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Original Research

Evaluation of orthodontic shear peel-band strength, adhesive remnants, site of bond failure and solubility of three commonly used cements when applied to pre-fabricated and customized bands: An *in-vitro* study

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ABSTRACT:
Aim: Compare mean retentive strength, site of band failure, adhesive remnants & solubility of three dental cements used for orthodontic banding. **Materials and methods:** Dual cure, GIC and zinc phosphate cement were tested. Ninety human premolar teeth were divided into two subgroups having 15 teeth each. Subgroup 1 was banded manually using stainless steel band material, subgroup 2 was banded with preformed bands. Buttons were welded to the buccal and lingual sides of the band for testing with universal testing machine to measure retentive strength. On band failure, visual assessment was made for amount of cement remaining on the tooth surface. Luting cements were evaluated for solubility at three different time intervals (1,3,7 days). **Results:** Dual cure cement had highest, zinc phosphate had lowest mean retentive strength. GIC bands failed at enamel-cement interface as compared to other groups. Dual cure cement shows less adhesive remnants on the tooth surface compared to other groups. Zinc phosphate showed highest solubility amongst the three groups at all three testing times. **Conclusion:** Dual cure cement showed highest retentive strength, least amount of cement remnants after debanding and least solubility followed by GIC and Zinc Phosphate cement respectively.
Keywords: Shear-peel band strength, site of band failure, adhesive remnants, solubility.

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INTRODUCTION:

Despite the introduction of acid etching of enamel by Buonocore[1], stainless steel bands are routinely used in orthodontic treatment for placing attachments on molar teeth in fixed appliance therapy. They are held in place by a combination of mechanical retention, as a result of the close fit of the band to the tooth, and any chemical adhesion provided by the band cement[2]. Use of dental cement for attachment of orthodontic bands to teeth was first described in the latter part of the 19th century[3-4]. Much of preventive, interceptive & corrective orthodontic treatment relies on the appliance retained by bands[5]. Ideally each band should remain cemented in place for the duration of fixed mechanotherapy, which may be as long as 24 – 30 months[6-8]. Failure of the band during the course of treatment gives rise to number of potential problems, including

- Local soft tissue discomfort if the band is displaced subgingivally
- Additional attendance for recementation leading to both patient & operator inconvenience
- Increased length of active treatment
- Decalcification or caries if the cement failure goes unnoticed for an extended period

Other than factors relating to human error, clinical success of molar bands is greatly dependent on the two properties of the cementing material: Solubility

& Tensile strength. Solubility is the susceptibility of a material to dissolution and it measures the resistance of a material to disintegration. An increase in solubility may cause degradation of the cement when it is exposed to saliva or other fluids in the oral environment. Increased solubility is followed closely by degradation which is a process of absorption and disintegration. The tensile strength of banding cements is measured as Shear peel band strength (SPBS), which is the amount of shear force the band and cement can resist before being dislodged[9]. Solubility can have a direct effect on the SPBS as has been studied previously[10-11].

Failure of a band may occur either at the band-cement or cement-enamel interface. When a band fails at the band-cement interface it signifies that there is no chemical bonding between the band material and the cement and the band was in place just because of mechanical retention. Similarly when a band fails at the cement-enamel surface this signifies that there was a chemical bond between the tooth enamel and the cement and failure has occurred at this interface. Failure of band at cement – enamel interface is a highly desirable property in prevention of enamel decalcification. This aspect of orthodontic banding has not been put under the lens in literature and the present study aims to shine some light on the same.

Another important factor, which remains to be studied in depth in orthodontic literature, is the difference in the mechanical properties of band cementation when using pre-fabricated bands v/s bands made manually. Nowadays, pre-fabricated bands are being used more frequently in clinical practice because of convenience to the operator as well as patient and reduction in chairside time.

This study aims to compare the differences when pre-fabricated or customized bands are cemented using 3 different cementing media in terms of shear-peel band strengths (SPBS), site of band failure, adhesive remnants and solubility of the cements.

MATERIALS AND METHODS:

Sample:

Ninety extracted human premolar teeth were mounted on cold cure acrylic blocks using rectangular moulds. The sample was divided into 3 groups;

Group I: Teeth were cemented with dual cure cement (Rely X ^{TM} ARC, 3M, ESPE)

Group II: Teeth were cemented with GIC (Fuji I, G.C. Dental Corp.)

Group III: Teeth were cemented with a zinc phosphate cement (Harvard, Ritcher and Hoffman Corp.)

Each of the three groups were subdivided into two subgroups having 15 teeth each. Subgroup 1- Fifteen premolars were banded manually using stainless steel band material (0.005” × 0.180”). Subgroup 2- Fifteen premolars were banded with pre-fabricated bands.

