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Effect of beverages on shear bond strength [SBS] and adhesive remnant index [ARI] of orthodontic metal brackets- An in-vitro study

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Abstract

Aim: To determine the effect of beverages on shear bond strength (SBS) and adhesive remnant index (ARI) of orthodontic metal brackets – an in vitro study.

Materials and methods: 60 intact human premolars were divided into four experimental groups of energy drink, carbonated drink, cold drink, alcoholic mouthwash solution and a control group of 12 human premolars which was immersed in distilled water. The immersion period was 30 days; duration being 10 minutes a day. Following the immersion period, the shear bond strength and adhesive remnant index of orthodontic metal brackets were assessed. The tests were accomplished using Instron and Visual Measurement Microscope respectively.

Statistical Analysis: Statistical analysis was undertaken using ANOVA and Tukey HSD tests to examine for the effects of adhesive material and food simulants upon bond strength. $p<0.005$ was considered statistically significant.

Results: The mean values of the shear bond strength (MPa) were higher with specimens immersed in Frooti and Gatorade compared to the other groups. The amount of reduction of the mean of shear bond strength at 30 days was least for distilled water. There was a highly significant difference between the bond strength for all of the storage media except for distilled water. Pepsi, Frooti and Gatorade showed the most significant ARI scores.

Conclusion: Samples immersed in Frooti and Gatorade exhibited the most significant reduction in SBS as compared to the control group. ARI of samples submerged in Pepsi, Frooti and Gatorade displayed the greatest values as compared to the control group.

Keywords: Shear bond strength, adhesive remnant index, metal brackets.

Introduction

Directly bonded fixed appliances have become the pillar of contemporary orthodontics. Simplicity of bracket placement together with an equitable clinical success rate and a decline in chair side time has eradicated the necessity for banding all the teeth. Bond failure of brackets in the course of orthodontic treatment is a frequently faced predicament. The rate of this recurrence has been found to differ between 0.5 and 17.6 percent.[1-3]

Numerous factors can influence bond failure, including poor operator technique, variation in the enamel surface, saliva contamination, bracket properties, masticatory forces, and patient behaviour. Healthy enamel surface is also needed for the retention of the bracket and an altered enamel surface may affect the retention. [4-8]

Dental caries and dental erosion both result in the loss of the mineral component of teeth. Dental caries comprises loss of minerals from the subsurface region of enamel and dentin because of exposure to weak acids from plaque. Dental erosion is a loss of surface tissue because of exposure to a variety of acids.[9] The most important factors affecting the development of erosion during orthodontic treatment are oral hygiene, nutrition, and orthodontic bonding techniques.

Sweets, carbonated fruit drinks, and other dietary acids lower the intraoral pH value below 5.5. [8-10] However, factors other than pH, such as type of acid, pKa, titratable acidity, buffering capacity, and temperature influence the dental erosive capacity of acidic liquids.11 The acidic properties of acids are determined by the amount of acid available [the titratable acidity] and the amount of acid actually present [concentration of H+ ions—pKa], and all these factors contribute to the erosive potential of a specific acid. In a beverage matrix, there are further complex interactions between solid and soluble components of the beverage, such as the acid/hydroxyapatite reaction again affecting the erosive potential.[12]

Acidic soft drinks include citric acid and phosphoric acid, and citric acid is far more effective than phosphoric acid in producing enamel erosion. In addition, during fixed orthodontic treatment, the excess adhesive around the brackets causes a gathering of dental plaque that increases the risk of decalcification.

Energy drinks are sugar-sweetened beverages like soft drinks and flavored juice drinks but differ in their constituents and proposed functions.[13] Energy drinks [e.g., Red Bull, Venom, Wild Tiger, etc.] contain massive doses of caffeine and other legal stimulants such as amino acids [e.g., taurine, carnitine, creatine], herbal supplements [e.g., ginseng], carbohydrates, glucuronolactone, inositol, niacin, panthenol, and B-complex vitamins.[14]

Yassin [2016] has studied the consumption of energy drink in Erbil city and he found that energy drink consumption is highly prevalent among adolescents and young adults to boost their energy.[15 The market target for every drink is primarily for children and young adults. In recent years the intake of readily accessible energy drinks has increased considerably with young adults making the most considerable portion of the consumers.[16]

Lee [17] et al quantified the effects of oral fluid simulants and food simulants upon the bond strength of dentine bonding composites. They discovered that exposure to 75% ethanol considerably reduced the bond strength after 30 days.

