

Application of maxillary sinus and nasal aperture morphology for forensic identification with the aid of CBCT imaging: A review

Mahabalesh Shetty K¹, Kumuda Rao², Premalatha K³

1 Department of Forensic Medicine and Toxicology, NITTE (Deemed to be University), KS Hegde Medical Academy, Derlakatte, Mangalore, India

2 Department of Oral Medicine and Radiology, NITTE (Deemed to be University), AB Shetty Memorial Institute of Dental Sciences, Derlakatte, Mangalore, India

3 Associate Dean, Professor, Oral and Maxillofacial department, Manipal College of Dental sciences, Mangalore, Manipal Academy of Higher Education, Manipal

Abstract

Bone remodelling of the cranium determines the enlargement of the maxillary sinus. The process involves the resorption of the internal walls of the maxillary sinus minutely exceeding the growth of maxilla. During this process, there is bone deposition taking place at the medial border of the nasal cavity, and simultaneous resorption of the lateral wall of the nasal cavity causing differences in quantitative measurements of the nasal aperture too. Maxillary sinuses have been reported to stay intact even though the skull and other bones of the cranium may be severely disfigured in victims who are incinerated or during external trauma. Any morphometric measurements like the width, the depth or the height may be used to investigate the accuracy and reliability of maxillary sinus data for purpose of human identification and sex estimation. These dimensions can be correlated with the measurements of the nasal aperture and this will also give an insight into the role of the midface in development of the cranium. These measurements are also important anthropometric parameters for classifying the race of an individual whose identity is unknown.

Keywords

Maxillary sinus; Nasal aperture; CBCT; Nasal cavity; Forensic facial reconstruction; Morphology

Introduction

The identification of unknown human remnants continues to be a challenge for Humanitarian and Law enforcement agencies worldwide. Metric data of human body parts has been given utmost importance amongst morphological research. The roles of forensic anthropology in legal medicine and archaeological institutes have become effectively evident in the identification of perpetrators of crime, unidentified bodies, estimation of age, sex, race, stature, aesthetic and functional loss, etc.¹ The pre-requisite and solution to ease of collection of such metric data lies in the analyses of body parts with 3-dimensional imaging modalities usually Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT).² Numerous studies have already highlighted the advantage of CBCT over other 3-dimensional imaging techniques, especially concerning head and neck areas. Additionally, CBCT offers distinct advantages over other technology as it is non-invasive and comparatively economical.

During many mass disasters, even when the skull and other bones were heavily disfigured and also in incinerated head remnants, maxillary sinuses have been reported to stay intact. The morphometric measurements which aid to investigate the

reliability of maxillary sinus parameters such as the width, the depth, and the height of maxillary sinuses and the accuracy to which they can also be used for individual identification as well as for sex estimation are interesting areas to be explored.

The anatomic association of the maxillary sinus with the human nasal aperture, and its effects on the various shapes and sizes, as well as the ethnic influences on both the structures may result in different appearances of the face. The nasal aperture is an anthropometric parameter of significance for designating the race and sex of the individual whose identity is unknown. A nasal index is an anthropometric index which is influenced by ethnicity and may be utilized for various applications in forensic identification.

This manuscript aims to review the applications of the maxillary sinus and nasal aperture dimensions as an aid for individual identification as well as sexual dimorphism and the application of CBCT imaging modality in determining the same.

Morphometric analysis of the nasal aperture measurements and nasal index

Various studies depicting the importance of morphometric analysis of the human skull have been published in recent years. But the analysis of the nasal aperture and its correlation to the maxillary sinus is sparsely found in the literature. Among the very few studies conducted, one study was conducted by Sharma et al. to provide baseline data of the nasal ergonomics for males and females of the Hindu community of Gwalior region. Nasal length, breadth, height and depth were measured

Corresponding Author

Dr Kumuda Rao

Email: drkumudaroo@yahoo.in

Mobile: +919448696705

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using a digital vernier calliper. This study provided baseline data for people of Gwalior region which would be valuable in nasal anthropometry for forensic application and medical management especially in reconstructive surgery, rhinoplasty.³

Establishing sexual dimorphism with the aid of 3D imaging is a new concept. Forensic estimation of sex requires population specific baseline data for precise identification. Applying such data, a study was conducted by Tengku et al. to measure the nano-facial parameters to model the nasal prostheses from the CT data of 30 normal healthy subjects. The study results which showed sexual dimorphism in males and females for nasal characteristics were applied during the prosthesis fabrication. It can be concluded that the baseline data derived from a 3-D imaging modality gives more advantages over the conventional methods prosthesis fabrication in terms of time and accuracy of nose shape.⁴

A study conducted by Moreddu et al. to evaluate correlations between sexual dimorphism and the dimensions of the Piriform aperture also used 3D-CT scan reconstructions. Landmarks positioning around the piriform aperture of the faces of 79 females and 91 males from Marseille (France) were analysed in conventional and geometric morphometrics methods. The facial measurements showed a statistically significant sexual dimorphism.⁵

In Indian context there is lack of anthropological baseline data for various populations. Kotian et al. performed a study of South Indian population from measurements of dimensions of nasal aperture and nasal index using Multidetector Computed Tomography scans to discover the possibility of sex determination. The height and width of nasal aperture from 84 males and 66 females aged 12 - 80 years was considered for the study which showed significant positive results.⁶

As reported in literature, the nasal dimensions and nasal index has been used in studies to establish the identity of individuals. The nasal aperture measurements as well as nasal index is a useful tool in revealing sexual dimorphism and also is an essential anthropological tool in human identification for analysing racial and ethnic differences.

