The effect of sandblasting on the retention of orthodontic bands

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Despite the increased popularity of bonded appliances in orthodontics, the use of bands on premolars and molars is still quite common. Gottlieb et al.[1] reported that more than 85% of orthodontists routinely bond brackets from first premolar to first premolar and band the remaining posterior teeth. A common perception regarding orthodontic treatment, shared by many practitioners and patients, is that the use of fixed orthodontic appliances may result in subsequent demineralization and caries. Studies have indicated that individuals treated with fixed orthodontic appliances show a higher incidence of enamel lesions compared with untreated individuals.[2-5] Banded teeth are often regarded as more susceptible to the effects of decalcification than bonded teeth because decalcification, when it occurs on bracketed teeth, first appears around the bracket where it can be detected relatively early. Banded teeth present a different problem because decalcification occurs beneath the band[6] and often proceeds unchecked, either until the band loosens and is recemented during treatment or until the band is removed at the end of treatment. Certain unfavorable properties found in most commonly-used orthodontic cements contribute, no doubt, to the frequency of decalcification beneath bands in some patients. These unfavorable properties include high solubility in oral fluids and low bond strengths.[3,4,7]

Zinc phosphate cement was developed and introduced as a dental cement in 1878[8] and serves as a standard with which newer cements can be compared.[9] It is supplied by the manufacturer in a powder-liquid form.

Abstract

A variety of luting cements are available for use with orthodontic bands. This in vitro study was conducted to evaluate the force required to cause debanding when zinc phosphate, polycarboxylate and glass ionomer cements are used as the luting agents; and to determine whether sandblasting the inner surface of orthodontic bands affects the force required to deband. The data were obtained by debanding cemented stainless steel bands from 20 extracted third molars.

Glass ionomer cement demonstrated the highest mean force value required to deband both the nonsandblasted and sandblasted orthodontic bands. Sandblasting the inner surface of the bands proved to be a significant ($P < 0.001$) method for increasing band retention for all three cements tested. The mean force required to deband using zinc phosphate, polycarboxylate and glass ionomer cements was approximately doubled following sandblasting.

Key Words

Cement • Glass ionomer • Sandblasting

Submitted: August 1994 **Revised and accepted:** May 1995 Angle Orthod 1996;66(3):207-214.

The American Dental Association classifies cements according to their physical properties and intended use. A type I zinc phosphate cement consists of fine grain particles and is intended to cement precision-fit castings; a type II zinc phosphate cement consists of medium grain particles suitable for all other purposes (i.e., orthodontic banding).[10] The present formula for zinc phosphate cement is very similar to the one used in the 1920s,[11] although fluoride was added in the 1960s to reduce acid solubility and to impede decalcification of tooth enamel.[12] The addition of fluoride may weaken the luting properties of the zinc phosphate cement,[13] which does not chemically bond to metal or tooth surfaces. Instead, it relies on mechanical bonding for retention and close physical adaptation to seal margins.[14] Zinc phosphate cement displays high solubility in the mouth and is brittle.[15] Its low tensile strength is also a major drawback.[13] Posterior bands are susceptible to band loosening and failure because this is where the greatest tensile and shear forces from mastication occur. Once a band becomes loose, it acts as an effective plaque trap, and the banded surface of the tooth cannot be cleaned. At this point, the surface of the exposed enamel is most susceptible to the acids produced by local microorganisms.

Polycarboxylate cement is a relatively new luting agent. It was introduced in 1968 by Smith,[15] and like zinc phosphate cement, is available in a powder-liquid form. Some evidence suggests that polycarboxylate cement, unlike zinc phosphate, may chemically adhere to the tooth structure by chelating with calcium ions in the tooth enamel.[16] The polyacrylic acid molecules formed in mixing this cement also have the ability to form ionic bonds with stainless steel.[16] These two bonding properties make polycarboxylate cements useful as a luting agent for orthodontic bands. All polycarboxylate cements contain fluoride as an ingredient to provide cariostatic properties and to increase their strength. However, the tensile strength of polycarboxylate cement has been found to be lower than that of zinc phosphate.[10] Also, polycarboxylate cements are highly viscous, which makes seating of orthodontic bands more difficult. Polycarboxylate cement has a relatively high solubility in the mouth[10,17] and short setting and working times.[9]

