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RESEARCH ARTICLE

DENTAL ANTHROPOLOGY –TODAY & TOMORROW (AN OVERVIEW)

*Sonalee Shah

Government Dental College, Raipur, Chhattisgarh, India

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ABSTRACT

Dental Anthropology is a scientific discipline, which deals with studies of sexual dimorphism, paleodemography, oral health, lifestyle, evolutionary trends, paleodiet, biodistance and paleopathology through the analysis of the dentition of extinct and modern human populations and hence, is concerned with the study of morphological variation (dental morphological features) and metrics of the dentition of human populations over time (prehistoric and modern) and in space (ie.ethnic influences) and their relation with the processes of adaptation and dietary changes that led to the evolution of the dental system and the human race.(1,3) Keeping in mind the dental evolutionary changes, the subject experts, focus on the use of teeth to resolve anthropological problems. Teeth exhibit a wide array of variables, ranging from those largely controlled by genes to those largely dictated by environment. Dental variables under genetic control include crown and root morphology and size, along with tooth number (i.e., missing and extra teeth, or hypodontia and hyperdontia). Dental variables that reflect environmental factors include tooth crown wear and chipping, caries, abscesses, periodontal disease, calculus, and linear enamel hypoplasia. Anthropological questions focusing on teeth include issues of population origins and relationships (tooth morphology, size, number), diet and behavior (attrition, crown chipping, tooth-tool use), health (caries, abscesses, periodontal disease, calculus), and developmental stress (hypoplasia, asymmetry). Modern Dental Anthropology is the result of systematic efforts carried out by research teams for decades in order to strengthen the scientific nature of the discipline and tried to explain the enormous biological diversity of human populations. Dental anthropology is also applied to living people, using many of the same techniques employed for analyzing ancient remains and, so, it can be viewed as the collaborative effort of various subjects like: anthropology, clinical dentistry, biology, paleontology, and paleopathology. The subject, therefore, involves analysis of tooth metrics, non-metric patterns common to various ethnic groups and tooth wear patterns and food or other habits to identify and compare the period of existence of the creature bearing those teeth.

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INTRODUCTION

Even though, the English Victorian naturalist Richard Owen (1804–1892), underscored teeth as "Firm substances attached to the parities of the beginning of the alimentary canal, adapted for seizing, lacerating, dividing and triturating the food, and are the chief agents in the mechanical part of digestive function", the task of human dentition of, the uptake and crushing of food is doubtlessly the most characteristic. All other functions of teeth are secondary such as, the use of teeth as weapon or tool, as a structure for the characterization of age and sex, or as ornamental objects.

***Corresponding author:* Sonalee Shah,**
Government Dental College, Raipur, Chhattisgarh, India.

Also for humans teeth have great significance for vocal articulation (Schumacher et al. 1990) and for the esthetics of the appearance (Alt 1994b). However, these functions emerged in the late phase of evolution before which, primitive tooth-like structures eg. Gill traps had facilitated food intake. Dental Anthropology is a scientific discipline, which deals with studies of sexual dimorphism, paleodemography, oral health, lifestyle, evolutionary trends, paleodiet, biodistance and paleopathology through the analysis of the dentition of extinct and modern human populations and hence, is concerned with the study of morphological variation (dental morphological features) and metrics of the dentition of human populations over time (prehistoric and modern) and in space (ie.ethnic influences) and their relation with the processes of adaptation and dietary changes that led to the evolution of the dental system and the human race (Leandro, 2016; Smith, 2018; Freddy Moreno Gomez, 2013).

Human teeth, along with the teeth of all vertebrates, are dictated by long-term evolution, not recent cultural advances & were formed under the influence of natural selection. Thus, for omnivores, including most primates, the dentition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores with dentition that has emphasis on slicing, dicing, and piercing elements or herbivores which have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing. However, the general primate dental pattern includes large, projecting canines that are primarily used in male-male competition for access to valued resources. For proper articulation of the two jaws, there is a space, or diastema, between the upper lateral incisors and canines to accommodate the lower canine. Paleoanthropologists often note canine reduction, homomorphic lower premolars, and lack of a diastema as hallmarks of early hominids. These traits are all linked to a single trait – canine size (Smith, 2018).

Hominoids and many other primates also differ from hominins in the form and relative size of the incisors. Humans have relatively small anterior teeth (incisors and canines) that are vertically implanted in the jaws. Monkeys and apes, by contrast, have broad, spatulate incisors that are disproportionately large compared to the cheek teeth (premolars, molars), and these are set obliquely in the jaw rather than vertically. This difference revolves around the degree to which different organisms manipulate food with their anterior teeth (Smith, 2018). Keeping in mind the dental evolutionary changes, the subject experts, focus on the use of teeth to resolve anthropological problems. Teeth exhibit a wide array of variables, ranging from those largely controlled by genes to those largely dictated by environment. Dental variables under genetic control include crown and root morphology and size, along with tooth number (i.e., missing and extra teeth, or hypodontia and hyperdontia). Dental variables that reflect environmental factors include tooth crown wear and chipping, caries, abscesses, periodontal disease, calculus, and linear enamel hypoplasia. Anthropological questions focusing on teeth include issues of population origins and relationships (tooth morphology, size, number), diet and behavior (attrition, crown chipping, tooth-tool use), health (caries, abscesses, periodontal disease, calculus), and developmental stress (hypoplasia, asymmetry) (Smith, 2018). Through analysis of teeth, it is possible to study the sexual dimorphism of an individual from the patterns of dental development and eruption, the expression of a protein known as amelogenin, dental morphology and dental dimensions (Freddy, 2013).

