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Research article

The effect of beer and milk tea on the shear bond strength of adhesive precoated brackets: An in vitro comparative study

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ABSTRACT

Objectives: The objectives of this study were to evaluate the long-term effects of beer and milk tea on the shear bond strength (SBS) of adhesive precoated brackets and conventional adhesive on brackets.
Methods: The 150 metal brackets were bonded to maxillary permanent premolars and divided into two groups based on adhesive type: (1) Transbond PLUS Color Change Adhesive (TP) and (2) Flash-Free adhesive precoated (APC FF). The bonding processes were carried out exactly as recommended by the manufacturer. Each group's samples were randomly divided into five subgroups with different immersion solutions and thermal cycles ($n = 15$): (1) at 24 h after bonding, (2) milk tea at 6 months, (3) milk tea at 1 year, (4) beer at 6 months and (5) beer at 1 year. The SBS differences between groups were analyzed using an independent-sample T test and one-way ANOVA with Dunnett's T3 as a post hoc analysis.
Results: The SBS of TP were 20.66 ± 4.88 (X ± SD MPa), 23.14 ± 2.33, 17.54 ± 5.12, 24.64 ± 2.26, and 20.91 ± 6.19 for subgroups 1 to 5, respectively. The SBS of APC FF were 13.86 ± 4.14, 17.02 ± 4.04, 13.74 ± 4.40, 15.77 ± 4.11, and 16.21 ± 3.51 for subgroups 1 to 5 respectively. However, the SBS of APC FF was significantly lower than TP for all subgroups ($p < 0.05$). Beer showed a minor influence on the SBS ($p > 0.05$). The TP milk tea subgroup increased significantly throughout the 1-year thermal age period ($p = 0.028$). Both TP and APC FF showed higher values in the milk tea subgroups after 6 months of thermal age than in the beer subgroups ($p < 0.05$).
Significance: The APC FF group showed significantly lower SBS than the TP group. We found that milk tea increased the SBS in both the TP and the APC FF groups. However, beer had no significant effect on either group.

1. Introduction

The goals of orthodontic treatment are to correct malocclusion and create normal occlusion. Correcting malocclusion can improve patient esthetics, oral health, oral function and stability [1]. Orthodontic appliances can be classified into fixed and removable appliances [1]. Orthodontic brackets are commonly used in orthodontic treatment, although the removable clear aligner can be used in orthodontic treatment and has been proven to be effective compared to conventional treatment [2]. However, there are some limitations to using the aligner, such as the complexity of cases and the price, which is higher compared to braces in some countries [3, 4]. Orthodontic fixed appliances are the treatment of choice in orthodontic treatment.

A fixed orthodontic appliance is a powerful tool that can be used to treat various types of malocclusion, but bracket failure during orthodontic treatment is the key factor that can extend the duration of treatment [5]. This might be due to an improper bonding process as well as inadequate materials, curing lights and adhesive [6, 7]. Furthermore, some diets may result in bracket failure [8, 9, 10, 11, 12]. Food or drink that decreases the intraoral pH value below the critical value of 5.5 creates enamel decalcification or erosion, affecting the bond strength of brackets [13, 14]. Examples of low pH food or drink are acidic fruits like lime, lemon, orange or soft drinks like Coca-Cola, Sprite, etc.

As mentioned above, an improper bonding process can lead to bracket failure, and saliva contamination while bonding the brackets on the teeth reduces its shear bond strength (SBS) [15]. APC Flash-Free Adhesive (APC FF), a light-cured precoated adhesive, was developed to reduce the bonding steps and clinical time by skipping the adhesive application on the bracket base and eliminating the requirement to remove flash because only a small amount of excessive resin will remain and create a smooth edge around the bracket base. However, studies on this type of bracket are limited [16, 17, 18]. Transbond PLUS Color Change Adhesive

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(TP) is one of several conventional adhesives. The manufacturer claims that this adhesive can tolerate moisture and the color change represents its characteristic, which changes from pink to clear after light-curing. The pink color is easily seen and clean during bonding [19].

Food and drink are basic elements for life, and Aristotle emphasized that “man is by nature a social animal” [20, 21]. Special drinks, such as alcoholic drinks and tea, are commonly used for celebration, socializing or leisure. However, alcohol-containing drinks have a pH that is lower than the threshold value, which can promote enamel erosion and may be a factor in bracket bond failure [9, 12]. Milk tea is another widely popular beverage among young people these days; however, its high sugar content causes the oral cavity to become acidic, which may weaken the bond strength of brackets [8, 22].

