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Trace Element Analysis of Human Tooth Enamel by LA-ICP-MS for Estimating Region of Origin

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Abstract

Tooth enamel is among the most durable substrates in the human body and as such has high recoverability in forensic anthropology cases. Its crystalline hydroxyapatite matrix has a slightly variable chemical composition which incorporates biologically available trace elements. The trace elements are derived from a diet and the water he or she consumes during the period of enamel formation. As a result, trace element profiles of enamel can reflect the geology, pollution, and certain cultural dietary factors of the area in which they resided during this period.

This research examines a sample of teeth with known demographic information from the Antioquia Modern Skeletal Reference Collection in Medellín, Colombia. A sample set of 75 teeth from 61 individuals born in areas throughout southwestern Colombia were analyzed using laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS), a minimally destructive, semi-quantitative technique. Analysis was performed at the Center for Archaeology, Materials, and Applied Spectroscopy (CAMAS) at Idaho State University.

33 elements were analyzed in the sample. Nonparametric methods were used to assess the relationship between elemental profiles and region of origin. Sr, Mo, Ag, Ba, Eu, and Tm concentration profiles were found to vary among regional groups. Al, Ni, Cr, Mn, Co, Sb, Sr, Sm, Eu, and U were found to predict region of origin. Differences in municipality were classified with 72% accuracy, variation across the department of Antioquia was classified with 67% accuracy, and the age of the geologic substrate was classified with 67% accuracy. The results suggest that trace element analysis of permanent tooth enamel may be of some use in estimating an individual’s region of origin in forensic anthropological contexts. Further research with both larger sample sizes and more geographic variation is necessary.

Methods

To test whether viable laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) data could be generated with minimal preparation, whole teeth were temporarily mounted in malleable clay and placed into the laser ablation sample chamber. 5 sample sites were placed along the longitudinal axis of each tooth. Rasters 600 µm long perpendicular to the axis were placed 0.5 mm apart. A 200 µm in diameter pass removed surface contamination, while the ablation pass was 100 µm in diameter within this pattern.

6 NIST standard glass samples with known concentrations across a wide range were used to calibrate intensity counts per second (cps) to parts per million (ppm). Ru and Ti were used as liquid internal standards to ensure instrument operation during sampling. Ca values for each sampling site were standardized to a stoichiometric estimate of Ca concentration in hydroxyapatite in order to account for matrix suppression effects.

Results

Municipality

• Samples are divided into “Medellin” (n=31) and “Not Medellin” (n=30). Medellin individuals should be more similar both geologically and culturally than other individuals.
• A Shapiro-Wilk test of normality (α=0.05) shows that only 8% of the elemental data are normally distributed so nonparametric statistics are used. The Kruskal-Wallis test (α=0.05) demonstrates that Sr, Mo, Ag, and Ba do not have the same median and distribution.
• A logistic regression (α(1)=0.05) uses Ca and Sr to classify municipality category with 72% accuracy.

Region

• Samples from the Antioquia department are divided into East (n=11), Metropolitan (n=32), and West (n=12) categories.
• The Shapiro-Wilk test of normality (α=0.05) shows that 29% of the data are normally distributed; nonparametric statistics are used. The Kruskal-Wallis test (α=0.01) shows that Mo, Ag, and Tm do not have the same median and distribution.
• Logistic regressions (α(1)=0.05) use Cr, Mn, Ni, Cd, Sr, and U to classify region with 67% accuracy.

Geology

• Samples are categorized based on the age of the underlying geological substrate. The categories are Pre-Cambrian Unidentified Igneous (n=33), Paleozoic (n=7), Mesozoic (n=13), and Cenozoic (n=6).
• The Shapiro-Wilk test of normality (α=0.05) shows that 34% of the elemental data are normally distributed. Nonparametric statistics are used. The Kruskal-Wallis test (α=0.01) demonstrates that Ba, Sr, and Tm do not have the same median and distribution.
• Logistic regressions (α(1)=0.05) use Cr, Mn, Ni, Cd, Sr, and U to classify geology with 67% accuracy.

Discussion and Conclusions

Trace Element Findings

• Region of origin is best predicted by elements that are primarily geological in origin.
• Medellin individuals, with shared geological and cultural characteristics, are most distinguishable.

Confounding Factors

• Human error including mislabeling during excavation, collection acquisition, or previous sampling or inaccurate recording of demographic information.
• Sampling error including contamination.
• Extreme concentration values due to individual metabolic differences, dietary variation, contamination from food preparation techniques, or effects of dental restorations.

Comparison to Sr Isotope Analysis

• Samples were previously subjected to Sr isotope analysis (Row 2012 – MS thesis, Boston University).
• Both Medellin/Non-Medellin and Antioquia/Non-Antioquia were found to have the same median and distribution at α=0.05 using a Mann-Whitney U test. No classifications could be made.
• Trace elements are more sensitive to minor geographic variation than Sr isotopes and offer greater potential for effective region of origin estimation.

Future Research

• Examine larger sample sizes with more geographic variation.
• Control data for such factors as tooth type, sex, age at death, and postmortem interval/conditions.
• Examine effects of diet, salivary contamination vs. blood transport of elements, and elemental distribution along the growth axis.

References available upon request.