



ORIGINAL ARTICLE

Effects of Ozone and Prophylactic Antimicrobial Applications on Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Objective: The present study aimed to evaluate the effects of ozone and prophylactic antimicrobial applications on the shear bond strengths and bond failure interfaces of orthodontic brackets.

Methods: Sixty human canine teeth were randomly divided into three groups (n=20), receiving the following treatments: Group I-pumice prophylaxis (Isler Dental, Ankara, Turkey)+37% orthophosphoric acid (Dentsply, Rio de Janeiro, Brazil)+Transbond XT primer and adhesive (3M Unitek, Monrovia, USA); Group II-prophylaxis paste (Topex, NJ, USA)+37% orthophosphoric acid (Dentsply, Rio de Janeiro, Brazil)+ Transbond XT primer and adhesive paste (3M Unitek, Monrovia, USA); and Group III-ozone application (Biozonix GmbH, Munich, Germany)+37% orthophosphoric acid (Dentsply, Rio de Janeiro, Brazil)+Transbond XT primer and adhesive (3M Unitek, Monrovia, USA). All specimens were stored at 37°C water for 24 h. Shear bond strength was assessed using a universal testing device (Autograph AGS-X; Shimadzu, Japan). Adhesive remnant index (ARI) scores were obtained through examination of teeth under stereomicroscope at 10x magnification after debonding.

Results: Shear bond strengths of orthodontic brackets were 16.10, 18.01, and 19.23 MPa for Groups I, II, and III, respectively. No statistically significant difference in shear bond strength of orthodontic brackets was found among the groups (p=0.273), based on Kruskal-Wallis analysis. Additionally, no significant difference was found in the ARI scores of each group using chi-square analysis (p=0.992).

Conclusion: Shear bond strength of orthodontic brackets and ARI scores was not found to be negatively impacted by ozone application.

Keywords: Ozone, bond strength, white spot lesions, orthodontic treatment

INTRODUCTION

One of the key problems that arises during fixed orthodontic treatment is the formation of white spot lesions (WSLs), as fixed orthodontic appliances increase plaque retention areas and make oral hygiene maintenance more difficult (1, 2). According to the literature, WSLs can form within 1 month following bracket placement (3). These opacities appear alongside the loss of mineral content in the enamel, which reduces translucency and has a negative effect on dental appearance (1, 2). Several strategies have been proposed to prevent the emergence of WSLs during orthodontic treatment, with the most important being proper tooth brushing of patients with fluoridated dentifrices. Furthermore, patients with high caries risk can be provided with recommendations for mouth rinses, varnishes, and other sources of fluoride. Additionally, lasers and orthodontic adhesives with antimicrobial properties can also be used by health professionals (2). In more recent practice, WSL prevention has been achieved through the application of ozone to dental enamel (4, 5).

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Ozone has a strong oxidizing effect but does not act on the tooth surface, thus not impacting the tooth's mineral properties (6). In terms of orthodontics, while existing data do not appear to support the ozone application alone as prophylaxis against WSL development (7), one recent study has shown the instantaneous lethal effect of ozone against *Streptococcus mutans* and *Lactobacillus acidophilus* cultured from elastic ligatures. Therefore, it is anticipated that combining ozone treatment with another long-acting preventive agent might become useful for patients with fixed appliances, in order to prevent WSL (8).

A prerequisite for successful orthodontic treatment with fixed appliances is the appropriate bonding of brackets to the enamel surfaces (9). Bond failures during fixed appliance treatment cause inconvenience for orthodontists, leading to longer appointments, additional costs, and, in some cases, extended treatment duration (10). Bonding stages include the cleaning, preparation, and sealing of enamel surfaces as well as the bonding of brackets (11). Microbial dental plaque and organic pellicle, which is constantly present on surface enamel, can be removed through cleaning. Pumice prophylaxis is well known to be a prerequisite for adequate enamel etching in orthodontic bonding procedures (12). The application of ozone to enamel can also be used during this stage. However, ozone may adversely affect the adhesion between adhesive and teeth because oxygen is a polymerization inhibitor (6). The impacts of ozone application on orthodontic bonding have been explored by very few researchers to date (13, 14). The present study therefore seeks to evaluate the effects of ozone application to dental enamel, before acid etching, on the shear bond strength and bond failure interfaces of orthodontic brackets. The null hypothesis is that ozone application may negatively affect the shear bond strength of teeth according to prophylactic antimicrobial applications.