Previous research has evaluated the effects of alcoholic beverages, herbal tea and green tea on conventional adhesive SBS [10, 11, 23], but no one has examined the effect on adhesive precoated brackets. Furthermore, no study has compared the effect of alcoholic drinks and milk tea on the SBS when using adhesive precoated with the conventional adhesive. The purpose of this study was to compare the SBS of APC FF and TP on metal brackets after being thermocycled and immersed in beer and milk tea. The null hypothesis was that there were no differences in SBS between APC FF and TP after being thermocycled and immersed in beer and milk tea. Our primary outcome measurement was the SBS of APC FF and TP after intervention. The secondary outcome measurement was the adhesive remnant index (ARI) score after debonding.

2. Materials and methods

This study was approved by the Ethics Committee of Srinakharinwirot University, Bangkok, Thailand (Approval No. SWUEC-033/2563). This is research with an exemption.

2.1. Sample

The sample size was calculated with G*Power (Version 3.1.9.2). The effect size convention (f) 0.45 was used to calculate the sample size (total sample size = 97 or N = 9.7 per group). The methods for this study were based on Vorachart et al. in 2021 [24].

The 150 extracted maxillary permanent premolars were obtained from dental clinics. All samples were sound teeth with no carious disease or crack lines, no adhesive, restoration or prosthesis on the buccal enamel and no previous exposure to chemical agents, such as hydrogen peroxide. Teeth with prior fixed orthodontic treatment and developing enamel abnormalities were excluded from the study. The extracted teeth were cleaned and preserved in distilled water (ISO 3696:1987, grade 3) in a refrigerator for no more than 6 months, with the storage medium replaced every 2 months [25].

2.2. Bracket and adhesive

Metal bracket MBT prescriptions with a slot size of 0.018 inches for the maxillary premolar (Victory Series Low Profile Brackets, 3M Unitek, USA) were used in this study. ImageJ software was used to measure the bracket base area, which was 9.9 mm^2.

All the samples were randomly divided into two groups based on the type of adhesive. Group 1 (n = 75) used Transbond Plus Color Change Adhesive (TP, 3M Unitek, USA) as the control group, and Group 2 (n = 75) used adhesive precoated brackets (APC FF, 3M Unitek, USA) as the experimental group.

2.3. Bracket placement procedure

All the bonding processes were performed by the same operator (WV) to standardize the bonding procedure. Before bonding, the teeth were polished with fluoride-free pumice, rinsed and air dried. The buccal enamel was rubbed with Transbond Plus Self-Etching Primer (3M Unitek, USA) for 5 s and gently blown for 2 s. For the control group, the operator applied TP to a bracket base, positioned the bracket at the midpoint of the facial axis of the clinical crown, firmly pressed the bracket and removed the excessive flash with the explorer and light cured it (2000 mW/cm^2, Mini LED SuperCharged, Acteon, France) for 10 s on the mesial and distal sides. For the group with APC FF, the operator removed the bracket from the package, positioned it on the tooth surface in the same manner as the TP group and light cured it without removing any flash (Figure 1). All specimens were stored in 25 °C distilled water for 24 h to complete polymerization.

2.4. Intervention

The 15 samples from each group were chosen at random to evaluate the SBS as a standard value. The remaining samples were randomly separated into four subgroups (n = 15) based on solution type and thermal cycling period.

The solutions used were 4 °C milk tea (Sunsu® RTD Classic Milk Tea, Uni-President (Thailand) Ltd., Thailand) and 4 °C beer (Chang® Classic Beer, Thai Beverage Plc., Thailand). The contents of the drinks as indicated by the manufacturers are shown in Table 1. A pH meter (pH Meter, Starter3100, OHAUS, USA) was employed to determine the pH of the milk tea and beer, which were 6.4 and 4.0, respectively.

