The effect of two commonly consumed energy drinks on the bond strength of conventional and APC® brackets: An in vitro study

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Background and Objective: One of the common problems during orthodontic treatment is a bond failure, which interferes with treatment course and results in increased treatment duration and more clinical time for rebonding of failed brackets. This study aimed to determine the effect of energy drinks on the shear bond strength and adhesive remnant index on two types of orthodontic metal brackets.

Materials and Methods: Sixty sound human premolars were divided into two groups of conventional and APC® brackets, and each group had three subgroups of control (artificial saliva), Wild Tiger and Red Bull storage. The test subgroups were immersed in the energy drinks for 5 minutes, twice a day for 30 days. Universal Testing Machine was used to measure the shear bond strength. Stereomicroscope was used to determine the adhesive remnant index at x20 magnification. One-way ANOVA was used to analyze the bond strength data; the Kruskal-Wallis test evaluated the adhesive remnant index score.

Results: Significant difference was observed in the shear bond strength of both groups and within the subgroups ($P \leq 0.05$). The bond strength of Red Bull subgroup was significantly lower than the other two subgroups in both groups. Regarding the adhesive remnant index, the conventional bracket subgroup had a failure at bracket-adhesive interface while APC® bracket subgroup had failure at the enamel-adhesive interface.

Conclusion: Energy drinks reduced the bond strength of both types of orthodontic metal brackets.

Keywords: Energy drinks; shear bond strength; adhesive remnant index.

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Introduction

Direct bonding has a key role in contemporary orthodontics; it has numerous advantages such as easy and faster bracket placement, acceptable clinical success rate and less expensive.[1] Adhesive pre-coated brackets (APC®) are a new generation of brackets considered to decrease chair-side time and thereby increase work productivity, the pre-coated orthodontic brackets (APC®; 3M Unitek Dental Products Monrovia, CA, USA) were presented in 1992. It seems to offer more uniform adhesive thickness and to reduce the number of steps the bonding procedures required.[2]

The constituents of the conventional adhesives such as Transbond XT (3M Unitek; Dental Products) differs from the pre-coated brackets in the percentage of the different ingredients added into the material. The precoated adhesive has more filler (80%) than the classic Transbond XT adhesive (77%), which is responsible for its higher viscosity and allow better adhesion between the bracket and tooth surface during the preliminary steps of bracket bonding.[3]

Bond failure is one of the most common problems in orthodontic treatment, which has been reported to happen up to 17.6%.[1,4] Several factors affect the bond failure including enamel

surface characteristic and texture, inappropriate orthodontist technique, salivary contamination of the prepared enamel surface, bracket properties, occlusion, and masticatory forces, patient's behavior, the acidic effect of the beverages.[5]

Energy drinks are sugar-sweetened beverages like soft drinks and flavored juice drinks but differ in their constituents and proposed functions.[6] 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 β-complex vitamins.[7]

The high percentage of energy drinks consumption was recorded in countries like the United States of America, Cuba, Vietnam, the United Kingdom, Thailand, Germany, Mexico, Poland, Australia, and Saudi Arabia.[8] It is no surprise as manufacturers claim these drinks can enhance energy levels as well as physical stamina, improve concentration and athletic performance.[9] 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.[10]

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.[11] To the best of our knowledge, no published study is comparing the bond strength of Adhesive Precoated brackets (APC™ Plus adhesive system) with the conventional brackets bonded with Transbond™ Plus color change adhesive or the effect of energy drinks on the bond strength of these adhesive systems. This study aimed to explore the effect of energy drinks on the bond strength of conventional and APC® brackets.

Materials and methods

Samples. Sixty human maxillary premolar teeth extracted for orthodontic purposes were collected. Which were free from caries, enamel cracks, erosion, hypoplastic enamel deformities, and fillings were used in this research. The teeth were washed off in running water to remove any traces of blood and then kept in distilled water in a fridge at 4 up to 3 months, which was changed every week to prevent bacteria growth and to minimize deterioration.[12] The samples were randomly assigned into two groups and then divided into three subgroups (Figure 1).