METHODS

Sixty caries-free and intact human canine teeth, extracted for periodontal purposes, were used in the present study. Written and informed consent was collected from all patients after the provision of a detail description of the purposes and nature of the study. All teeth were cleaned and polished with pumice and rubber cups for 10 s. Tooth selection criteria included a lack of visible enamel surface irregularities, cracks, and decalcifications. All specimens were then gathered and stored in a 10% NaOCl solution inside a refrigerator (4°C). Solutions were refreshed weekly to counteract bacterial growth. Approval for the present study was obtained from the Research Ethics Committee of Yüzüncü Yıl University School of Medicine, with the research conducted as per the ethical guidelines of the Declaration of Helsinki.

The selected teeth were randomly divided into three groups, with each receiving the following surface preparation and adhesive application treatments, according to the manufacturer's directions:

- Group I: pumice prophylaxis (Isler Pomza; Isler Dental, Ankara, Turkey)+37% orthophosphoric acid (Condicionador Dental Gel; Dentsply, Rio de Janeiro, Brazil)+primer and adhesive (Transbond XT; 3M Unitek, Monrovia, USA);
- Group II: prophylaxis paste (Sultan; Topex, NJ, USA)+37% orthophosphoric acid (Condicionador Dental Gel; Dentsply, Rio de Janeiro, Brazil)+primer and adhesive (Transbond XT; 3M Unitek, Monrovia, USA);
- Group III: 40sn ozone (Biozonix GmbH, Munich, Germany) application to buccal surfaces+37% orthophosphoric acid (Condicionador Dental Gel; Dentsply, Rio de Janeiro, Brazil)+primer and adhesive (Transbond XT; 3M Unitek, Monrovia, USA).

For all groups, 0.018 inch stainless steel canine brackets (Minidagonal Roth Brackets; Leone, Florence, Italy) were bonded to the tooth surfaces using orthodontic primer and adhesive (Transbond XT; 3M Unitek, Monrovia, USA) after enamel etching. The canine brackets were placed in the middle region of the buccal surfaces of teeth in the mesiodistal and occlusal-gingival direction and pushed firmly until the minimum amount of resin remained between the bracket base and tooth surface. A scaler was used to remove excess resin overflow. Adhesives were polymerized using an LED light source (Elipar FreeLight 2; 3M Espe, MN, USA) for 40 s: 10 seconds for each of the mesial, distal, occlusal, and gingival surfaces. All specimens were prepared during the same 24 h. A digital caliper (Mitutoyo, Miyazaki, Japan) was used to measure the bracket base areas, with a mean of 10.2 mm².

Teeth were embedded in 20 mm×10 mm×10 mm polymethyl methacrylate blocs (Meliodent; Heraeus Kulzer, Hanau, Germany), with the bracket bases parallel to the floor. All specimens were stored at 37°C water for 24 h. Samples were then attached to the universal testing device (Autograph AGS-X; Shimadzu, Japan) in order to conduct the shearing test. The crosshead speed of the device was set to 1 mm/min (13, 14). The direction of the debonding force was applied to the ligature groove parallel to the bracket base. The force required to dislodge the bracket was recorded in Newtons and converted to megapascals per the following equation:

Shear Force (MPa)=Debonding Force (N) / (W×H) (mm²).

Where W is the width of the bracket base, and H is the height of the bracket base (1 MPa=1 N/m²). After debonding, teeth were examined under stereomicroscope at 10× magnification. The remaining residual adhesive on the tooth was classified according to the adhesive remnant index (ARI) as defined by Artun and Bergland in 1984 (15). ARI scores range from 0 to 3, as follows: 0=no adhesive on the tooth; 1=less than 50% adhesive remaining on the tooth; 2=more than 50% adhesive remaining on the tooth; and 3=100% of the adhesive remaining on the tooth.

Statistical Analysis

Statistical analysis was performed using SPSS version 15.0 (SPSS Inc.; Chicago, IL, USA). The Shapiro-Wilk test was used to check the normality of the data distribution, whereas the Kruskal-Wallis test was used to assess the differences between groups.

