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Original Research

The Effect of Two Soft Drinks on Bracket Bond Strength and on Intact and Sealed Enamel: An *In Vitro* Study

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Abstract:

Background and Objectives: This study was conducted to evaluate the effect of two soft drinks, Coca-Cola and Mirinda orange on bracket bond strength, on adhesive remnant on teeth after debonding the bracket, and to observe by means of scanning electron microscope (SEM) the effect of these drinks on intact and sealed enamel.

Methods: 120 non-carious maxillary premolar teeth already extracted for Orthodontic purposes were taken and divided into three groups, i.e., Coca-Cola drink, Mirinda orange, and control (artificial saliva) group. Brackets were bonded using conventional methods. Teeth were kept in soft drinks for 15 days, for 15 min, 3 times a day, separated by intervals of 2 h. At other times, they were kept in artificial saliva. The samples, thus obtained were evaluated for shear bond strength using the universal testing machine and subsequently subjected for adhesive remnant index (ARI) scores. SEM study on all the three groups was done for evaluating enamel surface of the intact and sealed enamel.

Results: The lowest mean resistance to shearing forces was shown by Mirinda orange group (5.30 ± 2.74 Mpa) followed by Coca-Cola group (6.24 ± 1.59 Mpa) and highest resistance to shearing forces by control group (7.33 ± 1.72 Mpa). The ARI scores revealed a cohesive failure in control samples and an adhesive failure in Mirinda and cola samples. SEM results showed areas of defect due to erosion caused by acidic soft drinks on intact and sealed enamel surface.

Conclusion: Mirinda group showed the lowest resistance to shearing forces, followed by Coca-Cola group and with the highest resistance to shearing forces by the control group. There were significant differences between the control group and the study groups. Areas of defects, which were caused by erosion related to acidic soft drinks on the enamel surface around the adhesive, were seen. Areas of defects caused by Coca-Cola were more extensive when compared to Mirinda orange drink.

Key Words: Bond strength, scanning electron microscope, soft drinks

Introduction

The introduction of acid-etch technique has opened a new era in orthodontic bonding. The increased adhesion produced by acid pretreatment, using 85% phosphoric acid was demonstrated in 1955 by Buonocore.[1] In 1965, with the advent of epoxy resin, Newman[2] began to apply this to directly bond brackets in orthodontics.

Many factors affect the retention of the brackets during fixed orthodontic treatment.[3] Healthy enamel is also needed for the retention of the bracket, and an altered enamel surface may affect the retention.[4] Even though product development of adhesives is taking place at a rapid rate, decalcification of enamel around orthodontic brackets, seen clinically as white spot lesions, has remained a neglected part of orthodontic care.

Decalcification is defined as loss of calcified tooth substance, and it occurs when the pH of the oral environment favors diffusion of calcium and phosphate ions out of enamel.[4] Preventing this decalcification that occurs during orthodontic treatment is an important concern because these lesions are unaesthetic, potentially irreversible, and cariogenic.

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.[4-6] Factors other than pH, such as type of acid, pKa, titrable acidity, buffering capacity, and temperature influence the dental erosive capacity of acidic liquids.[7]

Enamel demineralization can occur, when the pH value in the mouth falls below 5.5. The pH values of many soft drinks in the market are well below this value.[8] Soft drinks with their acidic pH and increased adhesion have the potential to demineralize enamel.[8] Frequent consumption of soft drinks is increasing in children, because of easy availability, increasing promotion, and sales of various commercially available soft drinks. The term soft drinks refer to all drinks except alcohol, mineral water, fruit juice, tea, coffee, or milk-based drinks, which may or may not be carbonated. Recently, the consumption of soft drinks has increased. They are damaging because they contain high levels of sugar and also due to low pH levels (pH < 5.5). Soft drinks consumed frequently have been shown to cause extreme dental erosion.[9] Dental erosion is defined as the acid-induced loss of hard tissue, a chemical process in which bacteria play no part; and hence, dental erosion is not associated with dental plaque.

