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What is This?
Effects of Saliva and Sulfide Solutions on the Marginal Seal of Amalgam Restorations

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A number of studies, using dyes and isotopes, have shown that freshly placed amalgam restorations do not completely seal the cavities in which they are placed.1–6 In spite of this shortcoming, the generally satisfactory nature of amalgam restorations has led to further investigations, which have shown that there is a considerable reduction in the marginal penetration of isotopes as the amalgam ages.5–9 The cause of this decrease in marginal penetration has not yet been investigated fully, but it has been reasoned that "metallic ions and corrosive products" may fill in this area.8,7 It has also been suggested that salivary constituents deposit in the patent margins of such restorations and thus block the margins against further penetration by ions or dyes.6,7,10

In this study ninety-three freshly extracted teeth were used to place simple Class V amalgam restorations. The teeth were then stored for varying periods of time in sodium sulfide solutions, saliva, tap water, distilled water, and moist air in order to observe the effect of this storage on the marginal penetration of isotopes and dye. One hundred unstored teeth were used as comparative controls.

The dye used as a tracer was a 3.8 per cent aqueous solution of toluidine blue. The isotopes were S35 as sodium sulfate and Ca48 as calcium chloride. Dye and isotopes were used in combination.

Materials and Methods

Class V amalgam cavities were prepared and filled with silver amalgam† in 93 freshly extracted teeth which had not been allowed to dry out by storing in tap water. No base or lining material of any kind was used; nor was any medicament applied to the dentin. The cavities were mechanically cleaned and dried with air in the usual way. Three operators took part in the restoration of these teeth, and the amalgam was packed using the standard technique.

The teeth were then stored in various solutions for different periods of time (as shown in Table 1) before immersion in the dye/isotope tracer solution. With the exception of the teeth placed in saliva, all teeth were stored at room temperature.

The teeth stored in moist air were kept in a closed container with a large piece of cotton wool soaked in distilled water. Those stored in saliva were kept in an incubator at 37° C. during the period of storage. The saliva was protected from the air. The saliva was obtained from each experimenter and was changed daily.

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After storage, the roots of the teeth were covered with wax and the crowns were then immersed in dye/isotope solution for 1 week. The dye was a 3.8 per cent solution of toluidine blue and the strength of the isotope was 50 μc. per cubic centimeter for S\textsuperscript{35} and 20 μc. per cubic centimeter for Ca\textsuperscript{45}. Approximately one-half the teeth were stored in S\textsuperscript{35} and toluidine blue, and the other half in Ca\textsuperscript{45} and toluidine blue.

In addition to these ninety-three teeth stored in various ways, a group of twenty teeth which had been filled with amalgam in vivo were selected for parallel study. These restorations were of various types; they had been in service for various periods of time in the oral cavity and were carefully examined before selection, to avoid teeth in which recurrent caries existed.

### TABLE 1

<table>
<thead>
<tr>
<th>Time of Storage</th>
<th>Number of Teeth</th>
<th>Degree of Penetration* (by Isotopes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0 hours</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Sodium sulfide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5% 5 hours</td>
<td>24 hours</td>
<td>6</td>
</tr>
<tr>
<td>5% 1 hour</td>
<td>1 hour</td>
<td>0</td>
</tr>
<tr>
<td>10% 24 hours</td>
<td>10% 2 hours</td>
<td>3</td>
</tr>
<tr>
<td>10% 2 weeks</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Saliva</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 hour</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>24 hours</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2 weeks</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Tap water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2 weeks</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Distilled water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Moist air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2 weeks</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td></td>
</tr>
</tbody>
</table>

* Degree of penetration: 0 = limited to V-shaped edge of restoration; 1+ = penetration to less than half marginal depth; 2+ = penetration to base of cavity; 3+ = penetration into underlying dentin.

Preparation of the teeth for autoradiography and for microscopic examination was exactly as described by Going, et al.\textsuperscript{4,5} The teeth were cut in hemisections through the center of each filling on a special machine. Each hemisection was then placed on bared fast dental X-ray film\textsuperscript{*} to obtain autoradiographs (Figs. 1–9). At least one overexposed and one underexposed autoradiograph were obtained in order to judge proper exposure and maximal depth of marginal penetration by each isotope.

Each specimen was then examined under a binocular dissecting microscope at 10–40 magnifications to determine the depth of dye penetration.

Penetration by dye or isotope was evaluated as follows: 0 = limited to V-shaped edge of cavosurface angle; 1+ = penetration to less than half of marginal depth; 2+ = penetration to base of cavity; 3+ = penetration into dentin beneath the cavity.

\* Minimax ultra-speed periapical film.
Figs. 1–9.—Left and center columns: radioautographs showing penetration of radioisotopes (S^{35} and Ca^{45}) into margins of Class V amalgam fillings. Right column: hemisections showing marginal penetration of dye (toluidine blue).