RESULTS

After removal of the orthodontic brackets, no fracture was recorded on the enamel surface. The Shapiro-Wilk test was used to verify the normality of data distribution and homogeneity of

Table 1. Descriptive statistics for bond strengths of orthodontic brackets in all groups

	n	Mean	Std. deviation	*p
Group I	20	16.10	5.8	0.273
Group II	20	18.01	6.6	
Group III	20	19.23	5.6	

n: patient count
*Kruskal-Wallis test was performed, and the interaction was not statistically significant.

Table 2. Descriptive statistics for ARI scores

	ARI=0	ARI=1	ARI=2	ARI=3	*p
Group I	11	4	1	0	0.992
Group II	12	3	1	0	
Group III	12	3	1	0	

ARI: adhesive remnant index
*Chi-square analysis was performed, and the relationship was not statistically significant

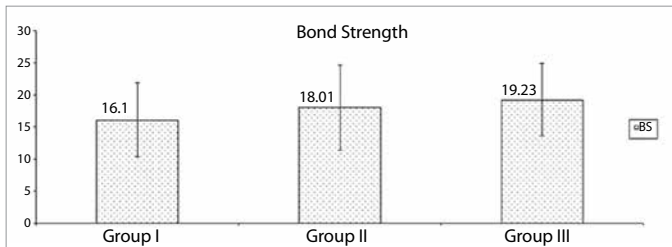


Figure 1. Bond strength of ozone, pumice prophylaxis, and prophylaxis paste

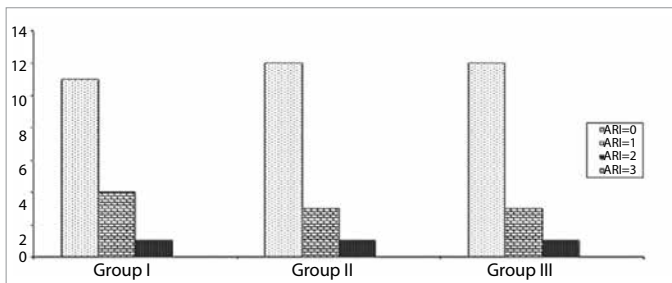


Figure 2. ARI scores of ozone, pumice prophylaxis, and prophylaxis paste
ARI: adhesive remnant index

variances among groups, with the normality assumption unmet, according to the results.

Table 1 and Figure 1 present the descriptive statistics for the shear bond strength of orthodontic brackets. The mean shear bond strengths of the orthodontic brackets (in megapascals) were 16.10 MPa for Group I, 18.01 MPa for Group II, and 19.23 MPa for Group III. While the highest orthodontic bracket strength was demonstrated in Group III and the lowest in Group I, no statistically significant difference was found among the groups (p=0.273) based on the Kruskal-Wallis test.

Descriptive statistics for the ARI scores are presented in Table 2 and Figure 2, with the distribution between the groups not being found to be statistically significant (0.992).

DISCUSSION

One of the most significant advances in orthodontics since the introduction of the edgewise technique has been the use of acid etching to bond brackets to enamel surfaces (16).

While there are problems involved in the direct bonding of orthodontic attachments to enamel surfaces, such as bracket failure and the decalcification of enamel during treatment, this has become a routine clinical procedure (13, 17, 18). It has been reported that enamel decalcification occurs due to an increase in the amount and prevalence of microbial dental plaque (3). An increase in the *S. mutans* and *Lactobacillus* counts, seen during orthodontic treatment, might affect the balance of the oral flora and produce a cariogenic disposition (19). Ozone, which is a strong antioxidant and antimicrobial, is reported to be one of the agents that can be used to suppress cariogenic oral flora in at-risk individuals (4, 20). However, owing to its strong oxidizing effect, ozone might have a negative impact on resin tooth adhesion (13). It was for this reason that the present study aimed to compare the effects of ozone and prophylactic pumice applications on the shear bond strengths and bond failure interfaces of orthodontic brackets.