In an *in vivo* study, it was found that the prevalence of dental erosion increased as the pH levels of the studied drinks decreased and as consumption increased. Other studies using scanning electron microscope (SEM) have shown that soft drinks produce large areas of enamel decalcification. In general, it is concluded that after immersion in beverages with low pH, the surface microhardness of the teeth is reduced.[9]

The appearance of white spot lesions caused by the demineralization of tooth enamel is a clinical problem associated with orthodontic treatment. Its prevalence is between 2% and 96% in patients with fixed appliances and is the result of demineralization process occurring around and beneath the brackets due to a decrease in pH.

Studies that use SEM to evaluate the effect of soft drinks on enamel sealed with orthodontic adhesives have observed areas of enamel showing an adhesive loss after exposure to soft drinks. This suggests that soft drinks consumption may provoke an increase in micro-leakage beneath brackets and also compromise bond strength.[10]

Studies[5,11,12] have demonstrated that saliva forms an important defense mechanism against erosion. It has been shown that all samples exposed to an erosive solution that were stored in saliva showed less erosion.

Hence, this study was undertaken to study the effects of two soft drinks (Coca-Cola and Mirinda orange) on the shear bond strength (SBS) of brackets and their effect on intact and sealed enamel by means of SEM.

Methods

This study was conducted to evaluate the effect of two soft drinks, Coca-Cola and Mirinda orange on SBS of orthodontic brackets and on the enamel surface.

One hundred and twenty premolar teeth, freshly extracted for orthodontic purposes, and free from enamel cracks, caries, and fillings were used in this research.

They were further subdivided into three groups: (Table 1)

1. Group I (SBS, $n = 60$)
2. Group II (SEM analysis with intact enamel [IE], $n = 30$)
3. Group III (SEM analysis with etched and sealed enamel, $n = 30$).

Table 1: Sample grouping for testing.

Groups	Group I (n=60)	Group II (n=30) (Intact enamel)	Group III (n=30) (Etched and sealed enamel)
Subgroup-a (Control)	20	10	10
Subgroup-b (Coca-Cola)	20	10	10
Subgroup-c (Mirinda orange)	20	10	10

The teeth were cleaned in water to remove any traces of blood and then they were placed in 0.1% thymol solution. Subsequently, they were stored in distilled water, which was changed at regular intervals to avoid deterioration. Then teeth in each group were mounted vertically on three different color-coded acrylic boxes for identification (green-artificial saliva, purple - Coca Cola, and red - Mirinda orange).

Bonding procedure: 60 metal premolar brackets were used. The base area of each bracket was calculated. The brackets were bonded on buccal surfaces with Transbond XT according to manufacturer's instructions. The buccal surfaces were polished with a rubber cup and polishing paste, etched with 37% *o*-phosphoric acid gel for 30 s, and then washed with water. Subsequently, the enamel surfaces were completely dried with compressed air. A thin layer of Transbond XT primer was applied to the tooth and light cured. The paste was applied to the bracket base and then pressed firmly onto the tooth. Excess adhesive was removed with a probe from around the base of the bracket and then the adhesive was light-cured, positioning the light guide on each interproximal side for 10 s.

Storage of test specimens and experimental groups

The specimens were divided randomly into three groups:

- Subgroup-a: Control
  The specimens were submerged in artificial saliva for 15 days, renewing saliva daily.
- Subgroup-b: Coca-Cola
  The specimens were submerged in Coca-Cola for 15 days, for 15 min, 3 times a day, separated by intervals of 2 h. At other times, they were kept in artificial saliva.
- Subgroup-c: Mirinda orange
  The teeth were submerged in Mirinda orange following the same procedure as in subgroup-b.

While artificial saliva was kept at room temperature, both Coca-Cola and Mirinda orange were stored at a temperature of 5°C. The pH of each medium was measured electronically (Table 2).