It has been determined that Bis-GMA based composites are liable to chemical softening by certain solvents. [18,19] It has been known for some time that dental composites are susceptible to degradation due to

hydrolysis. [20-22 Food simulants, also, alter the surface micro-hardness and wear characteristics of dental composites.[23] However, this softening and degradation has not been associated with increased bond failure rates in orthodontics as the average duration of orthodontic treatment is approximately 18 months, much shorter than the life expectancy of a dental restoration.[24]

Gedalia [25] et al determined the softening of the enamel surface after an hour of Coca-Cola application. The decrease of the pH value of the mouth to below 5.5 creates a medium for enamel erosion. A recent article showed that approximately half of all 14-year-old children have appreciable tooth wear and significant erosion and that this phenomenon is more prevalent in lower socioeconomic groups. [26,27]

O'Reilley and Featherstone [28] analyzed the amount of demineralization and remineralization around fixed orthodontic appliances. They stated that the demineralization did not occur because of the etching effect of the acid but because of dental plaque activation in the mouth.

Hall [29] et al and Meurmann [30] et al indicated that saliva forms an important defense mechanism against erosion. They demonstrated that all samples exposed to an erosive solution that were stored in saliva showed less erosion.

This investigation was performed to study the effects of common beverages on the shear bond strength and adhesive remnant index of orthodontic metal brackets in-vitro.

Materials and methods

This study investigated the effects of energy drink, soft drink, aerated drink, mouthwash containing alcohol on the resistance of metal brackets to shear forces in vitro, followed by assessing the Adhesive Remnant Index.

Sample Selection: 60 intact human premolars were divided into four experimental groups of energy drink, carbonated drink, cold drink, alcoholic mouthwash solution and a control group of 12 human premolars which was immersed in distilled water.

Inclusion Criteria

- Teeth extracted therapeutically for orthodontic purpose
- Intact teeth

Exclusion Criteria

- Decayed teeth
- Fluorosed/ Hypoplastic teeth
- Fractured teeth

Bonding of Brackets: The buccal surfaces of all teeth were etched with 37% phosphoric acid and washed with an air-water spray for 15 seconds. After air-drying each tooth surface, brackets were bonded to the teeth using Transbond XT [3M, Unitek, Monrovia, Ca., USA] primer and adhesive paste and curing was done for 10 seconds on the metal bracket [MBT .022 slot].

Immersion and Storage: Over a period of thirty days, the test groups were immersed in the respective beverages for 5 minutes, twice a day. For the remainder of the time, they were stored in distilled water while the control group was stored in distilled water during the entire experiment.

Sample testing: At the end of the conditioning period [30 days], the specimens were washed under running water and were ready for the shear bond strength test. [31] To this end, each group of teeth were removed from their substrate and mounted in self-polymerizing acrylic resin and Shear test was accomplished using an Instron machine [model 8874,US], with a crosshead speed of 0.5 mm/min. [32, 33]

Each specimen was installed in the mounting metal device and positioned on the base of the testing machine [which

was parallel with the horizontal plane]. The chisel end rod was fitted inside the upper arm of the testing machine with its chisel end downward to apply a force in an occluso-gingival direction that produced a shear force at the bracket base/enamel interface, until debonding occurred. When the bracket was debonded from the tooth by the force directed employed by the testing machine, the final magnitude of the reading was registered. The force was divided by the base area of the bracket to get the bond strength. and descriptive statistics were determined. The enamel surface of each tooth was inspected under a visual meter microscope [magnification 20X] to determine the pattern of the remaining adhesive. [34-38]

Statistical Analysis: Statistical analysis was undertaken using ANOVA and Tukey tests to examine for the effects of adhesive material and food simulants upon bond strength. $p<0.005$ was considered statistically significant.

Results

The descriptive statistics for the shear bond strengths of the 5 subgroups are shown in the Table. Mean bond strengths are given in Table 1.

All samples were significantly affected by the food simulants [P< 0.005].

Among the selected values, the lowest mean resistance to shearing forces was shown by Gatorade group [15.25 ± 2.22 Mpa] followed by Pepsi group [16.16 ± 2.40 Mpa], Listerine group [18.16 ± 3.58 Mpa] followed by Distilled water group [19.66 ± 3.79 Mpa] and highest resistance to shearing forces by Frooti group [24.83 ± 3.76 Mpa].

