Effects of a fluoride-containing casein phosphopeptide–amorphous calcium phosphate complex on the shear bond strength of orthodontic brackets

Sevi Burçak Çehreli*, Çağla Şar**, Ömür Polat-Özsoy**, Bahtiyar Ünver*** and Serhat Özsoy****

Departments of *Pediatric Dentistry and **Orthodontics, Faculty of Dentistry, Baskent University, ***Department of Mining Engineering, Faculty of Engineering, Hacettepe University and ****Ministry of Health Topraklık Dental Hospital, Ankara, Turkey

Correspondence to: S. Burçak Çehreli, Department of Pediatric Dentistry, Faculty of Dentistry, Baskent University, 11. sokak, No. 26 Bahcelievler, Ankara, Turkey. E-mail: seviburcak@yahoo.com

SUMMARY The purpose of this study was to investigate the effects of enamel pre-treatment with a new fluoride-containing casein phosphopeptide–amorphous calcium phosphate (CPP–ACP) complex on the shear bond strength (SBS) of brackets bonded with etch-and-rinse or self-etching adhesive systems.

The material comprised 66 extracted human premolars randomly divided into six equal groups with respect to the enamel pre-treatment and adhesive system employed: 1. No pre-treatment and brackets bonded with the etch-and-rinse adhesive system (Transbond XT). 2. Pre-treatment with fluoride-containing CPP–ACP paste (MI Paste Plus) and Transbond XT. 3. Pre-treatment with non-fluoride CPP–ACP paste (MI Paste) and Transbond XT. 4. No pre-treatment and brackets bonded with the self-etching adhesive system (Transbond Plus). 5 and 6. Enamel pre-treated as for groups 2 and 3, respectively, and the Transbond Plus. Bonded specimens were subjected to thermal cycling (x1000) before SBS testing. The residual adhesive on the enamel surface was evaluated after debonding with the adhesive remnant index (ARI). Data evaluation was made using one-way analysis of variance and Tukey test for SBS results, and Kruskal–Wallis test for ARI results.

The results showed that enamel pre-treatment with either fluoride or non-fluoride CPP–ACP paste had no significant effect on the SBS of the self-etching adhesive system (P > 0.05). Enamel pre-treatment with non-fluoride CPP–ACP in group 3 significantly reduced the SBS of the etch-and-rinse adhesive (P < 0.001), while pre-treatment with fluoride-containing CPP–ACP paste (groups 2 and 5) did not affect debonding values (P > 0.05). The fluoride-containing CPP–ACP did not compromise the SBS of brackets bonded with the tested etch-and-rinse and self-etching systems, but its non-fluoride version significantly decreased the SBS of the etch-and-rinse adhesive system.

Introduction

The presence of archwires, brackets, and bands compromises oral hygiene practice in patients undergoing fixed orthodontic treatment. As such, white spot lesions (WSL), the precursor of enamel caries, can frequently be seen due to the prolonged accumulation and retention of bacterial plaque adjacent to fixed orthodontic appliances (Øgaard et al., 1988a,b; Chadwick et al., 2005). In order to improve oral hygiene and prevent WSL formation, several methods have been suggested in orthodontic practice. A plethora of studies (Stratemann and Shannon, 1974; O’Reilly and Featherstone, 1987; Geiger et al., 1988; Øgaard et al., 1988a,b; Øgaard, 1989; Adriaens et al., 1990) have shown that various forms of topically applied fluoride before (Lehman and Davidson, 1981; Wang and Sheen, 1991), during (Bohrer and Gedalie, 1980; Freeman and Shannon, 1981), or after (Davidson and Bekke-Hoekstra, 1980) etching of enamel for bracket bonding can reduce or eliminate decalcification during orthodontic treatment. Other frequently recommended measures against WSL formation include the use of chlorhexidine rinses and fissure sealants (Polat et al., 2005; Heinig and Hartmann, 2008).

