Oral Science International 10 (2013) 49–52

Oral Science International

journal homepage: www.elsevier.com/locate/osi

Original Article

Effect of water contamination on the shear bond strength of self-ligating brackets

Maria Francesca Sfondrini, Danilo Fraticelli, Serena Di Corato, Andrea Scribante*, Paola Gandini

Department of Orthodontics University of Pavia, Italy

A R T I C L E I N F O

Article history:
Received 26 May 2012
Received in revised form 27 June 2012
Accepted 4 July 2012

Keywords:
Orthodontics
Bond strength
Self-ligating
Brackets
Contamination
Water

A B S T R A C T

Purpose: The aim of the present study is to evaluate the effect of water contamination on the shear bond strength (SBS) and adhesive remnant index (ARI) score of self-ligating brackets.
Materials and methods: One conventional bracket and three different self-ligating brackets were bonded onto 160 bovine permanent mandibular incisors, divided randomly into 8 groups. For each type of bracket, 20 samples were bonded on dry enamel and 20 after water contamination. After 24 h, all specimens were tested for SBS using an Instron Universal Testing Machine, and ARI scores were evaluated.
Results: All groups showed clinically adequate SBSs. Quick brackets bonded onto dry enamel showed significantly higher SBSs than all other groups tested, whereas the lowest shear strength values were recorded for Step, Quick, and Damon 3MX brackets bonded onto contaminated enamel and for Damon 3MX onto dry enamel. Frequency distribution of ARI Scores showed a prevalence of ARI “2” and “3” for all the groups tested.
Conclusions: Water contamination reduces the SBS of self-ligating brackets, but significant differences have been found only for Quick brackets. All groups showed a significant higher frequency of ARI Score of “2” and “3”.

1. Introduction

When orthodontic brackets are bonded to the teeth, three different agents are required: acid etchant, primer, and adhesive resin [1]. Through hydrophobic properties of resin bonding systems, tooth enamel must remain dry after acid etching [2]. Various clinical conditions do not permit ideal isolation of the site, so the presence of moisture is often possible when bonding in the oral cavity. Surface contamination has been considered as the most common reason for bond failure [3], particularly when orthodontic appliances are bonded in hard-to reach places [4]. Contamination causes the plugging of porosities produced by acid etching and a reduction in surface energy. In this way, resin penetration is impaired and micromechanical retention is compromised [5]. Under clinical conditions, contamination may be produced through the presence of saliva, gingival exudation, or bleeding, or through the presence of water when teeth are washed [6].

When brackets are bonded to enamel, two critical moments have been identified at which contamination may occur: after the enamel surface has been etched and after primer has been applied [7]. In the first case, enamel loses the typical chalky-white aspect showing the presence of the moisture and giving the possibility to dry. On the contrary when contamination occurs after primer application, the shiny-aspect of light-cured material can camouflage the presence of the moisture and the operator often cannot maintain a dry surface [8].

Self-ligating brackets have gained popularity in recent years, because of their advantages in reducing friction and more speedy chairside manipulation, associated with less subjective discomfort [9]. In fact the advantages of self-ligating brackets in reduction in the bracket-wire friction have become contentious, therefore the only certain advantage over conventional brackets has been found to be related to chairtime reduction [9]. Bracket bases of these devices are different from conventional bracket bases and have been tested for shear bond strength (SBS) on dry enamel [10,11]. To date, there are no studies that have compared the shear bond strength of different self-ligating brackets after water contamination.

Therefore, the purpose of this study was to evaluate the effects of water contamination on shear bond strength and on the adhesive remnant index (ARI) scores of different self-ligating brackets. The null hypothesis of the study was that there is no significant difference in shear bond strength values and debond locations among the various groups.

* Corresponding author at: University of Pavia, Dipartimento di Discipline Odontostomatologiche, Piazzale Golgi 2, 27100 Pavia, Italy.
E-mail address: andrea.scribante@unipv.it (A. Scribante).

1348-8643/$ – see front matter © 2012 Japanese Stomatological Society. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/S1348-8643(12)00071-7

Table 1
– Bonding procedure of the different groups tested.

