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Volumetric analysis of maxillary sinuses of Zulu and European crania by helical, multislice computed tomography

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Abstract

Introduction: The volumes of the maxillary sinuses are of interest to surgeons operating endoscopically as variation in maxillary sinus volume may mean variation in anatomical landmarks. Other surgical disciplines, such as dentistry, maxillo-facial surgery and plastic surgery, may benefit from this information.

Objectives: To compare the maxillary sinus volumes of dried crania from cadavers of European and Zulu descent, with respect to ethnic group and gender.

Methodology: Helical, multislice computed tomography (CT) was performed using 1-mm coronal slices. The area for each slice was obtained by tracing the outline of each slice. The CT machine calculated a volume by totalling the slices for each sinus.

Results: Ethnic and gender variations were found in the different groups. It was found that European crania had significantly larger antral volumes than Zulu crania and men had larger volumes than women. Race and gender interaction was also assessed, as was maxillary sinus side.

Conclusion: A variation in maxillary sinus volume between different ethnic groups and genders exists, and surgeons operating in this region should be aware of this.

Key words: Maxillary Sinus; X-ray; Tomography, Computed; Ethnic Groups

Introduction

The maxillary sinus is the largest of the paranasal sinuses. The functional role of the paranasal sinuses has often been disputed. Primary hypotheses have been: to add resonance to the voice; to warm and moisten air during inspiration; to play a role in mucus secretion; olfaction; and to lighten the skull.[1] A prominent feature of the maxillary sinus is its large volume. Its volume is likely to be related to its function. Healthy paranasal sinus function depends on drainage and ventilation, and obstruction results in disease.[2] Endoscopic sinus surgery aims to restore drainage and ventilation to these air-filled cavities.[2]

The maxillary sinus was selected for study because of its large volume. This research aimed to assess any variation in volume of the maxillary sinuses between men and women and between European and Zulu ethnic groups in order to provide information that may be relevant to surgeons operating endoscopically on the sinuses. Therefore, an understanding of the anatomy of the paranasal sinuses is very important, as the concept of obstruction of the ostiomeatal complex – leading to maxillary sinus disease – is fundamental to functional endoscopic sinus surgery.[3] A variation in volume could be related to a variation in anatomical landmarks. By identifying which parameters (namely, maxillary width, height and length) vary significantly between the groups it should be possible to establish which parameter contributes most to variation in volume.

Computed tomography (CT) was selected to investigate sinus volume because it is an advanced radiographic technique that yields highly accurate results.

The study was performed on dried crania as only the bony anatomical structure of the sinus was of interest.

Materials and methods

In order to investigate ethnic and sex volumetric differences in the maxillary sinus, 53 dried adult crania obtained from the Raymond Dart Collection of Human Skeletons (University of Witwatersrand) were selected according to the following criteria: 13 male and 13 female crania from persons of European descent and 13 male and 14 female crania from persons of Zulu descent.

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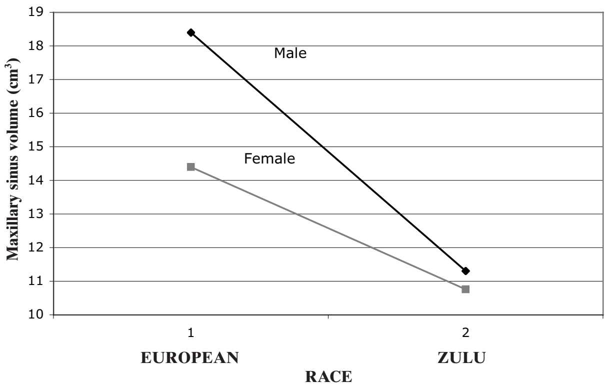

FIG. 1

Mean maxillary sinus volumes of European and Zulu male and female crania.

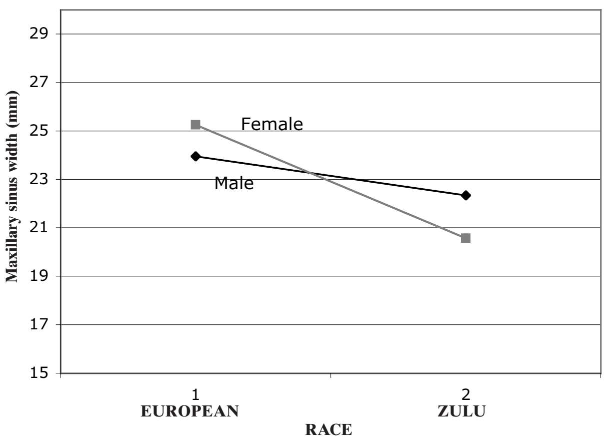

FIG. 2

Mean maxillary sinus widths for European and Zulu male and female crania.

