Review Article

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SIGNIFICANCE OF DENTAL ANTHROPOLOGY AND ITS ANALYTICAL METHODS: AN OVERVIEW

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ABSTRACT:

The scientific discipline dealing with studies of oral evolutionary trends, biodistance , paleodemography, paleodiet, sexual dimorphism and paleopathology using the analytical & comparative methods in order to compare the dentitions of extinct and modern human populations is referred to as Dental Anthropology. The analysis is done for noting the frequency & extent of Non-metric morphological variations (dental morphological features) as well as metric morphological patterns of the dentitions of the populations studied, over time (prehistoric and modern) and space impact (ie.ethnic influences) besides ,their relation to the processes of adaptation and diet changes which probably would have contributed to the evolution of the current dental system and thereby the human race.[1,3,5]

Teeth are influenced by a variety of factors including those largely controlled by genes to those governed by environment. In Dental Anthropology focus is on teeth related issues in terms of, population origins and population relationships. For the same reason, they use information on the tooth morphology, tooth size, tooth number, diet and presence of features indicating -attrition, crown chipping, tooth-tool use. Also, tooth health issues like -caries, abscesses, periodontal disease, calculus, hypoplasia and asymmetry are observed. Traits showing a wider distribution and higher frequency suggest a more ancient origin. [7]

Currently, certain novel techniques such as extraction of ancient DNA (aDNA), trace element content analysis and stable isotope analyses methods are also being employed. The development of microwear and confocal analyses of occlusal surfaces of teeth is found to be important for documenting tooth use and masticatory function. Dental anthropologists and forensic odontologists can thus, together decipher problems associated with craniofacial identification & can also collaborate in museum model reconstructions out of skull bones for Forensic Facial Approximation.

Key words : Dental Anthropology, Metric traits, Non-metric traits,Hubs,Nodes, Quantitative genetics, Epigenetics ,Tooth wear patterns

INTRODUCTION:

Teeth as referred to by the English Victorian naturalist Richard Owen (1804–1892), were thought of as "Firm substances attached to the parities of the beginning of the alimentary canal, adapted for seizing, lacerating, dividing and triturating the food, and called them the chief agents in the mechanical part of digestive function". So, according to him, the most characteristic function of human dentition needless to say, was of, the loading and crushing of food ,however, he overlooked all other functions of teeth that were secondary functions such as, the use of teeth as weapon or tool, as a structure for the characterization of age and sex, or as ornamental objects .For humans teeth also have great significance for vocal articulation (Schumacher et al. 1990) and for the esthetics.

In the initial evolutionary period Gill traps which were primitive tooth-like

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structures had facilitated food intake and all the modifications in structure as well as functions of teeth primary & secondary emerged in the later phase of evolution.

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The focus of Dental Anthropology is therefore, on the use of teeth to compare & interpret them in anthropological context.

<u>H/O of Dental Anthropology</u>:

The fundamental aspects of development, structure & functions of teeth were a part of Odontology, until in the 1960s and later they got incorporated in the rapidly developing discipline of dental anthropology.

Dental anthropology can be applied both to living people, using as well as to analyzing ancient remains with similar techniques employed.

Teeth, human as well as vertebrate ones, are dictated by long-term evolution with the influence of natural selection in their evolution. Thus, owing to natural selection in omnivores, including most primates, whose dentition processes a varied assortment of foods, the omnivore teeth are less specialized than those of carnivores in whom the dentition consists of teeth required for slicing, dicing, and piercing elements. Teeth of Omnivores are also different from those of herbivores in whom teeth are primarily used for crushing and grinding, with little need for slicing and dicing. The general omnivore/primate dental pattern therefore, consists of large, projecting canines primarily for use in male-male competition in order to get access to valued resources. Another feature of omnivore/primate dentition is a space, or diastema, between the upper lateral incisors and canines to facilitate proper articulation of the two jaws and also to accommodate the lower canine. Paleolithic evidence analyzing anthropologists have in their studies noted a change in this primate design in terms of -canine reduction, presence of homomorphic lower premolars, and lack of a diastema and marked them as hallmarks of early hominids. These changes they indicated were all linked to a single trait – canine size.[2]

Hominids and few other primates differ from Hominins in the form and relative size of the incisors. Therefore, monkeys and apes, have broad, spatulate incisors that are disproportionately large compared to their posterior teeth (premolars, molars), and also they are set obliquely in the jaw rather than vertically. Humans instead,have relatively small anterior teeth (incisors and canines) that are vertically implanted in the jaws. This difference is attributed to the extent to which different organisms manipulate food with their anterior teeth. [2]

Teeth are influenced by a variety of factors including those largely governed by genes to those governed by environment. In Dental Anthropology focus is on teeth related issues in terms of, population origins and population relationships. For the same reason, they use information on the tooth morphology, tooth size, tooth number, diet and presence of features indicating -attrition, crown chipping, tooth-tool use. Also, tooth health issues like -caries, abscesses, periodontal disease, calculus, hypoplasia and asymmetry are observed. Traits showing a wider distribution and higher frequency suggest a more ancient origin.(7)