The newest luting agent, introduced in 1971, is glass ionomer cement.[8] Glass ionomer cements are available in powder-liquid and dual- and single-paste light curable forms. Some manufacturers make the cement available in premeasured (powder-liquid) capsules for use with an amalgamator. Advantageous properties of this cement include low solubility in oral fluids, adequate shelf life, high compressive strength, and an ability to form chemical bonds with enamel, dentin, and metal.[8,10,13] The compressive strength of glass ionomer cement has been reported to be approximately 140 MPa (megapascals), somewhat higher than the 80-100 MPa for zinc phosphate.[13] The tensile strength of glass ionomer cement (7.5 MPa) is also higher than that of zinc phosphate (5.5 MPa). Glass ionomer cement has the ability to release fluoride ions from the set cement without any loss in strength.[8,18,19] The release of fluoride ions into adjacent enamel helps to prevent decalcification.[18] The viscosity of glass ionomer cement is lower than that of polycarboxylate cement[20] but similar to that of zinc phosphate cement.[21] The ability of glass ionomer molecules to form ionic bonds with stainless steel and chelate with enamel enhances its adhesive strength.[22] Consequently, several studies have reported fewer band failures when comparing the use of glass ionomer cement with zinc phosphate.[13,19,22] Glass ionomer cement also exhibits some unfavorable properties. It is relatively brittle, and it is susceptible to attack by water during the setting phase, resulting in a weaker bond.[8,10] Hence, as for all luting systems, a dry field should be maintained during the cementing and setting phases.

Current research into the surface treatment of metals to improve bonding in restorative dentistry may have some ramifications with respect to orthodontic banding procedures. Sandblasting has become the preferred surface treatment in metal bonding today.[23,24] This procedure involves spraying a stream of aluminum oxide particles under high pressure against the metal surface intended for bonding. For optimum bond strength, 80 to 100 psi of air pressure is required. Several sandblasting units are available on the market today, including the Microetcher (Danville Engineering, Danville, Calif). Aluminum oxide with a particle size of 50 micrometers has been found to be the most desirable for use in sandblasting and results in excellent bond strengths.[25-28] It has been found to roughen the surface of all metals (including stainless steel), and as a result, increase the surface area for both chemical and mechanical bonding.[24]

Sandblasting also reduces the thickness of the oxide layer, leaving a more firmly attached layer for bonding. Laboratory studies have shown that the metal bonding that occurs 1 week after sandblasting (thicker oxide layer) is 10% to 15% weaker than bonding that is done immediately (thin oxide layer) following sandblasting.[24] A thin oxide layer is needed for good wetting and bonding to the metal. Complete removal of this oxide layer, which occurs when bonding in an oxygen free environment (using an argon chamber), results in inadequate bond strengths.[29]

The purpose of the present in vitro study was to measure and compare the forces required to deband orthodontic stainless steel bands with and without sandblasting when using zinc phosphate, polycarboxylate, and glass ionomer cements.

Materials and methods

Nonsandblasted bands

Part one of this investigation involved measuring the force required to deband untreated (nonsandblasted) orthodontic bands that have been attached with three different types of orthodontic cement. The sample consisted of 30 extracted mandibular third molars with anatomy consistent with a mandibular first molar and free of any signs of demineralization. The teeth were collected from the office of a local oral surgeon and stored in a 10% formalin solution. A hole was drilled through the center of each tooth near the root furcation area and a .036 inch steel wire (5 cm long) was placed in the hole. The teeth were embedded in epoxy resin (Special Tray Forming Material, DeTrey) in plastic ice cube trays that measured 6 cm x 3.5 cm x 3 cm. The roots, with the retentive wire in place, were fully encapsulated by the resin. The exposed crowns were cleaned with a dental prophylactic paste (Zircate Prophy Paste, LD Caulk) to remove any foreign debris. Stainless steel orthodontic bands ("A" Company, San Diego, Calif) with buccal attachments and lingual buttons were fitted, seated, and adapted to each molar.[30] Each band was cemented in place with a polycarboxylate cement (Poly-F Cement, DeTrey) mixed according to the manufacturer's recommendations. Excess cement was removed from the occlusal and cervical margins of the band so that it would not influence the test results.

