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THE ROLE OF CRANIOFACIAL RADIOGRAPHS IN ASSESMENT OF SEXUAL DIMORPHISM IN FORENSIC ODONTOLOGY

Forensic Radiology

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ABSTRACT

Sex determination becomes the first priority in the process of identification of a deceased by a forensic investigator in the case of casualties, natural mass disasters, bomb blasts, crime investigations, and racial studies. Identification of gender using skeletal remains presents a great problem to forensic experts, especially when only remaining portions of bodies are recovered. Forensic odontology is the investigative and analytical section of dentistry that applies dental principles to legal issues and analyses dental evidence for human identification. Sex determination is a sub-branch of forensic odontology. It is an investigative aspect of dentistry that analyses dental evidence for human identification. It is very crucial, when information of the deceased is unavailable. Forensic odontologist can assist other experts to determine the sex of the remains using teeth and skull traits. Radiology plays a major role here as antemortem craniofacial radiographic records if available, make sex determination all the more unchallenging. This article reviews upon the various radiographic methods used, their different parameters and outcomes in sex determination in forensic odontology.

KEYWORDS

forensic, odontology, sexual dimorphism, craniofacial radiographs

INTRODUCTION

Forensic odontology plays an important role in the personal identification of victims with bodies mutilated beyond recognition due to major mass disaster. It is difficult for forensic experts to identify a person's gender from skeletal remains, especially when only body fragments are found.

Dentists can help other specialists identify the gender of the remains by examining the teeth and skull. Both male and female sexes have different tooth features, such as morphology, crown size, and root lengths. Additionally, variations in the cranial patterns also aid forensic odontologists in determining the victim's sex. [(1)]

Forensic radiology has been used in forensic sciences since time immemorial. Wilhem Conrad Roentgen created the first radiograph in 1895, marking the beginning of its history. Post-mortem radiography examination was introduced in 1898, three years later.

Forensic radiology so far, has depended almost exclusively on the radiographic and the static image captured on the OPG. [(2),(3)]

The Indian population exhibits a spectrum of both homogeneous and heterogeneous subpopulations in different geographical areas. However, forensic data on cranio-mandibular parameters in the Indian population is scarce. [(1),(14)]

Antemortem or post-mortem craniofacial radiographs according to multiple studies conducted previously can be of great help in identifying factors like sex and age of individual. Multiple structures like the frontal sinus, maxillary sinus, mastoid process, mandible, ramus, teeth, coronoid process, zygomatic arch, supraciliary arches, etc. present with sexual dimorphism as per studies so far. Now with the advent of higher 3-dimensional radiographic modalities, newer studies have confirmed the same and discovered newer parameters.

Hence a review of the craniofacial radiographic features for sexual dimorphism in forensic odontology is presented here. An attempt has been made to collect and present review of literature pertaining to radiographic studies for determination of sex.

REVIEW-

The different studies with their parameters used and consecutive outcomes are assembled in the table below: -

Table 1: - Studies for assessment of sexual dimorphism with their varying parameters, modalities used and outcomes.

Sr. no.	Author	Year	Parameter	Sample Size	Modality	Outcome – sex differentiation
1.	**Toshiko Ikeda, Motonobu Nakamura and Masatugu Itoh [10]**	**1999**	Zygomatic angle	**432**	**MRI**	Significant differences
2.	**Sithiporn Agthong, Thanasilp Huanmanop, and Vilai Chentanez [11]**	**2005**	Supraorbital, infraorbital, and mental foramina	**110**	**Crania**	Significant differences
3.	**Gapert et al [12]**	**2008**	Condylar measurements, including length, width, and intercondylar measurements	**146**	**Crania**	Significant differences
4.	**Fouad Ayoub et al [13]**	**2009**	Mandibular angle	**83**	**Lateral cephalograms**	Significant differences
5.	**Venkatesh G. Naikmasur, Rahul Shrivastava and Sunil Mutalik [14]**	**2009**	11 cephalometric parameters	**-**	**PA views and Lateral cephalograms**	Bi-zygomatic width, ramus height, and facial depth were the main contributors.
6.	**Vineeta Saini et al [15]**	**2011**	Ten standard cephalometric parameters	**112**	**Crania**	In stepwise analysis, bi-zygomatic breadth turned out to be the sole most useful parameter.
7.	**Rishabh Kapila, K.S. Nagesh, Asha R. Iyengar and Sushma Mehkri [16]**	**2011**	Mesiodistal dimensions of mandibular canines	**40**	**IOPA**	Significant differences
8.	**Shearer et al [17]**	**2012**	Brow-bridge volume.	**128**	**3D laser scanner**	Volume in males was significantly larger.
9.	**Juliana Isaza et al [18]**	**2012**	16 measurements of endocranial cavity	**249**	**Volumetric 3D reconstruction of computed tomography (CT)**	The most dimorphism was found in the maximum width of the foramen magnum, the maximum width of the basal

