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The effect of thermal cycling on the integrity of the orthodontic band — cement — tooth interfaces

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SUMMARY

Orthodontic bands are retained on the crowns of teeth by the luting action of the cement. Studies by several workers have demonstrated the inability of zinc phosphate cements to produce an effective marginal seal and have shown microleakage to occur along the walls of cavities restored with zinc phosphate cements. Differences in the coefficients of thermal expansion between enamel, dental cements and stainless steel suggest that temperature variations would increase the microleakage along the enamel/cement/steel interfaces. Preformed stainless steel bands were cemented with a zinc phosphate cement to the crowns of 60 extracted maxillary central incisor teeth. Thirty specimens were subjected to 13 000 cycles of temperature changes ranging between 6 and 70°C while 30 control specimens were retained at room temperature (20°C). All 60 specimens were then immersed in colloidal graphite, embedded in resin and the crowns sectioned in the sagittal plane. The cut surfaces were polished, mounted in DPX on glass slides and subjected to microscopic examination. The results showed that there was no significant difference in the extent of the defects observed between the experimental and control specimens at the band/cement/tooth interfaces. For the total sample, however, there was a significantly greater frequency of severe defects occurring along the palatal interfaces compared with those occuring along the labial interfaces.

OPSOMMING

Semente hou ortodonsiebande op tandkrone deur middel van meganiese hegting vas. Verskeie navorsers het getoon dat sinkfosfaatsemente nie 'n doeltreffende randseël lewer nie en dat mikrolekkasie rondom sinfosfaatsementherstellings voorkom. Dit kan verwag word dat temperatuurskommelings mikrolekkasie langs glasuur/sement/staal tussenvlakke sal vererger, weens die verskillende termiese uitsettingskoëffisiënte van hierdie drie materiale. Voorafvervaardigde vlekvrye staal ortodonsiebande is aan die krone van 60 verwyderde maksillêre sentrale snytande met sinkfosfaat sement gesementeer. Dertig monsters is aan 13 000 temperatuurskommelings tussen 6 en 70°C onderwerp terwyl die 30 kontroles by kamertemperatuur (20°C) bewaar is. Die 60 monsters is daarna in kolloïdale grafiet gedompel, in 'n hars ingebed en vervolgens is die krone sagitaal deurgesny. Die snitvlakke is gepoleer, op glasskyfies gemonteer en daarna mikroskopies ondersoek. Die resultate het geen betekenisvolle verskil tussen die kontroles en die eksperimentele monsters in die omvang van defekte by die band/sement/tand tussenvlakke getoon nie. Veelvuldige groot defekte het egter veel meer dikwels by die linguale tussenvlakke as by die labiale tussenvlakke voorgekom.

In a lecture to the American Society of Orthodontists in 1908, Ames explained that the adhesion of "oxyphosphate cements" resulted from mechanical bonding of the cement to the irregularities on the tooth surface. Although improvements in cement composition and manufacture have taken place since then, Ames' explanation still remains valid today.

In spite of the possibility of enhanced retention resulting from the chemical adhesion of polycarboxylate cements to enamel and stainless steel (Smith, 1968) data from clinical studies (Clark, Phillips and Norman, 1977; Mizrahi, 1977 a,b; 1979) and a laboratory study (Mizrahi, Cleaton-Jones and Austin 1981) suggested that, as with zinc phosphate and silico-phosphate cements, the major retentive action of polycarboxylate cement results from a physical luting action of the cement, rather than chemical adhesion.

The inability of zinc phosphate cements to achieve a marginal seal along the cement/tooth interface has been demonstrated by a number of workers. (Massler and Ostrovsky, 1954; Parris, Kapsimalis and Summit, 1960; Swartz and Phillips, 1961; Phillips *et al*, 1961; Trail and Sausen, 1962). Close scrutiny of these studies shows that accurately prepared cavities and carefully placed restorations were used for the evaluation of micro-leakage at various interfaces. In contrast to this precise physical arrangement, the orthodontic band cemented to the crown of a tooth is a comparatively inaccurate arrangement. Orthodontic band material possesses varying degrees of flexibility and exhibits work-hardening characteristics. It is adapted with a hand instrument to fit an irregularly shaped crown and the band is retained by a luting cement required to fill an irregular space exposed to the oral fluids at both the cervical and incisal margins.