Thermal aging was performed with water at 5 °C and 55 °C for 5000 and 10,000 cycles, with a dwell duration of 20 s and a transfer time between baths of 5 s, approximated adhesive aging in the oral cavity for 6 months and 1 year, respectively (TC301, Medical and Environmental Equipment Research Laboratory, KMITL) (Figure 2a) [26,27]. To replicate the frequency of consuming beverages once a week, the specimens were submerged in solutions for 15 min after each week of thermal cycling, which was calculated to be 200 cycles. The 200 cycles were calculated from the calculus that thermal cycling 10,000 cycles represent 1 year or 52 weeks. In order to stimulate once a week situation, we needed to perform 192.3 cycles. We decided to perform 200 cycles for a precise experiment. After 6 months and 1 year of thermal age, 15 specimens from each group were mounted in 0.75-inch-diameter-by-1-inch--long dental stone blocks.

The SBS was evaluated using a universal testing machine (EZ-LX, Shimadzu) with a 500-N load cell at a crosshead speed of 1 mm per min until the bracket detached from the tooth (Figure 2b). The loaded values displayed by the testing machine were displayed in newton (N). We converted the values into megapascals (MPa) by dividing with the bracket base area of 9.9 mm^2.

A stereomicroscope (SZ61, Olympus) with 10X magnification was used to assess the amount of adhesive left on the tooth surface (Figure 2c) and the percentage of adhesive residual area was confirmed by using the ImageJ software. The adhesive remnant score was determined using Artun and Bergland's [28] ARI as follows:

0 indicates that there is no adhesive left on the tooth;
1 indicates that there is less than half of the adhesive remaining on the tooth;
2 indicates that there is more than half of the adhesive remaining on the tooth; and
3 indicates that there is all adhesive left on the tooth.

2.5. Statistical analysis

The Kolmogorov-Smirnov test and Levene’s test were used to determine the normal distribution and equality of variances of the SBS. The independent-samples T test was used to examine the influence of adhesive type and drink on SBS, and one-way ANOVA with Dunnett’s T3 test as a post hoc comparison was used to analyze the difference in SBS among the thermal aging conditions. Descriptive statistics were utilized to display the ARI score. The statistical analysis was performed using the

