to acidic soft drinks. According to the results of the present study, Istak did not decrease the SBS of orthodontic metal brackets in vitro, in contrast to Coca-Cola. Further investigations are suggested to evaluate the effects of Istak, a kind of non-alcoholic beer, on enamel structure and bonded brackets in vitro and in the oral environment.

CONCLUSION

This investigation revealed that:

1) Coca-Cola significantly decreased the shear bond strength of orthodontic brackets.

2) There was no significant difference in the shear bond strength of brackets between the Istak and the control group.

3) Adhesive remnant index was not affected by different soft drinks.

4) There was no correlation between the shear bond strength and the adhesive remnant index in any of the three groups.

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