If one accepts that microleakage does occur at the cement/tooth interface in the carefully controlled restorative situation, then it is reasonable to assume that microleakage is even more likely to occur along the orthodontic band/cement/tooth interfaces. Schroeder *et al* (1974) did show that leakage beneath orthodontic bands was related to some extent to the type of cement used and to the different methods used for the removal of excess cement. In 1952 Nelson, Wolcott and Paffenbarger suggested that marginal percolation was caused by a difference in the coefficient of thermal expansion between the dental tissues and restorative materials and by the thermal expansion of fluids occupying the crevice between tooth and restoration. Subsequently many workers have investigated the effects of temperature changes when carrying out microleakage experiments. Guzman, Swartz and Phillips (1969) investigated the marginal leakage of restorations subjected to thermal stress and showed that the marginal adaptation of a silicate cement and two restorative resins were not impaired by thermal stress. The data from their studies did not reflect the differences in coefficients of thermal expansion of the different restorative resins. In a review of the methodologies used in microleakage studies, Kidd (1976) reported that the results of temperature cycling experiments have, almost invariably, shown increased leakage after subjecting specimens to thermal treatment. In view of the position of the orthodontic band on the tooth surface, as well as the variations in the physical characteristics of the components of the band/cement/tooth interface, the cemented orthodontic band should be susceptible to increased leakage resulting from thermal stresses within the oral environment. This study was undertaken to determine the effect of thermal stress on the integrity of the orthodontic band/cement/tooth interface.

MATERIALS AND METHODS

Sixty extracted human maxillary central incisor teeth were cleaned with pumice and water, stored in deionized water at room temperature and tagged with serial numbers. Hard, wide, preformed, stainless steel bands (Unitek)* with palatal and labial seating lugs were fitted and adapted to the crown of each tooth. Using random number tables to control the sequence, bands were cemented to the teeth using the same standardized procedure and mounting jig as described in a earlier study (Mizrahi, 1981).

From this group 30 specimens were randonly selected as controls and kept at room temperature. The serial numbers of the control and experimental specimens were recorded by a third party. The remaining 30 experimental specimens were subjected to thermal cycling in water baths ranging from 6°C to 70°C. The dwell time for specimens in each water bath was 15 sec-/cycle. After completion of 13 000 cycles, the control and experimental specimens were placed together in a container of colloidal graphite (DAG 504)** and gently shaken for 2½ h. Each specimen was then rinsed with water, surface dried and embedded in high clarity polyester resin blocks. When polymerized the resin blocks containing tooth crowns and cemented bands were mounted in a low speed section machine*** and sectioned in the sagittal plane using a water cooled diamond disc. The block for examination was detached by a transverse cut at the neck of the tooth. The cut surface was then polished using a water cooled polishing machine**** with 600 grit silicon carbide waterproof paper discs. The direction of the abrasive action of the disc was from cervical to incisal in order to remove the metal bur from the cut edge of the steel orthodontic band that could be obscuring the band/cement/tooth interface. The specimen was then dipped in DPX mounting medium, seated on a glass slide and a cover slip placed over the cut surface (Fig. 1).

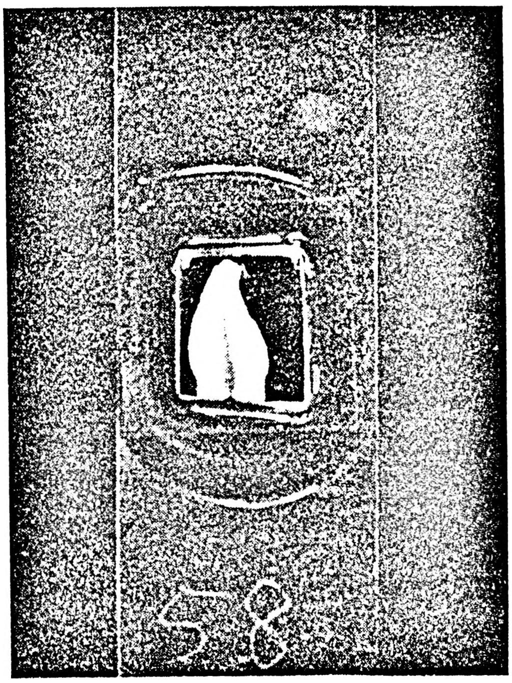

Fig. 1: Cut specimen mounted in DPX.

The mounting medium was allowed to set and the specimens were randomly selected for examination. The cut surface was examined with a binocular microscope using incident light at 40x magnification. The band/cement/tooth interfaces on both the palatal and labial surfaces were examined for the presence of colloidal graphite and visible defects (Figs. 2a, 2b).