						occipital region, and the maximum distance between the foramina ovalia.
10.	**Nidugala et al** [19]	**2013**	10 craniofacial parameters	**80**	**Crania**	bizygomatic, orbital and biorbital breadths showed greatest sexual dimorphism
11.	**Abdel Fatah EE, Shirley NR, Jantz RL, Mahfouz MR** [20]	**2014**	Endo- and ectocranial measurements	**222**	**3D reconstruction of computed tomography (CT)**	Size was a significant component for dimorphism, shape played a role, as well. Vault thickness is another characteristic; in the frontal region, females typically have thicker vaults than males, whereas in the occipital region, males typically have thicker vaults.
12.	**Aysar Razzaq Ali and Lamia H. Al-Nakib** [21]	**2013**	11 parameters were measured	**113**	**Digital lateral cephalometric**	All cranio-cephalometric measurements gave significant differences
13.	**Chandra et al** [22]	**2013**	Superior and inferior borders of mental foramen	**100**	**Panoramic radiographs**	Significantly larger values in males.
14.	**Belaldavar et al** [23]	**2014**	Frontal sinus	**300**	**Postero- anterior views**	Significantly larger values in males.
15.	**Shivaprakash et al** [24]	**2014**	Mandibular posterior ramus flexure	**104**	**Mandibles**	Significantly larger values in males.
16.	**Massarat Jehan, Vipendra Bhadkari, Akhilesh Trivedi and S.K. Sharma** [25]	**2014**	Bizygomatic distance, AP diameter & width of the maxillary sinus & intermaxillary distance	**191**	**CT scans**	Bizygomatic distance & maxillary sinus dimensions are both useful for gender determination.
17.	**Ranjith et al** [26]	**2015**	Maxillary sinus	**30**	**CT scans**	Values were larger in males
18.	**Suragimath et al** [27]	**2016**	Mental foramen	**400**	**Panoramic radiographs**	Significantly larger in males
19.	**Raiker et al** [28]	**2016**	Foramen magnum	**150**	**Sub-mento vertex radiograph**	Measurements were larger in males
20.	**Samatha et al** [29]	**2016**	Ramus and anteroposterior superioinferior angle of mandibular condyle.	**120**	**Panoramic radiographs**	Ramus breadth, Condylar height and Projective height of ramus were significantly larger in males
21.	**Barbora Musilova et al** [30]	**2016**	Entire exo-cranial surface size was analyzed using coherent point drift-dense correspondence analysis	**103**	**CT scans**	Supraorbital region, orbits, cheek bones, nasal apertures, mastoids, and external occipital protuberances showed most significant difference.
22.	**Sailaja Sambhana et al** [31]	**2016**	Mandible	**384**	**Panoramic radiographs**	All parameters of mandible showed significantly larger values in males except gonial angle.
23.	**Shruti Chandra et al** [32]	**2017**	Zygomatic arch	**60**	**Jug-handle radiographs**	Significantly larger in males
24.	**Stefan Schlager and Alexandra Rudell** [33]	**2017**	Zygomatic arch	**98 Chinese 96 Germans**	**3D scans**	Significantly larger in males
25.	**Wen Yang** [34]	**2019**	The network inputs consisted of six skull features that were measured via computer-aided measuring.	**267**	**Computer scanning-back propagation neural network.**	Significant differences with larger values in males.
26.	**Colmenares et al** [35]	**2019**	Skull base	**115**	**Submentovertex-radiographs**	Foramen magnum length and Bizygomatic breadth showed most significant differences
27.	**Mondal et al** [36]	**2022**	Morphometric and volumetric assessment of mastoid process	**60**	**Cone beam computed tomography scans**	Length, height, width and volume of mastoid process were significantly larger in males
28.	**Muhammad Faiz Mohd Fauad et al** [37]	**2021**	Third cervical vertebra	**432**	**Lateral cervical radiograph**	It became that there were significant variations in the height of the vertebral body, the length of the superior articular process, and the length of the superior portion of the C3 spinous process.
29.	**Ramhari et al 2022** [38]	**2022**	Mastoid to Gonion height and Bizygomatic width	**100**	**Postero-anterior cephalograms**	Bizygomatic width and Mastoid to Gonion height had a high sex discriminating ability

