Porcelain surface-conditioning techniques and the shear bond strength of ceramic brackets

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SUMMARY The aim of this study was to compare the effects of various porcelain surface-conditioning techniques, used either alone or in combination, on the shear bond strength (SBS) of ceramic brackets cured with a light emitting diode (LED). Thirty glazed porcelain facets were randomly divided into three groups of 10. In group I, the porcelain surfaces were etched with 9.6 per cent hydrofluoric acid (HFA) for 2 minutes before silane application, in group II, the porcelain surfaces were sandblasted with aluminium oxide particles, etched with 9.6 per cent HFA for 2 minutes, and silane applied, and in group III, the porcelain surfaces were sandblasted with aluminium oxide particles before silane application. Spirit ceramic brackets were bonded with a light-cured composite resin (Light Bond) and a LED. All specimens were stored in distilled water at 37°C for 24 hours and thermocycled. Bond strength was determined in shear mode at a crosshead speed of 0.5 mm/minute until fracture occurred.

Analysis of variance indicated a significant difference between groups (P < 0.001). The lowest SBS was found in group III (5.46 ± 1.34 , P < 0.001). No significant difference was found between group I (11.38 ± 1.65) and group II (10.45 ± 1.15 ; P > 0.05). Surface treatment with HFA and a silane coupling agent produced the highest bond strength. Sandblasting before HFA and silane application did not significantly increase bond strength. Silane application to sandblasted porcelain provided poor results *in vitro* and clinical trials are needed to determine its reliability for bonding ceramic brackets to ceramic crowns.

Introduction

As the number of adults seeking orthodontic treatment increases, bonding of orthodontic brackets to teeth restored with porcelain crowns is a new challenge. Since glazed porcelain surfaces are not amenable to resin penetration for orthodontic bonding (Smith *et al.*, 1988), mechanical or chemical pre-treatment of the surface is essential for successful direct bonding. However, as the conventional acid-etching technique is not effective in pre-treatment of non-enamel surfaces, four types of surface-conditioning techniques have been suggested:

- 1. Roughening the porcelain surface with a diamond drill or sandpaper discs (Kao *et al.*, 1988; Gillis and Redlich, 1998).
- 2. Sandblasting with aluminium oxide particles (Zachrisson *et al.*, 1996; Kocadereli *et al.*, 2001).
- 3. Chemical preparation with hydrofluoric acid (HFA; Whitlock *et al.*, 1994; Zachrisson *et al.*, 1996; Kocadereli *et al.*, 2001; Harari *et al.*, 2003) or acidulated phosphate fluoride (Jones, 1985; Sposetti *et al.*, 1986).
- 4. Use of silanes (gamma-methacryloxypropyl-trimethoxy silane) which provide a chemical link between porcelain and composite resin and increase the wettability of the porcelain surface (Newman *et al.*, 1984; Eustaquio *et al.*, 1988; Kao *et al.*, 1988; Smith *et al.*, 1988; Lu *et al.*, 1992; Whitlock *et al.*, 1994; Major *et al.*, 1995; Kocadereli *et al.*, 2001; Harari *et al.*, 2003).

Conflicting results exist in the literature on the effects of the above conditioning methods and various adhesives (Newman *et al.*, 1984; Eustaquio *et al.*, 1988; Kao *et al.*, 1988; Smith *et al.*, 1988; Lu *et al.*, 1992; Whitlock *et al.*, 1994; Major *et al.*, 1995; Kocadereli *et al.*, 2001; Harari *et al.*, 2003). In addition, light emitting diodes (LEDs) were not used for curing the adhesives in any of these studies.

In a recent investigation, ceramic brackets bonded on porcelain surfaces cured with LED provided higher shear bond strength (SBS) than those cured with a halogen light (Türkkahraman and Küçükeşmen, 2006). Therefore, the aim of this study was to compare the effects of various porcelain surface-conditioning techniques, used either alone or in combination, on the SBS of ceramic brackets cured with a LED.