Dentition thus cannot only be used to know about the Genetic & Environmental variables but, also to study the sexual dimorphism from information like- the difference in patterns of tooth development and eruption, the difference in expression of the type of amelogenin protein, tooth morphology and tooth dimension differences.[3]

Dentition studies in Primates and Hominid Fossils also fall within the purview of Dental Anthropology and research categories in Dental Anthropology primarily include study of : measurements, morphology, health, evolution, growth, genetics, usage & ethnographic treatment of teeth. [4]

Ancestry is significantly well indicated from tooth crown and root morphology analyses as they exhibit sufficient differences among the major groups of humankind and allow to differentiate European, African, Asian, and derived populations .Tooth size is not very helpful. The consistent findings of crown & root morphology analysis showed the affinities between Native Americans & Asians as well as their common distinctiveness from Europeans in Crown Morphology. Crown morphology variations may be as supplementary ridges, tubercles, patterns &/or cusps expressed on palatal, buccal or occlusal surface. Root morphology variations often present in the form of deviations in root number from the norm. It is important to note that, historical-evolutionary analyses of a morphological trait is useful only if a significant component of it is genetic. [2]

Various researches on tooth size (maximum mesio-distal diameter & Bucco-lingual diameter) indicate that size is more influenced by selection &/or environmental factors than crown shape. 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.

For each tooth, its morphology is genetically specific and nonrecurring, and the structure thus formed histoembryologically does not change or remodel itself unlike that of the bone, except when the teeth are subjected to mechanical wear or attrition and accumulation of secondary dentine. Teeth, therefore, have become the only element per se to provide biological and cultural information of an individual or a human population, possible due to below-mentioned reasons of:

1. High penetrance with a significant genetic control of tooth morphology
2. Environmental impact only in small fraction
3. The tooth characteristics and their geographical distribution showing good degree of correlation
4. Simple to observe and record
5. Enabling the comparison of data of past with present populations
6. The morphological changes of teeth indicating the dietary habits of the individual they belonged to and also the method in which food was processed then.
7. Teeth served as mirrors that gave an insight into the conditions of health, age, sex, habits and functional occupational habits as well as technological and cultural development of the population being studied.[3]

<u>The human dentition & its anthropological significance</u>[4]

1. Significance of the Human Dentition from an anthropological point of view is when we consider variations within & between modern populations because, in such comparisons, the dentition provides a relatively constant & nondirect source of the parametric data about processes during pre-& post natal development. This is attributable to the fact that, human dentition detail is one of the most unchanged data in the fossil record, both morphologically & as a repository of ancient DNA sequence information.
2. Changes in morphological contours of teeth & hence, in function, facilitate examination & comparision of inter-individual variation as a means for forensic identification.
3. Evolutionary models of oral microbial ecology now rely upon extraction of microbial DNA from deposits on tooth surfaces.
4. The developmental processes that give rise to morphological variation in human dentition & which are a result of temporal effects on individuals & populations during their lifespan are studied in terms of : developmental disturbance in their form & function that lead to variations within & among different groups of people, families, genders, ethnic areas & populations.
5. Information on methods & adaptive quality of the genome that incurs to it the ability of molding into a particular environment in a population can be obtained by family studies using population modeling of features that exhibit manifestation in family clusters.

6. Usage of linkage & association analyses from family data can be done to clarify the role of specific genes in physical characteristic developments and can give the information on genes & their environment interactions that yield a specific phenotype besides the analysis of role of the epigenome in tooth development & patterns of transmission of the features being analysed.

Reasons of using teeth & jaws in Dental Anthropology:

- The dentition with its harbouring jawbone are usually found in large numbers among paleontological and archeological findings ,primarily owing to their ability to resist post-mortal effects, therefore, many phyletic concepts are based solely on the analysis of tooth morphology.
- Teeth also play a significant role in anatomical investigations done by comparison and thus, help in rebuilding of information on phyletic mechanisms of importance in the evolution of mammals owing to the fact that "Tooth form varies with taxonomy and phylogeny and so can be used to rebuild evolutionary patterns". Dental data can therefore serve as "index fossils" in paleontology, paleo-zoology, and paleo- anthropology with availability of important details of environmental influences and food habits as well as answers to bio-stratigraphic queries.
- A high degree of morphological individuality coupled with their ease of visibility and assessment makes Teeth & Jaws a good source to be used to represent personal, familial, and population characteristics, in both living and past populations. Furthermore, they have good heritability making them useful in assessing evolutionary changes and population origins, developments and dynamics ,dietary and cultural behavior and environmental effects. They also bear the effects of environment & show its influence on teeth such as wear and disease ,so, this makes them well suited for research of dietary adaptations, regional variation in disease manifestations, epidemiological statusof environmental influences.
- 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 .[5]

The different types of teeth in mammals have been explained with the Butler’s field theory. A. A. Dahlberg, applied the concept of Butler’s field theory to the human dentition, where he used the phrase tooth districts to describe eight morphological classes corresponding to the four types of teeth in the two jaws.

