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Dental Anthropology in deciphering the ancestral background: A practical approach

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ABSTRACT-

The dental-facial complex is made up of three different types of tissues: skeletal tissues, soft tissues, and dental tissues. The components of the dental tissues like enamel, dentine, cementum, pulp, and gingiva have significant contributions to forensic science and thus have led to the evolution of a branch called 'Forensic Odontology'. The dental tissues, the tooth, and dentition as a whole are also well demonstrated in forensic odontology domains like age estimation, human identification, sex identification, ancestry or ethnicity determination, bitemark analysis, crime scene investigations, etc. As there is a strong genetic influence on tooth development and tooth morphology, dental traits may be used as a proxy for genetic materials. The expression of dental traits in a population is usually expressed in terms of frequencies. A huge database of dental traits' frequencies from different biogeographical clusters is available in the scientific literature. They are being used as reference data for comparison in dental anthropology studies. The present article highlights the role of dental non-metric traits in ancestry determination. A practical step-by-step approach to use the rASUDAS web-based application to assess the ancestry using dental traits is described here.

Keywords: Dental Anthropology, population genetics, dental crown non-metric traits, ancestry, ethnicity, forensic odontology.

Introduction

In Forensic science, forensic profiling plays an integral part in the human identification process. Parameters like age, sex, and ancestry are some of the important components of forensic profiling. There are both genotypic and phenotypic variations among human populations based on their geographic locations.[1] Genetic studies have shown interindividual variations within populations account for nearly 93-95% of genetic variation, while the difference among major population groups accounts for only 3-5%.[2] Genetic studies involving a set of 55 ancestry informative SNPs (AISNPs) have identified 9 different population subsets based on the biogeographic regions.[3,4] According to forensic anthropologists, there are six geographical races, Polynesians, Native Americans, Australoid, East Asians, Caucasoids. The direct influence of ethnicity on tooth morphology was not known.[5] The dental anthropology researchers have categorized the biogeographic populations into seven clusters, namely, American Arctic and Northeast Siberia, North and South America (i.e., Native American), East Asia (Japan, China, Mongolia), Southeast Asia and Polynesia, Australo-Melanesia and Micronesia, Sub-Saharan Africa (West and South Africa), and Western Eurasia (Northern Europe, Western Europe, and North Africa).[6] However, anthropologists usually classify the human race as Caucasoids, Mongoloids, Negroids, and Australoids (Australian aborigines). Forensic anthropologists assess the ancestry of skeletal remains using the morphological and metric traits of the skull.[7,8] The physical, skeletal, and dental characteristics collectively may contribute to the racial identification of a person.[9] Among the three characteristics, the dental characteristics are more reliable, especially in ancestry predicting of ancient skeletal remains. Earlier in 1920s the racial characteristics were not easily noticed in teeth. Between the 1920s and 1950s, there was not much scientific literature to prove that teeth are the hallmark of racial classification.[10] Later on, population-based studies have revealed differences in the frequency distribution of different grades of expression of dental morphological traits.[11] The Dental morphology is the dental phenotype

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that humans carry with them when they migrate from one geographic location to another.[12] Furthermore, teeth are known to vary morphologically between and with-in populations and the sexes.[13,14] Particularly, dental non-metric traits have shown affinities and variations among different population groups.[15] However, because of interbreeding and change in the gene pool, the resultant population possesses convergent morphological trait frequencies. Environmental factors also tend to play a role in the phenotypic manifestation of dental traits; however, this has not yet been fully quantified.[16-19] The variations in tooth morphology may be because of genetic influence and also due to alterations done either intentionally or unintentionally. (Fig.1) Some of the dental traits were considered dental markers of a particular race or population. Like for example the strong presence of Cusp of Carabelli is an indicator of Caucasian racial origin and the prominent lingual marginal ridges on the upper anterior dentition (Shoveling) is a marker for Mongoloid racial origin. Apart from ancestry determination, the teeth are also a valuable tool in sex determination in the human population.[20] The Odontometric parameters have shown an accuracy rate of 68% to 74% in sex identification of south East Indian population.[21] The teeth, thus, can be used to provide an estimate of the ancestry and sex of an unidentified individual, thus narrowing the search of missing persons and also enhancing the chances of identification.