The sinuses of the 53 dried crania (106 sinuses) were scanned in the coronal plane by a Toshiba Asteion multislicer helical CT machine using the Brainlab protocol. Four crania were scanned simultaneously using a purpose-built apparatus. Slices of 1-mm width were obtained with machine settings of 120 kV, 200 mA, and reconstruction detail was set to 'large'.

Raw data were transferred from the scanner to a Vitrea 2 workstation. These data were also transferred to a Dell Pentium 4 laptop computer to allow viewing by Osiris Dicom Format. The raw data were stored on compact disk. A magnetic optical disc of the raw data was also made directly from the Toshiba Asteion CT scanner. Analysis of the data and volumetric calculations were made by tracing the outline of the maxillary sinus for each 1-mm slice and calculating the area for each slice. The number of slices for each sinus was then totalled. The program of the CT machine did a volumetric calculation for each sinus once all the tracings for each sinus were complete.

In addition, the greatest antero-posterior length, the greatest vertical height and the greatest width were measured for each sinus in order to analyse which parameters contributed to variation in volume.

Results

Volume

Volumetric analysis revealed that European crania had larger maxillary sinuses than Zulu crania, and male crania had larger maxillary sinuses than female crania. The European male crania had the largest sinuses, with an average volumetric measurement of 18.40 cm^3. The Zulu female crania had the smallest sinuses, with an average volumetric measurement of 10.76 cm^3. Mean, maximum and minimum values for race and gender are shown in Table I.

The volumetric analysis of the maxillary sinuses yielded the following results.

Race was found to be highly significant, with European sinuses being much larger in volume than Zulu sinuses, $p < 0.001$ ($p = 0.000$).

TABLE I

MAXILLARY SINUS VOLUMES

	Mean (cm^3)	Maximum (cm^3)	Minimum (cm^3)	STD error
European female	14.40	23.01	9.91	0.714
European male	18.40	27.52	10.84	0.714
Zulu female	10.76	17.32	6.96	0.688
Zulu male	11.31	20.56	4.68	0.714

STD error = standard deviation/√sample size.

TABLE II

MAXILLARY SINUS WIDTHS

	Mean (mm)	Maximum (mm)	Minimum (mm)	STD error
European female	25.269	31	19	0.854
European male	23.962	31	12	0.854
Zulu female	20.571	32	12	0.823
Zulu male	22.346	31	13	0.854

STD error = standard deviation/√sample size.

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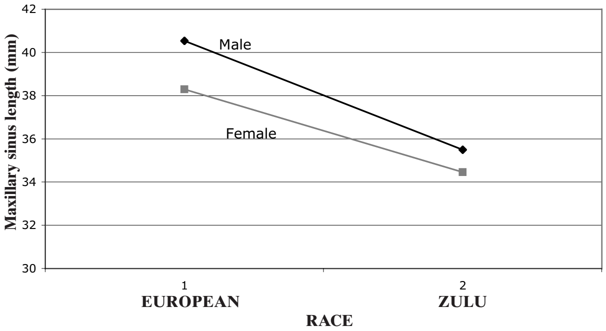

FIG. 3

Mean maxillary sinus lengths for European and Zulu male and female crania.

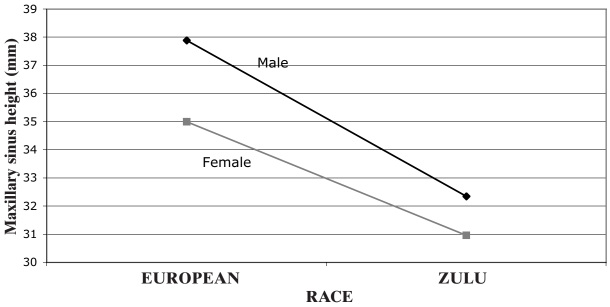

FIG. 4

Mean maxillary sinus heights for European and Zulu male and female crania.

Gender was found to be significant, with male sinuses having a much larger volume than female sinuses, $p < 0.05$ ($p = 0.002$).

Race and gender interaction was found to be significant [$p < 0.05$ ($p = 0.016$)], with European male sinuses being larger than European female sinuses by a greater amount than Zulu male sinuses were larger than Zulu female sinuses.

Figure 1 shows the mean maxillary sinus volumes for the European and Zulu crania and the average maxillary sinus volumes for the male and female crania in this study.

