The Effect of Sandblasting on the Retention of Orthodontic Bands: An in vitro Study

Vishal A Nalawade, Vinaya Sandesh Pai, Siry Krishna, Abraham Thomas, M Swetha, Goutham Kalladka

ABSTRACT

Aim and objectives: The purpose of this in vitro study was to explore the possibilities of increasing bond strength with use of efficient cements and by sandblasting the inner surface of the bands.

Materials and methods: Thirty sound human mandibular third molars were used for this investigation. Preformed stainless steel orthodontic bands were selected and buccal tubes and lingual buttons were welded to each band. The bands were first cemented with polycarboxylate cement. The bond strength was tested using universal testing machine. The above procedures were repeated, using the same bands and the same teeth, with zinc phosphate cement and glass ionomer type 1 cement (GIC). The bands were treated with aluminum oxide (50 μm) particles directed under 60 psi of air pressure. Then debanding force recording procedure was repeated for all three cements. The results were tested for statistical significance using two-tailed paired t-tests, with p < 0.01 and p < 0.001 as the test criterion.

Results: Comparable forces were required to remove the bands luted with zinc phosphate and polycarboxylate; approximately 20% more for GIC. With sandblasting the mean force required to deband was approximately doubled for GIC and zinc phosphate and more than doubled for polycarboxylate.

Interpretation and conclusion: GIC requires the highest force to deband when compared with polycarboxylate and zinc phosphate cements when used on nonsandblasted bands. In-office sandblasting appears to be an efficient method to increase the retention of orthodontic bands.

Keywords: Glass ionomer cement, Zinc phosphate cement, Polycarboxylate cement, Preformed bands, In-office sandblasting, Scanning electron microscope.


INTRODUCTION

Orthodontic bands have been in clinical use for more than 100 years. In spite of the widespread use of direct bonded brackets and tubes in clinical orthodontics, the conventional band still plays an important role in fixed appliance therapy.

Although bonding of orthodontic tubes to the teeth is receiving much current interest in the form of direct or indirect bonding, the vast majority of buccal attachments are still being cemented using stainless steel bands and conventional cements, considering the force levels in the posterior region.1

The retention of orthodontic bands to the tooth surface is important to ensure good fixed appliance therapy. The technique of air abrasion or sandblasting was introduced in 1950’s. It uses a high-speed stream of aluminium oxide particles propelled by compressed air.2

Purpose of this study was to compare the debanding force of orthodontic molar bands cemented using three different luting cements and to test the effectiveness of in-office sandblasting procedure on the retention of orthodontic bands.

MATERIALS AND METHODS

Specimen Preparation

On series of procedures a mold for mounting the teeth was fabricated with the help of a carving wax block, dental stone and elastomeric impression material.

Mounting of Specimen

Thirty extracted human mandibular third molars, which were extracted because of severe periodontal disease, were collected from Department of Oral and Maxillofacial Surgery, BIDS, Bengaluru. The teeth were stored in 10% formalin solution. The buccal surfaces of the teeth were kept parallel to the analyzing rod of the Ney’s surveyor and were mounted. Roots with the retentive grooves were fully encapsulated by the resin.

Band Selection and Numbering

Preformed stainless steel orthodontic bands (Ortho Org) were selected for each specimen and checked for size and fit on...
each molar. The buccal tubes and lingual buttons were welded approximately at the middle of the crown height with the spot welder at 4 Ampere. The acrylic blocks and the teeth mounted in them were numbered from 1 to 30, with carbide bur and diamond bur respectively.

Part one and part two of the study, i.e. recording debanding force, were conducted at the RV-TIFAC Composites Design Centre, Composites Technology Park, Kengeri, Bengaluru. Part three of the study, i.e. scanning electron microscope (SEM) photographs, was conducted in Indian Institute of Sciences, Bengaluru.