30.	**Nur Damia Iwani Zulkiflee et al** [39]	**2022**	Frontal sinus	**453**	107–112.	**Lateral skull radiographs**	Significant differences with larger values in males

The skull, after the pelvis is the most readily assessed portion of the skeleton for sex identification. Because the majority of the craniofacial structures are made of hard tissues, which are rather unyielding, they have the ability to distinguish between individuals and demographic groupings. However, until the secondary sexual features appear, determining the sex from the skull is unreliable. Unfortunately, no single morphological feature has been identified as distinctive for gender differentiation from the skull out of all those that have been described. Previous descriptions have included techniques with morphometric or anthropometric analysis that had an accuracy of 77–92%. [3] **Iscan,** [4] has stated in his review that osteometry is the procedure of choice for determining a person's sex. In a study incorporating osteometry, **Robinson and Bidmos** [5] assessed five discriminant function equations in the mandible and crania of white South Africans descending from three distinct European subgroups. The range of 72–95% was the classification accuracy for functions based on osteometry.

The degree to which gender may be distinguished precisely depends on the particular components of the skull that are present and how well-preserved they are. Since sexing an adult skull requires a particular collection of diagnostic features, the range described above may change. [3]

Compared to morphometric and anthropometric approaches, radiographs offer a more accurate, simple, reliable, and repeatable means of determining sex through linear and angular measures.

Skull radiographs have shown 80–100% accuracy in differentiating between genders. [6] Standardized skull radiography techniques, such as lateral and postero-anterior cephalometry, have increased this accuracy even more. They disclose additional characteristics and more grounds of comparison.

Radiographic projections for endocranial capacity, according to **Krogman** [6]**,** aid in gender distinction. He predicted that if both antemortem and postmortem skull radiographs are available, sex determination will be 100% accurate. 100 lateral cephalograms of Taiwanese descent were examined by **Hsiao et al** [7]. 18 criteria were generated with 100% accuracy in sex determination using the external occipital protuberance, frontal sinuses, superciliary ridges, and mastoid processes as the items of cephalometric measurements.

A similar study by **Patil and Modi** [8] on central Indian population, considering 10 cephalometric linear variables, reported an accuracy of 99%. **Hatipoglu et al** [9] used MRI to evaluate the craniometric sexual dimorphism.

The cranial volume, diploeic thickness at the glabellar area, vertex-basion, basion-opisthion, euryon-euryon, and glabella-opisthocranion distance were the variables employed. Overall, it was discovered that males had higher measurements.

Numerous studies have already employed various skull radiograph criteria to determine a subject's sex.

