Evaluation of sphenoid sinus volume and cranial base length in subjects with different sagittal skeletal malocclusions

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Abstract

**Objective:** The present investigation was performed to measure and correlate the volume of the sphenoid sinus (SSV) and the length of the anterior cranial base (CBL) in subjects with different sagittal skeletal malocclusions.

**Materials and methodology:** In this study, a total of 60 cone beam computed tomography (CBCT) scans of patients with different sagittal skeletal malocclusions were collected. Volumetric analysis of the SS and CBL was assessed with the Dolphin imaging software and the data was subjected to statistical analysis with SPSS.

**Results:** SSV in skeletal class II malocclusion was significantly higher than other malocclusions ($p = 0.000$). No significant correlation was noted between SSV and CBL ($p$ value>0.05) in any of the studied groups. Females with class III malocclusions had a higher SSV than males. ($p=0.046$).

**Conclusion:** The SSV was increased in subjects with Class II skeletal malocclusion when compared with other malocclusions. In females with Class III skeletal malocclusion the SSV was more than in males. SSV was not related to cranial base length.

**Keywords:** Anterior cranial base, Sphenoid sinus, skeletal malocclusions, cone beam computed tomography.

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INTRODUCTION

The sphenoid sinus (SS) is located in the center of the cranial base and is the most diverse and inaccessible paranasal sinus. [1] The sphenoid bone consists of a paired, air-filled sinus. [2] It is an obscure and irregularly shaped cavity. [3,4] The SS is first detected radiographically at 2 to 3 years of age, and by 12 to 14 years of age, it reaches its mature size, but the development of the SS continues for the rest of the lifetime. [2,3,5-6] Pneumatization begins in the ostia at the age of six months and progresses to all the regions and develops to the full size after fourteen years. As has been widely documented, the sinus may have varying degrees of pneumatization, with variations in size, shape, and kind of pneumatization. [1]

The average SSV for adult females and males is reported in recent research to be 775.1 to 792.0 ± 317.6 mm³ and 767.2 to 1000.5 ± 510.1 mm³ respectively, but it may vary depending on characteristics including age, gender, and race. [3,7] Previous studies have reported that Asians have a higher SSV because of the skull size being more than the body, whereas a relatively smaller SSV was noted in the Israeli population, hence proving the existence of variation in the SSV in various races. [3,8-9] In addition to age, gender, and ethnicity, it has been hypothesized that nasal airflow and positive air pressure in the nasopharynx influence the growth of the craniofacial structure and the paranasal sinuses. [2] Some authors claim that the growth of the paranasal sinuses is intimately related to the development of the teeth and the facial region of the skull. [5] First anatomical measurements of the shape and size of the paranasal sinus in humans were obtained by injecting various substances into cadavers or by capturing radiographs. Added evaluation of these structures has been made possible more recently because of the evolution of CBCTs which provides excellent skeletal definition with only a small dosage of radiation exposure. The development of segmentation on CBCT in recent years has made it simple for operators to generate a 3-dimensional model of the anatomical structures and to quantify lengths and angles as well as to assess volume, size, and shape. [2,9-11]

Understanding the development and evolution of the craniofacial complex is crucial for diagnosis, therapy planning, assessing treatment outcomes, and stability. [12,13] Technological advances exponentially increase because every advance helps fuel the next one. The field of craniofacial growth is no exception. [14] As we usher in a new era of digital dentistry with 3D planning headlining much of evidence-based learning, it is important to address and understand the factors responsible for maintaining a symbiotic relationship between technological advancements and patient needs. [15]

Orthodontists assess craniofacial growth using cranial base features as reference structures. The cranial base is divided into the anterior and the posterior cranial base. It is considered that the anterior cranial base (ACB) completes most of the growth prior to the skeletal structures of the face. Hence the ACB is considered a stable craniofacial feature that is used for cephalometric analysis and superimpositions during orthodontic treatment to evaluate the changes. [16,17] Recognition of anomalies in craniofacial growth is aided by knowledge of the typical pattern of cranial base development. [12,18-21]
Few studies have examined the measurement of SSV in various populations across time, and there is limited data suggesting a possible association between SSV and CBL in various sagittal skeletal malocclusions. [10,22] The aim of the study was to compare and correlate the SSV and the CBL in subjects with different sagittal skeletal malocclusions. The null hypothesis stated that there is no statistically significant difference in the SSV and CBL in subjects with different sagittal skeletal malocclusions.