Although tooth size is not a sensitive indicator of ancestry, tooth crown and root morphology exhibit sufficient differences among the major groups of humankind to allow discrimination at the level of European, African, Asian, and derived populations (Smith, 2018). One of the consistent findings was the affinities between Native Americans & Asians as well as their common distinctiveness from Europeans in Crown Morphology. However, various researches on tooth size (maximum mesio-distal diameter & bucco-lingual diameter) indicate that size is more responsive to selection &/or environmental factors than crown morphology. Variation in crown & root morphology may be present or absent & when present may be slight to pronounced thereby being Quasi – continuous instead of being discontinuous.

Crown morphology variations include accessory ridges, tubercles, styles &/or cusps expressed on lingual, buccal or occlusal surface. Root traits often manifest as deviations in root number from the norm. Historical and evolutionary analysis of a morphological trait is useful only if a significant component of it is genetic. Dental morphology is expressed to be genetically unique and unrepeatable in each tooth, and the tooth structure (metric and morphological) formed embryological histology does not change or remodel itself as with the bone, excluding mechanical wear or attrition and accumulation of secondary dentine, and teeth, in many cases have become the only element to be able per se to provide biological and cultural information of an individual or a human population, which is possible due to:

- High heritability and strong genetic control of dental morphology
- Little environmental influence
- Correspondence between the dental characteristics and geographical distribution
- Are easy to observe and record
- Permit to compare past with present populations
- Have the ability to reflect the dietary habits of an individual and how they process food
- Reveal the conditions of health, age, sex, habits and functional occupational habits and
- Make evident technological and cultural development of a population (Freddy, 2013)

Modern Dental Anthropology is the result of systematic efforts carried out by research teams for decades in order to strengthen the scientific nature of the discipline and tried to explain the enormous biological diversity of human populations (Leandro, 2016)

The human dentition & its anthropological significance (Grant, 2012)

- The Human Dentition is of significant anthropological interest when considering variation within & between modern populations as Teeth provide a relatively stable indirect source of information about processes occurring during pre-& post natal development. Also,Human dentition is one of the most stable sources of information in the fossil record, both morphologically & as a repository of ancient DNA sequence information.
- Variation in tooth form & function can provide opportunities for examining inter-individual ariation as a means for forensic identification.
- More recently, evolutionary models of oral microbial ecology have relied upon extraction of microbial DNA from deposits on tooth surfaces.
- The developmental processes that give rise to morphological variation in human dentition can be understood in terms of : developmental disturbance in form & function that lead to variations within & between individuals, families sexes, ethnic groups & populations which are a result of temporal effects on individuals & populations during their lifespan.
- The information on methods by which plasticity of the genome gives rise to adaptation to a particular environment in a population can be obtained by family studies using population modeling of traits that exhibit familial aggregation .

- Similarly,the information on genes & environment interactions to yield a specific phenotype can be obtained through usage of linkage & association analyses to elucidate the role of specific genes in trait developments
- Role of the epigenome in dental development & patterns of trait transmission is important can be yielded from family data.
- Understanding Human Dentition –A Complex System (Grant, 2012)

Gene plus environment interaction allows to understand dentition as a complex system with the help of conceptual framework in which the actions of genome ,the epigenome & gene products interplay with some factors having greater significance in terms of final phenotype ie.HUBS & others being bit players ie. NODES. Also some genes act on multiple dental phenotypes pleiotropically eg. Homeobox –like genes,as, they regulate expression of structural genes & often play a role reiteratively during development as HUBS. It is important to note here that, variation in form & functions of human dentition can be studied by analytical techniques like:

- Quantitative Genetics which heavily relies on inferred familial relationships.
- Molecular Genetics which allows to know putative influence of key genes
- Epigenetics which studies the influence of (potentially heritable) changes in local chemical mediators of gene transcription or translation (CpG methylation , Histone deactylation ,X inactivation etc.) with the help of Monozygous twins thus allowing to know differential modification of gene effects due to stochastic variation in local genetic milieu.

Reasons of using teeth & jaws in Dental anthropology:

- Teeth and jaws are usually abound among paleontological and archeological finds because of their resistance to post-mortal influences, therefore, many phylogenetic concepts are based solely on the interpretation of tooth forms.
- Besides, teeth play an important role for comparative anatomical investigations and for the reconstruction of phylo-genetic mechanisms in the evolution of mammals owing to the fact that "Tooth form varies with taxonomy and phylogeny and so can be used to reconstruct evolutionary patterns". Teeth have therefore become "index fossils" in paleontology, paleo-zoology, and paleo- anthropology.
- Teeth provide valuable information about environmental parameters and diet as well as answers to bio-stratigraphic question.
- Teeth & Jaws possess a high degree of morphological individuality representing personal, familial, and population characteristics, and they can be directly observed and evaluated in both living and past populations. Furthermore, because of their high heritability they are useful in assessing evolutionary and population origins, development and dynamics, they reflect dietary and cultural behavior and environmental effects. And finally, the non-genetic characteristics of teeth such as wear and disease make them well suited for research of dietary adaptations, regional variation in disease manifestations, epidemiological status and others.
- Moreover, the morphological complexity of human teeth is valuable clue for assessing the genetic lineage of the individual because it reflects complex aspects of evolution and the genetic traces of ancestors. It was recently used to trace ancestry by studying a genetic disease showing morphologic abnormalities such as congenital dental defects or dental malformation (Iscan 1989).

