available at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden

Bonding of brackets using a caries-protective adhesive patch

Patrick R. Schmidlin [a,*], *M. Schätzle* [b], *J. Fischer* [c], *T. Attin* [a]

[a] *Clinic of Preventive Dentistry, Periodontology and Cariology, University of Zurich, Center of Dental Medicine, Plattenstrasse 11, 8032 Zürich, Switzerland*

[b] *Clinic of Department of Orthodontics and Pediatric Dentistry, University of Zürich, Center of Dental Medicine, Zürich, Switzerland*

[c] *Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zurich, Center of Dental Medicine, Zurich, Switzerland*

ARTICLE INFO

Article history:
Received 22 August 2007
Received in revised form
26 October 2007
Accepted 3 November 2007

Keywords:
Shear bond strength
Bracket bonding
Orthodontic
Adhesion
In vitro

ABSTRACT

Objectives: The purpose of this study was to assess the shear bond strength (SBS) of metal brackets when placed with a caries protective adhesive patch.

Methods: Forty stainless steel brackets (Ormco) were bonded to 40 bovine enamel samples according to the following conditioning/bonding procedures using a resin-based orthodontic luting material (Heliosit Orthodontic, $N = 10$ per group): (A) 35% phosphoric acid (30 s), rinse and dry; (B) as in A but additional placement of a prototype adhesive patch (Ivoclar Vivadent) using a bonding agent (Heliobond); (C) application of a two-step self-etch adhesive (AdheSE); (D) as in C but additional patch placement. Samples were stored at 37 °C for 24 h. SBS was measured with a universal testing machine with a crosshead speed of 0.5 mm/min and the adhesive remnant index (ARI) was determined under a stereomicroscope (16×).

Results: Mean SBS (standard deviation) values were as follows: (A) 16.6 (6.4) MPa; (B) 12.2 (5.8); (C) 12.9 (5.0); and (D) 10.5 (4.7). Analysis of variance followed by Bonferroni correction revealed no statistically significant differences. In 2 (B) and 4 (D) specimens, complete retention of the adhesive patch was observed.

Conclusions: All treatment groups showed adequate bond strength values. The adhesive patch could therefore be applied in combination with orthodontic brackets and seal the enamel adjacent to the bracket.

1. Introduction

The occurrence of demineralizations around brackets, so-called white-spots, represents a problem during orthodontic treatment with considerable prevalence.[1,2] Main reasons for caries formation are inadequate patient self-care and poor diet control. In addition, when brackets are placed adhesively, dissolution of the highly calcified prismless enamel by acid-etching may contribute to an increased caries susceptibility.

Coating with a resin veneer has been described to be a valuable method to protect the enamel against caries.[3] However, this approach requires a complex operative procedure: chair-side, the individual veneer is fabricated using a paint-on technique to apply a first layer of glass ionomer cement, which is – in a second step – covered with a composite resin material using a transparent matrix. An adhesive patch (prototype patch, Ivoclar Vivadent, Schaan, Liechtenstein) specially designed to seal smooth enamel surfaces has recently been developed.[4] It is a methacrylic, elastic, cross-linked, urethane-based polymer material of approximately 80–100 μm thickness. On light exposure in the wavelength of 400–500 nm (blue light), full polymerization of the methacrylic groups occurs, rendering the patch hard and solid. It can be easily adapted to the enamel surface and copolymerize with

* *Corresponding author.* Tel.: +41 44 634 3284; fax: +41 44 634 4308.
E-mail address: patrick.schmidlin@zzmk.uzh.ch (P.R. Schmidlin).
0300-5712/$ – see front matter
doi:10.1016/j.jdent.2007.11.005