Using an Instron testing machine in tensile mode with a crosshead speed of 0.02 inches per minute, the force required to deband the cemented orthodontic bands was measured in kilograms and recorded in MPa (megapascals). Each mounted tooth was clamped in a holding device (Figure 1) attached to the ascending crosshead of the Instron machine. The top piece of the holding device had a large-diameter hole that allowed each tooth to protrude and sit directly below the hook attachment of the pressure transducer. This arrangement allowed all forces to be directed parallel to the long axis of the tooth during band removal. The orthodontic bands were attached to the hook by means of stainless steel slings constructed of 0.012 inch utility wire. The sling was 8 cm long and was looped over the tooth, attached to the lingual button on one side of the band and to the buccal attachment on the other.

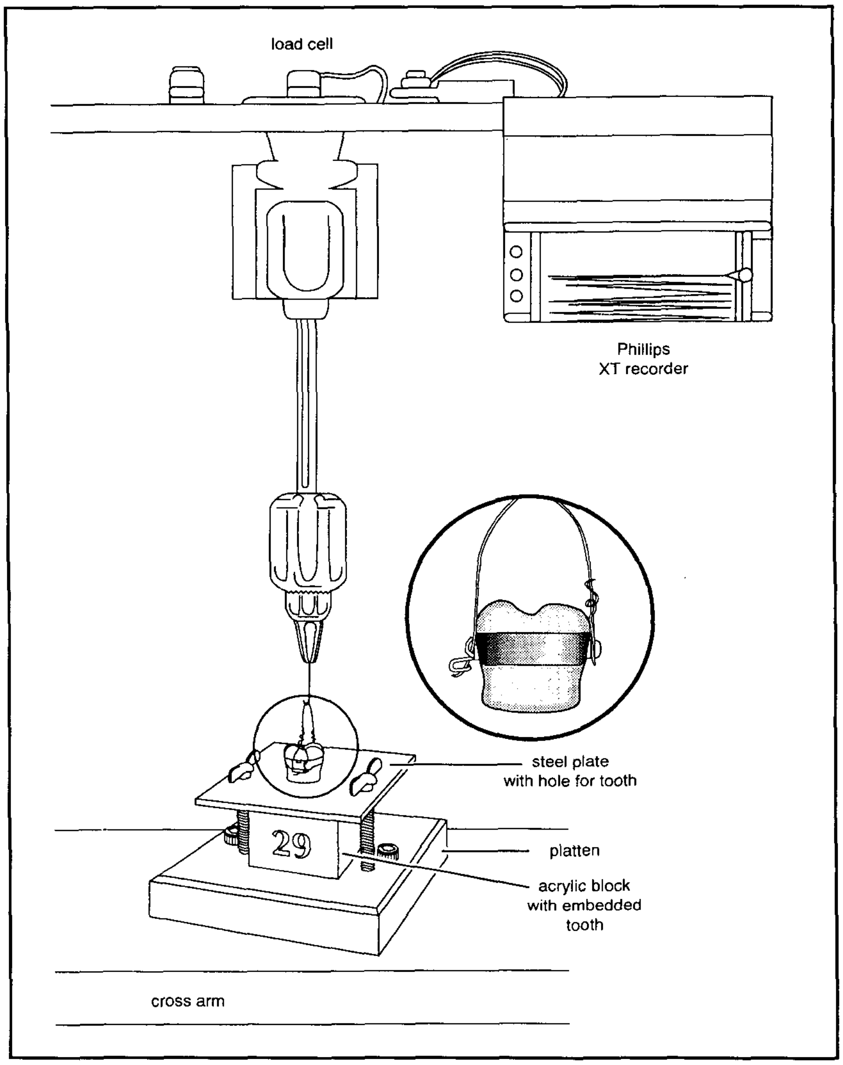

Figure 1

Figure 1 Apparatus used to measure force required to deband

The debanded molar teeth were cleaned using a Schure scaler and pumice to remove any remaining cement. The orthodontic bands were placed in an ultrasonic cleaning tank for 20 minutes to facilitate the removal of residual cement from the inside of the band.

The above procedures were repeated, using the same bands and the same teeth, with zinc phosphate (Zinc Phosphate with fluoride, Ormco, Glendora, Calif) and glass ionomer (Band Lok, Reliance Orthodontic Products, Itasca, Ill) cements.

