Sex estimation by maxillary sinus using computed tomography: a systematic review

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KEYWORDS

Maxillary sinus; Forensic dentistry; Sex determination analysis; Forensic anthropology

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ABSTRACT

Sex estimation is an important part of forensic human identification, and when primary methods cannot be applied, forensic anthropology becomes an important auxiliary method of identification. The maxillary sinus may remain intact even if the skull is severely damaged and could thus be used in forensic investigations. The objective of this study was to verify the effectiveness of the evaluation of the maxillary sinus as a technique for sex estimation. Articles published in the past 10 years were searched using PubMed, Web of Science, Scopus, and Cochrane databases, including those that used computed tomography to perform maxillary sinus measurements with the purpose of sex estimation. Studies that used radiographs to perform the measurements were excluded because they do not allow for a three-dimensional analysis. Studies that did not provide information regarding the origin of the analyzed population were also excluded. The selected articles were evaluated for methodological quality according to the indication of the objective, studied population, inclusion and exclusion criteria, parameters for obtaining the computed tomography image, measurements evaluated, bias discussion, and ethical authorization. From the 52 articles found, 18 were included. The populations studied included Indians, Iraqis, Iranians, Egyptians, Brazilians, French, Dutch, and Turkish. Height, width, length, and volume of the maxillary sinus were measured. The maxillary sinus can act as an auxiliary tool for sex estimation in forensic investigations.

INTRODUCTION

Human identification can be applied to living individuals, intact corpses, or human remains, and may employ several appropriate methods.[1] Evidence based on forensic science is accepted in a judicial environment, playing an important role in identifying individuals who cannot be recognized visually.[2]

The primary methods of identification recognized by the International Criminal Police Organization (INTERPOL) are fingerprint analysis, DNA, and forensic odontology. Secondary methods of identification include a personal description of the missing person, anthropological information, circumstantial evidence, documentation, and medical procedures performed.[3] Thus, in cases where the

remains are decomposed or charred, when the DNA is destroyed, and when there are no previous dental records, forensic anthropology becomes the method of choice to assist the identification process.[4]

Sex estimation is the first step in anthropological examination,[5] since it represents an important stage in the *post-mortem* profile.[6] In this sense, the evaluation of the skeleton and its remnants can provide useful information. However, acquisition of the entire body is often impossible, with only isolated parts of the body being recovered.[7] Additionally, there are situations where the skull itself is only partially recovered and not all conventional markers may be available for sex estimation.[8] In such situations, evaluation of the maxillary sinus can be useful because its structure can remain intact even if the skull and other bones are severely damaged.[9]

The maxillary sinuses are two cavities located in the maxillary bone that are filled with air. They have thin walls and reach maturity in humans at approximately 20 years of age when most permanent teeth are fully developed.[9] These sinuses may have variations in size, shape, and position, not only in different individuals but also on both sides of the same individual.[10] Thus, this systematic review aims to answer the following question: is the use of maxillary sinus measurements effective in estimating an individual's sex?

MATERIAL AND METHODS

Searches were conducted without language restriction for articles published in the last 10 years (2009-2018) in the following electronic databases: PubMed, Web of Science, Scopus, and Cochrane. The descriptors used were: "maxillary sinus", "paranasal sinuses", "maxilla", "forensic anthropology", "forensic dentistry", "sex", "sex characteristics", "sex differentiation", and "sex determination analysis", as shown in Table 1.

The initial selection was carried out by reading the titles and abstracts of the articles. When these did not provide enough information or if the given abstract was not available, the articles were downloaded and read in full to assess their eligibility. Studies found in more than one database were considered only once. Manual searches were also carried out on the reference lists of the selected articles to determine if any studies were not found by previous searches of the databases. The search and selection processes of the articles were carried out by two researchers and, in case of uncertainty regarding the inclusion or exclusion of any particular article, a third evaluator was consulted until a consensus was reached.

To be selected, studies should have been conducted in accordance with the following PICO format: P (population): subjects underwent maxillary sinus computed tomography (CT); I (intervention): measurements of the maxillary sinuses were performed; C (comparison): comparison between the measurements was recorded; and O (outcome): identification of sex was conducted. The following were excluded from this review: duplicates, literature reviews, studies that did not provide information regarding the origin of the population analyzed, and studies that used radiographs to perform the measurements, since they do not allow three-dimensional observation of the maxillary sinus.

