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Experimental Marginal Leakage Around Dental Amalgams Placed in Artificial Cavities

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Experimental marginal leakage of high- and low-Cu amalgam restorations placed in acrylic teeth, where the cavities were untreated or painted with denatured collagen and/or a CaP slurry, was assessed after specimens were stored in a 1% NaCl solution for ten days and for one yr. All specimens stored for ten days showed severe marginal leakage. High- and low-Cu amalgam restorations placed in untreated acrylic teeth cavities formed seals after a storage period of one yr, indicating that these materials are able to form a seal without interacting with a natural tooth cavity interface. Cavities treated with denatured collagen also formed seals in the long-term group. It was apparent that, when the CaP slurry was used, generally more leakage resulted after the year's storage period than when amalgam restorations were placed in uncoated acrylic cavity surfaces or in those painted with denatured collagen.

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Introduction.

A wide range of *in vitro* and *in vivo* marginal leakage tests has showed that dental amalgam restorations which leak initially develop a seal with time (Jodaikin, 1981). Although many variables have been used, all the studies appear to have focused on amalgam-tooth interfaces. No studies have been found which show that sealing can take place independent of *tooth* cavity substrates – such as Ca, P, and denatured proteins (which form as a result of cavity preparation) – nor the specific role that these substances play in the sealing mechanism(s).

The purpose of this study was to broaden our understanding of the sealing mechanism(s) by determining whether the sealing process could take place within an artificial tooth cavity using a low- and high-Cu dental amalgam. Further, the experimental marginal leakage effects of coating artificial tooth cavities with a CaP slurry and/or denatured collagen prior to obturation were investigated.

Materials and methods.

Cavities were prepared (~4 mm x 2.5 mm x 2.5 mm) in 112 anterior acrylic teeth‡ using a water-cooled tungsten carbide fissure bur in an air turbine handpiece.

A CaP slurry (0.2M $Na_2HPO_4.12\ H_2O$, 0.2M $NaH_2PO_4.H_2O$ and 0.4M $CaCl_2$ in 1 liter) and a 4 mg/ml denatured type I collagen+ (DT1C) aqueous solution were prepared. The latter was stored in a water bath at 37°C to prevent solidification during cavity preparation. The teeth with prepared cavities were then randomly divided into eight experimental groups of 14 teeth each, which were treated as follows:

Group 1: Cavities obturated with a low-Cu amalgam× only;

Group 2: Cavities obturated with a high-Cu amalgam# only;

Group 3: Cavities painted with DT1C and obturated with a low-Cu amalgam×;

Group 4: Cavities painted with DT1C and obturated with a high-Cu amalgam#;

Group 5: Cavities painted with a CaP slurry and obturated with a low-Cu amalgam×;

Group 6: Cavities painted with a CaP slurry and obturated with a high-Cu amalgam#;

Group 7: Cavities painted with DT1C, then with the CaP slurry, and obturated with a low-Cu amalgam×;

Group 8: Cavities painted with DT1C, then with the CaP slurry, and obturated with a high-Cu amalgam#.

All amalgams were manipulated according to the manufacturer's instructions, and the restoration surfaces were finished using a cotton wool pledget. Thereafter, the teeth within each group were immersed in sealed bottles containing 25 ml of a 1% NaCl solution to which a few grains of thymol had been added. The immersed specimens were maintained at 37°C and were aerated every 14 days in a U.V. sterilizing cabinet for several hours by opening the sealed containers.

