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Research Article

Effect of Calcium Ion Concentration in Irrigation Solution on Shear Bond Strength of Orthodontic Brackets and Ari Score

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ABSTRACT

The aim of this study was evaluate the effect of Calcium ion concentration in irrigation solution on shear bond strength of orthodontic brackets and Adhesive Remnant Index score. 3 groups of 20 extracted human premolars were bonded with metal bracketson buccal surfaces using 35% phosphoric acid for etching,soft, moderately hard and very hard water as rinsing solutions for groups 1, 2 and 3 respectively, and Transbond XT as bonding agent. Using a mounting jig the teeth were mounted in self-curing acrylic and then kept in 37˚C in an incubator for 24 hours. Shear bond strength was measured with a universal testing machine operating at the speed of 1.0 mm per minute. Adhesive remnant index was determined using a stereomicroscope.One- way ANOVA test revealed no statistically significant difference in shear bond strengths among the 3 groups tested ($p > 0.05$). The Kruskal-Wallis Test indicated a statistically significant difference in ARI scores only between soft and very hard groups ($p < 0.05$).Soft and very hard water increased the tendency to higher and lower ARI scores respectively.Using soft water as irrigation solution may decrease the risk of enamel detachment and concurrently provides acceptable SBS.

Keywords: shear bond strength, water hardness, irrigation solution, bracket bonding

1. INTRODUCTION

As composite resins provide the enough bond strength for clinical orthodontics, they have been traditionally the adhesive of choice for bonding orthodontic brackets[1].The major problem when using self-cure adhesives is the inability to control the setting time of this type of material[2],thus the most popular material for bonding orthodontic brackets has been light cure adhesives[3]. The bonded brackets should have enough bond strength to endure masticatory forces. A weak bond can result in high failure rates and subsequently have negative effects on cost and efficacy of orthodontic treatment and also on patient comfort[4].The failure has been reported tooccur in 0.5-55.8 per cent of bonds [5].Bonding is the most sensitive procedure in orthodontic treatment[6]. Different factors can cause bond failure such as dexterity of operator, type of etchant agent, the type of adhesive used, moisture control and ligation forces [6,7].Bonding of brackets needs a thoroughly dry surface and contamination during this technique sensitive procedure results in bond failure.A better understanding of bond failure can lead to better ways to reduce this problem [6]. Successful bonding needs penetrationof the bonding agent to the enamel surface[8].Acid etching creates a porous layer by removing about 10 µm of enamel surface. The micromechanical interlocking then is developed by polymerized resin tags which are formed into microporosities of etched enamel [9]. Contamination can result in poor mechanical interlocking because it can impair the penetration of resin by plugging the porosities [6].The existence of any impurities or remnants after acid etching can possibly influence the composite bond, thus the effectiveness of irrigation with tap water is still doubtful. The effect of different irrigation solutions, in this content, has shown controversial outcomes in earlier studies[10]. Many studies have been done concerning the effect of contaminants and water hardness on bracket bond strength.[6]The water of different geographical areas has different mineral contents [6].Additionally different ions can produce water hardness(Calcium and Magnesium are the most important ones) [11].So the purpose of this study was to evaluate the effect of Calcium ion concentration in irrigation solution on shear bond strength of orthodontic brackets and AIR score.

2. MATERIALS AND METHODS

This study was accomplished according to the ethical committee guidelines of Shahed University.60 human premolars freshly extracted for orthodontic purposes were collected. The inclusion criteria included: having intact enamel surface (being free of caries, restorations,erosions or cracks), which wasexamined under a light stereomicroscope at ×20 magnification, and having no history of chemical pretreatment, eg, H_{2O2}. The teeth were cleansedof soft tissue and calculus and then stored in abacteriostatic solution of 0.5% Chloramine T (Chloramine T trihydrate, Merck Corp. Germany)in room temperature for 1 week.The teeth were rinsedwith distilled water, and thenkept in distilled water until the examination time (the water was renewed twice a week for prevention of bacterial growth). The teeth were randomly divided into 3 groups of 20. The buccal surfaces of teeth were cleaned with slurry of non-fluoridated pumice powder and water using a contra-angle handpiece and rubber cup. All teeth were washed completely with distilled water anddried with an oil-free air stream. The buccal surface of each tooth was etched with 35% phosphoric acid gel (Ultra-Etch, Ultradent Products Inc., South Jordan, UT, USA) for20 seconds and rinsed with50 cc distilled water, moderately hard water (90 ppm) and very hard water (200 ppm)in groups I (the control group), II and III respectively using a syringeand then dried with an oil-free air streamto a chalky white surface. The degree of water hardness was based on the classification published by World Health Organization(Table I).