More recently, a milk protein derivative, casein phosphopeptide–amorphous calcium phosphate (CPP–ACP) has been recommended for caries prevention and enamel remineralization (Heinig and Hartmann, 2008). Topically administered CPP–ACP buffers free calcium and phosphate ion activity, maintaining a state of supersaturation with respect to tooth enamel that helps prevent demineralization and facilitates remineralization (Heinig and Hartmann, 2008). Thus, a wide spectrum of potential applications of CPP–ACP preparations, including prevention and treatment of WSL in orthodontics, has been recommended (Reynolds et al., 1995; Reynolds, 1997). Both laboratory and in situ studies have shown that CPP–ACP can remineralize human enamel subsurface lesions.
(Reynolds et al., 1995; Reynolds, 1997; Rose, 2000a,b). On the other hand, enamel remineralized with CPP–ACP has been shown to be more resistant to acids (Iijima et al., 2004), which may interfere with resin bonding. Such adverse effects may be more pronounced with the use of the new version of the CPP–ACP complex, which contains 900 ppm sodium fluoride. Enamel pre-treatment with fluoride can also interfere with the bonding mechanism of resins, resulting in reduced bond strength (Meng et al., 1998).

Consequently, the aim of this study was to investigate and compare the effects of fluoride-containing CPP–ACP paste versus its non-fluoride version on the shear bond strength (SBS) of orthodontic brackets bonded with etch-and-rinse or self-etching adhesive systems. The null hypothesis tested was that pre-treatment of enamel with the new fluoride-containing CPP–ACP paste would significantly decrease the SBS of both types of orthodontic adhesive systems.

Materials and methods

Specimen preparation

Human premolars, recently extracted for orthodontic purposes from adolescents, were used in the present study. The teeth were taken from individuals living in a non-fluoridated area. After extraction, the teeth were stored in distilled water and were subjected to testing approximately 6 months after collection. No sterilization of the teeth was undertaken prior to testing. Tooth selection criteria included absence of caries or cracks when inspected under visible light at ×4 magnification. After cleaning the enamel surfaces with a non-fluoridated pumice, the 66 selected teeth were randomly divided into six equal groups with respect to the enamel pre-treatments and adhesive systems employed:

Group 1: This group served as the control for the etch-and-rinse adhesive system. No pre-treatment was carried out. The enamel surface was etched with 37 per cent phosphoric acid for 30 seconds, rinsed with a water spray for 15 seconds, and air-dried. Metal brackets (Microarch Standart; GAC International, Bohemia, New York, USA) were bonded with the etch-and-rinse adhesive system, Transbond XT (3M Unitek, Monrovia, California, USA), in accordance with the manufacturer’s instructions.

Group 2: The enamel was pre-treated with a fluoride-containing CPP–ACP paste (MI Paste Plus; GC Europe, Leuven, Belgium). The enamel was acid-etched as in group 1. The brackets were bonded with the etch-and-rinse adhesive system, Transbond XT.

Group 3: The enamel was pre-treated with a non-fluoride CPP–ACP paste (MI Paste; GC Europe). Etching of the enamel and bracket bonding was performed as in groups 1 and 2.

Group 4: This group served as the control for the self-etching adhesive system. No pre-treatment was carried out. The brackets were bonded to the enamel with the self-etching adhesive system, Transbond Plus (3M Unitek), in accordance with the manufacturer’s recommendations.

Group 5: The enamel was pre-treated with the fluoride-containing CPP–ACP paste and the brackets were bonded to the enamel with the self-etching adhesive system, Transbond Plus.

Group 6: The enamel was pre-treated with a non-fluoride CPP–ACP paste. The brackets were bonded to the enamel with Transbond Plus.

The adhesives were light cured with a quartz–tungsten–halogen source (Hilux; Benlioglu Dental, Istanbul, Turkey) with a wavelength of 560 nm/cm² from both the mesial and the distal aspects of the brackets for 20 seconds each. Before photopolymerization, the irradiance of the light curing unit was confirmed with a built-in radiometer. Bonded specimens were first stored in deionized water at 37°C for 24 hours and then subjected to thermal cycling in deionized water at 5 ± 2°C–55 ± 2°C for 1000 cycles with a dwell time of 5 seconds. To facilitate degradation of bonds, the specimens were further stored in distilled water at room temperature for 6 weeks before debonding. The water was changed weekly (Kitasako et al., 2000; Cehreli et al., 2005).

SBS testing

Following water storage and thermal agitation, the roots were removed with a slow-speed diamond saw under water coolant. The crowns were embedded in self-curing acrylic resin within a mounting jig that aligned the labial surface of each tooth parallel to the direction of a shearing force. A universal testing device (model 4204; Instron, Canton, Massachusetts, USA) was used to apply shearing force in an occlusogingival direction to the bracket base at a crosshead speed of 1 mm/minute. The force required to dislodge the bracket was recorded in newtons (N) and converted to megapascals (MPa) using the following formula: bond strength (MPa) = debonding force (N)/[w x l] (mm²), where w = width of the bracket base, l = height of the bracket base, and 1 MPa = 1 N/mm². The orthodontic metal brackets had a base area of 12 mm² (Ogaard et al., 1988a,b).

