Sizing up the frontal sinus: clinical implications of sinus size and complexity

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Introduction

Human frontal sinuses are described as the fingerprint of the skull due to their high individual variation (Christensen 2004). While understanding the relationship between sinus size and complexity can have important clinical implications, these relationships are currently unknown. The purpose of this study is to determine how/if sinus size and morphology (complexity) relate. ***Our hypothesis is that as sinus size increases, so too does the complexity of the sinus.*** In other words, larger sinuses should present with more arcades (scalloping) compared to smaller sinuses.

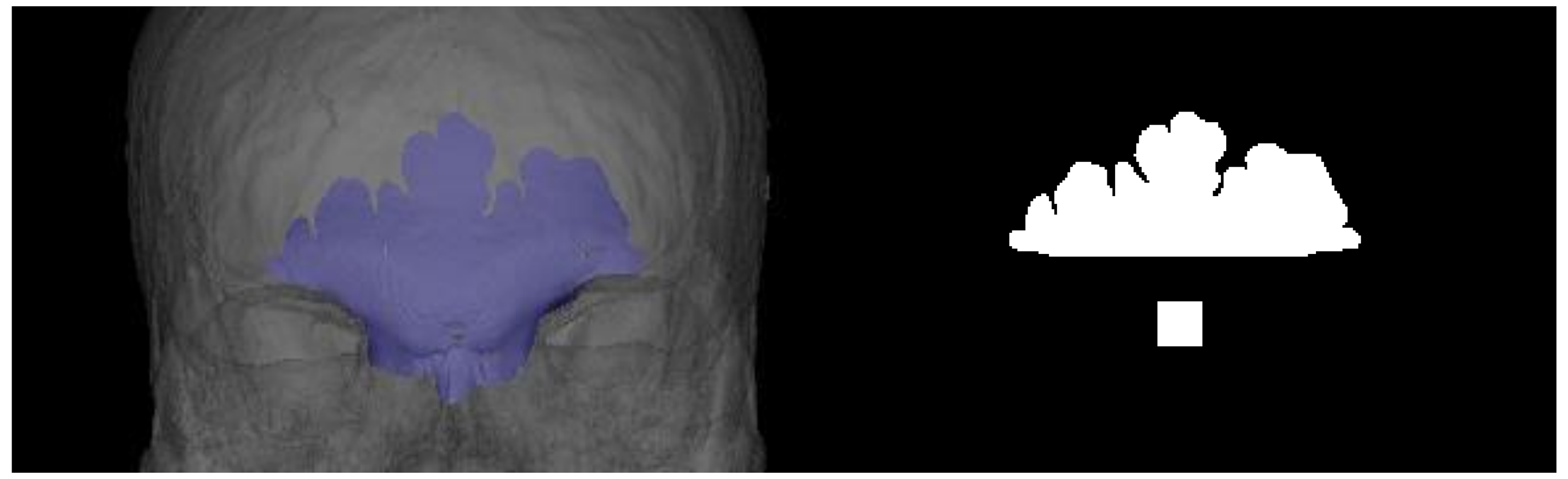

Figure 1. Sinus model in Frankfort orientation in 3D-Slicer (left), with corresponding 2D sinus outline and scale box from ImageJ (right).