MATERIALS AND METHODOLOGY

In this retrospective study, full case records of subjects who reported to the Department of Orthodontics and Dentofacial Orthopedics for orthodontic treatment at Saveetha Dental College and Hospital from June 2022 to April 2023 were assessed. After evaluating the records, a total of 60 CBCTs of patients aged between 18 to 35 years equally distributed in three different sagittal malocclusions based on cephalometric ANB angle were included in the study. Only good-quality CBCTs with fully erupted permanent dentition were considered in the study. Records of subjects with facial asymmetries, paranasal sinuses pathologies, and craniofacial syndromes were excluded.

Table 1: Demographic data

<table>
<thead>
<tr>
<th>Gender</th>
<th>Skeletal class I pattern</th>
<th>Skeletal class II pattern</th>
<th>Skeletal class III pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>10</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Females</td>
<td>10</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Total no of subjects</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

All the CBCTs were taken by a single operator using the Carestream 9600 CBCT scanner (Onex Corporation Canada) with an acquisition time of 40 sec, exposure of 120 KV 5 mA, and FOV (field of view) of 16 x 17 cm, voxel size: 300m x 300m x 300m. The CBCTs were taken with the subject standing upright (Frankfort horizontal plane parallel to the ground) and the subject’s teeth in maximum intercuspation.

Measurement of SSV

SSV was evaluated using a semiautomated tool for segmentation available in Dolphin Imaging software. For the four walls of the SS, the regions of interest were defined for assessing the SSV. After segmentation, the left and right SSV was measured in cubic millimeters (mm³). Figure 1 CBCT sagittal section depicting the SSV assessment.
Image analysis was done by an oral radiologist (AK) skilled in the analysis of tomographic images and in performing the volumetric measurements.

**Figure 1: Evaluation of SSV using Dolphin imaging software**

**Statistical Analysis**

IBM SPSS Statistics software version 23.0 (Armonk, NY) was employed to perform the statistics. Ten days later the same operator repeated the same measurements in 5 CBCTs in each group and the intra-examiner agreement was calculated using the intraclass correlation coefficient (ICC). Spearman’s Correlation, Kruskal-Wallis test, independent t-test and Two-way ANOVA was performed to assess the significant difference.

**RESULTS**

The ICC showed almost perfect intra-examiner agreement for SSV measurement and CBL measurement. A significant difference in SSV was noted in different malocclusions and it was highest in class II subjects (\(p=0.00\)), but no significant difference in CBL was noted as shown in Table 2. Figure 1 and 2 depicts a line diagram showing the mean SSV v/s sagittal skeletal pattern according to the gender and the mean CBL v/s sagittal skeletal pattern according to the gender. The Dunn’s pairwise comparison showed a significant difference between class I and class II (\(p=0.000\)) and between class II and class III (\(p=0.003\)) for SSV. However, there was no significant difference in the mean CBL between skeletal malocclusion (\(p=0.521\)). In all studied groups no significant correlation was noted between SSV and CBL (p value>0.05) as shown in Table 3. From the Independent t-test, we concluded that there was no significant difference in the mean SSV and CBL between males and females in skeletal malocclusion (\(p>0.05\)), except for class III skeletal malocclusion in SSV (\(p=0.046\)) as shown in Table 4. The two-way ANOVA test confirmed there is no
significant influence of gender; skeletal pattern and gender on SSV (p>0.05). However, there is a significant influence of skeletal pattern on SS (p=0.000). Similarly, there is no significant influence of gender, skeletal pattern, skeletal pattern and gender on CBL (p>0.05) as shown in Table 5.