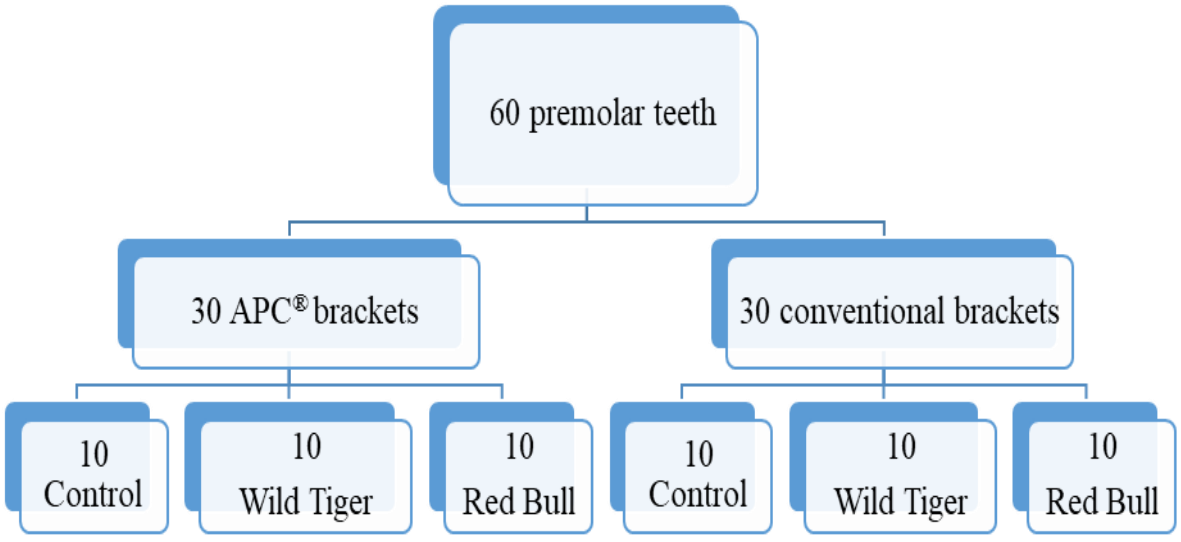

Figure 1: A schematic diagram showing sample grouping

Brackets. Thirty uncoated (Group I) and thirty APC® (Group II) upper pre-molar metal brackets (Victory Series®; 3M Unitek Dental Products, Monrovia, California, USA) were used. The brackets base area was provided by the manufacturer (9.61 mm2).

Bonding procedure. The bonding procedure was carried out at 23 ± 2 with the help of thermometer in the laboratory according to International Standardization Organization, TS 11405.[13] The specimens were mounted vertically in colored acrylic blocks in such way the buccal surface at a level slightly below the cervical line was visible. A straight surveyor rod was used to align the buccal surface of the teeth perpendicular with the bottom of the mold in a way the labial surface would be parallel to the applied force during the debonding test after that stored in distilled water (Figure 2).

The bonding procedure of the brackets was done accordant with the manufacturer's instructions. Fluoride-free pumice and a rubber cup was used to polish the buccal surfaces for 10 seconds and rinsed for 10 seconds and dried with oil and moisture-free compressed air for 5 seconds. They were then etched with 35% phosphoric acid gel (3M Unitek, CA, USA) for 15 seconds and the enamel was washed with water for 15 seconds and after that dried with compressed air until the enamel acquired a frosty white appearance. A layer of Transbond™ XT primer was placed to the tooth then slightly blown with a stream of compressed air and then for Group I; Transbond plus color change adhesive paste applied to the base of the uncoated bracket and then the bracket was centered mesiodistally and along the long axis of the tooth and subjected to 300 gm compressive force for 10 seconds with the help of surveyor and load.[14] Excess resin was removed with a probe from around the base of the bracket, and the resin was light-cured with APOZA LED (Taiwan made) for 40 seconds (10 seconds for mesial, distal, occlusal, and gingival margin)[15] at 1600 mW/cm2. Similarly, for Group II; the pre-coated brackets, the bonding procedure was performed.

