European Journal of Orthodontics 32 (2010) 224–227
doi:10.1093/ejo/cjp080
Advance Access Publication 11 September 2009

The effect of air abrasion preparation on the shear bond strength of an orthodontic bracket bonded to enamel

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SUMMARY The purpose of this study was to determine the method of preparation of enamel which best retains a bonded orthodontic bracket against a shear force. Two hundred and twelve human lower premolars were randomly divided into four equal groups. Group 1 underwent no air abrasion, group 2 received treatment with 25 μm aluminium oxide particles, group 3 with 50 μm particles, and group 4 with 100 μm particles. All groups were treated with a self-etching primer before bonding of an orthodontic bracket. Each tooth was tested in a JJ Lloyd M30K® machine to determine the maximum shear force required to dislodge the bracket from the tooth.

A one-way analysis of variance test conducted at a 95 per cent confidence level (CL) demonstrated that there was a significant difference ($P < 0.01$) with respect to the four methods of preparation of the enamel surface. An unpaired *t*-test was then applied at a 95 per cent CL. There was no statistically significant difference between groups 1 and 2. There was, however, a statistically significant difference between groups 1 and 3 ($P < 0.01$), as well as between groups 1 and 4 ($P < 0.01$). In addition, there was significant difference found between groups 2 and 3 ($P < 0.05$), groups 2 and 4 ($P < 0.01$), and groups 3 and 4 ($P < 0.05$).

Introduction

Air abrasion was first described by Black (1945) as a method of preparing cavity forms. Buonocore (1955) reported on the use of acid etching to increase adhesion to enamel. Forty years later, studies began to analyse the effects on enamel bond strength of acid etch alone versus a combination of air abrasion and acid etching (Roeder *et al.*, 1995).

Existing research has been diverse with respect to controlling variables. Some studies concerning the bond strength of an air abraded surface did not report the distance from the air abrasion tip to the tooth surface (Brown and Barkmeier, 1996; Nikaido *et al.*, 1996; Kanellis *et al.*, 1997) or used a distance of less than 2 mm (van Waveren Hogervorst *et al.*, 2000; Borsatto *et al.*, 2002; Peruchi *et al.*, 2002; Matos *et al.*, 2003). The duration of abrasion treatment was often stated at over 2 seconds (Brown and Barkmeier, 1996; Nikaido *et al.*, 1996; Kanellis *et al.*, 1997; Olsen *et al.*, 1997; Canay *et al.*, 2000; Borsatto *et al.*, 2002; Peruchi *et al.*, 2002; Matos *et al.*, 2003; Mujdeci and Gokay, 2004). Some investigations utilized surfaces other than the buccal (Brown and Barkmeier, 1996; Kanellis *et al.*, 1997; Borsatto *et al.*, 2002; Matos *et al.*, 2003), while other studies did not describe which surface was used (Nikaido *et al.*, 1996; Olsen *et al.*, 1997; Peruchi *et al.*, 2002). Two studies used bovine teeth (Nikaido *et al.*, 1996; van Waveren Hogervorst *et al.*, 2000), while another used human primary teeth (Peruchi *et al.*, 2002). Several studies ground teeth down with sandpaper prior to air abrading (Nikaido *et al.*, 1996; van Waveren Hogervorst *et al.*, 2000; Matos *et al.*, 2003; Mujdeci and Gokay, 2004). The angle of application of the particles was often not perpendicular to the tooth surface (Canay *et al.*, 2000; Borsatto *et al.*, 2002; Peruchi *et al.*, 2002; Matos *et al.*, 2003) or not stated (Brown and Barkmeier, 1996; Nikaido *et al.*, 1996; Kanellis *et al.*, 1997; Olsen *et al.*, 1997). Some investigations indicated that air pressure over 115 psi were used (Kanellis *et al.*, 1997; Olsen *et al.*, 1997; Mujdeci and Gokay, 2004) or did not mention what pressure was used (Brown and Barkmeier, 1996; van Waveren Hogervorst *et al.*, 2000). Studies did not explain how they controlled for the time required until the maximum declared pressure from the air abrasion tip could be reached from the moment of depressing the application button (Brown and Barkmeier, 1996; Nikaido *et al.*, 1996; Kanellis *et al.*, 1997; Olsen *et al.*, 1997; Canay *et al.*, 2000; van Waveren Hogervorst *et al.*, 2000; Borsatto *et al.*, 2002; Peruchi *et al.*, 2002; Matos *et al.*, 2003; Mujdeci and Gokay, 2004). Many authors drew conclusions while having utilized less than 12 samples per group (Brown and Barkmeier, 1996; Nikaido *et al.*, 1996; Borsatto *et al.*, 2002; Peruchi *et al.*, 2002; Matos *et al.*, 2003). Previous research relating the advantages of combining air abrasion and bonding orthodontic brackets has yielded varied conclusions (Brown and Barkmeier, 1996; Canay *et al.*, 2000; Borsatto *et al.*, 2002; Matos *et al.*, 2003).