The immersion times and schedules used in previous studies vary widely. In general, specimens were submerged in the soft drinks continuously for long periods,[13-15] whereas in the present research an immersion schedule was used that would reproduce as closely as possible the situation *in vivo*. In this way, assuming that these drinks are consumed 3 times a day and that it might take around 45 min to consume one drink, the specimens were submerged in the drinks for 15 min at a time and afterward in artificial saliva, a procedure that was repeated 3 times a day. The teeth were kept in saliva between immersions in the drinks in order to reproduce normal oral environment conditions and also to allow the possible remineralizing effects of saliva on enamel to take place.[16,17]

Bond strength test

Group I: Containing 60 specimens was subdivided into three groups, each having 20 teeth which were used to carry out SBS testing, with the universal testing machine.
Group Ia ($n = 20$): 20 samples were color-coded with green
Group Ib ($n = 20$): 20 samples were color-coded with purple
Group Ic ($n = 20$): 20 samples were color-coded with red.

Evaluation of adhesive remnant on teeth after debonding

The percentage of the bracket base surface area covered by adhesive was determined by Adhesive remnant index (ARI).[18]

The ARI scale ranges from 1 to 5:
1. All of the adhesive remaining on the enamel, with impression of the bracket base
2. More than 90% of the adhesive remaining on the enamel surface
3. <90% but more than 10% of the adhesive remaining on the enamel surface
4. <10% of the adhesive remaining on the enamel surface
5. No adhesive remaining on the enamel surface.

SEM

The 60 teeth for SEM study were further divided into two groups:
1. Group II IE ($n = 30$), where the buccal surfaces were polished with rubber cup and polishing paste
2. Group III enamel etched and sealed (ES) ($n = 30$) with Transbond XT primer, where the buccal surfaces were polished with a rubber cup and polishing paste, etched with 37% *o*-phosphoric acid gel, and primed with Transbond XT, which was later light cured for 20 s.

Of the 30 specimens that made up each group, 10 specimens of each group were placed in artificial saliva, Coca-Cola, and Mirinda orange, respectively. The immersion cycles described above for storage were followed.

All specimens were cleaned in distilled water with ultrasonic agitation for 30 min and gently air-dried. They were then affixed to SEM stubs; sputter coated with gold, and the enamel surface was examined under SEM, operating at 20 kV, at ×100 magnification. Images representative of the different surface treatments were captured and stored digitally.

Table 2: pH of three solutions.

Solutions	pH
Artificial saliva	6.8
Coca-Cola	2.5
Mirinda orange	2.7

Results

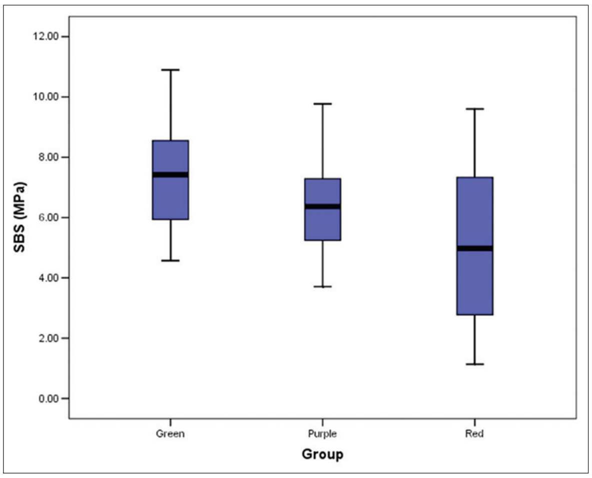
The following results were derived from this study using a total of 120 samples.

Comparison of mean SBS was done between the groups.