This is because the measurement of the volume of the maxillary sinus is obtained from three dimensions (Fig. 1).

To evaluate the methodological quality of the included articles, a score was applied according to Capitaneanu et al.[11] (Fig. 2). The articles were evaluated according to the objectives, definition of the examined population, established inclusion and exclusion criteria, defined parameters, measurements recorded, study bias, and ethical authorization. When the information requested in each item was answered with "yes", it was scored as "1", while the questions where "no" was obtained as an answer were scored as "0". The maximum score that could be achieved for each article was 11 points.

Table 1. Electronic databases, research strategies, and number of results.

Electronic databases	Research strategies	Total
PubMed	((("maxillary sinus" [MeSH Terms] OR "paranasal sinuses" [MeSH Terms]) OR "maxilla" [MeSH Terms]) AND ("forensic anthropology" [MeSH Terms] OR "forensic dentistry" [MeSH Terms])) AND ((("sex" [MeSH Terms] OR "sex characteristics" [MeSH Terms]) OR "sex differentiation" [MeSH Terms]) OR "sex determination analysis" [MeSH Terms]))	28
Web of Science	TS=((maxillary sinus OR paranasal sinuses OR maxilla) AND (forensic anthropology OR forensic dentistry) AND (sex OR sex differentiation OR sex characteristics))	19
Scopus	(TITLE-ABS-KEY (maxillary AND sinus OR paranasal AND sinuses OR maxilla)) AND (TITLE-ABS-KEY (forensic AND anthropology OR forensic AND dentistry)) AND (TITLE-ABS-KEY (sex OR sex AND differentiation OR sex AND characteristics))	5
Cochrane	"forensic dentistry" in Title Abstract Keyword OR “forensic anthropology” in Title Abstract Keyword AND "maxillary sinus" in Title Abstract Keyword OR "paranasal sinus" in Title Abstract Keyword AND "sex determination" in Title Abstract Keyword	0

Figure 1. Flowchart to identify studies in which maxillary sinus measurements were carried out to determine sex.

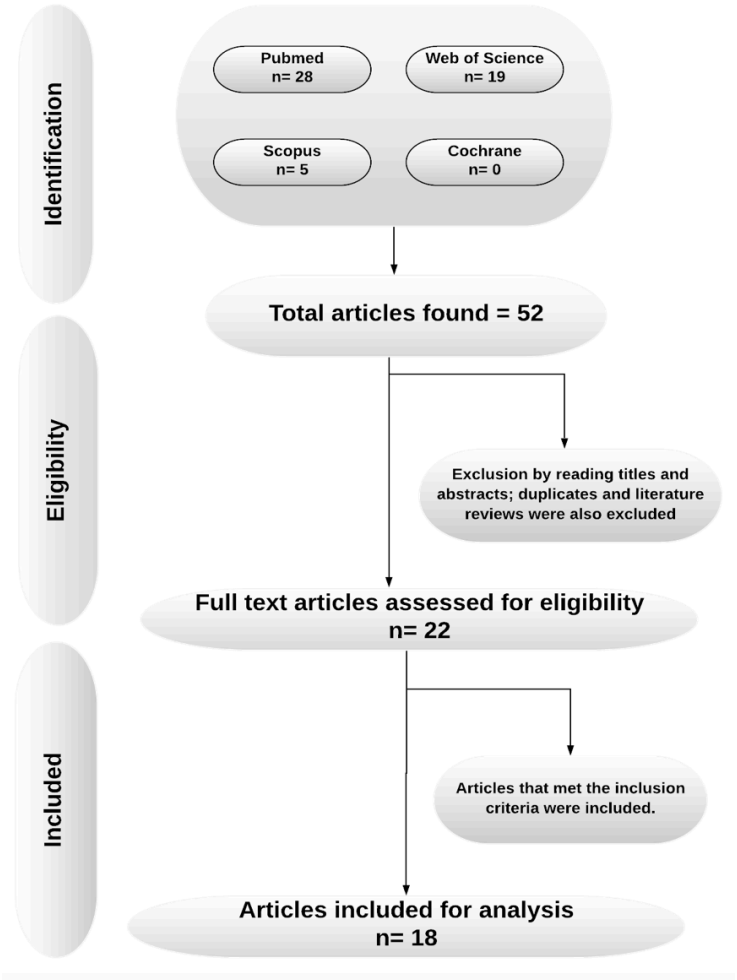

Figure 2. Criteria for research quality assessment. Source: Original article of Capitaneanu et al.[11] (Capitaneanu C, Willems G, Thevissen P. A systematic review of odontological sex estimation methods. *J Forensic Odontostomatol*. 2017;35(2):1–19.)