Table 1: Table showing common dental and palatal traits in the three racial groups in human population

Racial group	*Common dental and palatal traits*
Caucasoid	• Small lateral incisors (peg laterals) • Prominent Cusp of Carabelli in maxillary molars • Flattened mandibular second premolars • Dental crowding is common • Roots are short • Long, narrow and parabolic arch with high palatal vault
Negroid	• More than 2 lingual cusps in mandibular molars • Mid line diastema is common. • Mandibular prognathism • Hyperbolic arch with narrow palatal vault
Mongoloid	• Large size tooth • Extra distal roots on mandibular 1st molars • Accessory cusp in the mesio-buccal surface of Mand. 1st molar (Prostostylid) • Prominent Shoveling of incisors • Flat palatal vault

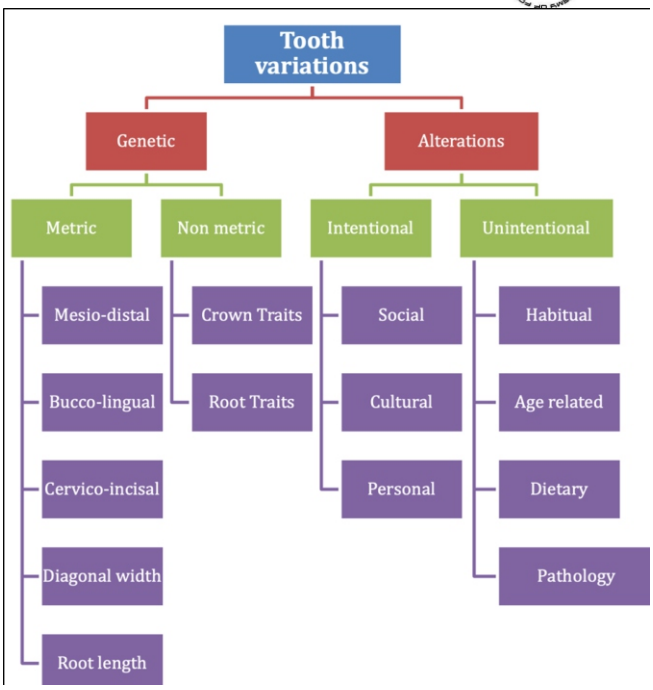


Figure 1: Classification of Tooth morphology variations

Dental Anthropology

The application of dental morphological features in predicting the ethnicity or the ancestry of unknown human remains led to the development of a branch of physical anthropology known as dental Anthropology. It is defined as the study of morphological variations and metrics of the dentition of human populations over time and space and their relation with the process of adaptation and dietary changes that lead to the evolution of the dental system and the human race.[22] The data from dental morphology has become a favoured dataset for dental anthropological studies (Table 1). This is because the dental structures are well preserved in archaeological and fossil records.[23,24]

Dental Nonmetric traits

The dental morphological traits in human dentition are the phenotypic reflections of the genetic makeup of the individual. When a standard recording process is applied, the non-metric traits could be a useful marker to assess the biological relatedness among the population subsets.[25] The population relationship measures based on dental morphology are significantly correlated with those based on neutral genetic data (on average $r = 0.574$, $p < 0.001$)[23]. Thus, the dental morphological traits may be used as a proxy for genetic materials in scenarios where obtaining the DNA sample for identification becomes difficult. Among the dental crown morphological traits, the cusp and groove patterns in the occlusal surface, and the marginal ridges in