An important concept that relates to the different types of teeth in mammals is Butler's field theory. When this concept was adapted to the human dentition by A. A. Dahlberg, he used the phrase tooth districts to describe eight morphological classes corresponding to the four types of teeth in the two jaws. Within each tooth district, there is a "key" tooth, which shows the most developmental and evolutionary stability in terms of size, morphology, and number. For humans, the key tooth in a given tooth district is usually the most mesial element (e.g., upper central incisor, lower first molar); the only exception is in the lower incisor district where the lateral incisor is the key tooth. The implication is that the key teeth best reflect the genetic-developmental programs controlling tooth development, whereas the distal elements of a field are more susceptible to environmental effects. This may be related to the relatively protracted period of tooth development in humans (Pang Min-Kyu, 2017). The derivation of historical relationships from dental data requires variables with a significant genetic component. Variables that meet this requirement fall under the broad headings of tooth size, crown and root morphology, hypodontia (missing teeth), hyperodontia (supernumerary teeth), and eruption sequence polymorphisms (Scott, 1997)

H/O of Dental Anthropology: Odontology, the precursor of dental anthropology, was the classical scientific discipline dealing with fundamental questions about the development and structure of teeth &, in the 1960s,it became incorporated in the rapidly developing discipline of dental anthropology. Dental anthropology is also applied to living people, using many of the same techniques employed for analyzing ancient remains and, so, it can be viewed as the collaborative effort of various subjects like: anthropology, clinical dentistry, biology, paleontology, and paleopathology.

Objectives of Dental anthropology

- Dental anthropology is not only useful for the exploration of the past, but it also influences clinical basic research. For example, the recognition of evolutionary trends, such as the size reduction of teeth and jaws, has important implications for clinical dentistry.
- Also, an objective of dental anthropology is the reconstruction of the phylogenetics of humans and primates.
- In recent decades, dental anthropology has had a great impact on phylogenetic research in paleoanthropology and has contributed to advances in related disciplines such as primatology, osteology, and population biology.
- For anthropologists studying archaeological, fossil, and forensic remains in order to understand the biology of ancient human communities and follow the course of evolution, it is essential to identify an individual from their fragmentary remains, particularly teeth. Teeth are unique among the resistant anatomical parts of fossil skeletons having been exposed to various forces throughout the person's life.

- The knowledge base of Dental Anthropology permits the study, analysis, interpretation, and understanding of information derived from the human dentition through their morphological, evolutionary, pathological, cultural and therapeutic variations. These structural considerations are viewed against a people's culture, notably the conditions of life, diet, and adaptation processes.
- An objective of Dental Anthropology is also, the biological reconstruction of early populations (prehistoric anthropology), using the ontogenetic and population related variability of teeth.
- Dental findings are used in investigations concerning estimation of least number of individuals, population or ancestry of the individuals, reconstruction of nutritional status and health history, occupational markers or features caused by habitual activities, trauma, or other lifetime events.
- One primary theme of this discipline is to study variation in size and shape of the teeth, as recorded in casts of dentition from living people or evaluated in the skulls of archaeological and fossil specimens using metric measurements and observations of non-metric traits , which vary depending on genetic or environmental factors. These traits are used as essential clues for determining the physical characteristics of an ethnic group, identifying the sex, and age of an individual, or tracing migration routes of people. (Scott & Turner 1971).

Steps of Dental Anthropology Implementation (7)

Collection & Handling: After proper collection & recording of the remains of skeleton with teeth as well as thorough & gradual analyses of sediment around it for disintegrated teeth or bones, they have to be transported with utmost care to avoid fragmentation of fraile parts like Mandible.

Metric Analysis methods: Researchers have presented various methods to measure teeth (e.g., Martin 1928; Selmer-Olsen 1949; Moores 1957; Goose 1963). Traits such as height and length are commonly used to indicate the size of the teeth. Diameter, width, or area are also measured. In particular, traits such as height are excluded from measurement because teeth of ancient humans are more extensively worn and the height would thus be irrelevant and incomparable to other specimens. Metric analysis is an efficient method for facilitating the comparison between specimens because it uses generally defined measuring points and methods. Each tooth size belongs to a category of average sizes specific to that ethnic group; therefore, the metric size of one group can be revealed through an appropriately sized sample. For measuring teeth, digital callipers have to be used and four traits are to be measured among those presented by Zubov (1968). An average value in millimeters (mms) is obtained by measuring one item twice, and pairs of measurements showing large differences are measured again. Tooth measurement points according to Pang (2004) are –

- Crown length measured from tooth face surface, bend ridge to cutting edge(front tooth) or protoconid cusp top (molar)
- Mesio-distal diameter of the crown measured as the longest distance between the bend ridge inside the crown and distal surface bend ridge parallel to the face surface of the teeth.
- Mesio-distal diameter of the crown cervix is the closest distance between the inner surface of the crown and tooth root boundary and distal surface parallel to the face surface of the teeth.
- Facio-lingual diameter of the crown is the longest distance between the bend ridge of the face surface and metaconid bend ridge is measured to be perpendicular to the surface at which the mesio-distal diameter of the teeth was measured.
- Module of the crown (mcor): VL (cor) + MD (cor) / 2

It is the relative size of the head and can be calculated through the average value of facio-lingual diameter and mesio-distal diameter. Normally, the full size is calculated only when crown height is considered but the height value that can be calculated through wear is limited. Therefore, the module of the crown is used in relative comparison or for descriptive purposes. For modern people the following criteria are applied:

- A small tooth type is < 10.20 mm. The small tooth type is also shown to be 10.0 mm, primarily among southern Europeans.
- The middle tooth type is 10.20-10.49 mm. Mongoloids and Northern Europeans mainly have the middle tooth type.
- The large tooth type is > 10.50 mm. The large tooth type appears frequently in groups mainly living in equatorial areas and the South Pacific. The large tooth type value is a maximum of 11.75 mm and is often seen in Australian Aborigines. Inuit and Native Americans also exhibit large tooth types.
- Index of the crown (I cor): VL (cor) / MD (cor) x 100

This generally refers to the ratio of the mesio-distal diameter to the facio-lingual diameter of the molar crown. As the index of the crown is higher, the crown looks longer in the facio-lingual direction when viewed from the top.