One way ANOVA test showed significant difference between the mean values of shear bond strength of the specimens [Table 2] immersed in the chosen food simulant for the duration of the storage period [F=20.333, P=0.000].

The Tukey's Honest significant test [HST] was performed to compare the values between each type of storage media to the control i.e., distilled water [Table 5]. This showed that there was no significant difference between samples stored in the different storage media except for those stored in Frooti and Gatorade where there was significant difference. [P < .000] [P< 0.008] respectively.

Regarding the adhesive remnant index, ANOVA showed significant value.

One way ANOVA test showed significant difference between the mean values of adhesive remnant index of the specimens [Table 3] following debonding after the shear bond test. [F=30.750, P=0.000].

Therefore, Tukey's pairwise comparison was done to establish which beverage displayed significant ARI scores [Table 4,5].

Pepsi, Frooti and Gatorade showed the most significant scores.

The above 3 groups demonstrated higher ARI scores than the remaining ones.

In other words, in these 3 groups, the failure primarily occurred at the bracket-adhesive interface, which means the adhesive bond strength to enamel and cohesive bond strength of the adhesive were higher than the adhesive bond strength to the base of the bracket.

While in the remaining groups, the failure occurred at the enamel-adhesive interface. In other words, they had less adhesive remaining on the enamel surface after debonding.

Table 1: Shear bond strength (MPa) for the four beverages and control group.

Groups	Pepsi	Listerine	Frooti	Gatorade	Distilled water
Mean	16.16	18.16	24.83	15.25	19.66
SD	2.40	3.58	3.76	2.22	3.79

Table 2: One Way ANOVA Test (SBS)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	785.600	4	196.400	20.333	.000
Within Groups	531.250	55	9.659		
Total	1316.850	59			

Table 3: One Way ANOVA TEST (ARI)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44.969	4	11.242	30.750	.000
Within Groups	19.742	54	.366		
Total	64.712	58			

Table 4: Tukey Test-SBS (Comparison of Other Beverages with Control Group)

(I) t		Mean Difference (I-J)	Std. Error	Sig.
Distilled water	Pepsi	3.50000	1.26880	.058
	Listerine	1.50000	1.26880	.761
	Frooti	-5.83333*	1.26880	.000
	Gatorade	4.41667*	1.26880	.008

Table 5: Tukey Test-ARI (Comparison of Other Beverages with Control Group)

(I) t		Mean Difference (I-J)	Std. Error	Sig.
Distilled Water	Pepsi	-1.50*	.258	.000
	Listerine	-.08	.258	.998
	Frooti	-1.58*	.258	.000
	Gatorade	-2.17*	.258	.000

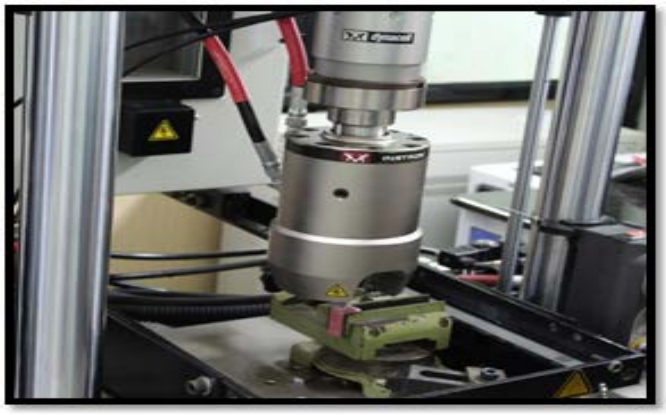

Figure 1: Sample in position on the base of the Instron machine.

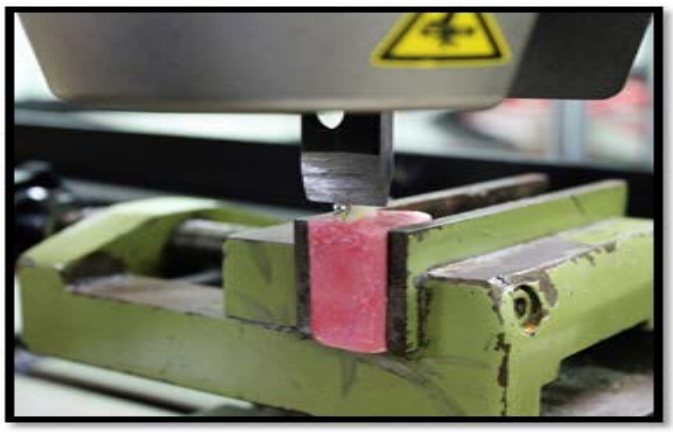

Figure 2: Load application by Instron machine at the bracket base/enamel interface for shear testing.