Following debonding, the teeth and brackets were examined under a stereomicroscope (Carl Zesis Inc., Oakland, California, USA) at ×10 magnification to determine any adhesive remaining, in accordance with the modified adhesive remnant index (ARI; Olsen et al., 1997). ARI scores range from 5 to 1: 5 = no adherence of composite on the enamel, 4 = less than 10 per cent of the composite remaining on the enamel, 3 = more than 10 per cent but less than 90 per cent of the composite remaining on the enamel, 2 = more than 90 per cent of the composite remaining on the enamel, and 1 = all composite remaining on the enamel, with the impression of the bracket base.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences 11.5 software (SPSS Inc.,
Chicago, Illinois, USA). Data were expressed as the mean ±
the standard deviation for the SBS levels and median
(minimum–maximum) for ARI scores, respectively. The
mean bond strength differences among groups were
analysed using one-way analysis of variance post hoc
Tukey test, and the Kruskal–Wallis test for evaluation of
ARI scores. A P value less than 0.05 was considered
statistically significant.

Results

The SBS values and ARI scores of the test groups are
presented in Table 1. The highest SBS values were observed
when the brackets were bonded to untreated (intact) enamel
(groups 1 and 4), with Transbond XT and Transbond Plus
yielding similar SBS values (P < 0.001). Pre-treatment of
enamel with the fluoride-containing CPP–ACP paste did not
affect the SBS of Transbond XT, which showed similar
debonding values with both control groups (P < 0.001). On
the other hand, enamel pre-treatment in group 3 with the
non-fluoride CPP–ACP paste significantly reduced the SBS
(P < 0.001). Enamel pre-treatment in groups 5 and 6 with
either the fluoride or the non-fluoride CPP–ACP paste had
no significant effect on the SBS of the brackets bonded with
the self-etching adhesive system, Transbond Plus (P > 0.05).

There were no significant differences among the ARI
scores of test groups (Table 1, P > 0.05). The lowest ARI
score was observed in group 1. Compared with their
controls, both adhesive systems displayed higher (but
statistically insignificant) ARI scores on enamel pre-treated
with CPP–ACP pastes.

Discussion

An increasing number of laboratory and animal studies
indicate the strong anticarcinogenic potential of CPP–
ACP-based compounds (Reynolds, 1997; Rose, 2000a,b).
Calcium and phosphate are essential components of enamel
in the form of highly insoluble complexes, but in the presence
of CPP, they remain soluble and biologically available on
enamel and even in dental plaque (Llena et al., 2009). This
provides a large reservoir of calcium and phosphate ions
(Reynolds, 2008), which inhibit demineralization and favour
remineralization under cariogenic attack (Llena et al., 2009).
The latter effect has recently been confirmed on WSL by
clinical scoring and laser fluorescence assessment
(Andersson et al., 2007) indicating that the proprietary
compounds of CPP–ACP not only promote regression of
WSL after debonding of fixed orthodontic appliances but can
also result in the disappearance of 63 per cent of WSL sites
after a 12 month clinical CPP–ACP regimen.

Kumar et al. (2008) demonstrated that CPP–ACP showed
higher remineralization potential when used in combination
with fluoride toothpastes. Furthermore, experimental
incorporation of fluoride into CPP–ACP complexes has

<table>
<thead>
<tr>
<th>Groups</th>
<th>SBS value (MPa)</th>
<th>ARI scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Median</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(minimum–maximum)</td>
</tr>
<tr>
<td>1.Transbond XT</td>
<td>8.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.61 ± 0.49</td>
</tr>
<tr>
<td>2.MI Paste + Transbond XT</td>
<td>8.82&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.54 ± 0.46</td>
</tr>
<tr>
<td>3.MI Paste + Transbond XT</td>
<td>5.74&lt;sup&gt;b,c,d&lt;/sup&gt;</td>
<td>1.67 ± 0.50</td>
</tr>
<tr>
<td>4.Transbond Plus</td>
<td>9.08&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.45 ± 0.44</td>
</tr>
<tr>
<td>5.MI Paste + Transbond Plus</td>
<td>8.11</td>
<td>1.59 ± 0.48</td>
</tr>
<tr>
<td>6.MI Paste + Transbond Plus</td>
<td>7.33&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.20 ± 0.66</td>
</tr>
</tbody>
</table>

<sup>a,b,c,d</sup>One-way analysis of variance.
<sup>e</sup>Kruskal–Wallis test.

