In vivo bonding of orthodontic brackets with glass ionomer cement

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In traditional, fixed orthodontic treatment, brackets are typically attached to acid-etched teeth with a composite resin. Bonding brackets to teeth, rather than banding them, may help patients maintain improved oral hygiene. Resin or ceramic attachments are an obvious esthetic improvement over metal bands.

Etching the enamal prior to attaching brackets requires accurate conditioning of the tooth surface and is a time consuming process. Etching also irreversibly damages the enamel surface. Partial loss of enamel has been reported when removing both metal and ceramic brackets, necessitating labial restorations.[1-5]

Glass ionomer cements (GIC) have been in clinical use for some years. In orthodontic treatment, they are popular as a luting cement for molar bands due to their fluoride release.[6,7] When bonding to the dental hard tissues, they work solely by molecular interactions between the calcium ions in the enamel and the carboxylic groups of the GIC.[8,9] Bonding orthodontic attachments with GIC thus appears to be a one-step procedure as no enamel etching is required.

The bonding strength of GIC to enamel is approximately one-half that of composite resin bonding after etching, 2 - 6 MPa (MN/m^2) and 5 - 25 MPa respectively. Preliminary investigations conducted at the University of Erlangen-Nürnberg in Germany on bonding conventional metal mesh brackets showed that when these attachments are lost, it is often due to the disintegration of the

Abstract

The adhesion of orthodontic bracket bases was examined in vivo 24 to 32 hours after bonding with glass ionomer cement (GIC). In contrast to bonding with composite resin, with GIC there is no need to etch the enamel surface of the tooth. Conventional metal brackets with mesh pad, bonded with GIC, showed an average shear bond strength of 3.6 ± 1.1 MPa, approximately one-fourth the bond strength of composite resin. Fracture sites were found exclusively at the mesh/GIC interface. Bonding between GIC and enamel must, therefore, be stronger than bonding between conventional resin and enamel. An experimental attachment with a modified base, consisting of brass rings 4 mm in diameter with a retention groove, was designed. In these experimental cases, fractures were found at the base/GIC interface and at the enamel/GIC interface. Shear bond strength of the experimental base was as high as 5.8 ± 1.0 MPa. These values approached those of brackets bonded with composite resin and acid etching. Bond strengths of up to the 3 MPa which occur during orthodontic treatment were achieved. Clinical trials with GIC bonding thus seem feasible and are being initiated.

Key Words

Glass ionomer cement • Bond strength • Etching enamel • Brackets • Orthodontic bonding

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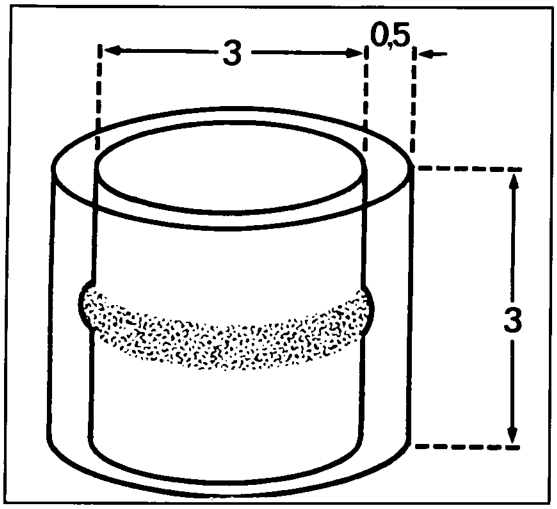

Figure 1

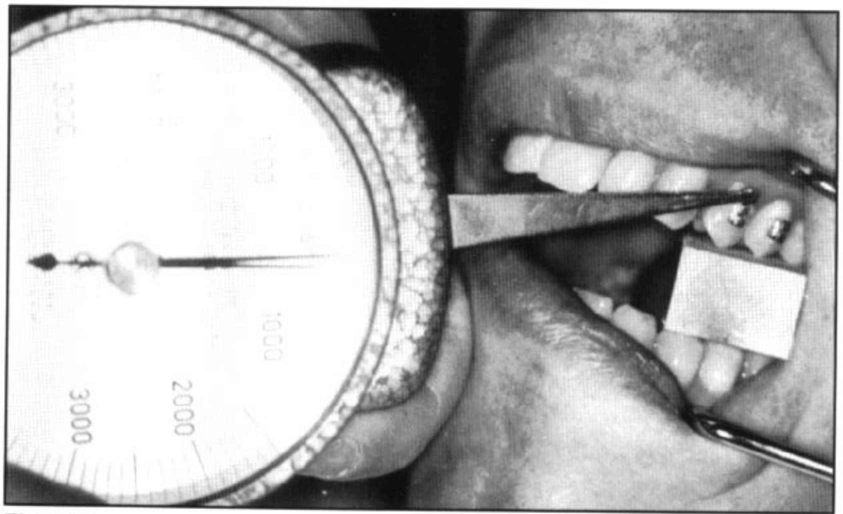

Figure 2

Figure 1
Schematic representation of the experimental bracket base with retention groove [in mm].

