The effects of various surface treatments on the shear bond strengths of stainless steel brackets to artificially-aged composite restorations

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Objective: To compare the shear bond strengths (SBS) of stainless steel brackets bonded to artificially-aged composite restorations after different surface treatments.
Methods: Forty-five premolar teeth were restored with a nano-hybrid composite (Tetric EvoCeram), stored in deionised water for one week and randomly divided into three equal groups: Group I, the restorations were exposed to 5 per cent hydrofluoric acid for 60 seconds; Group II, the restorations were abraded with a micro-etcher (50 μm alumina particles); Group III, the restorations were roughened with a coarse diamond bur. Similar premolar brackets were bonded to each restoration using the same resin adhesive and the specimens were then cycled in deionised water between 5 °C and 55 °C (500 cycles). The shear bond strengths were determined with a universal testing machine at a crosshead speed of 1 mm/min. The teeth and brackets were examined under a stereomicroscope and the adhesive remnants on the teeth scored with the adhesive remnant index (ARI).
Results: Specimens treated with the diamond bur had a significantly higher SBS (Mean: 18.45 ± 3.82 MPa) than the group treated with hydrofluoric acid (Mean: 12.85 ± 5.20 MPa). The mean SBS difference between the air-abrasion (Mean: 15.36 ± 4.92 MPa) and hydrofluoric acid groups was not significant. High ARI scores occurred following abrasion with a diamond bur (100 per cent) and micro-etcher (80 per cent). In approximately two thirds of the teeth no adhesive was left on the restoration after surface treatment with hydofluoric acid.
Conclusion: Surface treatment with a diamond bur resulted in a high bond strength between stainless steel brackets and artificially-aged composite restorations and was considered to be a safe and effective method of surface treatment. Most of the adhesive remained on the tooth following surface treatment with either the micro-etcher or the diamond bur.
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Introduction

The bond strength of composite resin to an aged composite restoration is frequently reduced, leading to early failure of the resin addition.[1–7] Because the usual method of 'etching' the surface of the aged restoration with phosphoric acid does not result in a satisfactory bond strength, mechanical and chemical methods of surface treatment have been tried. The mechanical methods include sandblasting[8] or roughening the surface of the restoration with rotating tungsten carbide[8] or diamond burs.[9] The chemical methods include longer exposure to phosphoric acid,[10–12] etching with hydrofluoric acid[13] or the application of silane/coupling agents.[8,12–15] However, there is no agreement on a preferred protocol.[16–18] The purpose of the present laboratory investigation

Table I. Standard composition and selected physical properties of Tetric EvoCeram, according to the manufacturer.

Standard composition	Per cent
Dimethacrylates	16.8
Barium glass filler, Ytterbium trifluoride, mixed oxide	48.5
Prepolymers	34.0
Additives, stabilisers and catalysts	0.7
Pigments	< 0.1
Selected physical properties	**MPa**
Flexural strength	120
Modulus of elasticity	10000
Compressive strength	250

was to compare the shear bond strengths (SBS) of stainless steel brackets bonded to artificially-aged composite restorations after different surface treatments.

Materials and methods

Specimen preparation

Forty-five recently extracted, non-carious human premolars with sound buccal surfaces were obtained. The teeth were cleaned, lightly pumiced and stored in distilled water at room temperature before use. A 6 mm diameter by 1 mm deep cavity was cut in the buccal surface of each tooth with a fissure bur and etched with 37 per cent phosphoric acid solution for 30 seconds. The cavities were then rinsed, air dried and a thin layer of Heliobond bonding resin (Ivoclar Vivadent Technical, Schaan, Liechtenstein) applied to the base of the cavity prior to filling it with a nano-hybrid resin-based composite Tetric EvoCeram (Ivoclar Vivadent Technical, Schaan, Liechtenstein). The composition and properties of Tetric EvoCeram are provided in Table I. The restorations were shaped with diamond burs and sandpaper discs and polished with rubber cups and paste. All specimens were stored in deionised water for one week at room temperature and randomly assigned to three equal groups:

Group I. The buccal surface was etched for 60 seconds with 5 per cent hydrofluoric acid (Ivoclar Vivadent Technical, Schaan, Liechtenstein) at room temperature, rinsed for 60 seconds with water and air dried.

