Gender Variations in Frontal Sinus Anatomy, as Determined by Computed Tomography: Implications for Cranioplasty and Sinus Surgery

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ABSTRACT

OBJECTIVES/HYPOTEHSIS:
To describe frontal sinus anatomy and explore gender variations that may have significance for cranioplasty and sinus surgery.

STUDY DESIGN:
Anatomical measurement study utilizing preexisted computed tomography studies performed at our institution.

METHODS:
150 subjects (100 male and 50 female) who underwent maxillofacial CT between 1/1/2008 and 6/11/2008 were enrolled. Frontal sinus dimensions and forehead measurements were taken at midline and at 10, 20, and 30 mm to the left and right of midline using sagittal, coronal, and axial images. The data was analyzed for significant differences between measurements made at the selected points in the frontal sinus, for left to right variations, and for gender variations.

RESULTS:
Mean anterior table thickness ranged from 2.6 to 4.1 mm and was thinnest at 10 mm left and right of midline (2.9 and 2.6 mm). Mean anteroposterior depth of the frontal sinus ranged from 8.0 to 9.3 mm and did not vary significantly at any distance from midline. Frontal sinus height was greatest at midline (mean = 24.5 mm) and progressively lessened at lateral distances. Mean total width at the level of the supraorbital ridge was 52.2 mm. For all measurements, no significant left to right variation was noted. Comparing between genders, males were found to have greater dimensions in most frontal sinus measurements, though these differences were only found to be significant at or close to midline. The male forehead was marked by more acute nasofrontal angle (119.9° versus 133.5°) and a steeper posterior forehead inclination (-7.2° versus -3.5°). The glabella was wider in males (44.4 versus 33.9 mm) and more frequently protruded beyond the ideal forehead slope line (51% vs. 30%).

CONCLUSIONS:
Using CT imaging, forehead and frontal sinus dimensions have been described. Generally, males had larger overall frontal sinus dimensions, and this was most pronounced in the medial area of the supraorbital ridge known as the glabella.

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INTRODUCTION

Surgery in and around the frontal sinus is utilized for a variety of indications including trauma, neoplasm, and sinusitis.[1] Additionally, alteration in the appearance of the frontal bone / anterior skull may be sought by patients for cosmetic reasons, such as those seeking to reduce undesired facial masculinity.[2]

Regardless of the indication for bony surgery of the frontal bones / anterior skull, knowledge of the anatomy of the frontal sinus is essential in best preparing the surgeon to achieve the desired cosmetic goal without precipitating untoward events. The goal of this study was to expand upon the current base of anatomical knowledge by quantifying gender variations in frontal sinus and forehead anatomy through the use of computed tomography imaging.

METHODS AND MATERIALS

This is a computer-assisted anatomical measurement study utilizing existing maxillofacial computed tomography (CT) studies performed at our institution. Consecutive one hundred male and fifty female (a total of 150 patients) who underwent maxillofacial CT between the dates of 1/1/2008 and 6/11/2008 were enrolled in this study.

All CT studies were performed by 64 multidetector-row CTs (Lightspeed. VCT, GE Medical Systems, Milwaukee, WI). Contiguous axial 1.25 mm thick slices were obtained through the maxillofacial bones, and all CT measurements were made on bone algorithm reconstructed and bone windowed images using an independent workstation (GE Advantage Windows, GE Medical Systems, Milwaukee, WI).

Frontal sinus dimensions and forehead measurements were taken at midline and at 10, 20, and 30 mm to the left and right of midline using sagittal, coronal, and axial images. These measurements are illustrated in *Figures 1*, *2, 3*, and *4*. The data was analyzed for significant differences between measurements made at the selected points in the frontal sinus, for left to right variations, and for gender variations.

For continuous variables, Student's t-test analysis was used. Fisher's exact test was used to assess for gender difference in the frequency of frontal sinus protrusion past the ideal slope line.

Data for the entire sample population is summarized in *Table 1*. Data by gender group is summarized in *Table 2.*

RESULTS

Figure 1 – Mid-sagittal Measurements
Reference lines: *Line A:* ideal slope, *Line B:* actual slope, *Line C:* nasal slope, *Line H (dotted line):* horizontal reference plane, *Line V (dotted line):* vertical reference plane, *Point N*: nasion
Angle ANV: angle of inclination of ideal forehead slope, Angle BNV: angle of inclination of actual forehead slope, Angle ANB: angle of deviation of actual from ideal forehead slope, Angle BNC: nasofrontal angle. Also shown in the figure is the measured distance of brow ridge protrusion beyond the ideal forehead slope line (Line A).