After periods of ten days and a year, batches of four and ten teeth were taken from each group, respectively, and subjected to a marginal leakage fluorescent dye test. This test was similar to a previously described regime (Jodaikin and Austin, 1981), except that it was conducted at 37°C. Two sections were cut (100μm to 200μm thick), and after being mounted, they were examined at x40 to x400 magnification with a U.V. fluorescent microscope. Two investigators independently graded the leakage scores according to the following system:

Score 0 – no dye penetration between the amalgam restoration and the cavity wall; score 1 – no dye penetration beyond one-third of the depth of the cavity wall; score 2 – dye penetration beyond the first third of the depth of the cavity wall but not into the amalgam-cavity floor interface; and score 3 – deepest dye penetration at the amalgam-cavity floor interface. This scoring system was applied to two sections per tooth specimen, and the highest score obtained for each specimen was adopted as the degree of experimental leakage for the specimen in question. After 20% of the specimens were re-examined by both investigators, it was found that inter-examiner reproducibility was 87.5% and intra-examiner reproducibility was 90 and 95% for the two examiners. For the analysis of the results, a conservative approach was adopted, and the higher score of the two examiners was used for the few samples where score differences were obtained. These results were subjected to both the Fischer exact probability and the Chi-square tests where applicable, and p values of < 0.05 and < 0.08 were selected as the levels of statistical significance, respectively. The latter value was selected based on the Bonferroni upper bound on the overall significance level (Feller, 1964) of the eight tests.

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‡Denton Dentsply Manufacturing, AD International (Australia) Pty. Ltd.

+E. Merck Gelatin ("Gelupert")

×New True Dentalloy, S.S. White, Philadelphia, PA

#Tytin, S.S. White, Philadelphia, PA

TABLE 1
MARGINAL LEAKAGE SCORES OF THE EXPERIMENTAL AND CONTROL GROUPS

Storage Time (scores)	Ten Days					One Year				
	n	0	1	2	3	n	0	1	2	3
1 Low Cu	4				4	10	4	5		2
2 High Cu	4				4	10	1	6	1	2
3 Low Cu + DT1C	4				4	10		6	2	2
4 High Cu + DT1C	4			1	3	10		6	1	3
5 Low Cu + CaP.S	4				4	10		3	2	5
6 High Cu + CaP.S	4				4	10		1	4	5
7 Low Cu + DT1C + CaP.S	4				4	10		1	4	5
8 High Cu + DT1C + CaP.S	4				4	10		2	2	6

Results.

All the specimens stored for ten days showed severe marginal leakage. Of the one-year batch, only the amalgams condensed against the acrylic without DT1C and/or the CaP slurry (CaP.S) showed scores of 0 (Table 1). No significant differences between any of the long-term groups were found when sealing scores of 0 were considered. Owing to slight leakage, probably due to marginal obturation faults, it was deemed prudent to consider scores $\leqslant 1$ as having showed sealing properties (Table 1). Comparisons between group 1 after ten days and one year using the Fischer exact probability test indicated a significant difference ($p<0.015$). When group 2 was analyzed in the same manner, a significant difference ($p<0.035$) was also obtained. It is thus evident that a sealing mechanism can develop without a natural tooth surface when low- and high-Cu amalgam restorations age in a 1% NaCl solution.

After comparing the long-term groups with one another using the Chi-square test, it was found that 11 of the 28 comparisons displayed significant differences (Table 2). It is apparent that, when the CaP.S was used (groups 5 to 8), generally more leakage resulted compared with groups 1 to 4, which did not include CaP.S application. This was usually significant when scores of $\leqslant 1$ were considered (Table 2).

It was also noted that all the high-Cu specimens which were not treated with the CaP.S (groups 2 and 4) formed a green deposit on and around the amalgams on visual examination after the one-year storage period.

Discussion.

