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Three-dimensional Evaluation of Maxillary Sinus Volume in Different Sex Groups Using Cone-beam Computed Tomography

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Abstract

Background/Objectives: Determining the sex of corpses is the first step of identification in a forensic analysis. Accurate anatomical knowledge for the maxillary-sinus serves as an important mediator of forensic sex determination.

Method/Statistical Analysis: This study included 57 patients (27 males and 30 females) of Dan-kook university dental hospital. Cone-beam computed tomography data images were imported and reconstructed into Three-dimensional models by an interactive medical image control system, Mimics 17.0 software. This study was analyze at 95% significance level using SPSS Version 20.0. The independent t-test was performed to compare the measured values among the two experimental groups.

Findings: The volume of the maxillary sinus measured with traditional radiography may differ from its actual size. The maxillary sinus can be more accurately measured using a 3D model restructured using the CBCT data as the 2D base compared to simple linear measurement in 2D model. In the present study, sex-specific volumes of the maxillary sinus were measured using a 3D model, and there were no significant differences in the volumes between the left and right for both men and women. However, between sexes, the mean left sinus volume was significantly greater among men (23.25) than women (17.59) ($p<0.05$). The mean right sinus volume was also significantly greater among men (22.46) than women (17.35) ($p<0.05$).

Improvements/Applications: This study obtained more accurate sex-specific anatomical data for the maxillary sinus using a 3D model. The volume of the maxillary sinus is valuable in researching sex determination.

Keywords: *Maxillary Sinus, Volume, Sex determine, 3D Measurement, Mimics.*

Introduction

Determining the sex of damaged corpses is the first step of identification in a forensic analysis[1]. Sex is determined based on various body parts, such as the skull, pelvis, and maxillary sinus. The maxillary sinus not only plays an important role in the formation of facial contour but also is an area with little damage in a corpse. Particularly, severely mutilated corpses or deaths from a disaster show severe damages to most bones in the skull, but the maxilla is known to incur little injury[2].

Sexual dimorphism refers to the differences of morphology and size between different sexes of the same species. The maxillary sinus is known to feature sexual dimorphism in various species[3]. Chatterjee et al. reported that the volume of maxillary sinus differs according to sex and that this is a useful feature in

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determining sex[4]. Take et al. measured the volume of the maxillary sinus for 94 adults and observed that men have larger volumes than women do[2]. Thus, accurate anatomical knowledge for the maxillary sinus and its sexual dimorphism serves as an important mediator of forensic sex determination

Many studies measured the sex-specific volume of the maxillary sinus[5]. However, two-dimensional (2D) computed tomography(CT) images cannot accurately reproduce the complex three-dimensional (3D) structure of the maxillary sinus, so the validity of its results is doubtful. The size of the maxillary sinus measured with traditional radiography may differ from its actual size. Furthermore, the exact margin of the maxillary sinus is blurred, as it is overlapped with surrounding soft tissues and structures. Because CT images are high resolution images, the boundaries of the maxillary sinus and surrounding soft tissues are clearly distinguished[6]. Cone-beam computed tomography (CBCT) can provide resolutions of a unit smaller than millimeter in a shorter scanning time and higher quality. The maxillary sinus can be more accurately measured using a 3D model restructured using the CBCT data as the 2D base compared to simple linear measurement in 2D model[7-8].

Based on this background, Based on this background, the present study used a 3D model to measure the sinus volume and assess the sex differences to provide basic data on sex determination using the maxillary sinus of Koreans.

Method

The CBCT data of 57(27 males and 30 females) patients who met the study criteria were obtained from the Department of Oral and Maxillofacial Radiology at Dan-Kook University Dental College Hospital. This study was approved by the Dentistry Hospital Clinical Examination Committee of Dan-Kook University (DUDH IRB 2015-12-022). Only patients with 28 teeth and with no missing teeth or systemic disease were selected. The mean age of all of the patients was 22.8 years.