Table 1
Comparison of cements on nonsandblasted (N) bands. Differences were compared using two-tailed t-test (n=20).

Cement	Mean force (MPa) required to deband	S.D.	Significance
Glass ionomer (N)	1.23	0.31	
Zinc phosphate (N)	1.01	0.54	N.S.
Glass ionomer (N)	1.23	0.31	
Polycarboxylate (N)	0.98	0.41	P < .01
Zinc phosphate (N)	1.01	0.54	
Polycarboxylate (N)	0.98	0.41	N.S.

Table 2
Comparison of cements using nonsandblasted (N) and sandblasted (S) bands. Significance of differences tested using the two-tailed t-test (n=20)

Cement	Mean force (MPa) required to deband	S.D.	Significance
Polycarboxylate (N)	0.98	0.41	
Polycarboxylate (S)	2.34	0.58	P < .001
Zinc phosphate (N)	1.01	0.54	
Zinc phosphate (S)	1.94	0.70	P < .001
Glass ionomer (N)	1.23	0.31	
Glass ionomer (S)	2.43	0.53	P < .001

Table 3
Comparison of cements on sandblasted (S) bands. Significance of differences tested using the two-tailed t-test (n = 20).

Cement	Mean force (MPa) required to deband	S.D.	Significance
Glass ionomer (S)	2.43	0.53	
Polycarboxylate (S)	2.34	0.58	N.S.
Glass ionomer (S)	2.43	0.53	
Zinc phosphate (S)	1.94	0.70	p < .01
Polycarboxylate (S)	2.34	0.58	
Zinc phosphate (S)	1.94	0.70	p < .01

Force required to deband sandblasted bands

The second part of this study involved measuring the force required to deband when the inside (luting) surface of the orthodontic band has been sandblasted. The bands and the teeth that served as the sample for the first part of this study were used again.

The experimental design was identical to that described above with one exception: The inside (luting) surface of each band was treated with aluminum oxide (50 μm) particles directed from the sandblaster under 80 psi of air pressure. Sandblasting was considered complete when the entire luting surface of the band took on a uniform frosty white appearance. Typically, this required approximately 15 to 20 seconds of sandblasting. All bands were sandblasted 24 hours prior to the cementation procedures.

Ten of the teeth embedded in the epoxy resin suffered crown or root fracture during testing. The final sample contained 20 teeth that could be tested completely.

Scanning electron microscopy

One nonsandblasted stainless steel orthodontic band and one sandblasted band were photographed using a scanning electron microscope (SEM) directed at the luting surface of the band. The photographs were taken at 25 KV at a magnification of 1000X.

Calculation of force required to deband

The luting surface of each stainless steel orthodontic band was measured. The band was cut with scissors, then laid out flat. Its length and width were measured to the nearest tenth of a millimeter using a Boley gauge. The force required to deband, as measured on the Instron machine, was recorded in kilograms on a Phillips XT recorder. The luting surface area and the debanding force were then used to calculate values of kilograms per square centimeter for each tooth. Multiplying by a conversion factor of 0.0981 gave the force required to deband expressed in megapascals (MPa).

Statistical analysis

The differences between the various mean values were tested for statistical significance using two-tailed paired t-tests, with P 0.05 the test criterion.

Results

The mean forces required to deband the nonsandblasted bands are shown in Table 1. Comparable forces were required to remove the bands luted with zinc phosphate (1.01 MPa) and bands luted with polycarboxylate (0.98 MPa); approximately 20% more force was required to remove bands luted with glass ionomer (1.23 MPa). The comparatively larger variability for the zinc phosphate values (SD = 0.54) contributed to the lack of statistical significance associated with the difference between zinc phosphate and glass ionomer.

The effect of sandblasting is shown in Table 2. With sandblasting, the mean force required to deband was approximately doubled for glass ionomer (2.43 MPa) and zinc phosphate (1.94 MPa) and more than doubled for polycarboxylate (2.34 MPa).

Table 3 shows that, when used on sandblasted bands, polycarboxylate behaved more like glass ionomer cement and required greater force to deband ($P < 0.01$).

Figures 2 and 3 are photographs obtained using a scanning electron microscope (SEM). Figure 3 shows an increase in surface roughness created by sandblasting.