The impact of various factors on orthodontic bracket bond strength has been evaluated in numerous studies in the existing literature. For instance, Charles et al. (21) demonstrate enamel pre-treatment methods such as conventional acid etching, air abrasion, and bur abrasion, finding the bond strength of conventional acid etching and bur abrasion to be higher than that of air abrasion. Prabhakar et al. (22) also compared conventional etching with different proportions of acidulated phosphate fluoride, finding that the conventional etching group showed the highest bond strength. In another study, Prasad et al. (23) investigated the effect of moisture, saliva, and blood contamination, concluding that contamination reduces shear bond strength. Additionally, Cacciafesta et al. (24) found bond strength to be significantly reduced by bleaching prior to bonding, whereas Hussein et al. (25) found bond strength to be unaffected by the application of 12% chlorhexidine for 1 week prior to bonding, in an in vivo study. Additionally, Scribante et al. (26) investigated the three different adhesives with two types of bracket base, finding Transbond XT to demonstrate the highest bond strength values. Aguiar et al. (27) also evaluated the adhesives and their curing mode, reporting that the light activation of certain cement systems increases bond strength, although the curing mode does not affect bond strength in all cases. Finally, de Sá Barbosa et al. (28) also compared water storage of 24 h and 12 months, finding the latter to decrease shear bond strength. All of the above factors were kept consistent in the present study, using conventional acid etching, Transbond XT adhesive, light curing, and 24-hour water storage.

As of the present study, a limited number of in vivo studies have evaluated the effects of ozone on the shear bond strength of orthodontic brackets. Of these studies, Cehreli et al. (13) and Al Shamsi et al. (14) found the shear bond strength of orthodontic brackets to be unaffected by applications of ozone to human teeth, at durations of 30 s and 10 s, respectively. Addition-

ally, Pithon and dos Santos (29) investigated the application of ozone water to 120 bovine teeth and concluded that the ozone water did not alter the bond strength of brackets bonded with composite resin. Cossellu et al. (6) also evaluated the effect of six different preventive treatment methods and found no compromising effect of casein-phosphopeptide-amorphous calcium phosphate and ozone on bracket bond strength. In accordance with these results, the current study showed that although bond strength was higher in the ozone application group than in the other groups, the difference between the groups was not statistically significant. Therefore, the null hypothesis was rejected.

In the present study, the bond strength of two different prophylaxis pastes was also evaluated, with no significant difference found. Mahajan et al. (12) similarly compared the different prophylaxis pastes with control groups and determined that the bond strength control group was lower than the others, but with no statistically significant difference between the prophylaxis groups.

In order to provide good adhesion and sustain forces arising from mastication and orthodontic mechanotherapy, bond strengths of at least 5-10 MPa are recommended (30). In addition, extremely high bond strengths (40-50 MPa) should be avoided as they may harm the enamel with the application of high debonding forces during, or at the end of, treatment (31). It is assumed that the acceptable shear bond strengths should be between 5 MPa and 50 MPa, even if the limits are within theoretical parameters. The findings of the present study reveal that all measured shear bond strength values were within the norm range of 5 MPa to 50 MPa, with no significant difference between groups ($p=0.273$).

After the removal of orthodontic brackets, it is observed that two types of bond failure (adhesive and cohesive) occur. These bond failures may occur in the bracket-adhesive interface (adhesive), adhesive-enamel interface (adhesive), adhesive layer (cohesive), or both (adhesive and cohesive) (32). Although bond failure, occurring in the bracket-adhesive interface, reduces the risk of enamel damage, it increases the difficulty involved in cleaning the enamel (33). The removal of excessive adhesive on the tooth surface may result in iatrogenic enamel damage such as enamel microcracks, scratches, abrasion, and inhibition of remineralization, leading to decalcification and caries (34).

ARI scores were used to evaluate the amount of adhesive remaining on the tooth surface. ARI is accepted as an efficient and simple method that does not require a specific tool and that can be safely used in the assessment of orthodontic bonding systems. Accurate scoring of ARI is an important issue. It is agreed that magnification of at least 10 \times must be used in the assessment of adhesive remnants on the tooth surface (35). The results of the present study revealed largely low ARI scores, with no statistically significant differences in ARI scores between groups. This finding, which indicates that bonding of the adhesive to the bracket base is stronger than the enamel surface, is consistent with previous studies (14, 36).

However, the main limitation of the current study is that the results were obtained in vitro. For this reason, the conduction of in

vitro studies that evaluate the application of ozone systems of different manufacturers on the shear bond strengths of orthodontic brackets is recommended.

CONCLUSION

According to the result of this in vitro study, ozone gas-as a useful prophylactic antimicrobial application used prior to etching and the placement of orthodontic brackets-had no negative impact on the bond strength values of orthodontic bracket or ARI scores.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Yüzüncü Yıl University School of Medicine.

Informed Consent: Written informed consent was obtained from all the patients who participated in this study.

Peer-review: Externally peer-reviewed.

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