Morphometric analysis of the maxillary sinus

The dimensional accuracy of maxillary sinus in cadavers even after heavy trauma signifies the importance of research related to the same. A study was carried out to analyse the accuracy and reliability of maxillary sinus by Sidhu et al. for gender determination using morphometric parameters. Morphometric parameters of maxillary sinus from lateral cephalogram of 50 subjects were analyzed using AutoCAD 2010 software (Autodesk, Inc.). The results showed that the discriminant function (DF) score close to 0.838 was supposed to be males,

whereas, those whose DF score was closer to -0.838 was indicative of females. Also, DF analysis revealed that 76% of the originally grouped cases were classified correctly.⁷

Estimation of various dimensions of the maxillary sinuses using 3D imaging modality was conducted by Kiruba et al. on 200 subjects using head CT and their correlation to the sex of individuals. The height, width, and depth of the maxillary sinuses were measured using a Philips Brilliance 64 CT. They concluded that these dimensions of maxillary sinuses obtained may be beneficial for the ENT surgeons when planning for endoscopic sinus surgery besides serving as support for gender determination in forensic identification.⁸ After the advent of the CBCT imaging modality Tambawala et al. conducted a study to evaluate the sexual dimorphism of maxillary sinus dimensions using the same. The height, depth, and width of bilateral maxillary sinuses from 30 CBCT scans was retrospectively measured and the data was subjected to statistical analysis. The overall values were significantly higher in the males when compared to the females. The height of the sinuses was determined using the best predictor in determining sexual dimorphism with the use of CBCT thus ruling out the complete dependence on the usage of other conventional 3-dimensional imaging for forensic applications.⁹

Significance of correlation between nasal aperture and maxillary sinus morphometric measurements

The anatomic proximity of nasal aperture and maxillary sinus in the facial skeleton, accounts for their direct relation between the growth pattern as well as anthropological measurements. A study was conducted by Przystańska et al. on CT images to assess age-related changes in maxillary sinus diameters correlated to diameters of the facial skeleton in which retrospective analysis of CT images of the head of 170 patients aged between 0–18 years was performed. Specific orientation points were identified in every patient and the distances were measured between them. The maxillary sinuses of every patient were bilaterally measured in three planes- horizontally, vertically, and antero-posteriorly. The correlation and determination coefficient through statistical analysis revealed that every measurement of maxillary sinus recorded correlated with mid-face dimensions.¹⁰ Hence, the data obtained from such a correlation can be applied for aesthetic nasal surgeries, prosthesis fabrication for nasal reconstruction and archaeological research other than for forensic identification purpose. Hence, in this review we highlight the importance of studies in this direction within various population subsets for baseline data collection and also applicability of the research that relates the described morphometric measurements identifiable using Cone Beam Computed Tomography which confers increased effectiveness to the method.

Significance of CBCT imaging over other modalities

With the limited horizon of 2D radiology in the field of imaging and diagnosis, the advent of CBCT has given new hope towards better management of patients as well as increased forensic applications. There is a dearth of subject data in the Indian scenario available for forensic applicability which can be overcome by widening the application of CBCT. There are numerous existing studies and the future scope of conducting studies on areas of forensic applicability like age estimation,¹¹ sex estimation,¹² airway spaces,^{13, 14} paranasal sinuses,¹⁵ soft tissue, and hard tissue landmarks and measurements,^{16, 17} in facial recognition and reconstruction,¹⁷ etc. CBCT being a 3D imaging modality had the advantage of being non-invasive, comparatively economic,¹⁸ lower radiation dose with better diagnostic accuracy having a 1:1 proportional ratio of face to image.^{19,20} Hence more studies in different populations, specifically in Indian population needs to be conducted to enhance the ability of this method of imaging in the practice of Forensic Odontology.

Conclusion

Morphometric measurements of maxillary sinus and nasal aperture need to be constantly studied due to their importance and the degree of difficulty in predicting. Hence, we highlight the importance of further study in this direction as there is no literature specifically relating to the same. Various specific points need to be chosen that can be readily identified and measured on a CBCT which will add applicability to the method. Besides, a larger sample size representative of particular population is required to be researched for higher accuracy in forensic identification and subsequent other applications as highlighted in the review.

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