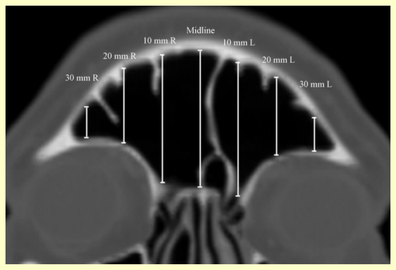

Figure 2 – Coronal Measurements
Illustration of measurements made in the coronal plane. Vertical height of the frontal sinus is measured at midline and at 10, 20, and 30 mm to the right and left of midline.

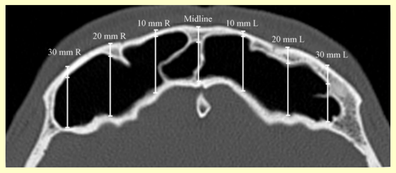

Figure 3 – Axial Measurements 1
Illustration of measurements made in the axial plane, taken at the most prominent level of the supraorbital ridge. Both the anteroposterior depth of the frontal sinus and the thickness of the anterior table were measured at midline and at 10, 20, and 30 mm to the left and right of midline.

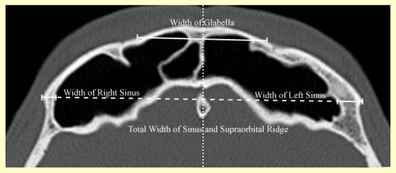

Figure 4 – Axial Measurements 2
Additional measurements made in the axial plane, taken at the most prominent level of the supraorbital ridge. Glabella, frontal sinus, and total supraorbital ridge width is measured.

Table 1 – Measurements in Total Sample Population

Measurement Parameter	*n*	Mean +/- 1 SD
Anterior Table Thickness		
Midline	143	3.5 +/- 1.7
10 mm Left of Midline	146	2.9 +/- 1.6
10 mm Right of Midline	142	2.6 +/- 1.2
20 mm Left of Midline	120	3.5 +/- 1.8
20 mm Right of Midline	118	3.3 +/- 1.5
30 mm Left of Midline	50	4.1 +/- 2.1
30 mm Right of Midline	44	3.6 +/- 1.8
Anteroposterior Depth of Sinus		
Midline	143	9.1 +/- 3.0
10 mm Left of Midline	146	9.3 +/- 3.1
10 mm Right of Midline	142	9.1 +/- 3.0
20 mm Left of Midline	120	8.7 +/- 3.4
20 mm Right of Midline	118	9.1 +/- 3.8
30 mm Left of Midline	50	8.8 +/- 3.8
30 mm Right of Midline	44	8.0 +/- 3.6
Height of Sinus		
Midline	143	24.5 +/- 9.7
10 mm Left of Midline	145	20.9 +/- 8.1
10 mm Right of Midline	142	21.8 +/- 8.9
20 mm Left of Midline	118	12.1 +/- 5.6
20 mm Right of Midline	118	13.6 +/- 6.4
30 mm Left of Midline	49	9.4 +/- 5.3
30 mm Right of Midline	44	10.3 +/- 5.7
Width of Sinus		
Width to Left of Midline	149	26.4 +/- 7.8
Width to Right of Midline	148	26.3 +/- 7.9
Total Width	150	52.2 +/- 15.1
Width of Supraorbital Ridge	150	99.4 +/- 5.1
Width of Glabella	148	41.0 +/- 12.2

Table 1. Summary of anatomical measurement data taken from all subjects included in this study.

