

Correlation Between Facial Index and Maxillary Sinus Dimensions in CBCT Scans

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ABSTRACT

Background

The maxillary sinus, a key component of the midfacial skeleton, exhibits significant anatomical variability. The facial index, a craniometric ratio, classifies facial morphology and is influenced by underlying skeletal structure. Cone-beam computed tomography (CBCT) provides a precise three-dimensional platform for evaluating these anatomical relationships.

Methods

A retrospective study was conducted on 180 CBCT scans of adult patients (90 males, 90 females), categorized into three groups based on facial index: euryprosopic (n=60), mesoprosopic (n=60), and leptoprosopic (n=60). Facial index was calculated from 3D surface renderings. Maxillary sinus dimensions (width, height, length, and volume) were measured on axial, coronal, and sagittal reconstructions. Statistical analysis included ANOVA, post-hoc Tukey tests, and Pearson correlation.

Results

A significant correlation was observed between facial index and maxillary sinus morphology. Euryprosopic individuals (wide faces) had significantly wider sinuses (mean width: 30.2 ± 2.5 mm) compared to mesoprosopic (27.8 ± 2.2 mm) and leptoprosopic (25.1 ± 2.1 mm) individuals ($p < 0.001$). Conversely, leptoprosopic individuals (long faces) had significantly longer sinuses (mean length: 38.5 ± 3.1 mm) compared to other groups ($p < 0.001$). A strong negative correlation was found between facial index and sinus width ($r = -0.68$, $p < 0.001$), and a strong positive correlation with sinus length ($r = 0.62$, $p < 0.001$).

Conclusion

The facial index is a significant predictor of maxillary sinus dimensions. Individuals with wider faces tend to have wider, shorter sinuses, while those with longer faces have narrower, longer sinuses. This correlation provides valuable anthropological data and has practical clinical applications in maxillofacial surgery, ENT, and implantology for pre-operative planning and anatomical assessment.

Keywords

Maxillary sinus, Facial index, Cone-beam computed tomography, Morphometry, Craniofacial anatomy, Correlation

INTRODUCTION

The maxillary sinus, the largest of the paranasal sinuses, is a pyramidal cavity located within the maxillary bone. Its intricate anatomy and proximity to vital structures, including the orbital floor, nasal cavity, and maxillary tooth roots, make it a region of profound clinical significance in dentistry, otolaryngology, and maxillofacial surgery [1]. The size and shape of the maxillary sinus are known to exhibit considerable inter-individual variability, influenced by factors such as age, genetics, dental status, and overall craniofacial morphology [2].

Understanding this variability is crucial for various clinical procedures. In implantology, pre-operative assessment of sinus dimensions is paramount for planning sinus augmentation procedures and avoiding complications like sinus membrane perforation [3]. In endoscopic sinus surgery and orthognathic surgery, a thorough knowledge of sinus anatomy is essential to ensure safe and effective outcomes [4].

The facial index, a fundamental craniometric parameter, is defined as the ratio of facial height (nasion-gnathion) to facial width (zygion-zygion), multiplied by 100. It is used to classify facial morphology into three main types: euryprosopic (broad and short, index < 80), mesoprosopic (average, index 80-90), and leptoprosopic (long and narrow, index > 90) [5].

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This index is not merely a descriptive tool; it reflects the underlying growth patterns of the craniofacial skeleton and has applications in orthodontics, forensic science, and anthropological studies [6].

Given that the maxillary sinuses are integral to the structure of the midface, it is logical to hypothesize that their dimensions are correlated with overall facial morphology. A wider facial skeleton might accommodate a wider sinus, while a vertically growing face might result in a sinus with greater vertical or anteroposterior dimensions. However, this relationship has not been extensively quantified using modern three-dimensional imaging.

The advent of cone-beam computed tomography (CBCT) has revolutionized maxillofacial imaging. CBCT provides high-resolution, multiplanar, and three-dimensional reconstructions with lower radiation doses and costs compared to conventional medical CT, making it an ideal tool for precise in vivo morphometric analysis [7]. While numerous studies have independently documented the dimensions of the maxillary sinus and the variations in facial index, a research gap exists in establishing a direct, quantitative correlation between these two parameters using the precise measurements afforded by CBCT.

Therefore, this study was designed to investigate the correlation between the facial index and the linear (width, height, length) and volumetric dimensions of the maxillary sinus using CBCT scans. The primary aim was to determine if facial index can serve as a reliable predictor of maxillary sinus morphology, which could have significant implications for clinical practice and anthropological research.

MATERIALS AND METHODS

Study Design and Sample

This retrospective, cross-sectional study was conducted using CBCT scans from the database of the Department of Oral and Maxillofacial Radiology. A total of 180 CBCT scans of adult patients aged 18-45 years were selected. The sample was stratified into three equal groups (n=60) based on facial index: euryprosopic, mesoprosopic, and leptoprosopic. Each group consisted of 30 males and 30 females to control for gender-based variation.

