Available online at https://www.mmpubl.com/

International Journal of Orthodontic Rehabilitation

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

Arshya Kumar[1], Srirengalakshmi Muthuswamy Pandian[2]

[1]Postgraduate Student, [2]Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai 600077.

How to cite this article: *Evaluation of sphenoid sinus volume and cranial base length in subjects with different sagittal skeletal malocclusions. Int J Orthod Rehabil 2023; 14 (2) 54 – 64.*

Doi: 10.56501/intjorthodrehabil.v14i2.870.

Received: 26-06-2023 *Accepted:10-07-2023* *Web Published:13-07-2023*

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.

Address for Correspondence

Dr. Srirengalakshmi Muthuswamy Pandian,
Associate Professor, Department of Orthodontics and Dentofacial Orthopedics,
Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences, Chennai 600077
Email: srirengalakshmi.sdc@saveetha.com
Contact number: +91 8867783552.

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 mm^3 and 767.2 to 1000.5 ± 510.1 mm^3 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

Gender	Skeletal class I pattern	Skeletal class II pattern	Skeletal class III pattern
Males	10	9	11
Females	10	11	9
Total no of subjects	20	20	20

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 (mm^3). *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.

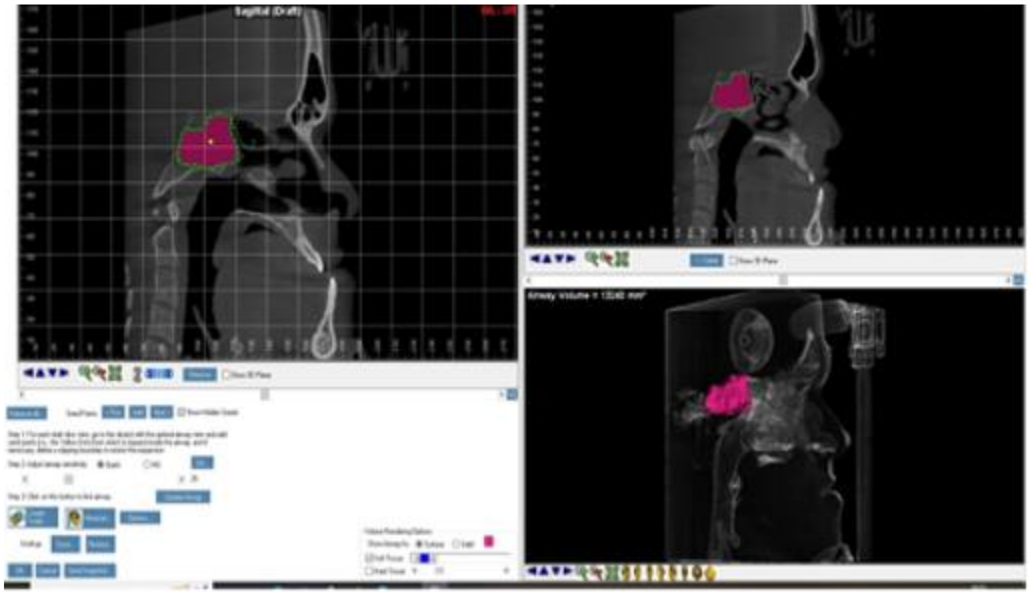

Figure 1: Evaluation of SSV using Dolphin imaging software

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

Measurement	Mean ± SD			p value
	Class I	Class II	Class III	
Sphenoid sinus volume (mm^3)	9795.9 ± 2200.5	12613.5 ± 1969.4	10419.1 ± 1482.4	0.000
Anterior Cranial base length (mm)	49.420 ± 1.961	50.015 ± 2.043	49.130 ± 1.9030	0.521

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

Correlation variables	Skeletal Malocclusion	Correlation coefficient (r)	p value
Sphenoid sinus volume vs Cranial base length	Class I	-0.024	0.920
	Class II	0.371	0.107
	Class III	-0.002	0.992

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

Measurement	Skeletal malocclusion	Mean ± SD		p value
		Male	Female	
Sphenoid sinus volume (mm^3)	Class I	9452.5 ± 2506.9	10139.3 ± 1917.3	0.500
	Class II	12801.4 ± 2051.4	12459.7 ± 1986.1	0.710
	Class III	9767.00 ± 1034.3	11071.2 ± 1620.0	0.046*
Anterior Cranial base length (mm)	Class I	50.010 ± 1.9880	48.830 ± 1.8415	0.185
	Class II	50.478 ± 2.2016	49.636 ± 1.9242	0.374
	Class III	48.710 ± 1.9336	49.550 ± 1.8745	0.337

Table 5: Two-way analysis for sphenoid sinus volume and anterior cranial base length for gender and skeletal malocclusion.