Table 2: Mean comparison of Sphenoid sinus volume and cranial base length between skeletal malocclusion

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphenoid sinus volume (mm³)</td>
<td>9795.9 ± 2200.5</td>
<td>12613.5 ± 1969.4</td>
<td>10419.1 ± 1482.4</td>
<td>0.000</td>
</tr>
<tr>
<td>Anterior Cranial base length (mm)</td>
<td>49.420 ± 1.961</td>
<td>50.015 ± 2.043</td>
<td>49.130 ± 1.9030</td>
<td>0.521</td>
</tr>
</tbody>
</table>

Table 3: Bivariate correlation between sphenoid sinus volume and cranial base length in Skeletal malocclusion

<table>
<thead>
<tr>
<th>Correlation variables</th>
<th>Skeletal Malocclusion</th>
<th>Correlation coefficient (r)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphenoid sinus volume vs Cranial base length</td>
<td>Class I</td>
<td>-0.024</td>
<td>0.920</td>
</tr>
<tr>
<td></td>
<td>Class II</td>
<td>0.371</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>Class III</td>
<td>-0.002</td>
<td>0.992</td>
</tr>
</tbody>
</table>

Table 4: Sub-group analysis for gender between skeletal malocclusion of sphenoid sinus volume and anterior cranial base length

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Skeletal malocclusion</th>
<th>Mean ± SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>Sphenoid sinus volume (mm³)</td>
<td>Class I</td>
<td>9452.5 ± 2506.9</td>
<td>10139.3 ± 1917.3</td>
</tr>
<tr>
<td></td>
<td>Class II</td>
<td>12801.4 ± 2051.4</td>
<td>12459.7 ± 1986.1</td>
</tr>
<tr>
<td></td>
<td>Class III</td>
<td>9767.00 ± 1034.3</td>
<td>11071.2 ± 1620.0</td>
</tr>
<tr>
<td>Anterior Cranial base length (mm)</td>
<td>Class I</td>
<td>50.010 ± 1.9880</td>
<td>48.830 ± 1.8415</td>
</tr>
<tr>
<td></td>
<td>Class II</td>
<td>50.478 ± 2.2016</td>
<td>49.636 ± 1.9242</td>
</tr>
<tr>
<td></td>
<td>Class III</td>
<td>48.710 ± 1.9336</td>
<td>49.550 ± 1.8745</td>
</tr>
</tbody>
</table>
Table 5: Two-way analysis for sphenoid sinus volume and anterior cranial base length for gender and skeletal malocclusion.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Variable</th>
<th>R-square</th>
<th>F value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphenoid sinus volume</td>
<td>Skeletal pattern</td>
<td></td>
<td>12.149</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.336</td>
<td>1.245</td>
<td>0.269</td>
</tr>
<tr>
<td></td>
<td>Skeletal pattern * Gender</td>
<td></td>
<td>0.947</td>
<td>0.394</td>
</tr>
<tr>
<td>Anterior cranial base length</td>
<td>Skeletal pattern</td>
<td></td>
<td>1.165</td>
<td>0.320</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.097</td>
<td>0.604</td>
<td>0.440</td>
</tr>
<tr>
<td></td>
<td>Skeletal pattern * Gender</td>
<td></td>
<td>1.524</td>
<td>0.227</td>
</tr>
</tbody>
</table>

Figure 2: Line diagram showing mean sphenoid sinus volume v/s sagittal skeletal pattern in males and females.
DISCUSSION

The ACB is formed by the cribriform plate of the ethmoid bone, the anterior region of the body, the smaller wing of the sphenoid bone and the orbital portion of the frontal bone. [23,24] Major growth of the ACB is thought to have finished prior to other skeletal components of the face. The ACB has thus been regarded as a stable craniofacial structure for a very long time. [25] SSV was assessed with the help of a semiautomated tool for segmentation in the Dolphin Imaging software. [9] In this study, no correlation was noted between the SSV and CBL in various sagittal skeletal malocclusions noted, but the mean SSV was increased in class II skeletal pattern ($p=0.000$). A significant difference between the SSV was noted between males and females in the class III sagittal pattern ($p=0.046$). A statistically significant result was noted on the influence of malocclusion on the SSV was significantly different ($p=0.000$).

