Absorption of Fluoride Following Inhalation and Ingestion of Alginate Impression Materials

F. HATTAB, B.D.S.

The fluoride (F) contents of ten alginate impression materials in powder form, were found to range from 0.44% to 2.42%. Plasma F concentrations showed no appreciable changes in five dental personnel exposed to aerosols of these powders during routine clinical work. Elevated plasma F levels (120–158 ng/ml) were recorded after ingesting 2 g (=10 mg F) of Zelgan® normal-set alginate. The bioavailability of F from the alginate was about 55% of the total F in the administered dose. It is concluded that routine clinical exposure to alginate does not cause any important change in plasma F levels, whereas accidental swallowing of alginate raises the plasma F level significantly.

INTRODUCTION

During the last decade, increasing attention has been given to the potential health hazards encountered in connection with the use of certain dental materials. Investigations have been conducted to determine the lead (Pb) contents of different alginate materials2-3 and its absorption by the blood via inhalation.2-4 The high fluoride (F) contents of alginate impression materials and its transfer to the teeth, saliva, and blood after impression-taking has been studied recently5-7. However, the amount of F in an alginate material that may be absorbed if inhaled or ingested has not yet been fully investigated.

According to the manufacturer’s instructions, the tin containing the alginate should be shaken before dispensing in order to loosen and fluff the powder. Vigorous spatulation is also recommended to ensure homogeneous mixing. Consequently alginate dust is commonly observed when opening the container after shaking or during spatulation.

The purpose of this study was to determine whether airborne alginate powder significantly alters the plasma F levels of dental personnel handling the material. A further object was to estimate the amount of F absorbed following ingestion of the material. The F contents of various alginate products was also determined.

MATERIALS AND METHODS

Experiment 1. Inhalation of F from Alginate Powder
Five dental personnel between 24 to 35 years of age volunteered for two trials. They were asked to refrain from eating and drinking F-rich items or using fluoridated dentifrices on the day of the exper-

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incent and that immediately prior to it. All subjects studied were residents of communities where the public water supply had a low F content (0.2 ppm).

Trial A. Three dental nurses, familiar with handling alginate materials, were instructed to use De Trey's Zelgan® and Surgident® alginate powders during an ordinary working day.

Trial B. Two dental personnel aged 35 years were instructed to shake a Zelgan® container twice for 30 seconds during a 15 minute intensive working session including preparation of several impressions.

Blood samples were collected before and after the start of the experiment to determine baseline plasma F levels for each participant. In Trial A subsequent samples were taken at 12 A.M. and 5 P.M. on the day of the experiment and at 8 A.M. on the following day. In Trial B blood samples were collected 5, 15, 30 and 60 minutes after the end of the working session.

Sample Collection and F Determination

Fingertip capillary blood samples were drawn using an automatic pipette and disposable polypropylene tips (Gilson). The tips were washed several times with deionized water and then dried. The blood samples were then transferred to polyethylene microcentrifuge tubes prewashed with deionized water and treated with 5 µl F-free heparin. They were then centrifuged for 2 min. at 12000 g. The plasma F concentration was determined using a combination F selective electrodes (Orion model 96-09), and digital pH/mV meter (Orion model 801A). Prior to analysis a 10% acetate buffer (7.5M, pH 5.2) containing 2% CDTA was added to the standard and samples. The “known addition method” was used for samples containing low F concentrations in order to verify direct measurements.6,9

The total F contents of the alginate powders was assayed using the diffusion technique with some modifications.6

Experiment 2. Absorption of F from Alginate Material

Four healthy volunteers between 26 to 35 years of age, participated in this study. The subjects lived in areas with low F water supplies (0.2 ppm). Instructions similar to those given prior participants were in force. The urinary F output was determined for each subject during the 24-hour control period as well as throughout the 24-hours following ingestion of the alginate.

After overnight fasting each subject ingested 2 g of Zelgan® alginate (~10 mg F), which had been cut into 4 small pieces and swallowed with 250 ml of tap water (0.25 ppm F). Prior to this a blood sample was taken to determine the background level of plasma F. Thereafter a series of capillary blood samples was taken at intervals of 0.25, 0.50, 0.75, 1, 1.5, 2, 3, 5, 7, 9 and 18 hours after ingestion of the alginate. On a separate occasion 3 mg F (as NaF) in a aqueous solution was given to 3 of the subjects. Urine and blood samples were subsequently collected and analysed for F as above. No food was given during the first 3 hours of the experiment.

Estimation of the Relative Bioavailability of F from Alginate

The plasma data was treated according to a one-compartment model. The area under the plasma concentration-time curve (AUC, hr/mg/ml) was estimated according to the trapezoidal rule11 from zero time to 18 hours. All pharmacokinetic calculations were based on net concentrations, i.e., registered total minus the background value at each time interval. The relative apparent bioavailability of F from the ingested alginate was calculated from the plasma and urine data.11 This was done by comparing the area under plasma concentration-time curve (AUC 0-18 hr) and the total amount of F excreted in urine (Xu 0-24 hr) of the ingested alginate to that found after the orally administered standard.

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Experiment 3. Diffusion of F from Alginate in Vitro
Four alginate powders containing between 5.4 to 22.0 mg/g F were mixed with water according to the manufacturer’s instructions. The mix was then introduced into a plastic cup (2 cm diameter) for 5 minutes. For each alginate, three samples corresponding to approximately 10 mg F were submerged in separate beakers containing 100 ml of deionized water or 0.1N HCl. The beakers were agitated continuously at 90 rpm and at room temperature. Aliquots were taken after successive time intervals up to 48 hours. The F concentration in the aliquots was measured directly using the F electrode calibrated with appropriate standard solutions.