Part One

Nonsandblasted bands: Polycarboxylate cement (Poly-F, Dentsply, Germany) was manipulated on the mixing pad as per the manufacturers’ recommendations. After mixing the cement, it was loaded onto the orthodontic bands. Each band was seated on the selected teeth with hand pressure and then with the band seater. The excess cement was removed from the occlusal and cervical margins of the bands with dry cotton roll. After waiting for 10 minutes, the specimens were stored in artificial saliva (wet mouth) at 37°C and 100% humidity for 24 hours in an incubator.

The mounted teeth were clamped to the holding device, allowing each molar crown to protrude and sit directly below the attachment apparatus of the universal testing machine (Lloyd LR50K, UK) with the crosshead speed of 0.5 mm (0.02") per minute. The orthodontic bands were attached with 0.4 mm (26 gauge) SS wire sling, the loop of which engaged the buccal tube and the lingual button of each band (Fig. 1). The maximum force recorded during debanding was chosen from the stress-strain curve for each specimen and was measured in Newton.

After debanding, the bands were placed into the respective pouches. The debanded teeth were cleaned with Ultrasonic Scaler (Woodpecker). The bands were cleaned in an ultrasonic tank for 20 minutes to remove any residual cement. The above procedures were repeated, using the same bands and the same teeth, with zinc phosphate cement (Harvard Cement, Germany) and GIC type 1 (GC, Japan).

Part Two

Sandblasted bands: The second part of study involved measuring the force required to deband when the inside (luting) surface of the orthodontic band has been sandblasted. For sandblasting, the luting surface of each band was treated with aluminum oxide powder (50 microns) directed from the sandblaster (MicroEtcher ERC, Danville; Fig. 2) under 80 psi of air pressure for 15 to 20 seconds, 24 hours prior to the cementation procedure. The procedure of cementation of bands with all the three types of cement and debanding was repeated in an identical manner as in the first part of the study.

The luting surface of each stainless steel orthodontic band was calculated by cutting the band with scissors and then measuring its length and width to the nearest tenth of a millimeter using a Vernier Caliper (Peacock, Ozaki Mfg Co Ltd, Japan). The force required to deband was measured on the Instron machine in Newton and converted to kilograms. The 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, force required to deband in Megapascal (MPa) was recorded (Tables 1 to 3).

\[
1 \text{ Newton} = 0.10197 \text{ kg}
\]

\[
\text{Force require for debonding (MPa)} = \frac{\text{Debonding force in kilograms}}{\text{Surface area of band in cm}^2} \times 0.0981
\]

Part Three

Scanning electron microscopy: One nonsandblasted stainless steel orthodontic band and one sandblasted band were selected randomly and sent for SEM. Luting surfaces of these bands were electrocoated with gold by using Fine Coat (JFC1100E,
Ion Sputtering Device) and then photographed under SEM (FEI, Quanta 200) at 20 kV at a magnification of 1,000×.

Statistical analysis: The differences between the various mean values were tested for statistical significance using two-tailed paired t-tests, with \( p < 0.01 \) and \( p < 0.001 \) as the test criterion.

RESULTS

The debanding force values were recorded in Newton and converted into MPa for statistical analysis.

In Table 1 comparison of debanding forces with different cements on nonsandblasted (N) bands is mentioned. The comparison was done between GIC and zinc phosphate, GIC and polycarboxylate and zinc phosphate and polycarboxylate. Comparable forces were required to remove the bands luted with zinc phosphate (0.9907 MPa) bands luted with polycarboxylate (1.0103 MPa); approximately 20% more force was required to remove bands luted with GIC (1.2177 MPa).

The comparison between debanding forces by using GIC with zinc phosphate as well as with polycarboxylate have shown statistical significance where \( p < 0.01 \). The results also denote that comparison of debanding forces by using zinc phosphate and polycarboxylate has no statistical significance where \( p > 0.01 \) (Table 1).

Table 2 shows that, when used on sandblasted bands, polycarboxylate behaved more like GIC and required greater force to deband. So the statistical comparison does not show significance \( (p > 0.01) \). On the other hand, statistical comparison between glass ionomer and polycarboxylate with zinc phosphate when used on sandblasted bands show the significance \( (p < 0.01) \).