- The index of the crown in modern humans always exceeds 100 in the maxillary molar, hence, its, average crown index in modern humans is approximately 120 with Europeans having values around 125 and Mongoloids show < 120.
- The index of the crown in modern humans has values of < 100 in the lower jaw.The mandibular first molar exceeds 100 in some cases. Criteria for the crown index classification of mandibular molars are as follows (Hrdlička 1923): the long tooth type is 90.0; the middle tooth type is 90.0-99.9; and the short tooth type is > 100.

- Anthropoids and early hominids show a value close to 100.
- This value increases over time and the mesio-distal diameter of Upper Palaeolithic and Mesolithic people becomes relatively smaller at approximately 130 or 150.
- In the lower jaw, the crown index increases as the mesio-distal diameter is reduced and Neanderthals show values of around 100. It then decreased to 90-100.
- Absolute crown size (robustness, Rb): VL (cor) x MD (cor) :

- This trait reflects the overall crown size with the module of the crown and is a characteristic often used in paleo-anthropology.
- Relative crown size (incisor index, canine index)

This comprises the ratio of the mesio-distal diameter of mesial incisors to the mesio-distal diameter of maxillary lateral incisors (incisor index: MD (cor)I^2 / MD (cor)I^1 x 100) and the ratio of mesial canine length to the mesio-distal diameter mandibular lateral canines (canine index: MD (cor)P^2 / MD (cor)P^1 x 100).

- In the evolutionary process, the size of lateral incisors is reduced and is thus helpful for identifying reduction in the size of the jaw.
- The incisor index among Europeans is quite small, approximately 75-78

In Mongoloids approximately 82-84. In equatorial people approximately 78-82(median values).

- Differences in the incisor index according to sex are also evident, being lower among women than men.
- The canine index is generally investigated on mandibular teeth. The values of most modern people exceed 100 and exceptional cases, people in polar regions show < 100.
- The canine index among fossil hominins (Homo erectus, Homo heidelbergensis) is < 100, while Australopithecines show values > 100, significantly higher than in modern humans.

Step-index of the crown (Si, step-index)

- Over the human evolutionary process, the first molar is considered to be the tooth least likely to be altered (Selmer-Olsen 1949). Among metric traits, the mesio-distal width maintains its genetic characteristics well because it is the least affected tooth.
- Based on these characteristics, the step-index is calculated as the ratio of the mesio-distal diameter of the first molar to that of canines and second and third molars.
- Deterioration of those teeth can be estimated when compared to the first molar.

Therefore, step-index comprises the following four indices.

- MD (cor)P^1 / MD (cor)M^1 x 100(first canine step-index) : The frequency used in the first canine step-index is relatively lower than other indices.
- MD (cor)P^2 / MD (cor)M^1 x 100(second canine step-index) : The second canine step-index observed in the lower jaw reflects an interesting fact in human evolution. As hominids have evolved, the second canine step-index steadily declined. In the evolutionary process from Australopithecines to modern humans, the most notable feature shown in teeth is the tendency of molarisation; for example Australopithecus: 100.6; Homo erectus: 91.0; Homo neanderthalensis: 85.0; Homo sapiens: generally 80 or below (some at 85). The results of a comparative study between modern ethnic groups are insignificant.
- MD (cor)M^2 / MD (cor)M^1 x 100(second molar step-index) : The second molar became smaller while the first molar became bigger throughout human evolution
- MD (cor)M^3 / MD (cor)M^1 x 100(third molar step-index) : As the second molar became smaller while the first molar became bigger throughout human evolution, the third molar step index decreased. Modern ethnic groups showing a maxilla third molar index close to 100 have not been reported and fossil humans have an index of approximately 100. Therefore, it may represent an interesting anthropological feature that explains changing biological characteristics over human evolution. In particular, ethnic groups living near the equator are characterised by a higher third molar step-index and hence, the origin of primitive characteristics can be inferred from early in the human evolutionary process.
- Gender-specific traits are also evident, as the step-index in women tends to be lower than in men.

In summary, the step-index is used as a key dental anthropological indicator for explaining the human evolutionary process because it shows large variations over time.

Non-metric analysis methods: The dental morphological or non-metric characters, are also called discrete, discontinuous, quasi-continuous or epigenetic traits and they are observed, recorded and analyzed with scientific evidence of high taxonomic value, frequency, variability, bilaterallity, sexual dimorphism and correspondence between features, conditions that allow them to be used in the estimation of biological relationships among populations by comparative analysis of human past and present groups, to try to clarify the historical, cultural and biological macro-and micro-evolution, leading to the understanding of displacement, migration paths and contacts that led to the settlement and ethnic variation of humanity. Until present, there are over 100 dental crown traits and root that have been recognized in the human dentition, but in most worldwide research are used no more than 17 features, mainly those located in the crown of incisors and molars of both dentitions. (Freddy Moreno Gomez.Sexual Dimorphism in Human Teeth from Dental Morphology & Dimensions: A Dental Anthropology Viewpoint.2013.Open Access Peer – reviewde chapter). Non-metric traits of teeth are important for showing the differences among modern human groups and examining their genetic relationships with ancestral populations. Non-metric traits are largely categorized based on the number and position of teeth and diversity of the tooth shape. The diversity of the tooth trait provides critical information for identifying the differences between local groups and untangling genetic relationships.

The commonly recorded non-metric traits are:

Congenitally missing teeth

- Teeth that are often missing include the third molar and maxillary lateral incisors.

When lateral incisors are congenitally missing, the incisors adjacent to the eye tooth (canine) look similar in many cases. This phenomenon has been expressed more frequently over the last millennium and a frequency up to 20% was reportedly expressed in some groups.

