

Does ozone water affect the bond strengths of orthodontic brackets?

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Background: Ozone water can be used to eliminate micro-organisms from the water systems in dental offices.

Objectives: To determine if ozone water diminishes the bond strength of orthodontic adhesives.

Methods: One hundred and twenty bovine mandibular incisors were randomly divided into four equal groups. The teeth were cleaned with pumice and washed either with tap water (Groups 1 and 3) or with ozone water Groups (2 and 4) before bonding stainless steel orthodontics brackets to the teeth with either a composite resin (Groups 1 and 2; Transbond XT, 3M Unitek, Monrovia, CA, USA) or a resin-modified glass ionomer cement (Groups 3 and 4; Fuji Ortho LC, GC America Corporation, Tokyo, Japan). The manufacturers' recommendations for bonding were followed. All samples were subjected to thermal cycling and the shear bond strengths were determined with a universal testing machine. The Adhesive Remnant Index (ARI) was used to score the amount of resin remaining on the teeth after debonding the brackets.

Results: There were no statistical differences in the shear bond strengths of the brackets debonded from enamel washed with either ozone water or tap water or between the groups bonded with the two adhesive resins ($p = 0.595$). The ARIs in Groups 2 and 3 were significantly different from the ARIs in Groups 3 and 4 ($p = 0.030$).

Conclusion: Ozone water did not alter the bond strength of brackets bonded with composite resins, but it did alter the sites of resin fracture when Fuji Ortho LC was used.

(Aust Orthod J 2010; 26: 73–77)

Received for publication: August 2009

Accepted: February 2010

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Introduction

Ozone water, which contains three times more oxygen than tap water, has been used to disinfect the water systems in dental units.^{1–3} Ozone is thought to penetrate the cell and oxidise intracellular amino and nucleic acids.² Cellular lysis depends to some extent on the severity of these reactions.^{4,5} The polymerisation and bond strengths of orthodontic adhesives used on teeth washed with ozone water may be affected by the high concentration of oxygen. We aim to determine if post-prophylaxis washing of bovine enamel with ozone water affects the bond strengths and sites of failure of orthodontic brackets bonded with different adhesives systems.

Materials and methods

Ozone water

The materials used to produce ozone water were: an oxygen cylinder with reduction valves and mano-

meters; an ozone generator (Ozone, mod. EAS 30 - UV) with a production capacity of 0.5 g/h (0.25 per cent, p/p, in the mixture of oxygen and ozone); a crystal reactor with a capacity of 100 ml, coupled to the ozone generator. To produce ozone water, a mixture of oxygen and ozone were bubbled through 100 ml of distilled water during autoclaving in the crystal reactor. To ensure sterilisation and cleaning of the system, ozone was bubbled through 100 ml of autoclaved distilled water, contained in the crystal reactor, for 20 minutes. This water was discarded and replaced with an equal volume of water to start the experiment. The ozone concentration in the water used was 0.6 mg/L.

Preparation of the teeth

One hundred and twenty extracted, bovine permanent mandibular incisors were collected and cleaned. They were then placed in 10 per cent formaldehyde

Table I. Comparisons of shear bond strength, in megapascals.

Group	Mean	SD	Minimum	Median	Maximum	ANOVA
1	21.02	2.41	17.27	22.07	24.24	A
2	20.07	1.94	16.70	20.21	23.1	A
3	19.81	2.34	16.23	20.06	22.9	A
4	19.44	1.87	17.23	18.73	23.2	A

Group 1: Transbond XT/tap water; Group 2: Transbond XT/ozone water; Group 3: Fuji Ortho LC/tap water; Group 4: Fuji Ortho LC/ozone water

Groups with the same letter were not significantly different from each other, $p > 0.05$

solution and stored in a refrigerator (8 °C) until required. Only caries-free teeth with intact buccal enamel, no previous chemical treatment (e.g. hydrogen peroxide) and no enamel cracks caused by the extraction forceps were used.