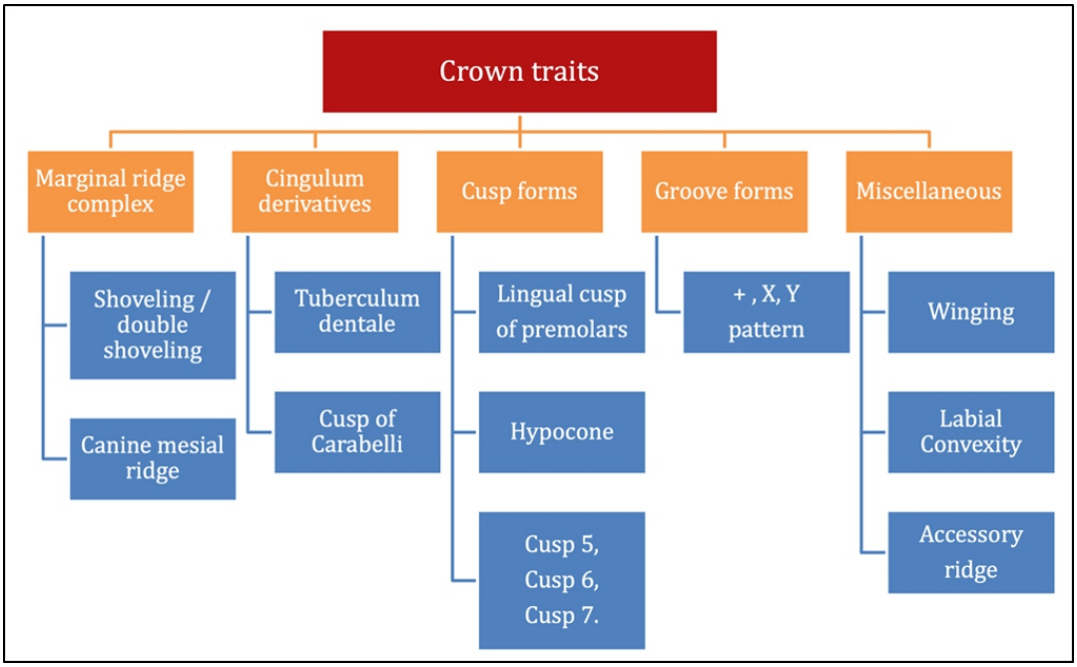
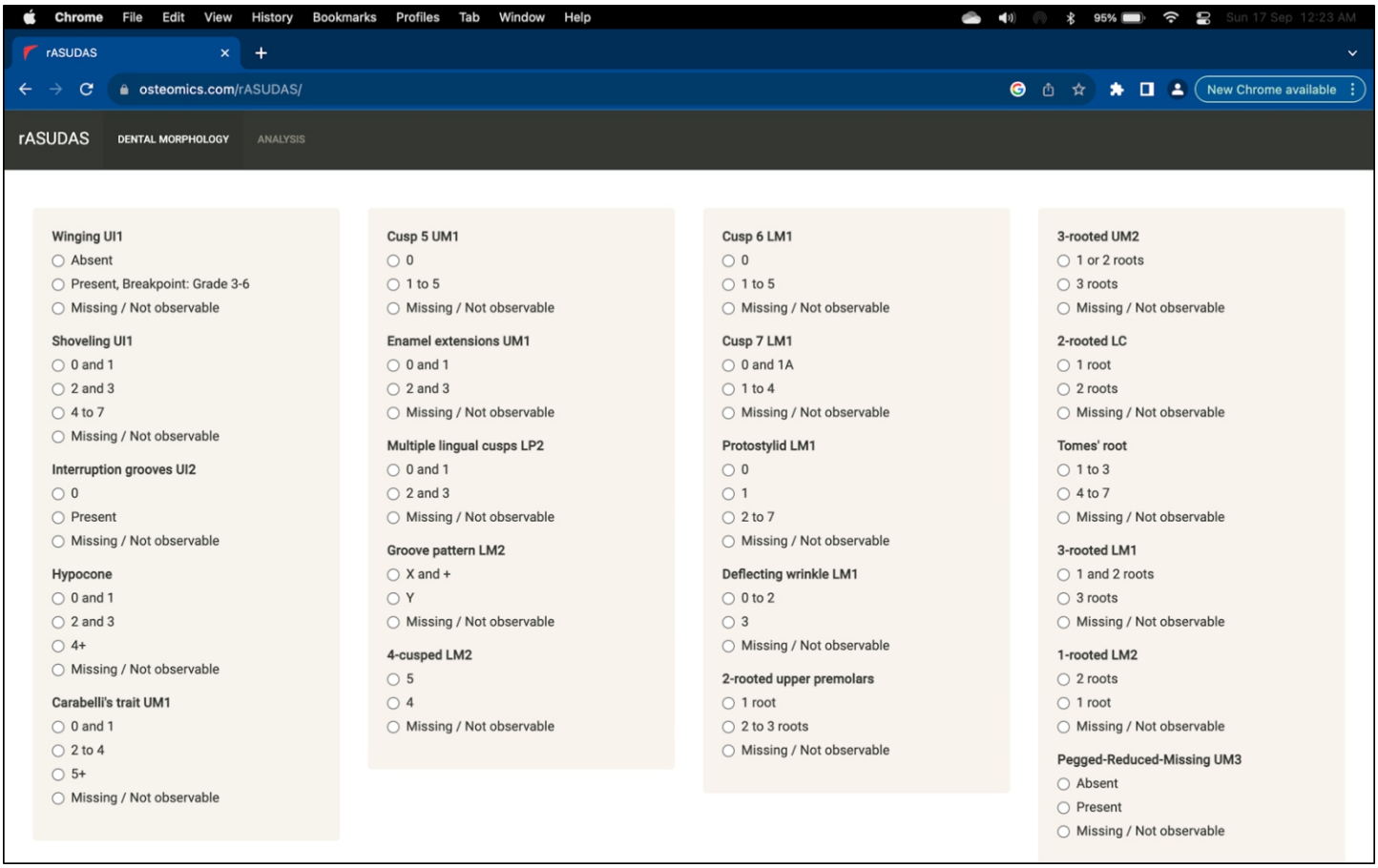
