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RESEARCH ARTICLE

GENDER AND RACE DETERMINATION IN FORENSIC ODONTOLOGY- AN OVERVIEW

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ABSTRACT

Forensic odontology is a branch of Forensic medicine which helps in identifying the victims or criminals in cases of disasters or crimes. Identification of gender of an individual is usually one of the first and foremost part of forensic investigation. In cases of mass disasters, accidents and chemical mishaps, the identification of race of the individual is also important for proper records. The various unique features of the craniofacial skeleton and dentition helps in this identification. The purpose of this review article is to discuss about the various methods for the identification of gender and race of an individual in forensic odontology.

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INTRODUCTION

Gender and race identification are important aspects of forensic odontology when there is any mass disaster, crime, accident, chemical mishap etc. Dental and facial features are helpful in identifying gender and race of the deceased person. Comparing post-mortem records with antemortem records usually helps in identifying individual person. Various morphological features of the teeth such as crown width and height, extra cusp, prominence of the ridges etc and the size of craniofacial bones help in identifying gender and race from the remains available from the site.

Gender Identification: There are various methods reported in the literature for identifying gender. They can be classified as morphological and molecular methods.[1] Morphological methods of sex determination include mainly the hard tissue analysis and soft tissue analysis.

Hard tissue analysis: Hard tissue analysis includes odontometric methods and orthometric methods. Odontometric methods include the features of dentition and orthometric methods include features of craniofacial skeleton and sinuses.

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Odontometric methods: Sexual dimorphism refers to the differences in size, stature, and appearance between male and female. This can be applied to dental identification also because no two mouths are alike.[2] Khangura et al[3] in their study on sex determination using mesiodistal (M-D) dimension of permanent maxillary anterior teeth found that maxillary canines show significant sexual dimorphism and can be used for gender identification. A study by Garn et al[4]reported that buccolingual dimension in male dentition were larger than female which was statistically significant. The mandibular canines usually exhibit greater sex difference in mesio distal crown size and inter canine width. The Mandibular Canine Index (MCI)[5] is derived as a ratio between canine crown width and canine arch width (measured in mm and is calculated as follows:

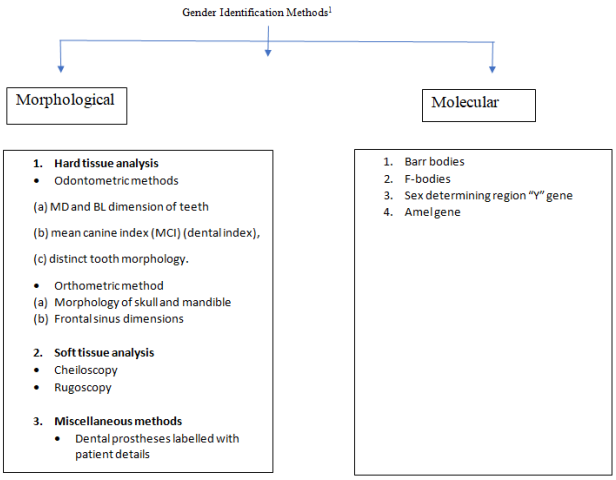
$$MCI = \frac{\text{Mesio distal crown width of mandibular canine}}{\text{Mandibular canine arch width}}$$

The standard MCI value was used as a reference to differentiate males from females, which is obtained by applying following formula:

Standard MCI (MCIs) = (mean male MCI − SD) + (mean female MCI + SD)/2

Calculation of sexual dimorphism can be done according to the formula given by Garn*et al*[4]. The standard MCI value, obtained by Rao et al. was 0.274.

Flowchart 1 demonstrates the various methods.



