SCIENTIFIC SECTION

Chlorhexidine-modified glass ionomer for band cementation? An *in vitro* study

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Objective: To compare the mean retentive strength, predominant site of band failure, amount of cement remaining on the tooth at deband and survival time of orthodontic micro-etched bands cemented with chlorhexidine-modified (CHXGIC) or conventional glass ionomer cement (GIC).

Design: In vitro study.

Setting: Dental Materials Laboratory.

Materials and methods: One-hundred-and-twenty intact, caries-free third molars were collected from patients attending for third molar surgery. These were stored for 3 months in distilled water and decontaminated in 0.5% chloramine. To assess retentive strength, 80 teeth were randomly selected and 40 were banded with each cement. Testing was undertaken using a Nene M3000 testing machine at a cross-head speed of 1 mm/min. Following debanding, the predominant site of failure was recorded as cement–enamel or cement–band interface. The amount of cement remaining on the tooth surface following deband was assessed and coded. Survival time for another 40 banded specimens, 20 cemented with each cement, was assessed following application of mechanical stress in a ball mill.

Main outcome measures: Retentive strength, predominant site of failure, amount of cement remaining on the tooth surface, survival time.

Results: Mean retentive strength for bands cemented with CHXGIC (0.32 MPa, SD 0.09) or GIC (0.28 MPa, SD 0.07) did not differ significantly ($p=0.05$). All bands failed at the enamel–cement interface. There was no significant difference in the amount of cement remaining on the tooth surface after deband for each cement type ($p=0.23$). The mean survival time of bands cemented with CHXGIC or GIC was 7.0 and 6.4 hours, respectively ($p=0.23$).

Conclusions: There was no significant difference in mean retentive strength, amount of cement remaining on the tooth after deband or mean survival time of bands cemented with CHXGIC or GIC. Bands cemented with either cement failed predominantly at the enamel–cement interface. The results suggest that CHXGIC may have comparable clinical performance to GIC for band cementation.

Key words: Chlorhexidine, glass ionomer cements, orthodontic bands

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Introduction

Fixed appliances facilitate plaque accumulation and the consequent development of generalized moderate hyperplastic gingivitis and enamel decalcification.[1,2] Their development may be prevented by the slow release of an antimicrobial, such as chlorhexidine[3,4] from the adhesives and cements used to attach the fixed appliance components[5] or from varnishes applied around bonded attachments.[6] Chlorhexidine is commonly used as 0.12% or 0.5% w/v for mouthwash or oral irrigant purposes.[3,7] A cationic antiseptic, belonging to the chemical group of bis biguanides, it consists of 1,6-bis-p-chlorophenyl-biguanidohexane. It has a broad spectrum of bactericidal action against Gram-positive and -negative organisms, as well as being fungicidal.[3]

Although bonding of brackets using composite resin and the acid-etch technique has become common practice, metal bands continue to be used particularly on molars,[8] due to high bond failure rate of molar tubes[9] and the use of other attachments, such as headgear. Glass ionomer cements (GIC) remain the most commonly used luting agents for cementation of orthodontic bands[8] and have inherent antimicrobial properties.[10]

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In vitro studies have been conducted to assess the microbiological effect of the addition of chlorhexidine dihydrochloride to composite, and GIC against cariogenic and periopathogenic bacteria.[5] The addition of 5% chlorhexidine dihydrochloride resulted in all cements producing an antibacterial effect against both types of bacteria. This was independent of the setting reaction, which initially produces a pH of 4 with GIC. This effect was still measurable after 42 days. The working and setting times of composite and GIC were not significantly affected by the addition of this chlorhexidine formulation.

The addition of chlorhexidine gluconate (1 and 5%) and chlorhexidine dihydrochloride (1 and 10%) have been shown, however, to alter the mechanical properties of restorative materials[11,12] with the 10% addition producing mechanical properties closest to those of the unmodified products.[12] Although a longer antibacterial effect has been exerted with greater chlorhexidine digluconate concentration incorporated into GIC, this was associated with a corresponding rise in cement solubility, which could lead to retentive sites for microflora.[11] Recently, the incorporation of chlorhexidine in GIC has been shown not to compromise its fluoride-releasing or microbial inhibitory properties.[13,14] If this cement formulation has similar mechanical and fatigue properties to the unmodified GIC, it could be useful in reducing decalcification, periodontal disease around the band margins and in overcoming problems of co-operation with adherence to use of an antimicrobial mouth rinse regime during fixed appliance treatment.