RESULTS
Table I shows the F contents of various products of alginate powder. The range was 0.44% to 2.42% F (4.4 – 24.2 mg/g).

Table I. The F Concentration in Different Alginate Impression Powders.

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer and Country of Origin</th>
<th>Concentration (mg/g)</th>
<th>Mean ± SD</th>
<th>n^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi-Technicol</td>
<td>GC Dental Industrial Corp., Japan</td>
<td>4.4 ± 0.09</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Xantogal</td>
<td>Bayer, West Germany</td>
<td>5.2 ± 0.19</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Orthogel</td>
<td>Dentaurum, West Germany</td>
<td>5.4 ± 0.47</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Kerr</td>
<td>Kerr Sybron Corp., USA</td>
<td>14.6 ± 0.71</td>
<td>4^b</td>
<td></td>
</tr>
<tr>
<td>Aligraf</td>
<td>Svedia, Sweden</td>
<td>15.7 ± 0.25</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Algicap(pink)</td>
<td>Ivoclar, Liechtenstein</td>
<td>17.9 ± 1.05</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Algicap(green)</td>
<td>&quot; &quot;</td>
<td>19.2 ± 1.11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Zelgan</td>
<td>Amalgamated Dental, England</td>
<td>18.7 ± 1.08</td>
<td>4^b</td>
<td></td>
</tr>
<tr>
<td>Surgident</td>
<td>Lactona, USA</td>
<td>22.0 ± 0.66</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SR-Ivopal</td>
<td>Ivoclar, Liechtenstein</td>
<td>24.2 ± 0.83</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

a= number of analyses
^b= Hrnab & Frosten 2,5

Experiment 1.
In Trials A and B the plasma F concentrations obtained directly from the calibration curve were between 10 to 17 ng/mL and when determined by the known addition technique they were 9.18 ng/mL. The number of alginate impressions mixed by the subjects during a normal day was seven to 14.

Experiment 2.
Figures 1 and 2 show that plasma peak levels of 120 to 155 ng/mL were obtained 0.5 to two hours after ingestion of the alginate (Fig.1), whereas peak levels of 140 to 176 mg/mL appeared within 30 minutes following ingestion of 3 mg F as NaF in an aqueous solution (Fig.2). The ingestion of alginate showed a tendency towards prolonged F profile curves, however, when compared with aqueous NaF (Figs.1 and 2).
<table>
<thead>
<tr>
<th>Subject</th>
<th>Body weight (kg)</th>
<th>2 g Alginic</th>
<th>3 mg F</th>
<th>Bioavailability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AUC&lt;sub&gt;a&lt;/sub&gt; 0-18hr (hr/mg/ml&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>Xu&lt;sub&gt;b&lt;/sub&gt; 0-24hr (µg F)</td>
<td>% of dose excreted</td>
</tr>
<tr>
<td>M.B.</td>
<td>58</td>
<td>728</td>
<td>2044</td>
<td>20.4</td>
</tr>
<tr>
<td>F.H.</td>
<td>59</td>
<td>622</td>
<td>1682</td>
<td>16.8</td>
</tr>
<tr>
<td>S.S.</td>
<td>61</td>
<td>315</td>
<td>2110</td>
<td>21.1</td>
</tr>
<tr>
<td>J.J.</td>
<td>70</td>
<td>979</td>
<td>3600</td>
<td>36.0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>661</td>
<td>2359</td>
<td>23.6</td>
</tr>
<tr>
<td>± SD</td>
<td></td>
<td>275</td>
<td>848</td>
<td>8.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Area under the plasma concentration from zero time to 18 hr.

<sup>b</sup> Total net F excreted from zero time to 24 hr.
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DISCUSSION

This study shows that the F concentrations in alginate impression powders is high, and that there is considerable variability between products. F salts are added to alginate powders in order to assure a hard, dense stone surface and to act as accelerators for the setting gypsum products. Plasma F concentrations determined during and after a working day or intensive working session are within the normal physiological range, i.e., 10 to 20 mg/ml. The other hand, F levels in plasma increased by an average of ten times the baseline values one half to two hours after the ingestion of alginate. The difference between inhalation and ingestion of alginate is due to the small amounts of F consumed by inhalation. However, de Freitas has raised the possibility of a hazardous effect of F inhaled with alginate aerosol. This was not the case as judged from the plasma F concentrations.

Recently, Whitford and Ekstrand have reported that the rate of F diffusion from alginate into 0.1 N HCl is approximately ten times greater than into water. The figures actually given, after 48 hours diffusion, were 0.50 mg F leached into water and 3.3 mg F into 0.1 N HCl. This would indicate a ratio of only 6.6. Current in vitro findings indicate that the F diffused into water from the various products is somewhat more than twice that reported by Whitford and Ekstrand who tested one product. The present study indicates that the F present in alginate material has a toxic effect on the health of dental personnel exposed to the inhalation of aerosols arising from alginate powder. On the other hand, accidental ingestion of alginate material might raise the plasma F level significantly. The current data supports previous findings that part of the F existing in alginates may readily be released and absorbed by the body fluids.

The ADA specifications for alginate impression materials states that these should not be harmful to human beings in the event of accidental ingestion of up to 10 ml. According to our findings, ingesting of 10 ml (= 11 g) alginate material could expose the human body to as much as 54 mg F in the case of Zetaplus and 70 mg F in the case of Ivoclar. Such doses might cause side effects, especially in children. It is therefore recommended that the manufacturers declare the F content of their alginate products. Furthermore, revaluation of the standard for these materials is advisable.

ACKNOWLEDGEMENT

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REFERENCES