Table 1 – Materials and application protocols used in the present investigation

Group	Step/material (LOT)	Composition	Application
A	1. Ultraetch[a]	35% phosphoric acid	Apply for 30 s, rinse for 40 s, air-dry
	2. Heliosit Orthodontic[b] (K07705)	Urethane dimethacrylate, Bis-GMA, decandiol dimethacrylate, silicon dioxide, catalysts, stabilizers	Apply the luting material on the bracket base, positioning and excess removal
B	1. Ultraetch[a]	See group A	See group A
	2. Heliobond[b] (K02259)	Bis-GMA, triethylene glycol dimethacrylate	Apply for 20 s, blow to a thin layer
	3. Patch[b] (R19018-3)	Methacrylate containing polyols, poly isocyanates, light initiator, filler	Firmly adapt on the enamel surface
	4. Heliosit Orthodontic[b]	See group A	See group A
C	1. AdheSE Primer[b] (K03633)	Dimethacrylate, phosphonic acid acrylate, initiators and stabilizers in an aqueous solution	Apply for 30 s (15 s brushing), disperse excess with a strong stream of air
	2. AdheSE Bond[b] (K03345)	HEMA, dimethacrylate, silicon dioxide, initiators and stabilizers	Apply for 20 s, blow to a thin layer
	3. Heliosit Orthodontic[b]	See group A	See group A
D	1. AdheSE Primer[b]	See group C	See group C
	2. AdheSE Bond[b]	See group C	See group C
	3. Patch[b]	See group B	See group B
	4. Heliosit Orthodontic[b]	See group A	See group A

[a] Ultradent, South Jordan, UT, USA.
[b] Ivoclar Vivadent, Schaan, Liechtenstein.

other resin-based dental materials. Previous investigations have shown good sealing and caries-protective properties as well as abrasion resistance of this prototype device when applied as a smooth surface sealing material.[5,6]

We hypothesize that this device would resist to orthodontically applied forces. It could therefore offer an effective protection around the bracket base by displacing base margins into areas of the tooth, which are more accessible to cleaning. This first investigation assessed the shear bond strength (SBS) of brackets placed with and without the patch when using an etch-and-rinse or a self-etch bonding approach. The null hypothesis tested was that there is no difference in SBS of both bonding procedures irrespective of whether a patch is used or not.

2. Material and methods

2.1. *Sample preparation and bonding procedure*

Forty bovine permanent mandibular incisors were extracted and stored in 0.5% chloramine solution prior to the experiment. The crowns were separated from roots and embedded with the labial surface facing downwards in a polyester resin (Castolite, Buehler Ltd., Lake Bluff, USA) in cylindrical molds 25 mm in diameter. After polymerization of the resin, teeth were ground under water-cooling with SiC paper of P240 grit, followed by P1000 grit to expose the enamel and create a smooth parallel surface. Teeth were randomly assigned to four groups of 10 teeth each with different enamel conditioning and bonding conditions (Table 1). In all samples, stainless steel brackets for central upper incisors (Ormesh, Slot .018 bracket width wide, LOT 06G396G, Ormco Corporation, Glendora, USA) were placed (Fig. 1):

- Group A: Teeth were etched with 35% phosphoric acid (Ultradent, South Jordan, UT, USA) for 30 s, rinsed with water for 40 s and air-dried. The orthodontic luting material (Heliosit Orthodontic, Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the bracket base. The latter was positioned on the tooth and excess material was removed.

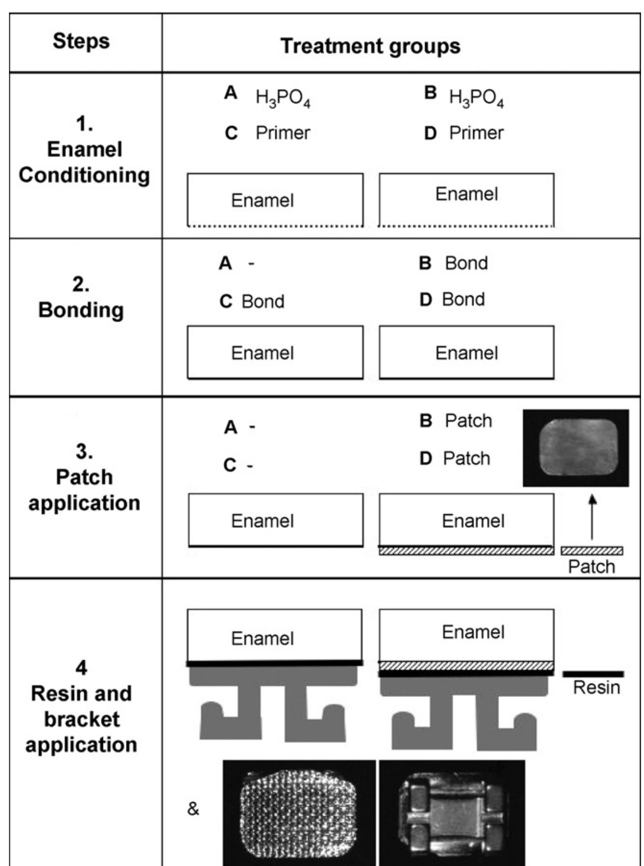

Fig. 1 – Group allocation.