Materials and method

Thirty glazed porcelain facets were produced by duplication of the labial surface of a maxillary first premolar. The facets were made from Vita porcelain (Vita, Bad Sackingen, Germany) by the condensing technique and baked under vacuum at 940°C. Each porcelain facet was individually embedded in autopolymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany). The mounted specimens were randomly divided into three groups of 10. Group I: (HFA + Silane) Porcelain surfaces were etched with 9.6 per cent HFA (Pulpdent, Watertown, Massachusetts, USA) for 2 minutes, rinsed with a water/ spray combination for 30 seconds, and dried before application of the silane. Silane primer (Ormco Porcelain Primer, Glendora, California, USA) was applied to the etched porcelain surface with a microbrush and allowed to dry for 5 minutes.

Group II: (Sandblasted + HFA + Silane) Porcelain surfaces were sandblasted with aluminium oxide particles and then etched with 9.6 per cent HFA for 2 minutes, rinsed with a water/spray combination for 30 seconds, and dried before application of the silane. Silane primer was applied on the etched porcelain surface with a microbrush and allowed to dry for 5 minutes.

Group III: (Sandblasted + Silane) Porcelain surfaces were sandblasted with aluminium oxide particles; silane primer was applied on the etched porcelain surface with a microbrush and allowed to dry for 5 minutes.

Spirit ceramic brackets (Ormco, Glendora, CA, USA) were bonded with a light-cured composite resin (Light Bond, Reliance Orthodontic Products Inc. Itasca, Illinois, USA). A thin uniform layer of sealant was applied on the etched porcelain surface with a microbrush and cured for 20 seconds. A thin coat of sealant was also painted on the ceramic bracket base and cured for 10 seconds before applying the paste. Using a syringe tip, the paste was applied to the bracket base. The bracket was then positioned on the porcelain tab and pressed lightly. Excess adhesive was removed with a sharp scaler. Specimens were cured with soft start mode LED (MiniLEDTM, Satelec, Merignac, France) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surface of the brackets).

All specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5 and 55°C using a dwell time of 30 seconds. Each specimen was loaded into a universal testing machine (Lloyd, Fareham, Hants, UK) using Nexjen software (Nexjen Systems, Charlotte, North Carolina, USA) for testing, with the long axis of the specimen perpendicular to the direction of the applied force. A standard knife-edge was positioned to make contact with the bonded specimen. Bond strength was determined in shear mode at a crosshead speed of 0.5 mm/ minute until fracture occurred. Values of failure loads (N) were recorded and converted into Megapascals by dividing the failure load (N) by the surface area of the bracket base (10.60 mm²).

Statistical analysis

Descriptive statistics, including the mean, median, standard deviation, and quartiles were calculated for each of the groups tested. One-way analysis of variance (ANOVA) and Tukey's test were used to compare the SBS of the groups. Significance for all statistical tests was predetermined at

P < 0.05. All analyses were performed with the Statistical Package for Social Sciences version 11.0.0 (SPSS Inc., Chicago, Illinois, USA).

Results

The descriptive statistics on the SBS (MPa) for the groups are presented in Figure 1. ANOVA showed a significant difference between the groups (P < 0.001; Table 1). The lowest SBS was measured in group III (P < 0.001). No significant difference was found between groups I and II (P > 0.05).

Discussion

Since glazed porcelain surfaces are not amenable to resin penetration for orthodontic bonding (Smith et al., 1988), mechanical or chemical pre-treatment of the surface is essential for successful direct bonding to porcelain. Although, various surface treatment methods have been suggested (Newman et al., 1984; Jones, 1985; Sposetti et al., 1986; Eustaquio et al., 1988; Kao et al., 1988; Lu et al., 1992; Whitlock et al., 1994; Major et al., 1995; Zachrisson et al., 1996; Gillis and Redlich, 1998; Kocadereli et al., 2001; Harari et al., 2003), each one has some disadvantages and limitations. Mechanical roughening with fine and coarse diamond burs and sandblasting are reported to provoke crack initiation and propagation within the ceramic (Kao and Johnston, 1991; Nebbe and Stein, 1996; Kocadereli et al., 2001). Since the crowns generally remain in the mouth after de-bonding, any damage to the ceramic surface should be avoided. On the other hand, HFA has been found to be a harmful and irritating compound for soft tissues. Organosilane coupling agents are suggested to enhance bonding brackets