Groups	Bonding procedure						
1	etching	washing	drying	adhesive	–	bonding bracket Step	Light curing
2	etching	washing	drying	adhesive	water application	bonding bracket Step	Light curing
3	etching	washing	drying	adhesive	–	bonding bracket Smart Clip	Light curing
4	etching	washing	drying	adhesive	water application	bonding bracket Smart Clip	Light curing
5	etching	washing	drying	adhesive	–	bonding bracket Quick	Light curing
6	etching	washing	drying	adhesive	water application	bonding bracket Quick	Light curing
7	etching	washing	drying	adhesive	–	bonding bracket Damon 3MX	Light curing
8	etching	washing	drying	adhesive	water application	bonding bracket Damon 3MX	Light curing

2. Materials and methods

2.1. Specimen preparation

A total 160 freshly extracted permanent bovine mandibular incisors were collected from a local slaughterhouse and stored in a solution of 0.1% (w/v) thymol. The criteria for tooth selection included intact buccal enamel with no cracks caused by the extraction forceps and no caries. The teeth were randomly assigned to 8 groups. Each group consisted of 20 specimens. The teeth were cleansed of soft tissue and embedded in cold curing, fast-setting acrylic (Leocryl, Leone, Sesto Fiorentino, Italy) and placed in metal rings. Each tooth was oriented so that its labial surface would be parallel to the force during the shear bond test.

2.2. Bracket bonding

One conventional stainless steel bracket (Step, Leone) and three different stainless steel self-ligating brackets (Smart Clip, 3M Unitek, Monrovia, CA, USA; Quick, Forestadent, Pforzheim, Germany; Damon 3MX, Ormco, Glendora, CA, USA) for maxillary central incisor were tested.

Before bonding, the facial surface of each incisor was cleansed with a mixture of water and fluoride-free pumice with rubber polishing cup on a low-speed handpiece for 10 s. The enamel surface was rinsed with water to remove any pumice or debris and dried with an oil-free air stream.

Two different enamel surface conditions were evaluated: dry and after soaking with water after priming. As shown in Table 1, the teeth were etched with 37% phosphoric acid gel (Phosphoric Etchant Syringes; 3M Unitek) for 30 s, followed by washing and drying. A thin layer of primer (Transbond XT, 3M Unitek) was applied to the etched enamel, air-dried, and polymerized for 20 s with a visible light-curing unit (Otholux XT, 3M Unitek). The teeth in groups 2, 4, 6, and 8 were moistened with a thin layer of water after primer polymerization with a microbrush onto the labial surface until they were totally contaminated.

All the brackets were then positioned on the teeth near the centre of the facial surface with sufficient pressure to express excess adhesive, which was removed from the margins of the bracket base with a scaler before polymerization. The brackets were then light cured for 10 s on the mesial side and 10 s on the distal one (total cure time 20 s).

2.3. Shear bond strength testing

After bonding all samples were stored in distilled water at room temperature for 48 h and then tested in shear mode on a Universal Testing Machine (Model 3343, Instron Industrial Products, Grove City, PA, USA). For shear testing, the specimens were secured in the lower jaw of the machine so that the bracket base of the sample paralleled the direction of the shear force. The specimens were stressed in an occlusogingival direction with a crosshead speed of 1 mm/min, according to previous studies [11,12]. The maximum load necessary to debond or initiate bracket fracture was recorded in Newton and then converted into MegaPascal (MPa) as a ratio of Newton to surface area of the bracket.

2.4. Adhesive remnant index score evaluation

After bond failure, the bracket bases and the enamel surface were examined by the same operator to assess the amount of adhesive left on the enamel surface and to determine the ARI. This scale ranges from “0” to “3” (Fig. 1). A score of “0” indicates no adhesive remaining on the tooth, “1” less than half of the adhesive remaining on the tooth, “2” more than half of the adhesive remaining on the tooth, and “3” all adhesive remaining on the tooth with a distinct impression of the bracket mesh. The ARI scores were used as a more complex method of defining bond failure site between the enamel, the adhesive, and the bracket base [13].

