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Cranial Base and Its Relation with Different Craniofacial Structures: A Review Article

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ABSTRACT:The cranial base or the floor of the cranial vault plays a very vital role in the development of other related facial structures like the maxilla, nose and the mandible, etc. Following the cranio-caudal growth pattern, the growth of the cranial base is achieved at the earliest and at a rapid speed attaining about 90% of the adult size by around 7 years of age. This article mainly focuses on the various aspects of the cranial base like its anatomy, growth, changes with age, differences between males and females, differences in the population around the world, its relation with the maxilla and mandible and how it affects their growth (horizontal and vertical) and causes different malocclusions.

KEYWORDS: Cranial Base, Anterior Cranial Base, Cranial Base Slope, Skeletal Malocclusions.

I. INTRODUCTION

The cranial base, although inconspicuously tucked within the core of the cranium, functions almost as an anatomical beam supporting the brain and the overlying cranial vault, while the viscero-cranium (facial skeleton) largely 'hangs' from its rostral end. Owing to its proximity and co-development with cranial sense organs—the otic, optic, and nasal placodes—the cranial base develops in an almost 'jigsaw-like fashion', accommodating, protecting, and supporting these specialized organs [1] .

Cranium is one of the first structures to develop and mature in the human body and also in the cranio-facial region. Nonetheless, because of the anatomical proximity of the cranial base with viscero- and neurocranial elements, its nature, timing and direction of growth determines the growth of other components of the cranio-facial complex and the developmental anomalies impacting the cranial base often manifest viscero- and neurocranial defects. The cranial base can be divided into anterior, middle and posterior parts of which the anterior cranial base is of immense importance [2,3].

The angular slope or length of the anterior cranial base (ACB) according to several studies, promotes the development of sagittal or vertical malocclusions. The race or region may also have an impact on the slope's degree. When compared to other reference planes, ACB is nevertheless thought to be reasonably stable during craniofacial growth.

For superimposition of cephalometric radiographs, ACB is frequently utilized, since the growth of ACB is more consistent in the first ten years of life and is finished earlier than that of other craniofacial structure. During the intrauterine period, the cranial base slope remains almost level. But the slope gets steeper and steeper as the brain grows exponentially. ACB develops quickly in the first five years of life and grows upto 90% of its total length. Throughout development, the growth of maxilla and mandible and their development pattern too is determined by the cranial base moving forward and downward [3] .

II. BASIC ANATOMY OF CRANIAL BASE

According to Wiley [4], the **base of the skull (**or **skull base)** forms the floor of the cranial cavity and separates the brain from the structures of the neck and face. The skull base and vault together forms the neurocranium.

The base of the skull is a bony diaphragm composed of a number of bones - from anterior to posterior:

- frontal bone
- ethmoid bone
- sphenoid bone
- temporal bones (paired)
- occipital bone
- parietal bones (paired)

Sutures hold these bones apart from one another.

These are separated from the inner surface of the base of the skull by the petrous ridge posteriorly and the sphenoidal ridge anteriorly by three regions or fossae:

These bones are separated from each other by sutures.

The inner surface of the base of the skull is divided by the sphenoidal ridge anteriorly and the petrous ridge posteriorly into three regions or fossae:

- anterior cranial fossa
- middle cranial fossa
- posterior cranial fossa

III. CHANGES IN ANTERIOR CRANIALBASE WITH AGE

The anterior cranial base is not a stable structure in its entirety; rather, different parts of this structure finish growing at different times during life. The presphenoid and ethmoid regions should be considered fully developed before the usual orthodontic age (by age 7 for the presphenoid regions and age 4 for the ethmoid regions); however, the frontal and sella turcica regions continue remodelling until early adulthood. This is because the anterior cranial base is composed of frontal (which includes nasion), ethmoid, presphenoid, and sellaturccica (which includes sella) regions.

According to Mona Afrand et. al. [5] there was only an average 1-mm growth in the length of the ethmoid region from ages 6 to 12, according to a longitudinal analysis of serial cephalometric radiographs.