- Group B: Teeth were conditioned using 35% phosphoric acid (Ultraetch, Ultradent) as described above and an adhesive material (Heliobond, Ivoclar Vivadent) was applied for 20 s and blown to a thin layer. A prototype patch (Ivoclar Vivadent) was placed on the enamel surface and carefully adapted. The orthodontic luting material (Heliosit Orthodontic, Ivoclar Vivadent) was applied on the bracket base, which was positioned on the tooth. Excess material was removed.
- Group C: A self-etching primer (AdheSE Primer, Ivoclar Vivadent) was applied for 30 s including 15 s of brushing and excess was dispersed with a strong stream of air. An adhesive (AdheSE Bond, Ivoclar Vivadent) was applied for another 20 s and blown to a thin layer. The orthodontic luting material (Heliosit Orthodontic, Ivoclar Vivadent) was applied on the bracket base, which was positioned on the tooth. Excess material was removed.
- Group D: The enamel was conditioned using the two-step self-etching material (AdheSE, Ivoclar Vivadent) as described above. The prototype patch was placed and carefully adapted. The orthodontic luting material (Heliosit Orthodontic, Ivoclar Vivadent) was applied on the bracket base and the bracket was positioned on the tooth. Excess material was removed.

In all samples, light curing was performed for 60 s (15 s from cervical, incisal, mesial and distal direction; Optilux 500, 700 mW/cm^2; Demetron Inc., Danbury, CT, USA).

Specimens were then stored in distilled water for 24 h at 37 °C.

2.2. Debonding procedure and evaluation

Bond strength testing was performed using a universal testing machine (Z010, Zwick, Ulm, Germany). The crosshead speed was 0.5 mm/min. The plastic cylindric carriers with the embedded teeth and the brackets were mounted on a joint and were aligned in the testing apparatus to ensure consistency for the point of force application and direction of the debonding force for all specimens. The direction of the debonding force was parallel to the enamel surface in an occluso-gingival direction. A stainless steel rod with a chisel configuration was used for debonding the brackets. The force was applied at the bracket base. The load at failure and the mean area of the bracket bases were recorded.

After shear bond strength (SBS) testing, the Adhesive Remnant Index (ARI) was assessed. The surfaces of the substrate were inspected with an optical stereomicroscope at a magnification of 16×.

0. no adhesive/patch left on the tooth;
1. less than half of the adhesive/patch left on the tooth;
2. more than half of the adhesive/patch left on the tooth;
3. all adhesive/patch left on the tooth, with distinct impression of the bracket mesh.

2.3. Data presentation and statistical analysis

Shear bond strength for each specimen was calculated from the load at failure and the recorded average surface area of the bracket base (17.6 mm^2). For the description of the data, mean values, standard deviations and corresponding 95% confidence intervals (95% CI) were calculated. Data were statistically compared using analysis of variance (ANOVA). Post hoc comparisons were performed using Scheffé-F-Test.

For the results of the ARI score evaluation, mean and median values and interquartile ranges (IQR) were reported. Kruskal–Wallis one-way test of variance followed by Mann–Whitney test for individual comparison were used. Bonferroni adjustment was applied for multiple testing. For all statistical analyses, the level of significance was set at 95%.

Table 2 – Shear bond strength (SBS) and force measurements

Group		Mean	S.D.	95% CI upper; lower
A	SBS (MPa)	16.6	6.4	11.7; 21.6
	Force (N)	292.6	113.2	205.6; 379.6
B	SBS (MPa)	12.2	5.8	8.0; 16.3
	Force (N)	232.1	89.3	163.4; 300.7
C	SBS (MPa)	12.9	5.0	9.3; 16.4
	Force (N)	236.1	87.6	168.8; 303.4
D	SBS (MPa)	10.5	4.7	7.1; 13.9
	Force (N)	193.1	83.1	129.2; 257.0

S.D.: standard deviation; CI: confidence interval. No statistical differences between the groups were found.

3. Results

In the shear bond strength test, no statistically significant differences between the experimental groups were found ($p > 0.05$; Table 2).