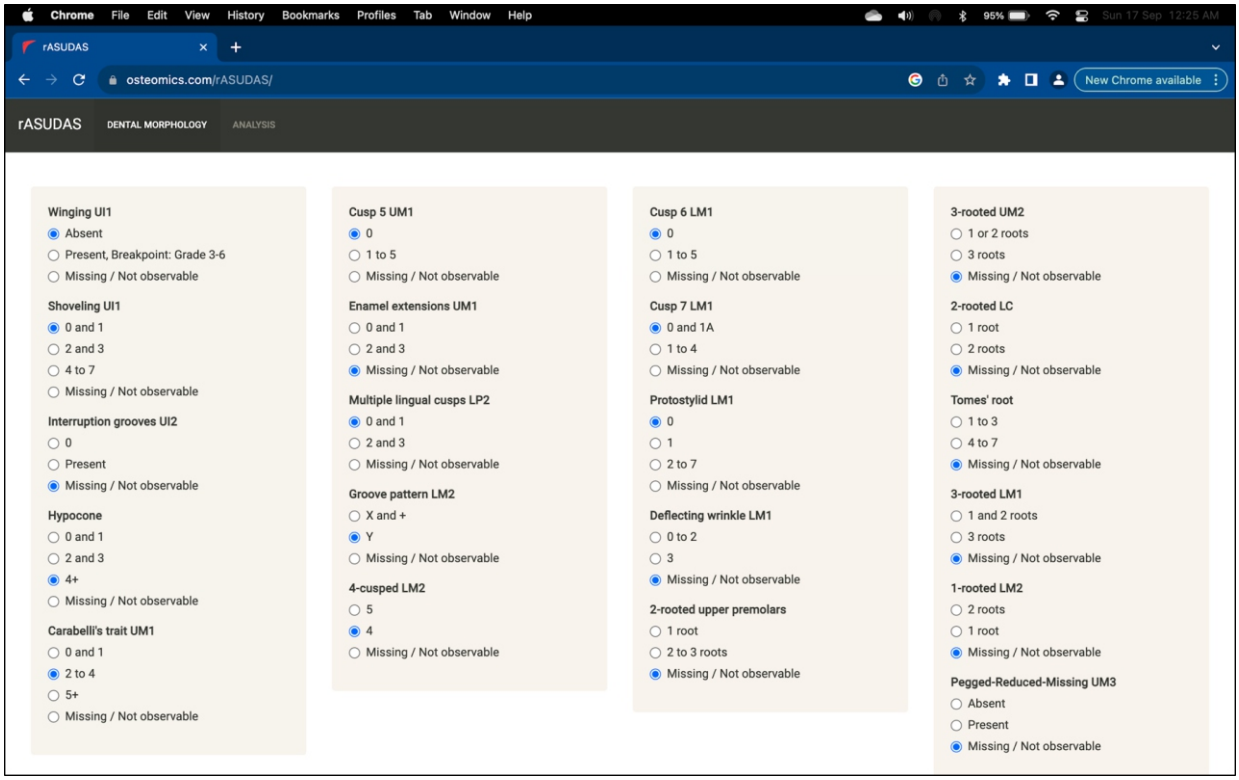