Figure 1 Box plot showing the shear bond strengths (MPa) of the groups. The horizontal line in the middle of each box plot represents the median value and horizontal lines the 25 and 75 per cent quartiles. Lines outside the box represent the 5 and 95 per cent quartiles.

Group I (HFA + Silane)		Group II (Sandblast + HFA + Silane)		Group III (Sandblast + Silane)		Significance	Post hoc tests		
Mean	SD	Mean	SD	Mean	SD		I–II	I–III	II–III
11.38	1.65	10.45	1.15	5.46	1.34	0.000	ns	***	***

 Table 1
 The results of the analysis of variance comparing the shear bond strength (MPa) of the groups.

***P < 0.001; ns, not significant; SD, standard deviation.

to porcelain surfaces, but they fail to provide clinically sufficient bond strengths when used alone (Zachrisson, 2000). To improve bond strengths, combinations of methods are recommended (Thurmond *et al.*, 1994; Barbosa *et al.*, 1995; Zachrisson, 2000; Kocadereli *et al.*, 2001).

Previous studies have shown that chemical conditioning with HFA (Whitlock et al., 1994; Zachrisson et al., 1996; Kocadereli et al., 2001; Harari et al., 2003) or silanes (Newman et al., 1984; Eustaquio et al., 1988; Kao et al., 1988; Smith et al., 1988; Lu et al., 1992; Whitlock et al., 1994; Major et al., 1995; Kocadereli et al., 2001; Harari et al., 2003) successfully increases the adhesion of the composite resin to the porcelain surfaces. However, conflicting results exist when HFA and silane are used together. Kocadereli et al. (2001) showed that porcelain surface preparation with HFA etching followed by silane application resulted in higher tensile bond strength. In contrast, Schmage et al. (2003) did not find any significant increase in bond strength when silane was used in conjunction with HFA. In the present study, the highest SBS were obtained with HFA and silane application. This is an expected result as HFA facilitates micromechanical retention and silane provides a chemical link between porcelain and composite resin. The contradictory results may be explained by the differences in storage conditions, bonding agents, and ceramic types.

Considering the harmful and irritating effects of etching with HFA (Jochen, 1973; Moore and Manor, 1982), some authors suggest silane application after sandblasting as an alternative with similar bond strengths (Kocadereli *et al.*, 2001; Schmage *et al.*, 2003). In contrast, Zachrisson (2000) reported that silane application to sandblasted porcelain did not provide clinically acceptable bond strengths and suggested abandoning this technique. Harari *et al.* (2003) reported considerably higher tensile bond strength with HFA than microetching with aluminium oxide particles. In agreement with these findings, the lowest SBS was found in the sandblasted and silane group. These results clearly show that the most significant factor in bond strength of ceramic brackets to porcelain teeth is etching with HFA.

It is questionable whether mechanical roughening with sandblasting before application of HFA significantly increases bond strength. According to present results, no statistically significant difference was found between groups I and II. No contribution of sandblasting was found when the surface was treated with HFA and silane. Considering the harmful effects of sandblasting to ceramic integrity, it is suggested that HFA and silane application are used for optimum bond strengths and undamaged porcelain surfaces.

Conclusions

- 1. Surface treatment with HFA and a silane coupling agent produced the highest bond strength.
- 2. Sandblasting before HFA and silane application did not significantly increase bond strengths.
- 3. Silane application to sandblasted porcelain provided poor results *in vitro* and clinical trials are needed to determine its reliability for bonding ceramic brackets to ceramic crowns.

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