CONCLUSIONS

There is an increasing need for the accurate and reliable assessment of biological sex in forensic cases when identifying missing human remains. In several previously studied groups, notable and statistically significant differences between the skulls of males and females have been discovered; this data aids in the prediction of the sex of unidentified individuals. In addition to examination of anatomical remains to identify sex of victim's radiographs are invaluable tools which assist in personal identification. Radiographs in this way rule out the need for invasive post- mortem procedures of the body of the deceased to identify the sex of the victim. We have to ponder more on this to assess if it can also be used for racial identification and age estimation which will be essential for identification in forensics.

REFERENCES:

1. Nagare SP, Chaudhari RS, Birangane RS, Parkarwar PC. Sex determination in forensic identification, a review. J Forensic Dent Sci 2018; 10:61-6.
2. Manigandan T, Sumathy C, Elumalai M, Sathasivasubramanian S, Kannan A. Forensic radiology in dentistry. J Pharm Bioall Sci 2015;7: S260-4.
3. R.H. Biggerstaff, Craniofacial characteristics as determinants of age, sex and race in forensic dentistry, Dent. Clin. North Am. 21 (1) (1977) 85–97.
4. M.Y Iscan, Forensic anthropology of sex and body size, Forensic Sci. Int. 147 (2005) 107–112.
5. M.S Robinson, M.A. Bidmos, The skull and humerus in the determination of sex: reliability of discriminant function equations, Forensic Sci. Int. 186 (1–3) (2009), 86.e1–5.
6. W.M. Krogman, The Human Skeleton in Forensic Medicine, Charles C. Thomas Pub Ltd, Springfield, Illinois, USA, 1962, pp. 114–122.
7. T.H. Hsiao, H.P. Chang, K.M. Liu, Sex determination by discriminant function analysis of lateral radiographic cephalometry, J. Forensic Sci. 41 (5) (1996) 792–795.
8. K.R. Patil, R.N. Modi, Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study, Forensic Sci. Int. 147 (2–3) (2005) 175–180.
9. H.G. Hatipoglu, H.N. Ozcan, U.S. Hatipoglu, E. Yuksel, Age, sex and body mass index in relation to calvarial diploe thickness and craniometric data on MRI, Forensic Sci. Int. 182 (1–3) (2008) 46–51.
10. Ikeda, T., Nakamura, M. & Itoh, M. Sex differences in the zygomatic angle in Japanese patients analyzed by MRI with reference to moiré fringe patterns. Aesth. Plast. Surg. 23, 349–353 (1999). https://doi.org/10.1007/s002669900297.
11. Agthong S, Huanmanop T, Chentanez V. Anatomical variations of the supraorbital, infraorbital, and mental foramina related to gender and side. J Oral Maxillofac Surg. 2005 Jun;63(6):800-4. doi: 10.1016/j.joms.2005.02.016. PMID: 15944977.
12. Gapert R, Black S, Last J. Sex determination from the occipital condyle: discriminant function analysis in an eighteenth and nineteenth century British sample. Am J Phys Anthropol. 2009 Apr;138(4):384-94. doi: 10.1002/ajpa.20946. PMID: 18924165.
13. Ayoub, Fouad & Rizk, Aline & Yehya, Mohamad & Cassia, Antoine & Chartouni, Sami & Atiyeh, Fady & Majzoub, Zeina. (2009). Sexual dimorphism of mandibular angle in a Lebanese sample. Journal of forensic and legal medicine. 16. 121-4. 10.1016/j.jflm.2008.07.014.
14. Naikmasur VG, Shrivastava R, Mutalik S. Determination of sex in South Indians and immigrant Tibetans from cephalometric analysis and discriminant functions. Forensic Sci Int. 2010 Apr 15;197(1-3):122.e1-6. doi: 10.1016/j.forsciint.2009.12.052. Epub 2010 Jan 18. PMID: 20083363.
15. Saini V, Srivastava R, Rai RK, Shamal SN, Singh TB, Tripathi SK. An osteometric study of northern Indian populations for sexual dimorphism in craniofacial region. J Forensic Sci. 2011 May;56(3):700-5. doi: 10.1111/j.1556-4029.2011.01707.x. Epub 2011 Mar 1. PMID: 21361935.
16. Kapila R, Nagesh KS, R Iyengar A, Mehkri S. Sexual dimorphism in human mandibular canines: a radiomorphometric study in South Indian population. J Dent Res Dent Clin Dent Prospects. 2011 Spring;5(2):51-4. doi: 10.5681/joddd.2011.011. Epub 2011 Jun 14. PMID: 23019509; PMCID: PMC3429995.
17. Shearer BM, Sholts SB, Garvin HM, Wärmländer SK. Sexual dimorphism in human browridge volume measured from 3D models of dry crania: a new digital morphometrics approach. Forensic Sci Int. 2012 Oct 10;222(1-3):400.e1-5. doi: 10.1016/j.forsciint.2012.06.013. Epub 2012 Jul 7. PMID: 22776689.
