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An *in vivo* and *ex vivo* study to evaluate the use of a glass polyphosphonate cement in orthodontic banding

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SUMMARY The purpose of this study was to examine the effectiveness of a new glass polyphosphonate cement (Diamond®) for orthodontic banding. Thirty-one subjects underwent *in vivo* testing to compare the failure rate of bands cemented using the test cement and bands cemented using a conventional glass polyalkenoate cement (Ketac-Cem®) over a 6-month period at the beginning of active appliance therapy. In an *ex vivo* experiment 60 extracted teeth were banded using either the test cement or a glass polyalkenoate cement, and subjected to a debanding force using a Lloyd universal testing machine until failure.

In the *in vivo* study the overall proportion of failure of the bands cemented with each cement was identical at 0.048. However, in the *ex vivo* study the probability of failure for the glass polyphosphonate cement was significantly higher than for the glass polyalkenoate cement, and the force to deband the glass polyalkenoate cement was greater than that of the glass polyphosphonate cement.

In the clinical setting the new glass polyphosphonate cement performed as well as a conventional glass polyalkenoate cement, and these results suggest that it could be used as an alternative cement for orthodontic banding. The results of the *ex vivo* test bring into question the usefulness of this laboratory test as an indicator of clinical performance.

Introduction

Stainless steel bands are routinely used as orthodontic attachments for 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. Ideally each molar band should remain cemented in place for the duration of the fixed appliance therapy, which may be as long as 24–30 months. Failure of the band during the course of treatment gives rise to a number of potential problems, including: local soft tissue discomfort if the band is displaced subgingivally; additional attendance for recementation, inconvenience for both patient and operator; increased length of active treatment; and decalcification or caries if the cement failure goes unnoticed.

A number of different band cements have been used since the introduction of fixed orthodontic appliances, including zinc phosphate, zinc polycarboxylates (Mizrahi, 1979, 1982), and more recently glass ionomers (Fricker and McLachlan, 1985). Currently the most popular orthodontic band cements are the glass ionomer, alternatively named glass polyalkenoate cements. They possess two desirable properties for an orthodontic band cement, namely the ability to release fluoride, and adhesion to both enamel and steel. Fluoride release is from the fluorosilicate glass of the cement or that absorbed or adsorbed from saliva or toothpastes, which is then subsequently released (Ashcraft *et al*., 1997). Reduced enamel decalcification has been observed when these cements have been compared with alternative orthodontic band cements (Copenhover, 1986; Rezk-Lega *et al*., 1991); this may be as a result of fluoride release or because band failure, when it does occur, does so at the band–cement interface rather than the enamel–cement interface (Norris *et al.*, 1986). It might be expected that the adhesive qualities of these cements would result in a low rate of band failure during treatment, but the reported *in vivo* band failure rates to date have ranged from as low as 0.56 per cent to as high as 26 per cent (Norris *et al.*, 1986; Mizrahi, 1988; Durning, 1989; Millett and Gordon, 1992). Nevertheless these failure rates are no higher than those seen with other band cements, but they have the added advantage of reducing the risk of enamel decalcification during treatment (Norris *et al.*, 1986).

A glass polyphosphonate cement, Diamond® (Kemdent®, Associated Dental Products Limited, Swindon, UK), has recently been introduced for use in restorative dentistry. The claimed advantages of glass polyphosphonates over conventional glass polyalkenoate cements are a rapid set, a high compressive strength, and a low solubility. The latter is said to result in a less unpleasant taste, a common complaint by patients when cementing bands with glass polyalkenoate cement. The aims of this present study were therefore threefold.

To determine *in vivo* the band failure rate of the glass polyphosphonate cement (Diamond®) versus a conventional glass polyalkenoate cement (Ketac-Cem®, ESPE America, Inc., Norristown, PA, USA), along with an evaluation of the taste of each cement and *ex vivo* to assess the force to deband for each cement.

Materials and methods

In vivo *study*

Thirty-one consecutive patients undergoing two-arch fixed appliance therapy were approached to take part in the investigation. Ethical approval was sought and granted by the local ethics committee and all patients gave their consent to participate in the study. Inclusion criteria were that all four first molars were to be banded with orthodontic attachments (microetched MBT bands, 3M Unitek, Bradford, UK) and the Straight-Wire Appliance (OmniArch®, GAC International, Inc., Islandia, NY, USA) was to be used. Patients were excluded from the study if any other attachments were to be added to the molar bands, such as headgear, palatal, or lingual arches. Subjects were also excluded if they had one or more first molars with large restorations affecting the buccal, palatal, mesial, or distal surfaces.

