

# 1767. Determination of Fluoride Penetration in Enamel by Dynamic-SIMS

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## Introduction

Dynamic secondary ion mass spectrometry (D-SIMS) is a semi-quantitative technique that allows determination of elemental depth profiles and chemical maps of materials. This technique has previously been used to investigate changes in the composition of dental hard tissues with depth and after treatment<sup>1-3</sup>.

Penetration ranges from a few nanometers to several hundred microns are obtainable, from analysis areas of a few micrometers to 0.5 mm. Detection sensitivity is typically in the parts per billion range for the fluoride ion.

## Objective

To examine fluoride incorporation into human enamel erosive lesions using D-SIMS, following treatment with a series of commercially available dentifrices containing different fluoride sources.

## Methods

Experiments were performed using acrylic resin-embedded polished human enamel specimens (~2 x 2 mm). Artificial erosive lesions were generated in the enamel via a 5-minute exposure to 1% w/v citric acid (pH 3.8). The lesions were then treated for 2 minutes with one of five agitated slurries (1:3 paste:deionized water), preformed from commercially available dentifrices. Three of the five toothpastes investigated contained sodium fluoride (NaF). Paste 1 was an anticaries paste containing 1350 ppm fluoride, paste 2 contained sodium pyrophosphate plus 1450 ppm fluoride, paste 3 contained 5% potassium nitrate (KNO<sub>3</sub>) plus 1450 ppm fluoride, paste 4 contained stannous fluoride (SnF<sub>2</sub>, 1100 ppm fluoride), and paste 5 contained amine fluoride (AmF, 1250 ppm fluoride). Each treatment was performed on two individual enamel specimens, and six areas of each specimen were imaged.

D-SIMS analysis was carried out using a CAMECA ims 4f mass spectrometer. A 15 KeV O<sub>2</sub><sup>+</sup> beam was used for D-SIMS imaging of samples from 200 x 200 μm and 70 x 70 μm areas of the cross-section of the specimens.

## Results

- D-SIMS cross-sectional imaging of enamel treated with either paste 1 or 3 (NaF or NaF plus KNO<sub>3</sub>) revealed a continuous 8–10 μm thick fluoride-rich surface layer (Figure 1).

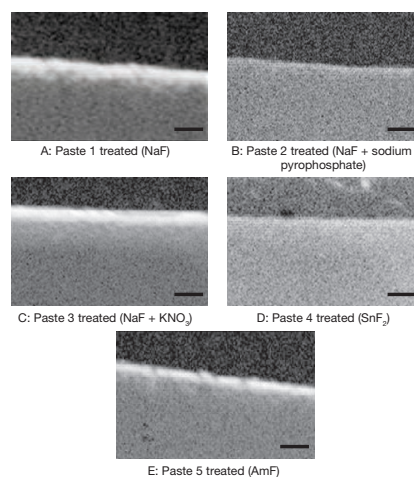


Figure 1. D-SIMS images of human enamel treated with toothpaste slurries (scale bar = 10 μm). AmF, amine fluoride; KNO<sub>3</sub>, potassium nitrate; NaF, sodium fluoride; SnF<sub>2</sub>, stannous fluoride.

- Enamel treated with pastes 2, 4, and 5 (NaF plus sodium pyrophosphate, SnF<sub>2</sub>, and AmF, respectively) resulted in the formation of fluoride-rich surface layers penetrating 3–4 μm, 3–5 μm, and 5–7 μm below the surface, respectively. This variation in fluoride with depth is displayed graphically via line scans (Figure 2) extracted from the images in Figure 1. The <sup>19</sup>F<sup>-</sup> profile for each treatment is compared with the <sup>31</sup>P<sup>-</sup> profile in each case.
- The fluoride source contained in toothpaste 4 is SnF<sub>2</sub>. Figure 2 also shows D-SIMS depth profiles for <sup>120</sup>Sn<sup>+</sup> and <sup>40</sup>Ca<sup>+</sup> ions from the enamel treated with toothpaste 4. This profile suggests that there is a degree of tin incorporation into the enamel above 40 μm after treatment with this toothpaste.

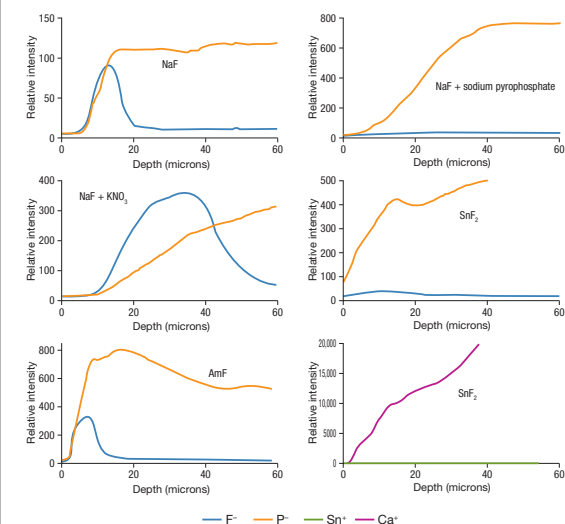


Figure 2. D-SIMS line scans for enamel treated with toothpastes. AmF, amine fluoride; KNO<sub>3</sub>, potassium nitrate; NaF, sodium fluoride; SnF<sub>2</sub>, stannous fluoride.

## Conclusions

- This D-SIMS study demonstrates that treatment of human enamel erosive lesions with fluoride-containing toothpastes leads to penetration of fluoride into the surface of the enamel.
- Fluoride penetration was 40–150% greater for the pastes containing NaF alone or NaF and KNO<sub>3</sub>, compared with those based on AmF, SnF<sub>2</sub>, or NaF plus sodium pyrophosphate.

## References

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