Table I: WHO classification of water hardness

Water hardness classification	mg/litre
soft	0–60 mg/litre
moderately hard	60–120 mg/litre
hard	120–180 mg/litre
very hard	> 180 mg/litre

Using a microbrush a thin layer of primer (Transbond XT, 3M, Unitek, USA) was applied to the etched surface, thinned with a gentle flow of air, and polymerized with aLED light curing unit (DEMI,Kerr corporation, USA)at output peak wavelength range of 450 – 470nm and output intensity from 1100 mW/cm2 to peak of 1330mW/cm2for 10 seconds.Finally the composite (Transbond XT, 3M, Unitek, USA)was applied to the base of metal brackets(Edgewise/Standard/Metal/Hook3/QltH/.018, TSNPT) and a bracket positioner was used to completely seat the brackets near the center of buccal surfaces. The excess of composite was removed with a dental probe and the curing was done for a total of 40 seconds (10 seconds for each side of bracket).All the procedures were done by a single operator. The samples were kept in distilled water at 37ºC for 24 hours in an incubator (ShimiFann, Iran).

Then the teeth were mounted in metallic cubes up to 1 mm behind the CEJ, with cold-curing, fast-setting acrylic (Acropars, Iran) using a mounting jig with a full dimention (0.017× 0.025 stainless steel) wire and a thin flat ruler to simulate the blade of testing machine in order to make the bracket base parallel with the blade (Fig. I),so that the base of bracket was parallel to the force during testing the shear bond strength (SBS) with a universal testing machine (Zwick/Roell, Z020, A.S.T. GmbH Dresden, Germany) at a cross-head speed of 1 mm/min with a sharp chisel-shaped blade in an incisal to cervical direction at the interface of bracket and tooth (Fig II). Bond strengths were recorded in megapascals (MPa) using test Xpert V11.0 software.

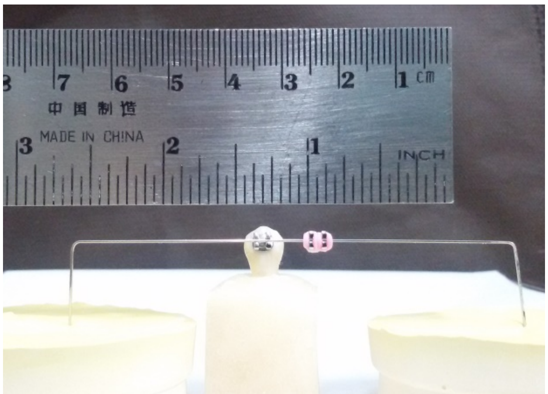

Fig I. mounting jig

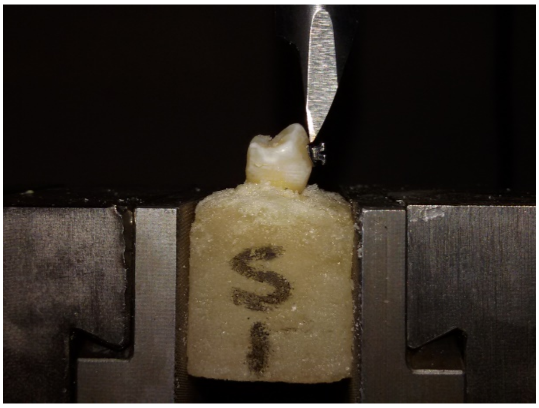

Fig II. Evaluation of SBS in universal testing machine

After debonding, enamel surfaces were examined under the stereomicroscope at a magnification of ×20 and the amount of adhesive remained on the enamel was determined according to the values of the adhesive remnant index (ARI), reported byArtun and Bergland [12]as follows:

score 0: no adhesive left on the tooth

score 1: less than half of the adhesive left on the tooth

score 2: more than half of the adhesive left on the tooth

score3: all adhesive left on the tooth with a distinct impression of the bracket mesh.

3. RESULTS

3.1. Shear bond strength:

The SBS values (in Megapascals) and the descriptive statistics are illustrated in Table II.The results of the One- way ANOVA revealed no statisticallysignificant difference among the 3groups tested ($p > 0.05$).

Table II. Descriptive statistics of shear bond strengths (MPa) of three groups tested

group		N	Minimum	Maximum	Mean	Std. Deviation
Soft	strength	20	17.62	30.12	24.3049	3.52278
	Valid N (listwise)	20				
moderately hard	strength	20	11.95	31.65	23.2673	5.55837
	Valid N (listwise)	20				
very hard	strength	20	17.22	26.74	22.1118	2.49431
	Valid N (listwise)	20				

3.2. Adhesive remnant index

The ARI scores are shown in Table III and the frequency distributions of ARI scores for the 3 groups tested are shown in Fig III. The Kruskal-Wallis Test indicated a statistically significant difference only between groups soft and very hard ($p < 0.05$).The most frequent ARI score in groups soft and very hard was score 1 and in group moderately hard were equally scores 1 and 2.