Each subject was allocated a number using a random number table (Altman, 1991) and this determined which first molars were cemented with the test glass polyphosphonate cement and which were banded using the conventional glass polyalkenoate cement. The 'split mouth technique' described by Glavind (1977) was used, so that in any individual the upper left and lower right first molars were cemented with one cement, and the upper right and lower left first molar with the alternative cement. Elastic separation was placed 1 week prior to the appointment for band cementation. The Ketac-Cem® cement was mixed at a 1:2 ratio of powder to liquid and the cementation procedure carried out according to the manufacturers' instructions at a single appointment by one operator (JRC). The Diamond® cement was mixed with the liquid at a ratio of one scoop of powder to two drops of liquid to produce a cement with adequate flow for the cementation procedure. Initial aligning nickel titanium archwires (Euroform™, Orthocare, Bradford, UK) were placed immediately following band cementation and orthodontic treatment then proceeded as usual. The patients were seen at 6-weekly intervals and archwire sizes changed as deemed clinically appropriate. The archwire sequence was 0.014 inch nickel titanium, 0.018 inch nickel titanium, 0.017 × 0.025 inch nickel titanium, and 0.019 × 0.025 inch stainless steel. At each patient visit the first molar bands were checked to ensure that no cement failure had occurred. Any band failure was recorded in the notes and the band recemented using the same cement. If the band was not available a new band was used with the same cement. Band failure data were retrieved from the notes at two intervals during the active orthodontic treatment in order to attempt to determine the effect of time on band failure: 3 and 6 months after band cementation.

At the time of initial band cementation the patients were asked to state whether either of the two cements tasted worse than the other. The patient was allowed to rinse with water between cementing with each material and asked to comment as to the taste once both materials had been used.

Ex vivo *study*

Sixty extracted sound third molar teeth were mounted in acrylic leaving the crown of the tooth exposed in each case. This sample was then randomly divided into two groups of 30, forming a test and a control group. Teeth in the test group were cemented with first molar bands (microetched MBT bands, 3M Unitek) using the glass polyphosphonate cement, according to the manufacturers' instructions. Teeth in the control group were cemented with first molar bands using the conventional glass polyalkenoate cement. As bands for third molar teeth are not available, first molar bands were used and adapted as closely as possible to the tooth, as previously described (Millett *et al.*, 1995). The banded teeth were subsequently stored in distilled water for 3 months at room temperature. The inner surfaces of the bands were smooth and had not been previously sandblasted or laser etched. At the end of the 3 month period, testing to failure was performed using a custom-made testing jig in a Lloyd Universal testing machine (Series 2000R, Lloyds Instruments, Southampton, UK). The crosshead speed was set at 2 mm/minute and each band was subjected to a debanding force. This force was directed from below the gingival edge of the pre-welded buccal tube and in an occlusal direction until failure of the cement lute was observed (Figure 1). The force (N) at failure was recorded for each tooth.

Results

The data were analysed using Stata 7 (StataCorp 2001, Stata Statistical Software: Release 7.0. Stata Corporation, College Station, TX, USA) with the significance predetermined at $\alpha = 0.05$. The data are summarized in Tables 1–3. A Kaplan–Meier survival analysis and log rank test was performed (Figure 2). Box plots for the *in vitro* results are illustrated in Figure 3.

In vivo study

The failure rates of the bands cemented with the test glass polyphosphonate cement and conventional glass

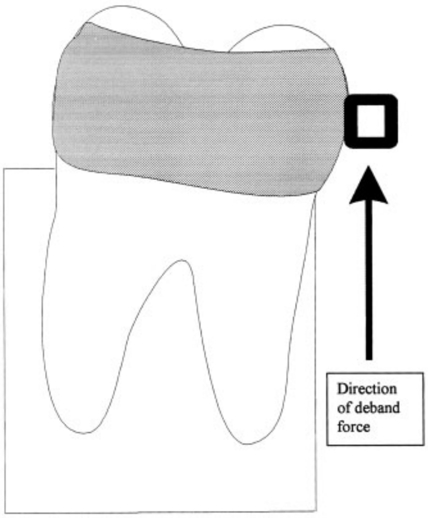


Figure 1 Illustration of a molar tooth embedded in an acrylic block. The arrow represents the direction of the debanding force applied to the buccal attachment of the cemented band.

polyalkenoate cements at 3 and 6 months post-cementation are recorded in Table 1. By 3 months, two of the 62 bands cemented with the glass polyphosphonate cement had failed and two of the 62 bands cemented with the conventional glass polyalkenoate cement had also failed. By 6 months four of the bands cemented with the glass polyphosphonate cement had failed and four of the bands cemented with the conventional glass polyalkenoate cement had also failed. None of the bands that had to be recemented subsequently failed again during the study period. The overall proportion of failure for each material was therefore identical at 0.048. The small number of band failures for both cements precluded any further statistical analysis.

