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Effects of a Fluoride Containing Casein Phosphopeptide-Amorphous Calcium Phosphate Complex on Shear Bond Strength and Adhesive Remnant Index of Teeth Eroded by Different Beverages: An In-Vitro Study

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KEYWORDS

Calcium Phosphate Complex, Shear Bond Strength

ABSTRACT:

INTRODUCTION-

One of the most commonly encountered complications that we come across during orthodontic treatment is loosening of brackets or bond failure. Dental erosion and loss of tooth structure have also been reported to reduce bond strength and cause bond failure. The frequency of dental erosion in the recent past has increased because of the increase in consumption of various acidic drinks and it has been reported to reduce the shear bond strength. Use of various remineralization agents have shown to increase enamel surface hardness post-dental erosion and it has been suggested as a prophylactic agent.

AIM-

To evaluate the effects of CPP-ACPF (casein phosphopeptide-amorphous calcium phosphate with fluoride), a remineralization agent on shear bond strength and adhesive remnant index of teeth, eroded by different beverages namely Coca-Cola and Lipton lemon flavoured ice tea

MATERIALS AND METHODS-

Fifty-two maxillary/mandibular premolars were chosen and allocated into four groups with 13 teeth in each with respect to beverage used for erosion and enamel pre-treatment: A1(Eroded by Coca-Cola: Pre-treatment with CPP-ACPF). A2(Eroded by Coca-Cola, no enamel Pre-treatment). B1(Eroded by Lipton lemon flavoured ice tea: Pre-treatment with CPP-ACPF). B2(Eroded by Lipton lemon flavoured ice tea: No pre-treatment). The specimens were then bonded and subjected to shear bond strength test. The remaining adhesive on the teeth were assessed after debonding with Modified Adhesive Remnant Index (ARI). Data evaluation was done by Kruskal Wallis, Chi-Square test.

RESULTS AND CONCLUSIONS-

1. Application of remineralization agents like CPP-ACPF on teeth eroded by aerated soft drinks, increased the median shear bond strength.

2. CPP-ACPF pre-treatment did not affect the SBS of teeth eroded by Lipton lemon flavoured ice tea.

3. Irrespective of the acidic beverage used for erosion, or the enamel pre-treatment with CPP-ACPF, statistically significant difference was not seen in the SBS between the groups which suggest the need for further clinical studies to find the effectiveness of the remineralization procedure.

4. Bond failure of brackets in all the groups was at enamel-adhesive interface leaving some residue on the enamel surface.

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INTRODUCTION

One of the most commonly encountered complications that we come across during orthodontic treatment is loosening of brackets or bond failure. Bond failure rate should be minimized as replacing loose brackets is inefficient, time-consuming, and costly. The frequency of this has been found to vary between 0.5 and 17.6 percent.[1] Numerous causes can lead to loosening of brackets which includes poor operator technique, variation in the enamel surface, saliva contamination, bracket properties, masticatory forces, and patient behavior.[1] Dental erosion and loss of tooth structure have also been reported to reduce bond strength and cause bond failure.

Recurring exposure of teeth to acidic medium together with functional and parafunctional forces causes dental erosion. Any acidic substance in the oral cavity has to initially pass through the acquired enamel pellicle (AEP). The AEP is a thin acellular biofilm composed of proteins, enzymes, glycoproteins, carbohydrates and lipids and it acts as a protective layer. Once the acid passes through the AEP, its hydrogen ions (H+) start breaking down the enamel crystals which leads to an initial demineralization indicated by a softening of the enamel and predisposing it to the effects of functional and parafunctional forces. [2]

Various drinks and food which are acidic or alcoholic can also be a major factor causing bond failure as they lead to dental erosion. Consumption of soft drinks which have low pH during orthodontic treatment decreases the SBS by reducing the hardness of the enamel around the brackets or composite resin disintegration. [1]

Consumption of soft drinks and various types of tea has increased in the recent past. Aerated soft drinks and packed fruit juices are consumed more by children and adolescents and during adulthood, they shift to consumption of different types of tea like iced tea, herbal tea and green tea as they become more health-conscious.