According to him, within each tooth district, there is a "key" tooth, which shows the most developmental and evolutionary stability in terms of size, morphology, and number. In humans, the key tooth of a given tooth district is usually the most mesial element (e.g., upper central incisor, lower first molar); with the only exception being the lower incisor district where the lateral incisor is the key tooth. This theory therefore, implies that the key teeth best manifests the genetic-developmental programs controlling tooth development, whereas the distal elements of a field are more susceptible to environmental effects & may be related to the relatively protracted period of tooth development in humans.[6]

Understanding Human Dentition –A Complex System [4]

Thus,genetic & environment interaction gives insight into dentition emerging as a complex system 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.

Another important fact is that, some genes act on multiple dental phenotypes pleiotropically, for example, 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 :

a. Quantitative Genetics which heavily relies on inferred familial relationships.
b. Molecular Genetics which allows to know putative influence of key genes
c. 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.

Objectives of Dental Anthropology

- The primary theme of this discipline is to study alteration in morphological parameters 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.
- Dental Anthropology data is useful for the information of the past and for its influence on clinical basic research. For example, the knowledge of evolutionary trends, such as the decrease in size of teeth

and jaws, has important implications for clinical dentistry.

- Dental Anthropology also aims to reconstruct the phyletics of humans and primates.
- Dental anthropology also has a great influence on phylogenetic research in Paleolithic anthropology and has therefore, been responsible of advances in related disciplines such as primatology, osteology, and population biology.
- Anthropologists study archaeological, fossil, and forensic remains for understanding the biology of ancient human communities and following the course of evolution, & it is done from the fragmentary remains of an individual, particularly teeth.
- The knowledge base of Dental Anthropology also 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 interpreted against a people's culture, notably the conditions of life, diet, and adaptation processes.
- Dental Anthropology may permit the biological rebuilding of early populations (prehistoric anthropology), using the ontogenetic and populational variability of teeth.
- Dental research data can be used in investigations related to 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 and prove to be of vital significance.

<u>Steps of Dental Anthropology Implementation</u>: [7]

1. COLLECTION & HANDLING

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 have to be done ,followed by transport of collected specimen with utmost care to avoid fragmentation of fragile parts like mandible to the laboratory, where ,their metric and non-metric analysis is done.

2. METRIC ANALYSIS METHODS

Various methods to measure teeth have been given by researchers like- Martin 1928; Selmer-Olsen 1949; Moorrees 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 some instances.

However, traits such as height are excluded from measurement because teeth of ancient humans are quite 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.

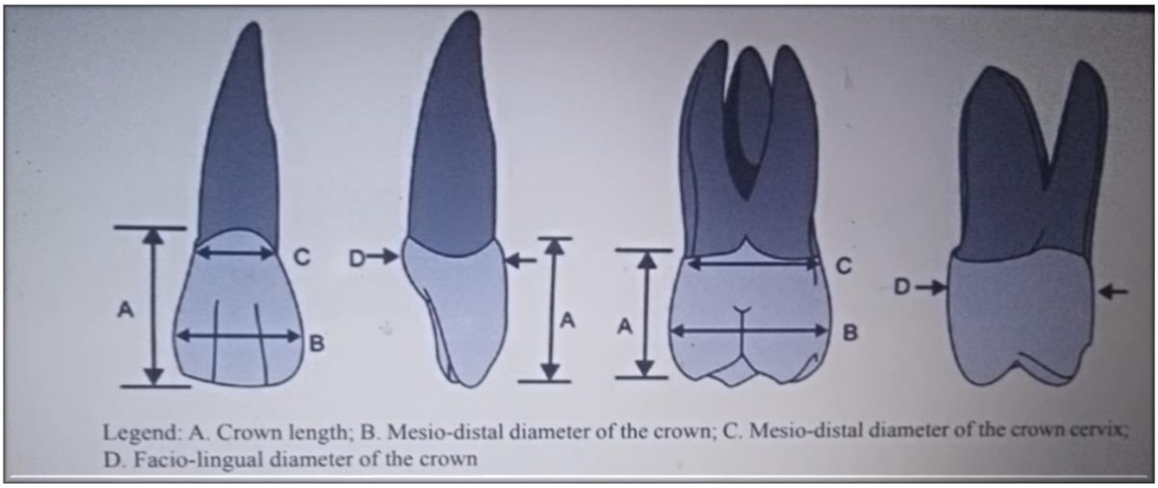

Fig-1 Tooth measurement points(Pang 2004)

