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Isotopes in Teeth- A Novel Forensic Tool for Identification

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Abstract:

Mass disasters and cases involving heinous crimes always pose a great challenge to the medico-legal experts. The traditional tools of personal identification methods that involve fingerprint analysis, DNA profiles, dentition and radiographs though highly effective in identification process rely on having ante-mortem records for comparison with the post-mortem data. Isotope analysis has its application in the study of ecological, geological and hydrological specimens. Isotope techniques are now being employed in forensic cases whereby investigators try to measure differences in isotopic fingerprints found within human remains. This article highlights the role of isotopes for provenancing human remains thereby resolving medico-legal cases with primary focus on teeth as a resilient specimen available.

***Keywords**: Isotopes, Forensic analysis, Identification, Skeletal Remains, Tooth Enamel*

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Introduction

Police and medicolegal experts worldwide face a huge challenge in terms of identification of unknown bodies due to mounting pressure from the judicial, civil and societal bodies. Eventually such bodies are identified by comparative analysis of post-mortem data with the available antemortem data based on dental or medical radiographs, DNA profiles along with the presence of other personal identification features such as (birthmarks, surgical scars etc.)

The application of these traditional tools of identification prove to be inconclusive in cases where a victim's body is decomposed or deliberately mutilated. In such cases investigators have to rely on the missing person's registry for possible matches. Acquiring additional information in the form of year of birth, gender along with models that predict residential patterns of inhabitants would assist forensic experts in their identification work. Age changes in teeth and bone form the basis of age estimation methods adopted by anthropologists when it comes to examination of skeletonized bodies, however these methods that predict age generally have an accuracy rate of around ±10 years, and would estimate age only at death. Aspartic acid racemization methods were thus developed that predicted age at a fairly good precision **(Alkass *et al.*, 2013).**

However, the aforementioned age estimation methods being temperature dependent fail in cases of fire charred victims, also since these methods predict age at death they are of limited value in cases of burnt or mutilated bodies **(Alkass *et al.*, 2011).**

Investigators thus have to look out for additional techniques (isotope analysis of human tissues- hair, nails tooth enamel) which rely on reconstructing models that will predict the life history of the deceased (based on geographic origin and socioeconomic factors) and thus aid in establishing the identity of the deceased.

Basic Principles of Isotopes

Sir Frederick Soddy coined the term isotope in the year 1913. In the periodic table all isotopes of an element occupy the same positions. The atomic number of an element is determined by the protons and electrons present in the nucleus of that particular element. The stable isotope form of any element consists of a majority of one isotope along with a minor percentage of its form e.g.: Carbon element comprises 98.89% of 12C while the remaining 1% consists of the stable isotope form of 13C **(Bartelink and Chesson, 2019).**

Iso-Scape Models

Stable isotopes can predict the life history of any unidentified decedent by evaluating the isotope compositions in various natural systems, for understanding the biological and associated geological processes with subsequent generation of predictive models.

These predictive models generate "iso-scapes" that can be used for predicting the origin of ecological and geological samples. Isotopic data thus generated provides a framework from which it is possible to reconstruct residential patterns/geographic regions of origin of an individual based on their isotopic signatures (bone, teeth, hair and nails). The isotopic fingerprint along with the biological information from the skeleton and the epigenetic fingerprint will help investigators in establishing the victim's identity in consideration **(Dotsika, 2018).**

Bio-Elements

The five bio-elements and their isotopes chiefly hydrogen, carbon, nitrogen, oxygen and Sulphur that constitute most of the body tissues of the organisms are analyzed for forensic studies. Strontium and lead isotopes are also being analyzed in forensic cases **(Bartelink and Chesson, 2019).**

Isotope Techniques

The isotope ratios are analyzed using IRMS technique (isotope ratio mass spectrometry). Initially there is thermal conversion of any sample into its simple gases i.e. (H as H2 and C as CO2, N as N2, O as CO2 and S as SO2 using an elemental analyzer EA. This step is followed by ionization, separation and quantification of the ions in the mass spectrometer via the interface.
The gases nitrogen carbon dioxide and sulphur dioxide are produced by combustion using an EA while hydrogen and carbon monoxide gases are produced using a high-temperature conversion (HTC) or pyrolysis plus EA. Isotope ratio infrared spectroscopy (IRIS) is a newer method for isotope analysis that involves estimating the isotope ratios based on the characteristic absorption of light by the differing isotopologues of gases **(Bartelink and Chesson, 2019).**

Human Tissues for Isotope Studies

Isotope ratios can be generated for different types of human tissues; however forensic science application is generally limited by the availability of tissues at the site, along with the uniqueness associated with each case. The "snapshot of time" rep resented by each tissue varies e.g. (diet patterns and geographic locations) are represented by bone. Teeth reflect (childhood diet and residence) whereas nails and hair highlight on the (recent travel history) of the decedent. Although human hair and nail samples are very important to investigators, in long-standing and unidentified cases these structures are not well-preserved leaving only the rigid tissues in the form of teeth and bone as the available specimens for analysis **(Bartelink and Chesson, 2019).**