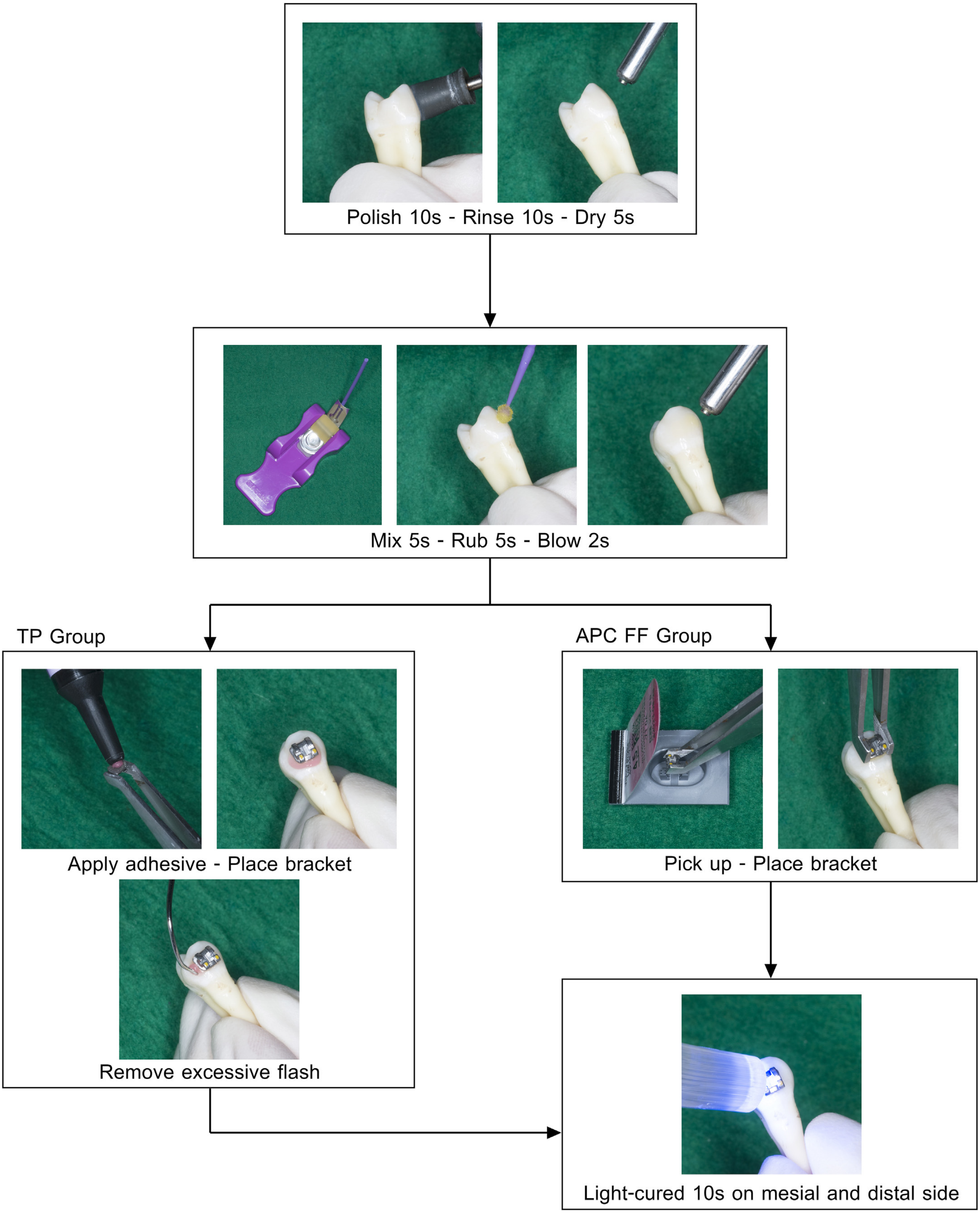

Figure 1. The bracket placement procedures were carried out in accordance with the manufacturer's instructions.

Table 1. The manufacturers' information of drinks used in this study.

Drinks and manufacturers	Contents
Sunsu® RTD Classic Milk Tea Uni-President (Thailand) Ltd., Nakhon Pathom, Thailand	86% black tea, 7% milk powder, 5% sugar, 1.5% creamer, 0.02% salt
Chang® Classic Beer Thai Beverage Plc., Ayutthaya, Thailand	Contents from fine quality malt, rice, and hop, with natural water, and selected yeast, especially for Chang Beer 5% alcohol by volume

SPSS 20.0 program (SPSS, Chicago, IL, USA), with a significance level of 0.05.

3. Results

According to the results, the null hypothesis was rejected. The SBS value of APC FF was significantly lower than that of TP ($p < 0.05$) in all situations and at all times.

The type of drink had an effect on the SBS value, especially milk tea. After 6 months of thermal age, both TP and APC FF had significantly greater SBS values in the milk tea subgroup. However, beer tended to reduce the SBS in the TP group. After 1 year of thermal aging, the SBS of TP and APC FF in the milk tea subgroup increased compared with that at 24 h. The SBS of TP in the milk tea subgroup was significantly higher than that in the beer subgroup ($p < 0.05$). This study found that the SBS of APC FF did not significantly differ across drink subgroups. The mean SBS values for all groups are shown in Table 2.

The amount of remaining adhesive was assessed under a stereomicroscope at 10X magnification. After bonding (24 h), the most prevalent ARI score of the TP and APC FF groups was 1. After 6 months of thermal age, the ARI scores of the TP and APC FF groups in milk tea were 2 and 1, respectively, and an ARI score of 3 was found only in the APC FF group. After 1 year of thermal age, the ARI score of the TP and APC FF groups in milk tea was 1, followed by a score of 2, and an ARI score of 3 was found only in the APC FF group. For beer, the most prevalent ARI scores of the TP and APC FF groups were 1 and 2, respectively. The thermal age did not seem to affect the ARI scores of

Table 2. The mean ± SD of Shear Bond Strength (MPa).

Timing	Solution	Adhesive	
		TP	APC FF
24 h	–	$20.66 \pm 4.88^{a*}$	13.86 ± 4.14 *
6 months	Milk tea	$23.14 \pm 2.33^{A*}$	$17.02 \pm 4.04^{C*}$
	Beer	$17.54 \pm 5.12^{A*}$	$13.74 \pm 4.40^{C*}$
1 year	Milk tea	$24.64 \pm 2.26^{Ba*}$	15.77 ± 4.11 *
	Beer	$20.91 \pm 6.19^{B*}$	16.21 ± 3.51 *

Abbreviations: APC FF, Flash-Free adhesive precoated brackets; SBS, shear bond strength; TP, Transbond Plus Color Change Adhesive.
Note: Same capital letters within the same column mean statistical differences among solution ($p < 0.05$). Same lowercase letters within the same column indicate statistical differences among timing ($p < 0.05$). Same symbols * show statistical differences between types of adhesives ($p < 0.05$).

