Original Article

Effects of Acidic and Green Tea Soft Drinks on the Shear Bond Strength of Metal Orthodontic Brackets

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Abstract

The objective was to evaluate the effects of two soft drinks on the shear strength of bonds between metal orthodontic brackets and enamel using two types of adhesives. Seventy-two maxillary premolars extracted for orthodontic treatment were randomly divided into two equal groups according to the adhesive systems used to bond the brackets: Transbond™ XT primer and Transbond™ Plus Self Etching Primer (SEP). The teeth in both groups were divided equally into three subgroups: 1) artificial saliva (control), 2) Coca-Cola®, 3) Oishi® green tea. The teeth were kept in the drinks for 15 minutes, two times a day over a 90-day period. The Shear Bond Strength (SBS) tests were performed with a universal testing machine. A scanning electron microscope was used to examine the effect of the drinks on enamel surfaces.The highest mean bond strength (17.52 MPa) was achieved in the Transbond™ XT primer/control group, and the lowest mean bond strength (6.26 M Pa) was in the Transbond™ Plus SEP/Coca-Cola® group. No significant differences were found in the shear bond strength among three subgroups using Transbond™ XT primer. For the Transbond™ Plus SEP, Coca-Cola® produced a significantly ($p < 0.05$) lower bond strength than did the control group. Erosion on enamel surfaces was observed in the Coca-Cola® group, while there were no extensive defects in the Oishi® group. ARI scores were similar among the group with the same adhesive primer. Coca-Cola® and Oishi® green tea did not affect the shear bond strength when conventional Transbond™ XT primer was used, whereas Coca-Cola® showed a negative effect on bond strength when Transbond™ Plus SEP was applied.

Key words: Orthodontic bonding; Shear bond strength; Soft drink

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Introduction

A reliable bond between bracket and tooth enamel is essential during orthodontic treatment with fixed appliances. Despite the improvement of dental adhesives, bracket bond failure is still found. Failure rates of 4 % - 17.6 % have been reported in clinical studies.[1-3] The success of bracket bonding can be negatively affected by many factors, such as saliva contamination, poor operating technique, bracket base, enamel surface, and masticatory forces.[4-7] Moreover, some foods and drinks are found to have the potential to cause bond failure.[8,9] Acidic and alcoholic drinks have been reported to soften enamel around the brackets,[8,10] while some studies found that those drinks can deteriorate the adhesive resin.[9,11] Acidic soft drinks , which usually contain phosphoric acid or citric acid, can decrease the pH value of the mouth to below 5.5; and create the medium for enamel decalcification or erosion.[12] Erosion is a defect on the enamel surface. It can decrease the bracket retention.[12,13] In 2009 Ulusoy *et al*[14] reported that rosehip fruit tea might be a causative factor in the failure of bracket bonds. Soft drinks consumption is common worldwide. Apart from carbonated soft drinks, "Ready-To-Drink (RTD) green tea" is very popular, especially among adolescents and in Asia-Pacific countries. RTD green tea contains tea extract, sweeteners, additional flavorings, and other ingredients. Routinely drinking RTD green tea could affect the bracket-enamel bonding. In Thailand, Coca-Cola® and Oishi® are examples of the leading brands of carbonated soft drinks and RTD green tea, respectively.

To our knowledge, there is no study reporting the effect of RTD green tea on the strength of bonds between orthodontic brackets and enamel. In addition, no study appears to reveal the effects of soft drinks on bond strength when using self-etch adhesives. The self-etch adhesive systems combine both the conditioner and primer into one acidic-primer step. Therefore, acid conditioning and rinsing steps as instructed in conventional bonding systems are no longer required. The self-etch primers can etch and infiltrate the enamel simultaneously.[15] This *in vitro* study was carried out to evaluate the effect of two soft drinks, i.e., Coca-Cola® and Oishi® RTD green tea, on Shear Bond Strength (SBS) of orthodontic brackets when using a conventional (Transbond™ XT adhesive and primer, 3M Unitek, California, USA) and a self-etch adhesive system (Transbond™ Plus Self Etching Primer (SEP) and Transbond™ XT adhesive, 3M Unitek, California, USA). The studied hypothesis was that those two soft drinks would not affect the SBS of the brackets, regardless of adhesive systems used. This study was also aimed to observe the effect of these drinks on the enamel surface using Scanning Electron Microscope (SEM).