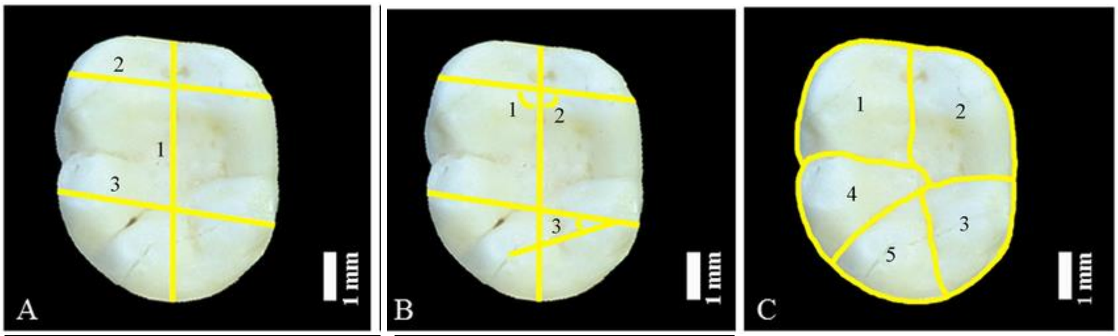

Fig-2A) Linear dimensions:
1) mesiodistal length
2) buccolingual width at mesial cusps
3) buccolingual width at distal cusps.

Fig-2B) Angles:
1) position of mesiobuccal cusp
2) position of mesiolingual cusp
3) position of hypoconulid

Fig-2 C) Absolute cusp areas**:**
1) protoconid
2) metaconid
3) entoconid
4) hypoconid and
5) hypoconulid.

For measuring teeth, digital callipers were used and four traits were measured among those presented by Zubov (1968). An average value in millimeters (mm) was obtained by measuring one item twice, and pairs of measurements showing large differences were measured again. The tooth measuring points elaborated below were given by Pang et al. in 2004.

a. Crown length –It was measured from tooth face surface, bend ridge to cutting edge(front tooth) or protoconid mesiolingual cusp top on maxillary molar.Protoconoid being one of the main functional shapes with the fundamental design of double bladed tools occurring in tooth forms such as tribosphenic,dilamdodont and zalambdodont.

b. Mesio-distal diameter of the crown-It was 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.

c. Mesio-distal diameter of the crown cervix It was measured as 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.

d. Facio-lingual diameter of the crown – It was measured as the longest distance between the bend ridge of the face surface and metaconid (distobuccal cusp) bend ridge such as to be perpendicular to the surface at which the mesio-distal diameter of the teeth was measured.

e. Module of the crown (mcor): VL (cor) + MD (cor) / 2

It was given by the relative size of the head and calculated through the average value of facio-lingual diameter and mesio-distal diameter. Normally, the full size can be 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.

f. 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. The index of the crown is higher,so, 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 becoming 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.

g. Absolute crown size (robustness, Rb): VL (cor) x MD (cor) :

This trait was used to reflect the overall crown size with the module of the crown and is a characteristic often used in paleo-anthropology.

h. Relative crown size (incisor index, canine index)

It was taken as 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 has reduced and is thus helpful for identifying reduction in the size of the jaw.
- The incisor index among Europeans has been found to be 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) however, is < 100, while Australopithecines show values > 100, significantly higher than in modern humans.

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

- Over the human evolutionary process, the first molar has been 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 was calculated as the ratio of the mesio-distal diameter of the first molar to that of canines and second and third molars.

- Deterioration of second and third molars can thus be estimated when compared to the first molar.

Therefore, step-index comprises the following four indices.

1. 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.

2. 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 has steadily decreased. In the evolutionary process from Australopithecines to modern humans, the most notable feature shown in teeth was the tendency of molarisation. Hence, the observations showed that in Australopithecus: 100.6; Homo erectus: 91.0; Homo neanderthalensis: 85.0; Homo sapiens: generally 80 or below (some at 85). However,the results of a comparative study between modern ethnic groups were insignificant.

3. 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

4. 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 be indicative of an interesting anthropological feature that explains changing biological characteristics over human evolution. In particular, ethnic groups living near the equator were found to be characterized 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 were also evident, as the step-index in women tends to be lower than in men.

In summary, the step-index was used as a key dental anthropological indicator for explaining the human evolutionary process because it showed large variations over time.[(7)]

3. NON-METRIC ANALYSIS METHODS:

The physical features of teeth, are also called as, discrete, discontinuous, quasi-continuous or epigenetic features as they were observed, recorded and analyzed with scientific evidence of high taxonomic value, frequency, variability, bilaterallity, sexual dimorphism and correspondence between features. The evaluation of reasons for their occurrence ,thus, allowed them to be used in the estimation of biological relationships among populations by comparative analysis of human past and present groups, in order to clarify the historical, cultural and biological macro- and micro-evolution, thereby leading to the understanding of displacement, migration paths and contacts that led to the various settlements and ethnic variations of humanity.