Width

The widths of the maxillary sinuses were measured from the outermost point of the lateral wall of the maxillary sinus, directly through to the medial wall, for each sinus. Table II shows the mean, maximum and minimum width values and STD error (standard deviation/√sample size) for the European male and female crania and the Zulu male and female crania.

The statistical analysis of the width measurements showed the following.

Race was found to the highly significant, with European sinuses being wider than Zulu sinuses, $p < 0.001$ ($p = 0.000$).

Gender was found not to be significant, $p = 0.783$.

Race and gender interaction was deemed to be significant, $p = 0.072$, as Figure 2 shows that the European male sinuses were wider than European female sinuses, while the Zulu male sinuses were narrower than Zulu female sinuses.

Length

The length of the maxillary sinus was obtained by taking the longest anterior-to-posterior measurement of the cavity. The mean lengths, maximum value, minimum values and STD error (standard deviation/√sample size) were recorded for each ethnic group and are summarized in Table III.

The statistical analysis of the maxillary sinus lengths showed the following.

Race was highly significant, with European sinuses being much longer than Zulu sinuses, $p < 0.001$ ($p = 0.000$).

Gender was significant, with male sinuses being longer than female sinuses, $p < 0.05$ ($p = 0.042$).

Race and gender interaction was not significant as male sinuses were longer than female sinuses by approximately the same amount. The above is reflected in Figure 3.

TABLE III

MAXILLARY SINUS LENGTHS

	Mean (mm)	Maximum (mm)	Minimum (mm)	STD error
European female	38.308	49	33	0.800
European male	40.538	48	33	0.800
Zulu female	34.464	40	30	0.770
Zulu male	35.500	42	24	0.800

STD error = standard deviation/√sample size.

TABLE IV

MAXILLARY SINUS HEIGHTS

	Mean (mm)	Maximum (mm)	Minimum (mm)	STD error
European female	35.000	43	29	0.815
European male	37.885	48	31	0.815
Zulu female	30.964	39	24	0.786
Zulu male	32.346	39	25	0.815

STD error = standard deviation/√sample size.

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Height

The height of the maxillary sinus was measured from the uppermost point of the superior wall of the sinus directly through the sinus to the lowermost point of the inferior wall of the sinus. The mean heights, maximum value, minimum values and STD error (standard deviation/√sample size) were recorded for each ethnic group and are summarized in Table IV.

The statistical analysis of the heights of the maxillary sinuses showed the following.

Race was highly significant, with European sinuses having a greater height than Zulu sinuses, $p < 0.001$ ($p = 0.000$).

Gender was significant, with male sinuses having a greater height than female sinuses, $p < 0.05$ ($p = 0.010$).

Race and gender interaction was not found to be significant, $p = 0.355$, with Zulu and European male sinuses being similarly higher than Zulu and European female sinuses, as shown by Figure 4.

- **This is a cadaver study of the volume of the maxillary sinus in the differing ethnic groups found in South Africa**
- **Skulls of patients of European decent had larger maxillary antra than did those of Zulu decent and, perhaps unsurprisingly, males had maxillary sinuses that were larger in volume than females**
- **The author suggests that these findings may be of help to surgeons operating in this area as sinus volume may, in turn, affect anatomical landmarks within the nose**

Discussion

The results of this research show that there are ethnic and gender variations in the volume of the maxillary sinuses. Previous research focused on assessing sinus volume, but this research is unique as it identifies variation in volume based on both ethnic group and gender.

The volume of the pneumatized portion of the maxillary sinus is important when evaluating paranasal sinus function. Disease of the sinuses and resultant obstruction results in decreased volume of these air cavities. By performing this study on dried crania the most accurate volume of this cavity was obtained, as soft tissue and disease in live persons would compromise measurement of the true volume of the cavity. A variation in volume of the maxillary antrum may be related to a variation in anatomy (such as the position of the ostium and location of the uncinate process). These findings would have implications for functional endoscopic sinus surgery.

In another study, Anagnostopoulou *et al.*[4] made casts of the maxillary sinuses of dried skulls. The volumes of the casts were measured by immersion. In this study volume was just one parameter used to classify the maxillary sinus according to its shape. These authors found an average volumetric reading for the right maxillary sinus of 11.6 cm^3 and for the left sinus of 11.9 cm^3 in a sample of 119 crania of Hellenic origin. The current study found an average right maxillary sinus volume of 16.39 cm^3 in European crania and 11.13 cm^3 in Zulu crania. Left maxillary sinus volumes were 16.42 cm^3 for European crania and 10.99 cm^3 for Zulu crania. Bezold[5] found an average right maxillary sinus volume of 14.1 cm^3 and an average left maxillary sinus volume of 13.7 cm^3, while Schumacher *et al.* (cited by Anagnostopoulou *et al.*[4]) found an average right maxillary sinus volume of 9.4 cm^3 and an average left maxillary sinus volume of 8.6 cm^3. The results of the present study clearly demonstrate that European crania have significantly larger maxillary sinuses than Zulu crania and that gender is a significant factor when comparing the maxillary sinus volumes of European and Zulu crania. Male sinuses in both groups were significantly larger than the female sinuses of the respective groups.

