Elemental Imaging of Teeth Samples with LA-ICP-MS

Introduction

Trace element distribution in teeth offers a unique window into metal exposure during early development. Unlocking this information requires advanced analytical techniques. One such method—**Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)**—has proven to be a game-changer in elemental analysis of solid biological samples. LA-ICP-MS combines high sensitivity, broad elemental range, and excellent spatial resolution. It enables not only precise quantification but also **depth profiling and 2D/3D elemental mapping**, making it ideal for bioimaging applications. Over the past two decades, this technique has gained significant traction in fields like **toxicology, environmental exposure studies, and archaeological science**.

To further enhance the accuracy of LA-ICP-MS in dental analysis, **hydroxyapatite (HA) calibration standards doped with trace metals** have been successfully developed and applied. These standards mimic the mineral matrix of teeth, ensuring reliable quantitative results.

In this report, we showcase our workflow for the **development of multi-element HA calibration standards** and demonstrate their application in the **bioimaging of trace elements in deciduous teeth samples** using LA-ICP-MS.

All analyses were carried out using a **Teledyne Iridia 193 nm excimer laser** system with a **Cobalt ablation cell**, integrated with an **Agilent 8800 triple quadrupole ICP-MS (ICP-QQQ-MS)**. Elemental imaging and quantitative data—including calibration curves, detection limits, and quantification thresholds—were processed using **HDIP Software**.

Quantification of the analyte elements in the HA standards

We used **acid digestion followed by solution ICP-MS** to determine the concentrations of key analytes and calcium in our HA calibration standards. These results (Table 1) confirm the successful incorporation of multiple elements at target levels, forming a robust foundation for quantitative bioimaging.

STDS	Ca (%)	Mn (µg g^{-1})	As (µg g^{-1})	Cd (µg g^{-1})	Ba (µg g^{-1})	Pb (µg g^{-1})
Blank	37.31	0.16	0.00	0.00	0.13	0.00
STD1	36.08	1.32	1.54	1.28	1.20	1.21
STD2	35.08	2.55	2.59	2.49	1.99	2.34
STD3	36.08	6.82	6.66	6.36	5.29	6.26
STD4	34.99	13.88	13.29	12.69	10.44	12.74
STD5	35.03	28.63	27.40	25.63	20.99	26.25

Homogeneity of HA Standards

The homogeneity of each HA standard was verified via LA-ICP-MS imaging. As shown in **Figure 1**, the trace elements were **evenly distributed throughout the material**, confirming the reliability of the standards for accurate, reproducible analysis.

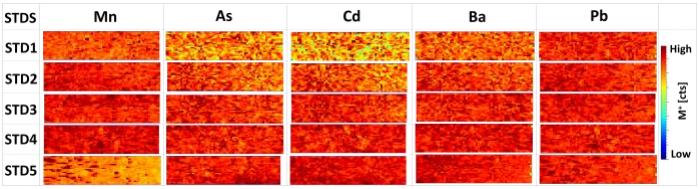

Figure 1. Homogeneity of HA standards.

Calibration and Sensitivity

Calibration data demonstrate strong linear response and excellent sensitivity across all targeted elements, reinforcing the effectiveness of our calibration approach.

Element	Calibration Curve Equation	R^2	RSD, %	LOD*, µg g^{-1}	LOQ*, µg g^{-1}
^{55}Mn	y = 365.4x + 107.2	0.9997	1.5	0.07	0.24
^{75}As	y = 42.0x + 5.6	0.9998	1.8	0.19	0.63
^{114}Cd	y = 39.7x – 1.9	0.9994	2.8	0.36	1.20
^{202}Ba	y = 74.8x + 6.0	0.9999	0.9	0.05	0.15
^{208}Pb	y = 274.1x + 75.0	0.9997	2.1	0.02	0.07

*LOD and LOQ values were calculated for a single pixel.

Bioimaging of Trace Elements in Deciduous Teeth

Using our HA calibration standards, we analyzed two cross-sections of deciduous teeth with LA-ICP-MS. The resulting images show the spatial distribution of lead (Pb), manganese (Mn), and barium (Ba) across the samples. These bioimaging results, illustrated in Figure 2 (Section 1) and Figure 3 (Section 2), highlight the power of our platform for tracking elemental exposure over time.

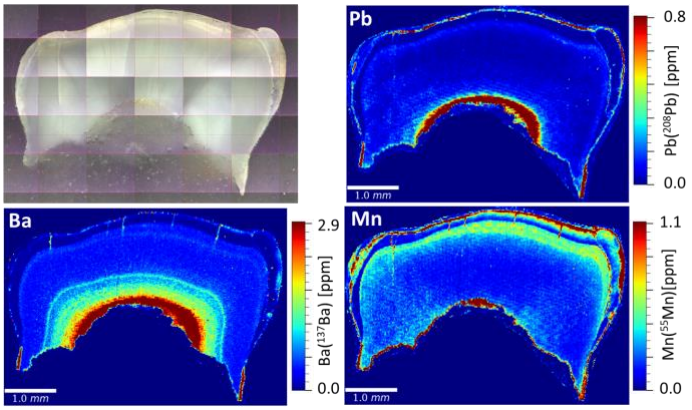

Figure 2. Quantified element distribution in the section 1.

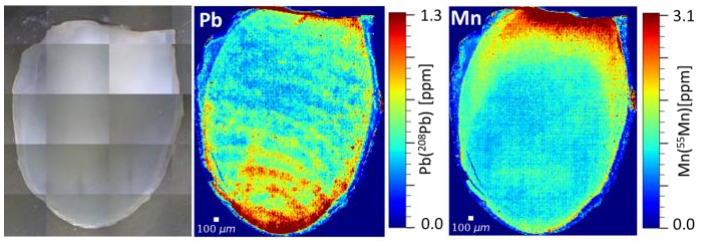

Figure 3. Quantified element distribution in the section 2.

Our integrated LA-ICP-MS workflow, supported by meticulously prepared multi-element HA calibration standards, delivers highly detailed, quantitative elemental maps of teeth. This capability is opening new doors for biomedical research, public health, and heritage science, offering a precise method to assess historical and environmental exposure at a biological level.