A comparison of the effect of sandblasting is shown in Table 3. With sandblasting the mean force required to deband was approximately doubled for glass ionomer (2.4267 MPa) and zinc phosphate (1.9563 MPa) and more than doubled for polycarboxylate (2.3460 MPa). So the comparisons between nonsandblasted and sandblasted bands are statistically significant \( (p < 0.001) \).

Scanning Electron Microscopy

Figures 3A and B are the SEM photographs at 20 kV at a magnification of 1,000×. The photographs obtained show an increase in surface roughness created by sandblasting.

DISCUSSION

Integrity of an orthodontic appliance is essential for the continuity of treatment mechanics. Although direct bonding of fixed orthodontic appliance attachment is a routine practice for anterior teeth, molars are often banded because the failure rates tend to be lower than that of bonded attachments. Several methods have been described to improve the mechanical retentive surface of bands including sandblasting with 50 or 90 micron aluminum oxide powder, use of tungsten carbide bur, green stone, etc. Improved retention is mainly due to increase of surface area contact of the bands with the tooth surface as compared to the bonded attachment surface area.\(^5,6\)

The first molars still show highest incidence of band failure.\(^7\) One reason is the convergence of the three strongest muscles of mastication—masseter, temporalis and internal pterygoid in the area of first molar and second bicuspid. Mandibular molars have a greater tendency to have loose bands; hence, they were chosen for this study.

According to Matasa\(^8\) the strongest bonding is achieved when the bond is ‘cohesive’, that is, the adhesive remains after debonding in almost equal proportion on both the substrates. A comparison of the mean force required to deband nonsandblasted orthodontic bands showed GIC to be stronger than both polycarboxylate and zinc phosphate cements.\(^9\) Both polycarboxylate and GIC have the ability to bond chemically with stainless steel and enamel; zinc phosphate does not bond chemically with either.

Previous research has shown that GIC has the highest tensile strength, followed by polycarboxylate and zinc phosphate cements.\(^10\) In the present study the mean force value to deband was highest for glass ionomer, with zinc phosphate

The Effect of Sandblasting on the Retention of Orthodontic Bands: An in vitro Study

<table>
<thead>
<tr>
<th>Cement</th>
<th>Mean force (MPa)</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass ionomer (N)</td>
<td>1.2177</td>
<td>0.0275</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Zinc phosphate (N)</td>
<td>0.9907</td>
<td>0.0325</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Glass ionomer (S)</td>
<td>1.2177</td>
<td>0.0275</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Polycarboxylate (N)</td>
<td>1.0103</td>
<td>0.0308</td>
<td>NS</td>
</tr>
<tr>
<td>Zinc phosphate (N)</td>
<td>0.9907</td>
<td>0.0325</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Polycarboxylate (N)</td>
<td>1.0103</td>
<td>0.0308</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table 2: Comparison of cements on sandblasted (S) bands. Differences were compared using two-tailed t-test (n = 30)

<table>
<thead>
<tr>
<th>Cement</th>
<th>Mean force (MPa)</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass ionomer (S)</td>
<td>2.4267</td>
<td>0.0439</td>
<td>NS</td>
</tr>
<tr>
<td>Polycarboxylate (S)</td>
<td>2.3460</td>
<td>0.0559</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Glass ionomer (S)</td>
<td>2.4267</td>
<td>0.0439</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Zinc phosphate (S)</td>
<td>1.9563</td>
<td>0.0604</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Polycarboxylate (S)</td>
<td>2.3460</td>
<td>0.0559</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Zinc phosphate (S)</td>
<td>1.9563</td>
<td>0.0604</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table 3: Comparison of cements on nonsandblasted (N) and sandblasted (S) bands. Significance of differences were tested using two-tailed paired t-test (n = 30)
not significantly different from polycarboxylate. 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 0.96 MPa, while the forces for glass ionomer and polycarboxylate cement increased by 1.2 and 1.33 MPa respectively. Both GIC and polycarboxylate cements were found to be significantly stronger than zinc phosphate cement at the p < 0.01 level.