Discussion

A comparison of the mean force required to deband nonsandblasted orthodontic bands showed glass ionomer cement to be stronger than both polycarboxylate and zinc phosphate cements. Both polycarboxylate and glass ionomer cement have the ability to bond chemically with stainless steel and enamel; zinc phosphate does not bond chemically with either.[10] One would therefore assume that bands cemented with zinc phosphate would be easier to remove.

On the other hand, it is important to remember that the overall mean force required to deband reflects not only chemical bonding but mechanical bond capability as well. The mechanical bond capability of each cement can be related to its tensile strength. In this regard, previous research has shown that glass ionomer cement has the highest tensile strength, followed by polycarboxylate and zinc phosphate cements.[31] The mean force value to deband was highest for glass ionomer, with zinc phosphate not significantly different from polycarboxylate (Table 1). It would appear that the mechanical bonding capability of the cements used is the primary determinant when using bands that have not been sandblasted.

The mean force values to deband using sandblasted bands were very different. In fact, the mean force to deband approximately doubled for each cement after the bands had been sandblasted. Specifically, the mean force to deband for zinc phosphate cement increased by 0.93 MPa, while the forces for glass ionomer and polycarboxylate cement increased by 1.2 MPa and 1.36 MPa, respectively. Both glass ionomer and polycarboxylate cements were found to be significantly stronger than zinc phosphate cement at the $P < 0.01$ level.

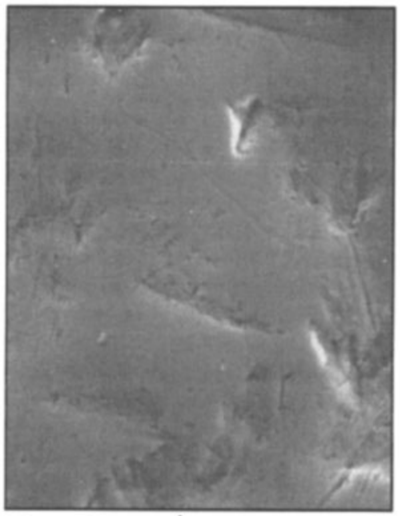

Figure 2

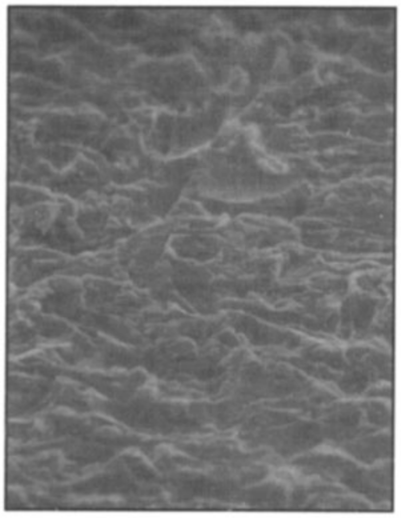

Figure 3

Figure 2
SEM photograph of the inner surface of a nonsandblasted orthodontic band shows a relatively smooth surface (magnification 1000X).

Figure 3
SEM photograph of the inner surface of a sandblasted orthodontic band shows evidence of increased surface roughness (magnification 1000X).

The sandblasting process enhances the retentive nature of the band by increasing the surface area and thinning the oxide layer of the stainless steel band. Since zinc phosphate cement does not bond chemically with either enamel or stainless steel, any increase in the force to deband it must be attributed to an increase in mechanical bonding alone. In contrast, both glass ionomer and polycarboxylate cement are capable of both chemical and mechanical bonding with enamel and stainless steel.[10] Although all three cements displayed significant increases in the force values required to deband, the larger increases observed for glass ionomer and polycarboxylate cements can be attributed to both the enhanced chemical and mechanical bond potentials provided by the sandblasting. One might note also that despite sandblasting, the force to remove glass ionomer luted bands was much less than the strength of a resin-to-enamel bond, which is on the order of 25 Mpa.[32]

The mean force values required to deband using glass ionomer and polycarboxylate cements were significantly different when using nonsandblasted bands ($P < 0.01$), yet they were not significantly different when using sandblasted bands (see Table 3). In contrast, the mean force values required to deband using zinc phosphate and polycarboxylate cements were not significantly different on nonsandblasted bands, but did differ significantly ($P < 0.01$) when tested on sandblasted bands (Table 3). Therefore, it would seem probable that the sandblasting process enhances the chemical bonding capability of glass ionomer and polycarboxylate cements, although, as with the nonsandblasted bands, mechanical bonding capability is the primary determinant for the increased adhesion of sandblasted bands.