I. Was the research question or objective clearly stated?
II. Was the study population clearly specified and defined?
III. Were inclusion and exclusion criteria for subjects included in the study sample:
  A. pre-specified?
  B. applied uniformly to all participants?
IV. Were the studv parameters clearly defined?
V. Were the outcome measures:
  A. clearly defined?
  B. validated?
  C. reliable (intra / inter observer)?
VI. Were the study bias discussed, related to:
  A. selection bias
  B. analytical bias
VII. Did the study have ethical clearance?

RESULTS

The searches in the electronic databases found 52 articles, of which 22 were considered eligible after reading the titles and abstracts. After removing duplicates and applying the inclusion and exclusion criteria, 18 articles were included in this review (Fig. 1).

Table 2 illustrates that the results of the methodological assessment and the scores received by the studies varied between 5[12–14] and 8[15–17] points. All the studies were scored in questions about the objective, population, and inclusion and exclusion criteria. However, six studies[13,15,16,18–20] did not indicate the parameters used, and therefore, did not receive a score in this regard. The discussion of bias was also not mentioned by any of the authors, and this item was not scored in the methodological scoring. Regarding the ethical approval of the research, nine articles[7,15–17,20–24] addressed this item and were scored.

Information about the sample size, age range, populations studied, measurements recorded, and accuracy rate was extracted from the studies included in this review (Table 3). The sample size of the studies was varied from 30[2,19] to 288[12] individuals. Most authors conducted research in more than one age group, and only Kanthem et al.[19] did not specify that point.

Regarding the studied population, there was a geographical diversity among the surveys, which included participants with Indian,[2,13,14,19,22,23] Iraqi,[18,21,24] Iranian,[12,16,26] Egyptian,[17,25] Brazilian,[15] French,[20] Dutch[27] and Turkish[7] origins. Concerning the measurements recorded, some studies[20,26] used only the volume of the maxillary sinus as a measure, although the height, length, and width of the maxillary sinus were the most frequently recorded measurements.

The accuracy of sexual estimation was not reported by three authors;[13,18,26] nevertheless, Jehan et al.[13] explained that the bizygomatic distance is considered a strong parameter to be used. Some studies have established the anteroposterior diameter of the maxillary sinus[7,14] and width of the left maxillary sinus[21,23] as possible choices for sexual estimation, obtaining the maximum values of accuracy of 75.7% and 61.3%, respectively. Other gender-discriminating variables were also defined, such as the height of the maxillary sinus[16,24] and maximum distance between the left and right sinuses,[12] with respective precision of 77.7% and 65.6%, respectively.

Table 2. Analysis of methodological scores

AUTHOR	I	II	III	IV	V	VI	VII	Total
Ahmed et al. (2015)[21]	1	1	2	0	2	0	1	7
Akhlaghi et al. (2017)[12]	1	1	2	0	1	0	0	5
Amin & Hassan (2012)[25]	1	1	2	1	1	0	0	6
Ekizoglu et al. (2014)[7]	1	1	2	1	1	0	1	7
Etemadi, Seylavi, & Yadegari (2017)[26]	1	1	2	1	2	0	0	7
Gamba et al. (2017)[27]	1	1	2	1	1	0	0	6
Gomes et al. (2018)[15]	1	1	2	1	2	0	1	8
Jasim & Al-Taei (2013)[18]	1	1	2	1	2	0	0	7
Jehan et al. (2014)[13]	1	1	2	0	1	0	0	5
Kanthem et al. (2015)[19]	1	1	2	0	2	0	0	6
Paknahad, Shahidi, & Zarei (2017)[16]	1	1	2	1	2	0	1	8
Prabhat et al. (2016)[2]	1	1	2	1	1	0	0	6
Radulesco et al. (2017)[20]	1	1	2	1	1	0	1	7
Sharma, Jehan, & Kumar (2014)[14]	1	1	2	0	1	0	0	5
Sherif et al. (2017)[17]	1	1	2	1	2	0	1	8
Tanushri et al. (2015)[22]	1	1	2	1	1	0	1	7
Urooge & Patil (2017)[23]	1	1	2	1	1	0	1	7
Uthman et al. (2011)[24]	1	1	2	0	2	0	1	7

