Reaction of the human dental pulp to silver amalgam restorations

The effect of insertion of amalgam of high plasticity in deep cavities

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The purpose was to study the effect of amalgam with known relative sealing properties. In 28 bicuspids deep cavities were prepared and filled according to the wet technique, 14 with amalgam A, shown to give a good seal, and 14 with another amalgam, B, which gave a comparatively less good seal. Seven teeth in each group were extracted after 1 week and 7 after 1 month. In a further 6 teeth the method of preparation was checked. The effect of the packing pressure was studied in 11 other teeth with lined cavities of varying depth. The teeth were examined histologically. All teeth in the material proper showed pulpal inflammation of varying severity, somewhat more pronounced in teeth with amalgam B. The method of preparation used had caused no significant changes. Two of 6 teeth studied regarding the effect of packing in deep cavities showed extensive fresh haemorrhages. No such reaction was found in teeth with less deep cavities. The initially high mercury content together with the shortness of the distance between the pulp and the floor of the cavity were probably the decisive factors. An effect of leakage and of packing pressure could, however, not be excluded.

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The effect, on the pulp, of filling shallow cavities with amalgam was the subject of a previous paper (*Granath & Möller*, 1971). The cavities had been filled according to the wet technique (*Jørgensen*, 1967). The frequency of inflammation was high and ascribed mainly to the initially high mercury content of the amalgam. This assumption was supported by, among other things, the fact that the sealing achieved with one of the two amalgams used had proved very good in air pressure tests. The inflammatory changes were very mild, possibly because of the relatively long distance between the cavity and the pulp.

The significance of a short distance, however, in connection with the use of the wet technique is not known. The present investigation, in which the same methods were used as in the previous study of teeth with shallow cavities, was therefore undertaken to elucidate the biological effect, on human dental pulp, of experi-

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mental restorations of silver amalgams with known relative sealing properties and with high plasticity at the time of insertion into deep cavities.

MATERIAL AND METHODS

The material and methods resembled those in the previous investigation (*Granath & Möller*, 1971). Deep buccal cavities were prepared in 28 healthy unanaesthetised bicuspids. At the time of the experiment a cavity was said to be deep if it had a total depth of about 3 mm, with the result that in most cases a change in colour of the floor of the cavity was observed because of its proximity to the underlying pulpal tissue.

Fourteen cavities were filled with amalgam A, which had been shown to give a good seal, and 14 with another amalgam, B, which gave a comparatively less good seal (*Granath*, 1971). Seven of the teeth in each group were extracted after 1 week and 7 after 1 month.

In addition 6 teeth were extracted immediately after preparation of the cavities for checking the preparation method. In order to find out whether the results varied with the packing pressure applied, a further 6 teeth were used. These 6 teeth were extracted immediately after the dentin walls of the cavity had been coated with a liner (Tubulitec®) and the cavity had been filled with amalgam. The liner has been shown not to cause pulpal irritation (*Brännström & Nyborg*, 1969) and to prevent penetration of amalgam components (*Söremark et al.*, 1968). In another 5 teeth the effect of the packing pressure was studied in less deep cavities, but under otherwise similar conditions.

The actual changes to be recorded were the presence and signs of inflammation, reduction in the number of odontoblasts, presence of odontoblast nuclei in the dentin, and ruptured vessels indicated by fresh haemorrhages. The shortest distance between the floor of the cavity and the pulp was measured.

Statistics

A statistical analysis was made of the differences between cases with amalgam A and those with amalgam B, and between 1-week and 1-month cases. The null hypothesis was that there were no differences between amalgam A and B, nor between 1-week and 1-month cases. The analysis was carried out as a two-sided test, since the earlier clinical investigation (*Granath & Möller*, 1971) had not shown any statistically significant differences between amalgam A and B inserted in shallow cavities, or between 1-week and 1-month cases, with respect to the biological effect on the pulp.

The hypergeometric probability distribution applicated to tests of the equality of two proportions was used. Significance was determined according to tables by *Lieberman* and *Owen* (1961). Differences significant at the 5% level were said to be statistically significant.

The symbols used are defined as follows:

N = number of items in a lot
n = number of items in a sample taken from the lot
k = number of defective items in the lot
x = number of defective items observed in the sample.

According to the tables, the probability (designated Pr in this study) of finding exactly x defective items in the sample is marked p (x) = p (N,n,k,x), and the probability of finding x defective items or fewer in the sample is denoted by P (x) =