Top row shows a control series of teeth stored in moist air for 2 weeks prior to immersion in dye/isotope tracer solutions for 2 weeks. Center row shows the marked reduction in marginal penetration after storage of fillings in sodium sulfide 10 per cent aqueous solution for 2 weeks. Bottom row shows similar reduction in marginal penetration by dye and isotopes after storage in human saliva (changed daily) for 2 weeks.

Solutions: S^{35} = 5 μc; Ca^{45} = 1 μc; toluidine blue 3.8 per cent aqueous solution; storage time in moist air, sodium sulfide or saliva = 2 weeks; immersion time in dye/isotope solutions = 1 week; radioautograph time on Minimax fast dental X-ray film = S^{35} for 2 weeks; Ca^{45} for 96 hours.
The deepest degree of penetration was recorded for each specimen (Table 1). Isotopes were in each case far more penetrating than the dye.

Results

As in previous studies, specimens filled with amalgam and placed immediately into the dye/isotope solution showed penetration of the isotope through the margins and into the underlying dentin in 80 per cent of the specimens examined (Table 1).

**Immersion in Sodium Sulfide Solutions.**—There was a marked reduction in marginal penetration by dye and isotopes in those specimens stored in sodium sulfide solutions for 2 weeks when compared to the controls immersed in the tracers immediately after restoration (Figs. 4–6). All specimens showed less than 2+ penetration, and one-third of the specimens showed no marginal penetration at all by isotope. The reduction in marginal penetration was discernible after immersion in the sulfide solution for 24 hours, and it increased with time of immersion (Table 1). Dye penetration was reduced more than isotope penetration (Fig. 6). Penetration by Ca\textsuperscript{45} was reduced more than that by S\textsuperscript{35} (Figs. 4 and 5).

**Immersion in Saliva.**—There was little reduction in the marginal penetration in the specimens immersed in saliva for 1 hour and for 24 hours. However, specimens which had been immersed in saliva for 2 weeks showed a marked decrease in marginal penetration by both the isotopes and the dye (Table 1 and Figs. 7–9). This decrease was comparable to the effect produced by 2 weeks’ immersion in 10 per cent sodium sulfide solution. All specimens showed less than 2+ penetration, and one-sixth showed no penetration at all by isotopes.

Dye penetration was reduced more than isotope penetration. In this series the penetration of S\textsuperscript{35} was reduced more than that of Ca\textsuperscript{45} (Figs. 7 and 8).

The reduction in marginal penetration after 2 weeks’ storage in saliva or sodium sulfide solution was statistically highly significant when compared to controls stored in distilled water or in moist air (P < 0.001).

**Immersion in Tap Water.**—Storage in tap water for 2 weeks resulted in only a slight decrease in marginal penetration of both dye and isotopes. This reduction was much less than the reduction produced by sodium sulfide solutions or saliva in the same period of time (Table 1).

**Immersion in Distilled Water and Storage in Moist Air.**—Marginal penetration of dye and isotope was not reduced at all after 2 weeks’ storage in distilled water or in moist air. The pattern of penetration was the same as in amalgam restorations which were immersed in dye/isotope solutions immediately after restoration (Table 1).

**Old Amalgam Restorations.**—A marked reduction in the marginal penetration of isotope/dye solution was observed in the twenty amalgam restorations which had been in service in the mouth for more than 6 months and did not show any recurrent marginal decay. None of these specimens showed any penetration of dye or isotope deeper than one-half the depth of the margin (1+).

Discussion

This study showed that the marginal interface between the amalgam filling and the dentin can be blocked against the ingress of dyes and isotopes by chemical action of sodium sulfide solutions and by saliva. The decrease in the marginal penetration of isotopes and dyes after a 2-week immersion of the amalgam restorations in sodium sulfide...
solution or saliva was comparable with the decrease in marginal penetration observed in a series of which twenty clinically satisfactory amalgam restorations which had been in service in the mouth for long periods of time. This observation is supported by the work of Stowell, Taylor, and Wainwright, who have also observed that after 2 weeks or more in saliva, amalgam restorations showed a marked reduction in marginal penetration by I\(^{131}\). Reduction of marginal penetration was also noted by Swartz and Phillips in vitro and in vivo.\(^8,9\) Although Ca\(^{4+}\) penetrated completely around all restorations less than 48 hours old, leakage was markedly reduced in specimens that were 1 month old. Swartz and Phillips have reported a definite correlation between their in vivo and in vitro studies.

This study supports the observation that the margins of amalgam restorations may become impervious to the penetration of isotopes and dyes in a relatively short time and that, as Stowell et al. have suggested "the first one or two weeks following the placement of an amalgam restoration might be the danger period when penetration into the underlying tooth structure is likely to occur."\(^10\)

**Summary**

The effect of storage in saliva and sodium sulfide solution on the marginal penetration of amalgam restoration by isotopes and dyes was investigated. A marked decrease in marginal penetration was observed after 2 weeks' storage in saliva or sodium sulfide solution. This reduction in marginal penetration was similar to that observed in amalgam restorations placed in vivo at least 6 months prior to extraction and immersion in dye/isotope solutions.

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**References**