Table 2 Summary of taste results.

Number of patients who preferred the taste of Diamond®	14
Number of patients who preferred the taste of Ketac-Cem®	8
Number of patients who did not express a preference	9

The results of the taste test are presented in Table 2. A Chi-squared analysis ($P = 0.02$) showed that there was no significant difference between the taste of the two cements.

Ex vivo *study*

Summary force to deband data (N) are shown in Table 3. The survival probability and log rank test for the glass polyphosphonate and glass polyalkenoate cements are shown in Figure 2. This reveals that the probability of failure for the glass polyphosphonate cement was significantly higher than for the conventional glass polyalkenoate cement. For example, only 30 per cent of bands cemented with glass polyphosphonate cement would remain cemented to the tooth if a force of 50 N were applied, compared with 70 per cent of the bands cemented with glass polyalkenoate. The box plots of the force to deband (Figure 3) also show that the force to deband of Ketac-Cem® was greater than that of Diamond®.

Discussion

In vivo study

After 6 months of active treatment the overall failure rate for bands cemented with Diamond® in this study was 4.8 per cent, exactly the same as that for bands

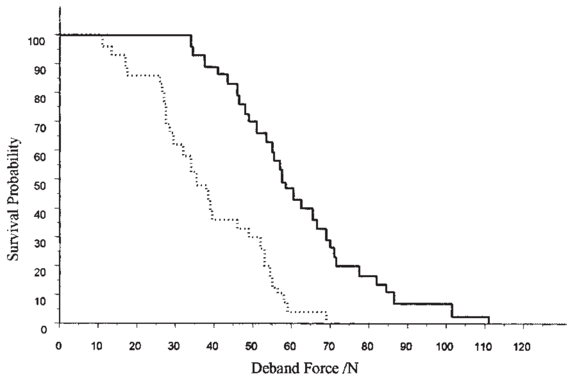
Table 1 Summary of *in vivo* failure distribution.

Quadrant	Tooth	Diamond®								Ketac-Cem®							
		0–3 months				3–6 months				0–3 months				3–6 months			
		M		F		M		F		M		F		M		F	
		S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
1	1	6	1	8	0	7	0	7	1								
1	2									7	0	8	0	6	1	8	0
1	3	7	0	7	1	7	0	7	1								
1	4									7	0	8	0	5	2	8	0
2	1									6	1	9	0	6	1	9	0
2	2	7	0	9	0	6	1	9	0								
2	3									7	0	8	1	7	0	9	0
2	4	7	0	9	0	7	0	8	1								
Summary		27	1	33	1	27	1	31	3	27	1	33	1	24	4	34	0

Tooth, tooth code; M, male; F, female; S, success; N, failure; Summary, summary of success and failure.

Table 3 Summary of force to deband data.

Material	Observations	Median (N)	Mean (N)	SD	Min.	Max.
Diamond®	30	36.2	37.73	15.23	10.38	68.97
Ketac-Cem®	30	57.91	61.43	18.70	33.8	110.61



	Material	Log rank	$P > X^2$
	Diamond®	14.73	0.001
	Ketac-Cem®	45.27	

Figure 2 Kaplan–Meier survival probability and log rank test for the two test materials at 3 months.

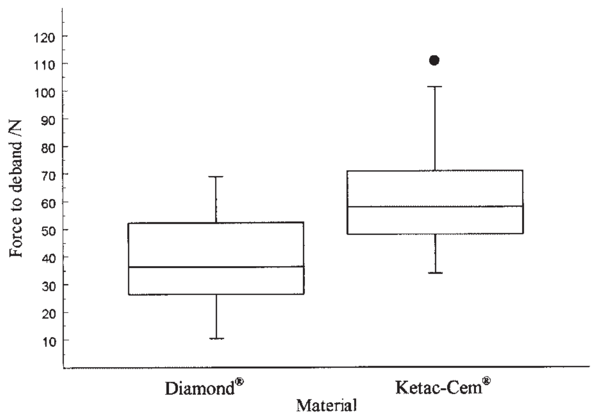


Figure 3 Box plots of the force to deband (N) of the two materials under test.

cemented with Ketac-Cem®. Previous studies of the clinical performance of glass polyalkenoate cements report failure rates ranging from 0.56 per cent (Norris *et al.*, 1986) to 26 per cent (Durning, 1989). However, some caution should be exercised in comparing these results, as the effect of variations such as the duration of treatment will have a marked influence on the recorded failure rate, i.e. a longer treatment time giving rise to a higher number of failures. In the present investigation the small number of bands that failed during treatment precluded further analysis to determine the effect of time on band failure rates. Nevertheless, the clinical performance of Diamond® in this study was sufficiently good to consider it as an alternative to Ketac-Cem® when cementing bands on molar teeth.