Using an eyepiece with a graticule scale, the total length of the interface was recorded and the length of any defect was also recorded. The extent of the defect was calculated as a percentage of the total lenth of the interface for both the palatal and labial surfaces separately. Twenty specimens were randomly selected and

* Unitek Corporation 2724, South Peck Rd, Monrovia, California, U S A

** DAG — Acheson Colloids Ltd, Prince Rock, Plymouth, Devon, U K

*** Isomet — Buehler, Evanston, Illinois, U S A

**** Kent Mark II, Engis Ltd, Maidstone, England

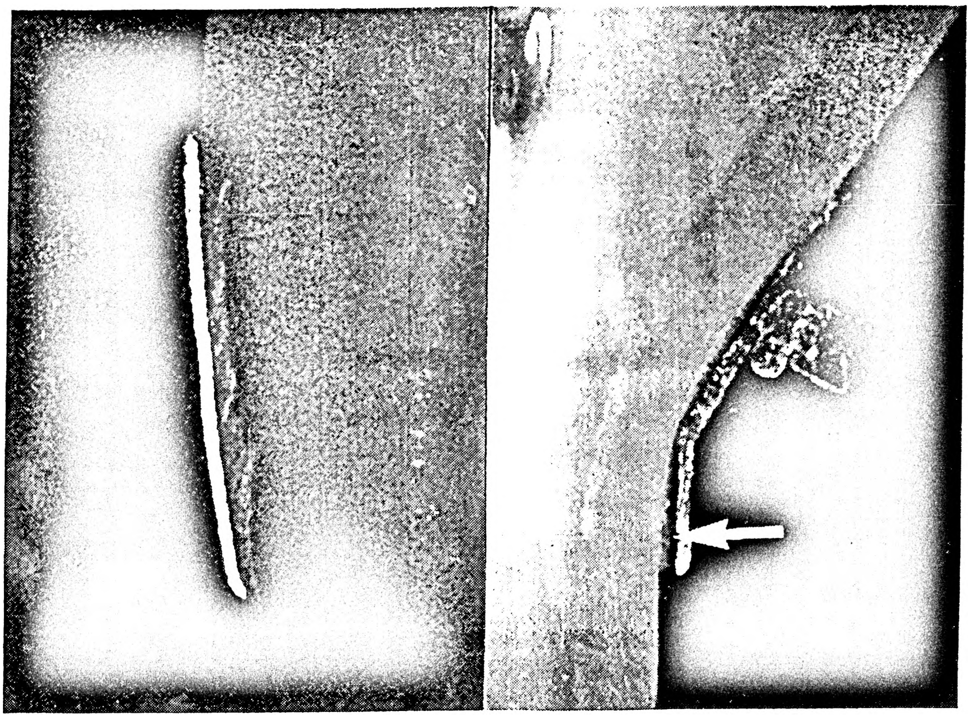

Fig. 2: Band/cement/tooth interfaces showing the presence of a defect between the band and the cement (see arrow) along the palatal surface A and the absence of any defect along the labial surface B. Original magnification x40.

reexamined to test for examiner reliability. A different group of 20 specimens randomly selected were examined by a second examiner in order to test the reproducibility of the scoring technique. The Student's t test for paired samples showed no significant difference at the ,01 level between the first and second evaluation for 20 specimens reexamined by the same examiner. Similarly there was no significant difference between the extent of the defects recorded for 20 specimens examined by two different examiners.

RESULTS

The extent of the defects were calculated for both the labial and palatal aspects of all the specimens, the serial numbers were then checked against the original list and the control and experimental specimens identified. The mean extent of the defects expressed as a percentage of the length of the interfaces are given in Table 1. The Student's t test for independent samples showed no significant differences between the means for the control and experimental groups on either the labial or palatal surfaces. As the reliability of this test may be questioned on the grounds of a possible skewed distribution of the data, further tests were carried out on frequency distributions. The data were divided into 4 groups based on the extent of the defect, that is, defects ranging from 0 to 25 per cent, 26 to 50 per cent, 51 to 75 per cent and 76 to 100 per cent. The Chi-square test showed that there were no significant differences between the frequencies of experimental and control specimens in each of the four groups for both the labial and palatal surfaces.