Orthodontic brackets are frequently dislodged from the surface of the tooth due to normal occlusal forces transmitted during mastication to the brackets (Gorelick *et al.*, 1984). To avoid excess time and expense for the patient and dentist, bonding must be reliable. The purpose of this study was to determine the best preparation method of the tooth enamel surface to retain a bonded orthodontic bracket against a shear force. The goal through this research was to control for previously uncontrolled variables while using a significant sample size.

Materials and methods

As this was a secondary analysis of data that could not be linked to any individual, ethical approval was not required.

The teeth were selected based on buccal surfaces being free of attrition, caries, and restorations. Two hundred and twelve extracted human lower premolars were randomly divided into four equal groups. A sample size of greater than 30 was chosen to have an acceptable amount of variance to give a natural standard distribution. From the time of extraction, the teeth were stored in formaldehyde until they were mounted in a 1 × 1 inch square aluminium block and held upright in fast set mounting plaster (Whip Mix Corporation, Louisville, Kentucky, USA). Debris was removed from the teeth by hand scaling, followed by prophylaxis with a rubber cup using a pumice and water mixture with medium pressure in a low-speed hand piece for 3 seconds (KaVo Dental GmbH, Biberach, Germany). All samples were then stored in water at room temperature.

Group 1 served as the control and therefore received no air abrasion treatment. After having been air-dried, groups 2, 3, and 4 received air abrasion treatment with 25, 50, and 100 μm aluminium oxide particles (Aurum Ceramic Dental Laboratories, Saskatoon, Saskatchewan, Canada), respectively. This treatment utilized the Basic Professional air abrasion gun (Renfert, St Charles, Illinois, USA) with a straight tip, positioned at a fixed distance of 2.1 cm, a constant outflow of 70 psi, for a constant duration through a fixed aperture, perpendicular to the buccal surface of the tooth (Figure 1). A rotating wheel at a constant speed of 73 rpm with an aperture was used so the air abrasion gun could be started and reach its maximal pressure of 70 psi before the aperture was reached. The aperture allowed for a constant air abrasion treatment time of less than 1 second. Subsequently the teeth were rinsed and air-dried.

Transbond™ Plus self etching Primer (3M Unitek, Monrovia, California, USA) was used as per the manufacturer's directions: agitated in the package for 5 seconds, agitated on the buccal surface of the tooth for 5 seconds, and then thinned with a stream of gentle air. Victory Series™ premolar metal brackets (3M Unitek) with pre-applied adhesive were centred mesiodistally at 3.5 mm from the occlusal surface on the buccal surface of the tooth using a bracket-positioning gauge (3M Unitek). Excess expressed material was removed with a #36 gold foil knife (Hu-Friedy, Chicago, Illinois, USA). The bracket was cured for a total of 40 seconds from each of the four directions of the buccal surface. All teeth were stored in water at room temperature for 72 hours.

The teeth were then removed from the water bath and tested in the JJ Lloyd M30K® machine (Lloyd Instruments Ltd., Fareham, Hants, UK) to determine the maximum shear force required to dislodge the bracket from the tooth. A 5 kN load cell was mounted above the testing arm. The crosshead speed was 2 mm/minute. The teeth were placed so that the long axis of the arm of the JJ Lloyd M30K® was parallel to the bonded buccal surface of the tooth in an occlusoapical direction (Figure 2). Maximum force applied was recorded in kilonewtons (kN) and divided by the surface area determined by the manufacturer of the bracket of 9.1 mm^2. This yielded a value in kN/mm^2. The values were then converted into megapascals (MPa), through the use of a ratio of 1 kN/mm^2:1000 MPa. A one-way analysis of variance (ANOVA) test was used to determine if there was significance between any groups at a 95 per cent confidence level (CL). An unpaired *t*-test was then applied at a 95 per cent CL.

Figure 1 Mounted tooth undergoing air abrasion treatment through the aperture of rotating wheel.

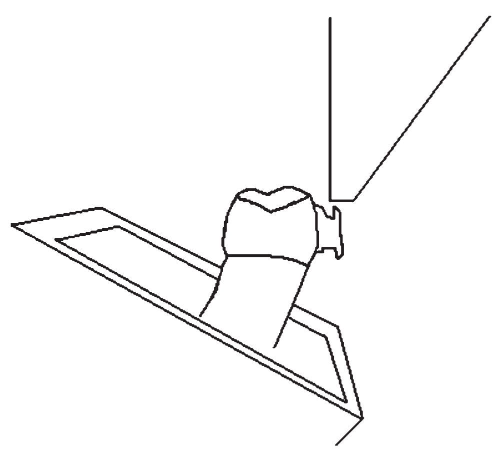

Figure 2 Tooth with bracket mounted to receive shear force by descending blade of JJ Lloyd M30K®.

Results

After data collection, the mean shear bond strength was calculated to be 7.244 MPa for group 1, 7.736 MPa for group 2, 8.751 MPa for group 3, and 10.24 MPa for group 4 (Figure 3).