Figure 3: Sample ready for observation in the Visual Measurement Microscope.

Discussion

Bonding failure of brackets frequently occurs in daily orthodontic practice, lengthening the treatment time and increasing the treatment costs. [29] To gain strong and reliable adhesion between the tooth enamel and brackets is the main goal of orthodontic practice. Patients' diet and the acidity of foods and drinks can impact on shear bond strength of orthodontic brackets. [24, 30, 39]

Recently, consumption of soft drinks has increased [40] in children and adolescents; these drinks have a negative impact on tooth structure. [41]

The current study was conducted to evaluate the effects of a cold drink, a carbonated drink, a sports drink, an alcoholic mouthwash on the shear bond strength and adhesive remnant index of orthodontic metal brackets, in vitro.

The optimal SBS of orthodontic brackets should be both adequate to keep them in place during the treatment and allow them to separate easily from the tooth surface at the end of the treatment. [26,30] Reynolds reported the needed minimum clinical SBS for brackets as 5.9 to 8.7 MPa. [42] 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 Mascia and Chan [43], Gillis and Redlich [44] and Oncag. [42]

Intermittent exposure to a weathering agent would result in much slower diffusion rate due to desorption of the agents during the non-exposure time. However, any damage caused by the agent could remain and accelerate the agent's incorporation on re-immersion. Also, surface and subsurface binding of the agent may compete with the desorption process. The agent may not completely desorb due to competition with the force created by the diffusion gradient to continue diffusion into the specimen. [45] Clinically the agent may either be absorbed by the adherent debris [such as food particles] at the interfacial margins or produced by decomposition. [46]

The in vivo evaluation, beside ethical reasons, is very complicated, time consuming, and expensive. Thus, in vitro methods simulating oral condition have been designed in order to predict the clinical performance and longevity, but the complicated in vivo oral condition can only partially be simulated in vitro. Thus, there is no in-vitro test capable of reproducing the complex processes found in vivo. In vitro tests are, therefore, limited to quality control of material properties. Such properties may indicate what might happen in vivo, but the correlation between in vitro data and clinical performance is in many cases unknown. [22]

Distilled water was chosen as the control to simulate wet oral conditions provided by saliva, as in other bracket bonding studies. [24,31,47,48]

The immersion times and schedules used in past studies varied widely. In this study, 60 specimens divided equally were kept for 10 minutes a day, in their respective drink groups daily for thirty days. The remaining time it was kept in distilled water to mimic the normal oral environment. In this way, it can be assumed that these drinks were consumed in small quantities throughout the day. [42] This is an in vitro study, intended to reproduce in vivo situation. In the experiment, different drinks that were commonly utilized by target groups which are Pepsi, Frooti, Gatorade, Listerine mouthwash [which is meant to be used for maintaining oral hygiene] and also distilled water [control] were used as manipulative variables.

The present study showed a significant reduction in the shear bond strength of orthodontic brackets in the cold drink and sports drink group compared to control group. Some previous studies showed a significant reduction in SBS of brackets exposed to Coca-Cola. Oncag et al. [42] 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 [44] 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, no SBS reduction was indicated in the Coca Cola while there was significant reduction in the cold drink and sports drink group, both of which contain citric acid.

The results obtained are similar to the results of Navaro's et al [32] study who reported that bond strength values for teeth treated in Coca-Cola and Schweppes Limon were not significantly different from those in their control group. Also, these results were in consistent with a study done by Sirabanchongkran et al. [34]

Conversely, this result contradicts with some of the studies conducted [35,36] that found Coca-Cola showing a reduction in shear bond strength of orthodontic brackets. Coca-Cola is an acidic media, and it can decalcify tooth. Calcium may leach out from the teeth, thus softening and eroding the dental hard tissues which will then facilitate abrasion. Furthermore, the structure of bisphenol A glycidyl methacrylate-based composite resins which is the main composition of the adhesive used in the study would

be degraded with acid and acidic drink consumption as mentioned by Sirabanchongkran et al. [34] The matrix of the adhesive would soften leading to filler leaching out, thus lowering the bond strength of the brackets. [24]

It has been reported that acidic drinks can affect the bracket bond strength in two ways.