The sandblasting process enhances the retentive nature of the band by altering the surface nature of the band 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 mechanical bonding alone can increase the mean debanding force. In contrast, both GIC and polycarboxylate cement are capable of both chemical and mechanical bonding with enamel and stainless steel. Although all three cements displayed significant increase in the force values required for debanding, the larger increase observed for GIC and polycarboxylate cements can be attributed to both the enhanced chemical and mechanical bond potentials provided by the sandblasting.

The mean force values required to deband using GIC and polycarboxylate cements were significantly different when using nonsandblasted bands (p < 0.01), yet they were not significantly different when using sandblasted bands. 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. Therefore, it would seem probable that the sandblasting process enhances the chemical bonding capability of GIC and polycarboxylate cements, although, as with the nonsandblasted bands, mechanical bonding capability is the primary determinant for the increased adhesion of sandblasted bands.

The mean force values required to deband using GIC and polycarboxylate cements were significantly different when using nonsandblasted bands (p < 0.01), yet they were not significantly different when using sandblasted bands. 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. Therefore, it would seem probable that the sandblasting process enhances the chemical bonding capability of GIC and polycarboxylate cements, although, as with the nonsandblasted bands, mechanical bonding capability is the primary determinant for the increased adhesion of sandblasted bands.

The SEM study illustrates the relatively smooth luting surface of a nonsandblasted orthodontic band, in comparison, to 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.

Millett et al evaluated the effect of sandblasting in both laboratory and clinical trials. The authors found 27% increase in bond strength whereas in the present study we recorded two-fold increase in bond strength. This study was in vivo; so the factors like masticatory muscle forces and occlusal forces may be responsible for the lower bond strength as compared to our in vitro study.

Wood et al have conducted study similar to the present study. Similar to our study GIC demonstrated the highest mean force value required to deband both the nonsandblasted and sandblasted orthodontic bands. The mean force required to deband was approximately doubled following sandblasting as it is observed in our study.

Whereas in the present study sandblasting approximately doubled the force required for debanding, a three-fold increase in composite resin-to-metal adhesion following treatment by sandblasting has been reported in study by Zachrisson et al. The most obvious reason is that the tensile strength of composite resin is much higher than that of the cements used here. Also, most of the crowns were conical in shape which made a perfect fit of the bands difficult to achieve. Consequently the two-fold increase in the force required to deband obtained in this study using sandblasted orthodontic bands was deemed reasonable.

The use of the same 30 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.

Since, the same bands were fitted and adapted six times over the course of the study, some degree of deformation occurred. The sequence for testing for both nonsandblasted and sandblasted bands was polycarboxylate followed by zinc.
phosphate and then GIC because it was expected that GIC would yield the highest force required to deband. There was a trend for GIC 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 GIC would have yielded even higher values than recorded if the sandblasted bands had not been deformed.

GIC has also exhibited fewer enamel lesions when compared to zinc phosphate cement during the course of orthodontic therapy.\textsuperscript{17,18} It is less soluble in the oral fluids\textsuperscript{19} than zinc phosphate and polycarboxylate cements and has higher tensile strengths than the other two cements, which makes it less susceptible to failure under the forces of mastication. Finally, GIC can bond with enamel, dentin and metal. For these reasons, GIC is the orthodontic cement of choice,\textsuperscript{20} and in order to further maximize the bonding capability of any orthodontic cement, sandblasting the inner surface of the band is recommended.

CONCLUSION

- GIC requires the highest force to deband when compared with polycarboxylate and zinc phosphate cements when used on nonsandblasted bands.
- Sandblasting the luting surface of the stainless steel orthodontic band approximately doubles the retention strength of zinc phosphate and GIC and more than doubles the strength of polycarboxylate cement.
- There could be a further increase in bond strength if the teeth surfaces were also etched.

REFERENCES