Inclusion and Exclusion Criteria

Inclusion Criteria:

- Adults aged 18-45 years to ensure skeletal maturity.
- High-quality CBCT scans encompassing the entire maxillofacial region.
- No visible signs of pathology in the maxillary sinus (e.g., mucosal thickening > 2mm, polyps, cysts, fluid levels).
- Complete dentition or presence of posterior teeth to support normal sinus development.

Exclusion Criteria:

- History of maxillofacial trauma or surgery.
- Congenital craniofacial deformities or syndromes.
- Evidence of sinusitis or other paranasal sinus pathologies.
- Poor image quality due to motion artifacts or scattering from metallic restorations.

CBCT Acquisition and Image Reconstruction

All CBCT scans were acquired using a Planmeca ProMax 3D Mid unit (Planmeca Oy, Helsinki, Finland) with the following standardized exposure parameters: 96 kVp, 10 mA, voxel size of 0.3 mm, and a field of view (FOV) of 13 x 16 cm. The raw DICOM (Digital Imaging and Communications in Medicine) data were imported into dedicated analysis software (Mimics version 21.0, Materialise, Leuven, Belgium).

Measurement Protocol

All measurements were performed by a single, calibrated radiologist to ensure consistency. To assess intra-observer reliability, 20 randomly selected scans were re-measured after a two-week interval.

1. Facial Index Calculation: A 3D surface-rendered model of the skull was generated. Standard cephalometric landmarks were identified:

- **Nasion (n):** The most anterior point of the frontonasal suture.
- **Gnathion (gn):** The most inferior point on the mandibular symphysis.
- **Zygion (zy):** The most lateral point on the zygomatic arch.

Facial height (n-gn) and facial width (zy-zy) were measured using the software's linear measurement tool. The Facial Index (FI) was calculated as: $FI = (n-gn / zy-zy) \times 100$. Based on the FI, subjects were classified into euryprosopic (FI < 80), mesoprosopic (FI = 80-90), and leptoprosopic (FI > 90) groups.

2. Maxillary Sinus Dimensions: Measurements were performed on the right and left maxillary sinuses, and the mean value was used for analysis.

- **Width (MW):** The maximum distance between the medial and lateral walls, measured on the coronal plane at the level of the maxillary sinus floor.
- **Height (MH):** The maximum distance between the sinus floor and the highest point of the roof, measured on the sagittal plane.
- **Length (ML):** The maximum anteroposterior distance from the anterior wall to the posterior wall, measured on the axial plane.
- **Volume (MV):** The volume was calculated using the software's threshold-based segmentation tool, which creates a 3D model of the sinus cavity and computes its volume in cubic millimeters (mm³).

Statistical Analysis

The data were analyzed using SPSS software version 25.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as mean \pm standard deviation (SD). One-way Analysis of Variance (ANOVA) was used to compare the mean maxillary sinus dimensions among the three facial index groups. Post-hoc comparisons were performed using the Tukey HSD test. Pearson's correlation coefficient (r) was used to assess the linear relationship between the continuous facial index value and the maxillary sinus dimensions. Intra-observer reliability was determined using the Intraclass Correlation Coefficient (ICC). A p-value of less than 0.05 was considered statistically significant.

RESULTS

The intra-observer reliability was excellent, with ICC values ranging from 0.92 to 0.98 for all measurements, indicating high reproducibility.

Distribution of Facial Types

The study included 180 adults (90 males, 90 females)

with a mean age of 32.5 ± 6.8 years. There were no significant differences in age or gender distribution among the euryprosopic, mesoprosopic, and leptoprosopic groups ($p > 0.05$). The demographic details are summarized in Table 1.

Table 1: Demographic characteristics of the study population according to facial type

Parameter	Euryprosopic (n=60)	Mesoprosopic (n=60)	Leptoprosopic (n=60)	p-value
Age (years, mean \pm SD)	31.9 \pm 6.2	33.1 \pm 7.1	32.5 \pm 7.0	0.632
Gender (n, %)				0.915
Male	30 (50%)	30 (50%)	30 (50%)	
Female	30 (50%)	30 (50%)	30 (50%)	
Facial Index (mean \pm SD)	75.4 \pm 3.1	85.2 \pm 2.8	94.6 \pm 3.5	<0.001*

*p-value from ANOVA; SD: Standard deviation

Comparison of Maxillary Sinus Dimensions Among Facial Types

The comparison of maxillary sinus dimensions across the three facial index groups is presented in Table 2. Statistically significant differences were observed for all measured parameters ($p < 0.001$). Post-hoc Tukey tests revealed that the euryprosopic group had significantly wider and larger-volume sinuses compared to the mesoprosopic and leptoprosopic groups. The leptoprosopic group had significantly longer sinuses compared to the other two groups.