If the MCI value of a specimen is less than or equal to the standard MCI, the individual is categorized as female; a value more than the standard MCI would group the person as male. A recent study by Sandhya Jain et al[6] on Malwa population of central India found that standard canine index as 0.262. Various nonmetric features like a distal accessory ridge, number of cusp in mandibular first molar can also be used in gender identification. Distal accessory ridge in canine is more pronounced in male compared to female.[7] Female exhibit lesser number of cusp in the mandibular first molar compared to male (distobuccal or distal cusp).[8] This feature can be attributed to the evolutionary reduction in the size of the lower jaw in females.[9]

Orthometric methods: Orthometric methods includes analysis of morphology and dimensions of craniofacial bones, mandible and frontal sinus. The shape and dimensions of these structures differ in males and females and therefore can be used for gender identification.The frontal sinus is well developed in males whereas is it is less developed in females. A study by Kotrashetti Vet al[10] shows that mean values of the frontal sinus height, width and area are greater in males. Right frontal sinus is larger than the left sinus in both the sex. The details of various differences in the skull traits in males and females are given in table 1.

Soft tissue analysis: Soft tissue analysis includes cheiloscopy and rugoscopy.

Cheiloscopy: The study of lip prints is called Cheiloscopy. Lip prints are unique patterns on lip which helps in identification of a person. There is various classification of lip prints. Lip prints were classified by Suzuki and Tsuchihashi[11]and a modification of this classification waproposed by Sandhya Jain et al[12]. In this modified method, the upper and lower lip was divided into 8 equal zones by three vertical lines passing through midline and sides (figure1). Each of the segment was then evaluated for lip patterns.

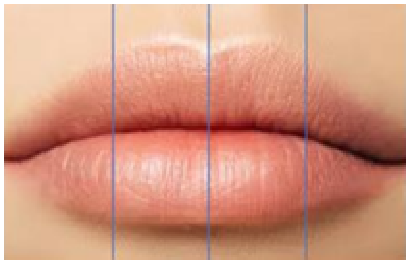


Fig.1. Division of lips into 8 zones

The pattern which was existing in more than 75% of lip was taken as the predominant lip print pattern of that individual.

Type I: Straight vertical grooves that run across the entire lips.
Type I': Vertical grooves similar to Type I that do not run across the entire lip.
Type II: Branched Y pattern.
Type III: Intersected grooves.
Type IV: Reticular grooves.
Type V: Undetermined.

Rugoscopy: Rugae are the anatomical folds or soft tissue ridges present on the anterior part of the palate. The study of palatal rugae is known as rugoscopy or palatoscopy.[13] Its shape, direction and unification remain consistent throughout life. It is a reliable method in identification of an individual and is also effective for determining sex of an individual.[14] Classifications of rugae given by Thomas & Kotze and Kapali et al[15,16] include number, shape, length and unification of rugae.

Based on length rugae can be classified as:

- Primary- >5mm.
- Secondary- 3 to 5mm.
- Fragmentary-<3mm.

Based on the shape, rugae can be classified into 4 types:

- Curved: crescent shape.
- Wavy: serpentine shape.
- Straight: They run directly from their origin to termination.
- Circular: Rugae that display a definite continuous ring

Unification occurs when two rugae are joined at their origin or termination.

- Diverging: when two rugae had the same origin from the midline but immediately branched laterally.
- Converging: Rugae with different origins from midline, but are joined laterally.

Miscellaneous methods: Dental prostheses labeled with the patient's name and further unique identifiers such as sex, phone number, address, job and national identity number may play an important role in forensic odontology. Labeled prosthesis act as an antemortem record. Denture labeling can be classified as inclusion system and marking system. Inclusion system uses metal, nonmetal, micro label, and chips. Marking system uses spirit-based pen or pencil. Lead paper is the best-suited denturemarker.[17,18]

Molecular Analysis: Molecular Analysis by DNA is the most advanced and accurate method for gender identification. The extracted DNA from the teeth of a deceased person can be compared with the ante mortem DNA samples.

Blood, clothes, hairbrush, cervical smear or biopsy sample can provide a good source of ante mortem DNA. The different types of DNA are nuclear DNA and Mitochondrial DNA. Extraction of DNA can be done by cryogenic grinding or by grinding the tooth to extract the DNA. Cryogenic grinding involves cooling the whole tooth to extreme low temperature using liquid nitrogen.