Table 3. Summary of selected articles

Study	Subjects	Age (years)	Population 's origin	Measurements evaluated	Sex estimation accuracy (%)	Conclusion	QAS *
Ahmed et al. (2015)[21]	119 (M: 57 F: 62)	20–75	Iraqis	Length Width Height	61.3	The diameters of the maxillary sinus can be used as a complement for sex estimation.	7
Akhlaghi et al. (2017)[12]	288 (M: 144 F: 144)	Older than 20 years	Iranians	Maximum height Anteroposterior diameter Width Distance between sinuses	56.2–65.6	In young adults, the parameters of the maxillary sinus had considerable value in sex determination, while in the age group above 50 years, the sinus was small and insufficient for sex determination.	5
Amin & Hassan (2012)[25]	96 (M: 48 F: 48)	20–70	Egyptians	Anteroposterior, transverse, and cephalo-caudal measurements Size	66.7	The cephalo-caudal measurement and the size of the left maxillary sinuses can be useful to support sex determination.	6
Ekizoglu et al. (2014)[7]	140 (M: 70 F: 70)	18–63	Turkish	Anteroposterior, transverse, and cephalo-caudal diameters Volume	77.15	The dimensions of the maxillary sinus will be useful in sex determination.	7
Etemadi, Seylavi, & Yadegari (2017)[26]	70 (M: 35 F: 35)	Older than 18 years	Iranians	Volume	Uninformed	The maxillary sinus volume does not serve as a definite and reliable indicator of sex.	7
Gamba et al. (2017)[27]	160 (M: 80 F: 80)	20–60	Dutch	Height Length Width	75	The developed formula can be applied for sexual prediction as an auxiliary method for human identification in the Dutch population.	6

Table 3. Continuation

Study	Subjects	Age (years)	Population's origin	Measurements evaluated	Sex estimation accuracy (%)	Conclusion	QAS *
Gomes et al. (2018)[15]	94 (M: 45 F: 49)	20–35	Brazilians	Height Length Width Distance between the maxillary sinuses Distance between the infraorbital foramina Volume	84	The formula presented an accuracy of 84% for sex estimation and can be applied as a complementary method of human identification in the Brazilian population.	8
Jasim & Al-Taei (2013)[18]	120 (M: 60 F: 60)	40–69	Iraqis	Volume Width Depth Height	Uninformed	The volume and dimension of the maxillary sinus were greater in males then females. Maxillary sinus measurements with CT could be useful to support sex and age estimation.	7
Jehan et al. (2014)[13]	191 (M: 106 F: 85)	20–70	Indians	Bizygomatic distance Intermaxillary distance Anteroposterior dimension Width	Uninformed	Bizygomatic distance measurements and dimensions of the maxillary sinus can be useful to support sex determination in forensic medicine when other methods are inconclusive.	5
Kanthem et al. (2015)[19]	30 (M: 17 F: 13)	-	Indians	Height Depth Width Volume	15–85.4	The dimensions of the maxillary sinus, especially the volume on the right side, are valuable in the study of sexual dimorphism.	6
Paknahad, Shahidi, & Zarei (2017)[16]	100 (M: 50 F: 50)	20–54	Iranians	Height Width Length	76	Maxillary sinus measurements can be used as an additional tool for sex determination.	8
Prabhat et al. (2016)[2]	30 (M: 15 F: 15)	20–50	Indians	Length Width Height Volume	83.3	The length, width, height, and volume of the maxillary sinus can be used to predict sex.	6