The results of the taste test would suggest that the glass polyphosphonate was no more acceptable than the glass polyalkenoate cement. However, care must be exercised in interpreting such results since both cements were used at the same sitting, with the possibility that the taste of one cement may have affected the taste of the other.

Ex vivo study

During testing, the force to deband was recorded as the point at which the cement was visually assessed to have 'cracked'. This was often lower than the maximum force recorded during the testing procedure, because the force required to move the band over the maximum bulbosity of the tooth after cement failure was often greater. The Kaplan–Meier survival probability results in this study for Ketac-Cem® do not compare favourably with the Weibull survival probability results reported by Millett *et al.* (1995). In the latter investigation, 5 per cent of non-sandblasted bands cemented with Ketac-Cem® would have failed with a force of 50 N compared with 30 per cent in the present study. However, bands in the study by Millett *et al.* (1995) were tested 24 hours after cementation compared with 3 months in this study. Also, the point of cement failure was taken as the maximum force recorded during debanding, unlike in the present study. The force to deband data shows a wide range and large standard deviation. This may be due in part to the less than ideal fit of first molar bands on third molar teeth and resulting differences in the thickness of cement used during band placement. It is also acknowledged that visual inspection of surface defects involves a subjective assessment by the operator.

Although the *ex vivo* results in this present investigation reveal that the force to deband of Ketac-Cem® is significantly higher than that of Diamond®, the fact that there was no difference in the clinical performance over the 6 month test period would suggest that this laboratory test is not a good indicator of clinical performance.

Conclusions

The results of this *in vivo* cross-mouth control study showed no difference in the band failure rates of the new polyphosphonate cement and the conventional glass polyalkenoate cement over the test periods 0–3 and 3–6 months. However, the results of the *ex vivo* experiment demonstrated a statistically significant difference in the observed force to deband of the two cements 3 months after cementation: Ketac-Cem® demonstrated a higher force to deband than Diamond®. It would seem that glass polyphosphonate cements may be used for orthodontic banding, but the results bring into question the usefulness of this laboratory test as an indicator of clinical performance. Further work is required to investigate the ability of glass polyphosphonate to prevent enamel decalcification in clinical use.

The results of patient questioning on taste would seem to indicate that for those who expressed a preference, 14 patients preferred the glass polyphosphonate cement while eight preferred the glass polyalkenoate, although statistically there was no significant difference.

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References

Altman D G 1991 Practical statistics for medical research. Chapman & Hall, London

Ashcraft D B, Staley R N, Jakobsen J R 1997 Fluoride release and shear bond strengths of three light-cured glass ionomer cements. American Journal of Orthodontics and Dentofacial Orthopedics 111: 260–265

Copenhover D J 1986 *In vitro* comparison of glass ionomer cement's ability to inhibit decalcification under orthodontic bands. American Journal of Orthodontics 89: 528 (Abstract)

Durning P 1989 A clinical and laboratory investigation into the cements used to retain orthodontic bands. MDS Thesis, University of Newcastle-Upon-Tyne, UK

Fricker J P, McLachlan M D 1985 Clinical studies of glass ionomer cements. Part I—A twelve month clinical study comparing zinc phosphate cement to glass ionomer. Australian Orthodontic Journal 9: 179–180

Glavind L 1977 Effect of monthly professional mechanical tooth cleaning on periodontal health in adults. Journal of Clinical Periodontology 4: 100–106

Millett D T, Gordon P H 1992 The performance of first molar orthodontic bands cemented with glass ionomer cement-A retrospective analysis. British Journal of Orthodontics 19: 215–220

Millett D T, McCabe J F, Bennett T G, Carter N E, Gordon P H 1995 The effect of sandblasting on the retention of first molar orthodontic bands cemented with glass ionomer cement. British Journal of Orthodontics 22: 161–169

Mizrahi E 1979 The recementation of orthodontic bands using different cements. Angle Orthodontist 49: 239–246

Mizrahi E 1982 Success and failure of banding and bonding. A clinical study. Angle Orthodontist 52: 113–117

Mizrahi E 1988 Glass ionomer cements in orthodontics—An update. American Journal of Orthodontics and Dentofacial Orthopedics 93: 505–507

Norris D S, McInnes-Ledoux P, Schwaninger B, Weinberg R 1986 Retention of orthodontic bands with new fluoride-releasing cements. American Journal of Orthodontics 89: 206–211

Rezk-Lega F, Øgaard B, Arends J 1991 An *in vivo* study on the merits of two glass ionomers for the cementation of orthodontic bands. American Journal of Orthodontics and Dentofacial Orthopedics 99: 162–167