The aim of this study was to assess the effect of incorporation of chlorhexidine in GIC on its mechanical properties when used for band cementation. The null hypotheses tested were that there was no difference in mean retentive strength, predominant site of band failure, amount of cement remaining on the enamel at deband and survival time of orthodontic bands cemented with either chlorhexidine-modified (CHXGIC) or conventional glass ionomer cement (GIC).

Materials and methods

One-hundred-and-twenty intact, caries-free human third molars were collected from patients aged 18–25 years attending for third molar surgery. Teeth were stored for 4 months in distilled water in a refrigerator following decontamination in 0.5% chloramine for 1 week. Soft tissue remnants were removed before placement in the chloramine solution. Teeth were collected and the work undertaken in this project prior to the new COREC (Central Office for Research Ethics Committees) guidelines, which came into effect on 1st March 2004.

Cements

The conventional GIC chosen was Ketac-Cem (Espe, Gmbh, Seefeld/Oberbay, Germany) and this was modified by the addition of 10% chlorhexidine digluconate (CHXGIC). The latter cement formulation was chosen as it demonstrated, *in vitro*, increased and sustained antimicrobial activity against *Streptococcus mutans* compared with GIC alone or GIC with incorporation of 5% chlorhexidine digluconate.[13] In addition, fluoride-releasing characteristics of the CHXGIC were not compromised compared with the GIC.[13,14]

Retentive strength testing

In preparation for assessment of band retentive strength, 80 teeth (40 maxillary and 40 mandibular molars) 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. Forty teeth (20 maxillary and 20 mandibular molars) were destined for band cementation with GIC and the remainder of the teeth for band cementation with CHXGIC. This sample size was chosen as 30 or more specimens has been regarded as suitable for this type of experimental testing.[15]

The teeth were cleaned with a pumice slurry, washed in distilled water and dried in a stream of compressed air. As bands do not exist for third molars, optimally sized orthodontic upper and lower first molar bands (3M Unitek, Monrovia, CA, USA) were selected and carefully adapted to the crown of each tooth using a stainless steel band seater. In order to prevent the thin lingual cleats from becoming distorted during retentive strength testing, a length of 0.7 mm stainless steel round wire was welded to each end of the cleat of all 80 bands using an orthodontic welder. All bands were micro-etched by the manufacturer. Forty bands were then cemented with CHXGIC and 40 with GIC. The powder/liquid ratio recommended for luting purposes by the manufacturers was adopted, i.e. 1 scoop of powder to 2 drops of liquid. The 10% chlorhexidine digluconate solution replaced the liquid for the CHXGIC group. Once each band had been positioned accurately on the molar crown and pressed firmly into place, excess cement was removed with dry cotton rolls. Specimens were then allowed to bench cure for 5 minutes before transfer to a humidor at 37°C.