- Congenital lack of the third molar occurs most often in Mongoloids with an expression rate up to 30%. In contrast, expression frequency is lowest among blacks in Africa. Congenital lack of the third molar is thought to have become steadily more common through the late Palaeolithic and Mesolithic until today (Brothwell et al. 1963)

- Other congenitally missing teeth (Tratman 1950) are very rare, but in the case of mandibular mesial incisors, the expression rate is relatively high among Mongoloids. However, the occurrence rate is less than 2%, remarkably lower than other teeth.
- Canines are often congenitally missing, but they show an expression rate of less than 3%.
- When observing congenitally missing teeth, it is essential to distinguish between unerupted teeth and teeth lost prior to death. Unerupted teeth can be discerned in radiographs. Tooth loss before death can be determined if the dental alveolus is absorbed or characteristically bent and unbalanced; alveolar holes will be evident. If the lost tooth was in contact with the adjacent teeth at least once, traces are evident on the contact surface.

Snaggletooth

- This refers to an irregular tooth and may be an incisor or molar.
- Its shape may or may not be similar to a normal tooth.
- This affects permanent and deciduous teeth, but the frequency among the latter is quite low.

a. Bilaterally rotated incisors(winging) –

- Most frequent among the mesial incisors, this trait refers to the ‘twisting’ of the lateral side toward the cheek. These are also known as V-shaped or wing-shaped teeth (Dahlberg, 1959; Enoki and Nakamyra 1959).
- An expression rate of up to 45% is known in the Mongoloid group, but rarely occurs in Europeans

b. Peg-shaped teeth -

- Such teeth are abnormally small and resemble a peg.
- They mainly occur in maxillary lateral incisors & may be due to a congenital defect.
- The expression rate of approximately 3% is seen in modern human groups and is slightly higher in Europeans.

c. Crowding of teeth –

- If permanent teeth are too crowded, one or two are pushed out of their normal positions.
- In this case, crowding occurs because the tooth sizes remain the same but the jaw size shrinks.
- Consequently, the alveolus becomes smaller & thus, teeth cannot erupt normally, and they sometimes become rotated. This trait occurs mainly in maxillary incisors.

d. Shovel-shaped incisors (shoveling) -

- This genetic characteristic is the most frequently studied among the morphological traits of teeth. After it was first mentioned by Hrdlička (1920), research showing a high frequency of this trait among Mongoloid peoples has been published (e.g., Hanihara 1966).
- Shovelling refers to when the enamel of the edge of the mesial and distal incisors is extended toward the tongue. This lingual edge ridge is projected sufficiently to form the enamel border, creating a fossa in the lingual centre.
- Viewed from the lingual side, these incisors resemble a shovel. They are largely divided into four types depending on the degree of shovelling and the depth of the lingual fossa.

e. Double shovel-shaped incisors (double-shovelling, labial marginal ridges) –

- This trait refers to the extension of the enamel on the mesial and distal edge ridge of maxillary incisors toward the cheek and tongue (Dahlberg & Mikkelson 1947). The degree of expression varies. If it is extensive on the buccal side, it is more projected because the development of the mesial edge is stronger than on the lateral side (Mizoguchi 1985). This trait is observed in incisors and canines but the expression rate of double shovelling is the highest in maxillary mesial incisors.

f.

g. Canine distal accessory ridge –

h.

- This characteristic refers to the accessory ridge of the distal surface on the lingual side of the mandibular canine. It is classified into five types depending on the degree of expression (Scott 1977). An expression rate of 20-60% is shown in modern human groups with a higher frequency seen in Mongoloids and Native Americans & with lower frequencies among Europeans.

i. Terra’s tubercle –

j.

- This additional tubercle occurs on the edge ridge of the inner surface of the maxillary first canine. It is also known as a marginal tubercle or dens evaginatus. It is generally seen on the inner surface, but appears on the mesial and distal surfaces in some cases. Among Koreans, the expression rate of Terra’s tubercle on the inner surface was higher in ancient populations (Hu et al. 1999) in comparison to modern ones.

Carabelli’s cusp –

- This abnormal tubercle appears on the lingual side of the protoconid of the maxillary first molar. It is also called the fifth cusp. The shapes of Carabelli’s tubercle are diverse, ranging from small pits to complete cups. Several classification methods were devised by researchers including Dahlberg et al. (1956). Four classification methods of Scott and Turner (2004) are generally used. Carabelli’s tubercle is thought to be a feature stemming from recent evolutionary processes, and frequencies vary among modern humans. This trait is not evident in fossil hominins.

Protostylid cusp –

- The protostylid refers to an accessory cusp occurring in front of the buccal side of the mandibular molar. It mainly appears in fossils such as Australopithecus and Meganthropus in Java, or Sinanthropus in China (Dahlberg 1951). No evidence of this trait is seen among modern people with the exception of the Pima Indians (southwestern United States), who exhibit frequency of 29.6% (Dahlberg et al. 1982).

Groove patterns of premolars –

- The shape of the lingual cusps in maxillary and mandibular premolars is observed. In most cases, the upper jaw has one lingual cusp, but the number of lingual cusps in the mandible appears diverse. An occlusal groove pattern is determined depending on the number of lingual cusps and the occlusal groove shape.