In addition, this study found no significance between maxillary sinus sides when analysing race, gender and the interaction between race and gender. Thus, there was no statistical difference between the volumes of the left and right maxillary sinuses of the one cranium.

Analysis of the interaction between race and gender in the two ethnic groups showed that European male sinuses were larger than European female sinuses by a greater amount than Zulu male sinuses were larger than Zulu female sinuses.

In respect of age, Uchida *et al.*[7] found no significant differences in the volume or linear measurements of the maxillary sinus. Sanchez Fernandez *et al.*[8] found that maxillary sinus volumes increased until 15 years of age and thereafter maintained similar values. As the crania in this study were all over 15 years of age the relationship between age and volume was not investigated further.

In respect of dentition, Ariji *et al.*[9] found that the difference in right and left dentition had no influence on maxillary sinus volume over the age of 20 years. The current research used only two crania under the age of 20 years and therefore it was felt that dentition would not significantly affect the volumetric results. The author intends to investigate this aspect in another paper.

From a craniometric perspective, the total distance across both sinuses was measured in order to assess whether any difference in volume was due to a difference in cranium size. Total distance was measured from the outermost aspect of the lateral wall of one maxillary sinus, directly through the sinus across the nasal cavity, through the opposite sinus to the outermost aspect of its lateral wall. It was found that the crania were all of similar size, except the Zulu female group, which comprised slightly smaller skulls. This means that in this study the difference in maxillary sinus volume was not due to a difference in cranium size.

Such variation in volume of the antrum does have implications for endoscopic sinus surgery, and it

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follows that any significant volumetric variation between persons of different ethnic origin or gender would alert the sinus surgeon to expect some anatomical variation. The complications of endoscopic sinus surgery have been well documented by numerous authors. Major and minor complications can occur due to the surgeon losing depth perception and having difficulty ascertaining the location of the surgical instrumentation.[10] This study may reduce the incidence of surgical complications by alerting the surgeon to expect a difference in the size of the antrum in the different ethnic groups and to expect a corresponding shift in anatomical landmarks. It would be expected that a smaller maxillary sinus would result in a more inferior attachment of the posterior edge of the uncinate process and a more lateral positioning of the ostium of the maxillary sinus. In addition, the orbit would be more at risk with a smaller maxillary sinus because more of the orbital wall would be exposed. The author's future research will be aimed at identifying any anatomical differences that would impact on the surgeon and any distinct variation in the shape of the maxillary sinus.

Information about the volume of the maxillary sinus will also be of value to related disciplines. In the field of maxillo-facial surgery it may be of value for reconstructive surgery and in dental implant surgery, in which bone grafting is essential, the volume of the maxillary sinus is highly relevant.[7] Other sciences, such anatomy and anthropology, may also find these results useful.

Conclusion

The results of this research show that significant ethnic and gender variation in the volume of the maxillary sinus exists. In a cadaver study of male and female European and Zulu dried crania, European male maxillary sinuses were 62.7 per cent larger than Zulu male maxillary sinuses. European female maxillary sinuses were 33.8 per cent larger than Zulu female maxillary sinuses. Overall, European maxillary sinuses are 48.6 per cent larger than Zulu maxillary sinuses. Maxillary sinuses were smaller in Zulus in all parameters.

The greatest height difference demonstrated was the 17 per cent difference between males of different ethnicity. This is of clinical significance as the position of the ostium and uncinate process differs by 17 per cent in its vertical dimension. As maxillary sinus length was also demonstrated to be 14 per cent longer in the male European crania compared with the male Zulu crania, the ostium and the uncinate process would be expected to be lower and more anterior in Zulu men.

The clinical significance of the maxillary sinus volume and linear measurement differences is directly related to the anatomical structures and their proximity to, or distance from, each other. A variation in the volume of the maxillary sinuses between persons of European and Zulu descent confirms such variations in the positioning of the relevant anatomy, such as the position of the ostium and location of the uncinate process.

These finding have important implications for functional endoscopic sinus surgery.

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Ms C. L. Fernandes takes responsibility for the integrity of the content of the paper.
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