Usually about 17 crown traits and root traits particularly, those located in the crowns of incisors and molars of both dentitions, have been studied in the human dentition in most researches. [(3)]

Non-metric traits of teeth show the differences among modern human groups and aid in 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 shapes. The diversity of the tooth trait thus,provides critical information for identifying the differences between local groups and untangling genetic relationships.

The commonly recorded non-metric traits areas follows:

a. **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% has reportedly been expressed in some groups.

- Congenital lack of the third molar was most often seen in Mongoloids with an expression rate up to 30%. In contrast, expression frequency was found to be 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 age 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 dixfferentiate between unerupted teeth and teeth lost prior to death. Unerupted teeth can be discerned in radiographs. Teeth lost before death can be determined if the dental alveolus is absorbed or characteristically bent and unbalanced with evident alveolar holes. If the lost tooth was in contact with the adjacent teeth at least once, traces are evident on the contact surface.

b. **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.

c. **Bilaterally rotated incisors(winging)** –

- It is most frequent among the mesial incisors, and is referred to as 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 it rarely occurs in Europeans

d. **Peg-shaped teeth** -

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

e. **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.

f. **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 has shown a high frequency of this trait among Mongoloid people.
- Shovelling is,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.

g. **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.
- When it is extensive on the buccal side, it is more projected because the development of the mesial edge is more stronger (Mizoguchi 1985).
- This trait is observed in incisors and canines but the expression rate of double shovelling has been found to be the highest in maxillary mesial incisors.

h. **Canine distal accessory ridge** -

- 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% was shown in modern human groups with a higher frequency seen in

Mongoloids and Native Americans and with lower frequencies among Europeans.

i. **Terra's tubercle** -

- This additional tubercle occurs on the edge ridge of the inner surface of the maxillary 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.

j. **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). 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.

k. **Protostylid cusp** –

- The protostylid refers to an accessory cusp occurring in front of the buccal aspect 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 has been seen among modern people with the exception of the Pima Indians (southwestern United States), who exhibit frequency of 29.6% (Dahlberg et al. 1982).

l. **Groove patterns of premolars** –

- The shape and number of the lingual cusps in maxillary and mandibular premolars has been 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 lingual cusps, it has a Y shape.

m. **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) had 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.

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

- The occlusal cusp type of mandibular molars can be 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 molars 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 are believed to have recently developed in modern humans.
- Evolution from Y5 to +4 through +5 or Y4 is thought to be a general trend.

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

- The presence of the crest connecting the protoconid-metaconid of the trigonid of mandibular molars is recorded for this observation.
- 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.

p. **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 some cases, this ridge is straight and refracted by being inclined toward the central fossa. This trait rarely appears in the third molar.
- The expression rate among first and second molars is > 50% among Mongoloids and Native Americans, but does not exceed 15% in Europeans.(7)

q. **LEH**-

As tooth asymmetry seems to pose certain limitations as a broad scale indicator of comparative stress levels, dental anthropologists have now shifted their attention to the analysis of irregularities in the tooth crown that arise during enamel and dentine formation. One such manifestation growth irregularities which can be easily perceived is the linear enamel hypoplasia (LEH). LEH takes the form of horizontal circumferential bands and/or pits on the tooth crown. The key stimulus in earlier human populations for its development ,probably was some combination of nutritional deficiency and disease morbidity during amelogenesis.

Thus, morphometric measurements of teeth are an efficient method to facilitate comparisons between human populations because they use generally defined measuring points by 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 ,on the other hand,potentially indicate characteristics specific to one ethnic group and so its 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 the studied 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 the use of standard methods in this field, many newer techniques such as extraction of ancient DNA (aDNA), trace element content analysis and stable isotope analyses are used.

The use of DNA analysis allows access to genetic information

- at the personal level,
- at the intrapopulation level, and
- at the interpopulation level.

Trace elements and stable isotope analysis helps to detect the subsistence strategies, endogamy versus exogamy patterns, migration patterns , social differentiation methods, ontogenetic trends, assessment of toxic accumulation of elements such as Pb or As, and Paleolithic era prevalent pathological features.

Additionally, the development of study of tooth microwear patterns and confocal analyses of occlusal surfaces of teeth can also be done for documenting tooth use and masticatory function.

Significance of Anthropology in Forensics:[8]

Although forensic anthropologic analyses may seldom lead to a direct identification, it often helps to narrow the search field, and so, may indirectly lead to an identification. Many anthropologic analyses also involve the craniofacial complex, wherein the forensic anthropological observations often prove helpful as they produce information that is relevant to a dental identification as well as Forensic facial Approximation.

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 the 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 thus,together decipher problems associated with craniofacial identification. They can also collaborate in museum model reconstructions out of skull bones.[9]

Wilkinson C, 2010 in her review article had enumerated the facial reconstruction technique and it involved 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.[10]

Stage 1 (Anatomical modeling):

The first stage in facial reconstruction involves modeling of muscles and relevant anatomical structures on skull, utilizing strict anatomical guidelines of origin and insertion and a thorough knowledge of their existing variations. This stage has relatively low level of sculptural expertise and higher level anatomical acquaintance involved. Forensic odontologists are well versed with dental anatomy ,hence, the knowledge and clinical experience imparted by them, 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, ears 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 and 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 is a subject in the 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 Babylonian 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 incorporated this proportion during assessment of face and related structures for diagnosis and treatment planning and therefore may be useful while performing FFA.