The CBCT data of the subjects who satisfied the study criteria were obtained in Digital Imaging and Communications in Medicine(DICOM) format from a CBCT scanner (Alphard 3030, Asahi, Kyoto, Japan). CT scanning was performed with the following image scaling parameters: slice increment, 0.39 mm; slice thickness, 0.39 mm; and matrix, 512 x 512 pixels. After the corresponding DICOM file was imported from MIMICS software (version 17, Materialise, Leuven, Belgium), a 3D model of the skull was created based on the uploaded CBCT image, and this model was used to visually confirm the presence of maxillary sinus [Figure 1].In this study, 2 investigators each used MIMICS to create 3D models and evaluate the volume of the maxillary sinus in 57 patients.

This study performed statistical analyses using SPSS (version 20.0, Statistical Package for the Social Sciences, IBM, USA), with differences considered significant at the 95% level. The general characteristics of the subjects were analyzed using frequency analysis. The independent-samples t-test was performed to detected sex-related differences in the measured values.

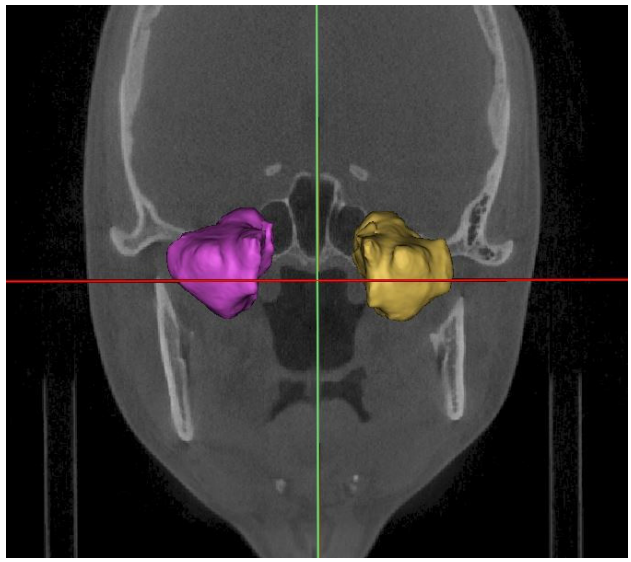

Figure 1. 3D reconstruction of the left and right maxillary sinus

Result and Discussion

In the present study, sex-specific volumes of the maxillary sinus were measured using a 3D model. There were no significant differences in the volumes between men and women [Table 1].

Table 1. Comparison of the maxillary sinus volume of sides

Parameters	Patients (n)	Sides	AVerage (cm^3)	STD. Deviation	p-value
Male	27	LEft	23.25	6.94	0.678
		Right	22.47	6.95	
Female	30	LEft	17.59	4.83	0.849
		Right	17.35	4.84	

However, between sexes, the mean left sinus volume was significantly greater among men (23.25) than women (17.59) (p = 0.001). The mean right sinus volume was also significantly greater among men (22.46) than women (17.35) (p = 0.002) [Table 2].

Table 2. Comparison of the maxillary sinus volume of sex

Parameters	Sex	Patients (n)	Average (cm^3)	STD. Deviation	p-value
Left	Male	27	23.25	6.94	0.001
	Female	30	17.59	4.83	
Right	Male	27	22.47	6.95	0.002
	Female	30	17.35	4.84	

Discussion

Forensic research is highly crucial for identifying the sex of a mutilated cadaver that had gone through death by physical injury due to a fire or strong chemicals. The maxillary sinus is denser and thus damaged less than other bones used in sex identification such as the pelvic bone, longitudinal bone or skull. Therefore, it can be used for the challenging task of determining sex using the human skeleton[9-10]. Until now, sexual dimorphism has been studied using bones like the foramen magnum, occipital bone, frontal bone and maxillary sinus. Analysis of sexual dimorphism in the foramen magnum demonstrated the presence of dimorphism. Moreover, it was concluded as the major bone that can be used to understand sexual dimorphism[10-11]. Since the maxillary sinus has the advantage of high density and resistance to damage, it is suitable for sex determination and thus more research on sexual dimorphism should be conducted in the maxillary sinus.