Examination of the frequency distribution for defects occuring on the palatal and labial interfaces of the total sample showed an interesting pattern (Fig. 3). Only 9 specimens showed defects ranging from 0 to 25 per cent on the palatal surface, while for the labial surface, 38 specimens fell into this group. This difference was statistically significant ($p< 0,01$). At the other end of the range 41 specimens showed defects ranging from 76 to

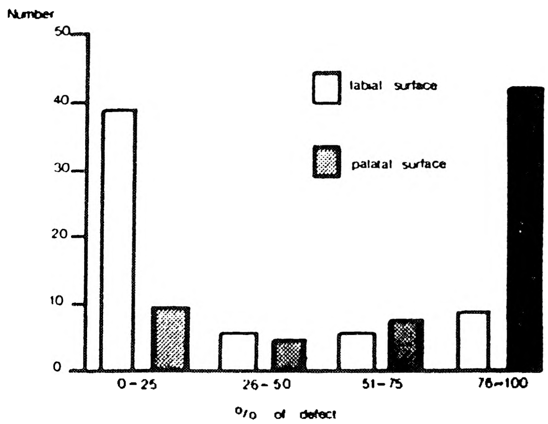

Fig. 3: A frequency distribution based on the extent of defects occurring along the labial and palatal surfaces.

Table 1: The extent of the defects occurring in the control and experimental specimens, calculated as a percentage of the length of the interface.

	Control Group		Experimental (Thermal Cycled)	
	Labial	**Palatal**	**Labial**	**Palatal**
	%	%	%	%
Mean	29,2	64,4	22,2	86,5
S.D.	37,0	37,8	33,5	28,8

100 per cent on the palatal surface, while for the labial surface, only 12 specimens fell into this group. This difference was, once again, statistically significant ($p < 0,01$). All the defects appeared to occur along the band/cement interface rather than at the tooth/cement interface.

DISCUSSION

The results of this study showed that, within the parameters of the experimental procedure, thermal cycling did not significantly affect the integrity of the band-/cement/tooth interfaces.

A feature of this study was the gross nature of the defects, particularly on the palatal surface. This was in contrast to the more microscopic nature of the leakage defects noted in studies on restorative materials where dyes and radioactive isotopes are used to assess leakage. This feature had become apparent in earlier pilot studies and it was for this reason that a particulate medium such as colloidal graphite was used as an adjunct to delineate the defects, rather than a liquid dye.

The maxillary central incisor tooth was specifically chosen for this study in order to allow evaluation of the behaviour of the band/cement/tooth interface on both the convex labial surface and the concave palatal surface. The frequency distribution of the defects shown in Fig. 3 clearly shows the greater susceptibility of the concave palatal surface to the development of defects at the band/cement interface. This feature was probably the result of the steel band material pulling away from the cement after the band was seated on the crown. Stainless steel band material does have certain spring qualities which are further enhanced by work hardening. It is conceivable, therefore, that when the band is seated on the tooth and pressure is applied with hand instruments in order to adapt the band material as closely as possible to the contours of the crown, stresses are introduced into the metal; the gradual release of these stresses may result in the pulling away of the band material from the set cement.

In the study by Schroeder *et al* (1974) where premolar teeth were used, there was no difference between the penetration of Ca^{45} on the convex buccal (32 per cent) and lingual (33 per cent) surfaces, while there was greater penetration on the flatter proximal surfaces (38 to 40 per cent). This variation related to the shape of the tooth surface was shown to an even greater extent in the present study.

The presence of defects beneath the othodontic band is of clinical significance with regard to the development of enamel demineralization during orthodontic treatment. While the defect remains between the band and the cement, the enamel is, to a certain extent, protected. Once the cement layer breaks down, however, the enamel surface becomes vulnerable to enamel demineralization. Mizrahi (1981) showed that following orthodontic treatment, there was an increase in the prevalence of enamel demineralization on the lingual third of maxillary incisor teeth. Over the last 15 yr the conventional orthodontic bands, particularly on maxillary incisor teeth, have gradually been replaced by directly bonded brackets using the acid etch technique. The clinical problems related to the band/cement/tooth interface as indicated in this study are obviated by the use of directly bonded brackets. They still remain pertinent, however, in cases where conventional bands are still commonly used on premolar and molar teeth.

CONCLUSIONS

Within the experimental parameters of this study, the results showed that thermal cycling from 6°C to 70°C did not significantly affect the integrity of the orthodontic band/cement/tooth interface as assessed by the extent of the defects at the interfaces on the labial and palatal surfaces. However, this study did show a significantly greater frequency of severe defects on the palatal surface compared with the labial surface of maxillary central incisor teeth.

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