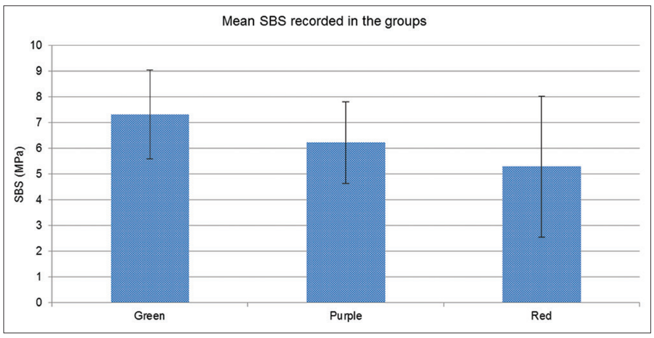
The brackets were debonded using the Universal testing machine and the SBS was evaluated for all samples. Adhesive that remained after the bracket removal was assessed using magnifying glass and scored according to modified ARI proposed by Bishara *et al.*[13] Following this procedure a SEM study was done to compare the surface changes seen on IE surface and etched and sealed enamel.

When comparing the groups, higher mean SBS was recorded in Group Ia group followed by Group Ib and Group Ic, respectively. The difference in mean SBS among the groups was found to be statistically significant ($P < 0.05$) (Graphs 1 and 2).

Higher mean ARI score was recorded in Group Ic followed by Group Ib and Group Ia, respectively. The difference in mean



Graph 1: Box-plot of shear bond strength.



Graph 2: Mean shear bond strength recorded in the groups.

ARI among the groups was found to be statistically significant ($P < 0.001$) (Graph 3).

SEM

Interpretation

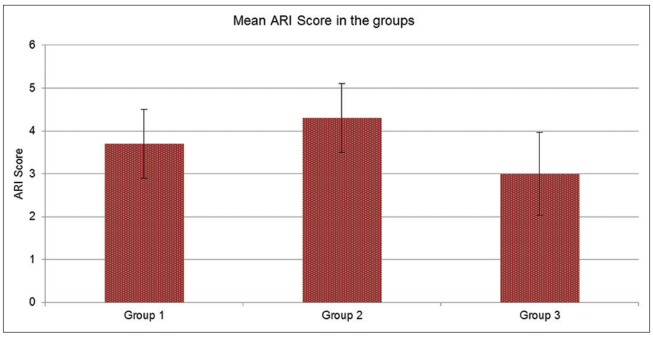
Group II (IE) Intact Enamel

Weibull survival analysis showed maximum probability failure of 75 % in group Ib [Coca- Cola] and group Ic [Mirinda orange] and a minimum probability failure of 40% in group Ia [control]. The results confirm that probability failure of bracket bond strength is significantly less in the control group Ia [Artificial saliva] than the group Ib[Coca- Cola] and group Ic [Mirinda orange]. This study further confirms statistically significant decrease in shear bond strength of group Ib [Coca-Cola] and group Ic [Mirinda orange] and adequate bond strength in group Ia [control] (Table 3).

Group IIa (Control): The control group showed a healthier enamel surface (Figure 1).

Group IIb (Coca-Cola): The enamel surface in the test specimens in Coca-Cola group showed increased surface irregularities, areas of crater-like depression, and extensive erosion pattern (Figure 2).

Group IIc (Mirinda orange): The enamel surface in the test specimens in Mirinda orange group showed milder surface irregularities when compared to that of the Group IIb (Coca-Cola) (Figure 3).



Graph 3: Mean adhesive remnant index score in the groups.

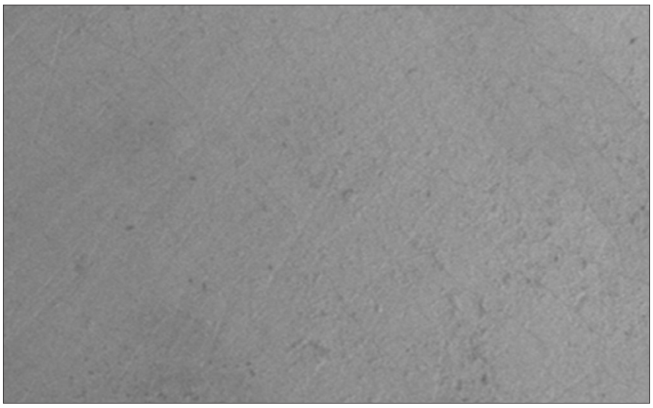


Figure 1: Scanning electron microscope: Intact enamel (Artificial saliva).