Testing medium for solubility

Artificial salivary medium was prepared with pH 6.75 The components of the artificial salivary medium used for this study were as follows:

NaCl	0.400g
KCl	0.400g
$CaCl_2H_2O$	0.795g
NaH_2PO_4	0.69g
$Na_2S\ 9H_2O$	0.005g
Urea	1.0g
Distilled water	1000ml

Assessment of band retentive strength

In preparation for assessment of band retentive strength, 90 premolars were notched in the apical third using a diamond bur and then mounted to below the amelocemental junction in the center of a block of self-curing acrylic, with the long axis of each tooth vertical. The teeth were cleaned with a pumice slurry, washed in distilled water and dried in a stream of compressed air. Stainless steel buttons were welded to each of the bands on the buccal as well as the lingual so that the bands could be pulled out by the universal testing machine.

Each banded specimen was loaded into the jig (Figure 1) by means of a 0.9-mm stainless steel loop that engaged fully under the button both on buccal as well as lingual side of each band. The maximum force recorded during debanding was chosen from the stress – strain curve for each specimen as the maximum force required for debanding.

(Figure 1)

Site of band failure:
After each cement band failed, the predominant site of failure was assessed visually by one assessor to be at the enamel-cement or cement-band interface.

Assessing the cement remnants:
A visual assessment was made for the amount of cement remaining on the tooth surface by one operator and coded with a modification of the Adhesive Remnant Index (ARI) of Årtun and Bergland[12]. This was coded as follows-

0- No cement remains on the tooth surface
1- Less than half of the crown surface under the band is covered by cement
2- More than half the crown surface under the band is covered by cement
3- Full crown under the band is covered by cement

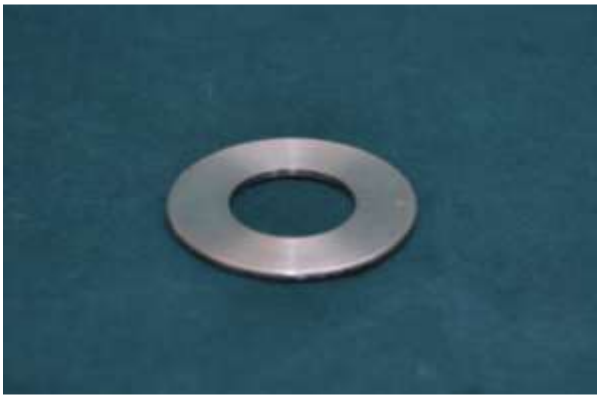
This scoring was done looking at the crown of tooth specimen after debanding. This was repeated for every specimen of every group and scores were given.

To check the solubility of luting cements

Luting cements were evaluated for solubility at three different time intervals

1. After 1 day
2. After 3 days
3. After 7 days

Fabrication of stainless steel moulds
Standardized moulds for fabrication of the luting cement samples were made from stainless steel using precise milling devices. Moulds with dimension of 20 mm internal diameter and 1.5mm height were precisely milled from stainless steel (Figure 2). Diameter and thickness of the dies were measured with a digital micrometer (Mitutoyo Corporation, Japan) with an accuracy of upto 0.01 mm.

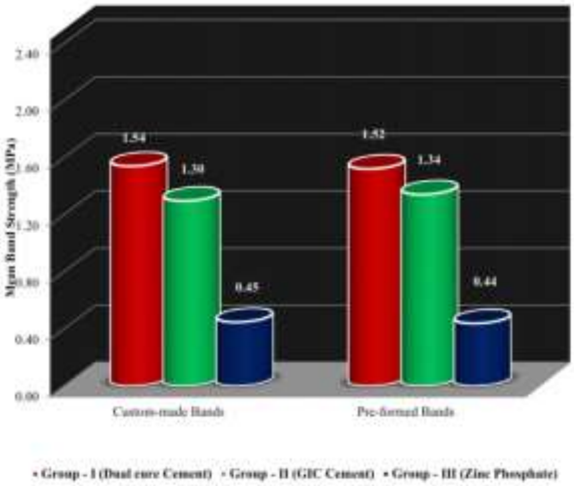


(Figure 2)

Testing of the samples for solubility
After removal from the mould, 30 specimens for each luting cement measuring 20mm in diameter and 1.5mm in thickness were stored for 24 hrs. in an incubator at 37^0 C (Figure 3). The samples were weighed using a digital analytical balance**,** until a continuous mass (m_1) was attained. They were then placed in artificial salivary medium in an incubator maintained at 37^0 C for a period of 1, 3 and 7 days. After every time interval, specimens were removed dried with an absorbent paper and placed in a dessicator for an hour. They were then weighed again and the mass was recorded (m_2). Percentage solubility was calculated as 100 times the difference between initial and final weight of the specimen (i.e. weight loss), divided by the initial weight of the specimen i.e. $\{(m_1\text{-}m_2)/m1\}$ x100.