The teeth were embedded in PVC reducing bushes (Tigre, Joinville, Brazil) with acrylic resin (Clássico, São Paulo, Brazil), leaving only the crowns exposed. To facilitate mechanical testing, the buccal surfaces of the crowns were placed perpendicular to the shearing base of the dies. The embedded teeth were placed in distilled water and stored in a refrigerator (8 °C) until required for testing.

The mounted teeth were randomly divided into four equal groups. The buccal surfaces of the teeth were cleaned for 15 seconds with a paste made from extra-fine pumice (S.S. White, Juiz de Fora, Brazil) mixed with either tap water (Groups 1 and 3) or ozone water (Groups 2 and 4) and rubber prophylaxis cups (Viking, KG Sorensen, Barueri, Brazil). The teeth were then rinsed with an air - tap water spray (Groups 1 and 3) or an ozone water spray (Groups 2 and 4) for 15 seconds and dried with oil-free air for 15 seconds. The rubber cups were replaced after they had been used on five teeth in the same group.

Stainless steel 0.018 inch upper central incisor brackets (Morelli, Sorocaba, Brazil), with a mean base area of 14.2 mm², were bonded to the teeth in Groups 1 and 2 with Transbond XT (3M Unitek, Monrovia, CA, USA) and to the teeth in Groups 3 and 4 with Fuji Ortho LC (GC America Corporation, Tokyo, Japan). The resin was applied to each bracket base and the bracket seated on the tooth with 300 g force using a Correx gauge for 10 seconds. The force was applied uniformly to ensure an even

Table II. ARI scores.

Group	ARI score*			
	0	1	2	3
1	3	3	15	9
2	9	6	12	3
3	0	3	15	12
4	0	12	18	0

* 0, no adhesive remaining on the tooth; 1, less than half of adhesive remaining on the tooth; 2, more than half of the adhesive remaining on the tooth; 3, all adhesive remaining on the teeth

adhesive thickness between bracket and enamel, and the adhesive flash was removed with a dental probe. A Light Curing Unit 2500 (3M Dental Products, Oakdale, CA, USA) with an intensity of 550 mW/cm² was applied at a distance of 1 mm to each side of the bracket for 10 seconds (Total curing time: 40 seconds). The light intensity was calibrated for each bracket using a radiometer (Demetron, Danbury, CT, USA).

The bonded teeth were left undisturbed for 30 minutes to ensure complete polymerisation of the adhesive. After a 24-hour period of immersion in distilled water the specimens were alternately cycled (500 cycles) through distilled water baths at 5 °C and 55 °C, with a dwell time of 15 seconds in each bath.⁶

Mechanical testing and statistical analyses

A purpose-built device was used to stabilise the specimens during mechanical testing. The brackets were debonded with an Emic DL 10.000 universal testing machine (São José dos Pinhais, Paraná, Brazil) at a crosshead speed of 0.5 mm/minute. A shear load was applied to the bracket base with a chisel-shaped rod and the force required to dislodge the bracket recorded. The shear bond strength (SBS) in megapascals (MPa) was calculated from this data. Following debonding the enamel surfaces were examined with a stereomicroscope (Stemi 2000-C; Carl Zeiss, Göttingen, Germany) at x16 magnification and the adhesive remnant index (ARI) recorded. With the latter index: 0, no adhesive left on the tooth; 1, less than half the adhesive left on the tooth; 2, more than half the adhesive left on the tooth; 3, all of the adhesive left on the tooth.

Table III. Group comparisons of the ARI, probability values.

Groups	1	2	3	4
1		0.128	0.508	0.155
2			0.030	0.511
3				0.024
4				

Significant values in bold

Statistical analyses were performed using the Statistical Package for the Social Sciences version 13.0 (SPSS Inc, Chicago, IL, USA). An analysis of variance (ANOVA) was used to determine whether there were significant differences among the groups and the Tukey HSD test was applied post-hoc if necessary. The Kruskal-Wallis and Mann-Whitney U tests were used to compare the ARI scores.