Table III. ARI scores of different groups

			ARI				Total
			.00	1.00	2.00	3.00	
group	Soft	Count	0	8	7	5	20
		% within group	0.0%	40.0%	35.0%	25.0%	100.0%
	moderately hard	Count	0	9	9	2	20
		% within group	0.0%	45.0%	45.0%	10.0%	100.0%
	very hard	Count	4	9	7	0	20
		% within group	20.0%	45.0%	35.0%	0.0%	100.0%
Total		Count	4	26	23	7	60
		% within group	6.7%	43.3%	38.3%	11.7%	100.0%

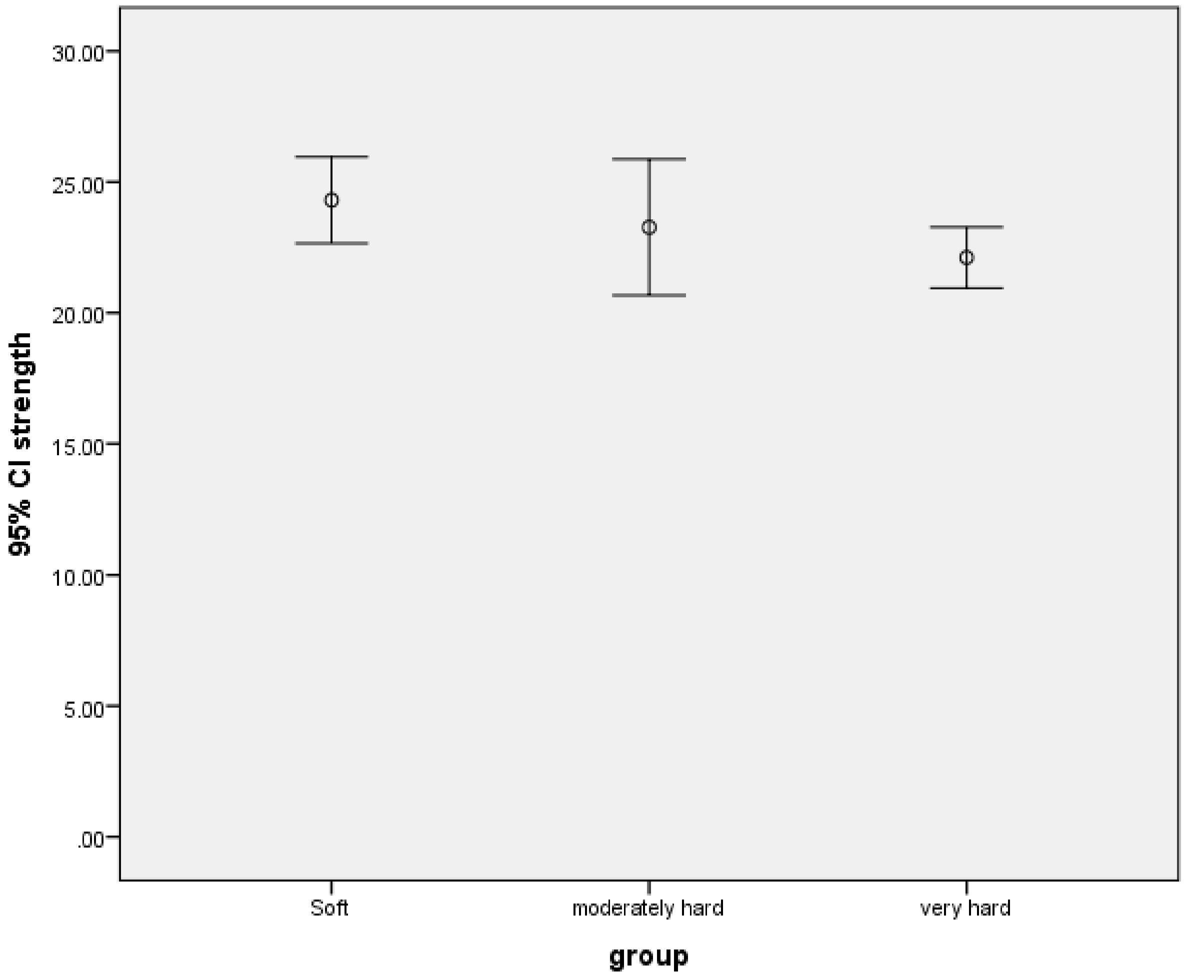

Fig III. The frequency distributions of ARI scores for the 3 groups tested

DISCUSSION:

Different rates of bracket failure are reported in the literature. Bracket failure occurs for various reasons and in different stages of orthodontic treatment [13]. The frequency of bracket failure has encouraged manufacturers to promote bracket retention mechanisms [14].Numerous studies have assessed the effect of moisture, saliva, blood and other contaminants on bond strength of orthodontic bracket and resin composites to the teeth.[15-19]Moisture has been found as the most common reason for bond failure[6,20-22].Effect of water hardness on bond strength of brackets was evaluated by Phaphe et al [6]. However several elements can affect the hardness of water from which the most important ones are Calcium and Magnesium ions [4,11,23,24]. During the years a great deal of attention has been paid to improve the bonding techniques. Nonetheless, bonding failure still exists because of contamination during the procedure[25].Two primary tests used for evaluating bond strength of orthodontic adhesives, measure shear and tensile bond strengths. We chose SBS testlike many other in vitro studies [6,7,19,26-31].