Table 1. Showing skull traits of two sexes[10,37]

Trait	Male	Female
General size	Large Endocranial volume > 200 cc	Small lighter with thin walls
Architecture	Rugged	Smooth
Glabella	More pronounced	Less pronounced
Orbits	Square, lower, smaller with rounded margins	Rounded, higher, larger, sharp margins.
Supra-orbital ridges	Prominent	Less prominent
Fore head	Steeper & less rounded	Vertical, round &fantile
Check bones	Heavier, laterally arched	Lighter & more pronounced
Zygomatic arch	More pronounced	Less pronounced
Frontal eminence	Small	Large
Parietal eminence	Small	Large
Occipital area	Muscle lines & protuberance marked	Muscle lines & protuberance less marked
Mastoid process	Medium to large, round & blending	Small to medium smooth & pointed
a.Base	Sites of muscle insertion are marked	Less marked
b.Digastric groove	Deep	Less deep
c.Condylar facet	Long and slender	Shorter and broad
Occipital Condyle	Larger	Small
Palate	Larger,broader, U-shaped	Small & parabola shaped
Frontal sinus	Well devoloped	Less devoloped
Nasal aperture	High & narrower margins & sharp	Lower & broader
Foramina	Larger	Smaller
Externalauditory meatus	Bony ridge along the upper border is prominent	Often absent
Foramen magnum	Large and long	Small and round
Mandible size	Larger & thicker	Smaller & thinner
Chin	Square	Rounded
Body height	Greater at symphysis	Smaller at symphysis
Ascending Ramus	Greater breadth	Smaller breadth
Gonial angle	Less obtuse (125˚) prominent & inverted	More obtuse not prominent & inverted
Condyles	Larger	Smaller

Table 2. Showing distinguishing features of various races

Mongoloid	Caucasoid	Australoid	Negroid
1.Shovel shaped incisors 2.Greater curvature of incisors 3. Dens evaginatus 4. Five cusp forms of upper molars 5. Extra distolingual root in lower molars 6. Taurodontism 7. Enamel extensions to the furcation area 8. Parabolic archform	1. Narrow arch and crowded teeth 2. Chisel shaped anterior teeth 3. Cusp of carabelli	1. Large arch size 2. Large molar teeth (Megadont) 3. Severe attrition 4. Edge to edge bite 5. Mesial drift of teeth 6. Enamel pearls between roots	1. Small teeth with spacing and midline diastema 2. Supernumerary teeth 3. Rarely impacted third molars 4. Class III malocclusion 5. Open bite 6. Bimaxillary protrusion

The more conservative method for DNA isolation involves opening of root canals and scrapping the pulp area with a notched medical needles. There are various methods for analyzing the extracted DNA.[1]They are restriction fragment length polymorphism, polymerase chain reaction (PCR), microarrays, etc

Barr bodies: The deeply stained chromatin material innuclei of cells in female are known as Barr bodies. It is seen only in females. The termbarr bodies was coined by Murray barr. They have an important role in the determination of sex of an individual. The chromatin materials represent inactivation of one of the X chromosomes in each somatic cell in females occurring during early embryonic development. This process is called aslyonization named after Lyon.[19] Barr bodies are basophilic structures measuring 0.8 × 1.1 microns. They exhibit various shapes such as spherical, rectangular, plano-convex, biconvex, and triangular. In electron microscopy, they resemble as various alphabetical letter such as V, W, S, or X. Papanicolaou stain is used for seeing barr bodies which are present in the nucleus. Negative results can be attained under certain pathological conditions as they can be associated with variations in size and shape of Barr bodies. A study by Das et al[20] stated that up to 4 weeks after death, sex can be determined from the study of X and Y chromosomes.