Concerning ARI scores, no statistically significant differences between the experimental groups were found ($p > 0.05$; Table 3). Low ARI scores were found for the groups without patch application (groups A and C). Only one sample showed adhesive remnants of more than 50% in the latter groups (in group A). In contrast, 2 and 4 patches remained completely attached on the enamel surface in groups B and D, respectively. Two and 4 patches in the latter groups were completely debonded. The adhesive interface between the patch material and the orthodontic resin remained intact in the cases where the patch was removed during failure. In these cases that showed a fully or partly intact patch on the

Table 3 – Frequency distribution of the adhesive remnant index (ARI) score

Group	ARI scores (N)						
	0	1	2	3	Mean	Median	IQR
A	7	2	1	–	0.4	0	1
B	4	2	2	2	1.2	1	2
C	7	3	–	–	0.3	0	1
D	2	2	2	4	1.8	2	2

IQR: interquartile range. No statistical differences between groups were found.

enamel surface, complete adhesive failure between the two resin materials occurred.

The null hypothesis was accepted for both, SBS and ARI score evaluations.

4. Discussion

The present study demonstrated that the adhesive patch prototype under investigation could be used as an intermediate resin layer under metal brackets without hampering bonding efficacy of the brackets. The results of the present study have also demonstrated that the application of a self-etching primer was not significantly different from that of brackets bonded with the conventional acid-etch technique, which is in accordance to other studies.[7–9] The etch-and-rinse approach, however, showed slightly higher bond strength values than the self-etch groups, whereas for both adhesive strategies, the application of a patch resulted in slightly decreased bond strength values.

In the present investigation, we used bovine teeth. Their size and availability make them preferable for bond strength research. There is some concern, however, on whether data obtained with bovine teeth can be applied to human teeth and whether it is valid in a clinical situation. Properties of bovine enamel are comparable to human enamel and bond strength measured for bovine enamel has been shown to be equal to or lower than that to human enamel.[10] Comparative data obtained from the orthodontic literature concerning this topic are scarce. Studies have shown, however, that use of bovine teeth is a reliable substitute to human counterparts in bonding studies of orthodontic adhesion.[11] A study by Oesterle and co-workers found that the bond strength to bovine enamel was 21–44% lower than that to human enamel.[12] In view of this aspect, the data of the current investigation did not overestimate bond strength of this novel approach. However, force location and debonding force direction may also influence SBS results. In this study we applied the force near to the bracket base parallel to the flattened enamel surface. These basic settings may alternatively have increased the measured shear bond strengths.[13,14] These methodological aspects should also be taken into account when comparing results of different studies and when interpreting reference values for optimum bond strength in the literature. In addition, the storage period could be another critical issue in evaluating the efficacy of specimens in orthodontic adhesive systems. The results should be interpreted with caution, not only in view of some of the above-mentioned experimental limitations of this evaluation, but also in the absence of thermomechanical loading. However, as this was a first comparative feasibility study to assess the bonding efficiency, results allow for detection of possible treatment differences when using one substrate under standardized conditions.

Although the area around the bracket bases is critical and is prone to form white-spot lesions in the absence of adequate oral hygiene procedures, the area under the brackets also needs attention. Microleakage around orthodontic brackets has been shown to lead to an increased risk of decalcification even under the bracket base.[15] The polymerization shrinkage of the adhesive material is addressed as one reason for microleakage.[15] We now claim that the adhesive patch may be a useful tool for future application experiments in orthodontic therapy to prevent decalcification under and around orthodontic brackets. The patch has no shrinkage and eliminates the oxygen-inhibition of the bonding agent. The device under investigation may therefore offer the unique potential to act as an impermeable and wear-resistant two-layer resin barrier,[5,6] which allows adequate bracket adhesion. Sealing of minimally invasive cavities using this device has already been shown to have the potential to significantly reduce caries formation and microleakage at filling margins.[16] The latter study has also shown that there was no undermining caries at the patch margins. In addition, the caries profile was not deeper as compared to the unprotected surrounding enamel. The presented idea of sealing restorative margins or brackets with patch margins in areas easily accessible for self-cleaning, a kind of ‘‘extension for prevention’’, is an innovative approach, which merits further investigation. However, this concept is not new. Miwa and co-workers described the concept of enamel protection using an enamel coating with an individually manufactured resin veneer before bracket bonding.[3,17] In contrast to this approach, the flexible pre-cured patch could be easily adapted to the enamel surface and co-polymerized to the bracket in a less time-consuming manner. Ideally, brackets with a pre-attached patch could be manufactured in order to place the patch-bracket complex in one step. Conceptually, the device should ensure good clinical adhesion, a goal, which should be achievable according to the present laboratory data, while being easily removable in one unit to reduce or avoid adhesive material removal after the debonding procedure. This objective is not completely achieved according to the results obtained in the present investigation. The adhesion of the patch to the enamel was strong enough to lead to considerably low ARI values, which indicated remnants of the patch on the enamel surface.