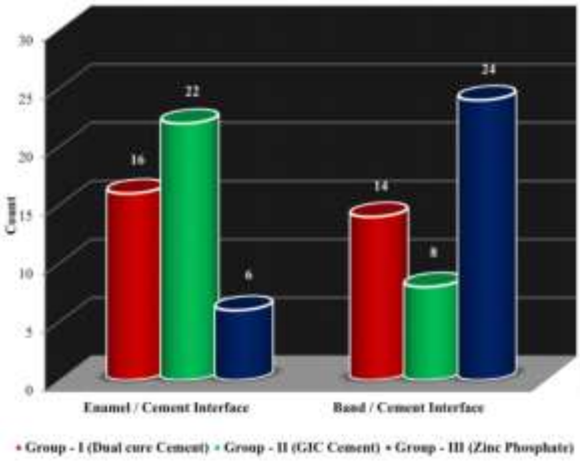
(Figure 3)

RESULTS
There was statistically significant difference in shear-peel band strengths among the three cement groups. Multiple comparison test using the Tukey's post hoc tests revealed significant difference between all three groups. Group - I had more retentive strength than the remaining groups in both preformed and custom-made band groups. There was no significant between custom-made and pre-formed bands for any of the groups. (Figure 4)



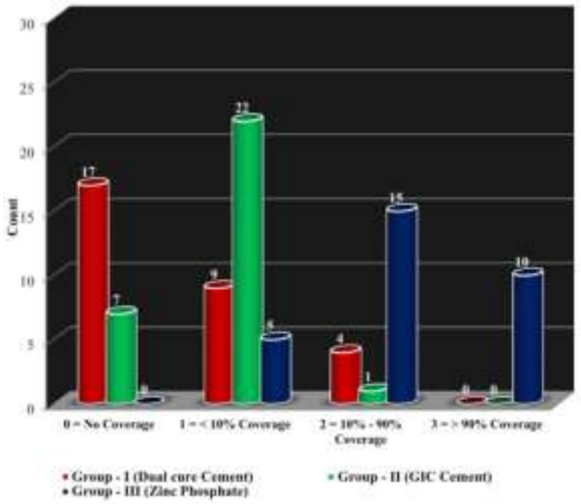
(Figure 4)

There was statistically significant difference in proportion of site of failure among the study groups. It was observed that Group – II has lower mean rank followed by Group – I and Group – III; this indicated that maximum bands from group – II (GIC cement) failed at enamel-cement interface as compared to other groups. Similar findings were observed for both preformed and custom-made band groups. (Figure 5)



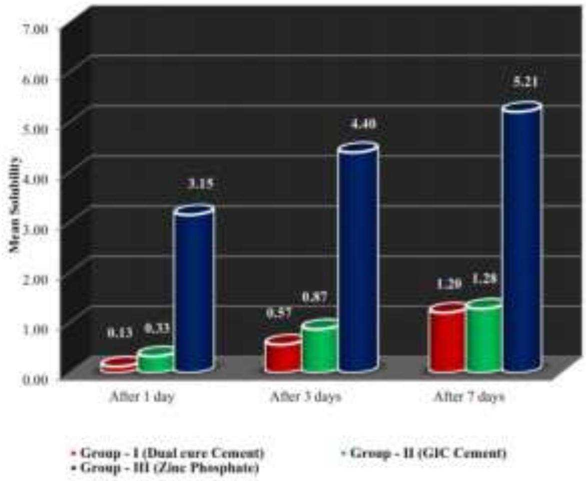
(Figure 5)

There was statistically significant difference in ARI scores among the three cement groups. It was observed that Group–I had lower mean rank followed by Group–II and Group–III; it indicates that group–I (dual cure cement) has more proportion of 'no coverage of crown with cement remnants' as compared to other groups. Similar findings were observed for both preformed and custom-made band groups. (Figure 6)



(Figure 6)

There was statistically significant difference in mean solubility among the three cement groups seen after 1 day, 3 days and 7 days. Group III showed highest solubility amongst the three groups in all three testing times. There was no difference in mean solubility between groups I and II. (Figure 7)



(Figure 7)

DISCUSSION

Retention of orthodontic bands to the tooth surface is important to ensure successful fixed appliance therapy. A number of different band cements have been used since the introduction of fixed orthodontic appliances. For most of this century, zinc phosphate cement has been used widely for band cementation[13-16], but it has several disadvantages[17-18] like,

- Being brittle
- Having relatively high solubility in the mouth
- Weak adherence to tooth structure
- Does not form any degree of chemical bond to either stainless steel or enamel and relies on mechanical means for its retentive effect

Glass ionomer cements[19] are now in widespread use for band cementation[20]. These cements bond to both enamel and metal, adhesion occurring via ionic or polar molecular interactions. Some studies debated that dual-cure cements had better mechanical properties than the conventional GIC[21]. On doing a literature search, very little or no information was obtained on the difference in the properties of all 3 cements when used with pre-formed bands and customized bands.