Figure 2: Tooth alignment inside acrylic resin using

Storage of test specimens. Once bracket bonding completed, all the samples were stored in the artificial saliva at 37in the incubator for 24 hours to allow complete polymerization of the resin.[16] After that, the test samples of each group (APC® and uncoated brackets) were divided randomly into three subgroups:

I. Control group (n = 20): The specimens were submerged for 30 days in artificial saliva [KCl, NaCl, Na2S·9H2O NaH2PO4·2H2O, COCL22H2O, and urea (China made)], in the incubator at 37 and it was renewed daily.

II. Red Bull group (n = 20): The specimens were submerged in Red Bull for 30 days, for 5 minutes twice a day to imitate the consumer's intake time, separated by equal intervals. At other times, they were stored in the artificial saliva in the incubator at 37which was renewed daily.

III. Wild Tiger (n = 20): The teeth were Submerged Wild Tiger following the same procedures as for group II.

While the artificial saliva was stored at room temperature, both Red Bull and Wild Tiger were kept at a temperature of 5°C. The pH of each solution was measured electronically 3 times (CYBERSCAN ION 510, EUTECH INSTRUMENTS PTE LTD, SINGAPORE), and the means for results were reported. The acidity of the

drinks was also measured by a titration test using phenolphthalein indicator to find the acidic molecules.

Shear bond strength (SBS) test. SBS was measured with a universal testing machine (TERCO-MT3037, SWEDEN) with a (0-20) KN load cell at a crosshead speed was 1 mm/minute used to debond the brackets.[17,18] The specimens were set at the base plate of the machine so that the sharp end of the chisel placed against the edge of bracket base, exerting a force parallel to the tooth surface in an occluso-gingival direction (Figure 3). The force needed to debond each bracket was recorded in Newtons (N) and changed into megapascals (MPa) as a ratio of Newtons to the surface area of the bracket (MPa = N/mm2).[19]

Figure 3: Application of occluso-gingival load

Adhesive remnant index (ARI). Following debonding of brackets, enamel surface of all teeth and orthodontic brackets base were examined under a stereomicroscope (MO-TIC ST-39 series) at x20 magnification to assess the amount of adhesive resin left on the tooth surface. The adhesive remnant index score proposed by Endo et al.20 used to determine the debonding characteristics of each sample.

Statistical analysis. Descriptive statistics were calculated including means, standard deviation, minimum and maximum value, frequency, percentage.

The Shapiro-Wilk normality test and the Levene's variance homogeneity test were applied to the bond strength and adhesive remnant index score data. One-way ANOVA and LSD post hoc test used for comparing shear bond strength between groups (p-value < 0.05). Kruskal–Wallis test was used to know the distribution of ARI scores across the categories of the groups (p-value > 0.05) and Dunn-Bonferroni post hoc test with Bonferroni correction used for assessing pairwise comparison of adhesive remnant index scores (p-value < 0.05).

Results

Table 1 shows the acidic properties of energy drinks. The mean shear bond strength, standard deviation, minimum, and maximum values of both groups are shown in Table 2. Group II (Control) showed the highest mean SBS value of 23.10 ± 2.93 and Group I (Red Bull) yielded the lowest SBS value of 10.72 ± 2.69.

Table 1: Acidic properties

Type of drink	pH value	Titration value
Wild Tiger	2.70	0.24
Red Bull	3.11	0.20

One-way ANOVA showed a statistically significant difference in the means among all the groups (P < 0.05) and LSD post hoc test showed that among the conventional bracket group there was a statistically significant difference between the control group with Wild Tiger and Red Bull. As for APC® bracket group, there was a statistically significant difference between the control group and Red Bull group. While concerning the difference between conventional and APC® bracket group, there is statistically significant difference between the control (Conventional) with control (APC), Wild Tiger (Conventional) with Wild Tiger (APC), and Red Bull (Conventional) with Red Bull (APC).