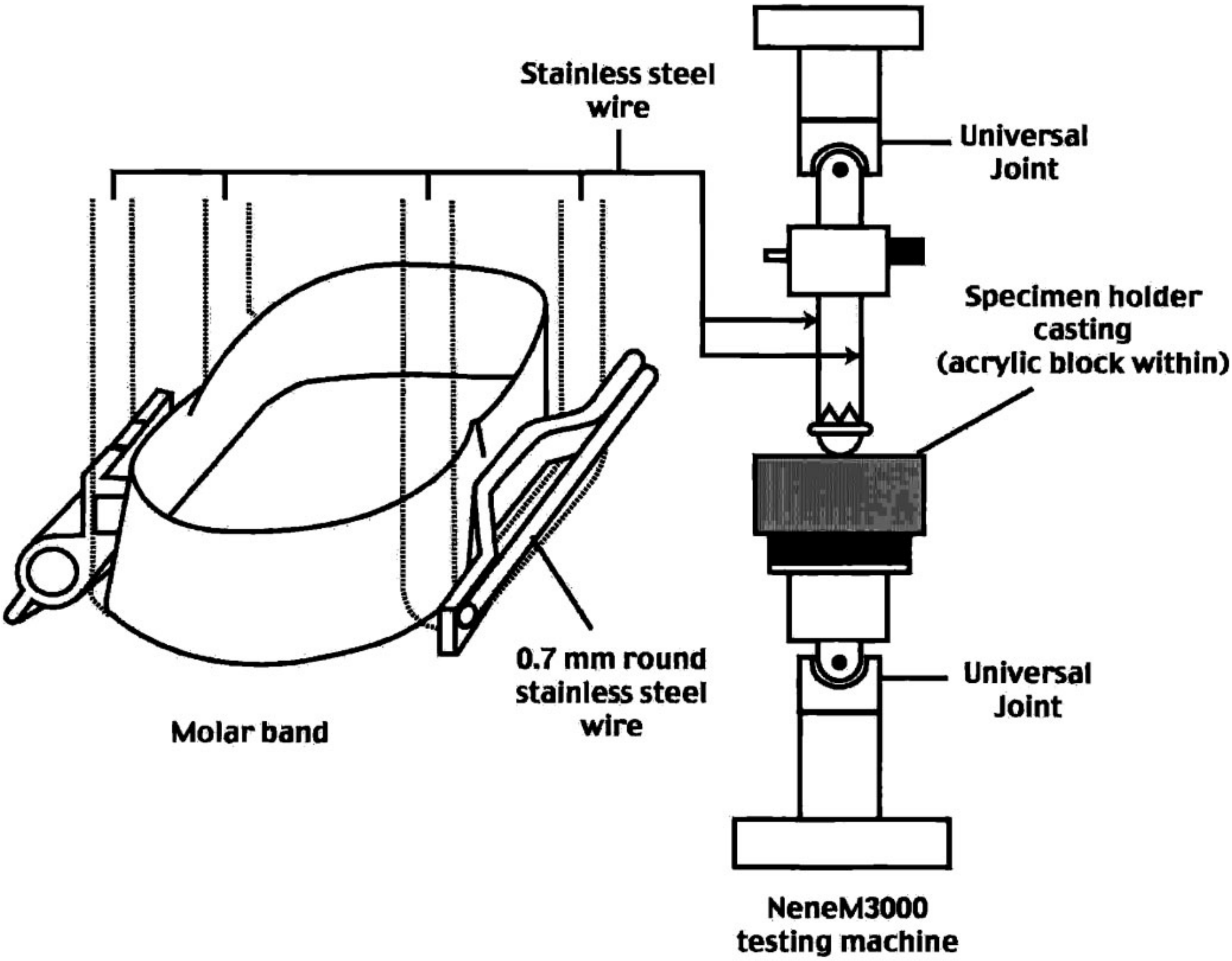

Figure 1 Diagrammatic representation of a specimen in the testing apparatus and close up of the welded attachments to the band

Twenty-four hours later, band retentive force was measured for each specimen using a Nene M3000 testing machine with a cross-head speed of 1 mm/minute. Each specimen was loaded into the jig via stainless steel loops that engaged under the prewelded buccal tubes and lingual cleats on the band (Figure 1). Testing proceeded for each specimen until the band was removed from the tooth. The maximum debanding force (N) was interpreted from the stress–strain curve as the maximum force recorded during debanding and not as the point at which linearity is interrupted, this latter point being difficult to assess objectively for this specimen type.[15–17] The surface area of each band was provided by the band manufacturer (3M Unitek) and was used to allow the calculation of retentive strength (force per unit area) for each specimen. As the bands were micro-etched, which makes surface area determination difficult, the data supplied were nominal, rather than exact surface area values.

Site of failure and cement remnant

After each cemented band failed, the predominant site of failure was assessed visually by one assessor to be at the enamel–cement or cement–band interface. A visual assessment was also made of the amount of cement remaining on the tooth surface. 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, all the crown under the band is covered by cement.

Survival time

Forty more banded specimens (20 cemented with CHXGIC and 20 with GIC) were prepared. For each cement group, 10 maxillary and 10 mandibular molars were used. Although a sample size of 10 specimens per group has been used in similar tests with the GIC used here,[15] 20 specimens per group were deemed necessary due to a possible higher level of variability in the outcome with the new cement (CHXGIC). The banded specimens were not mounted in acrylic resin, but were placed in a ball mill. Although previously used for mineral processing, the ball mill has been adapted for use in dental materials testing by altering the charge and testing temperature according to the material under test. For the purpose of applying a mechanical load to banded orthodontic specimens, the mill contained 470 g of ceramic spheres and 250 ml of distilled water at 37°C. Operating under these conditions, reproducible results have been obtained within a short period of time for this specimen type.[18] After each hour of testing at 100 rev/minute, the failed specimens, those with loose bands, were removed from the mill. After replacing the distilled water with a fresh sample at 37°C, testing recommenced until all specimens had failed.