18. Isaza J, Díaz CA, Bedoya JF, Monsalve T, Botella MC. Assessment of sex from endocranial cavity using volume-rendered CT scans in a sample from Medellín, Colombia. Forensic Sci Int. 2014 Jan;234:186.e1-10. doi: 10.1016/j.forsciint.2013.10.023. Epub 2013 Oct 31. PMID: 24252424.
19. Nidugala H, Bhargavi C, Avadhani R, Bhaskar B. Sexual dimorphism of the craniofacial region in a South Indian population. Singapore Med J. 2013 Aug;54(8):458-62. doi: 10.11622/smedj.2013154. PMID: 24005453.
20. Abdel Fatah EE, Shirley NR, Jantz RL, Mahfouz MR. Improving sex estimation from crania using a novel three-dimensional quantitative method. J Forensic Sci. 2014 May;59(3):590-600. doi: 10.1111/1556-4029.12379. Epub 2014 Feb 6. PMID: 24502609.
21. Ali, Aysar & al-nakib, Lamia. (2013). The Value of Lateral Cephalometric Image in Sex Identification. Journal of Baghdad College of Dentistry. 25. 54-58. 10.12816/0014931.
22. Chandra A, Singh A, Badni M, Jaiswal R, Agnihotri A. Determination of sex by radiographic analysis of mental foramen in North Indian population. J Forensic Dent Sci. 2013 Jan;5(1):52-5. doi: 10.4103/0975-1475.114556. PMID: 23960416; PMCID: PMC3746474.
23. Belaldavar C, Kotrashetti VS, Hallikerimath SR, Kale AD. Assessment of frontal sinus dimensions to determine sexual dimorphism among Indian adults. J Forensic Dent Sci. 2014 Jan;6(1):25-30. doi: 10.4103/0975-1475.127766. PMID: 24695810; PMCID: PMC3970383.
24. Shivaprakash S, Vijaykumar AG. Sex determination by using mandibular ramus posterior flexure - a prospective study. Int J Health Sci Res. 2014;4(1):155-159.
25. Jehan, Massarat & Bhadkari, Vipendra & Trivedi, Akhilesh & Sharma, S.K. (2014). Sexual Dimorphism of Bizygomatic distance & Maxillary sinus using CT scan. IOSR Journal of Dental and Medical Sciences. 13. 91-95. 10.9790/0853-13329195.
26. Kanthem RK, Guttikonda VR, Yeluri S, Kumari G. Sex determination using maxillary sinus. J Forensic Dent Sci. 2015 May-Aug;7(2):163-7. doi: 10.4103/0975-1475.154595. PMID: 26005308; PMCID: PMC4430577.
27. Suragimath G, Ashwinirani SR, Christopher V, Bijjargi S, Pawar R, Nayak A. Gender determination by radiographic analysis of mental foramen in the Maharashtra population of India. J Forensic Dent Sci. 2016 Sep-Dec;8(3):176. doi: 10.4103/0975-1475.195114. PMID: 28123279; PMCID: PMC5210112.
28. Raikar NA, Meundi MA, David CM, Rao MD, Jogigowda SC. Sexual dimorphism in foramen magnum dimensions in the South Indian population: A digital submentovertex radiographic study. J Forensic Dent Sci. 2016 Sep-Dec;8(3):180. doi: 10.4103/0975-1475.195104. PMID: 28123285; PMCID: PMC5210118.
29. Samatha K, Byahatti SM, Ammanagi RA, Tantradi P, Sarang CK, Shivpuje P. Sex determination by mandibular ramus: A digital orthopantomographic study. J Forensic Dent Sci. 2016 May-Aug;8(2):95-8. doi: 10.4103/0975-1475.186367. PMID: 27555726; PMCID: PMC4970421.
30. Barbora Musilova, J ˇ an Dupej, Jana Velem ´ ´ınska,´ Kathia Chaumoitre, Jaroslav Bruzek, Exocranial surfaces for sex assessment of the human cranium, Forensic Science International http://dx.doi.org/10.1016/j.forsciint.2016.11.006.
31. Sambhana S, Sanghvi P, Mohammed RB, Shanta PP, Thetay AA, Chaudhary VS. Assessment of sexual dimorphism using digital orthopantomographs in South Indians. J Forensic Dent Sci 2016;8:180.
32. Chandra, Shruti & Chandra, Sunira & Dwivedy, Shweta & Srivastava, Akanksha & Shrestha, Pratikchhya & Thakur, Richa. (2020). EVALUATION OF ZYGOMATIC ARCH IN DETERMINATION OF SEXUAL DIMORPHISM: AN INSTITUTE BASED STUDY. 4. 6.
33. Schlager S, Rüdell A. Sexual Dimorphism and Population Affinity in the Human Zygomatic Structure-Comparing Surface to Outline Data. Anat Rec (Hoboken). 2017 Jan;300(1):226-237. doi: 10.1002/ar.23450. PMID: 28000405.
34. Yang W, Liu X, Wang K, Hu J, Geng G, Feng J. Sex Determination of Three-Dimensional Skull Based on Improved Backpropagation Neural Network. Comput Math Methods Med. 2019 Jan 13;2019:9163547. doi: 10.1155/2019/9163547. PMID: 30774706; PMCID: PMC6350606.
35. González-Colmenares G, Sanabria Medina C, Rojas-Sánchez MP, León K, Malpud A.