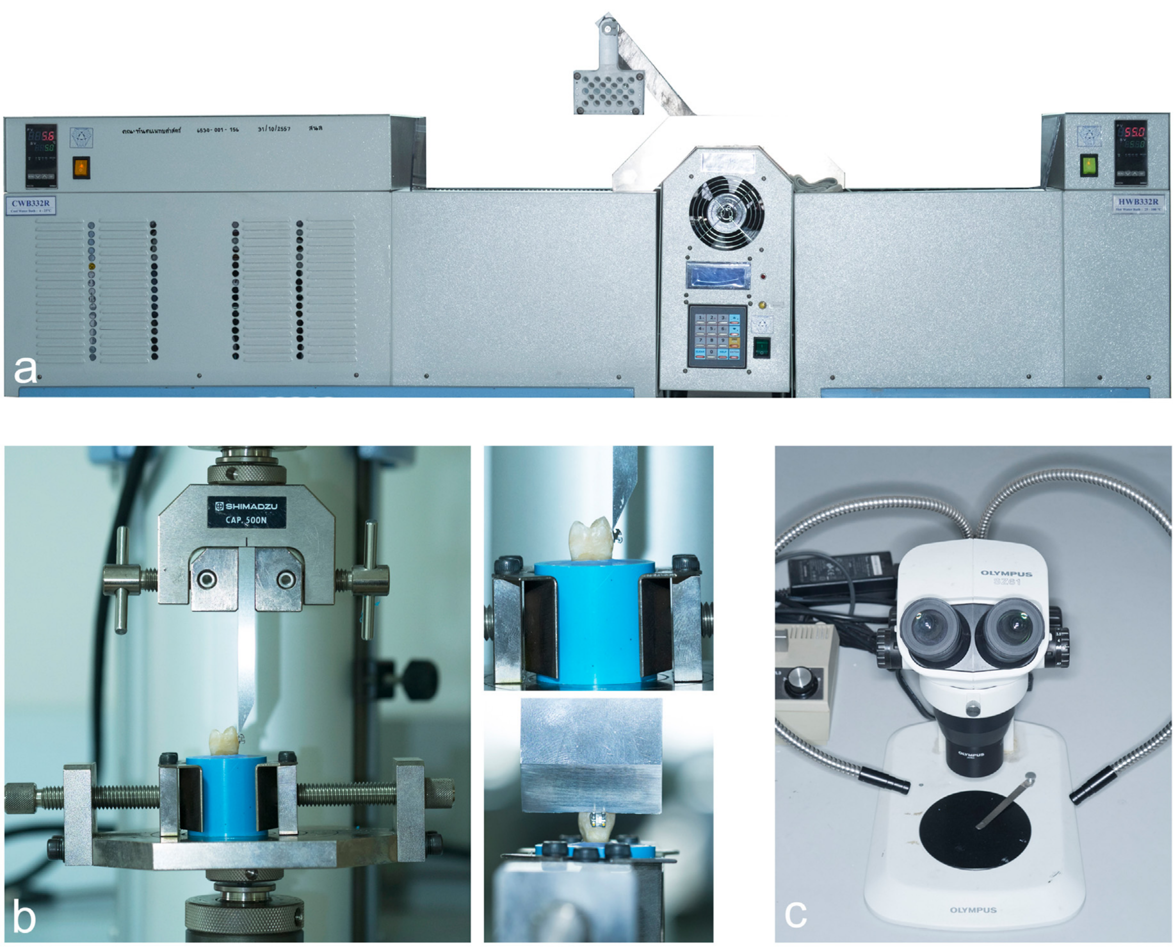

Figure 2. The machines used in this study, (a) the thermocycling machine, (b) the SBS test using the universal testing machine, and (c) the ARI score evaluated under the stereomicroscope.

the TP and APC FF groups in beer; only at 6 months of thermal aging did the APC FF group show scores of 1 and 2. We also found a score of 3 in this group (Table 3). Pictures of the ARI scores of the TP and APC FF groups are shown in Figures 3 and 4.