Table 3. Continuation

Study	Subjects	Age (years)	Population's origin	Measurements evaluated	Sex estimation accuracy (%)	Conclusion	QAS *
Radulesco et al. (2017)[20]	103 (M: 50 F: 53)	13–97	French	Volume	68	The volume of the maxillary sinus can be useful for sex estimation in forensic medicine	7
Sharma, Jehan & Kumar (2014)[14]	102 (M: 61 F: 41)	20–60	Indians	Anteroposterior dimension Width Height Volume	67	The volume and dimensions of the maxillary sinus can be useful for sex identification	5
Sherif et al. (2017)[17]	100 (M: 50 F: 50)	18–60	Egyptians	Maximum craniocaudal diameter (CCD) Maximum width Average width Maximum depth Intermaxillary distance	72-76	The maxillary sinus shows the highest level of accuracy in estimating sex.	8
Tanushri et al. (2015)[22]	40 (M: 20 F: 20)	20–60	Indians	Width Height Length	67	The length, width, and height of the maxillary sinuses predict an individual's sex with a reasonable degree of accuracy.	7
Urooge & Patil (2017)[23]	100 (M: 50 F: 50)	20–50	Indians	Width Length Height Area Perimeter Volume	71	The female group showed statistically significant higher values for the width of the left maxillary sinus, but the other parameters showed no significant difference between sexes.	7
Uthman et al. (2011)[24]	88 (M: 43 F: 45)	20–49	Iraqis	Width Length Height Distance between both sinuses	73.9	The CT images can provide adequate measurements for the maxillary sinuses.	7

DISCUSSION

Sex estimation is an important part of forensic human identification. However, there may be situations in which primary techniques cannot be employed as a result of *post-mortem* degeneration of the human body[20] in addition to the absence of dentition. Evaluation of the maxillary sinus can emerge as a viable methodology for sex estimation in such situations.[28]

Measurement of the dimensions of the maxillary sinus can be performed with great speed and accuracy with a CT scan[29]. One of its advantages is that there is no overlapping of structures outside the plane of interest. Additionally, the availability of *ante-mortem* tomographic films can offer useful elements for the exact reproduction of the examination after death.[30]

When different age groups are studied, different results are obtained. According to a previous study, younger individuals may have larger maxillary sinus dimensions,[22] while another study reported no difference in the sinus dimensions related to age and the measurements evaluated.[20] The maxillary sinus is known to increase in size throughout childhood and adolescence, but there are still very few detailed descriptions of subsequent changes in adults and the elderly.[31] Moreover, advanced age is not necessarily related to tooth loss, but studies usually consider only the patient's age, forgetting an important factor, which is edentulism. Thus, it is relevant that the status of the dentition is cited, since sex estimation through evaluation of the maxillary sinus without the presence/absence of teeth being included in the analysis, is not entirely possible.[32]

Regarding the measurements evaluated in patients with dentate and edentulous jaws, different values can be found in the literature for each dimension analyzed. Some studies[18,33] claim that there are no differences in values for the volume, width, and depth of the maxillary sinus, while greater measurements were obtained for the height in individuals with tooth loss.[18] It is known that the extraction of a posterior dental unit stimulates more severe resorption of the alveolar crest promoted by the absence of masticatory function.[34] In addition, the initial bone remodeling that occurs during alveolar ossification promotes new bone organization in the edentulous region, whereas an increase in tooth loss and consequent less bone stress drives its degradation. Thus, dentition affects the pneumatization of the maxillary sinus and is also related to the presence of oral atrophy.[32]

The studies selected for this review analyzed several measurements of the maxillary sinus to determine the accuracy of each of them in estimating sex. The vast majority of the results demonstrated that the dimensions of the maxillary sinuses were larger in males than in females.(2,7,20–22,24–27,12–19) This was explained initially by the fact that men require larger lungs to support their relatively larger muscles and body organs. Moreover, physiological changes in the size and shape of the nasal cavity occur because of the necessity of breathing, such as heating and humidifying the inhaled air. Thus, by occupying the remaining space within the nasomaxillary complex, the maxillary sinus also increases in size.[14]

The variations in the identified accuracy rates (15%,[19] 61.3%, and[21] 84%[15]) can be motivated by different aspects. First, the great geographical diversity in the studies included in this review can be noted, as populations from India, Iraq, Iran, Egypt, Brazil, France, the Netherlands, and Turkey were analyzed. In a more heterogeneous population, for example, the Brazilian population, sexual dimorphism is easier to identify when compared to more homogeneous population groups, such as the Europeans. Thus, it should be borne in mind that each population has distinct morphological characteristics, being influenced by both genetic and environmental factors.[27] In addition, the accuracy values can also be impacted by elements, such as bone fragment conditions,[33] the methodological and statistical analyses adopted, different radiographic techniques, and unequal sample sizes.[16]