F‑bodies: F- body is a bright fluorescent spot present in Y chromosome which is visible when stained with fluorescent dye quinacrine. Therefore F-bodies can also be usedfor identifying sex. F- bodies had been identified from dental pulp also. Casperson et al.[21] stained pulpaltissue with quinacrine mustard and demonstrated that Y chromosome fluoresced more brightly than other chromosomes when viewed under ultraviolet light. He suggested that alkylating agents like quinacrine accumulate and acts on the DNA portion rich in guanine. Dried bloodstains, saliva, hair, and extracted dental pulp contain DNA and can act as sample for F- body identification. Seno and Ishizu carried out the detection of Ychromosome in the nuclei of dental pulp. They found that over 30% of the male pulpal tissue showed positivity for F-bodies. F-bodies could be examined even in teeth as old as 5 months after extraction.[22]

Sex determining region "Y" gene (SRY)

Sex determining region "Y" gene (SRY) codes for the sex-determining region Y protein, which is responsible for further development as male. SRY is located on the short (p) arm of the Y chromosomes at the position 11.3. More accurately, from base pair 2,786,854 to base pair 2,787,740.[23] Therefore, SRY gene canbe used as a sex-typing marker in forensic odontology. In certain syndromes, maternal – fetalmicrochimerism and dissimilar sex between donor and recipient during transplantation (chimerism) false positive results can be obtained.[24,25] A study by George et al.[26] identified gender by amplification of SRYgene. They used

real-time PCR from isolated epithelial cells of removable partial denture. They found that saliva-stained acrylic dentures can act as a source of DNA of the unidentified person and co-amplification of SRY gene with other routine sex typing markers will help in gender identification. Reddy et al. studied the epithelial cells adherent to toothbrush as a source of DNA for sex determination using real-time PCR. All male sample in their study showed positive results and out of 15 female samples four were wrongly identified as males.[27]

Amel gene: AMEL gene is involved in the formation of amelogenin. Amelogenin is the protein responsible for amelogenesis. AMEL X gene is present in 106 bps and AMELY is present in 112bps of the DNA. The female has two identical AMEL genes or alleles and the male has two different AMEL genes. This can be used to determine the sex of the remains with very small samples of DNA.[8]

Race Determination: Existing races of man differ in terms of color of skin, hair, shape of skeletal bones, proportions of the body, etc. It is very difficult to determine the racial affinity of an unknown individual with the help of dentition. There are some dental characteristics which are predominant in some racial groups which can help in the racial identification process.[28] There is various classification of races. Classification by Coon in 1962, on the basis of phenotypic physical features are Caucasoid, Mongoloid, Australoid, Negroid, and Capoid.[29]

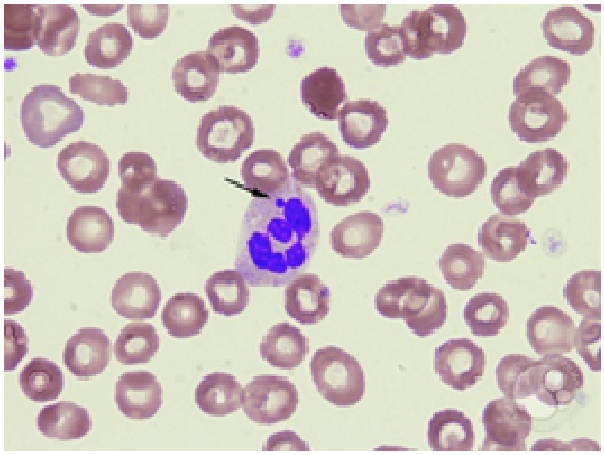


Figure 2. Barr bodies

Caucasoids, Mongoloids, Negroids, and Australoids (Australian aborigines) are four major groups considered in the world. Skin, hair, head shape, face type, eyes, nose skeletal size, and dentition are considered as distinguishing features in the study of races. However, racial characteristics are not diagnostic features; they are considered as suggestive features in determining the racial origin of the individual. Teeth are most important and reliable sources of information during racial differentiations.[28] Dental traits include ridges, bulges, crown and root of the teeth, number of teeth, occlusal and bony relationship, and individual tooth measurement which vary in size.[30]These dento-anthropologic structures are important and reliable sources of information in determining racial affinities.[31]The distinguishing features of various races are given in Table 2.