Materials and Methods

Teeth and brackets

Seventy-two maxillary premolar teeth extracted for orthodontic treatment were used in this study. All teeth had intact enamel without caries, restorations, fluorosis, or other defects. The teeth were stored in 0.1 % thymol solution for one to seven months prior to the bonding procedure. Stainless steel brackets for maxillary premolar teeth (Gemini Series; 3M Unitek, Monrovia, California, USA) were used in the study. The base area of bracket was 10.61 mm^2.

Bonding procedure

The test specimens were handled and prepared by the same operator. The buccal surface of each tooth was polished with fluoride-free pumice slurry and a rubber cup for 10 seconds, and then rinsed with water for 10 seconds. Excess water was removed from the tooth surface by oil-free compressed air. The teeth were randomly divided into two groups according to the adhesive systems used to bond the brackets: Conventional Transbond™ XT (3M Unitek) and Transbond™ Plus SEP (3M Unitek). The processes of application of these two adhesives are described below.

Conventional Transbond™ XT system: The buccal enamel was etched with 37 % orthophosphoric acid for 15 seconds, and was rinsed with water for 10 seconds. After that, the enamel surface was dried with oil-free compressed air (for 5 seconds). A layer of Transbond™ XT primer was applied on the surface, and Transbond™ XT resin adhesive paste was placed on the bracket base. Then, the bracket was positioned properly on the center of the buccal surface with the axis of the bracket parallel to the axis of the tooth, and was pressed firmly onto the tooth. The excess adhesive was removed from around the base of the bracket, and the adhesive was polymerized with a curing light (1,100 mW/cm^2, MiniLED™, Acteon, Niort, France) for 10 seconds on each side of the bracket edge.

Transbond™ Plus SEP: The Transbond™ Plus SEP was applied on the buccal enamel with a rubbing motion for three seconds and gently air-blown for five seconds. This was followed by placement of Transbond™ XT resin adhesive paste to the base of the bracket, which was then bonded to the tooth surface in the same manner as in the Transbond™ XT group.

The adhesives used in this study, along with their manufacturers and batch numbers, are listed in Table 1. All the materials were used according to the manufacturers' recommendations.

Table 1 *The adhesives used in this study*

	Adhesives	Batch No.	Manufacturers
N = 36	Transbond™ XT		3M Unitek, Monrovia, California, USA
	- Transbond™ XT Adhesive Primer	N207652	
	- Transbond™ XT Adhesive Paste	N213164	
N = 36	Transbond™ Plus Self Etching Primer (SEP)	422906B	3M Unitek, Monrovia, California, USA

Storage of test specimens and experimental groups

The specimens in each adhesive group were randomly divided into three equal subgroups:

- Control: The specimens were immersed in artificial saliva at 37 ºC for 90 days. The saliva was renewed every day.

- Coca-Cola® (Thai Namthip Ltd., Bangkok, Thailand): The specimens were immersed in Coca-Cola® for two sessions of 15 minutes with an intervening interval of six hours every day, for 90 days. The rest of the time they were kept in the artificial saliva at 37 °C.

- Oishi® RTD green tea (Oishi Group Public Co., Ltd., PathumThani, Thailand): The specimens were immersed in Oishi® RTD tea using the same procedures as for the Coca-Cola® group.

The artificial saliva used in this study was prepared from 0.4 g NaCl, 1.21 g KCl, 0.78 g $NaH2PO_4$ $2H_2O$, 0.005 g Na_2S $9H_2O$, 1 g $CO(NH_2)_2$, 1,000 mL of distilled and deionized water, and 10 N sodium hydroxide.[8] The contents of soft drinks as revealed by the manufacturers are listed in Table 2.

Table 2 *Soft drink contents according to the manufacturers' information*

Soft drinks and manufacturers	Contents
Coca-Cola® (Thai Namthip Ltd., Bangkok, Thailand)	Phosphoric acid, Fructose, Carbon Dioxide, Caffeine, Coca extract
Oishi® RTD green tea (Oishi Group Public Co., Ltd., PathumThani, Thailand)	94 % Green tea, 6 % Fructose syrup

The pH value of each medium was measured electronically with the pH meter (Mettler TOLEDO MP225 pH Meter, Mettler-Toledo GmbH, Schwerzenbach, Switzerland) at room temperature.