Table 2 – Measurements of Gender Variation

Measurement Parameter	*n*	Male Mean +/- 1 SD	*n*	Female Mean +/- 1 SD	*p*
Ideal Forehead Inclination	100	-7.2° +/- 4.6°	50	-3.5° +/- 3.9°	< 0.05
Deviation of Actual From Ideal Inclination	100	20.9° +/- 7.3°	50	10.2° +/- 4.4°	< 0.05
Nasofrontal Angle	100	119.9° +/- 11.8°	50	133.5° +/- 10.1°	< 0.05
Frequency of Frontal Sinus Protrusion Beyond "Ideal" Forehead Slope	100	51/100	50	15/50	< 0.05
Protrusion of Glabella Beyond Ideal Forehead Slope	100	4.0 +/- 1.7 mm	50	2.2 +/- 1.0 mm	< 0.05
	n	Mean +/- 1 SD (mm)	*n*	Mean +/- 1 SD (mm)	*p*
Anterior Table Thickness					
Midline	94	3.9 +/- 1.9	49	2.9 +/- 1.1	< 0.05
10 mm Left of Midline	98	3.1 +/- 1.8	48	2.5 +/- 1.1	< 0.05
10 mm Right of Midline	95	2.8 +/- 1.3	47	2.3 +/- 0.8	< 0.05
20 mm Left of Midline	82	3.8 +/- 1.9	38	3.0 +/- 1.2	< 0.05
20 mm Right of Midline	81	3.4 +/- 1.5	37	2.9 +/- 1.3	NS (p = 0.059)
30 mm Left of Midline	38	4.2 +/- 2.1	13	3.8 +/- 1.9	NS
30 mm Right of Midline	29	3.4 +/- 1.9	15	3.9 +/- 1.7	NS
Anteroposterior Depth of Sinus					
Midline	95	9.7 +/- 3.1	49	7.9 +/- 2.4	< 0.05
10 mm Left of Midline	98	10.1 +/- 3.1	48	7.6 +/- 2.3	< 0.05
10 mm Right of Midline	95	9.9 +/- 2.9	47	7.4 +/- 2.5	< 0.05
20 mm Left of Midline	82	9.2 +/- 3.5	38	7.7 +/- 2.8	< 0.05
20 mm Right of Midline	81	9.4 +/- 3.7	37	8.4 +/- 3.8	NS
30 mm Left of Midline	38	9.0 +/- 4.2	13	8.1 +/- 2.4	NS
30 mm Right of Midline	29	8.5 +/- 4.1	15	7.1 +/- 2.1	NS
Height of Sinus					
Midline	94	24.7 +/- 9.8	49	24.2 +/- 9.5	NS
10 mm Left of Midline	97	21.9 +/- 7.7	48	19.0 +/- 8.7	< 0.05
10 mm Right of Midline	95	23.1 +/- 8.9	47	19.0 +/- 8.1	< 0.05
20 mm Left of Midline	80	12.6 +/- 5.9	39	11.1 +/- 4.9	NS
20 mm Right of Midline	81	14.4 +/- 6.6	37	12.0 +/- 5.5	NS
30 mm Left of Midline	38	9.5 +/- 5.7	13	9.2 +/- 4.1	NS
30 mm Right of Midline	29	11.5 +/- 6.1	15	8.0 +/ -4.2	NS
Width of Sinus					
Width to Left of Midline	99	27.2 +/- 7.8	50	25.0 +/- 7.7	NS
Width to Right of Midline	98	26.8 +/- 7.9	50	25.4 +/ 8.0	NS
Total Width	100	53.2 +/- 15.4	50	50.4 +/- 14.5	NS
Width of Supraorbital Ridge	100	100.5 +/- 4.7	50	97.1 +/- 5.1	< 0.05

Table 2. Summary of anatomical measurement data taken from each gender group.

Mean anterior table thickness ranged from 2.6 to 4.1 mm and was thinnest at 10 mm left and right of midline (2.9 and 2.6 mm). Mean anteroposterior depth of the frontal sinus ranged from 8.0 to 9.3 mm and did not vary significantly at any distance from midline. Frontal sinus height was greatest at midline (mean = 24.5 mm) and progressively lessened at lateral distances. Mean total width at the level of the supraorbital ridge was 52.2 mm. For all measurements, no significant left to right variation was noted. Comparing between genders, males were found to have greater dimensions in most frontal sinus measurements, though these differences were only found to be significant at or close to midline. The male forehead was marked by more acute nasofrontal angle (119.9° versus 133.5°) and a steeper posterior forehead inclination (-7.2° versus -3.5°). The glabella was wider in males (44.4 versus 33.9 mm) and more frequently protruded beyond the ideal forehead slope line (51% vs. 30%).

DISCUSSION

Anthropometric studies have helped to delineate gender variations in facial skeletal anatomy, and these findings have been utilized as a guide in feminization cranioplasty and forehead reconstruction. In previous studies, which typically employ surface measurements or plain film radiography, many of the most prominent gender differences have been found to exist in the supraorbital and frontal cranial region of the facial skeleton.[3] Compared to men, women exhibit a more continuous and mild curvature of the forehead, with a less prominent supraorbital ridge and subtle to absent bossing of the forehead. The nasofrontal angle is more acute and the glabella fuller and more protruding in males.[4]

Our study has confirmed many of these findings in addition to providing further data on the three-dimensional anatomy of forehead and frontal sinus. Importantly, our study quantifies and supports the concept of a prominent glabella as a distinctively masculine trait. Statistically significant gender variations in the supraorbital ridge were only found at or close to midline, in the area identified as the glabella. Here, males clearly possessed a more prominent forehead features as measured by the greater thickness of the anterior table, deeper anteroposterior dimensions, and a wider and more anteriorly protruding glabella.

CONCLUSIONS

Using CT imaging, forehead and frontal sinus dimensions have been described. Generally, males had larger overall frontal sinus dimensions, and this was most pronounced in the medial area of the supraorbital ridge known as the glabella. These anatomical characteristics should be taken into account when operating in or around the frontal sinus.

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