Mongoloid: The most distinguishing feature of Mongoloid dentition is shovel shaped incisors. It is found on the lingual surface of the incisors. The fusion of the lateral or marginal ridges forms a raised cingulum and creates a deep lingual fossa. The ridge fades toward the incisal portion of teeth, and this gives the tooth a "shovel" or "scoop" shape appearance (Figure 2). Approximately 90% of Mongoloids inclusive of Eskimos and American Indians shows this condition.[32] Sometimes, there may be a groove on the lingual surface at the cervical margin up to the root surface and "Screw like or Finger like" projections from the cingulum toward the incisal margins. Frequently, the prominent lingual marginal ridges which produce the Mongoloid shovel-shaped incisor extends onto the labial surface. These produce a mesiodistal concavity of the labial surface and are termed "double-shovel shaped" incisor.[33]

Incisors of Mongoloids show a greater curvature than Caucasoids. Mongoloids premolar occasionally display a tubercle on the buccal cusp and this condition is called as Dens evaginatus. Singaporean Chinese exhibited bilateral five cusp forms on upper third molar and 43% of second molars. While in the lower molars, the distal (5^{th}) cusp is usually more lingually placed than Caucasoids. Occasionally, extra distolingual root in the lower first molar and third molar and even in second deciduous molar are also seen.

Mongoloids show shorter anatomical roots, but thicker root trunks. Increased growth of root trunk leads to taurodontism. Furthermore, in Mongoloids, the enamel contour extends sometimes between the bifurcation of the roots. It is more frequently seen on the buccal surface of the mandibular molars.[34] Cusp of Carabelli is usually not present in Mongoloids, which is considered as one of the notable features in this race. If present, it is usually a reduced form. In general, Mongoloids have a parabolic arch, especially lower arch with large incisors, canines, small premolars, and large molars behind them.[35]Incidence of 3 cusp maxillary first molar in Indian Malwa population was previously reported in the literature.[36]

Caucasoid: Caucasoids usually have crowding of teeth because of the narrow "v-" shaped arch.[34] The anterior teeth of Caucasoids are described as "chisel shaped" having smaller and smoother lingual surface. Approximately 37% of Caucasoid have a distinguishing feature called the cusp of Carabelli (Figure 2).[37] This is seen on the mesiopalatal cusp of the maxillary first permanent molars and the maxillary second deciduous molars. Sometimes, this trait may vary as pits, furrows, or slight protuberance. Some Central Europeans have a wide-based prominent cingulum on the lingual surface of their incisors rather than rolled smooth continuum common to the most Europeans. Shovel-shaped incisors are exhibited among in about 30%–36% of the Danish and Swedish population, 46% of the Palestinian Arabs, and also in 51% of the Indians.[38] According to Lunt, maxillary lateral incisors of Europeans are more likely to appear as shovel shaped.[32]

Australoid: Australoids usually have a large arch size which accommodates larger-sized teeth. Molars are of bigger sizethan that of any other living race (termed as megadont). The mesiodistal diameter of the first molar is 10% longer than that found in Norwegian Lapps and White American.[39,40] Theyhave large premolars also, but the anteriorteeth are relatively small. Severe attrition and mesial drift of teeth is a common finding in this race. Attrition leads to edge-to-edge bite and typical spatulate anterior teeth.[41] Shovel-shaped

incisors and the appearance of cusp of Carabelli are rare. According to Campbell, there may be the presence of enamel pearls exhibited between the roots and the third molars may be missing.[42]

Figure 3. Shovel shaped incisors

Figure 4. Shows cusp of carabelli

Negroids: The Negroidshave small teeth with spacing and midline diastema. There is an increased incidence of supernumerary teeth. The lower first premolar has two distinct cusps; sometimes even three cusps. The presence of the cusp of Carabelli and shovel-shaped incisor is uncommon in Negroids. The third molars are rarely impacted and clinically present in most of them. Class III malocclusion and open bite,bimaxillary protrusion are common malocclusion present in Negroids. Both maxillary and mandibular alveolar bone are protruded with incisor slanted labial.[43]

Conclusion

The forensic odontology mainly deals with identification of a deceased person in cases of disasters, crimes, natural calamities etc. The gender and race determination of an unidentified person is an important step in identifying the individual person. There are some features of the craniofacial bones and dentition which shows sexual dimorphism and helps in gender and race determination. This paper gives an overview of such methods which are very useful in forensic odontology.

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