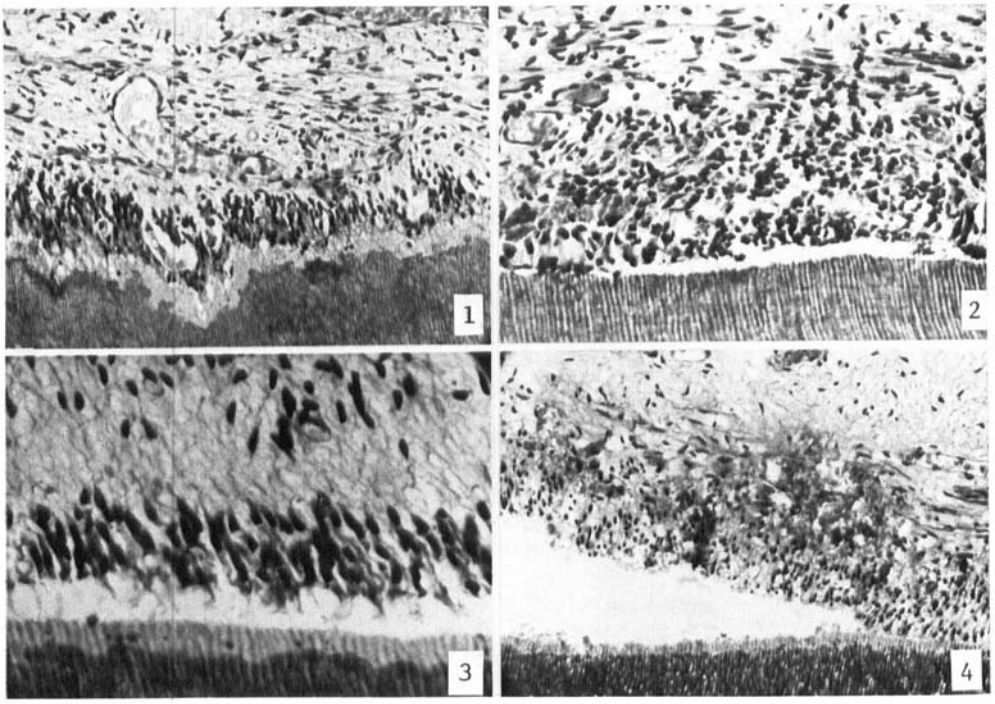

Fig. 1. Dilated vessels adjacent to the predentin beneath the cavity; × 120
Fig. 2. Dilated and ruptured vessels and accumulation of inflammatory cells; × 180
Fig. 3. Cavity preparation caused no changes in the pulp except rupture between predentin and odontoblast layer; × 300
Fig. 4. Packing pressure caused an extensive fresh haemorrhage in the pulp in addition to rupture between predentin and odontoblast layer; × 120

P (N,n,k,x). If $n<k$, it is necessary only to interchange n and k to read the probabilities directly from the tables.

RESULTS

The results are given in Table I, summarized in Table II, and exemplified in Figs. 1—4. Four specimens had to be discarded because of too long a distance between the cavity and the pulp, 1 in each group with amalgam A and 2 in the 1-week group with amalgam B. In the remaining 24 cases the mean of the shortest distance from the floor of the cavity to the pulp was 0.29 mm with a standard deviation of 0.16 mm.

Inflammation was invariably demonstrable in the form of dilated capillaries and inflammatory cells in the odontoblast layer — cell-rich zone boundary associated with the dentinal tubules involved in the cavity preparation (Fig. 1). Two of the 12 cases with amalgam A and 5 of those 12 with amalgam B showed a moderate or dense infiltration of inflammatory cells (Fig. 2). The difference between the 2 groups was statistically not significant. On the other hand, analysis of subgroups with respect to the distance to the pulp revealed nothing arguing against the existence of a real difference between amalgam A and amalgam B.

The reduction in the number of odontoblasts varied so widely with the distance between the floor of the cavity and the

Table I. *Pulpal changes in odontoblast layer — cell-rich zone boundary in 24 bicuspids with experimental restorations of silver amalgams of high plasticity at time of insertion into deep cavities*

Amalgam	Observation time	Shortest distance cavity — pulp, mm	Dilated capillaries	Inflammatory cells	Reduction in number of odontoblasts	Odontoblast nuclei in dentin	Ruptured vessels
A	1 month	0.13	×	f §	large	f	
»	»	0.58	×	f §	small	f	
»	»	0.35	×	f §		f	
»	»	0.27	×	f	small	f	
»	»	0.27	×	f	»	f	
»	»	0.33	×	f	»	f	×
B	»	0.28	×	m	»	f	×
»	»	0.20	×	d	large	f	×
»	»	0.26	×	f §	small	f	×
»	»	0.06	×	d	large	f	×
»	»	0.24	×	f	»	f	
»	»	0.26	×	f §	small	f	×
»	»	0.36	×	f §	large	n	×
A	1 week	0.45	×	f §		f	×
»	»	0.59	×	m	large	n	×
»	»	0.14	×	m	»	n	×
»	»	0.05	×	f	»	n	
»	»	0.53	×	f §	small	n	
»	»	0.57	×	f	»	n	×
B	»	0.32	×	s §	large	n	×
»	»	0.17	×	m	»	n	×
»	»	0.17	×	d	»	n	×
»	»	0.23	×	s	small	n	×
»	»	0.17	×	f	large	n	×

s = slight (scattered cells), m = moderate, and d = dense infiltration (accumulated cells) refer to density of cells, while f = few and n = numerous refer to amount of cells.

§ In these cases inflammatory cells were observed in pulp inside cell-rich zone.