Due to bilateral structure overlapping in this region, finding the cribriform plate structure on lateral cephalometric radiographs might be challenging. Consequently, it takes skilled eyes and high-quality lateral x-rays to locate and use the cribriform plate as a reference structure for 2-dimensional growth investigations. Nonetheless, since 3D imaging methods do not care about structural overlap, taking the cribriform plate into account during a 3D superimposition could be helpful.

The anteroposterior length of the presphenoid region stabilized after 7 years of age, as assessed by different methods. Some positional activity was observed in histological assessments of the region presphenoid in pre-pubertal stage. Although modifier activity in this region will not change the length of the presphenoid region, it will change its height.

According to Ranly [35], approximately 86% of anterior cranial base development is considered complete by the age of 4.5 years; however, the remaining growth contributes to increased length of the anterior skull base (sella-nasion) even after puberty. Increased thickness of the frontal bone, apposition in the glabella region, and increased size of the frontal sinus contribute to the increased length of the anterior cranial base and forward migration of the nasion in adulthood (3.3 increase % in frontal bone segment from age 6 to early adulthood.

According to Knott [36] reported that the nasion moves downward or upward, depending on the angle of measurement or in relation to the skull base structure where the measurement is made. Contradictory results are reported in this study may be due to low or no statistical analysis, depending on measurement. The amount of upward movement of nasion was statistically insignificant (less than 1) over the 2-year period.

IV. SLOPE OF CRANIAL BASE

The cranial base, especially the anterior cranial base(ACB) is a significant reference landmark used in cephalometrics for diagnosing orthodontic patients. Several studies have shown that the angular slope or length of the anterior cranial base enhances the development of sagittal or vertical skeletal malocclusions. The degree of its slope could also vary depending on the race or area. Nevertheless, ACB is still relatively stable throughout craniofacial growth compared with other reference planes [3].

The cranial base slope is almost flat throughout the fetal life. However, as the brain grows exponentially, the slope increasingly becomes steeper [3]. In the first 5 years of life, ACB shows rapid development and completes its growth by 90% [7,8]. During growth, the cranial base, moves forward and downward, thereby determining the growth and development patterns of both the maxillary and mandible.

The literature suggests a constant angle of 7° between anterior cranial base i.e. S-N & the natural head position i.e. Frankfurt Horizontal (FH) planes. The cephalometric diagnosis can be affected by variations in the Frankfort Horizontal and Sella Nasion inclination. If the given SN-FH value more or less than 7°, a corresponding alteration is seen in the relation of the maxilla and mandible to the cranium (SNA, SNB, and SND) values to offset the discrepancies due to the inclination of the anterior cranial base. However various studies done by Alves and Huh, have shown that the FH-SN angulation can vary in differentpopulation[9,10] due to which the universal use of 7° as a constant angle cannot be

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acceptable. According to Varghese, the FH-SN angle was similar between skeletal Class I, II and III relationships [11].population[9,10] due to which the universal use of 7° as a constant angle cannot be acceptable. According to Varghese, the FH-SN angle was similar between skeletal Class I, II and III relationships [11].

V. GLOBAL COMPARISON OF CRANIAL BASE MORPHOLOGY

The south-east Asians including people from India, Nepal, Srilanka, Bangladesh etc. are known to have small cranial base owing to the short body stature based on Bergman's rule or Island rule of ecogeographical conditions.

Among the shape of the cranial vault, the major difference was found in the proportion of length/breadth ratio, where the Australians-Melanesians and Africans showed greater dimension in length than breadth whereas populations of the Europeans and North-east Asian showed more globular pattern of cranial base. The non-Africans showed a more Brachycephalic cephalic shape, reason hypothesized to the reduction in the masticatory forces due to gracilization of the temporalis muscle and decreased stress on the lateral side of the head or to adapt to the cold climatic conditions the surface area is reduced [37,38].