4. Discussion

In this study, the SBS values of APC FF were significantly lower than those of TP in all situations, which was consistent with the findings of Vorachart et al. [24], who performed the experiment with metal brackets bonded with a self-etch technique. In contrast with prior studies that bonded ceramic brackets using the total-etch method, Marc et al. [18] reported that the SBS of APC FF (21.77 ± 9.18 MPa) was not significantly lower than that of conventional adhesive (26.26 ± 10.33 MPa). Additionally, González-Serrano et al. [29] found no significant differences between the TP (23.7 ± 4 MPa) and APC FF (24.0 ± 5.4 MPa) groups. This indicates that bonding the APC FF metal bracket using the self-etch technique resulted in significantly lower the SBS than bonding the metal bracket with conventional adhesive or ceramic brackets with both types of adhesives using the total-etch approach.

Table 3. Distribution frequency and percentages of ARI scores.

Adhesive	Timing	Solution	ARI score (Prevalence in %)				Total (%)
			0	1	2	3	
TP	24 h	-	1 (6.7)	**11 (73.3)**	3 (20.0)	0 (0)	15 (100)
	6 months	Milk tea	0 (0)	7 (46.7)	**8 (53.3)**	0 (0)	15 (100)
		Beer	0 (0)	**11 (73.3)**	4 (26.7)	0 (0)	15 (100)
	1 year	Milk tea	0 (0)	**9 (60.0)**	6 (40.0)	0 (0)	15 (100)
		Beer	0 (0)	**11 (73.3)**	4 (26.7)	0 (0)	15 (100)
APC FF	24 h	-	0 (0)	**11 (73.3)**	3 (20.0)	1 (6.7)	15 (100)
	6 months	Milk tea	0 (0)	5 (33.3)	**6 (40.0)**	4 (26.7)	15 (100)
		Beer	0 (0)	**6 (40.0)**	**6 (40.0)**	3 (20.0)	15 (100)
	1 year	Milk tea	0 (0)	**13 (86.7)**	1 (6.7)	1 (6.7)	15 (100)
		Beer	0 (0)	**8 (53.3)**	7 (46.7)	0 (0)	15 (100)

Abbreviations: APC FF, Flash-Free adhesive precoated brackets; ARI, adhesive remnant index; TP, Transbond Plus Color Change Adhesive.
Note: The bold numbers represent the most frequent score in each group.

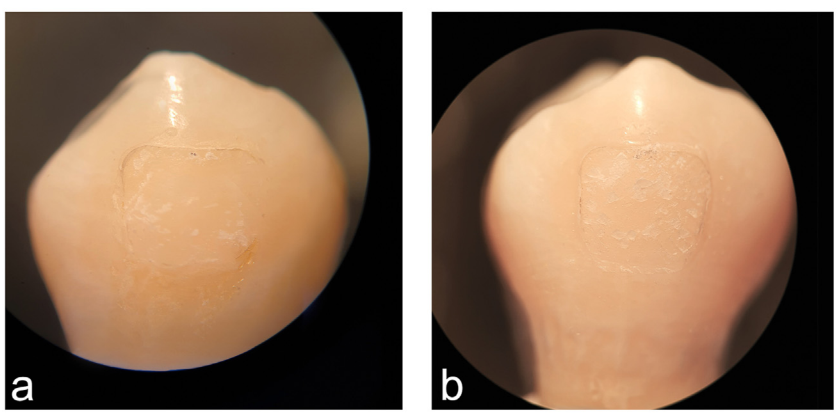

Figure 3. Surface of the specimens after debonding TP adhesive under a stereomicroscope (10X). ARI score 1 and 2 were found: (a) the ARI 1 from TP milk tea 1 year subgroup, and (b) the ARI 2 from TP milk tea 6 months subgroup.