Figure 2
The attachments are sheared off with the lever arm attached to the dynamometer. A soft splint protects the lower teeth.

bond between the bracket pad and the adhesive. Bond strength is thus mostly influenced by the strength of the base/GIC interface, not by the bonding material itself.

The aim of this study was to measure in vivo the bonding properties of conventional mesh-backed brackets bonded with GIC. To improve bond strength with GIC, a new experimental bracket base was designed and evaluated.

Materials and methods

Using capsulated GIC (Ketac-Fil, Espe, Seefeld, Germany) 61 brackets were placed in 16 test subjects. The subjects were 20 to 26 years of age, had not received orthodontic treatment, and had given informed consent. Only intact maxillary premolars and molars were used. In the first part of the study, 36 conventional metal brackets (Dentaurum, Pforzheim, Germany) with a flat bonding area of 10.8 mm^2 were placed. Since fracturing under shearing pressure always occurred at the mesh/GIC interface, 25 newly-designed experimental bracket bases were used in the second part of the study (Figure 1). They consisted of 3 mm-high brass rings which were 4 mm in diameter, and 0.5 mm thick (bonding area 12.6 mm^2). A groove on the inside of the ring facilitated GIC retention. The rings were oversized for experimental reasons to apply the shearing force: subsequent transformation of the ring into a bracket would require a 50% reduction in ring height.

Before bonding, the buccal surfaces were cleaned with pumice, sprayed with water and dried. Rubber dams were not used. The GIC was triturated in the capsule for 10 seconds, according to the manufacturer's instruction. Slightly more GIC than required was applied to the pads of the conventional brackets before they were pressed onto the teeth. Excess cement was removed at once with a probe and the cementing gap was covered with varnish (Visiobond, Espe, Seefeld, Germany) to protect the GIC from moisture during setting.

The experimental brass rings were prepared by sealing the side most distant from the tooth with celluloid tape. The cement was mixed and squeezed from the capsule into the rings. The rings were then applied to the teeth, the excess cement was removed and varnish was applied. After five minutes the tape was removed and the resulting GIC areas were also varnished (Figure 4A).

The test subjects were not instructed in taking care of the attachments during eating or oral hygiene. After 24 to 32 hours, all the attachments were removed.

During the shearing experiment the test subjects were instructed to bite on a soft splint in order to protect their teeth. A lever arm attached to a hand-held dynamometer (Hahn & Kolb, Stuttgard, Germany) was placed with its tip over the cervical portion of the attachments close to the tooth surface. With a slow and steady hand movement, the arm was pressed downwards. The attachments were sheared off with a tangential force of up to 50 N (Figure 2). The applied force was measured with the dynamometer. An attempt was made to apply the force almost parallel to the long axis of the tooth. The force required to detach the attachments was recorded and converted in relation to the bonding area into shear bond strength measured in MPa. After debonding it was determined whether the fracture site occurred at the base/GIC interface, within the GIC or at the enamel/GIC interface. Attachments with adhesive fractures at the enamel surface were evaluated under a stereoscopic high-power microscope (x30 mag-