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. [3] They are detrimental because of the elevated levels of sugar they carry and most of them are acidic in nature. Frequently consumed soft drinks like Coca-Cola cause more dental erosion because they contain acids like phosphoric acid, citric and carbonic acid. Phosphoric acid is more harmful as it is more acidic and causes more erosive lesions on the tooth surface. [10]

Although teas are known to be safe, most of these have high erosive potential because of their fruit products containing hydroxyl organic acids, such as citric, malic, and oxalic. Few studies have reported dental erosion caused by tea. [1] Most of these soft drinks and tea have a pH below the critical limit for enamel demineralization (pH <5.5) thus leading to erosive lesions on the tooth surface. [3]

Dental erosion can be avoided by increasing the acid resistance of the tooth structure or by remineralization processes which requires calcium, phosphate and fluoride. Casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) which is derived from cow's milk reduces the demineralization process of the enamel and enhances the remineralization process. This is because casein, an amino acid, changes according to the pH. In low pH, ACP detaches from CPP, which elevates the calcium and phosphate levels in the saliva. The CPP-ACP complexes easily combine with the fluoride ions to form CPP-ACPF. [5] CPP-ACPF acts as a reservoir for fluoride as well as calcium and phosphate ions for remineralization. This CPP-ACPF complex, when added to dentifrices, mouth rinses, chewing-gum, varnishes or sprays delivers extra bioavailable calcium and phosphate ions. Demineralization caused by acidic and alcoholic drinks are reported to get reversed by these agents.

Even though studies have been done on soft drinks, tea, non-alcoholic beers etc. and it is proven to cause erosion and decrease in bond strength and it is also known that CCP-ACPF causes remineralization of teeth for at least 2 weeks and limits demineralization up to 12 weeks [6], till date no study has been done to see if it improves the bond strength of eroded teeth. Adhesive remnant index (ARI) is used to determine the bond failure location whether it is adhesive bracket interface or adhesive tooth interface. Thus, this study sought to evaluate the effects of CPP-ACPF on bond strength and adhesive remnant index of teeth eroded by two different beverages namely Coca-Cola and Lipton lemon flavoured ice tea.

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AIM OF THE STUDY

To evaluate the effects of CPP-ACPF (casein phosphopeptide-amorphous calcium phosphate with fluoride), a remineralization agent on shear bond strength and adhesive remnant index of teeth, eroded by different beverages namely Coca-Cola and Lipton lemon flavoured ice tea

OBJECTIVES

- To evaluate the shear bond strength and adhesive remnant index of teeth eroded by Coca-Cola and treated with CPP-ACPF followed by bonding with Transbond XT and curing with LED curing gun
- To evaluate the shear bond strength and adhesive remnant index of teeth eroded by Lipton lemon flavoured ice tea and treated with CPP-ACPF followed by bonding with Transbond XT and curing with LED curing gun

MATERIALS AND METHODOLOGY

MATERIALS AND ARMAMENTARIUM

1. Pre-adjusted edgewise metal brackets of first and second maxillary and mandibular premolar teeth (3M Unitek)
2. 37% phosphoric acid
3. Transbond XT primer (3M Unitek)
4. Transbond XT adhesive (3M Unitek)
5. LED curing lamp (PANAMA CE LED curing light)
6. CPP-ACPF (GC Tooth mousse Plus)
7. Universal testing machine (Instron)
8. Stereomicroscope
9. Coca-Cola
10. Lipton lemon flavoured ice tea
11. Distilled water
12. 0.1% Thymol solution
13. Digital pH meter

SOURCE OF DATA/ LABORATORY DETAILS:

- The teeth used in this study were selected from patients requiring premolar extraction for orthodontic therapy visiting the Department of Orthodontics and Dentofacial orthopedics. The extracted human premolar teeth were collected from the Department of Oral and Maxillofacial Surgery, KLE Academy of Higher Education & Research, VK Institute of Dental Science, Belagavi
- The study was done in the Department of Orthodontics and Dentofacial Orthopedics, KLE Academy of Higher Education & Research, VK Institute of Dental Science, Belagavi
- The laboratory procedures were undertaken in Dr Prabhakar Kore's Basic Science Research Centre, KLE Academy of Higher Education & Research, VK Institute of Dental Science, Belagavi
- The shear bond strength of the brackets was assessed at Praj metallurgical lab, Pune
- Specimens were evaluated under the Stereo microscope for checking adhesive remnant index (ARI) at Department of Oral Pathology, KLE Academy of Higher Education & Research, VK Institute of Dental Science, Belagavi

INCLUSION CRITERIA:

- Maxillary or mandibular, first or second premolar teeth.

EXCLUSION CRITERIA:

- Teeth with visible or detectable caries.
- Teeth with restorations.
- Teeth with hypoplastic lesions, stains, cracks and white spot lesions.
- Teeth with surface defects (erosion, attrition, abrasion).
- Root canal treated teeth.