Group III (etched and sealed enamel)

Group IIIa (Control): The control group showed healthier enamel surface with etched and sealed enamel (Figure 4).

Group IIIb (Coca-Cola): The enamel surface showed a greater degree of demineralization and also erosion was seen on the sealed enamel surface (Figure 5).

Group IIIc (Mirinda orange): The enamel surface of the test specimens in Mirinda orange group also showed demineralization and mild erosion in the sealed area. But, the degree of demineralization is less when compared to Group IIIb (Coca-Cola) (Figure 6).

When comparing Group II (IE) and Group III (etched and sealed enamel), Group II (IE) showed greater enamel demineralization. This was, especially more in the Coca-Cola group than in the Mirinda orange group.

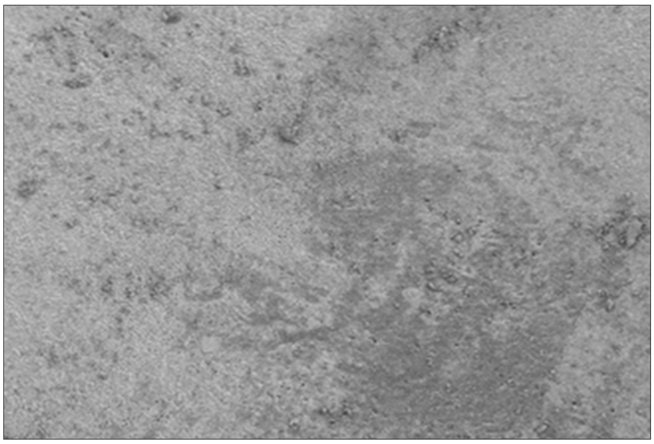


Figure 2: Scanning electron microscope: Intact enamel (Coca-Cola).

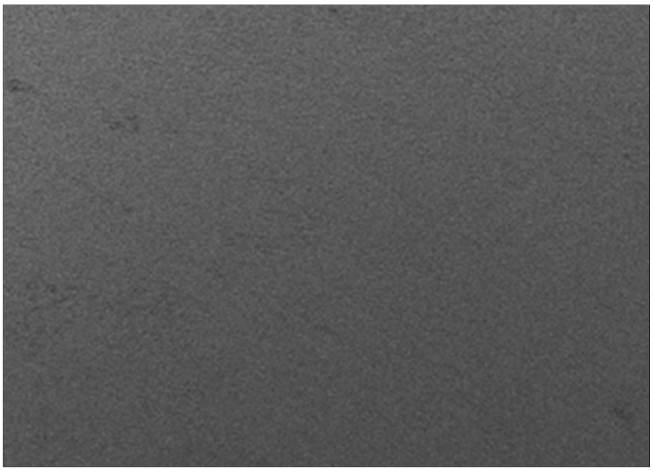


Figure 3: Scanning electron microscope: Intact enamel (Mirinda orange).

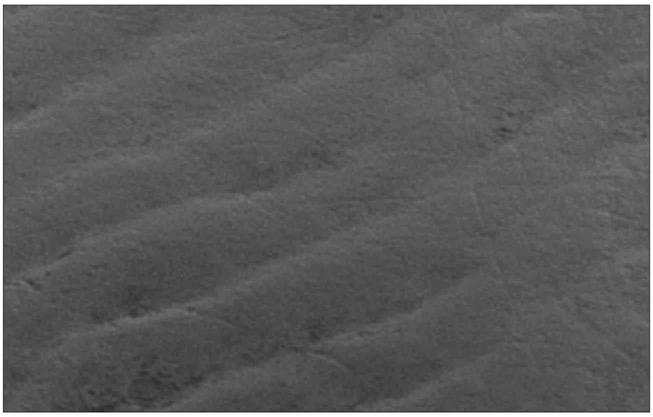


Figure 4: Scanning electron microscope: Etched and sealed enamel (Artificial saliva).