Statistical analyses

Mean retentive strength values for each cement group were compared using a *t*-test. Weibull analysis[19,20] was used to calculate probability of failure at given values of applied force. Chi-squared analysis was used to compare the mode of band failure. Mean survival times (MST) were determined for each group using survival analysis (BMDP IL, University of California, USA). A log rank test was then used to compare mean survival times.

Results

Band retention data are summarized in Table 1. The mean retentive strength of bands cemented with CHXGIC (0.32 MPa, SD 0.09) was not significantly different from that of bands cemented with GIC (0.28 MPa, SD 0.07, $p=0.05$). Weibull data are also shown in Table 1 and demonstrated graphically in Figure 2. The Weibull moduli were 4.29 and 4.07 for CHXGIC and GIC, respectively. The higher modulus value for CHXGIC indicates greater reliability with this cement. The high values of correlation coefficient of linearized least squares fit indicate that the data fit closely the Weibull distribution function.

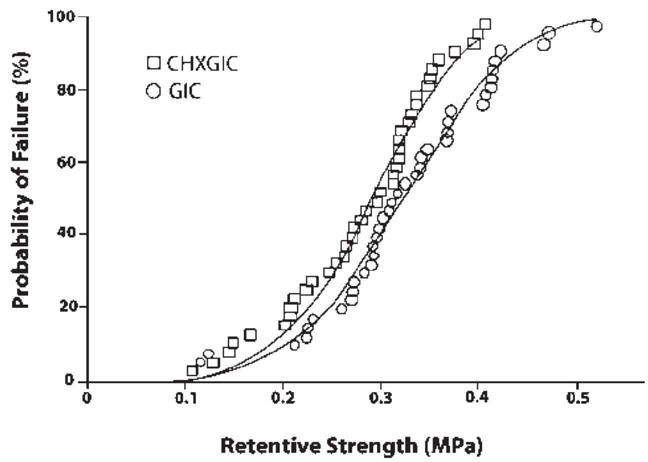

Figure 2 Weibull curves for 40 bands cemented with CHXGIC and 40 bands cemented with GIC

Visual examination of the site of band failure showed that specimens cemented with either cement failed predominantly at the cement–enamel interface. Twenty-two of the specimens banded with CHXGIC and 24 of the specimens banded with GIC had no cement remaining on enamel following deband. There was no significant difference in the amount of cement remaining on the enamel under the band following deband for either cement group (Table 2; $p=0.23$).

The survival time plots for bands cemented with either cement are shown in Figure 3. The mean survival time

Table 2 Predominant site of failure and cement remnant codes for 40 bands cemented with CHXGIC and 40 bands cemented with GIC

Predominant site of failure	CHXGIC	GIC
Enamel–cement interface	40	40
Cement–band interface	0	0
Cement remnant code		
Code 0	22	24
Code 1	18	16
Code 2	0	0
Code 3	0	0

Table 1 Band retentive data for 40 bands cemented with CHXGIC and 40 bands cemented with GIC

Cement	*n*	Mean retentive strength(MPa)	SD	Minimum MPa	Maximum MPa	Weibull retentive strength	Characteristic modulus (MPa)	Correlation coefficient
CHXGIC	40	0.32	0.09	0.09	0.52	4.29	0.36	0.99
GIC	40	0.28	0.07	0.10	0.4	4.07	0.32	0.99

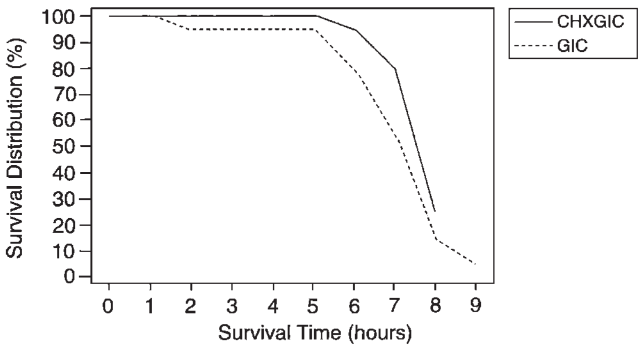

Figure 3 Survival time plots for 20 bands cemented with CHXGIC and 20 bands cemented with GIC

for bands cemented with CHXGIC or GIC was 7.0 and 6.4 hours, respectively (p=0.23).