SAMPLE SIZE ESTIMATION

Sample size estimation based on comparison between two means (Demineralized dentine Vs CPP-ACPF treated demineralized dentine) by an article by Martins LP, et.al., 2018

STATISTICAL TEST:

- Kruskal-Wallis, chi-square

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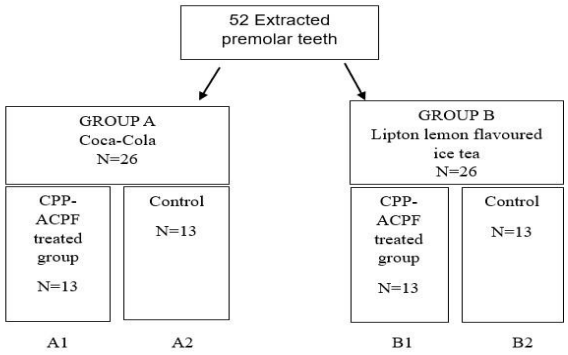
METHODOLOGY:

Human premolars extracted for orthodontic purposes were used in the study. After extraction the teeth were stored in 0.1% thymol solution to prevent any fungal or bacterial growth. The teeth were thoroughly cleaned of debris, calculus and soft tissues. The pH of both the beverages were tested before using them. The pH of both the beverages were tested using an electronic pH meter (EUTECH instruments pH meter 510). The pH meter was calibrated using test solutions with a known pH value (Fisher Scientific buffer solution pH 7.0). The pH of Lipton lemon flavoured ice tea was found to be 2.90 and that of Coca-Cola was 2.20. All the groups were treated with the acidic drinks for 90 days, in three sessions of 5 minutes each, during the day. In between the erosion procedure the teeth were kept in distilled water.52 selected teeth were randomly divided into four equal groups with respect to the acidic drink used.



Group A1: The teeth were eroded with Coca-Cola and the enamel was then rubbed with CCP-ACPF for 4 mins. The enamel surface was then washed, dried and etched with 37% phosphoric acid for 15 seconds, rinsed with a water spray for 10 seconds and air dried. A thin layer of primer was applied over the etched enamel surface and cured for 20 sec. Metal brackets (3M Unitek) were bonded with etch-and-rinse adhesive system, Transbond XT (3M Unitek) and cured with LED curing gun for 40 sec.

Group A2: The teeth were eroded with Coca-Cola. The enamel surface was then washed, dried and etched with 37% phosphoric acid for 15 seconds, rinsed with a water spray for 10 seconds and air dried. A thin layer of primer was applied over the etched enamel surface and cured for 20 sec. Metal brackets (3M Unitek) were bonded with etch-and-rinse adhesive system, Transbond XT (3M Unitek) and cured with LED curing gun for 40 sec.

Group B1: The teeth were eroded with Lipton lemon flavoured ice tea and the enamel was then rubbed with CCP-ACPF for 4 mins. The enamel surface was then washed, dried and etched with 37% phosphoric acid for 15 seconds, rinsed with a water spray for 10 seconds and air dried. A thin layer of primer was applied over the etched enamel surface and cured for 20 sec. Metal brackets (3M Unitek) were bonded with etch-and-rinse adhesive system, Transbond XT (3M Unitek) and cured with LED curing gun for 40 sec.

Group B2: The teeth were eroded with Lipton lemon flavoured ice tea. The enamel surface was then washed, dried and etched with 37% phosphoric acid for 15 seconds, rinsed with a water spray for 10 seconds and air dried. A thin layer of primer was applied over the etched enamel surface and cured for 20 sec. Metal brackets (3M Unitek) were bonded with etch-and-rinse adhesive system, Transbond XT (3M Unitek) and cured with LED curing gun for 40 sec.

Assessment of shear bond strength

Bonded specimens were stored in distilled water at 37˚ C for 24 hours, until it was subjected to the shear test. A universal test machine with a load cell of 500 N, operating at a speed of 1mm/min was used for shear bond test. Each specimen was placed with its long axis parallel to the direction of the applied force. The specimens were stressed in an occluso-gingival direction with a uniform crosshead speed of 1mm/min. The maximum force necessary to debond or initiate bracket failure was recorded in Newton. The SBS in Megapascals (MPa) was computed as a ratio of force in Newton to the surface area of the bracket.

Adhesive remnant index

After debonding, all the teeth in both the control and experimental groups were analyzed using light stereomicroscope at 10 x magnification to determine the failure interface. Any adhesive left on the surface of teeth after debonding was assessed and scored according to the modified adhesive remnant index.