CONCLUSIONS

The measurement of the maxillary sinus dimensions can serve as an auxiliary method for estimating sex, but should be applied with caution, since its efficacy may vary because of various factors, such as the population, conditions in which the maxillary sinus was found, and radiographic techniques adopt

REFERENCES

1. Vidya C, Shamasundar N, Manjunatha B, Raichurkar K. *Evaluation of size and volume of maxillary sinus to determine gender by 3D computerized tomography scan method using dry skulls of south indian origin. Int J Curr Res Rev.* 2013;5(3):97-100.
2. Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. *Computed tomography based forensic gender determination by measuring the size and volume of the maxillary sinuses. J Forensic Dent Sci.* 2016;8(1):40-6.
3. Hill AJ, Hewson I, Lain R. *The role of the forensic*

odontologist in disaster victim identification: Lessons for management. Forensic Sci Int. 2011;205(1-3):44-7.
4. Patil N, Karjodkar FR, Sontakke S, Sansare K, Salvi R. *Uniqueness of radiographic patterns of the frontal sinus for personal identification. Imaging Sci Dent.* 2012;42(4):213-7.
5. Khangura RK, Sircar K, Singh S, Rastogi V. *Sex determination using mesiodistal dimension of permanent maxillary incisors and canines. J Forensic Dent Sci.* 2011;3(2):81-5.
6. Saccucci M, Cipriani F, Carderi S, Carlo GDI, D'Attilio M, Rodolfino D, et al. *Gender assessment through three-dimensional analysis of maxillary sinuses by means of Cone Beam Computed Tomography. Eur Rev Med Pharmacol Sci.* 2015;19(2):185-93.
7. Ekizoglu O, Inci E, Hocaoglu E, Sayin I, Kayhan FT, Can IO. *The use of maxillary sinus dimensions in gender determination: a thin-slice multidetector computed tomography assisted morphometric study. J Craniofac Surg.* 2014;25(3):957-60.
8. Goyal M, Acharya AB, Sattur AP, Naikmasur VG. *Are frontal sinuses useful indicators of sex? J Forensic Leg Med.* 2013;20(2):91-4.
9. Teke HY, Duran S, Canturk N, Canturk G. *Determination of gender by measuring the size of the maxillary sinuses in computerized tomography scans. Surg Radiol Anat.* 2007;29(1):9-13.
10. Bangi BB, Ginjupally U, Nadendla LK, Vadla B. *3D evaluation of maxillary sinus using computed tomography: A sexual dimorphic study. Int J Dent.* 2017;2017:9017078.
11. Capitaneanu C, Willems G, Thevissen P. *A systematic review of odontological sex estimation methods. J Forensic Odontostomatol.* 2017;35(2):1-19.
12. Akhlaghi M, Bakhtavar K, Kamali A, Maarefdoost J, Sheikhazadi A, Mousavi F, et al. *The diagnostic value of anthropometric indices of maxillary sinuses for sex determination using CT-scan images in Iranian adults: A cross-sectional study. J Forensic Leg Med.* 2017;49:94-100.
13. Jehan M, Bhadkaria V, Trivedi A, Sharma SK. *Sexual Dimorphism of Bizygomatic distance and Maxillary sinus using CT Scan. IOSR-JDMS.* 2014;13(3):91-5.
14. Sharma SK, Jehan M, Kumar A. *Measurements of maxillary sinus volume and dimensions by computed tomography scan for gender determination. J Anat Soc India.* 2014;63(1):36-42.
15. Farias Gomes A, de Oliveira Gamba T, Yamasaki MC, Groppo FC, Haiter Neto F, Possobon RDF. *Development and validation of a formula based on maxillary sinus measurements as a tool for sex estimation: a cone beam computed tomography study. Int J Legal Med.* 2019;133(4):1241-9.
16. Paknahad M, Shahidi S, Zarei Z. *Sexual Dimorphism of maxillary sinus dimensions using cone-beam computed tomography. J Forensic Sci.* 2017;62(2):395-8.