Group II. The buccal surface was abraded with 50 μm alumina particles directed perpendicular to the surface of the restoration for 7 seconds with a micro-etcher (Danville Engineering Incorporated, Danville, CA, USA). The cleaning and drying procedures described in Group I were applied.

Group III. The buccal surface was roughened with a coarse diamond bur with grit sizes 125–150 μm (863 Grit, Drendell and Zweilling, Berlin, Germany) rotating at high speed with a constant water spray. The rotating bur was passed over the composite surface three times. The cleaning and drying procedures described in Group I were again applied.

Stainless steel upper first premolar brackets (Dentaurum, Ispringen, Germany) were bonded to the composite restorations with a no-mix adhesive resin (Resilience, Confi-Dental Products Company, Louisville, CO, USA). A thin layer of adhesive primer was painted on the surface of each restoration. The adhesive resin paste was applied to the bracket base and the bracket seated on the surface of the restoration with a force of approximately 5 N. Excess adhesive resin was removed with an explorer before polymerisation with a curing light according to the manufacturer's directions. All specimens were thermocycled 500 times between 5 °C and 55 °C with a dwell time of 30 seconds between each cycle. To facilitate debonding, the teeth were mounted in acrylic resin blocks (Orthoresin, De Trey, Dentsply, Weybridge, UK) such that the buccal surfaces were close to parallel with a debonding blade.

Shear bond strength

The brackets were debonded with a universal testing machine (Z020, Zwick GmbH, Ulm, Germany) at a crosshead speed of 1 mm/min. The shear force was applied at the bracket-tooth interface. The force required to shear the bracket was recorded and the SBS calculated in megapascals (MPa).

Adhesive remnant index

The buccal surfaces and bracket bases were examined with a stereomicroscope (Olympus, SZX9, Tokyo, Japan) at x20 magnification and the adhesive remaining on the teeth was scored with the adhesive remnant index (ARI):[19]

0, no adhesive left on the tooth

1, less than half of the adhesive left on the tooth

2, more than half of the adhesive left on the tooth

3, all of the adhesive left on the tooth with the mesh pattern visible.

Table II. Comparison of the shear bond strengths of stainless steel brackets bonded to composite restorations after various surface treatments.

Group and surface treatment	N	Mean (SD) (MPa)*	p†	
			Group I Hydrofluoric acid	Group II Air abrasion
Group I				
Hydrofluoric acid	15	12.85 (5.20)		
Group II				
Air abrasion	15	15.36 (4.92)	0.32	
Group III				
Diamond bur	15	18.45 (3.82)	**0.006**	0.18

*ANOVA, $p = 0.008$
† Tukey post-hoc test, significant value in bold

Table III. Comparison of the adhesive remaining on composite restorations following different surface treatments.

Group and surface treatment	N	ARI score count (Per cent)		
		0	1	3
Group I				
Hydrofluoric acid	15	10 (66.7)	0	4 (26.7)
Group II				
Air abrasion	15	0	3 (20)	5 (33.3)
Group III				
Diamond bur	15	0	0	14 (93.3)

Chi-squared, $p = 0.00$
Hydrofluoric acid vs Air abrasion, $p = 0.001$
Hydrofluoric acid vs Diamond bur, $p = 0.000$
Air abrasion vs Diamond bur, $p = 0.003$

Statistical analysis

A statistical analysis was performed using SPSS software, Ver. 17.0 (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). The SBSs were compared with the one-way analysis of variance (ANOVA) and Tukey's post hoc test. The chi-squared test was used to compare the distributions of the ARI scores in the groups. The level of significance was set at $p < 0.05$.