Figure 2: Types of Dental Crown Non-metric traits, commonly observed in modern Human population

Step 2: Click the 'DENTAL MORPHOLOGY' task bar. This page will show the list of 21 traits with multiple options on the expression.

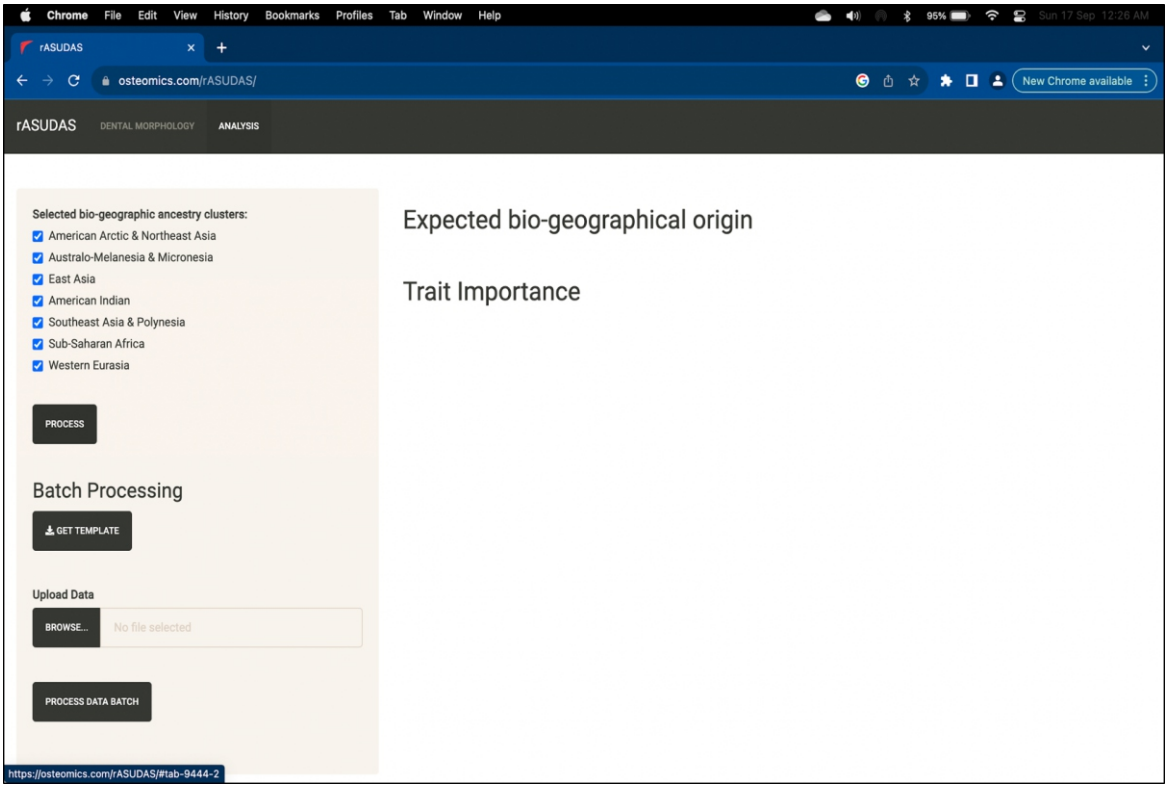


Step 3: Examine the expressions of the traits on the respective teeth using the dental model or extracted teeth (for root traits) of the same individual. Click the relevant option under each traits.