Nejamin et al (2019) performed a CBCT study evaluating the SSV based on facial type, skeletal class and gender. It was concluded that there was no correlation between the SSV, skeletal classes ($p=0.12$) and sex ($p=0.0946$). The present investigation concluded, no correlation between SSV and CBL in various sagittal skeletal malocclusions was observed. However, it was noted that in the Class III skeletal pattern, there was a significant increase in the SSV in females ($p=0.046$). [2]

Singh et al (2021) performed a CBCT study evaluating the morphological features of the SS like sinus condition, age and gender. The average SSV noted was $6576.92 \pm 3748.12$ mm$^3$ and a higher SSV was noted in males as compared to females with a significant difference ($p = 0.013$). In the present study, the average SSV was noted to be $10942.83 \pm 1884.1$ mm$^3$. The SSV and CBL between males and females were not significantly different, except in the Class III skeletal pattern where there was a significant increase in the SSV in females ($p=0.046$). [3]
Gibelli et al (2017) assessed the SSV according to sex and variants of pneumatization using a CT scan. The study concluded that the SSV had a statistically significant difference but did not compare based on skeletal malocclusion. The average SSV in males was $1000.5 \pm 510.1 \text{ mm}^3$ and in females $792.0 \pm 317.6 \text{ mm}^3$. This investigation concluded that the SSV was $10.673.63 \pm 1864.2 \text{ mm}^3$ in males and $11223.4 \pm 1841.13 \text{ mm}^3$ in females and no significant difference was noted between the genders.\(^{[10]}\)

Yesiltepe S et al (2022) performed a CBCT study to evaluate sphenoid sinus pneumatization in various sagittal patterns. It was noted that the SS pneumatization was indistinguishable in subjects with different sagittal skeletal malocclusions. This study concluded that there was no correlation between the SSV and CBL in various sagittal skeletal malocclusions but an increase in SSV was noted in Class II skeletal pattern.\(^{[1]}\)

Gong et al (2016) conducted a study evaluating the cranial base characteristics in anteroposterior malocclusions. It was concluded that CBL was reduced significantly in subjects with class III skeletal malocclusion compared to skeletal class I malocclusion and increased in subjects with class II skeletal pattern. In the present study, no significant difference was noted between the CBL in various sagittal skeletal malocclusions ($p= 0.521$).\(^{[26]}\) Al Maatiah et al (2022) performed a study evaluating the cranial base measurements in different anteroposterior skeletal relationships using Bjork-Jarabak analysis. It was concluded that there was no significant difference in anterior CBL (N-S) and posterior CBL (S-Ar) in the different sagittal skeletal patterns. Similar results were found in the present study.\(^{[27]}\) No previous studies have assessed the correlation between SSV and CBL in different sagittal skeletal malocclusions.

**Limitations**

A larger sample size can be used to further evaluate the results. The present study included only the Dravidian population, while previous studies have evaluated variations in the paranasal sinus volume and cranial base length in different races.

**CONCLUSIONS**

The SSV was increased in subjects with Class II skeletal malocclusion when compared with other malocclusions. In females with Class III skeletal malocclusion the SSV was more than in males. SSV was not related to cranial base length.

**CONFLICT OF INTEREST**

No conflicts of interest

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AUTHORS CONTRIBUTION:

AK: Methods, examination, acquiring and analysis of data, preparation of original draft.

SMP: Designing and conceptualizing, validation, reviewing and editing, supervision, resources and visualization.

REFERENCES


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