In brief, 72 specimens were divided into six equal groups (N = 12) according to the adhesive used and soft drinks to which they were exposed:

Group 1: Transbond™ XT primer/Control
Group 2: Transbond™ XT primer/Coca-Cola®
Group 3: Transbond™ XT primer/Oishi® RTD green tea
Group 4: Transbond™ Plus SEP/Control
Group 5: Transbond™ Plus SEP/Coca-Cola®
Group 6: Transbond™ Plus SEP/Oishi® RTD green tea

Shear bond strength (SBS) test

After 90 days, all specimens were mounted in acrylic blocks to carry out SBS testing. SBS was measured in the Instron® universal testing machine (Model number 5566, Instron Calibration Laboratory, Norwood, Massachusetts, USA) with a load cell of 500 kN. A shear test using a thin debonding plate with a crosshead speed of 0.5 mm per minute was applied to the bracket-tooth interface in an occluso-gingival direction until the bracket detached from the tooth. The force when debonding occurred was recorded in Newtons (N) and the SBS was calculated in megapascals (MPa) as the ratio of Newtons to the area of the bracket base (MPa = N/mm^2).

The adhesive remnant index (ARI) was also recorded under 3x magnification according to Artun and Bergland.[16] Score 0 signified that there was no adhesive left on tooth surface. Score 1 signified that there was less than 50 % of the adhesive left on the tooth surface. Score 2 signified that there was more than 50 % of the adhesive left on the tooth surface. Lastly, score 3 meant that all of the adhesive was left on the tooth surface.

The tooth surfaces of specimens in each media after debonding were examined with SEM (JEOL JSM-5910 LV; JEOL Ltd., Tokyo, Japan). Images of tooth surfaces were recorded and stored digitally.

Statistical analysis

The analysis was carried out using the SPSS program version 19.0 (SPSS, Chicago, IL, USA), and the level of significance was set at $p < 0.05$. As the SBS data were normally distributed (Kolmogorov-Smirnov test) and exhibited homogeneous variance (Levene's test), a two-way ANOVA was applied to assess the significance of the difference in bond strength among the study groups. Tukey's test was used for post-hoc comparisons.

Results

Means and standard deviations of SBS are presented in Table 3. Two-way ANOVA showed that

dental adhesives and soft drinks affected the SBS of enamel-bracket bonds ($p < 0.05$). The interaction between these two factors was not statistically significant ($p < 0.05$). The highest mean SBS (17.52 MPa) was achieved in the Transbond™ XT primer/control group, and the lowest mean bond strength (6.26 MPa) was found in the Transbond™ Plus SEP/Coca-Cola® group. The post hoc test for multiple comparisons showed that there were no significant differences between the SBS in the three groups using Transbond™ XT primer. For the Transbond™ Plus SEP, Coca-Cola® produced a significantly lower bond strength than did the control group. However, no significant difference was observed between Oishi® RTD green tea and control group.

Table 3 *Means and standard deviations of shear bond strengths (MPa) of the study groups and the pH of each medium*

	pH	Transbond™ XT primer	Transbond™ Plus SEP
Control	8.51	17.52^{a} (± 2.98)	11.94^{b} (± 4.61)
Coca-Cola®	2.46	16.23^{a} (± 3.28)	6.26^{c} (± 3.66)
Oishi® RTD green tea	5.96	16.32^{a} (± 2.01)	9.14^{bc} (± 4.05)

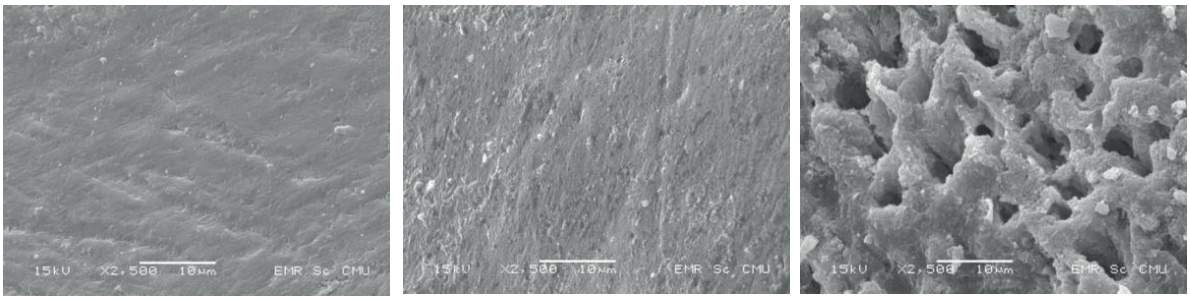
Means with the same superscript letters were not significantly different.

