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Correlation between the Strength of Glass Ionomer Cements and Their Bond Strength to Bovine Teeth

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This study examined the possible correlation between the strength of glass ionomers and their adhesive strength to bovine teeth. The shear bond strengths of three different brands of glass ionomer mixed at four different P/L ratios to bovine teeth were measured 24 hours after the cement specimens were prepared. The correlation between shear bond strength and mechanical strength reported in our previous study was also examined. No significant ($p>0.05$) increases in the bond strength to bovine teeth were found in any of the cements when the mixing ratio increased. The present study showed no significant ($p>0.05$) correlation between mechanical strength of cement and its bond strength to bovine teeth. Rather than trying to increase the strength of the cement, it would be more effective to enhance the adhesive bond strength through procedures such as surface conditioning or cleaning of the tooth structure when glass ionomers are used as luting agents.

Key words: Glass ionomer cement, Bond strength, Mechanical property

INTRODUCTION

When cast restorations are cemented to teeth, there are two adhesive cement interfaces: the cement-metal interface and the cement-tooth substrate interface. The success at cementing cast restorations is clinically determined not only by the strength of the adhesive bond at the interface, but also by the structural integrity of the cement layer. Glass ionomer cements (glass polyalkenoate cements) have several advantages over other cements. However, they are known to lack strength of the material itself, though not of the adhesive bond to the substrate[1]. In our previous study[2], the mechanical strength of glass ionomer cements influenced their shear bond strength to metal surfaces. For non precious alloys, the greater the strength of the glass ionomer cement, the higher the adhesive strength was between cement and metal. However, this relationship was not so for precious alloys. Thus, the correlation between the inherent strength of glass ionomer cement and its adhesive strength depends on the adherend. Little information is available on the relationship between the strength of glass ionomer cement and its adhesive strength to tooth substrate.

The purpose of this *in vitro* study was to examine a possible correlation between the adhesive strength of glass ionomer cements − to bovine enamel and dentin − and the intrinsic strength of these glass ionomer cements. The hypothesis tested was that an improvement in the mechanical properties of glass ionomer cement would also improve the adhesion between cement and the tooth.

MATERIALS AND METHOD

Materials

Three different, commercially available glass ionomer cements for luting (Fuji I, HY-BOND GLASIONOMER-CX, and DNT Ionomer), which were used in our previous study[2], were tested (Table 1). To alter the strength of the cements, each glass

Table 1 Glass ionomer cements tested

Product Name	Manufacturer	Batch No.	P/L ratio*	Code
Fuji I	GC	P: 190661 L: 190661	1.8g/1.0g	FI
HY-BOND GLASIONOMER CX	SHOFU	P: 049605 L: 069651	2.0g/1.0g	CX
DNT Ionomer	Dai Nippon Toryo	P: 65001 L: 65503	1.6g/1.0g	DNT

*Manufacturer's recommended ratio

ionomer was mixed at four different powder/liquid ratios (weight (g) of powder/weight (g) of liquid): 1) manufacturer's recommended ratio (MRR); 2) MRR−0.2; 3) MRR−0.4; and 4) MRR+0.2. Table 1 also includes the manufacturer's recommended ratio for each cement.

Determination of shear bond strength of cement to tooth

The crown portion of an extracted, bovine mandibular incisor was embedded in epoxy resin in a Teflon mold (25.4 mm in diameter, 10 mm in depth). A flat labial enamel surface or a dentin surface was obtained by grinding with #180 and #400 SiC abrasive papers under water. The bonding surface of the enamel specimen or dentin specimen was finished with #600 SiC abrasive paper under water. The specimens were then cleaned for 30 seconds with ultrasonic irrigation and stored in distilled water until the cement was bonded.

The enamel or dentin specimen surface was gently dried with a stream of air. A split Teflon mold (6 mm in diameter, 3 mm in depth) was then positioned on the enamel or dentin specimen surface embedded in the epoxy resin block. Each cement was mixed at one of the mixing ratios, and then the mold was filled with the cement mixture using a syringe. The top surface of the filled mold was immediately covered with a glass plate. Five minutes after the start of mixing, a load of 147 N was applied perpendicular to the top surface of the cement specimen for 15 minutes at 23±1℃. The Teflon mold was removed after loading, and the specimen was stored in distilled water at 37℃ until the start of the bonding test.

The shear bond strength between the cement and the tooth was determined. The specimen was secured in a mounting jig and loaded parallel to the adhesive interface formed between either the bovine enamel or dentin, and the cement (Fig. 1). Shear bond strength was measured using a universal testing machine (Instron 4302) at a cross-head speed of 0.5 mm/min at room temperature 24 hours after the cement specimens were prepared. Five specimens were examined for each material at each mixing ratio.