The modified adhesive remnant index (ARI) [35]
ARI scores range from 5 to 1
5 - No adherence of composite on enamel
4 - Less than 10% of composite remaining on the enamel
3 - More than 10% but less than 90% of composite remaining on the enamel
2 - More than 90% of composite remaining on the enamel

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1 - All composite remaining on the enamel, with the impression of the bracket base

RESULTS

The purpose of this study was to determine whether there is a change in the shear bond strength and adhesive remnant index of teeth eroded by acidic drinks which are pre-treated with a remineralization agent (CPP-ACPF) compared to the group without pre-treatment.

INTERPRETATION OF RESULTS

Table 1 shows 52 teeth divided into 4 groups with 13 samples in each group according to the beverage used for erosion and Pre- Treatment procedure

RESULTS OF SHEAR BOND STRENGTH

Table 2: Shows the shear bond strength of each group containing 13 samples each. Shear bond strength was recorded in Newtons(N) which was converted into Megapascals using following formula:

$$\text{Shear bond strength} = \frac{\text{stress at failure (“N”)}}{\text{Surface area of bracket base}}$$

Mean and standard deviations, minimum, maximum, 25th median, 50th median, 75th median for shear bond strength in each group were calculated.

Group A1 exhibited the maximum median Shear bond strength i.e. 13.23 and group A2 exhibited the lowest i.e. 9.93. But Kruskal-Wallis chi square test showed that the difference was not statistically significant.

Graph 1 shows graphical representation of median shear bond strength in Mega Pascals for the groups. Group A1 exhibited the maximum shear bond strength i.e. 13.23.

RESULTS OF ADHESIVE REMNANT INDEX

After debonding, the adhesive left over on the bonded site was assessed and ranked using Modified Adhesive Remnant Index (ARI)

Table 3 shows the comparison between groups for ARI index

Graph 2 shows the graphical representation of comparison of ARI index between the groups. The predominant mode of bracket failure for all the groups were such that there was less than 90% of adhesive left on the tooth surface i.e. having Score 3 and 4 which are clinically acceptable. The comparison between the groups were statistically insignificant. None of the groups had score 5 indicating less enamel damage.

TABLE 1: GROUPING OF SAMPLES USED IN THE STUDY

S.NO	GROUP NAME	Beverage used for erosion and Pre- Treatment procedure
1	A1	Coca-Cola, CPP-ACPF treated
2	A2	Coca-Cola, No pre-treatment
3	B1	Lipton lemon flavoured ice tea, CPP-ACPF treated
4	B2	Lipton lemon flavoured ice tea, No pre-treatment

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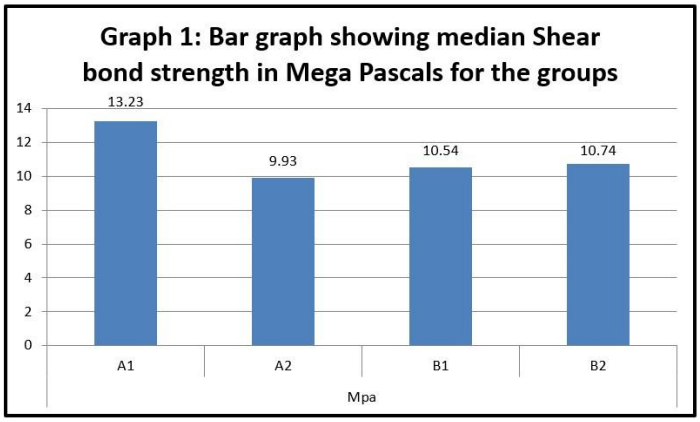
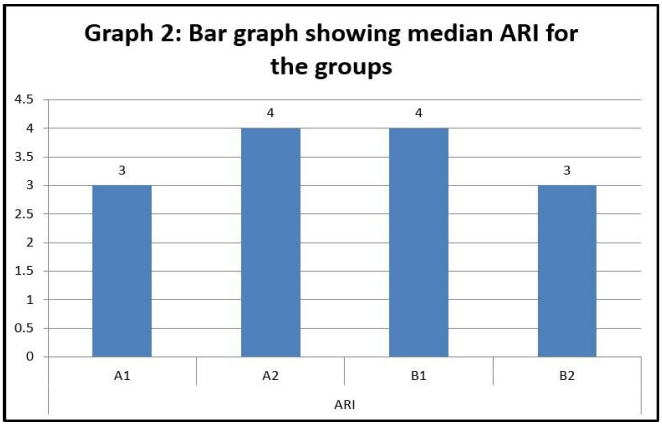
TABLE 2: COMPARISON BETWEEN THE GROUPS FOR SHEAR BOND STRENGTH