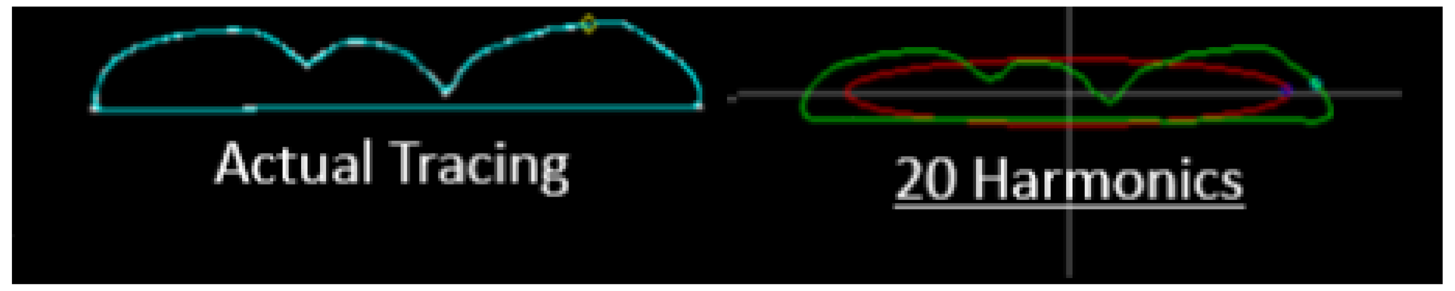

Figure 2. Screenshots from SHAPE software of Elliptical Fourier analysis (EFA) figures, which compare digitized outlines (green) to an ellipse (red).

Materials & Methods

Sample consisted of thirty dried museum crania CT scanned at the Smithsonian Institute (note, this project is IRB exempt). 3D cranial and frontal sinus models were aligned in Frankfort orientation in 3D-Slicer (**Fig. 1**). The inferior sinus was demarcated by the superior orbital border, and 2D images were obtained in ImageJ.

Size measures included sinus area, height, and breadth. Sinus shape was determined by the 2D outlines using Elliptical Fourier analysis (EFA) (**Fig. 2**). The number of arcades were also counted as a measure of complexity.

EFA outlines underwent principal components (PC) analysis to study initial variation in shape. Linear regression established relationships between shape and size. Chi-squared tests investigated associations between arcade number and size categories (small, medium, large).

All statistical analyses were conducted in SPSS v25 & SHAPE software, with 0.05 indicating significance.

Table 1. Descriptive statistics for sinus size.

	Min	Max	Mean	S.D.
Area (cm^2)	0.468	20.04	6.829	5.602
Breadth (cm)	1.467	8.605	5.246	1.994
Height (cm)	0.488	3.495	1.714	0.941