Acrylic teeth were used in this study to provide a convenient interface lacking in natural tooth cavity substrates. The short-term control results of this study and two-month pilot studies (Jodaikin and Goldstein, unpublished) indicate that, even after sorption effects, leakage occurs at amalgam-acrylic interfaces, showing that these teeth are a suitable model for the required purpose of this experiment. Components of the smear layer which probably forms when the predominant tooth protein substance, type I collagen (Prockop *et al.*, 1979), is heat-denatured during cavity preparation (Jenkins, 1978) may play a role in the sealing mechanism due to sorption and/or the formation of metalloproteins. Thus, DT1C was included in the study, as was the CaP.S, since Ca and P have been reported together with amalgam elements at tooth-amalgam interfaces (Sarkar *et al.*, 1981) and may thus play a role in the sealing process. A 1% NaCl solution containing thymol was used as the storage corrosion medium. The thymol grains were introduced to inhibit growth of micro-organisms, and the 1% NaCl solution was used as it was adopted by Sarkar *et al.* (1981). Although it is imperative to realize that *in vivo* dental amalgams are subjected to a host of corrosive factors (which include saliva, microflora, mastication, and diet), the 1% NaCl was also selected for the purposes of this study, since it reduces the introduction of additional variables.

The low- and high-Cu amalgams showed similar experimental marginal leakage trends, which correlate with those in other studies (Duperon *et al.*, 1971; Boyer and Torney, 1979; Hembree and Andrews, 1979; and Jodaikin and Austin, 1981). However, this study showed that they are both able to form a seal independent of tooth cavity substrates. This would counter the notion that tooth cavity wall substrates (such as proteins which swell owing to sorption or combine with corrosion products to form metalloproteins) are necessary for the formation of a mechanical experimental seal, especially in corrosion-resistant alloys.

The results (Table 2) show no significant difference between the amalgams obturated against acrylic (groups 1 and 2) and those with a DT1C layer at the interface (groups 3 and 4). This differs from the trend where smear layer removal enhanced sealing (Jodaikin and Austin, 1981), but it may be attributed to the time and temperature differences during the storage period and/or to the fact that the previous study (Jodaikin and Austin, 1981) was conducted *in vivo* using different dental amalgams. It is apparent that whenever the CaP.S was used, sealing was generally significantly less than when the CaP.S was not applied to the cavity surface (Table 2). This may be attributed to the loss of the CaP.S into the storage medium, leaving an interface space, and/or to the effects of the CaP.S on the corrosion process. The latter is highlighted by the observation

TABLE 2
RESULTS OF THE CHI-SQUARE TESTS APPLIED TO THE SPECIMENS STORED FOR ONE YEAR

	Low Cu	High Cu	Low Cu DT1C	High Cu DT1C	Low Cu CaP.S	High Cu CaP.S	Low Cu DT1C CaP.S	High Cu DT1C CaP.S
1 Low Cu								
2 High Cu	N.S.							
3 Low Cu + DT1C	N.S.	N.S.						
4 High Cu + DT1C	N.S.	N.S.	N.S.					
5 Low Cu + CaP.S	$p<0.08$	N.S.	N.S.	N.S.				
6 High Cu + CaP.S	$p<0.01$	$p<0.05$	$p<0.08$	$p<0.08$	N.S.			
7 Low Cu + DT1C + CaP.S	$p<0.01$	$p<0.05$	$p<0.08$	$p<0.08$	N.S.	N.S.		
8 High Cu + DT1C + CaP.S	$p<0.05$	$p<0.08$	N.S.	N.S.	N.S.	N.S.	N.S.	

which indicated that all of the long-term high-copper specimens formed green deposits, possibly $CuCl_2.3Cu(OH)_2$ (Brune, 1981; Marshall *et al.*, 1982), which were clearly visible, whereas the specimens where the CaP.S had been used showed no visible green deposits. This indicates that variables such as the use of different liners (for example, calcium hydroxide, which could leak out) and patient saliva variations (Ca and P have saliva ranges of about 0.5-3 and 2-23 mmol/L, respectively; Jenkins, 1978) may affect corrosion and sealing processes.

It is apparent that the formation of a seal is not an isolated and simple process. The various materials used to restore teeth, their interactions, physiological factors, and other effects such as diet may determine the type of seal and speed with which it is formed. It is thus important to identify and characterize the seals which form and understand the roles of the various oral and biomaterial factors in their formation. This will facilitate clinical studies of the effects of various types of seals on the longevity of amalgam restorations.

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