The ARI scores which identified the bond failure mode after debonding were shown in Table 4. The majority of bond failures were adhesive in nature. In all groups bonded with Transbond™ SEP, more than 50 % of the adhesive was removed with the bracket base (ARI 0 or 1). Some imprints of the adhesive were found in the groups bonded with Conventional Transbond™ XT primer (ARI 2, 3).

Table 4 *Frequency and percentage of ARI scores for each study group*

		N (%)	ARI scores			
			0	1	2	3
Transbond™ XT primer	Control	12 (100 %)	1 (8.33 %)	10 (83.33 %)	0	1 (8.33 %)
	Coca-Cola®	12 (100 %)	0	9 (75.00 %)	0	3 (25.00 %)
	Oishi® RTD green tea	12 (100 %)	1 (8.33 %)	7 (58.33 %)	3 (25.00 %)	1 (8.33 %)
Transbond™ Plus SEP	Control	12 (100 %)	5 (41.67 %)	7 (58.33 %)	0	0
	Coca-Cola®	12 (100 %)	10 (83.33 %)	2 (16.67 %)	0	0
	Oishi® RTD green tea	12 (100 %)	7 (58.33 %)	5 (41.67 %)	0	0

The results of SEM (2,500X magnifications) tests were shown in Fig. 1 The enamel surface outside the bracket in the Coca-Cola® group (Fig.1C) showed significant erosion, while those that had been immersed in Oishi® RTD green tea (Fig. 1B) did not show extensive defects compared with intact enamel in the control group (Fig. 1A).



A B C

Figure 1 *Scanning Electron Microscopy (SEM) evaluation (2,500X magnifications) of the tooth surface outside the bracket. A. Control B. Oishi® RTD green tea C. Coca-Cola® groups*

Discussion

This *in vitro* study was designed to reproduce the situation *in vivo*; by assuming that Coca-Cola® and Oishi® RTD green tea are consumed two times a day and each consumption period would be 15 minutes. The specimens were kept in artificial saliva at 37 °C between submersions in the drinks to simulate normal oral conditions.

In this study, the enamel-bracket bond strength values in the conventional Transbond™ XT groups were significantly higher than in the Transbond™ Plus SEP groups, and the mean SBS was highest in the control group, in which the specimens were not exposed to soft drinks. The bond strength values when using conventional Transbond™ XT system did not show significant differences between the three subgroups: control, Coca-Cola®, and Oishi® RTD green tea. These findings were similar to the results of Navarro *et al* (2011), who reported that bond strength values for brackets immersed in Coca-Cola® and Schweppes® Limon were not significantly different from those in their control group.[17] Some studies found that Coca-Cola® has a negative effect on bracket-enamel bonding.[8,12] However, those studies were designed to immerse the specimens in soft drinks three times a day, and one study used distilled water to imitate the oral environment,[12] whereas in this study, the specimens were exposed to soft drinks only twice a day to replicate as closely as possible the soft drink consumption in orthodontic patients. In addition, this study created the oral environment by keeping the specimens in artificial saliva at 37 ºC between submersions in soft drinks, which may enable a remineralizing effect of saliva on enamel to occur.[18,19] Coca-Cola® is an acidic media and it can decalcify tooth.[20] It leaches the calcium out of the teeth, softens and erodes the dental hard tissues, and facilitates abrasion. In addition, acid and acidic drink adsorption may degrade the structure of bisphenol A glycidyl methacrylate-based composite resins which is the main composition of the adhesive used in this study. The matrix of the adhesive can be softened and the filler can leach out, then lowering the bond strength of the bracket.[9] In this study, acidic medium could decrease

the bond strength only in the Transbond™ Plus SEP groups from the lower mechanical retention compared to conventional bonding system.