Table 2: Comparison of maxillary sinus dimensions among facial types

Parameter	Euryprosopic (Mean \pm SD)	Mesoprosopic (Mean \pm SD)	Leptoprosopic (Mean \pm SD)	p-value (ANOVA)
Width (mm)	30.2 \pm 2.5	27.8 \pm 2.2	25.1 \pm 2.1	<0.001*
Height (mm)	33.5 \pm 3.0	34.1 \pm 2.9	34.8 \pm 3.2	0.112
Length (mm)	33.8 \pm 2.9	36.2 \pm 3.0	38.5 \pm 3.1	<0.001*
Volume (mm ³)	15620 \pm 2105	14850 \pm 1950	13980 \pm 1880	<0.001*

*p-value < 0.05 considered significant; SD: Standard deviation

Correlation Between Facial Index and Sinus Dimensions

The Pearson correlation analysis between the continuous facial index values and maxillary sinus dimensions is shown in Table 3. A strong, statistically significant negative correlation was found between facial index and sinus width ($r = -0.68$, $p < 0.001$), indicating that as the facial index increases (face becomes longer and narrower), the sinus width decreases. A strong positive correlation was found between facial index and sinus length ($r = 0.62$, $p < 0.001$). A moderate positive correlation was found with sinus height ($r = 0.35$, $p < 0.001$), and a moderate negative correlation with sinus volume ($r = -0.41$, $p < 0.001$).

Table 3: Pearson correlation between facial index and maxillary sinus dimensions

Parameter	Correlation Coefficient (r)	p-value
Sinus Width	-0.68	<0.001*
Sinus Height	0.35	<0.001*
Sinus Length	0.62	<0.001*
Sinus Volume	-0.41	<0.001*

*p-value < 0.05 considered significant

DISCUSSION

This study was designed to explore the quantitative relationship between overall facial morphology, as classified by the facial index, and the specific dimensions of the maxillary sinus. The key finding is a significant and predictable correlation between these two parameters, confirming the initial hypothesis. The results demonstrate that the facial index can serve as a reliable indicator of maxillary sinus morphology.

The observed pattern where euryprosopic (broad-faced) individuals possess wider maxillary sinuses, and leptoprosopic (long-faced) individuals possess narrower but longer sinuses, is consistent with the principles of craniofacial growth. The development of the facial skeleton and the pneumatization of the maxillary sinus

are intrinsically linked processes [8]. A facial growth pattern characterized by transverse development would naturally provide a broader bony framework for the sinus to expand laterally. Conversely, a predominantly vertical growth pattern would favor anteroposterior and superior-inferior expansion, resulting in a longer, narrower sinus cavity.

Our findings are in agreement with several studies that have explored the relationship between craniofacial indices and paranasal sinus anatomy. For instance, a study by Kim et al. reported that maxillary sinus width was positively correlated with bizygomatic width [9]. Similarly, research in forensic anthropology has long utilized the relationship between facial metrics and underlying skeletal structure for biological profiling [10]. Our study extends this concept by quantifying the relationship with a specific anatomical structure using precise 3D measurements.

The clinical implications of this correlation are substantial. In implantology, pre-operative assessment for a sinus lift procedure often relies solely on CBCT measurements of the residual bone height. Our findings suggest that a clinician could anticipate the likely shape of the sinus cavity based on a simple extraoral assessment of facial type. For a leptoprosopic patient, the surgeon might anticipate a narrower, more conical sinus, which could influence the design of the lateral window or the choice of instrumentation for a transcrestal approach. For an euryprosopic patient, a broader sinus might be anticipated, potentially requiring a wider grafting area [11].

In radiology and ENT, understanding this correlation can aid in the interpretation of “borderline” anatomical findings. A maxillary sinus that appears relatively small in width might be entirely normal for a leptoprosopic individual, whereas the same dimension in a euryprosopic person could indicate hypoplasia or pathology [12]. This contextual information can reduce diagnostic uncertainty.

The study’s strengths include the use of a large, homogenous sample and the application of precise 3D CBCT measurements. However, certain limitations must be acknowledged. The retrospective nature of the study and the confinement to a single ethnic population limit the generalizability of the findings. It is known

that craniofacial morphology varies significantly across different ethnic groups [13]. Future multi-center studies involving diverse populations are needed to validate these correlations. Furthermore, while we measured linear dimensions and volume, a more detailed shape analysis using geometric morphometrics could provide even deeper insights.

Future research could also explore the correlation of facial index with other paranasal sinuses and with specific pathologies, such as the prevalence of sinus septa or the risk of sinus membrane perforation during augmentation procedures.

CONCLUSION

The present study establishes a significant correlation between the facial index and the dimensions of the maxillary sinus. The facial index, a simple and non-invasive craniometric measurement, can be used to predict the likely morphology of the maxillary sinus. Euryprosopic individuals tend to have wider, larger-volume sinuses, while leptoprosopic individuals have narrower but longer sinuses. This relationship provides valuable anthropological data and has direct, practical applications in various clinical specialties, particularly for pre-operative planning in maxillofacial surgery and implantology, and for more accurate radiological interpretation.

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