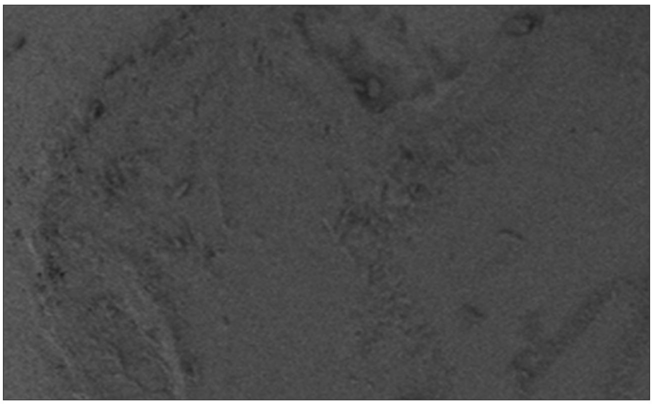


Figure 5: Scanning electron microscope: Etched and sealed enamel (Coca-Cola).

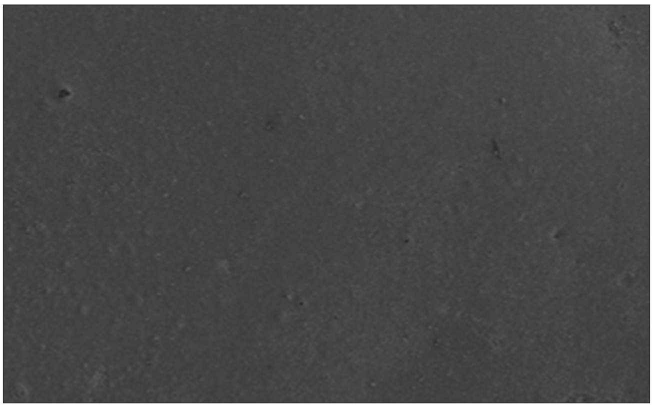


Figure 6: Scanning electron microscope: Etched and sealed enamel (Mirinda).

Discussion

Bonding of orthodontic brackets has become an accepted clinical technique since 1970 (Zachrisson, 1994). Bonding has largely replaced banding and is superior to banding in terms of gingival and dental health and esthetics. The bonding procedure is based on enamel alteration created by acid etching of enamel as developed by Buonocore.[1] The advantages of direct bonding are easy bracket placement, acceptable clinical success rate, and reduction in chairside time. Significant bond failure is reported to vary between 0.5% and 16%.[19-22]

Table 3: Weibull analysis.

S. No.	SBS (MPa)			Cut-off (MPa)
	Group Ia	Group Ib	Group Ic	
1	4.57	4.96	9.60	7
2	9.28	5.42	9.32	7
3	9.39	6.19	4.78	7
4	9.09	6.10	5.09	7
5	6.26	3.79	6.28	7
6	7.89	6.79	6.21	7
7	7.82	8.24	6.33	7
8	7.20	9.77	4.87	7
9	7.34	6.56	8.40	7
10	10.90	7.60	2.31	7
11	7.94	8.08	1.74	7
12	5.80	6.55	3.24	7
13	5.50	5.40	1.14	7
14	6.08	6.97	1.73	7
15	7.50	5.09	7.68	7
16	6.62	3.87	6.98	7
17	4.62	7.63	4.66	7
18	5.46	3.71	4.78	7
19	8.01	5.40	1.54	7
20	9.28	6.59	9.28	7

SBS: Shear bond strength

However, the fact is that damage caused to the enamel cannot be ignored. Even though many efforts have been made to avoid enamel damage and demineralization, such as crystal growth technique for bonding,[23] studies done by it was found that bond failures by other methods are higher when compared with the conventional method. This irreversible surface enamel demineralization can be further aggravated by the frequent ingestion of soft drinks. As soft drinks consumption is emerging as a social trend in urban India, asking the patient to avoid consumption of soft drinks is easier said than done. Further concrete evidence is needed to convince the patient.