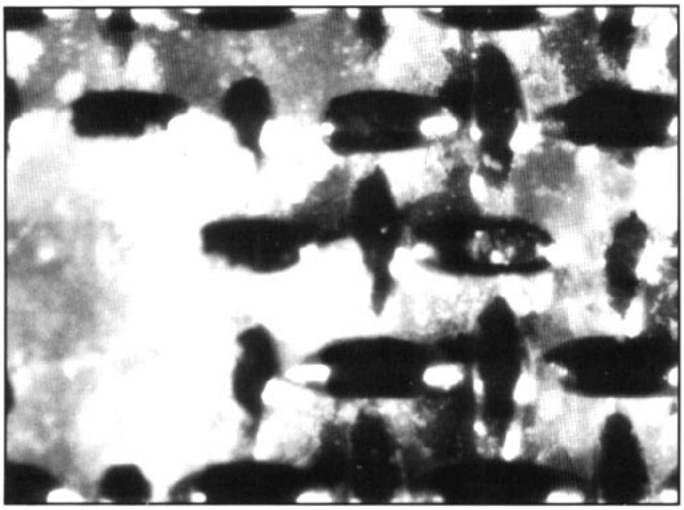

Figure 3A

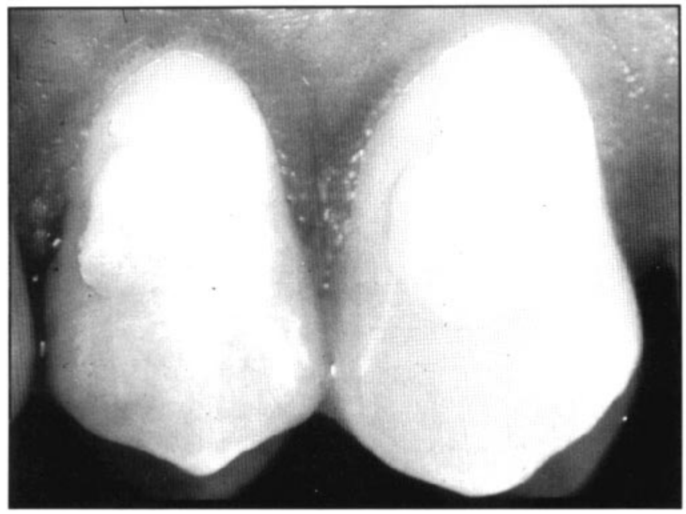

Figure 3B

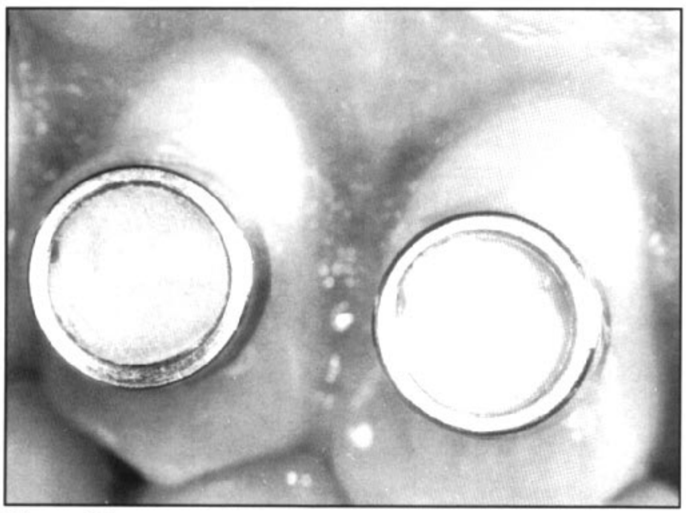

Figure 4A

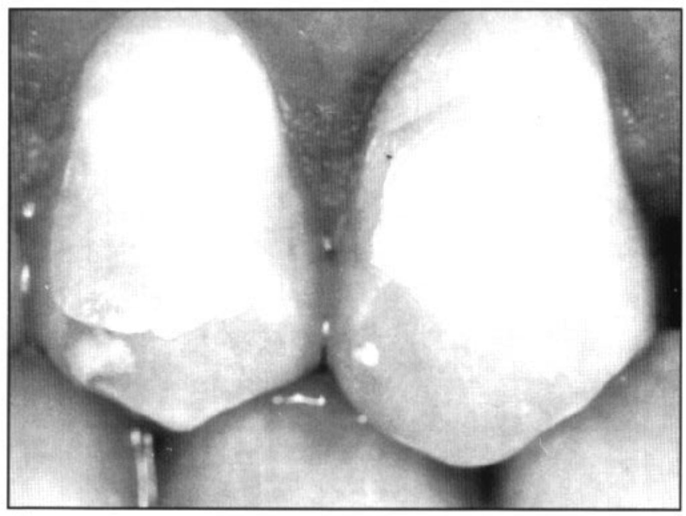

Figure 4B

Figure3A-B
A: Fracture area at the mesh retention base of a metal bracket.
B: Fracture area on the teeth.

Figure 4A-B
A: Cemented experimental attachments.
B: Fracture area on the teeth.

nification) for any residual particles of enamel. At the end of the experiment GIC remnants on the tooth were removed with an ultrasonic instrument or scaler and the enamel was polished. The difference in shear bond strength between the brackets and the experimental rings was statistically analyzed using Student's t-Test.