Dental research based studies are instrumental in providing tissue thickness data for individuals of different ethnicity, age, sex, body-mass 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 developed a radiographic technique based on stages of development of teeth, and is still considered to be the gold standard in age estimation of growing individuals, although various other techniques have also been proposed later. The color of teeth as elements of recognition are also correlated to the skin color as well as race are a part of prosthodontics curriculum for selection of hue & chroma of teeth for denture patients.[9,10]

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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Teeth wear patterns in Dental Anthropology[11]:

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Tooth wear of Human teeth in Hunter-Gatherers when analysed by physical anthropologists to find correlation between tooth wear and culture, gender, age, craniofacial geometry, tooth size, dental crown traits, diet and environment has provided a great amount of information over the years. For a long time, anthropological understanding of tooth wear in them was focused mainly, on the abrasiveness of food, cultural practices, and the use of teeth as tools .

Later populations however, show little abrasive wear because of the consumption of processed, softer food & much of the wear in our modern societies results from erosion and attrition. Therefore, unlike hunter-gatherers attrition is common in current populations.

Fig-3a) Snaggle Teeth

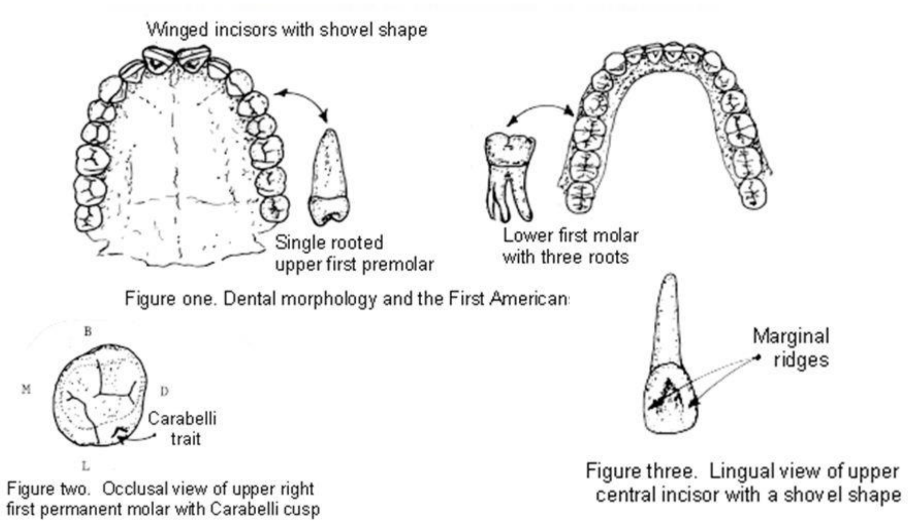

Fig-3b) Shovel Incisors, Carabelli Trait and Three rooted Mandibular molar

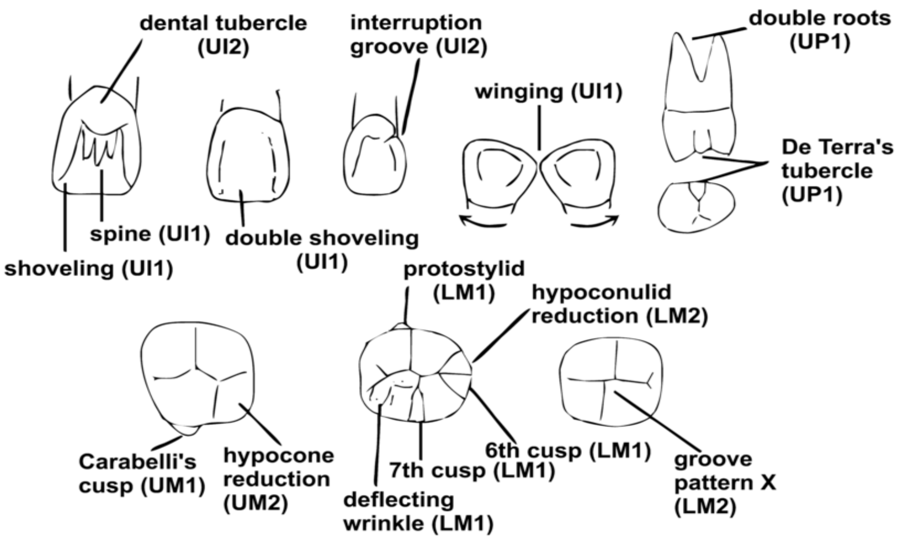

Fig-4: Various Non-metric Morphological alterations

Fig-5a:**Protostylid in mandibular molar** **Fig-5b:**Talon's cusp

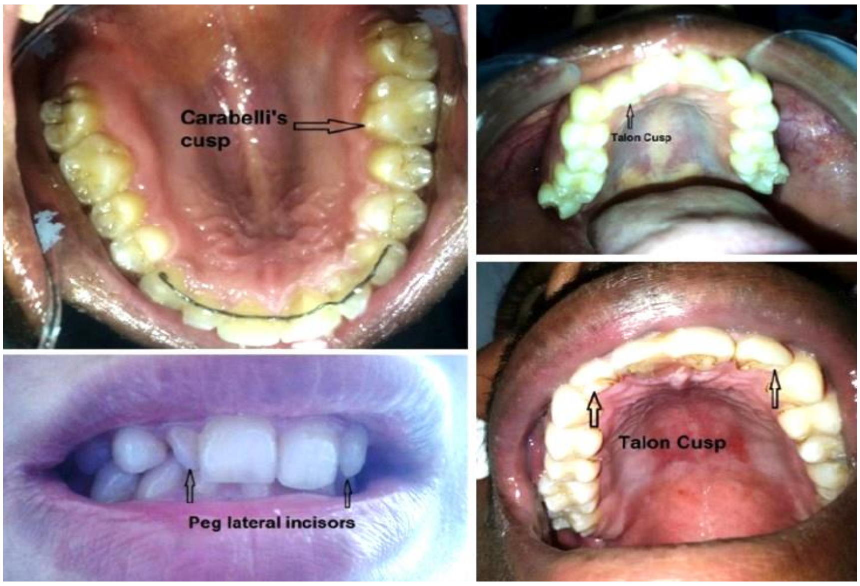

Fig-5c: Carabelli cusp, Talon cusp & Peg lateral

The main mechanism that changed the morphology of teeth over time particularly was abrasion in the hunter-gatherer populations, suggesting that, dental occlusions are dynamic and continually changing. As a result, a "canine-protected" occlusion during youth tended to change progressively into "group function," causing a number of consequential adaptive changes. However, with continued tooth wear, continual eruption of teeth also occurred and compensated for the wear .This was a feature seen commonly in other nonhuman species as well. The established occlusal vertical dimension at any given point of time was therefore, noted as, a by-product of these two opposing processes. As the cusps reduced in height and disappeared, the "tear-drop" cycle of the masticatory stroke became wider and, with excessive wear, was likely to cause corresponding remodeling of the glenoid fossa also.[11]

Besides change of "canine-protected" occlusion to "group-function"occlusion, Interproximal grooving was also seen as a noncarious interproximal lesion usually on the distal surfaces of posterior teeth in especially in Australian Aborigines. It is believed to have resulted from cultural practices where the teeth were 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 causing distal abrasive wear called “interproximal grooving.”

“X-occlusion” or “alternate intercuspation” were also observed among Australian Aborigines living in their traditional lifestyle and although, by “modern” dental opinion, such dentitions it would be considered nonfunctional, yet, the dentitions of these individuals were fully functional.