Saccucci revealed that the average sinus volume of male and female is similar and thus sex determination using such structure is impossible[12]. In contrast, the present study found that sinus volume was greater in male than in female. The left sinus volume in male was 23.25mm^3 and right 22.47mm^3 which were both significantly larger than in female, 17.59mm^3 and 17.35mm^3 (p = 0.001, p = 0.002). Gomes et al. worked on the sex determination equation using sinus volume measurements and obtained results similar to our study, male (19.54) and female (15.28). Fernandes also showed that the average sinus volume was greater in male than in female[13]. For Egyptians, the size of the maxillary sinus is a useful feature for sex determination[3]. Kanthem also found that the average sinus volume is significantly greater in male (39.93mm^3) than in female (21.53mm^3) although the values were significantly different from our male data[14]. In Kanthem's data, the male sinus volume had a wide range with the minimum of 26.06mm^3 and maximum 53.51mm^3. These average values of the data make it difficult to trust the results of the research.

The present study measured the sinus volume using a 3D model and assessed the sex differences in order to provide a basic database of sex determination using the maxillary sinus of Koreans based on CBCT data. We used a software that can calculate the volume of the maxillary sinus. CBCT is an effective method for diagnosing maxillofacial structure[15]. CBCT data has been shown to be a useful tool for maxillary sinus analysis and the accuracy of the results has been verified [16-18]. The anatomy depicted by CBCT is helpful for volume measurements. In this study, the 3D data of the maxillary sinus obtained from CBCT enabled accurate assessment for sexual dimorphism research using the maxillary sinus.

Conclusion

Sex determination is important in forensic identification. This study obtained more accurate sex-

specific anatomical data for the maxillary sinus using a 3D model. CBCT is a significant development in radiology, enabling more accurate measurement. The three-dimensional information obtained from CBCT provides the opportunity to see beyond the plane and the spatial overlap of structures and to visualize the fine differences using a true 1:1 imaging. Such research is highly crucial for sex identification of an individual in estimation anthropology and criminal investigations and the volume of the maxillary sinus is valuable in researching sex determination.

Ethical Clearance: Not required

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Conflict of Interest: Nil

References

1. Sidhu R, Chandra S, Devi P, Taneja N, Sah K, Kaur N. Forensic importance of maxillary sinus in sex determination: a morphometric analysis from Western Uttar Pradesh, India. European Journal of General Dentistry. 2014 Feb;3(1):53. DOI: http://www.ejgd.org/article.asp?issn=2278-9626;year=2014;volume=3;issue=1;spage=53;epage=56;aulast=Sidhu.
2. Teke HY, Duran S, Canturk N, Canturk G. Determination of sex by measuring the size of the maxillary sinuses in computerized tomography scans. Surgical and Radiologic Anatomy. 2007 Dec;29(1):9-13. DOI:https://link.springer.com/article/10.1007/s00276-006-0157-1.
3. Kanthem RK, Guttikonda VR, Yeluri S, Kumari G. Sex determination using maxillary sinus. Journal of forensic dental sciences. 2015 May;7(2):163-167. DOI:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4430577/.
4. Chatterjee D, Ghosh TB, Ghosh BB. Size variation of mastoid air cell system in Indian people at different age groups: a radiographic planimetric study. The Journal of Laryngology & Otology. 1990 Aug;104(8):603-605. DOI:https://www.cambridge.org/core/journals/journal-of-laryngology-and-otology/article/size-variation-of-mastoid-air-cell-system-in-indian-people-at-different-age-groups-a-radiographic-planimetric-study/153711E0B88C9FE07DC9BB2B8911817D.
5. Barghouth G, Prior J, Lepori D, Duvoisin B, Schnyder P, Gudinchet F. Paranasal sinuses in children: size evaluation of maxillary, sphenoid, and frontal sinuses by magnetic resonance imaging and proposal of volume index percentile curves. European radiology. 2002 Jun;12(6): 1451-1458. DOI:https://link.springer.com/article/10.1007/s00330-001-1218-9.
6. Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process; volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. Otolaryngology—Head and Neck Surgery. 2005 Mar;132(3):429-434. DOI:https://journals.sagepub.com/doi/abs/10.1016/j.otohns.2004.11.012.
7. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. American journal of orthodontics and dentofacial orthopedics. 2005 Dec;128(6):803-811. DOI:https://www.sciencedirect.com/science/article/pii/S0889540605009741.
8. Tsiklakis K, Syriopoulos K, Stamatakis HC. Radiographic examination of the temporomandibular joint using cone beam computed tomography. Dentomaxillofacial Radiology. 2004 Jan;33(3):196-201. DOI:https://www.birpublications.org/doi/abs/10.1259/dmfr/27403192.
9. U Ukoha, OA Egwu, IJ Okafor, AE Anyabolu, GU Ndukwe, I Okpala. Sexual dimorphism in the foramen magnum of nigerian adult. Int J Biol Med Res. 2011;(2):878–81. DOI:https://scholar.google.com/scholar?cluster=11116272808330122401 & hl=en & oi=scholar.
10. Khatieeb MM. Sexual dimorphism of calvarial thickness parameter in different skeletal patterns. Mustansiria Dent J. 2011;(8):144–51. DOI:https://www.iasj.net/iasj?func=article & aId=46715.
11. Radhakrishna SK, Shivarama CH, Ramakrishna A, Bhagya B. Morphometric analysis of foramen magnum for sex determination in South Indian population. Nitte Univ J Health Sci. 2012;(2):20–2. DOI:https://scholar.google.com/scholar?hl=en & as_sdt=0%2C5 &