The results of the ARI analyses are presented in Table 3. As could be seen, there was a higher frequency of ARI scores of 1 and 2 in all groups, which indicated that failure was mainly in the adhesive cement. The conventional bracket group did not show any score 0, while the APC bracket group showed score 0.

Kruskal-Wallis test showed that the distri-

bution of ARI score is not same across the categories of the groups and the Dunn-Bonferroni test with Bonferroni correction showed there was a statistically significant difference between the two pairs, the conventional (Red Bull) group with APC (Control and Wild Tiger) (Figure 4).

Table 2: Descriptive statistics and ANOVA of shear bond strength

Groups	Storages	Bone Strength				
		Mean	Standard Deviation	Minimum	Maximum	ANOVA Sig.
I- Conventional Bracket	Control	16.34	4.68	10.41	23.93	0.000
	Wild Tiger	12.59	2.11	9.37	15.61	
	Red Bull	10.72	2.69	7.28	15.61	
II- APC Bracket	Control	23.10	2.93	18.73	28.10	
	Wild Tiger	20.29	3.23	13.53	24.97	
	Red Bull	17.69	3.89	11.45	22.89	

Table 3: Distribution and percentages of adhesive remaining on the tooth after debonding

ARI Scores count(percent)						
Groups	N	Score 0	Score 1	Score 2	Score 3	Kruskal-Wallis Sig.
Conventional (Control)	10	0(0%)	2(20%)	7(70%)	1(10%)	0.001
Conventional (Wild Tiger)	10	0(0%)	2(20%)	4(40%)	4(40%)	
Conventional (Red Bull)	10	(0%)	1(10%)	3(30%)	6(60%)	
APC (Control)	10	2(2%)	5(50%)	3(30%)	0(0%)	
APC (Wild Tiger)	10	2(20%)	4(40%)	4(40%)	0(0%)	
APC (Red Bull)	10	0(0%)	6(60%)	3(30%)	1(10%)	

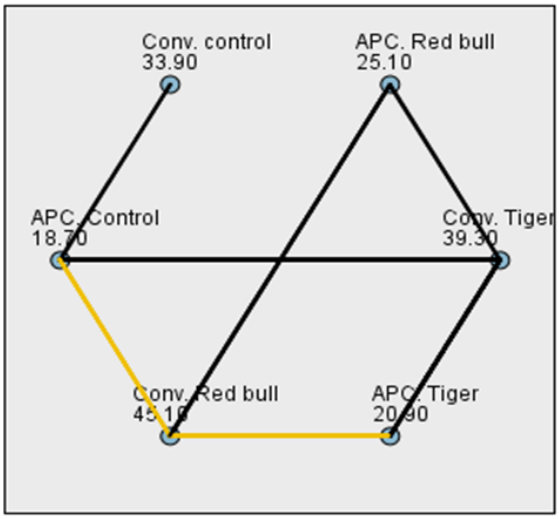

Figure 4: Dunn-Bonferroni pairwise comparison.

Discussion

The present study showed that the APC™ Plus adhesive system had significantly higher bond strength than the conventional brackets bonded with Transbond™ Plus color change adhesive. Both adhesive systems contain hydrophilic monomer and release fluoride. The hydrophilic nature of the adhesive permits fluoride diffusion through cured, cross-linked matrix in an aqueous medium.[21,22] The findings of this study might be due to the different percentage of the ingredients present in the adhesive.[3]

This study is in agreement with Guzman et al.[23] reported that the APC bracket had significantly higher bond strength than conventional brackets immediately after bonding, but they didn't find any difference in bond strength after 24 hours or thermocycling. This confirms a gradual increase in bond strength after 24 hours. Several other studies didn't notice any difference in the bond strength between APC or conventional brackets.[2,24-30]

In contrast, several studies found that the bond strength of APC II brackets was significantly lower than the conventional system. This is due to the difference in the percentage of the ingredients of the two system. Specifically, APC brackets contain 80% fillers, 12% Bis-GMA, and 8% of Bis-EMA.