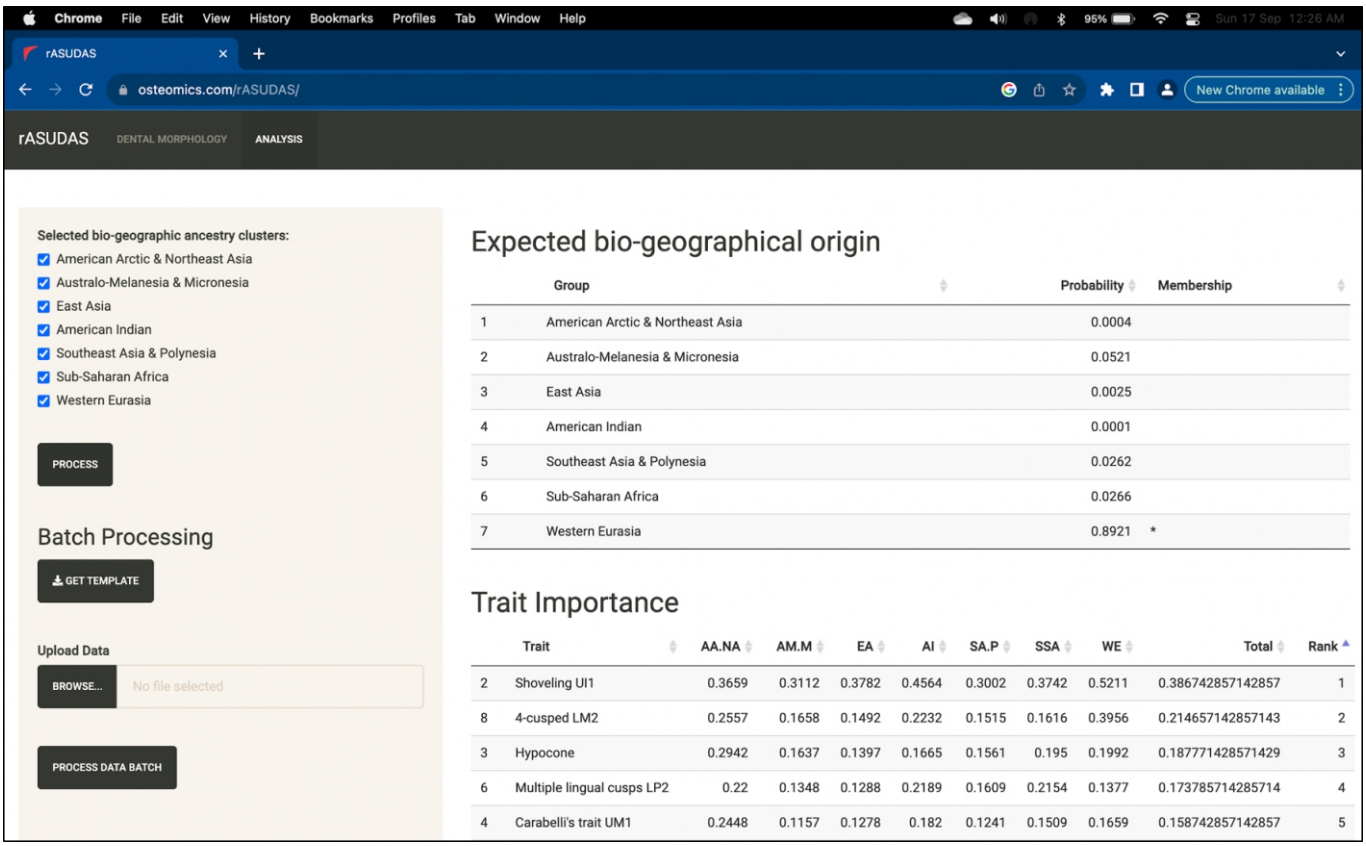


Step 4: Once the options for all the traits are selected, click 'ANALYSIS' task bar. This is open the following page. Select the relevant bio-geographic ancestry clusters among the 7 clusters or select all the clusters, depending on the objective.

Then click 'PROCESS' taskbar.



Step 5: On clicking the 'PROCESS' taskbar, the result page will open. This page will show the probability value of the bio-geographical origin of that particular individual whose dental model / teeth was used in the analysis. In the below example, it is seen that there is 89.2% probability that the person has ancestral traits of Western Eurasian origin.



the lingual surface of anterior dentition are considered highly variable and are important candidates for population-based studies. The usefulness of the dental nonmetric traits for ancestry assessment depends on the following three basic requirements: (1) significant reference data from populations around the world; (2) standardized protocols for scoring traits; and (3) rigorous statistics that can be used with categorical data.[6] There are more than 100 different morphological dental traits reported in human dentition.[26] Detailed Anthropological descriptions of 30 to 40 such traits are available in the literature. The dental non-metric traits may be classified into crown traits and root traits. (Fig. 2) The crown traits can be assessed using the dental models and by visual clinical examination. For assessing the root traits, the extracted tooth or the radiographs can be utilised. The generation of basic criteria for recording and interpretation of the non-metric data was the main objective of dental anthropology studies. Moreover, availability of the population-based data on a larger scale for comparison is going to be an added advantage to such studies.[27] The efforts to standardize the dental traits were made by Hanihara (1956), Dahlberg (1963), Turner, Nichol, and Scott (1991).[28-30] Moreover, there is no 100% certainty in assessing the ancestry using the dental traits, because of population admixtures and change in gene pool.