Sex estimation from skull base radiographs in a contemporary Colombian population. J Forensic Leg Med. 2019 Feb;62:77-81. doi: 10.1016/j.jflm.2019.01.006. Epub 2019 Jan 20. PMID: 30684829.
36. Mondal B, Vaishali MR, David MP, Roopashri G, Kumar V, Ponnuswamy IA. Assessment of the usefulness of morphometric and volumetric analysis of mastoid process for gender determination in forensic odontology: A retrospective cone beam computed tomographic study. J Indian Acad Oral Med Radiol 2022;34:82-6.
37. Mohd Fauad, Muhammad & Alias, Aspalilah & Ku Mohd Noor, Ku Mastura & Woon, Choy & Ng, Wei & Chung, Eric & Wu, Yuan-Seng. (2021). Sexual dimorphism from third cervical vertebra (C3) on lateral cervical radiograph: A 2-dimensional geometric morphometric approach. Forensic Imaging. 24. 200441. 10.1016/j.fri.2021.200441.
38. Sathawane R, Tripathi S, Sukhadeve V. Introduction of a new parameter 'Mastoid to Gonion height' and its comparative evaluation with established PA cephalometric parameters in sex determination: An analytical study. J Indian Acad Oral Med Radiol 2022;34:218-22.
39. Nur Damia Iwani Zulkiflee, Aspalilah Alias, Mansharan Kaur Chainchel Singh, Helmi Mohd Hadi Pritam, Eric Chung, Rani Sakaran, Nurul Hannim Zaidun, Ker Woon Choy,Sexual Dimorphism of Frontal Sinus: A 2-Dimensional Geometric Morphometric Analysis on Lateral Skull Radiographs,Forensic Imaging,Volume 29,2022,200506,ISSN 2666-2256,https://doi.org/10.1016/j.fri.2022.200506.