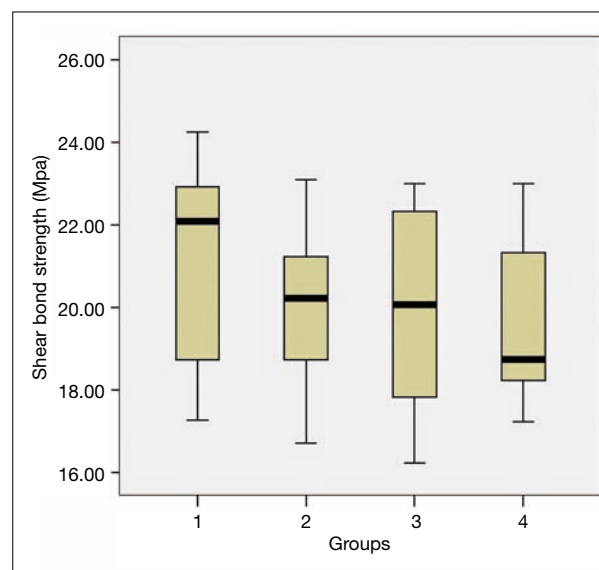
Results

The results are given in Tables I to III and Figure 1. The SBS of the brackets washed with ozone water (Groups 2 and 4) were slightly less than the brackets washed with tap water (Groups 1 and 3), but the differences were not statistically significant.

There were, however, statistically significant differences in the ARI between Groups 2 and 3 and Groups 3 and 4 (Tables II and III).

Discussion

Contamination of piped water supplies with micro-organisms poses a health danger to patients. Ozone, which has an antimicrobial action, is used to prevent the formation of biofilms in water pipes and to disinfect water distribution systems in dental offices.^{4,7–10} Although ozone water is widely used, little is known of its effects on the polymerisation processes of adhesive and restorative materials. We postulated that the additional oxygen molecules in ozone water, which contains three times more oxygen than tap water, may hamper the polymerisation processes in orthodontic adhesive materials and affect the shear bond strengths and sites of fracture of the materials.^{11–21} We found no statistically significant differences in the shear bond strengths of resins when ozone water was used to wash the enamel prior to bonding, but the sites of resin fracture during debonding were affected. Used in this limited way, we

**Figure 1.** Box plots of shear bond strength values.

concluded that ozone water did not affect the bond strengths of brackets bonded with Transbond XT and Fuji Ortho LC composite resins.

The materials we evaluated (Transbond XT and Fuji Ortho LC) are widely used in the clinic and in shear bond strength studies.^{22–25} Although we found no statistically significant differences between the SBSs of the materials, the mean SBS of the brackets bonded with Transbond XT were slightly higher and more variable than the brackets in comparable groups bonded with Fuji Ortho LC resin. The mean shear bond strengths we found agree with previous studies that have used Transbond XT and Fuji Ortho LC,^{23,24} and fell within the range of values (5–20 Mpa) considered by Owens²⁶ to be suitable for clinical use.

Lower mean ARI values, indicating that less adhesive remained on the teeth after debonding, were found in the groups washed with ozone water (Groups 2 and 4) than those washed with tap water (Groups 1 and 3). These differences were significant between Groups 2 (Transbond XT/ozone water) and 3 (Fuji Ortho LC/tap water) and between Groups 3 (Fuji Ortho LC/tap water) and 4 (Fuji Ortho LC/ozone water). These results are clinically important, since with a slight reduction in ARI promoted by the ozone water, the enamel surface is less protected during the bracket removal process, and fractures of the enamel are more likely to occur.

We also found a reduction in the mean ARI between the teeth bleached with different concentrations of hydrogen peroxide, although there was no statistical difference between the bond strengths.²⁷ In the present study with ozone water, the differences in ARI can be attributed to the presence of oxygen molecules in the bond area. It is worth pointing out that the concentration of ozone in the water we used was 0.6 mg/L, the same concentration was used by Velano,²⁸ in her study of the micro-biocidal action of ozone water. This concentration appears to be ideally suited to disinfect dental water systems and prevent the formation of biofilms.

Conclusion

The hypothesis that ozone water would interfere in the shear bond strength of orthodontic brackets was not proved. Washing the enamel with ozone water before orthodontic bracket bonding did not diminish the shear bond strength, but it did alter the sites of resin fracture when Fuji Ortho LC was used.

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