Values with the same superscript letters indicate significant differences at
P < 0.001.

been shown to provide significantly greater levels of
remineralization in situ and in vitro (Reynolds et al., 2008)
compared with those achieved with CPP–ACP or fluoride
alone (Reynolds et al., 2008). Thus, incorporation of
fluoride in proprietary CPP–ACP compounds appears to be
a logical step towards achieving the synergistic effect of
CPP–ACP and fluoride in reducing caries experience. On
the other hand, the potential adverse effect of fluoride pre-
treatment on resin bonding (Gwinnett et al., 1972;
Sheykholeslam et al., 1972; Meng et al., 1998) justifies
the present research to investigate the effects of caries
prophylaxis with the 900 ppm fluoride-containing CPP–
ACP compound on the SBS of orthodontic brackets.

In the present study, both the etch-and-rinse and the self-
etch adhesive systems showed a slight but statistically
insignificant reduction in SBS to fluoride-containing CPP–
ACP pre-treated enamel. Although further research on the
mechanism causing this decrease is warranted, these results
necessitate rejection of the null hypothesis since enamel
pre-treatment with the fluoride-containing CPP–ACP
compound did not compromise the bond strength of the
tested etch-and-rinse and self-etch adhesive systems. Two
reasons might be responsible for these findings: firstly, the
sodium fluoride present in the fluoride-containing CPP–
ACP paste could interact with the ACP component of the
casein complex, rendering both inorganic components
ineffective (Azarpazhooh and Limeback, 2008; Rehder
Neto et al., 2009). Undoubtedly, the experimental nature of
the present study limits verification of this assumption,
which merits further research. Secondly, the fluoride present
in the CPP–ACP compound might have actually been
deposited on the enamel surface as nanocomplexes (Cross
et al., 2004), but such fluoride pre-treatment of intact
surface enamel may have little if any adverse effect on the
SBS of the tested adhesives. Indeed, a number of laboratory
studies have indicated that fluoride prophylaxis of enamel before bracket bonding does not necessarily reduce the bond strength of orthodontic adhesive resins (Bishara et al., 1989; Wang and Sheen, 1991; Garcia-Godoy, 1993). Accordingly, pre-treatment of enamel with the tested fluoride-containing CPP–ACP complex appears to be a safe prophylactic (or therapeutic) procedure in terms of bracket bond strength achieved with the present adhesive systems.

Based on two recent studies that evaluated the effects of non-fluoridated CPP–ACP formulations on orthodontic bond strength (Kecik et al., 2008; Xiaojun et al., 2009), a proprietary non-fluoridated CPP–ACP paste was utilized for comparative purposes. The present results showed that the non-fluoride CPP–ACP paste did not affect the SBS of the self-etching adhesive system, Transbond Plus, and that the SBS value was similar to those achieved with both adhesive systems on enamel pre-treated with the fluoride-containing CPP–ACP. These results corroborate the findings of previous studies, which demonstrated that CPP–ACP pre-treatment does not alter the SBS of the etch-and-rinse adhesive system, Transbond XT, to bovine enamel (Kecik et al., 2008) or of the chemically cured Unite bonding material, or operator variability (Adebayo et al., 2007).

Conclusions
Within the experimental limitations of the present study, the following conclusions were drawn:

1. The fluoride-containing CPP–ACP compound did not compromise the bond strength of brackets bonded with the tested etch-and-rinse and self-etching systems. Moreover, the non-fluoride version of the CPP–ACP compound did not alter the SBS of the self-etching system, yielding bond strength values similar to the latter two groups.

2. Enamel pre-treatment, with the non-fluoride version of the CPP–ACP paste, decreased the SBS of Transbond XT to a value lower than the 6–8 MPa bond strength value recommended by Reynolds (1975) and Whitlock et al. (1994) as adequate for orthodontic purposes. Based on this result, the use of Transbond XT on non-fluoride CPP–ACP pre-treated enamel cannot be recommended.

References


Bohrer J, Gedale I 1980 Fluoride concentration in enamel treated with 50% phosphoric acid and NaF with subsequent decalcification in acid gel. Journal of Dental Research 59: 1022–1025


Downloaded from https://academic.oup.com/ejo/article-abstract/34/2/193/632351 by guest on 07 February 2019
Rose R K 2000a Binding characteristics of Streptococcus mutans for calcium and casein phosphopeptide. Caries Research 34: 427–431