Examination of fracture mode

After the shear bond strength test, the fractured surfaces of the enamel and dentin specimens were photographed with a stereomicroscope at ×50 magnification. The photographs were scanned (GT-8700, Epson) and saved on a computer. The area of remained cement on the enamel or dentin specimen was calculated using graphics software (Photoshop, version 7, Adobe). The failure mode of the cement was classified and recorded as: 1) cohesive failure; 2) adhesive failure; and 3) mixed failure. Cohesive failure was defined as fracture mainly occurring within the cement, and adhesive failure was defined as fracture mainly occurring at the tooth/cement interface. When more than 75% of the bonded area appeared to consist of fractured cement, the specimen was classified as a cohesive failure. Failure was defined as adhesive when the tooth surface was exposed on more than 75% of the bonded area. When 25-75% of the failure was both adhesive and cohesive, these failures were considered to be mixed failure.

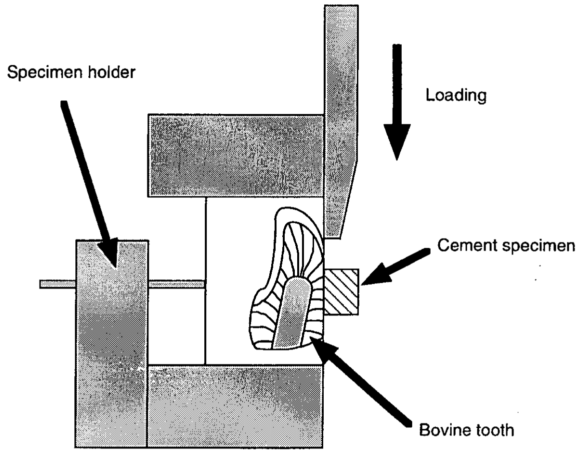

Fig. 1 Diagram of apparatus for measuring shear bond strength. (Note: Diagram shows the shear bond test for dentin specimen.)

Statistical analysis

Results from the shear bond strength test were statistically compared using ANOVA/Scheffé's multiple comparison test at alpha=0.05. The correlation between shear bond strength and compressive strength or diametral tensile strength reported in our previous study[2] was also examined.

RESULTS

Shear bond strength to enamel or dentin

No significant ($p>0.05$) increases in the bond strength to bovine enamel and dentin were found in any of the cements when the mixing ratio increased. For CX, the bond strength to the enamel surface tended to be higher than that to the dentin surface. On the other hand, DNT had greater bond strength to dentin than to enamel (Fig. 2). A majority of the failure modes in the enamel specimens were adhesive; in the dentin specimens, the failure mode was predominantly mixed failure (in FI and DNT) (Table 2).

Relationship between shear bond strength and strength of cement

Figs. 3 and 4 plot the mean shear bond strength values for all the cements against the mean compressive strength values (Fig. 3) or the diametral tensile