scioq=Morphometric+anal ysis+of+foramen+ magnum+for+sex+ determination+in+South & q=Morphometric+analysis+of+ for a men+magnum+for+sex+determination+in+South+ Indian+ population & btnG=.

12. Fernandes CL. Forensic ethnic identification of crania: The role of the maxillary sinus - A new approach. Am J Forensic Med Pathol. 2004 Dec;(25):302–13. DOI:https:// journals.lww.com/ amjforensicmedicine/Fulltext/2004/12000/Forensic_Ethnic_Identification_of_Crania__The_Role.6.aspx.
13. Sahlstrand-Johnson P, Jannert M, Strömbeck A, Abul-Kasim K. Computed tomography measurements of different dimensions of maxillary and frontal sinuses. BMC Med Imaging. 2011 Apr;11:(8):1471-2342. DOI:https://bmcmedimaging.biomedcentral.com/articles/10.1186/1471-2342-11-8.
14. Chau AC, Fung K. Comparison of radiation dose for implant imaging using conventional spiral tomography, computed tomography, and cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009 Apr;107(4):559–65. DOI:https://www.sciencedirect.com/science/article/pii/S1079210408008421.
15. Al-Rawi NH, Uthman AT, Sodeify SM. Spatial analysis of mandibular condyles in patients with temporomandibular disorders and normal controls using cone beam computed tomography. Eur J Dent. 2017 Jan-Mar;11:(1):99–105. DOI:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5379844/.
16. Loubele M, Jacobs R, Maes F, Denis K, White S, Coudyzer W, et al. Image quality vs radiation dose of four cone beam computed tomography scanners. Dento Maxillo Facial Radiology. 2008 Jan;37(6):309–18. DOI:https://www.birpublications.org/doi/abs/10.1259/dmfr/16770531.
17. Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarment DP. Accuracy of three-dimensional measurements using cone-beam CT. Dento Maxillo Facial Radiology. 2006 Jan;35(6):410–6. DOI: https://www.birpublications.org/doi/abs/10.1259/dmfr/20987648.
18. Tolstunov L, Thai D, Arellano L. Implant-guided volumetric analysis of edentulous maxillary bone with cone-beam computerized tomography scan. Maxillary sinus pneumatization classification. J Oral Implantol. 2012 Aug;38(4):377–90. DOI:https://www.joionline.org/doi/full/10.1563/AAID-JOI-D-11-00212.