Whereas, the corresponding values of Transbond XT comprise 77%, 14%, 9%, respectively. These changes help the adhesive pre-coated brackets to increase its viscosity, which leads to adhere more readily to the tooth during the initial stage of the bracket bonding.[3,31-32]

The results demonstrated that energy drinks reduced the mean SBS of orthodontic brackets when
compared with the control group. Statistically, Red Bull energy drink significantly reduced the bond
strength of both conventional and APC brackets, whereas Wild Tiger significantly just reduced the bond strength of conventional brackets and there was no significant difference regarding the effect of
energy drinks on the bond strength of both bracket types.

It has been reported that acidic drinks can affect the bracket bond strength in two ways. It can either weaken the adhesive material structure which the resin matrix is softened and fillers leach out results in decreasing bracket bond strength[33] or by demineralization of the enamel around the bracket, since these acidic drinks have a low pH value, high titrable acidity, sugar content in the drinks that are metabolized by plaque micro-organism to produce organic acid, and by calcium chelation properties of the beverage as these energy 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.[34,35]

Manufacturers have modified the composition of these acidic drinks either by reducing the acid content of the beverages or by diluting the beverages with water to reduce their demineralization effect. Wild Tiger energy drink contains three types of acids: citric acid, benzoic acid, and taurine; while Red Bull energy drink contains citric acid and taurine. Although, the titration result showed that Wild Tiger needs more base to neutralize than the Red Bull, but the shear bond strength of the Red Bull group was lower than the Wild Tiger group. These findings might be due to that the titration test does not specify the amount of specific acid present in the drink; however; it just shows the overall concentration of titrable acids present in the solution. This may mean that the amount of citric acid present

in the Red Bull might be higher than Wild Tiger. It is also proved that citric acid in low doses increases the pH and decreases the acidogenicity of dental plaque and reduces cariogenicity of non-alcoholic drinks.[34] That's maybe reason Wild Tiger energy drink yields higher shear bond strength.

The other reasons Wild Tiger did not significantly reduce the SBS of APC brackets might be either due to the adhesive composition of APC brackets or adhesiveness of the acidic substance[36], and resistance to pH changes[34].

As there is no previous study reporting the effect of energy drinks on the SBS of brackets bonded with color change adhesives to enamel, therefore, comparison to prior studies are not possible, but there are numerous studies reported the effect of acidic beverages on the SBS of bracket due to the similarity in the acidic properties we can compare between the results of this study with them. There are many studies reported acidic soft drinks with low pH, and high titratable acidity reduced the bond strength of orthodontic brackets bonded to the enamel surface.[5,15,37-39]

The conventional bracket groups demonstrated higher ARI scores than pre-coated bracket groups. In other words, within the conventional bracket group, 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. On the other hand, the adhesive pre-coated brackets showed the failure occurred at the enamel-adhesive interface. In other words, the APC brackets had less resin remaining on the enamel surface after debonding. This can be because of the fact the APC brackets have a premeasured uniform layer of adhesive coated in a way that leaves much less adhesive after application. It's also possible that this is a result of the consistent pressure carried out in setting the adhesive on the mesh throughout machine pre-coating of the bracket manufacturing, allowing improved penetration of the bracket mesh.

There was a statistically significant difference between conventional (Red Bull) bracket group with APC (control) and APC (Wild Tiger) bracket groups, and there was no evidence of a difference between the other groups. This difference might be due to the relatively high bond strength of APC (Control and Wild Tiger) bracket groups when compared low bond strength of conventional (Red Bull group), which led to the distribution of ARI score not be same across the categories of the groups.

Conclusion

The pre-coated brackets had higher bond strength than conventional brackets. The acidic energy drinks reduced the bond strength of both bracket types, so the orthodontist should advise the patients not to consume these acidic drinks throughout the treatment course. The conventional brackets showed less damage to the enamel surface in contrast to the pre-coated brackets.

Conflict of interests

The authors report no conflicts of interest.

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