AMORPHOUS CALCIUM PHOSPHATE–CONTAINING ORTHODONTIC CEMENT FOR BAND FIXATION: AN IN VITRO STUDY

Aim: To evaluate the shear bond strength (SBS) and fracture mode of amorphous calcium phosphate (ACP)–containing and conventional glass-ionomer cement (GIC) for band fixation. Methods: Sixty extracted human third molars were embedded in acrylic resin blocks, leaving the buccal surface of the crowns parallel to the base of the molds. The teeth were randomly divided into two groups containing 30 teeth each. GIC (group 1, Ketac-Cem) or ACP-containing orthodontic cement (group 2, Aegis-Ortho) was applied onto microetched strip band material (4.0 × 3.8 mm), which was then attached to the tooth surfaces. With a universal testing machine, each cemented band strip was shear mode loaded until failure. Thereafter, all teeth and band strips were examined under 10× magnification. The remaining cement was assessed with a modified Adhesive Remnant Index (ARI). The SBS data were analyzed using the t test and the fracture modes by the chi-square test. Results: There was no significant difference between the bond strength of group 1 (GIC, mean: 28.9 ± 15.2 MPa) and group 2 (ACP-containing cement, mean: 26.3 ± 11.8 MPa). The fracture modes differed significantly between the two groups (P < .01). Conclusion: Both groups had a similar level of SBS. The fracture sites of the ACP-containing cement were predominantly in the enamel-cement interface. World J Orthod 2010;11:129–134.

Key words: bond strength, amorphous calcium phosphate, glass-ionomer cement, shear bond strength, band cementation

Although bonding of brackets using composite resin and acid-etching techniques have become common practice, orthodontic bands continue to be used (particularly on molars) due to the high failure rates of bonded molar tubes, especially when devices such as headgear are used. Initial caries results from decalcification of the enamel surface or subsurface, which is also referred to as white spot formations or lesions. This kind of initial caries commonly corresponds with the use of bonded brackets and cemented bands. Because they are positioned posteriorly in the mouth, teeth with bands are more difficult to clean, which results in a greater accumulation of plaque. Gillgrass et al reported that microleakage between cement and enamel can lead to microbial ingress and consequently enamel demineralization beneath bands. Therefore, orthodontic bands are believed to cause more enamel demineralization than brackets.
To prevent white spot lesions, research has focused largely on fluoride intervention. The anticariogenic and remineralizing effects of a long-lasting fluoride release from conventional glass-ionomer cements (GICs) are well-accepted. There are also indications that resin-modified glass-ionomer cements have a similar effect. However, these cements do not prevent enamel demineralization if bands are loose or if the cement has been removed.

Schumacher et al. developed biologically active restorative materials that may stimulate the repair of tooth structure through the release of various materials including calcium and phosphate. Amorphous calcium phosphate (ACP) is a bioactive filler that can be encapsulated in a polymer base. In response to changes in the oral environment caused by bacterial plaque or acidic food, calcium and phosphate ions will be released from such composites and be deposited into the enamel as an apatite, which is similar to the naturally existing hydroxyapatite.

ACP has the properties of both a preventive and restorative material, which justifies its use as a sealant, composite, and more recently as a cement for not only general dental purposes but also for orthodontic band cementation. ACP-filled composites have been shown to recover 71% of the lost mineral content of decalcified enamel. One ACP-containing cement is Aegis-Ortho (Bosworth), which is light-curing and boosts the formation of hydroxyapatite. This advantage can be maintained for a considerable time, thus preventing future white spots.

Recent studies demonstrated the remineralization potential and bond strengths of ACP-containing materials, but no study has investigated their strength for cementation of orthodontic bands.

The aim of this in vitro study was to compare the shear bond strength (SBS) and fracture mode of a commercially available orthodontic cement containing ACP with a conventional GIC. The null hypothesis was that there are no significant differences in (1) bond strength and (2) fracture mode between these two materials.