Variable	Group	N	Mean	Std. Dev	Min	Max	25th	50th (Median)	75th	Kruskal-Wallis test
N	A1	13	129.35	49.38	77.15	222.55	86.675	119.05	164.525	Kruskal-wallis chi-square: 3.40, df-3, p-value 0.334, Not significant
	A2	13	101.54	40.59	60.1	199.2	73.9	89.35	113	
	B1	13	98.86	22.46	61.75	141.55	84.525	94.85	119.025	
	B2	13	98.70	14.77	76.2	130.8	88.3	96.65	109.925	
Mpa	A1	13	14.39	5.49	8.57	24.73	9.635	13.23	18.29	Kruskal-Wallis chi-square: 3.40, df-3, p-value 0.334, Not significant
	A2	13	11.28	4.51	6.68	22.13	8.21	9.93	12.555	
	B1	13	10.98	2.49	6.86	15.73	9.395	10.54	13.225	
	B2	13	10.97	1.64	8.47	14.53	9.81	10.74	12.215	
Interpretation: There was no significant difference between the shear bond strengths as well as ARI values between the groups when compared by Kruskal-Wallis test.										

TABLE 3: COMPARISON BETWEEN THE GROUPS FOR ADHESIVE REMANT INDEX (ARI)

Variable	Group	N	Mean	Std. Dev	Min	Max	25th	50th (Median)	75th	Kruskal-Wallis test
ARI	A1	13	3.15	0.69	2	4	3	3	4	Kruskal-wallis chi-square: 3.44, df-3, p-value 0.328, Not significant
	A2	13	3.15	1.07	1	4	2	4	4	
	B1	13	3.38	0.87	1	4	3	4	4	
	B2	13	2.92	0.64	2	4	2.5	3	3	
Interpretation: There was no significant difference between the shear bond strengths as well as ARI values between the groups when compared by Kruskal-wallis test.										





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DISCUSSION

Dental erosion according to Tencate and Imfeld (1996) is the clinical term that is used to describe the physical results of a pathologic, chronic, localized loss of dental hard tissue that is chemically etched away from tooth surface by acid/chelation without bacterial involvement [10]

Dental erosion is also termed as the progressive loss of hard dental tissues by chemical process not involving bacterial action and it has been reported to be a major cause for tooth surface loss. The three main factors which lead to dental erosion have been discussed under three main classes 1) Dietary 2) Regurgitation 3) Environmental. [7]

The present study is mainly concerned with dietary causes of tooth loss which is caused by acidic foods and drinks and in particular acidic drinks. Citric acid, phosphoric acid and malic acid are present in most soft drinks and fruit juices which is very commonly consumed by adolescents and children making them a major cause for concern. [10] Phosphoric acid present in aerated drinks like Coca-Cola poses a very high risk for erosion which is also the same acid used for etching.

In addition to soft drinks, consumption of different kinds of tea along with food is becoming very popular these days like green tea, iced tea, and herbal tea because of the added health benefits they report to have. As most of these are consumed without milk various fruit flavours are added to them to make them more palatable like lemon, apple, peach etc. which makes it more acidic compared to the regular tea as it contains hydroxyl organic acids, such as citric, malic, and oxalic acid (Hughes et al.). [1]

In a study done by Phelan and Rees they had found that Lipton lemon flavoured ice tea and lift instant tea had high neutralizable acidity levels, both of these products contain citric acid and Vitamin C (ascorbic acid), which are strong organic acids because of which Lipton iced tea produced high amounts of erosion. [36]

According to a recent systematic review by Chan et al the risk factors which showed an association with dental erosion according to their severity were carbonated drinks (51%), fruit juice (29%), sports/energy drinks (29%), and tea (29%) for beverages; confectionery (43%), sauces (43%), citrus fruits (26%), and vinegar/pickles (26%) for food; and a swishing drinking habit/retaining drink in the mouth (41%) and consumption of acidic drinks/food/beverages at bedtime (29%) for dietary habits. [8]

Dissolution of enamel occurs when the pH falls below the pH of 5.5 which is reported to be the critical limit for enamel demineralization. [3] The pH of Coca-Cola was found to be 2.2 initially and it fell to 2.10 after 5 minutes. The pH of Lipton lemon iced tea was found to be 2.92 initially and fell to 2.90 5 minutes later.