Future studies should assess the long-term adhesion ability and leakage behavior of the device. Well-controlled clinical studies should then be performed to evaluate the clinical applicability and the caries-protective potential of this approach.

5. Conclusions

The patch under investigation showed SBS values comparable to an etch-and-rinse and a self-etch adhesive approach without this device. The adhesive patch could therefore be successfully applied in combination with orthodontic brackets in order to seal the enamel adjacent to the bracket base and reduce the risk of leakage and decalcification.

References

1. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. *American Journal of Orthodontics* 1982;**81**:93–8.
2. Ogaard B. Prevalence of white spot lesions in 19-year-olds: a study on untreated and orthodontically treated persons 5 years after treatment. *American Journal of Orthodontics and Dentofacial Orthopedics* 1989;**96**:423–7.

3. Miwa H, Miyazawa K, Goto S, Kondo T, Hasegawa A. A resin veneer for enamel protection during orthodontic treatment. *European Journal of Orthodontics* 2001;**23**:759–67.
4. Schmidlin PR, Zehnder M, Zimmermann MA, Zimmermann J, Roos M, Roulet JF. Sealing smooth enamel surfaces with a newly devised adhesive patch: a radiochemical in vitro analysis. *Dental Materials* 2005;**21**:545–50.
5. Schmidlin PR, Kluck I, Zimmermann J, Roulet JF, Seemann R. Caries-preventive potential of an adhesive patch after thermomechanical loading—a microbial-based in vitro study. *Journal of Adhesive Dentistry* 2006;**8**:7–12.
6. Schmidlin PR, Gohring TN, Roos M, Zehnder M. Wear resistance and surface roughness of a newly devised adhesive patch for sealing smooth enamel surfaces. *Operative Dentistry* 2006;**31**:115–21.
7. Vicente A, Bravo LA, Romero M, Ortiz AJ, Canteras M. Shear bond strength of orthodontic brackets bonded with self-etching primers. *American Journal of Dentistry* 2005;**18**: 256–60.
8. Davari AR, Yassaei S, Daneshkazemi AR, Yosefi MH. Effect of different types of enamel conditioners on the bond strength of orthodontic brackets. *Journal of Contemporary Dental Practice* 2007;**8**:36–43.
9. Bishara SE, Oonsombat C, Ajlouni R, Laffoon JF. Comparison of the shear bond strength of 2 self-etch primer/adhesive systems. *American Journal of Orthodontics and Dentofacial Orthopedics* 2004;**125**:348–50.
10. Fowler CS, Swartz ML, Moore BK, Rhodes BF. Influence of selected variables on adhesion testing. *Dental Materials* 1992;**8**:265–9.
11. Saleh F, Taymour N. Validity of using bovine teeth as a substitute for human counterparts in adhesive tests. *Eastern Mediterranean Health Journal* 2003;**9**:201–7.
12. Oesterle LJ, Shellhart WC, Belanger GK. The use of bovine enamel in bonding studies. *American Journal of Orthodontics and Dentofacial Orthopedics* 1998;**114**:514–9.
13. Klocke A, Kahl-Nieke B. Influence of force location in orthodontic shear bond strength testing. *Dental Materials* 2005;**21**:391–6.
14. Klocke A, Kahl-Nieke B. Effect of debonding force direction on orthodontic shear bond strength. *American Journal of Orthodontics and Dentofacial Orthopedics* 2006;**129**:261–5.
15. James JW, Miller BH, English JD, Tadlock LP, Buschang PH. Effects of high-speed curing devices on shear bond strength and microleakage of orthodontic brackets. *American Journal of Orthodontics and Dentofacial Orthopedics* 2003;**123**:555–61.
16. Schmidlin PR, Seemann R, Filli T, Attin T, Imfeld T. Sealing of minimally invasive class ii fillings (slot) using an adhesive patch: sealant margin extension for prevention. *Operative Dentistry* 2007;**32**:480–5.
17. Yamada N, Miyazawa K, Miwa H, Tabuchi M, Kondo T, Goto S. Application of direct laminate veneer for enamel protection during orthodontic treatment: an in vivo evaluation. *Dental Materials Journal* 2005;**24**:603–9.