ASUDAS[14,15]

The standards developed at Arizona State University by Turner et al give a detailed description of 36 non-metric traits. The reference plaque developed by them, known as Arizona State University Dental Anthropology System (ASUDAS) was available as dental plaster replicas.[31] Nowadays, a reference set of 27 traits, known as Turner-Scott Dental Anthropology System (DAS) developed by Richard Scott is made available by a company, Bone Clones®, (Bone Clones Inc., CA, USA). (Fig.3) To understand the ancestor-descendent relationship, dental anthropologists utilize the standards to record the score of the expressed traits of a population of interest and then compare the data with similar datasets of different population groups by applying statistical methodologies. The frequency of the traits that varied more than 30% among the groups is usually considered for ancestry analyses.[32]

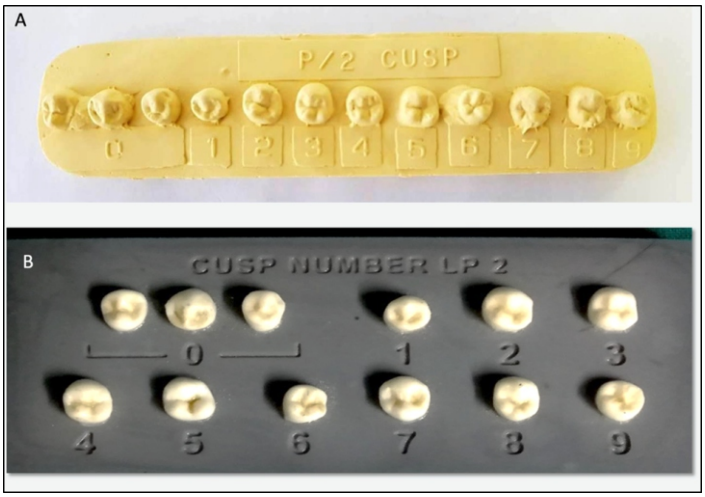


Figure 3: A. The ASUDAS reference plaque for scoring the lower 2nd premolar cusp trait. **B.** The same standard in Turner-Scott Dental Anthropology System (DAS).

rASUDAS[6]

It is a web-based application developed in 2015 by David Navega and João Coelho for estimating ancestry from dental traits. This tool employs R programming language and the ASUDAS standards using a Bayesian classifier algorithm, to estimate ancestry based on dental morphological trait frequencies. An individual's dental trait findings are the input data, which is compared to the pre-existing databases from seven population clusters. The algorithm outputs the ancestral group and associated posterior probability. The rASUDAS application is freely available on the link https://apps.osteomics.com/rASUDAS/. The alpha version of the application is based on 17 dental traits. In the beta version, some of the rare traits in the alpha version were removed and some new traits were added making a total of 21 traits. So, a better understanding of the dental traits, the knowledge of the standard references, the recording procedures, and statistical applications is required to assess the ancestry in dental anthropology. The hands-on training on the use of the rASUDAS application is regularly conducted by the author, where the trainees get practical experience in estimating the ancestry using their pair of dental models.

Steps involved in ancestry estimation using rASUDAS application:

Step 1: Click open the rASUDAS page from https://osteomics.com

Conclusion

Dental non metric traits have a possible role in ancestry assessment in the field of forensic anthropology and forensic odontology. There is abundant population-based data on the frequencies of the expressed dental traits.[33,34] Such reference data and standard protocols need to be utilized to explore the ancestry related queries, though not as stand-alone methodology, instead in corroboration with the skeletal data. The Indian population is mixed and diverse with varied ethnic origins. Hence the dental traits' expression needs to be assessed from different geographic regions of the country. The practical application of rASUDAS web-based tool is highlighted, so that a validation of this tool from Indian population from different regions may be attempted by those interested in dental anthropology.

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