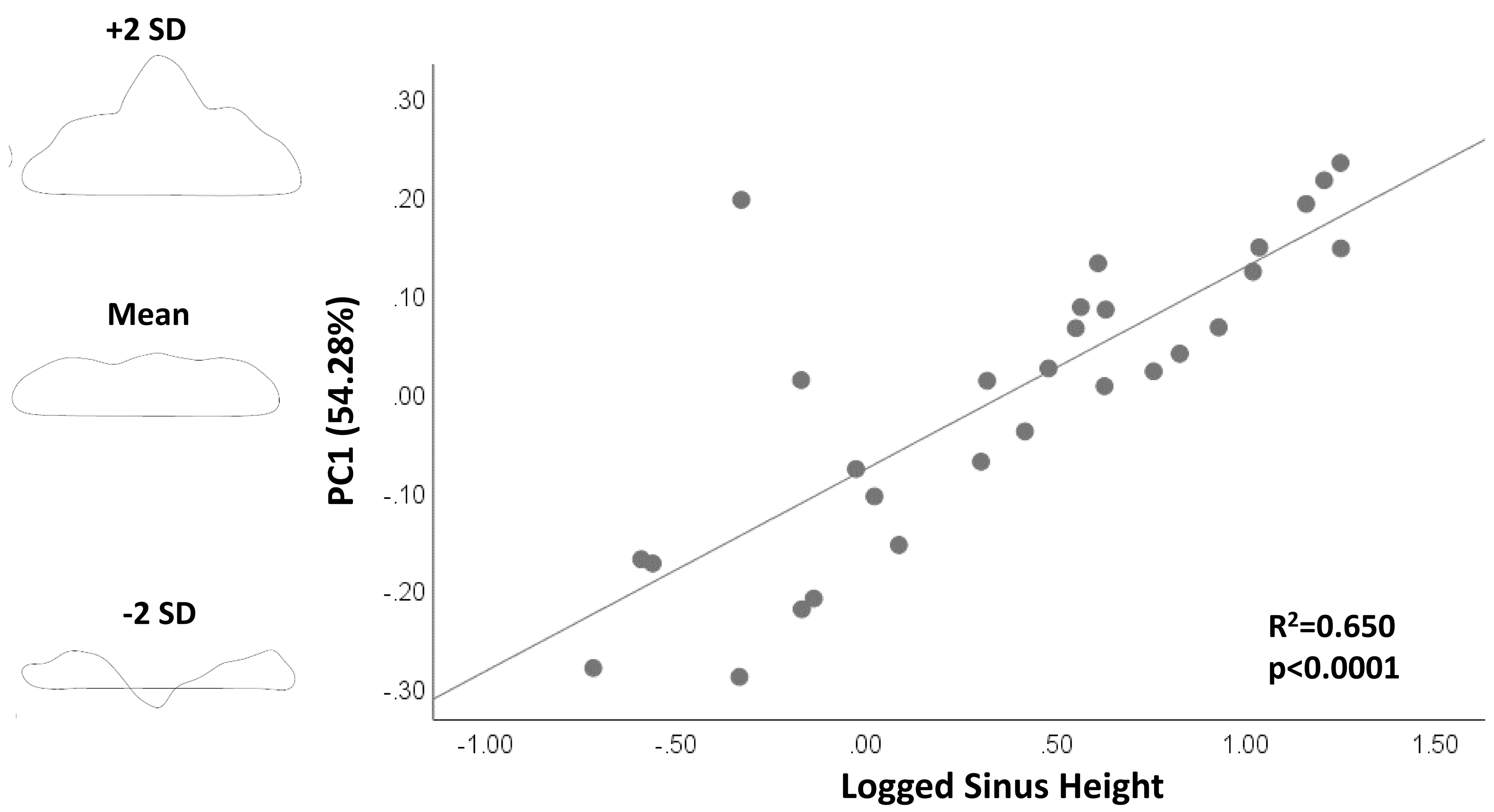

Figure 3. Plot of PC1 (with estimated outlines) versus logged frontal sinus height.

Table 2. Pearson Correlation results (R-values) for sinus size and shape variables; all variables significant at the 0.001 level.

	Arcades	Area	Breadth	Height	PC1
Arcades	-	.835	.854	.837	.590
Area	.835	-	.928	.952	.712
Breadth	.854	.928	-	.922	.611
Height	.837	.952	.922	-	.796
PC1	.590	.712	.611	.796	-

Table 3. Chi-Square results between sinus size and complexity.

X^2=17.429; p=0.002	Simple (1-5 arcades)	Moderate (6-9 arcades)	Complex (10+ arcades)	Totals
Small (<$3cm^2$)	6	4	0	10
Medium (3-$10cm^2$)	2	8	1	11
Large (> $10cm^2$)	0	3	5	8
Totals	8	15	6	29

Results

Principal components analysis: PC1 (54.28% of the variation) tracks height to breadth dynamics in the sinus models and was the only PC to correlate significantly with any sinus variables.

Linear regression analysis (Fig. 3) & Pearson Correlations (Table 2) illustrate relationships between sinus size and complexity, with the strongest, positive correlations between sinus area and height (R=0.952; p<0.0001) and between PC1 and sinus height (R=0.796; p<0.0001).

Chi-square results (**Table 3**) also show association between the number of arcades and sinus size (X^2=17.429; p=0.002)

Discussion

Conclusion: Early analyses indicate a strong positive correlation between sinus size and height, and between sinus size and complexity. Thus, we support our initial hypothesis.

Clinically implications: Sinus variability can impact surgical procedures and recovery (Chen, et al. 2020, Crocetta, et al. 2020). Thus, studies on sinus variability can give guidance on possible standardization of frontal sinus disease diagnosis and surgery to prevent surgical complications. For example, smaller sinuses may allow for reduced incision size and fewer post-operative complications.

Future analysis. Additional analyses investigating variation between males and females, as well as more precise relationships between sinus morphology and overall cranio-facial morphology are warranted.

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References available upon request