Another feature observed across different species and phyla through evolution is the Scissorial point cutting particularly,among herbivores, and was also strongly evident in human and nonhuman primates. It lead to the scooping of dentine resulting in a , less-worn enamel that would act as a sickle-shaped blade that moved 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 which was developed over 50 years ago by Ron Every. He, by his 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. He 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 .

Thus, tooth wear mechanisms, in particular abrasion, have been present since the reptilian-mammalian transition. [12]

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In most species common pattern of wear was observed between opposing posterior teeth wherein, the buccal cusps of the lower molars were seen to wear faster than the lingual cusps, and ,the reverse was true for maxillary molars. This, according to Dentists and anthropologists is due to a “tear-drop” masticatory action, together with a power-stroke. Interesting fact is that, subsequent to the wear off working cusps, accessory cusps which are seen on the palatal surfaces of the upper teeth (e.g., Carabelli trait) and on the buccal cusp of the lower molars (protostylids) were able to “take over” the load. 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. It was observed that,some societies even “filed down” anterior teeth for aesthetic reasons or had teeth avulsed as a cultural practice.

The teeth of both the early hunter-gatherers and the later agriculturists showed a rapid pronounced tooth wear, but ,of significance was , the angle of crown wear rather than the absolute degree of wear that helped to distinguish between these groups. This variation was a result of the major differences in subsistence and food preparation. Hunter-gatherers developed flatter molar wear due to the mastication of tough fibrous food, while, agriculturists developed oblique molar wear due to a diet based on ground grains and food cooked in water, so, leading to a reduction in the role of the teeth in breaking down foods. Thus, pattern of tooth wear & its quantity gave an indication about the diet of the population studied and vice-versa.[12]

This can be explained by the fact that, mastication occurs in two cycles, and, each is characterised by a different type of tooth wear. The initial cycle is 'puncture crushing', in which teeth do not contact, but by repeated force, crush the food bolus, &,over a period of time these teeth develop blunting wear over the tooth surface. The next part is a cycle of 'chewing' in which the teeth shear and grind across functional surfaces of each other producing characteristic oblique wear facets. For the hunter-gatherers since the fibrous foods were prominent in the diet, teeth often did not make contact during mastication and molar wear was more evenly distributed, resulting in a relatively low wear plane angle in advanced tooth wear. In contrast, the prepared food of the agriculturalist, caused the molar teeth to contact for longer periods and displayed a more restricted pattern of wear and a steeper wear angle. In general ,therefore, an assessment of the angle of tooth wear, rather than the absolute degree of wear, should be done to support dietary inferences and highlight changes in mastication and diet in some of our earliest ancestors.