### METHODS AND MATERIALS

#### Sample preparation

Sixty extracted human mandibular third molars were stored in distilled water in a refrigerator following decontamination in 0.5% chloramine before being embedded in acrylic resin blocks with the buccal surfaces of the crowns parallel to the base of into two groups, each containing 30 teeth. To standardize specimen preparation, only one operator (E.Y.) performed band material preparation and cementation.

GIC (Ketac-Cem, 3M ESPE) or ACP-containing orthodontic cement (Aegis Ortho) were applied to the microetched strip band material, which was cut to the dimension of 4.0 × 3.8 mm. These strips were attached to tooth surfaces according to the procedures described below.

**Group 1.** Powder and liquid Ketac-Cem were mixed and applied directly to the surface of each material strip. Following placement, excess cement was removed with a scaler and the material was allowed to bench cure for 5 minutes.

**Group 2.** The tooth surface was covered with a thin layer of Aegis Ortho. A similar amount was applied to the microetched strip band material, which was immediately pressed onto the cement on the tooth surface. Following the manufacturer’s recommendation, excess cement was removed with a scaler and the material was allowed to bench cure for 5 minutes.

**Debonding procedure**

The embedded specimens were secured in a jig attached to the base plate of a universal testing machine (Hounsfield Test Equipment, Salfords). A chisel-edge plunger was mounted onto the movable crosshead of the testing machine and positioned so that the leading edge was aimed at the enamel-cement interface. The crosshead moved with a speed of...
0.5 mm/min. The maximum load necessary to detach the band material was recorded in Newtons (N), and the SBS (1 MPa = 1 N/mm²) was calculated by dividing the force by the band base area (15.20 mm²).

Residual adhesive

After band failure the breakage site was assessed at 10× magnification. The remaining cement on the tooth surface was assessed visually by one operator (T.U.) and rated according to a modification18 of the adhesive remnant index (ARI) of Årtun and Bergland19 as follows:

0 = no cement on the tooth surface
1 = less than half of the tooth surface under the band material covered by cement
2 = more than half the tooth surface under the band material covered by cement
3 = the entire tooth surface under the band material covered by cement

Statistical methods

All statistical analyses were performed with SPSS 13.0 software (SPSS). Descriptive statistics, including mean, standard deviation, standard error, and minimum and maximum values, were calculated for both groups. The Shapiro-Wilk normality test and the Levene variance homogeneity test were used to analyze the SBS data, which showed a normal distribution and homogeneity of variance. The Student t test for two independent variables was used to compare the SBSs of the two tested materials. Fracture modes were analyzed using the Pearson chi-square test. Significance was predetermined at P < .05.

RESULTS

The descriptive statistics for each group are presented in Table 1. The mean bond strengths of group 1 and group 2 were 28.9 ± 15.2 MPa and 26.3 ± 11.8 MPa, respectively. According to the Student t test, this difference is not significant. Thus, the first null hypothesis could be accepted.

The fracture mode of the specimens is shown in Table 2. In group 1, a greater percentage of fractures were at the band-cement interface (score 3 = 65%),
whereas in group 2, most of the failures occurred at the cement-enamel interface (score 0 = 60%). This difference was significant \( P < .01 \) and is why the second null hypothesis was rejected.

**DISCUSSION**

Various new products, including those for band cementation, have been assessed in different clinical and laboratory studies.\(^8,18,20–27\) Most of the laboratory studies with various orthodontic band cements indicated a significantly different shear/peel strength and site of bond failure.\(^18,20,22,23\) In two clinical investigations, Fricker\(^24\) compared modified light-activated cement for orthodontic bands over a 12-month period, whereas in the Millett et al\(^25\) investigation, the observation lasted 5 years.

Several authors tested materials to prevent demineralizations under orthodontic bands. Foley et al\(^26\) compared three band cements and suggested the use of fluoride-releasing materials. Millett et al\(^27\) investigated chlorhexidine-modified GIC for band cementation to minimize plaque accumulation and subsequent development of generalized gingival hyperplasia and enamel demineralization. They suggested that this modified material may perform clinically similar to standard GIC. However, ACP-containing cement, which has a positive effect against demineralization, was never before tested for orthodontic bands.