The term "soft drinks" refers to all kinds of drinks except alcoholic ones, either carbonated or non-carbonated.[9] It consists of acidic content such as phosphoric acid, which reduces the pH of the oral cavity.[24] The increased consumption of soft drinks causes enamel erosion.[25] The structure of enamel surface is crucial for bracket retention. Any modification of enamel surface may affect this retention.[26]

In dental caries, loss of minerals from the enamel subsurface occurs due to acids released from the microbial plaque. In enamel erosion, exposure to extrinsic acids results in demineralization and the factors contributing to the progression of erosion are poor oral hygiene and inadequate bonding procedures.[27,28] It is reported that consumption of acidic and alcoholic drinks causes softening of the enamel due to loss of minerals from enamel and can decrease bracket retention.[29-31] It also causes an increase in the micro-leakage under brackets.[28]

Sixty premolars were selected for this study, as it was easier to obtain an intact tooth of an orthodontic extraction. The samples were divided into three groups, each containing 20 teeth. The brackets were debonded using a universal testing machine and SBS was evaluated for all samples.

Acidic soft drinks may have two concomitant effects on the bond strength of orthodontic brackets. It can directly deteriorate the structure of adhesive materials, on the other hand, it can cause erosive lesions on the enamel surface around the brackets, and hence decrease the bond strength.[21,32,33] The results indicating a minimal difference in SBS among the groups in the present research ($P > 0.05$) were similar to another study.[34] SBS of the Coca-Cola group was slightly greater than the Mirinda orange group.

The results of the present study are contrary to the studies[35,36] showing that phosphoric acid-based drinks have lower SBS potential than citric acid-based drinks. Low dose citrate increases the pH and decreases the acidogenicity of the dental plaque, and its use is recommended to reduce the cariogenicity of non-alcoholic soft drinks.[37] A study[38] showed that soft drinks with a low pH, a phosphoric acid base, and a citric acid base could decrease the SBS of the brackets.

The values obtained by SBS testing for all groups were statistically evaluated by Analysis of variance to calculate the *P* value. The mean SBS of Group Ia (control) sample was 7.33 ± 1.72 Mpa, Group Ib (Coca- Cola) was 6.24 ± 1.59 Mpa, and that of Group Ic (Mirinda orange) was 5.30 ± 2.74 Mpa. The lowest mean resistance to shearing forces was shown by Mirinda orange group (5.30 ± 2.74 Mpa) followed by Coca-Cola group (6.24 ± 1.59 Mpa) and highest resistance to shearing forces was by the control group, i.e., artificial saliva (7.33 ± 1.72 Mpa).

In this study conducted, pH was critically low for Group Ib (2.5) and Group Ic (2.7). These groups showed significantly lower values of SBS when compared to the control group, i.e., the artificial saliva (6.7). When evaluating SBS of Group Ib (Coca-Cola) and Group Ic (Mirinda orange) it was found that Group Ib (Coca-Cola) had a greater SBS than Group Ic (Mirinda orange).

Weibull survival analysis was done to predict the number of bonds likely to fail at a clinically acceptable strength of 7 Mpa. Weibull analysis is a survival analysis, which has the ability to provide reasonably accurate failure analysis and failure forecasts with extremely small samples. Small samples also allow cost-effective component testing. This analysis can be used even with inadequacies in the data.

The ARI was done on all 60 samples. Any adhesive that remained after the bracket removal was assessed and scored according to ARI proposed by Bishara.[20]

When a bonded bracket is removed, failure at one of the following interfaces must occur: between the bonding material and the bracket, within the bonding material itself, or between the bonding material and the enamel surface.