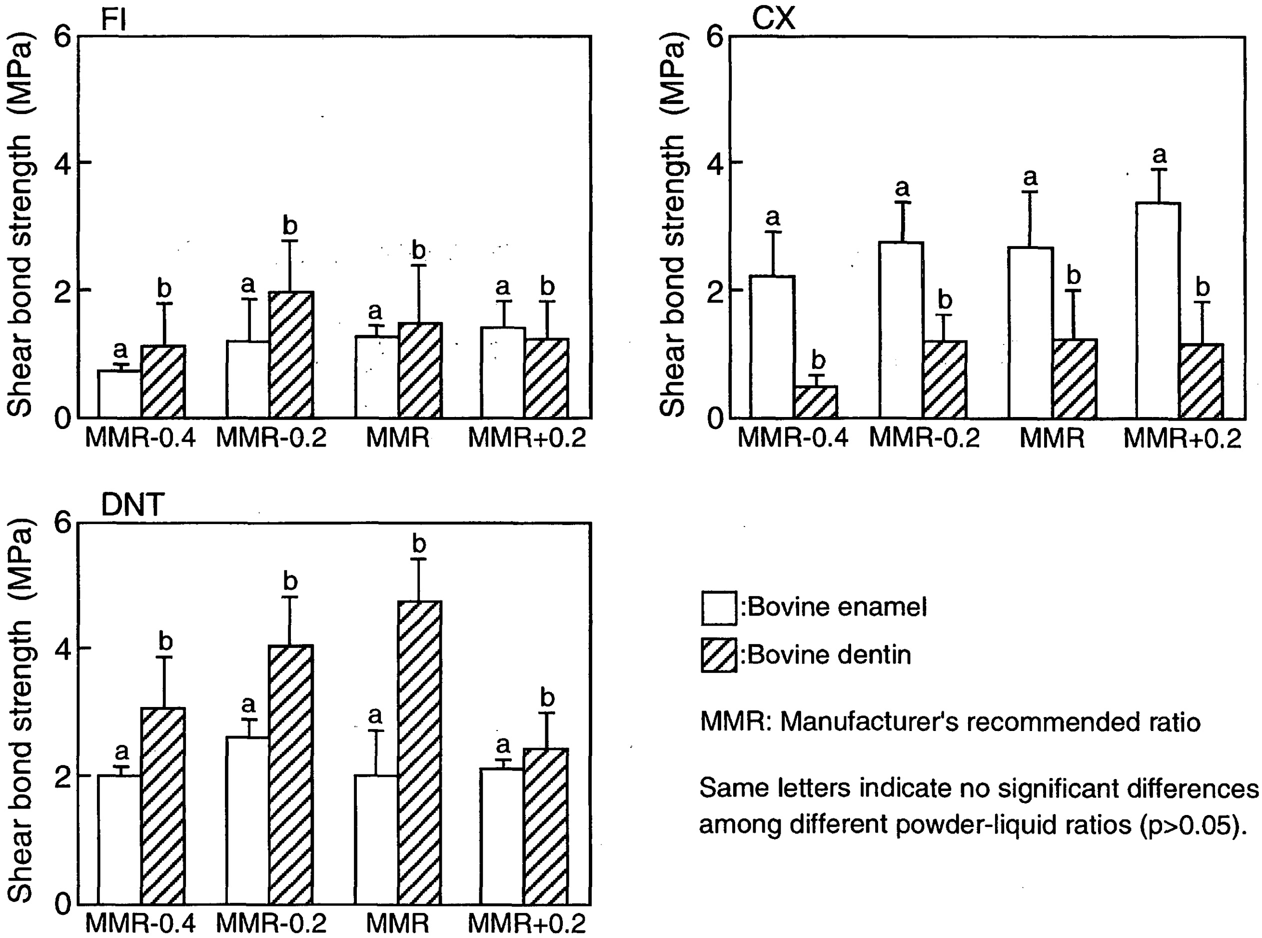

Fig. 2 Shear bond strength of each glass ionomer made with different mixing ratios to bovine enamel and dentin.

Table 2 Failure mode of each glass ionomer to bovine teeth at different P/L ratios after shear bonding test

			Failure mode (%)		
			Cohesive	Adhesive	Mixed
FI	Bovine Enamel	MRR−0.4	0	40	60
		MRR−0.2	0	60	40
		MRR	0	100	0
		MRR+0.2	0	100	0
	Bovine Dentin	MRR−0.4	0	40	60
		MRR−0.2	0	0	100
		MRR	0	0	100
		MRR+0.2	0	0	100
CX	Bovine Enamel	MRR−0.4	0	20	80
		MRR−0.2	0	20	80
		MRR	0	20	80
		MRR+0.2	0	40	60
	Bovine Dentin	MRR−0.4	0	100	0
		MRR−0.2	0	100	0
		MRR	0	100	0
		MRR+0.2	0	100	0
DNT	Bovine Enamel	MRR−0.4	0	100	0
		MRR−0.2	0	100	0
		MRR	0	100	0
		MRR+0.2	0	100	0
	Bovine Dentin	MRR−0.4	0	20	80
		MRR−0.2	0	0	100
		MRR	0	0	100
		MRR+0.2	0	20	80

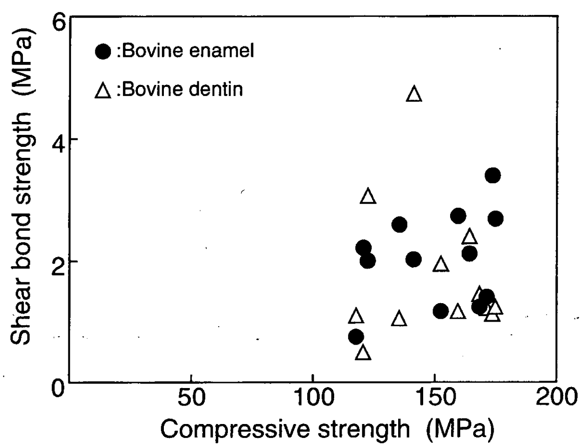

Fig. 3 Relationship between shear bond strength and compressive strength of cement.