The present study showed that dual-cure cement provided the highest shear-peel band strength viz. 18.5% more than glass ionomer cement, while zinc phosphate provided the least shear-peel band strength. However, no significant difference was observed between pre-formed or custom-made bands. The present study also showed that the mean % solubility was least for samples from the dual cure cement group i.e. glass ionomer cement group showed 2.5 times more solubility than dual cure cement group after 1 day interval, 1.5 times more solubility than dual cure cement for both after 3 days interval and after 7 days interval. Zinc phosphate cement group showed 9.5 times more tendency for solubility than glass ionomer cement and 24.2 times more tendency for solubility than dual cure cement after 1 day interval, 5 times more and 7.7 times more solubility than glass ionomer cement group and dual cure cement group respectively after 3 day interval and 4 times more and 4.3 times more solubility than glass ionomer cement group and dual cure cement group respectively after 7 days interval.

Both solubility and SPBS are co-related in the oral environment since increase in solubility favors rapid degradation of the cement which in turn predisposes to their debanding[22]. This leads to interference in orthodontic treatment mechanics and also a nuisance to both the patient and orthodontist. Higher solubility of GIC than dual-cure cement may be due to the plasticizing effect of the solvent, whereas the resin network in dual-cure cement reduced the diffusion of the solvent into the cement matrix[23]. Thus, dual-cure cements may show a better performance in the oral environment than GIC and zinc phosphate cement when either pre-formed or custom made bands are used.

The present study also shows that maximum number of bands in GIC group failed at the enamel-cement interface viz. 1.5 times more than the number of bands from dual cure cement and 3.6 times than the bands from zinc phosphate cement while in zinc phosphate cement group maximum bands failed at the band-cement interface. The bands which fail at the cement-enamel interface are highly desirable as there is least chance of secondary caries between the cement-enamel interface. The band which fail at the cement-band interface show that there is no chemical bond to that surface, only mechanical retention. An interesting finding is that both pre-formed and custom-made bands show similar sites of failure of all the luting cements. This aspect of banding needs more research as there is lot of human error which is possible during the fabrication and cementation of customized bands.

The present study also showed that the adhesive remnant score (ARI) after the tooth deband was least for samples from the dual-cure cement group and highest for zinc phosphate group. There was no statistically significant difference between GIC and dual cure cements in relation to the adhesive remnant score. This is expected as dual cure cement is a hybrid cement composed of both GIC and composite resin. Thus, whenever the bands are cemented with dual cure cement and glass ionomer cement it is easier to clean up the tooth surface after deband whereas when they are cemented with zinc phosphate cement the tooth cleanup after deband is tougher. Both pre-formed and custom-made bands showed similar results.

In the absence of mechanical stress, laboratory studies[24] have demonstrated no significant difference in band retention with either zinc phosphate or glass ionomer cements, but glass ionomer cements have proved superior to zinc phosphate cements after application of mechanical stress. This finding had been confirmed clinically by a reduction in band failure rate[25] when glass ionomer cement is used for band cementation. Glass ionomer cement provided more retentive strength than zinc phosphate cement, which could be because it chemically adheres to tooth enamel, dentin as well as to stainless steel whereas, zinc phosphate does not to bond to tooth enamel, dentin and stainless steel, it stays attached to the tooth only by means of mechanical retention. The reason for the increased susceptibility of zinc phosphate luting agent to dissolution has been credited to the formation of a weak cement matrix formed with zinc ions. This matrix structure is more susceptible to dissolution than that of glass ionomer cement which is formed with calcium & aluminium ions forming a stronger matrix[26].

Within the limitations of the study, the authors find that when all 4 factors are considered the dual-cure cement has the most desirable properties for use in orthodontic banding in the clinical setting.

CONCLUSION

- Dual cure cement provided maximum band retentive strength and Zinc phosphate provided minimum band retentive strength.
- Maximum bands in the GIC and Dual cure groups failed at the enamel / cement interface. Bands in the zinc phosphate cement group failed at cement / band interface.
- Adhesive remnant score was minimum for dual cure cement and maximum for zinc phosphate cement.
- No significant difference was found between custom made and preformed bands in terms of

mean band retentive strength, site of failure & adhesive remnant scores.
- Dual cure cement exhibited lowest while Zinc phosphate cement exhibited highest mean percentage solubility in artificial salivary substitute after all three time intervals.

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