The North-east Asians were found to have large processing cheek bones over the maxillary and zygomatic regions. This was found to be the characteristic feature of Siberians who had to adapt to the cold climatic conditions through increased maxillary sinus volume and flat face due to prognathic zygoma.

The Europeans had a reduction in the frontal incline and flat narrow occipital bone whereas, the North-east Asians had inclined forehead with a lifted occipital region.

The difference between Northeast Asians and Southeast Asians is represented by the contrast of the high face with the inclined occipital lambda and low face with the narrow cranial base [6].

VI. CRANIAL BASE MORPHOLOGY DIFFERENCE IN MALE AND FEMALE

According to the study done by Marco Milella done in 2021 [12] , the cranial sexual dimorphism is based on Weiners Law(to explain the cause of an event or behavior). His report states that: (a) males present overall more variance in size and shape, although it states only for total cranial size; (b) differences between sexes are dominated by size and to a lesser extent by its shape (c) shape only accounts for a minor proportion of variance; (d) the cranial base shows almost no dimorphism for shape among males and females; and (e) facial form i.e. the shape rather than its size is the most accurate predictor of skeletal sex.

According to Rosas and Bastir [13] demonstrated that the human calvaria is larger in males than in females in a Portuguese sample. However, those authors also reported specific cranial morphological changes between sexes, such as the height of the piriform cavity (longer in males) and the shape of the face, which presented a relatively more curved naso-glabellar profile and less prognathic alveolar regions in males. Pronounced facial differences between sexes have also been shown . For example, Bigoni et al. [14] explored in a sample of Bohemians dating to the first half of the 20th century and found that the most significant dimorphism was expressed in the upper face (wider, lower and more antero-posteriorly flattened in males) and in the midsagittal curvature of the cranial vault (pronounced glabella and inion, flattened frontal and lambda regions, pronounced vaulting of the bregma area in males).

Analysis of a modern French sample done by Musilová, Dupej, Velemínská, Chaumoitre, & Bruzek (2016), demonstrated that larger muscle insertions are associated with variances specific to increased sexual dimorphism, especially in the face and nuchal regions. The glabellar and supraorbital areas were two of the most dimorphic regions, and they were evaluated as one of the most important traits in the midfacial region, which is highly influenced by facial expressions. Wider and more robust zygomatic arches are typical for males and are one of the most reliable traits for sexing as well [15].

Franklin et al. (2006) also demonstrated that cranial sexual dimorphism in southern Africans was mainly associated with relative facial breadth (larger in males) and the contour of the forehead (less vertical in males), in addition to differences in the expression of the supramastoid crest and alveolar prognathism (all more accentuated in males). He also found that cranium of males was relatively more dolichocephalic compared to a more brachycephalic shape in females. [6]

VII. RELATION OF ANTERIOR CRANIAL BASE LENGTH WITH JAW BASES

According to Fabio Savoldi et. al. (2021), the evaluation of anteroposterior maxillary complex length by using its ratio with the anterior cranial base may be more clinically relevant than adopting absolute measurements, which may not be optimal for the identification of disproportions. The use of relative measurements revealed that a shorter maxilla (and not premaxilla or palatine bone) was associated with a shorter maxillary complex [16].

According to Peter Proff et.al. (2007), mandibular length relative to anterior cranial base length is increased in skeletal Class III, whereas maxillary length is not consistently affected. The reduction of total cranial base length observed in skeletal Class III apparently results from various minor local changes rather than from the shortening of the anterior and/or the posterior cranial base legs. Cranial base flexure is more prominent in skeletal Class III and this is related to changes in the posterior cranial base and to anterior displacement of the condyles and the mandible [17].

VIII. GENETICS AND ITS ROLE IN THE DEVELOPMENT OF CRANIAL BASE AND ASSOCIATED SYNDROMES

Embryology, evolution and genetics have given us an understanding of the development of the craniofacial structures- the most sophisticated part of the body. Any alterations to specific embryological processes, such as brain patterning, cell migration, tissue fusion and bone differentiation can cause craniofacial disorders.