Discussion

The mean retentive strengths for bands cemented with either cement did not differ significantly. One possible contributory factor is the powder/liquid ratio of each cement mix used for banding. For GIC, powder liquid proportioning was according to manufacturer's instructions for luting purposes. The same proportioning (one scoop to two drops of liquid) was used for CHXGIC, with 10% CHX replacing the liquid. The cement mixes for either CHXGIC or GIC are, therefore, likely to have had similar viscosity which could contribute to similar retentive strength.

Although it is of interest to know the strength of a cement, it is more useful to the clinician to know whether the cement will exhibit this strength in a reliable manner. Weibull statistics, which are valid whether or not the data are normally distributed, allow this information to be obtained readily. Weibull analysis generates moduli, which have practical implications when comparing bond strengths: a high value indicates a close grouping of failures, whilst a low value indicates a wide spreading of failures and a low reliability.[20] The Weibull modulus obtained for CHXGIC was 4.29 compared with 4.07 for GIC indicating that the former may demonstrate more consistent bond performance in the clinical setting.

For all specimens, bond failure occurred at the enamel–cement interface indicating that the addition of 10% chlorhexidine digluconate to the conventional GIC used in this study, does not appear to visibly alter its bonding properties to enamel. This site of failure has been identified previously for micro-etched bands cemented with the same GIC as used in the present study.[15,17] Bond failure at the enamel/ cement interface may, however, lead to greater potential for decalcification due to microleakage of bacteria and their substrates.[21] This may be offset by the antimicrobial activity of chlorhexidine and/or by the uptake, and release of chlorhexidine/fluoride from toothpastes, mouthwashes or varnishes, which would confer cariostatic benefits.[22,23] Different failure sites are likely to be found with resin-modified glass ionomer cements.

Following debanding, no cement remained on the enamel for most specimens cemented with either cement type. In addition, a similar number of teeth in each cement group had less than 50% of the enamel under the band covered by cement at deband. There was no significant difference between the cement groups in cement remnant scores indicating that tooth clean-up following debanding is likely to be similar whether bands are cemented with either cement.

In addition to the Weibull analysis employed for the estimation of survival capabilities of each cement, fatigue characteristics of each cement were explored by subjecting the banded specimens to mechanical testing in a ball mill. Although forces in the ball mill are diverse and of varying magnitude, and the precise mechanism of band failure with this testing system is currently unknown, bond failure is likely by the impact force and mechanical action of the ceramic spheres on the banded specimens.[18] This possibly leads to slow crack propagation with the cement. Although the usefulness of a debanding test has been questioned as an indicator of clinical performance for band cements,[24] the ball mill technique has been a useful predictor of clinical behavior for banded specimens.[15] There was no significant difference in mean survival time for specimens banded with either cement indicating the likelihood of similar clinical performance of both band cements. This is in accord with the findings of the Weibull analysis.

Further work is required to assess the impact of incorporation of chlorhexidine in the newer resin-modified glass ionomers used for band cementation.

Conclusions

- There was no significant difference in mean retentive strength, amount of cement remaining on the tooth after deband and mean survival time of bands cemented with CHXGIC or GIC. Bands cemented with either cement failed predominantly at the enamel–cement interface.
- Bands cemented with CHXGIC may have comparable clinical performance to those cemented with GIC.

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Contributors

Declan Millett was responsible for study design, obtaining funding, supervision of the laboratory experiment, analysis and interpretation of data, drafting of the manuscript and final approval of the article. Bridget Doubleday was responsible for study conception and design, as well as making a substantial input to the grant application, drafting and final approval of the paper. Michael Alatsaris made substantial contribution to the study design and interpretation of the data, drafting and final approval of the article. David Wood was responsible for the study conception and design, obtaining funding, data interpretation, revision of the article and for final approval. Freidy Luther was responsible for study conception and design, obtaining grant funding, revision and final approval of the article. Deirdre Devine was responsible for study design, obtaining funding, revision and final approval of the submitted manuscript. Jan Love was responsible for analysis and interpretation of the data, critical revision of the content and final approval of the manuscript. Declan Millett is the guarantor.

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