Measurement	Variable	R- square	F value	p value
Sphenoid sinus volume	Skeletal pattern	0.336	12.149	0.000
	Gender		1.245	0.269
	Skeletal pattern * Gender		0.947	0.394
Anterior cranial base length	Skeletal pattern	0.097	1.165	0.320
	Gender		0.604	0.440
	Skeletal pattern * Gender		1.524	0.227

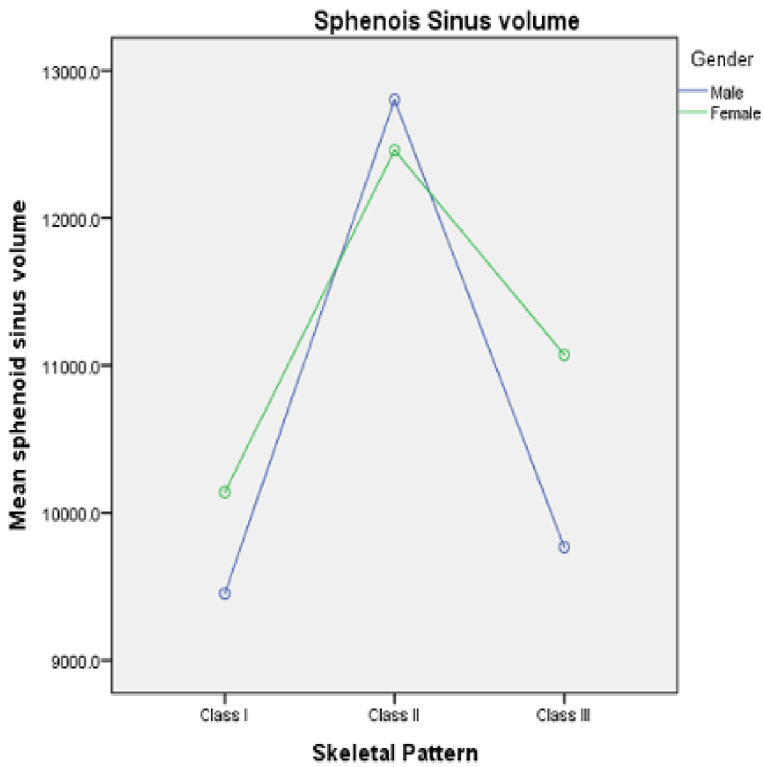

Figure 2: Line diagram showing mean sphenoid sinus volume v/s sagittal skeletal pattern in males and females

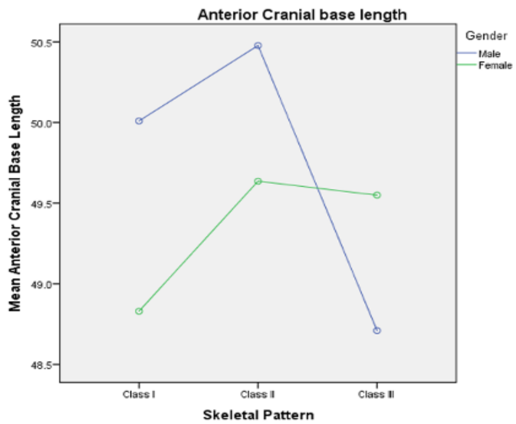

Figure 3: Line diagram showing mean anterior cranial base length v/s sagittal skeletal pattern in males and females

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 ± 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 ± 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 ± 510.1 mm^3 and in females 792.0 ± 317.6 mm^3. This investigation concluded that the SSV was 10.673.63 ± 1864.2 mm^3 in males and 11223.4 ± 1841.13 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

FUNDING

No funding from the public, private sector or institutional organizations.

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

1. Yesiltepe S, Kurtuldu E, Bayrakdar IS, Yilmaz AB. Cone beam computed tomography evaluation of sphenoid sinus in different sagittal skeletal pattern. Eur Oral Res. 2022 Sep 5;56(3):143–8.
2. Nejaim Y, Farias Gomes A, Valadares CV, Costa ED, Peroni LV, Groppo FC, et al. Evaluation of volume of the sphenoid sinus according to sex, facial type, skeletal class, and presence of a septum: a cone-beam computed tomographic study. Br J Oral Maxillofac Surg. 2019 May;57(4):336–40.
3. Singh P, Hung K, Ajmera DH, Yeung AWK, von Arx T, Bornstein MM. Morphometric characteristics of the sphenoid sinus and potential influencing factors: a retrospective assessment using cone beam computed tomography (CBCT). Anat Sci Int. 2021 Sep;96(4):544–55.
4. Wiebracht ND, Zimmer LA. Complex anatomy of the sphenoid sinus: a radiographic study and literature review. J Neurol Surg B Skull Base. 2014 Dec;75(6):378–82.
5. Özer CM, Atalar K, Öz II, Toprak S, Barut Ç. Sphenoid Sinus in Relation to Age, Gender, and Cephalometric Indices. J Craniofac Surg. 2018 Nov;29(8):2319–26.
6. Pallanch JF, Yu L, Delone D, Robb R, Holmes DR 3rd, Camp J, et al. Three-dimensional volumetric computed tomographic scoring as an objective outcome measure for chronic rhinosinusitis: clinical correlations and comparison to Lund-Mackay scoring. Int Forum Allergy Rhinol. 2013 Dec;3(12):963–72.
7. Anon JB, Rontal M, James Zinreich S. Anatomy of the Paranasal Sinuses. Thieme Medical Publishers; 1996. 224 p.
8. Kim J, Song SW, Cho JH, Chang KH, Jun BC. Comparative study of the pneumatization of the mastoid air cells and paranasal sinuses using three-dimensional reconstruction of computed tomography scans. Surg Radiol Anat. 2010 Jul;32(6):593–9.