2.5. Statistical analysis

Statistical analysis was performed with the Stata 7 Program (Stata Corp, College Station, TX, USA). After power calculation, descriptive statistics, including the mean, standard deviation, median and minimum values, were calculated for all groups. Normality of distributions was assessed with Kolmogorov–Smirnov test. Analysis of variance (ANOVA) was then applied to determine whether significant difference in debond strength values existed among the various groups. The Tukey–Kramer’s test was used for *post hoc* comparisons. The chi-square test was used to determine

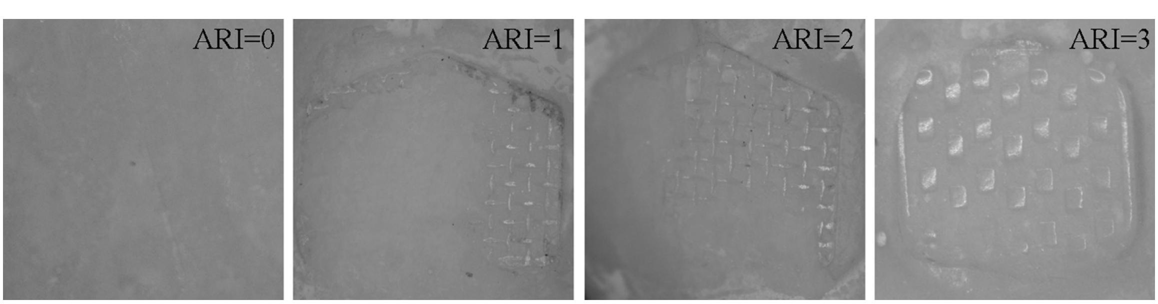

Fig. 1. Mean and SD (*N*) of shear bond strengths of the different groups tested.

Table 2
Descriptive statistics (MPa) of shear bond strengths of the different groups.

Group	Bracket	Surface	*n*	Mean	SD	Min	Mdn	Max	Tukey[a]
1	Step	Dry	20	14.55	3.80	8.77	13.86	14.55	A
2	Step	Water	20	11.72	3.13	7.35	11.52	11.72	A, C
3	Smart Clip	Dry	20	14.87	4.78	7.98	14.75	14.87	A
4	Smart Clip	Water	20	14.05	4.04	8.18	12.65	14.05	A
5	Quick	Dry	20	20.28	4.46	15.01	18.95	20.28	B
6	Quick	Water	20	12.74	3.69	8.62	10.79	12.74	A, C
7	Damon 3MX	Dry	20	11.21	1.87	8.95	10.50	11.21	A, C
8	Damon 3MX	Water	20	10.31	3.29	5.00	11.24	10.31	C

[a] Mean with same letters are not significant.

significant differences in the ARI scores among the different groups. Significance for all statistical tests was predetermined at $p < 0.05$.

3. Results

3.1. Shear bond strength

Descriptive statistics for the shear bond strength (MPa) of the 8 groups tested are illustrated in Table 2. Shear forces are given in Megapascals (MPa). The results of the ANOVA indicated significant differences among the various groups ($p < 0.0001$). *Post hoc* test showed that Quick brackets bonded onto dry enamel showed significantly higher shear bond strengths than all other groups tested ($p < 0.05$). Lowest shear strength values were recorded for groups 2 (Step brackets onto contaminated enamel), 6 (Quick brackets onto contaminated enamel), 7 (Damon 3MX brackets onto dry enamel), and 8 (Damon 3MX brackets onto contaminated enamel).

After water contamination mean shear bond strength lowered for all the brackets tested when compared with dry enamel groups, but this decrease was significant ($p < 0.05$) only for Quick brackets.

3.2. ARI scores

Frequency distribution of ARI Scores showed a prevalence of ARI “2” and “3” for all the brackets tested under both dry and water moistened enamel (Table 3). No significant difference was detected among the various groups ($p > 0.05$).

4. Discussion

The null hypothesis of the study has been rejected. In the present investigation, Quick self-ligating brackets bonded onto dry bovine enamel showed significantly higher shear bond strength values than other groups. Lowest shear strength values were recorded for groups 2 (Step brackets onto contaminated bovine enamel), 6 (Quick brackets onto contaminated bovine enamel), 7 (Damon 3MX brackets onto dry bovine enamel) and 8 (Damon 3MX brackets onto contaminated bovine enamel).