Results

The mean shear bond strengths of the brackets in Group I was 12.85 MPa (Range: 7.82–20.72 MPa); in Group II it was 15.36 MPa (Range: 7.59–24.50 MPa) and in Group III it was 18.45 MPa (Range: 10.61–25.61 MPa). Only the shear bond strengths of the brackets in Groups I (treatment with hydrofluoric acid) and III (roughened with a diamond bur) were significantly different (Table II).

The ARI scores for stainless steel brackets bonded to the aged composite restorations are provided in Table III. In Group I, wide variation occurred in the ARI scores. In 10 teeth, there was no adhesive left on the tooth surface but at least half of the adhesive was left after debonding the remaining teeth. At least half of the resin was left on the teeth in Groups II and III. The ARI scores for Groups I (hydrofluoric acid) and II (air abrasion), Groups I and III (diamond bur) and Groups II and III were significantly different.

Discussion

The effects of three methods of surface treatment on the shear bond strengths of orthodontic brackets bonded to artificially-aged composite restorations were investigated. A significantly lower bond strength after surface treatment with hydrofluoric acid compared with abrasion using a diamond bur was found. No significant difference was detected between the bond strengths following abrasion with a micro-etcher or a diamond bur. The examined methods of surface treatment increased the shear bond strengths above the values considered to be clinically acceptable, and failure occurred either at the restoration – adhesive interface (after treatment with hydrofluoric acid), within the adhesive (after air abrasion) or at the bracket – adhesive interface (after roughening the restoration with a diamond bur).

The clinical situation was simulated by preparing standardised restorations in extracted human premolars and ageing the restorations artificially by thermocycling each tooth 500 times. The mechanical abrasive methods promoted interlocking and chemical bonding of the restoration by roughening the surface layer of the aged restoration. Hydrofluoric acid is thought to dissolve the glass microfillers which are a characteristic of the Tetric EvoCeram and leave gaps or pores for micromechanical retention of the bonding adhesive. While laboratory studies of shear bond strengths are less time-consuming and less expensive, clinical bond strengths have been shown to be approximately 40 per cent lower than those measured in laboratory models.[20] There is also evidence of a gradual decrease in bond strength between new and old composite resins after ageing and storage in saliva.[1,3,21]

The bond strength between an orthodontic bracket and a composite restoration should be sufficient to withstand the forces generated by mastication, last the duration of orthodontic treatment but allow straightforward removal at the end of treatment without damage to the underlying restoration. The minimum bond strength for orthodontic purposes falls within the range of 6 to 8 MPa.[22,23] In the present study, the mean shear bond strengths ranged from 12.85 to 18.45 MPa and all were well above the bond strength recommended for clinical use.[22,23] The bond strengths of the specimens treated with hydrofluoric acid (Group I) and micro-abrasion (Group II) were more variable than those roughened with the diamond bur (Group III). Based on the current findings, surface treatment of composite restorations with any of the investigated methods should result in bond strengths able to last the duration of orthodontic treatment. However, a significantly high bond strength between the adhesive resin and a restoration has disadvantages. Fracture or loss of the underlying restoration during debonding could occur and remnants of adhesive require removal. The additional cost of clean-up or replacement of the restoration must be considered.

Hydrofluoric acid, even in low concentrations, is a hazardous chemical that is ill-advised for clinical practice. If used, an adequate tissue barrier and high volume suction must be available. It is not recommend as a routine method of treating the surfaces of composite restorations to enhance bonding.

Micro-etcher abrasion requires protection of the eyes, nose and throat to prevent tissue irritation from the fine powder particles. It was found that lightly abrading the surface of an aged restoration with a coarse grit diamond bur was simple and clinically effective.

Conclusions

Surface treatment with a diamond bur resulted in the highest bond strength between stainless steel brackets and an artificially aged composite restoration.

All methods of restoration surface treatment resulted in high bond strengths.

High shear bond strength following abrasion with either a micro-etcher or a diamond bur resulted in adhesive remnants remaining after bracket debonding.

For safety reasons, surface treatment of composite restorations with hydrofluoric acid is not recommended prior to bonding.

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