Results of our study indicated that SBS of brackets did not change,by increasing calcium ion concentration in rinsing water.Itoh et al also reported that water contamination had no effect on bond strength but saliva and blood could decrease that [22]. Saliva and blood have shown different characteristics caused by the types and amounts of organic and inorganic components [32].The effect of water contamination on shear bond strengthofdifferent self-ligating brackets was evaluated by Sfondrini et al [19].Their results indicated that water contamination could only bring about significant decrease in SBS of Quick brackets while in dry condition, this bracket had significantly higher SBS compared with other groups. Different mesh pad designs can affect the penetration of resin and subsequently the bond strength [19].However the highest and the lowest bond strengths, which were significantly different from other groups, were related to a single brand of bracket, so the decrease of SBS can be attributed to water contamination that was applied after the primer. In our study increase in the Calcium ion concentration of water did not show any significant effect on SBS, but we used the water before the application of primer. Effect of filter water, 0.9% sterile normal saline solution and deionized water on the SBS of orthodontic brackets was investigated by Klangton and colleagues [26].Washing the etchant using these three types of solutions did not cause statistically significant difference in SBS values which is in agreement with our result, however the calcium ion concentration was the only component changed between our groups but in Klangton's study the washing solutions had different compositions. In a study by Sung et al [11]effects of various irrigation solutions on microleakage of Class V compositerestorations was evaluated. It has3 differences with our study. First, they evaluated microleakage rather than SBS. Second, similarly to Klangton's [26] irrigation solutions were of different compositions and third, the designed cavities was half in enamel and half in cementum.However their results showed no significant difference between different groups which can indicate the similar integrity of therestorations.In another study by Sung et al [29] the effect of irrigation solutionswas investigated using different types of composites and irrigation solutions. The SBS was significantly lower using normal saline as irrigation solution for One-step or Solo bondings. It can be concluded that the usage of special types of irrigation solutions for special types of bondings can influence the bond strength. Other groups in this study showed outcomes similar to ours, although different compositions of irrigation solutions differentiatethis study from our study.

We found only one study by Phaphe et al [6] in which the effect of water hardness on SBS of orthodontic brackets was evaluated. Similar to our study they used three types of water: soft, moderately hard and very hard but on the contrary to our results that indicated no significant difference between three groups, their results showed significantly higher SBS valuesusing soft water. The samples of water in Phaphe's study contained different ions which were responsible for water hardness and so can be considered as a confounding factor that could possibly affect the results of their study. So we decided to evaluate only Calcium, one of the most important ions which govern water hardness.

When a bracket is removed from tooth surface, this removal can take place in three surfaces: between bracket and adhesive, within the adhesive, and between the enamel and adhesive [33-35].In our studycomparison of ARI scores revealed a statistically significant difference between groups soft and very hard.This means that using softwatercaused the tendency to higher scores of ARI unlike the very hard water.The relationship between ARI score and SBS values has been debated in previous investigations [21,36,37].A study has recommended that the amount of residual composite resin on tooth may not be related to SBS but it is controlled by the properties of bonding material and bracket base design [19].The results of our study also was not indicative of a direct relationship between ARI and SBS. Since we did not find significant difference between SBS values, the difference in ARI scores can be attributed to the location where bond failure occurs, that is, in group soft unlike the group very hard fewer failures were taken place in the interface of enamel and adhesive.So it can be deduced that the effect of rinsing water was not to the extent that can influencethe bond strength but it was able to affect the amount of residual resin on enamel surface after bond failure.

5. CONCLUSIONS

Under the conditions of this study, the following conclusions were made:

- No statistically significant difference in SBS values was seen, increasing the concentration of calcium ion present in rinsing water.
- Soft water and very hard water increased the tendency to higher and lower ARI scores respectively and this difference was statistically significant.

- Altogether in higher ARI scores there is a risk of scratching the enamel while removing the residual resin which can be reduced using proper techniques for resin removal. However in low ARI scores there is a probable risk of enamel fracture and detachment that of course is a much greater risk.
- Using soft water as irrigation solution may decrease the risk of enamel detachment and concurrently provide acceptable SBSthe same as water samples with lower concentration of calcium ion.

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