Table II. *Pulpal changes in odontoblast layer — cell-rich zone boundary in 24 bicuspids with experimental restorations of silver amalgam with high plasticity on insertion into deep cavities*

	Dilated capillaries	Inflammatory cells		Odontoblast nuclei in dentin		Ruptured vessels
		few cells or slight infiltration	moderate or dense infiltration	few	numerous	
No. with amalgam A						
examined after 1 week (6)	6	4	2	1	5	4
» 1 month (6)	6	6		6		1
and with amalgam B						
examined after 1 week (5)	5	3	2		5	5
» 1 month (7)	7	4	3	6	1	6

Table III. *Model for arrangement of values for the statistical analysis**)

	Odontoblast nuclei in dentin		
	few	numerous	
One week	1	10	11
One month	12	1 = x	13 = n
	13	11 = k	24 = N

*) see p. 188

pulp that the groups could not be properly compared. It cannot, however, be excluded that the use of amalgam B might result in a greater reduction of odontoblasts than amalgam A.

Numerous degenerated odontoblast nuclei were found in the dentin in all cases examined after 1 week except in 1 treated with amalgam A and in 1 of those examined 1 month after treatment with amalgam B. The difference between the 1-week and the 1-month cases were statistically significant, since Pr ($x \leq 1$) + Pr ($x \geq 10$) = 0.00135 as indicated in Table III. The number of nuclei in the dentin did not vary with the distance to the pulp.

Of the 1-month cases treated with amalgam A, ruptured vessels, indicated by an extravasation of a few erythrocytes, were found in 1 case. The corresponding figure for amalgam B was 6. The difference between the 2 groups was statistically significant [Pr ($x \leq 1$) + Pr ($x \geq 6$) = 0.029, where x is the number with ruptured vessels in the cases with amalgam A]. The difference could not be explained by differences in the distance to the pulp. There was no statistically significant difference between the 1-week groups.

Control examination of the preparation revealed a rupture between the predentin and the odontoblast layer in the teeth studied (Fig. 3). No other changes were noted. The mean shortest distance from the cavity to the pulp was 0.33 mm with a standard deviation of 0.19 mm.

In the 6 teeth extracted immediately after the cavities had been filled with amalgam to assess the significance of the packing pressure in deep cavities, extensive fresh haemorrhages were seen in the area in question in 2 teeth (Fig. 4), and a few extravasated erythrocytes in 3 teeth. There was no haemorrhage in the remaining tooth. The mean shortest distance from the cavity to the pulp was 0.39 mm with a standard deviation of 0.08 mm.

Three of the 5 teeth used for studying the effect of the packing pressure in less deep cavities contained a few extravasated erythrocytes. The other 2 teeth showed no signs of intrapulpal bleeding. The mean shortest distance between the cavity and the pulp was 1.38 mm with a standard deviation of 0.16 mm. The difference in cavity depth between the series used for studying the effect of the packing pressure was statistically significant ($p<0.001$) according to Student's t-test.

All the measurements were made by one of the authors. Some were checked by the other, and insignificant differences were found between the values recorded.

DISCUSSION

In contrast with the mild vascular dilatation found in the previous investigation of teeth with shallow cavities, all of the teeth in the present investigation showed more pronounced inflammation. In view of the sealing properties of the amalgams it seems reasonable to ascribe this mainly to their initially high mercury content together with the short distance between the pulp and the floor of the cavity. Therefore, the results cannot be expected to apply to the use of the so-called conven-

tional amalgam technique. Comparison is of little relevance as long as investigations on the effect of precondensed amalgam report nothing about its sealing properties.

The presence of the numerous odontoblast nuclei in the dentin 1 week after treatment, which is thought to be caused by an increased intrapulpal pressure due to the inflammation (*Stanley & Swerdlow*, 1958), suggests that the seal was incomplete (*James & Schour*, 1955). The numerically higher frequency of moderate and dense infiltration of inflammatory cells and ruptured vessels (see below) in group B than in group A in the 1-month cases may, perhaps, be an expression of leakage. On the other hand, it should be emphasized that an incomplete seal does not necessarily result in clinical leakage.

The difference in the number of odontoblast nuclei in the dentin between the 1-month and 1-week groups probably indicates a decrease in inflammation with time. With reference to the frequency of inflammatory cells and ruptured vessels mentioned in the preceding paragraph, the absence of differences between amalgam A and amalgam B teaches nothing about differences, if any, in the severity of inflammation. More odontoblasts in the dentin may perhaps have undergone autolysis in the cases with amalgam B than in those with amalgam A.

The packing pressure had apparently affected the pulp. It is probable that the haemorrhages in the teeth in which the effect of the packing pressure was studied was caused by extraction after the vessels had been weakened by the packing of the amalgam. This conclusion is based on the absence of haemorrhage in the teeth used for control of the cavity preparation. The possibility of such mechanical damage to the vessels as can contribute to extensive intrapulpal bleeding in connection with extraction must therefore be considered in the investigation of the effect of amalgam restorations on the pulp.

The investigation appears to warrant the conclusion that in future studies of the effect of mercury the depth of the cavity used should be such that the packing pressure does not give rise to damage of the above-mentioned type. The investigation also showed that in routine clinical work with amalgam of high plasticity, the dentin of deep cavities should be insulated.

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