There are some studies on the performance of orthodontic self-etch adhesives, but a report regarding the effects of soft drinks on the strength of bonds to brackets when using these adhesives has not been found so far. This study investigated the effect of soft drinks on Transbond™ Plus SEP. The study found that the Coca-Cola® group showed the lowest mean SBS (6.26 MPa), and significantly lower than in the control group (11.94 MPa), whereas the SBS in the Oishi® RTD green tea group (9.14 MPa) did not show significant difference with either the control or Coca-Cola® group. As there is no previous study reporting the effect of soft drinks on the SBS of brackets bonded to enamel with self-etch adhesive system, comparisons with previous studies are not possible. However, from this study's results, it appears that Coca-Cola® has a negative effect on bracket retention when using Transbond™ Plus SEP. On the other hand, there were no significant statistical differences in SBS between the RTD green tea group and the control group, regardless of adhesive systems.

The enamel defects observed under SEM in the Coca-Cola® group were far more extensive than in the RTD green tea group. Oishi® RTD green tea, with mild acidic pH level, contains no acid, whereas there is phosphoric acid in Coca-Cola®. It has been stated that the erosive capacity of soft drinks is associated with their acidity[10], which supports this study's results. Phosphoric acid-based drinks, like Coca-Cola®, have also been reported to have a more severe erosive effect on tooth enamel than do citric acid-based drinks.[1] Enamel defects observed using SEM in this study were similar to the results from other studies, which have revealed the erosive defect on enamel caused by acidic soft drinks such as Coca-Cola®.[10,21] Herbal tea is also found to cause enamel loss, especially when fruit products containing organic acid were added.[22-24] Oishi® RTD green tea produced mild erosive pattern on enamel. In this study, artificial saliva would remineralized the enamel defects. Saliva might have protective effect on enamel surface.[19] However, the findings of Dinçer *et al*[10] found this defense mechanism only in the group that was not exposed to acidic soft drinks. Further investigation on saliva remineralization and erosive soft drinks may also be needed.

Consuming of soft drinks could influence the tooth surface and bond strength especially with self-etch primer in this study. The dentists should educate the patients to prevent harmful effect more than good brushing technique.[25] Moreover, orthodontist should limit the etched area only where bracket to be bonded.[10] If the etched area is large, the adhesive can later dissolve when in contact with acidic soft drinks, demineralization can occur.

The findings from this study indicated that the enamel-bracket bond strength in the conventional Transbond™ XT groups was significantly higher than in the Transbond™ Plus SEP groups. On the contrary, previous *in vitro* studies showed that Transbond™ Plus SEP provided similar or higher bond strength than did conventional etch-and-rinse adhesives.[26-29] Nonetheless, the results from short-term clinical studies were still contradictory.[30-33] A clinical trial over an 18-month period found that the failure rates of Transbond™ XT system and Transbond™ Plus SEP were not significantly different.[3] However, this clinical trial did not follow the manufacturer's directions in terms of the application method of Transbond™ Plus SEP. The investigators applied the self-etch primer with a rubbing motion onto enamel for 10 - 15 seconds instead of for three seconds, as recommended. Because of the differences in bonding techniques, research methods, and duration of studies, it is difficult to compare the success rates of adhesive systems between studies.

Type of soft drinks did not affect the ARI scores among the study groups. ARI value was related to the level of SBS. With higher bond strength, there was a tendency with higher ARI score. Type of adhesive may affect the ARI scores. Transbond™ XT groups providing higher bond strength comprised all level of ARI scores

(0 to 3), whereas Transbond™ Plus SEP groups scored only 0 and 1. The results was similar to the other studies.[28,29]

To the authors' knowledge, this is the first study that evaluated the effects of soft drinks on the strength of enamel-bracket bonds using self-etch adhesives. Further studies on different drinks and different adhesives on bond strength in orthodontic bracket use may be necessary.

Conclusion

In this study, there were no significant differences in SBS after exposure to Coca-Cola®, Oishi® RTD green tea, and no exposure to soft drinks (control group) when the bracket was bonded to enamel by conventional Transbond™ XT system, whereas when Transbond™ Plus SEP system was applied, Coca-Cola® showed the lowest bond strength, significantly lower than in the control. Adhesive remainings on tooth surface were similar among groups with the same adhesive. Under SEM, eroded enamel was found in teeth immersed in Coca-Cola®.

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