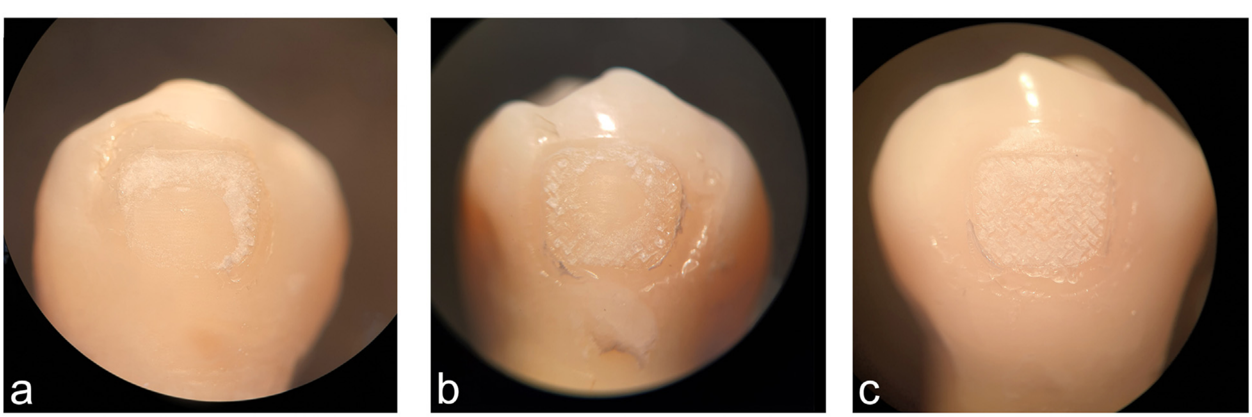

Figure 4. Surface of the specimens after debonding APC FF adhesive under a stereomicroscope (10X). ARI score 1, 2 and 3 were found: (a) the ARI 1 from APC FF milk tea 1 year subgroup, (b) the ARI 2 from APC FF beer 6 months subgroup, and (c) the ARI 3 from APC FF milk tea 6 months subgroup.

The findings showed that beverage had an effect on both control and experimental adhesives. In this investigation, the pH values of beer (4) and milk tea (6.4) were close to the artificial saliva pH values of 3.8 and 6.8 used in the studies by Toodehzaeim and Khanpayeh [22], respectively. They submerged specimens in artificial saliva at pH values of 3.8, 4.8, 5.8, and 6.8 for 2 months before testing the SBS and found that artificial saliva at a pH of 3.8 induced the lowest SBS (6.12 ± 2.04 MPa) when compared to other pH groups, similar to our finding that beer had a lower SBS than milk tea.

Prolonged beer exposure tended to decrease the SBS value of TP. Beer is an acidic alcoholic drink that can decrease the surface microhardness of dental restorative composites by softening the bisphenol A-glycidyl methacrylate (BIS-GMA) copolymer [30]. Hobson et al. [9] suggested the use of an alcoholic mouth rinse at the end of orthodontic treatment to easily remove brackets. Palani et al. [12] determined the SBS of composite with enamel after immersing the specimens in three types of alcoholic drinks for 30 min and 90 min daily for 30 days, demonstrating that the increased alcohol concentration, lower pH and longer exposure duration could reduce SBS between composite and enamel. In our study, the beer subgroup results were not significantly lowered than baseline (24 h after bonding), which might have been due to the short duration of each beer exposure session (15 min). This might imply that if the patient simply drinks beer once a week and the exposure period is under 15 min, the SBS of the bracket will be unaffected.

Another popular acidic beverage is soft drinks such as Coca-Cola, Sprite and Schweppes. Although the effect of soft drinks on conventional adhesive has been studied, their impact on APC FF, particularly APC FF with a metal bracket, which was recently made available, has not been investigated. Because of the acid content, it can erode the enamel surface; therefore, consuming acidic soft drinks on a regular basis while wearing fixed orthodontic appliances may reduce bracket retention [13, 31].

On the other hand, long-term exposure to milk tea enhanced the SBS of TP and tended to increase the SBS of APC FF, which differed from previous reports. This divergence might be explained by the differences in methodologies and content of drinks, particularly drink pH. Ulusoy et al. [10] investigated the effect of herbal teas (black, mint-mate herbal, mint-lemon herbal, and rosehip fruit tea) on bracket SBS bonded using the total-etch method and conventional adhesive. They immersed specimens in each solution for three 5-min sessions with equal intervening intervals for 90 days, discovering that only rosehip fruit tea significantly reduced the SBS; the others had no effect. Rosehip fruit tea has the lowest pH of 2.4, whereas the others have pH values ranging from 5.6 to 7.1. Sirabanchongkran and Wattanapanich [11] immersed specimens in drinks for 15 min twice a day for 90 days and found that ready-to-drink green tea (pH of 5.96) had no effect on the bracket SBS when using either the total-etch or self-etch technique.