Bone and Teeth Samples

Bio apatite crystals are carbonate and phosphate fractions that are usually analyzed for isotope studies. Collagen in the bone tissue contains carbon isotopes that reflect only the dietary protein component of the diet, in contrast to bio appetite crystals that reflect the whole diet consisting of (carbohydrates, proteins and lipids).The oxygen isotopes present in the carbonate fraction of the bio appetite crystals reflect the residence patterns during the early phase of tissue formation that is attributed to the strong relationship that exists between the water ingested by an individual and the oxygen isotope ratios of carbonate and phosphate minerals **(Bartelink and Chesson, 2019; Dotsika, 2018).** Bone tissue undergoes constant remodeling throughout life at different rates; in contrast teeth are dense and static tissue, which once formed undergoes no post-mineralization remodeling nor has any elemental exchange with its environment. Enamel maintains its original elemental signatures encoded during mineralization. Thus, lack of remodeling and the miniature archival quality of teeth makes it the biomaterial of choice for elemental isotopic analysis. Digenesis affects bone more severely than enamel or dentin because of its increased porosity. Teeth are under strict genetic constraints governing their development hence they are less sensitive to any sort of external environmental changes and poor nutrition along with prolonged illness; both of which affect the completed length and form of bony structures **(Hammerl, 2013).**

Isotope Bio-Elements in Victim Identification

Dietary pattern of an individual can be predicted by the isotope analysis of carbon and nitrogen elements whereas the birthplace of an individual can be traced by the oxygen and strontium isotope analysis. 12C and 13C Carbon isotopes are assimilated by plants in the process of photosynthesis. Carbon isotopes get integrated into the organic collagen and the inorganic component of hydroxyapatite crystals of mineralized tissues as a result of consumption of these plants by animals that feed on them. Analysis of the carbon isotope ratios from samples of bone and teeth help to predict the nature of diet of an individual (herbivorous along with predominant composition of the diet in the form of specific crops) **(Radhakrishnan, 2011).** Studies have also highlighted that estimating 13C values can help to predict the geographic origin of an individual and thus obtained data could help in forensic identification work **(Alkass *et al.*, 2011).**

Nitrogen

15N and 14N nitrogen isotope ratios that are analyzed from the collagen tissues in bone and teeth can reveal important dietary information regarding an individual. In humans estimating the 15N values of structural proteins in bone and dentin tissue reflects the relative levels of meat protein in the diet. Thus, reduced 15N values could categorize the individual to be a vegan.

Oxygen

The naturally occurring isotope forms of oxygen i.e. (16O, 17O and 18O) are analyzed in forensic studies. In humans' oxygen gets incorporated into the body basically through drinking water that in turn gets integrated into the mineralized tissue (e.g., bone and teeth) **(Radhakrishnan, 2011).** There exists a linear correlation between the oxygen composition of the environmental water and to the ingested water by an individual.

Different regions have distinct oxygen isotope signatures that is based on the climatic conditions that prevail there. Thus, once integrated into the body tissue they create a unique location tracer within the living organism. Tooth enamel being a highly stable and static tissue, resistant to post-depositional processes, diagenic resistance makes it a valuable biomaterial for oxygen isotope analysis that can aid in determining the geographic location of an individual based on its oxygen isotopic signatures.

Strontium

Strontium isotope ratio estimated from human tissues correlate with the strontium isotopes of a particular geological system with subsequent transfer of strontium into the surrounding ecosystem **(Chesson, *et al.*, 2018).** Thus, the strontium isotope estimates of bone and teeth reflect the region inhabited by an individual. Strontium isotopes namely 87S and 86S are analyzed in forensic studies. During early phases of tooth formation ingested strontium readily substitutes for calcium in the inorganic hydroxyapatite crystals forming an immobile structure. Since strontium is processed through the food chain strontium isotopes measured in the teeth highlight the average strontium ingested during childhood **(Radhakrishnan, 2011).**

Isotope Analysis in Forensic Sciences

Keyoner *et al.* (2013) analyzed the 87Sr and 86Sr ratios of tooth apatite and bone tissue from bodies buried at Harappa cemetery in Pakistan and Ur cemetery in Mesopotamia. They found a substantial variation in Sr values of Harappan individuals, probably suggesting a foreign place of origin in contrast to individuals buried at Ur, who displayed minimal variation in Sr values suggesting a local origin. Alkass demonstrated that 14C isotope studies on teeth predict the year of birth of individuals with a minimal error of 1.8±1.3 years that is similar to other studies in literature **(Alkass *et al.*, 2013; Spalding *et al.*, 2005; Alkass *et al.*, 2011; Alkass *et al.*, 2010).** The isotope studies conducted by Nicholas **Herrmann *et al.* (2013)** along with several other forensic studies concluded that dental enamel 18O isotope values emphasize on the birth location of an individual whereas; hydrogen isotope values estimated from the hair keratin help in determining the location of death.

Conclusion

Isotope and elemental characteristics of biomaterials such as bone, teeth and hair are proving to be promising investigative tools for forensic investigators; in addition to the traditional methods of identification. Nationally and internationally agreed and validated protocols need to be formulated for the preparation and analysis of human remains. The Indian peninsula is widespread with varied geographical and environmental features. Isotope studies on teeth have yet to gain momentum in India. The available infrastructures for isotope studies are limited to geological, oceanological and archaeological specimens **(Mahajan and Sathe, 2020)**. Signatures of tissues other than teeth keep changing. This article highlights the significance of teeth in isotope studies as a tool for investigators since teeth preserve the record of our birthplace even after death.

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