It can either weaken the adhesive material structure by which the resin matrix is softened and fillers are leached out resulting in decreasing bracket bond strength [24] or by de-mineralization of the enamel around the bracket, since these acidic drinks have a low pH value, high titrable acidity, sugar content. These are metabolized by plaque micro-organism to produce organic acid, and by calcium chelation properties of the beverage as these sports drinks contain citric acid, which is identified as strong chelator of tooth mineral. Even though some drinks appear to be less erosive than others within the same class. [37,38]

The sites of failure can occur within the bracket, between the bracket and the adhesive, within the adhesive, and between the tooth surface and the adhesive. [49] ARI scores were used to identify the amount of adhesive remaining on the teeth. The results of this study showed that the cold drink, carbonated drink and sports drink 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 1, that is, at the enamel – adhesive interface. ARI score 1 means that more adhesive has adhered to the bracket base and less adhesive remains on the tooth structure. This diminishes clean-up time and is less troublesome for the patients. Thus, it is not harmful to the structural integrity of the enamel.

Significant ARI scores were demonstrated by the cold drink, carbonated drink and sports drink group when compared with the control group i.e., distilled water.

It may be that the carbonated water and phosphoric acid in Pepsi are responsible for softening the resin matrix resulting in the leaching out of fillers and the decrease in bond strength. The destructive potential of drinks on enamel and resins can be influenced by several parameters, including frequency and timing of intake, the period in the mouth, temperature, sugar content of the drinks, and type of resin. As Pepsi is marketed as a drink that can be served chilled, in the present study it was applied cold, directly from the refrigerator. In addition, the salivary protective effect can play a major role in the mouth, in moderating the negative effect of acidic drinks on enamel – bracket retention [33], which was lacking in this study.

Sports drink and cold drink also contain citric acid which in low doses increases the pH and decreases the acidogenicity of dental plaque and reduces cariogenicity of non-alcoholic drinks. [50] A single acidic attack is therefore of minor importance but if repeated, the ability of the saliva to deal with the acid becomes lessened. Hence, the danger is the frequent use of soft drinks over time. [51]

As there is no previous study reporting the effect of sports drinks and cold drinks on the SBS of brackets bonded with adhesive to enamel, therefore, comparison to prior studies are not possible. However, as there are numerous studies which have reported the effect of acidic beverages on the SBS of bracket due to the similarity in the acidic properties, it is possible to compare the results of this study with them. There are numerous studies which reported that acidic soft drinks with their low pH and high titratable acidity further the bond strength reduction of orthodontic brackets bonded to the enamel surface. [30, 45, 52, 53]

Limitations

The in vitro condition of this study does not take into account the possible effects of any other beverages which could be consumed by the patients as well as any acidic food that may be consumed. The control used was distilled water which may not have adequately replicated the actions of saliva, namely its re-mineralizing and buffering action.

The teeth used were extracted from different individuals of varying ages. Hence, the mineralization level of each tooth differs and could be affected by their lifestyles, oral hygiene and socioeconomic level.

Furthermore, the major disadvantage in such studies is that the information of beverages consumed by the individual before bonding is seldom discerned which may well be a confounding factor while evaluating the results.

Conclusion

In this study, shear bond strength and adhesive remnant index of orthodontic metal brackets were assessed after sample immersion in four commonly consumed beverages for thirty days with distilled water being the control. The tests were accomplished using Instron and Visual Measurement Microscope respectively.

Samples immersed in Frooti and Gatorade exhibited the most significant reduction in SBS as compared to the control group.

ARI of samples submerged in Pepsi, Frooti and Gatorade displayed the greatest values as compared to the control group.

These results were found to be contrary to the existing literature. The difference in results could be attributed to the difference in the samples i.e., the age of the patients, their dietary habits prior to commencing orthodontic treatment etc.

This study being in-vitro in nature may not have adequately replicated the complex oral cavity with its various enzymes, acids and the buffering action of saliva.

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