A number of disorders of the craniofacial complex have been found to be associated with specific genes like the Pfeiffer Syndrome associated with FGFR-1 [18], Crouzon and the Apert Syndrome with the FGFR-2 gene [19], the TWIST gene in the Saethre–Chotzen syndrome [20,21]. Haploinsufficiency of the human homeobox gene ALX4 causes skull ossification defects [22].

These are just a few of the thousands of syndromes with their associated genes and the following malocclusions that occur simultaneously along with the development defects of the cranial base due to retardation or alteration of the growth of other structures of the craniofacial complex.

IX. CRANIAL BASE ANGLE AND ITS RELATION WITH DIFFERENT MALOCCLUSIONS

According to Ahmed et. al. [17], Klocke et. al [23], Chin et. al. [24], Hussain et.al.[25], there exists a significant difference in the cranial base angle, and both maxillary and mandibular lengths among all three malocclusion groupsgiving an indication that the cranial base angulation plays an evident role in determining the type of developing sagittal malocclusion pattern, and that both jaw base lengths can be considered as significant factors that affect the appearance of a specific type of malocclusion.

Meanwhile, no significant difference was found in all linear cranial base variables coinciding with the findings of Dhopatkar et al. [26], Proff et al. [27] and Polat and Kaya [28]. On the contrary, Hussein et al. [25] found a significant difference in all linear cranial base variables used among their study sample. This could be attributed to the variation in their study sample which comprised both Class I and Class III subjects only unlike ours which comprised all three classes of malocclusion.

X. CRANIAL BASE AND ANTERO-POSTERIOR JAW BASE RELATIONSHIP

Over the past few years, the anteroposterior relationship between the maxilla and the cranial base has been a point of interest to many scholars. Järvinen was amongst the first researchers to find a link between SNA and the cranial base angle (NSAr). However, he also found out that this link was most likely due to the rotation of SN plane, and that SNA is unreliable to determine the anteroposterior position of the maxilla [27]. This finding was confirmed by Rana et al. concluding that the anteroposterior position of maxilla was predetermined by genetic or epigenetic factors without being affected by the cranial base flexure [20].

According to Ahmed et. al. [17], an inverse correlation exists between SNA and N-S-Ba in both Class II and Class III malocclusion groups, meaning that any decrease in the N-S-Ba angle is accompanied by an increase in the SNA angle. This finding was similar to the findings of Hopkin et al. [31] and Kasai et al. [32] indicating that the maxilla tends to protrude as the cranial base angle decreases.

XI. CRANIAL BASE AND VERTICAL JAW BASE RELATIONSHIP

Very little data exists in the current literature on the cranial base effect on the vertical jaw base relationship in subjects of different skeletal patterns. Some suggest that the mandibular positional deviation resulting from the increase in the cranial base angle is associated with an anterior open-bite condition [33]. While others found no difference in the cranial base measurements between both normal and anterior open bite subjects [34].

Linear cranial base variables were found to have a substantial correlation with the facial height, where a significant positive correlation was found between both anterior and posterior cranial base lengths and the total facial height. That is to say that, as both cranial base lengths increase, the total facial height also increases [17]. This finding was coinciding with the findings of Kasai et al. [32], thus confirming that the cranial base length contributes majorly to the facial height in different skeletal patterns.

CONCLUSION

The cranial base lays the foundation stone for the development of other structures of the craniofacial complex. It guides and gives direction to the maxilla, mandible and other structures of the face. The length, slope, and angle of the cranial base has a huge impact on the growth of both the jaws. Any changes from the average values can lead to malocclusions ranging from mild to severe which may require interceptive, corrective or invasive treatment. Any genetic malformations or any severe systemic disease (during the growing stage) can also cause severe craniofacial deformations.

Therefore, it is very necessary for an orthodontist to understand and know the cranial base and the related malocclusions that it may cause due to any alterations.

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