In the present investigation, self-ligating stainless steel brackets registered similar values in dry conditions to values reported in the literature [10,11]. Other reports showed that water contamination results in a significant [8,14] or not significant [15,16] reduction in shear bond strength of conventional brackets. Regarding self-ligating brackets in the literature there are only a few studies that evaluated shear bond strength [10,11], but none considered water contamination after primer application. In the present study after water contamination, mean shear bond strength was lowered for all the brackets tested when compared with dry enamel groups, but this decrease was significant ($p < 0.05$) only for Quick brackets. This is probably due to the different mesh pad design of these brackets, because the morphology of the base design may improve penetration of the adhesive material [11]. On the contrary, under water contamination these brackets registered lower shear strength values, with no significant differences with other moistened groups. In fact new bracket bases have micro retentions that can help to reduce the effect of contaminants on bond strength. Despite the lowering of shear values after water application being significant only for Quick brackets, protection from water contamination is anyway strongly recommended.

Reynolds [17] suggested that a minimum bond strength of 6–8 MPa was adequate for most clinical orthodontic needs. These bond strengths are considered to be able to withstand masticatory and orthodontic forces. In the present investigation all the bond strength values, both when brackets were bonded onto dry and water-contaminated enamel, were above this minimal requirement.

In the present study, bovine enamel was used. Previous studies showed that bovine and human enamel are similar in their physical properties, composition, and bond strengths [18,19]. Bovine lower incisors are used for two main reasons. First, it is easier to obtain a sufficient number of sound bovine teeth than human teeth. Second, the bigger surface area of bovine lower incisors allows preparation of more than one specimen from the same tooth. Thus, control specimens can be obtained from the same surface. Bovine teeth, derived from animals of similar genetic lineage and dietary environment, might show higher homogeneity of mineral composition than different human teeth, which are collected from various donors with diverse dietary or fluoride supplementation [20,21].

In the present investigation, the evaluation of the ARI scores indicated no significant difference in bond-failure site among the 10 groups. A previous investigation [22] suggested that the amount of residual composite might not be related to shear bond strength

Table 3
Frequency of distribution of adhesive remnant index (ARI) scores.

Group	Bracket	Surface	ARI = 0	ARI = 1	ARI = 2	ARI = 3
1	Step	Dry	2 (10%)	1 (5%)	10 (50%)	7 (35%)
2	Step	Water	0 (0%)	3 (15%)	9 (45%)	8 (40%)
3	Smart Clip	Dry	0 (0%)	3 (15%)	9 (45%)	8 (40%)
4	Smart Clip	Water	1 (5%)	1 (5%)	13 (65%)	5 (25%)
5	Quick	Dry	0 (0%)	2 (10%)	7 (35%)	11 (55%)
6	Quick	Water	0 (0%)	0 (0%)	6 (30%)	14 (70%)
7	Damon 3MX	Dry	1 (5%)	2 (10%)	7 (35%)	10 (50%)
8	Damon 3MX	Water	2 (10%)	3 (15%)	8 (40%)	7 (35%)

but it is governed by factors caused by bracket base design and properties of the adhesive. The brackets tested in the present study recorded ARI scores of "2" and "3". This is in agreement with other studies [10,23] that evaluated shear bond strength of self-ligating brackets onto dry enamel. This score indicates failure in the interface bracket-adhesive probably due to a greater force between enamel and adhesive, with less risk of enamel fracture during debonding.

In the present study, none of the teeth showed enamel fracture after testing.

5. Conclusions

The present study demonstrated that:

Water contamination does not affect the shear bond strength on bovine enamel, except for Quick brackets, which recorded a significant reduction in shear strength after moistening.

Quick brackets bonded onto dry bovine enamel showed significantly higher shear bond strengths than all other groups tested, whereas the lowest shear strength values were recorded for Step, Quick, and Damon 3MX brackets bonded onto contaminated bovine enamel and for Damon 3MX onto dry enamel.

Frequency distribution of ARI Scores showed a prevalence of ARI "2" and "3" for all the groups tested, indicating failure in the interface bracket-adhesive.

Disclosure

There are no conflicts of interest to declare for any author involved in the present study.

Acknowledgments

The authors wish to thank 3M/Unitek, Forestadent, Leone, and Ormco for providing the materials tested in this study.