The introduction of ACP in dentistry allows reversing enamel demineralization. Only a few articles have investigated the incorporation of calcium phosphates into orthodontic composites. Sudjalin et al\(^28\) evaluated the effects of sodium fluoride (NaF) and 10% casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) on enamel demineralization adjacent to orthodontic brackets. He found that the addition of CPP-ACP, NaF, or CPP-ACP/NaF significantly prevented enamel demineralization when used for bonding. Foster et al\(^15\) and Dunn\(^17\) compared the SBS of metallic orthodontic brackets bonded to enamel using ACP-containing cement to that of brackets bonded with a conventional orthodontic composite and found a lower but acceptable bond strength value for the former.

Similar to earlier laboratory investigations, conventional GIC Ketac-Cem was used as the control in this study. Ketac-Cem is a second-generation water-hardening cement whose polyacid is a copolymer of acrylic and maleic acid freeze-dried into the powder. The glass ionomer is formed by an acid-base setting reaction between aluminosilicate glass and the polyacid.

In the present study, microetched standard strip band material was employed to simulate contemporary clinical practice. Microetching has been shown to improve bond strength\(^20,21\) and thus reduce clinical band failure rates.\(^29\)

The 30 teeth used per cement group have been recommended as optimal for studies of this nature.\(^30\) Also, specimen storage before testing complied with the guidelines in the orthodontic literature.\(^21,29,30,31\) In one study, acrylic blocks rather than teeth were used, to which 6.0 \( \times \) 6.0 mm strips of stainless steel band were attached with a cyanoacrylate adhesive, but only 10 specimens were bonded with each cement type.\(^21\)

Williams et al\(^23\) indicated that when using third molars to investigate band strength in vitro, it is likely that the cement thickness varies considerably for each individual tooth. They further emphasized that not only the film thickness but also the film uniformity is important. Thus, to test the pure SBS and failure characteristics, standard strip material was adapted to every tooth surface in this study.

In the present investigation, the mean SBS of GIC and ACP-containing cement were 28.9 ± 15.2 MPa and 26.3 ± 11.8 MPa, respectively. Millett and McCabe\(^32\) reported that in vitro GIC studies typically show large standard deviations in bond strength values that may create concern over the reliability of both the test system and the bond strength achieved. These high ranges can also be seen in the current study. They suggest that the manipulation of GICs is technique-sensitive. It should be noted that this range was lower for the ACP-containing cement (14.6 to 58.4 MPa) than that of the standard GIC.
(6.6 to 59.2 MPa). This might be due to its inferior bond strength and standard deviation (Table 1). The lower standard deviation indicates, though, that the ACP-containing cement produces a relative consistent bond.

A minimum bond strength of 5.9 to 7.8 MPa has been suggested as adequate for most clinical purposes in orthodontics.33 On this basis, Ketac-Cem and Aegis Ortho can be expected to perform clinically adequate. However, bands on molars are likely to be subjected to greater shear forces than attachments bonded to teeth more anteriorly in the mouth.2 Moreover, clinical conditions may significantly differ from an in vitro setting,34 as there are stress, temperature fluctuations, variable electrolytes, microorganisms, and other factors.

In the ACP-containing cement specimens of this study, failure occurred predominantly (60%) at the enamel-cement interface. For the remaining specimens, less than half of the surface under the strip material was covered with cement. This concurs with the results of previous research in which microetched bands were used.29 With Ketac-Cem, most (65%) samples had a remnant score of 3, indicating that the entire tooth surface under the band material was covered by cement. These findings are not confirmed by a previous study in which these cements were also used.29 Although the percentage of GIC remaining on the band after debanding has been recorded in a previous publication,18 this study did not utilize strip band material, which is why the results cannot be compared objectively with those of the present study. On the basis of this study’s findings, cleanup after debanding might be slightly faster if bands are cemented with ACP-containing cement rather than conventional GIC.

CONCLUSION

From the results of this study, the following conclusions can be drawn:

The mean SBS of standard strip molar band material with microetched surfaces cemented with ACP-containing cement did not differ significantly from conventional GIC.

The amount of GIC cement remaining on the tooth after removal was significantly larger than that of ACP-containing cement.

REFERENCES