- If the number of lingual cusps is one, it has an H or U shape & if it has two, it has a Y shape.

k. **Cusp patterns of molars** -

- The cusp shape and grooves of molars have been utilised to describe the features among modern human groups including the relationships between their ancestors and descendants.
- The maxillary molar usually has three to four cusps with grooves dividing them.
- To record cusp size, Dahlberg (1951) classified the development of all four cusps into : the "4" type the smaller size of hypocone into the "4-" type the distal smaller cusp without hypocone into the "3+" type the no hypocone into the "3" type.

l. **Mandibular molar occlusal cusp type –**

- The occlusal cusp type of mandibular molar is determined by the number of cusps and grooves.
- There are generally 4-5 cusps depending on the type of groove.
- The types of grooves are classified into T, Y and X shape.
- Therefore, the occlusal groove types of mandibular molar are classified into the shapes of Y6, Y5, Y4, Y3, +6, +5, +4, X6, X5, X4 etc. (Zubov 2006).
- The Y5 type is found among most fossil hominins and the remaining types were recently developed in modern humans.
- Evolution from Y5 to +4 through +5 or Y4 is thought to be a general trend.

m. **Mandibular molar distal trigonid crest** -

- The presence of the crest connecting the protoconid-metaconid of the trigonid of mandibular molars is recorded.
- The lateral accessory ridge of the protoconid cusp and lateral accessory ridge of the metaconid cusp are often combined, forming a crest connected like a bridge.

n. **Deflecting the wrinkle of the mandibular molar lingual front cusp –**

- The occlusal ridge of the metaconid of mandibular molars generally leads straight from the cusp top toward the growth groove.
- In cases, in which this ridge is straight and refracted by being inclined toward the central fossa sometimes occurs. This trait rarely appears in the third molar.
- The expression rate among first and second molars is > 50% in Mongoloids and Native Americans, but does not exceed 15% in Europeans.

o. **LEH-**

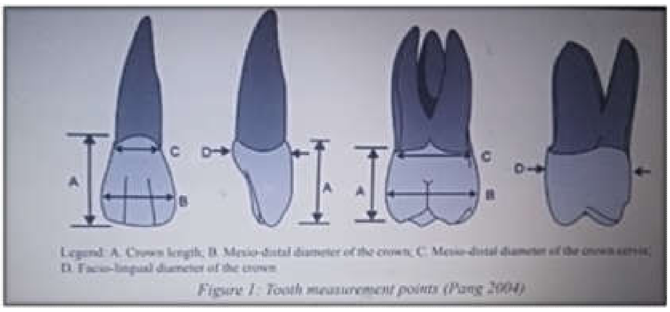
As dental asymmetry appears to have certain limitations as a broad scale indicator of comparative stress levels, dental anthropologists have shifted their attention to the analysis of irregularities in the tooth crown that arise during amelogenesis (enamel formation) and dentinogenesis (dentine formation). The most readily observed manifestation of such growth irregularities is linear enamel hypoplasia (LEH), which takes the form of horizontal circumferential bands and/or pits on the tooth crown for which the key stimulus in earlier human populations probably involved some combination of nutritional deficiency and disease morbidity durin amelogenesis. Thus, Morphometric measurements of teeth are an efficient method to facilitate comparisons between human populations because they use generally defined measuring point in which teeth can be used to reveal the affinity between ethnic groups as well as to determine sex and to estimate age of individuals. Non-metric morphological variations in human teeth potentially indicates characteristics specific to one ethnic group. Such data can be useful for showing cultural or physical characteristics of a particular ethnic group . In addition, it may provide clues about the origins and migration routes of those ethnic groups through comparisons of data from people in surrounding regions. Those traits showing a wider distribution and higher frequency suggest a more ancient origin. (7). Apart from classical methods in this field, many innovative techniques such as extraction of ancient DNA (aDNA), trace element and stable isotope analyses are used in this context. Three applications of aDNA analysis are of interest: access to genetic information at the individual, at the infrapopulation, and at the interpopulation level. Trace element and stable isotope analysis is helpful in the detection of subsistence strategies, endogamy versus exogamy, migration, social differentiation, ontogenetic trends, toxic accumulation of elements such as Pb or As, and paleopathological features. Also, the development of microwear and confocal analyses of occlusal surfaces of teeth is done for documenting tooth use and masticatory function.

Significance of Anthropology in Forensics:(8) Although forensic anthropologic analyses seldom lead to a direct identification, it often helps to narrow the search field, which may indirectly lead to an identification. In addition, many anthropologic analyses involve the craniofacial complex ,which may often produce information that is relevant to a dental identification as well as Forensic facial Approximation. (9)Forensic Facial Approximation (FFA) or forensic facial reconstruction is a three-dimensional recreation of face of an entity from skull remains which adequately resembles deceased person to allow identification of individual. FFA involves an assimilation of anatomy, forensic science, anthropology, osteology and above all craftsmanship to artistically recreate the identity of the deceased. Both forensic anthropologists and forensic odontologists can together decipher problems associated with craniofacial identification. They can also collaborate in museum model reconstructions out of skull bones.

Wilkinson C, 2010 in her review article has enumerated that facial reconstruction technique involves three elements: 1) Anatomical modeling; 2) Morphology determination; and 3) Depiction of resulting face to the public . A forensic odontologist can be involved in each of these stages mentioned and can play a pivotal role in sculpturing the correct reconstruction.

Stage 1 (Anatomical modeling): The first stage in facial reconstruction involves modeling of muscles and relevant anatomical structures on skull, utilising strict anatomical guidelines of origin and insertion and a thorough knowledge of their existing variations. This stage of anatomical modeling is comparatively easy. This stage has relatively low level of sculptural expertise and higher level anatomical acquaintance involved. forensic odontologists are well versed with dental anatomy that is taught as a part of their curriculum,hence, the knowledge and clinical experience imparted, may serve effective in reducing challenges associated with this stage of FFA.

Stage 2 (Morphology determination): The morphology of soft tissue envelope over the bony housing in the critical areas of nose, ear as well as mouth governs the overall morphology of face, that may be governed by changes in age as well as gender. An additional criterion important for FFA would be knowledge of facial profile of individual as it has a bearing on articulation of maxillary and mandibular jaws as well as occlusion of teeth.