9. Cohen O, Warman M, Fried M, Shoffel-Havakuk H, Adi M, Halperin D, et al. Volumetric analysis of the maxillary, sphenoid and frontal sinuses: A comparative computerized tomography based study. Auris Nasus Larynx. 2018 Feb;45(1):96–102.
10. Gibelli D, Cellina M, Gibelli S, Oliva AG, Codari M, Termine G, et al. Volumetric assessment of sphenoid sinuses through segmentation on CT scan. Surg Radiol Anat. 2018 Feb;40(2):193–8.
11. Pirner S, Tingelhoff K, Wagner I, Westphal R, Rilk M, Wahl FM, et al. CT-based manual segmentation and evaluation of paranasal sinuses. Eur Arch Otorhinolaryngol. 2009 Apr;266(4):507–18.
12. Malta LA, Ortolani CF, Faltin K. Quantification of cranial base growth during pubertal growth. J Orthod. 2009 Dec;36(4):229–35.
13. Krieg WL. Early facial growth accelerations. A longitudinal study. Angle Orthod. 1987 Jan;57(1):50–62.
14. Vaid NR, Adel SM. Contemporary Orthodontic Workflows: A Panacea for Efficiency? Semin Orthod. 2023 Mar 1;29(1):1–3.
15. Pandian SM, Subramanian AK, Ravikumar PA, Adel SM. Biomaterial Testing in Contemporary Orthodontics: Scope, Protocol and Testing Apparatus. Semin Orthod. 2023 Mar 1;29(1):101–8.
16. Afrand M, Ling CP, Khosrotehrani S, Flores-Mir C, Lagravère-Vich MO. Anterior cranial-base time-related changes: A systematic review. Am J Orthod Dentofacial Orthop. 2014 Jul;146(1):21–32.e6.
17. Cudia G, Michelizzi C. [Predispositions of the cranial base in the Delaire analysis]. Mondo Ortod. 1991 May-Jun;16(3):337–41.
18. Bastir M, Rosas A, O’higgins P. Craniofacial levels and the morphological maturation of the human skull. J Anat. 2006 Nov;209(5):637–54.
19. Dhopatkar A, Bhatia S, Rock P. An investigation into the relationship between the cranial base angle and malocclusion. Angle Orthod. 2002 Oct;72(5):456–63.
20. Coben SE. The spheno-occipital synchondrosis: the missing link between the profession’s concept of craniofacial growth and orthodontic treatment. Am J Orthod Dentofacial Orthop. 1998 Dec;114(6):709–12; discussion 713–4.
21. Budiardjo SB, Karim AF, Indriati S, Wahono NA, Suharsini M, Fauziah E, et al. Length of anterior cranial base and Frankfort horizontal plane: A lateral cephalometric study in 11–16-year-old children. J Phys Conf Ser. 2018 Aug;1073:022014.

22. Sánchez Fernández JM, Anta Escuredo JA, Sánchez Del Rey A, Santaolalla Montoya F. Morphometric study of the paranasal sinuses in normal and pathological conditions. Acta Otolaryngol. 2000 Mar;120(2):273–8.
23. Singh GD, McNamara JA Jr, Lozanoff S. Finite element analysis of the cranial base in subjects with Class III malocclusion. Br J Orthod. 1997 May;24(2):103–12.
24. Kasai E, Kondo S, Kasai K. Morphological variation in the anterior cranial fossa. Clin Exp Dent Res. 2019 Apr;5(2):136–44.
25. Smith TD, McMahon MJ, Millen ME, Llera C, Engel SM, Li L, et al. Growth and Development at the Sphenoethmoidal Junction in Perinatal Primates. Anat Rec . 2017 Dec;300(12):2115–37.
26. Gong A, Li J, Wang Z, Li Y, Hu F, Li Q, et al. Cranial base characteristics in anteroposterior malocclusions: A meta-analysis. Angle Orthod. 2015 Nov 3;86(4):668–80.
27. Al Maaitah EF, Alomari S, Al-Khateeb SN, Abu Alhaija ES. Cranial base measurements in different anteroposterior skeletal relationships using Bjork-Jarabak analysis. Angle Orthod. 2022 Jun 20;92(5):613–8.

Published by MM Publishers
https://www.mmpubl.com/ijorthrehab