Failure at the enamel surface is not desirable because the bonding material may tear the enamel surface as it pulls away from it. The interface between the bonding material and the bracket is the usual and preferred site of bracket debonding.[39]

In this study, after evaluating the ARI score, higher mean score was recorded in Group Ic followed by Group Ib and Group Ia, respectively. The difference in mean ARI among the groups was found to be statistically significant ($P < 0.001$). In order to find out among which pair of groups there existed a significant difference, a Mann–Whitney test was carried out. The results showed that difference in mean ARI scores was found to be statistically significant between Group Ia and Group Ib ($P < 0.05$), Group Ia and Group Ic ($P < 0.05$) as well as between Group Ib and Group Ic ($P < 0.001$). Chi-square test revealed that the association between ARI scores and the groups was found to be statistically significant ($P < 0.01$). Higher number of samples in Group Ia had an ARI score of 3 and majority of the samples in Group Ib had an ARI score of 4. In Group Ic, majority of the samples had an ARI score of 5 or 4.

The phosphoric acid-based Coca-Cola (Group Ib) and citric acid-based Mirinda orange (Group Ic) with significantly low pH showed a greater number of samples with bracket bond failure between the bonding material and enamel surface. In the control (Group Ia), most specimens showed bracket debonding showed bracket debonding occurring mostly at the interface of bonding material and the bracket which is the most desirable way of debonding. A study[23] compared the erosive capabilities of a citric acid-based orange juice drink and phosphoric acid-based diet cola drink. It was found that the phosphoric acid-based diet cola had more erosive potential than the citric acid-based juice drink.

Following this procedure a SEM was conducted to assess the surface changes seen on the enamel. Samples were randomly selected from each group to be studied under SEM. All samples to be examined were gold-coated and subjected to SEM under magnification of ×100. The SEM results were interpreted and compared within the groups.

Group II with IE showed the highest level of enamel demineralization in group IIb followed by Group IIc. Group IIa, the control group, showed healthier enamel surface. Group IIb, i.e., the Coca-Cola drink group showed larger areas of demineralization when compared to Group IIc, i.e., the Mirinda drink group.

Group III with etched and sealed enamel showed a greater level of enamel demineralization in Group IIIb followed by

Group IIIc. Here, again enamel demineralization was more in Coca-Cola drink group, i.e., Group IIIb when compared to the Mirinda orange drink group, i.e., Group IIIc.

When Coca-Cola drink group and Mirinda orange drink group were compared with SEM, the enamel defects in Coca-Cola drink group were more extensive and noticeable than the Mirinda orange drink group. This could be because the erosive effect of phosphoric acid in Cola group was more than the citric acid in Mirinda orange drink group. While Mirinda orange drink group was found to be less erosive than Coca-Cola drink group, yet some amount of erosion was still evident when compared to the control group. The enamel surface of etched and sealed enamel was found to be less erosive with SEM when compared to the enamel surface with IE.

Thus, among the two soft drinks, Coca-Cola drink group showed greater erosive potential than the Mirinda orange. But, Mirinda orange drink group had lower resistance to shearing forces when compared to Coca-Cola drink group. Therefore, patients should be advised to consume fewer soft drinks, the choice of drink for the prevention of dental erosion and the frequency of its consumption should be reduced as it decreases the strength of the brackets. Hence, the Orthodontist should properly guide the patient and give instructions to improve the efficiency of orthodontic treatment.

Conclusion

The present *in vitro* study concluded that:

- The maximum SBS was seen in the control group (artificial saliva), followed by Coca-Cola group and the minimum bond strength was recorded in Mirinda orange group
- Higher mean ARI score was recorded in Mirinda orange group followed by Coca-Cola group and with lowest mean ARI in control group (artificial saliva), respectively. The difference in mean ARI among the groups was found to be statistically significant
- When comparing Group II (IE) and Group III (etched and sealed enamel), Group II (IE) showed greater enamel demineralization, which was specially more in the Coca-Cola group than in the Mirinda Orange group.

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