A one-way ANOVA test conducted at a 95 per cent CL demonstrated that there was a significant difference ($P < 0.01$) with respect to the four methods of preparation of the enamel surface. An unpaired *t*-test was then applied at a 95 per cent CL. There was no statistically significant difference between groups 1 and 2. There was, however, a statistically significant difference between groups 1 and 3 ($P < 0.01$), as well as between groups 1 and 4 ($P < 0.01$). In addition, there was significant difference between groups 2 and 3 ($P < 0.05$), groups 2 and 4 ($P < 0.01$), and groups 3 and 4 ($P < 0.05$).

Discussion

In the current study, all four groups were etched prior to bonding as research has shown that air abrasion is not an acceptable replacement for etch prior to bonding (Olsen *et al.*, 1997; van Waveren Hogervorst *et al.*, 2000). When applied to enamel, air abrasion produces a rough irregular surface with increased surface area. This may improve the effectiveness of etch by increasing the wettability of the enamel (Roeder *et al.*, 1995).

The present study found no significant bond strength difference when using 25 μm particles and not using air abrasion. This finding is consistent with studies assessing differences between 27 μm particles and not air abrasion (Roeder *et al.*, 1995; Borsatto *et al.*, 2002; Matos *et al.*, 2003). However, these results vary from those of Mujdeci and Gokay (2004), who reported an increase in bond strength when using 25 μm particles in place of a control.

The improved bond strength found in this study when using 50 μm particles in place of no air abrasion was consistent with the findings of Canay *et al.* (2000) but not those of Roeder *et al.* (1995) or Brown and Barkmeier (1996), who found no significant difference between these groups. Interestingly, Nikaido *et al.* (1996) found decreased bond strength when using 50 μm particles compared with no air abrasion. As previously indicated, varying results between previous studies are likely due to the many uncontrolled and unreported variables in methodology.

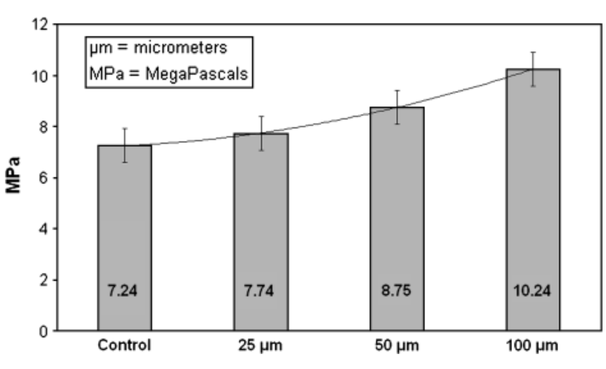

Figure 3 Mean shear bond strength following different air abrasion particle size treatment.

The increased bond strength found when using 50 μm particles in place of 25 μm particles differed from Roeder *et al.* (1995), who found no difference between the use of these two sized particles. This is the first study comparing 100 μm air abrasion particles on a smooth enamel surface with no air abrasion, 25 μm, and 50 μm air abrasion particles.

Air abrasion has been noted to damage the enamel surface at a level equivalent to the use of 37 per cent phosphoric acid etch applied for 30 seconds (van Waveren Hogervorst *et al.*, 2000). Further studies should analyse the effects of various sized particles on the surface enamel while maintaining control of variables and utilizing clinically acceptable parameters.

Some clinicians have questioned the safety of air abrasion systems. In a study by Wright *et al.* (1999), health hazard testing was carried out by the occupational Health and Safety Resource Centre after having gathered samples using suction methods. They concluded that their findings were insufficient to prove that the air abrasion systems pose a health hazard to patients or those operating the air abraders.

In a study on the effects of air abrasion on the gingiva, Kozlovsky *et al.* (2005) aimed air abrasion particles at the most occlusal gingiva adjacent teeth. They observed that localized trauma to the gingiva resulted in epithelial erosive changes, which was dependent on: stand alone versus hand-piece air pressure device and duration of exposure. The authors reported a distance of 5 mm but did not mention the psi of the air abraders utilized.

Conclusion

The results of this study show that the strongest method for bonding an orthodontic bracket, listed in decreasing order, was to use 100 μm aluminium oxide air abrasion treatment, followed by 50 μm aluminium oxide air abrasion treatment, followed by 25 μm aluminium oxide air abrasion treatment, or no air abrasion treatment.

Brackets bonded to teeth for orthodontic purposes should ideally remain fixed to the teeth throughout treatment. The ideal bond strength of a bracket to the surface of a tooth has not yet been determined. This study has shown that improved retention may occur with adjunctive treatment of air abrasion. Stronger bonds are achievable but this may be attained at the expense of enamel fracturing when the bracket is eventually debonded at the end of treatment. Future research should focus on determining the ideal bond strength.

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Funding

College of Dentistry at the University of Saskatchewan.

Acknowledgements

Transbond™ Plus Self Etching Primer and Unitek Victory Series™ premolar metal brackets were donated by 3M Unitek and the aluminium oxide by Aurum Dental Laboratories.

The authors wish to thank the Department of Operative Dentistry, University of Saskatchewan, Saskatoon, Canada for its guidance, Mr Kevin Banman for his technical assistance and Dr Patrick Devey Concordia University, Montreal, Quebec, Canada for his statistical analysis.

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