Sandblasting roughens the surface of the metal, which increases the area available for bonding. The thickness of the oxide layer is also reduced, leaving a more firmly attached layer for bonding.[24]

The SEM photograph shown in Figure 2 illustrates the relatively smooth luting surface of a nonsandblasted orthodontic band. In comparison, Figure 3 reveals the corrugated surface of a sandblasted band. The increase in surface area would seem to enhance the probability of mechanical and chemical bonding taking place with the various cements used.

Whereas sandblasting approximately doubled the force required for debanding, a threefold increase in composite resin-to-metal adhesion following treatment by sandblasting has been reported in other studies.[33-35] There are several reasons a threefold increase did not occur in the present study. The most obvious reason is that the tensile strength of composite resin is much higher than that of the cements used here. Second, the sample of extracted molars was composed of third molar teeth to which first molar orthodontic bands were adapted. Although the bands could be reasonably well adapted to the third molars, a sample of extracted first molar teeth would have provided better conditions for band fitting. Also, most of the crowns were conical in shape which made a perfect fit of the bands difficult to achieve. Consequently the twofold increase in the force required to deband obtained in this study using sandblasted orthodontic bands was deemed reasonable.

It is interesting to compare this study with one conducted by Durning et al.[36] They also found that there was no significant difference in band retention between zinc phosphate and glass ionomer cement when using nonsandblasted bands. However, in the Durning study, when mechanical stress was applied to the banded teeth, glass ionomer cement proved to be significantly superior to zinc phosphate in retaining orthodontic bands. These data would support glass ionomer as the cement of choice for orthodontic bands. Because the strength of a resin-to-enamel bond is approximately 25 MPa,[32] the possibility that glass ionomer is too strong is not a concern.

The use of the same 20 teeth throughout the course of the study for each of the three cements being studied was an attempt to minimize the variability that would have existed using different teeth for each cement. Extracted human teeth with intact enamel surfaces were necessary so that any chemical bonding between enamel and the cements being tested could occur. For this reason, synthetic teeth of identical shape and size could not be used, nor could heavily restored teeth.

Since the same bands were filled and adapted six times over the course of the study, some degree of deformation occurred. The order of testing for both nonsandblasted and sandblasted bands was polycarboxylate followed by zinc phosphate and then glass ionomer cement because it was expected that glass ionomer would yield the highest force required to deband. There was a trend for glass ionomer cement to show the highest force required to deband for both nonsandblasted and sandblasted bands, despite being tested under the most compromised conditions of all three cements. It may be that glass ionomer cement would have yielded even higher values than recorded if the sandblasted bands had not been deformed.

Several studies, both in vitro and in vivo, have shown significantly more band failure for zinc phosphate cement than for glass ionomer cement.[13,19,22] There is then, no reason to believe that the findings of this in vitro study are not applicable to the clinical situation.

Glass ionomer cement has also exhibited fewer enamel lesions when compared to zinc phosphate cement during the course of orthodontic therapy.[13] It is less soluble in the oral fluids than zinc phosphate and polycarboxylate cements[10] and has higher tensile strengths than the other two cements, which makes it less susceptible to failure from the forces of mastication. Finally, glass ionomer cement can bond with enamel, dentin, and metal. For these reasons, glass ionomer cement is the orthodontic cement of choice. And in order to further maximize the bonding capability of any orthodontic cement, sandblasting the inner surface of the band is recommended.

Conclusions

1. Glass ionomer cement required the highest force to deband in comparison with polycarboxylate cement on nonsandblasted bands and zinc phosphate cement on sandblasted bands.
2. Sandblasting the inner (luting) surface of a stainless steel orthodontic band approximately doubles the retention strength of all three cements.

Acknowledgments

The authors wish to acknowledge The Canadian Fund for the Advancement of Orthodontics for their generous support of this research as well as J.M. Wanklin, R.J. McConnell, and W.S. Hunter for significant assistance in the revision of the manuscript.

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