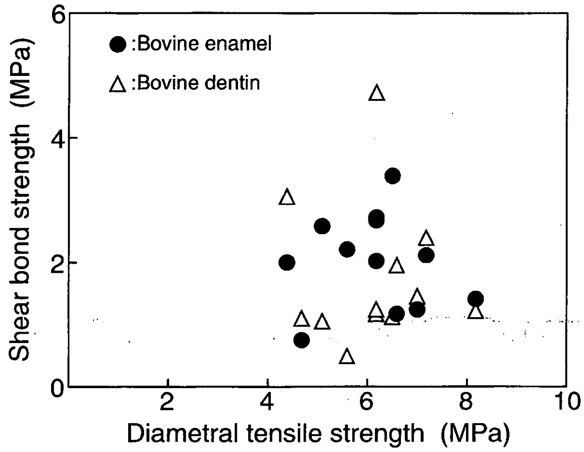

Fig. 4 Relationship between shear bond strength and diametral tensile strength of cement.

strength (Fig. 4) reported in our previous study[2] for each mixing condition. The figures also include the correlation coefficient values when the correlation was significant. The present study did not find a significant ($p>0.05$) correlation between either the diametral tensile strength or compressive strength and bond strength to tooth substrate.

DISCUSSION

The bond strength of glass ionomer cements to tooth structures is affected by several factors such as surface roughness, surface condition of the tooth structure, and age of the dentin[3-11]. Enamel consists mainly of hydroxyapatite, and dentin is composed of hydroxyapatite and organic components like collagen fibers. Therefore, the composition of tooth structure is not homogeneous. The mechanism of glass ionomer bonding to tooth structure has not yet been clearly identified. However, there seems to be little doubt that it primarily involves chelation of carboxyl groups (of the polyacids) with calcium (in the apatite of enamel and dentin)[12]. Bond strength to enamel is always higher than that to dentin because of the greater inorganic content of enamel and its morphological homogeneity[12]. The mechanism of adherence of glass ionomer cement to metal is also clear. Polar and ionic interactions, such as those between hydrogen and metal ion bridges, may contribute to the bonding between cement and metal. As the reaction proceeds, hydrogen bridges are progressively replaced by metal bridges, with the metal ions originating from the cement or substrate or both, thus providing a more rigid, permanent attachment[13].

In the present study, no significant ($p>0.05$) increases in the bond strength to bovine enamel or dentin were found in the cement specimens mixed at different P/L ratios. However, in our previous study[2], the bond strength to metal was found to be affected by the P/L ratio of cements. Specimens prepared at a lower P/L ratio had lower strength, resulting in a lower bond strength when the cement was bonded to a metal surface[2]. For FI, the bond strength values to precious metal were similar for enamel or dentin. The adhesive strengths of DNT to tooth structure were significantly greater ($p<0.05$) than those to precious alloys (2.0-4.7 MPa vs. 0.7-1.8 MPa), and were similar to non precious alloys. The shear bond strength of CX to enamel tended to be higher than to Au-Ag-Cu alloy (2.2-3.4 MPa vs. 0.8-1.5 MPa). The results obtained in the present and previous studies indicated that glass ionomer cements adhered better to enamel than to precious alloys, and the bond strength was similar to those of non precious alloys. These results might be due to the fact that precious metals have lower surface energy compared to apatite and oxidized metal surfaces[13]. The interfacial bond formed between glass ionomer and solid substrate is stronger than the cohesive bonding in polymeric materials, which results in the shear failure of glass ionomers[14]. If an adhesive bond is weak relative to the strength of the cement, an adhesive failure would likely happen at the interface between the cement and substrate[13]. Observation of the fracture mode after tensile bond test demonstrated that specimens with lower bond strength fractured adhesively at the interface between the cement and the enamel or dentin[13]. In the present study, the fracture mode of the enamel or dentin specimens with lower adhesive strength was also adhesive failure at the interface between the cement and enamel or dentin.

Although the retentive ability of glass ionomer cements to metal depended on their greater mechanical strength (as compared to zinc phosphate and polycarboxylate cements)[15], this study showed no significant ($p>0.05$) correlation between either the diametral tensile strength or compressive strength of the cement and bond strength to enamel or dentin. This finding is probably one reason why the bond strength of cements to enamel or dentin was much lower than the mechanical strength of the glass ionomer cements tested in our previous study[2]. The elastic modulus or flexural strength of a cement was related to its bond strength[16,17]. Therefore, the mechanical properties − except the inherent strength reported in our previous study[2] − of cements and the characterization of cements are necessary to be further investigated in future experiments.

In conclusion, the compressive strength or diametral tensile strength of glass ionomers does not affect the shear bond strength of cements to bovine enamel or dentin surfaces. Rather than trying to increase the strength of the cements, it would be more effective to enhance the adhesive bond strength through procedures such as surface conditioning or cleaning of the tooth structure when glass ionomer cements are used as luting agents.

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