Articulation of teeth is important for facial articulation &forensic odontologists can help in improving accuracy of facial approximation. For approximation of facial features of an individual on skull, the study of balance and harmony of face is important. scientific and evolutionary basis of this symmetry called divine proportion or golden proportion or phi (Φ), that is geometrically equal to 1:1.618 or even as a proportional number (...3:2, 5:3, 8:5, 13:8...) is a subject in curriculum of forensic odontologists. This divine proportion has been the basis of a beauty mask developed by Marquardt SR and Stephen R in 2002, alleging it to be applicable to every attractive face, irrespective of age and race . The strong evolutionary significance of this golden proportion has been carried from Egyptian and Babylon dynasties, representing ideal correlation of parts, be it in their pyramids of Giza or cult constructions or bas-relieves or ornaments, and more recently extending to parts of human body, or to be more exact, teeth and denture. This golden proportion also extends to various vertical and transverse parameters of facial skeleton, studied in photographs and radiographs. Further, it extends to macroesthetic entities of smile like visibility of teeth on posed smile and also ratio of vertical and horizontal dimensions of teeth, as proposed by Rickets R M. A forensic odontologist (also a dental professional) who customarily incorporates this proportion during assessment of face and related structures for diagnosis and treatment planning may use this expertise while performing FFA. In addition, study of facial morphology in light of physical anthropometric data necessitates some terminologies used in craniometry as well as cephalometry. Dental research based studies are instrumental in providing tissue thickness data for individuals of different ethnicity, age, sex, bodymass and facial profile, that prove essential for performing FFA & may ultimately be translated on for FFA skull with help of anatomist along with forensic anthropologist.

Stage 3 (Depiction of resulting face to the public): This particular stage involves adornment of face with recognizable traits related to: skin color, age related changes, wrinkles, facial hair, also eye color, hair or clothing. The proficiency of forensic odontologist in various dental age estimation techniques may prove beneficial in this stage as prediction of age may be the first step towards applicability of age related changes on the skin. Demirjian a radiographic technique based on stages of development of teeth, is still considered to be the gold standard in age estimation of growing individuals, although various other techniques have also been proposed. The color of teeth as elements of recognition are also correlated to the skin color as well as race, that are well studied in dental undergraduate prosthodontic curriculum while selection of hue, chroma of teeth for denture patients (Aman Chowdhry, 2018) human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele-ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing. For omnivores, including most primates, the den-tition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores or herbivores human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele-ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing.

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For omnivores, including most primates, the den- tition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores or herbivores For organisms that use teeth to process food, tooth loss is directly related to survival – lose your teeth, lose your life (Lucas 2004). Cultural buffering during the later stages of human evolution removed this dramatic relationship, but dental conditions are nonetheless dictated by long-term evolution, not recent cultural advances. For that reason, human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele-ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing. For omnivores, including most primates, the den-tition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores or herbivores (Ungar 2010)

Teeth wear patterns in Dental Anthropology: For organisms that use teeth to process food, tooth loss is directly related to survival – lose your teeth, lose your life (Lucas 2004). Cultural buffering during the later stages of human evolution removed this dramatic relationship, but dental conditions are nonetheless dictated by long-term evolution, not recent cultural advances. For that reason, human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele-ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing. For omnivores, including most primates, the den- tition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores or herbivores (Ungar 2010). Human tooth wear in pre-contemporary populations has been studied by physical anthropologists before the last century. Efforts to find associations between tooth wear and culture, gender, age, craniofacial geometry, tooth size, dental crown traits, diet and environment, and so forth, have provided many new insights over the years. Anthropological understanding of tooth wear in pre-contemporary populations was focused, mainly, for many years, on the abrasiveness of food, cultural practices, and the use of teeth as tools . Contemporary populations show little abrasive wear because of the consumption of processed, softer food. Therefore, much of the wear in our modern societies results from erosion and attrition. While attrition is common in current populations, there is evidence that attrition caused by tooth grinding may have always been a common behaviour in humans. Dental occlusions are dynamic and continually changing. Tooth wear, particularly abrasion in precontemporary hunter-gatherer populations, is the main mechanism that changes the morphology of teeth over time. A “canine-protected” occlusion during youth tends to change progressively into “group function,” causing a number of consequential adaptive changes. As the tooth wear progresses, continual eruption of teeth compensates for the wear (a feature seen commonly in other nonhuman species as well). The established occlusal vertical dimension at any given point of time is, therefore, a by-product of these two opposing processes. As the cusps reduce in height and disappear, the “tear-drop” cycle of the masticatory stroke becomes wider and, with excessive wear, corresponding remodeling of the glenoid fossa also tends to occur.