References

[1] Newman GV. Bonding plastic orthodontic attachments to tooth enamel. *J NJ Dent Soc* 1964;35:346–58.

[2] Grandhi RK, Ortho C, Combe EC, et al. Shear bond strength of stainless steel orthodontic brackets with a moisture-insensitive primer. *Am J Orthod Dentofacial Orthop* 2001;119:251–5.

[3] Silverstone LM, Hicks MJ, Featherstone MJ. Oral fluid contamination of etched enamel surface: an SEM study. *J Am Dent Assoc* 1985;110:329–32.

[4] Sayinsu K, Isik F, Sezen S, et al. Light curing the primer – beneficial when working in problem areas? *Angle Orthod* 2006;76:310–3.

[5] Rajagopal R, Padmanabhan R, Gnanamani J. A comparison of shear bond strength and debonding characteristics of conventional, moisture-insensitive, and self-etching primers in vitro. *Angle Orthod* 2004;74:264–8.

[6] Littelewood SJ, Mitchell L, Greenwood DC, et al. Investigation of a hydrophilic primer for orthodontic bonding: an in vitro study. *J Orthod* 2000;27:181–6.

[7] Shaneveldt S, Foley TF. Bond strength comparison of moisture-intensive primers. *Am J Orthod Dentofacial Orthop* 2002;122:267–73.

[8] Cacciafesta V, Sfondrini MF, De Angelis M, et al. Effect of water and saliva contamination on shear bond strength of brackets bonded with conventional, hydrophilic and self-etching primers. *Am J Orthod Dentofacial Orthop* 2003;123:633–40.

[9] Harradine NVT. Self-ligating brackets: where are we now? *J Orthod* 2003;30:262–73.

[10] Northrup RG, Berzins DW, Bradley TG, et al. Shear bond strength comparison between two orthodontic adhesives and self-ligating and conventional brackets. *Angle Orthod* 2007;77:701–6.

[11] Sfondrini MF, Gatti S, Scribante A. Shear bond strength of self-ligating brackets. *Eur J Orthod* 2011;33:71–4.

[12] Sfondrini MF, Gatti S, Scribante A. Effect of blood contamination on shear bond strength of orthodontic brackets and disinclusion buttons. *Br J Oral Maxillofac Surg* 2011;49:404–8.

[13] Årtun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod* 1984;85:333–40.

[14] Vicente A, Mena A, Ortiz AJ, et al. Water and saliva contamination effect on shear bond strength of brackets bonded with a moisture-tolerant light cure system. *Angle Orthod* 2009;79:127–32.

[15] Santos BM, Pithon MM, Ruellas AC, et al. Shear bond strength of brackets bonded with hydrophilic and hydrophobic bond systems under contamination. *Angle Orthod* 2010;80:963–7.

[16] Vicente A, Toledano M, Bravo LA, et al. Effect of water contamination on the shear bond strength of five orthodontic adhesives. *Med Oral Patol Oral Cir Bucal* 2010;15:e820–6.

[17] Reynolds IR. A review of direct orthodontic bonding. *Br J Orthod* 1975;2:171–8.

[18] Nakamichi I, Iwaku M, Fusayama T. Bovine teeth as possible substitutes in the adhesion test. *J Dent Res* 1983;62:1076–81.

[19] Oesterle LJ, Shellhart WC, Belanger GK. The use of bovine enamel in bonding studies. *Am J Orthod Dentofacial Orthop* 1998;114:514–9.

[20] Wegehaupt F, Gries D, Wiegand A, et al. Is bovine dentine an appropriate substitute for human dentine in erosion/abrasion tests? *J Oral Rehabil* 2008;35:390–4.

[21] Sfondrini MF, Scribante A, Cacciafesta V, et al. Shear bond strength of deciduous and permanent bovine enamel. *J Adhes Dent* 2011;13:227–30.

[22] O'Brien KD, Watts DC, Read MJF. Residual debris and bond strength – is there a relationship? *Am J Orthod Dentofacial Orthop* 1988;94:222–30.

[23] Chalgren R, Combe EC, Wahi AJ. Effects of etchants and primers on shear bond strength of a self ligating esthetic orthodontic bracket. *Am J Orthod Dentofacial Orthop* 2007;132:577.e1–5.