In the populations after industrialisation, however, microwear patterns within facets were typical & had parallel striations that were orientated in a horizontal or oblique direction on posterior teeth and in an anterior-lateral direction on anterior teeth and such pattern lead to two diametrically opposing conclusions.[11]

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Fig-6: Molar cusp & groove patterns

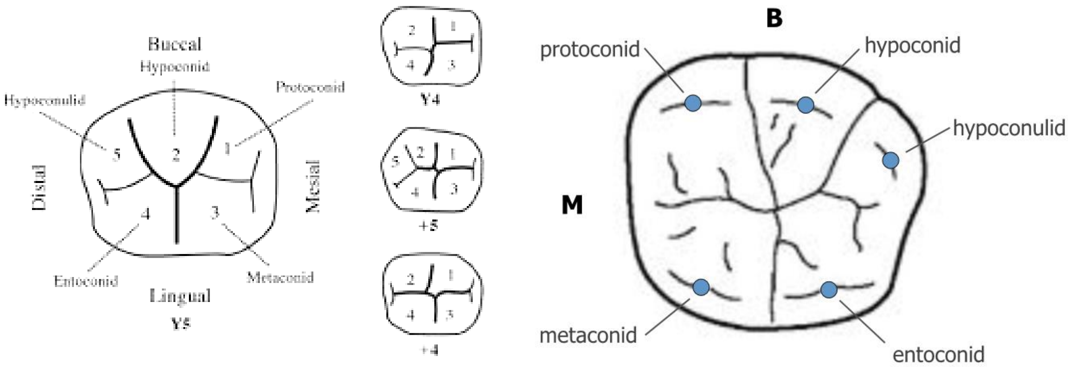

Fig-7: LEH(Linear Enamel hypoplasia) and age estimation with the help of LEH in Fossils

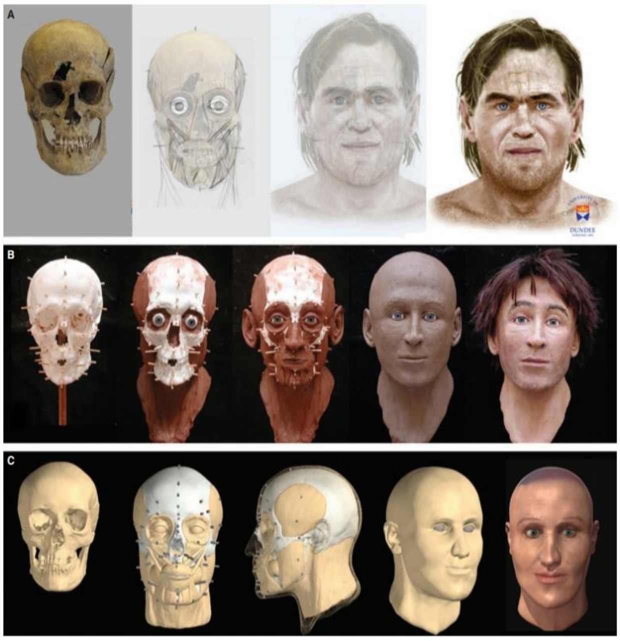

Fig. 1 Facial reconstruction methods: (A) two-dimensional manual, (B) three-dimensional manual, (C) three-dimensional computerized.

Fig. 4 Muscle attachment markings for temporalis (A), masseter (B) and zygomatic (C) muscles. ZMi, zygomaticus minor; ZMa, zygomaticus major.

Fig-8: Facial Reconstruction steps and methods

CONCLUSION:

The morphology of the teeth of a dentition after macroscopic wear & microwear patterns of teeth, at the time of observation & analysis, thus, provides valuable information about food habits, texture of food and health status of the period to which it belongs. Additionally, biomonitoring of trace elements can also assist in evaluating an individual's nutritional and environmental status.

The interdisciplinary interactive data of Dental Anthropology, can thus, significantly enhance the scope of the interpretations in the frame of this discipline.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. At present, Dental Anthropology encompasses the results of systematic efforts of various research teams for decades that has strengthened the conceptual nature of the discipline and these attempts thus allow the explaination of the enormous biological diversity of human populations. However, continued research is still essential to fully synchronize the research data from various regions on various analytical parameters of teeth for standardization.

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