Plants, tea and green tea contain natural polyphenols, which have several functions in the oral cavity, such as bacterial control and antioxidation, and have recently been employed as “processing cofactors” to improve the mechanical and functional properties of biomaterials [32]. Previous studies have used tea or green tea to reverse the SBS between adhesives and bleached enamel, with antioxidants being capable of neutralizing free radicals produced by bleaching treatment [33, 34]. Epigallocatechin gallate is one of the most important polyphenols used in dental applications (EGCG). Fonseca et al. [35] demonstrated that adding 0.5–1% (w/w) EGCG to adhesive resin could preserve the SBS while reducing the water solubility and water sorption of the adhesive. Porto et al. [36] found that 0.01 and 0.05% (w/v) quercetin caused a significant rise in micro tensile bond strength when applied to dentin. In this study, the higher SBS of the milk tea group might have been the result of the polyphenol content in the product. We sent the milk tea that we used in our study for investigation of the chemical component and found that it contained 1.89 mg/ml total polyphenol (test report No. TRCM64/14130, Central Laboratory (Thailand) Co., Ltd.), which was between the concentrations used by Fonseca et al. [35] and Porto et al. [36].

Previous research employed thermocycling to imitate thermal changes in the oral cavity. Yuasa et al. [37] used a self-etch system and conventional adhesive to bond metal brackets and stored the specimens in 37 °C artificial saliva for 24 h for 2 years and 6000 thermocycles. They observed that there was no significant difference in SBS values between storage methods. González et al. [29] showed that thermocycling caused a significant drop in SBS values for conventional and APC FF adhesives. According to the results of this study, thermal aging had a significant effect only on the TP milk tea subgroup by raising the SBS over 1 year of thermal aging and tended to increase the SBS of the ACP FF milk tea subgroup, with no statistically significant differences in the other groups. This might mean that the type of beverage has a greater impact on SBS than thermal aging.

The limitation of this study was that it was an in vitro study that attempted to simulate intraoral temperature fluctuations while not accounting for the intraoral environment in real life, such as saliva buffering capacity, bacterial metabolism and pH changes. Furthermore, the chemical interactions between polyphenols and adhesives remain unclear, which should be investigated further.

The residual adhesive on the tooth surface was examined after debonding. The TP group obtained scores of 1 and 2, whereas the APC FF group had scores of 1, 2 and 3, although the most frequent ARI score in both groups was 1. Our finding about the ARI score of TP conformed with the study of Ulusoy et al. [10], who reported that the most common bond failure was ARI 1 in all types of tea groups. In contrast to Sirabanchongkran and Wattanapanich [11], they reported that ARI 0 was the most frequent of the samples bonded using a self-etching system--conventional adhesive and immersed in green tea. In this study, the APC FF tended to leave more residual adhesive after debonding, which probably required more time to remove and might have increased the area of enamel loss during adhesive removal because adequate cleaning without inducing enamel loss was difficult to achieve [38]. However, the influence of alcoholic beverages and milk tea on the failure mode of both traditional adhesive and APC FF requires additional investigation in future research.

During the trial, we noticed that APC FF metal brackets did not totally detach from the tooth surface soon after bond failure, unlike brackets bonded with TP. The failure moment of APC FF could be compared to when removing objects adhered to a surface with double-sided tape; the tape can be totally stuck on one side or partially torn and does not break all at once. This might be either an advantage or a disadvantage of the APC FF metal bracket. The advantage is that when the bracket fails, some part of it attaches to the tooth, which can reduce the chance of swallowing the bracket. However, there is a chance that the bracket failure will not be detected.

5. Conclusions

Even though the SBS of the TP was significantly higher than that of the APC FF, the APC FF is a novel intervention material with an acceptable SBS in long-term usage with routine consumption of milk tea or beer. The beverages influenced on the SBS, with milk tea showing a greater SBS value than beer, especially in the TP group, however, due to sugar content, excessive consumption of milk tea may increase the risk of dental and overall health problems. The SBS will be fine for alcohol consumers if exposed to beer for only 15 min each week.

Declarations

Author contribution statement

Weerada Vorachart; Kulthida Parakonthun: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Nonglak Sombuntham: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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