17. Sherif NAEH, Sheta AAEM, Ibrahim ME, Kaka RAEM, Henaidy MF. *Evaluation of the paranasal sinuses dimensions in sex estimation among a sample of adult egyptians using multidetector computed tomography. J Forensic Radiol Imaging.* 2017;11:33-9.
18. Jasim HH, Al-taei JA. *Computed tomographic measurement of maxillary sinus volume and dimension in correlation to the age and gender (comparative study among individuals with dentate and edentulous maxilla). J Baghdad Coll Dent.* 2013;25(1):87-93.
19. Kanthem RK, Guttikonda V, Yeluri S, Kumari G. *Sex determination using maxillary sinus. J Forensic Dent Sci.* 2015;7(2):163-7.
20. Radulesco T, Michel J, Mancini J, Dessi P, Adalian P. *Sex estimation from human cranium: forensic and anthropological interest of maxillary sinus volumes. J Forensic Sci.* 2018;63(3):805-8.
21. Ahmed AG, Gataa IS, Fateh SM, Mohammed GN. *CT scan images analysis of maxillary sinus dimensions as a forensic tool for sexual and racial detection in a sample of kurdish population. Eur Sci J.* 2015;11(18):272-81.
22. Tanushri, Naeem A, Nadia K, Saluja SA, Taseer B, Akhtar H. *Evaluation of gender by measuring the size of maxillary sinus using computed tomographic scan in Indian population. J Int Oral Heal.* 2015;7(10):88-92.
23. Urooge A, Patil BA. *Sexual dimorphism of maxillary sinus: A morphometric analysis using cone beam computed tomography. J Clin Diagnostic Res.* 2017;11(3):ZC67–70.
24. Uthman AT, Al-Rawi NH, Al-Naaimi AS, Al-Timimi JF. *Evaluation of maxillary sinus dimensions in gender determination using helical CT scanning. J Forensic Sci.* 2011;56(2):403-8.
25. Amin MF, Hassan EI. *Sex identification in Egyptian population using multidetector computed tomography of the maxillary sinus. J Forensic Leg Med.* 2012;19(2):65-9.
26. Etemadi S, Seylavi G, Yadegari A. *Correlation of the maxillary sinus volume with gender and some of craniofacial indices using cone beam computed tomography. Biosci Biotech Res Comm.* 2017;10(3):580-6.
27. Gamba T de O, Yamasaki MC, Groppo FC, da Silveira HLD, Boscolo SM de A, Sanderink GCH, et al. *Validation study of a new method for sexual prediction based on CBCT analysis of maxillary sinus and mandibular canal. Arch Oral Biol.* 2017;83:118-23.
28. Rani SU, Rao GV, Kumar DR, Sravya T, Sivaranjani Y, Kumar MP. *Age and gender assessment through three-dimensional morphometric analysis of maxillary sinus using magnetic resonance imaging. J Forensic Dent Sci.* 2017;9(1):46.
29. Fernandes CL. *Forensic ethnic identification of crania: The role of the maxillary sinus: A new approach. Am J Forensic Med Pathol.* 2004;25(4):302-13.
30. Reichs KJ. *Quantified comparison of frontal sinus patterns by means of computed tomography. Forensic Sci Int.* 1993;61(2-3):141-68.
31. Karaskas S, Kavakli A. *Morphometric examination of the paranasal sinuses and mastoid air cells using computed tomography. Ann Saudi Med.* 2005;25(1):41-5.
32. Möhlhenrich SC, Heussen N, Peters F, Steiner T, Hölzle ÃF, Modabber A. *Is the maxillary sinus really suitable in sex determination? A three-dimensional analysis of maxillary sinus volume and surface depending on sex and dentition. J Craniofac Surg.* 2015;26(8):e723-726.
33. Shahbazian M, Xue D, Hu Y, van Cleynenbreugel J, Jacobs R. *Spiral computed tomography based maxillary sinus imaging in relation to tooth loss, implant placement and potential grafting procedure. J Oral Maxillofac Res.* 2010 Jan 19;1(1):e7.
34. Dursun E, Keceli HG, Dolgun A, Velasco-Torres M, Olculer M, Ghoreishi R, et al. *Maxillary sinus and surrounding bone anatomy with cone beam computed tomography after multiple teeth loss. Implant Dent.* 2019 Jun;28(3):226-36.