Interproximal grooving can be considered to be a type of noncarious interproximal lesion most often seen on the distal surfaces of posterior teeth in hunter-gatherer populations, particularly Australian Aborigines (Figure 2). This type of abrasive wear results from cultural practices where the teeth are used as tools. For example, at times when kangaroo tendon was chewed and passed between the teeth, it could slip interproximally and wear the distal surface of a tooth as the tendon was pulled anteriorly.For.eg. The passing of kangaroo tendon between posterior teeth caused distal abrasive wear called “interproximal grooving.” “X-occlusion” or “alternate intercuspation” are two terms used to define a characteristic mode of occlusion observed among Australian Aborigines living in their traditional lifestyle . The dentitions of these individuals are fully functional yet, according to “modern” dental opinion, such dentitions would generally be considered nonfunctional and orthodontic treatment would likely be recommended. Scissorial point cutting is a common evolutionary feature across different species and phyla. This feature has been described in the literature, is universal among herbivores, and is also strongly evident in human and nonhuman primates. The scooping of dentine allows the resulting, less-worn enamel to act as a sickle-shaped blade that moves against a similar blade facing in the opposite direction in the opposing arch. An extension to this well-documented account, which explains how teeth not only grind but actually cut food, is the theory of thegosis. This theory was developed over 50 years ago by Ron Every, whose observations of different species (including humans) identified that tooth grinding was a sharpening mechanism of the sickle blades resulting from differential wear to enhance the masticatory efficiency. Every extended his observations to specialisations within other species (e.g., baboons, wild boars), and showed how tooth grinding occurred during stressful encounters (fight-or-flight response) often in order to sharpen the canines—their biological weapons. This theory was further extended to the notion that tooth grinding in humans is built into our genetic codes, and is, therefore, an instinctive universal behavior. Tooth wear mechanisms, in particular abrasion, have been present since the reptilian-mammalian transition. For organisms that use teeth to process food, tooth loss is directly related to survival – lose your teeth, lose your life (Lucas 2004). Cultural buffering during the later stages of human evolution removed this dramatic relationship, but dental conditions are nonetheless dictated by long-term evolution, not recent cultural advances. For that reason, human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele-ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing. For omnivores, including most primates, the den- tition processes a more varied assortment of foods so their teeth are not as specialized as those of carnivores or herbivores (Ungar 2010). There is an acknowledged common pattern of wear observed between opposing posterior teeth in most species. The buccal cusps of the lower molars wear faster than the lingual cusps, while the palatal cusps of the upper molars wear faster than the buccal cusps. Dentists and anthropologists agree that a “tear-drop” masticatory action, together with a power-stroke, can explain this pattern of wear. Interestingly, accessory cusps are seen on the palatal surfaces of the upper teeth (e.g., Carabelli trait) and on the buccal cusp of the lower molars (protostylids). These accessory cusps are able to “take over” the load as the working cusps wear. This example shows how tooth wear, from an evolutionary perspective, is a selective force that is likely to have been responsible for changes in dental morphology. Also, there are recorded differences in wear patterns between males and females in some precontemporary populations because of differences in the tasks undertaken by each sex. Some societies even “file down” anterior teeth for aesthetic reasons or have teeth avulsed as a cultural practice.

Quantity & pattern of tooth wear can also provide additional dietary information. Historically, the teeth of both the early hunter-gatherers and the later agriculturists are characterised by rapid pronounced tooth wear, but it is the angle of crown wear rather than the absolute degree of wear that can help to distinguish between these groups. This variation is related to the major differences in subsistence and food preparation. Hunter-gatherers developed flatter molar wear due to the mastication of tough fibrous food. Agriculturists on the other hand developed oblique molar wear due to a diet based on ground grains and food cooked in water, which resulted in a reduction in the role of the teeth in breaking down foods (Forshaw, 2014).

The mechanism to account for this difference is explained by dividing mastication into two cycles, each characterised by a different type of tooth wear. In the initial cycle termed 'puncture crushing', teeth do not contact, but repeatedly crush the food bolus, producing blunting wear over the tooth surface. This is then followed by a cycle of 'chewing' in which the teeth shear and grind across each other producing characteristic oblique wear facets. For the hunter-gatherer when fibrous foods were prominent in the diet, teeth did not often make contact during mastication and molar wear is more evenly distributed, resulting in a relatively low wear plane angle in advanced tooth wear. However, with the prepared food of the agriculturalist, the molar teeth were in contact for longer periods and display a more restricted pattern of wear and a steeper wear angle. In general an assessment of the angle of tooth wear, rather than the absolute degree of wear, can be used to support dietary inferences and highlight changes in mastication and diet in some of our earliest ancestors. In the post-industrial populations. Microwear patterns within facets characteristically have parallel striations that are orientated in a horizontal or oblique direction on posterior teeth and in an anterior-lateral direction on anterior teeth. This microwear patterning has been described in the past leading to two diametrically opposing conclusions. Hence, both past & present populations get influenced by prevailing fashions, often with severe consequences. Tongue and lip piercing fall into this category, commonly causing mechanical damage to adjacent teeth.(10) For organisms that use teeth to process food, tooth loss is directly related to survival – lose your teeth, lose your life (Lucas 2004). Cultural buffering during the later stages of human evolution removed this dramatic relationship, but dental conditions are nonetheless dictated by long-term evolution, not recent cultural advances. For that reason, human teeth, along with the teeth of all vertebrates, were formed under the influence of natural selection. For animals that eat meat, the dentition has slicing, dicing, and piercing ele- ments with minimal emphasis on crushing and grinding teeth. Conversely, browsers and grazers process large quantities of plant foods and thereby have teeth devoted primarily to crushing and grinding, with little need for slicing and dicing.
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Conclusión

The physical condition of the dentition can provide valuable information on diet and health status. Studies of macroscopic wear and dental microwear yield evidence of dietary texture. Biomonitoring of trace elements assist in evaluating an individual's nutritional and environmental status (Forshaw, 2014). It is important to deepen the interdisciplinary spirit of Dental Anthropology. The knowledge and skills of dentists, physicians, bio archaeologists, forensic anthropologists, biochemists, biologists, historians and social anthropologists can exponentially enhance the scope of the interpretations in the frame of the discipline. This statement, firstly proposed about 40 years ago and sustained to the present as an essential pre requisite to modern bioarchaeology, remains highly effective and needs to be reconsidered in each analysis performed because, by clearly reflecting biological characteristics of modern humans,it is evident that the metric and non-metric traits of teeth could play a key role as anthropological indicators (Leandro, 2016; Pang Min-Kyu, 2017)

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