Results

The mean shear bond strength of conventional brackets after 24 to 32 hours in vivo was 3.5 ± 1.1 MPa. Data were based on 34 brackets as two metal brackets were lost in one subject during mastication. The fracture sites were found invariably at the mesh/GIC interface (Figure 3A). GIC remnants were found on the enamel over the entire bonding area (Figure 3B).

The experimental bracket bases had a mean bond strength of 5.8 ± 1.0 MPa (Table I). Fractures occurred in the GIC itself as well as at the enamel/GIC interface (Figure 4B). Under microscopic examination, the GIC and enamel surfaces were found to be smooth. There was no evidence of enamel fractures. Clinical inspection also failed to reveal any enamel defects. The attachments modified as brass rings showed a bond strength approximately 2.3 MPa higher than that of conventional brackets with mesh pad (statistically significant, $p < 0.05$).

Discussion

Shear stresses exerted on attachments during orthodontic treatment range from 1 to 3 MPa.[10] During mastication, even higher forces can occur temporarily and brackets can be debonded by random contact.

Studies have shown that brackets bonded with composite resin following enamel etching show average bond strengths ranging from 2 to 13 MPa.[3,10-12] These studies of shear and tensile stresses involve purely in vitro assessments in order to facilitate standardization. The weakest site between the bonding brackets and composite resin is usually the contact area of the mesh retention

Table I
Shear bond strength of conventional metal brackets and experimental bracket bases bonded with GIC ($p < 0.05$). Two attachments were lost during mastication.

Bracket Bases	n	Shear bond strength [MPa] x	SD	Range	
Conventional	34	3,6	1,1	1,7	5,0
Experimental	25	5,8	1,0	3,9	7,8

pad. Bond strengths of composite resin to enamel are between 5 and 22 MPa.[10,11,13,14] Resin or ceramic brackets are often used with a silane-coupled agent on the base to further improve bonding,[14] but this complicates debonding. If retention of the brackets to the etched surfaces is too strong, there is a danger of irreversibly damaging the enamel with fractures occurring up to 0.1 mm deep.[3] For this reason, this in vivo study does not include a control group with attachments bonded with composite resin adhesive.

Results of past studies involving the bonding of GIC to enamel showed values ranging from 2.5 to 10 MPa.[8,9,15-18] Conditioning the enamel with phosphoric or citric acid did not improve bonding.[8,15] During removal, cement was debonded from the enamel or the cement itself was damaged. Shear and tensile bond strengths of GIC were quoted as 5 to 10 MPa.[9,19] In contrast to composite resin with the acid-etching, cement does not penetrate the deeper enamel layers and can be easily removed with a scaler or an ultrasonic device. No enamel is damaged during debonding and the natural structure of the enamel remains unaltered. After removal a thin, light-microscopic invisible layer of GIC may remain on the enamel surface.[15]

During the first part of this study the most likely fracture site proved to be at the interface between the mesh pad and the GIC. In the second part, an experimental bracket base without a mesh was tested. The inner groove of the ring attachment assures retention without weakening the attachment/GIC interface. This modified bracket pad improved bonding. Fractures during the shearing test were found only in the GIC itself and at the enamel surface. The bonding properties fell within the lower range of those values which can be achieved when bonding brackets with a composite resin. The shear bond strength of up to 3 MPa, which arises during orthodontic treatment, was achieved.

In the present study, the observation period of in vivo bonding of GIC was restricted to a 32-hour maximum out of consideration for the test subjects. In vitro investigations evaluating GIC when used as a bonding agent for brackets with mesh pad showed similar bond strengths which decreased after thermocycling[20] or in contrast, increased over a period of 7 days.[21] In an in vitro study comparing composite resin and GIC in direct bonding of brackets, GIC exhibited 80% of the bond strength of composite resin.[22] Results of studies in which just the enamel adhesion of the GIC was tested over a longer period of time showed that after two weeks of thermocycling the bond strength remained virtually unchanged.[18] Another study found values of 3.5 - 5.2 MPa after 6 days of storage in distilled water.[16]

In addition to not requiring acid-etching, another advantage of GIC is the fluoride release factor. In patients with inadequate oral hygiene, defects in the enamel adjacent to the attachments are often subjected to demineralization, the full extent of which only becomes apparent when the brackets are debonded.[7,23,24] Cariostatic effects are not only described in GIC restorations, but demineralization also occurs less often under orthodontic bands cemented with GIC.[6,25]

The results of this study showed that GIC is suitable for use as a bonding material for orthodontic attachments providing bond strength can be improved by developing modified bases. The clinical use of GIC as a bonding material is presently being studied in a group of selected patients undergoing orthodontic treatment.

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