Saliva is the main protective mechanism present in the oral cavity against acidic substances which acts as a buffering agent, aids in the formation of acquired enamel pellicle and also provides a supersaturated solution of calcium phosphate. A fall in pH increases the salivary secretion buffering the acidic substance, the fluoride ions in the saliva also inhibits demineralization. [11] Even though protective mechanisms are there, continuous usage of these beverages or holding and swishing it in the oral cavity is detrimental to the tooth structure.

Debonding of brackets during the treatment is a commonly encountered problem and even though it could be because of a wide variety of reasons one of them is erosive damage to the tooth surface itself causing a reduction in bond strength [6], [9],[8] had all come to the same conclusion that teeth eroded by various acidic drinks statistically significantly reduces the bond strength.

To reduce this the best way would be the elimination of the cause, which is avoiding acidic drinks and food during the treatment. Since this is not always possible as it is dependent on patient cooperation, another way is the prevention of erosion or reducing the extent of the lesion by various methods which requires calcium, phosphate and fluoride. Casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) with fluoride sold under the brand name GC Tooth Mousse plus has been reported to reduce the demineralization process for up to 4 weeks and aid in the remineralization process for up to 12 weeks after the application. [6]

Various studies have been done to see the effect of CPP-ACPF on demineralized teeth and all of them

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had a positive result where the shear bond strength had improved compared to the untreated control group [15], [24], [25], [27], [28], [30], [32]

In the present study the teeth were eroded by two acidic drinks i.e. Coca-Cola and Lipton lemon flavoured ice tea which were later treated with CPP-ACPF before acid etching and bonding to determine if it reduced the erosive lesions and whether it could increase the bond strength of the eroded teeth as observed in the demineralized teeth.

Reynolds suggested that a minimum bond strength of 6 to 8 MPa was adequate for most clinical orthodontic needs. These bond strengths are considered able to withstand masticatory and orthodontic forces. [34] In the current study we saw that the minimum bond strength obtained even in the control group was 6.86 which is clinically acceptable indicating that if the erosion is not extensive bonding can be done without any Pre-treatment.

While comparing the median bond strength between group A1 and A2, group A1 had a higher bond strength i.e. CPP-ACPF treated group exhibited a higher median bond strength compared to the control group even though it is statistically insignificant suggesting that when the teeth are highly eroded CPP- ACPF containing tooth pastes can be given to patients for remineralization without compromising the bond strength and it can aid in increasing the bond strength in teeth which are eroded by aerated soft drinks.

In the Lipton iced tea treated groups i.e. B1 and B2, the median bond strength of B1 group had not increased compared to B2, this could be because the citric acid in the drink may act as a chelator capable of binding calcium from enamel or dentin creating a higher degree of undersaturation [10] and indicating that the calcium and phosphate in the tooth paste might not have been sufficient to cover up the undersaturation effect.

In the present study the main objective was to see if the bond strength could be increased before bonding as we would have some control over the consumption of the beverage after bonding by advising the patients not to consume the drink after starting the treatment. One of the reasons why the bond strength did not decrease to a larger extent compared to the other studies which were eroded by soft drinks, could be because in this study the beverage treatment was done before bonding, causing only some damage to the enamel surface unlike in the other studies where there would be damage to the enamel and also the adhesive causing softening of the enamel and adhesive reducing the bond strength to a much larger extent.

Most of the specimens in the study gave an ARI score of 3 and 4 similar to the results obtained by Ulusoy et al [1] this indicates that some amount of adhesive was always left on the teeth indicating that bond failure mostly happened between the enamel adhesive interface reducing the clean-up time and reducing the chances of enamel fracture. This also indicates that adhesive-bracket bond was stronger compared to enamel-adhesive bond. The adhesive left on the enamel can later be removed with tungsten carbide bur followed by finishing.

CONCLUSION

1. Application of remineralization agents like CPP-ACPF on teeth eroded by aerated soft drinks, increased the median shear bond strength.
2. CPP-ACPF pre-treatment did not increase the SBS of teeth eroded by Lipton lemon flavoured ice tea.
3. Irrespective of the acidic beverage used for erosion, or the enamel pre- treatment with CPP-ACPF, statistically significant difference was not seen in the SBS between the groups which suggests the need for further clinical studies to find the effectiveness of the remineralization procedure.
4. Bond failure of brackets in all the group was at enamel-adhesive interface leaving some residue on the enamel surface.

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