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Review

Assessment of Anteroposterior Skeletal Relationship Using Different Cephalometric Analysis

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Abstract

In orthodontic diagnosis and treatment planning, precise anteroposterior measurements of jaw relationships are essential. For efficient diagnosis and treatment planning, the sagittal mismatch between the maxilla and mandible is assessed using a variety of angular and linear measurements, especially in orthognathic surgical cases. Cephalometric diagnosis is a crucial part of orthodontic care. This review aimed to identify and summarize the different methods of cephalometric analysis to evaluate anteroposterior skeletal relation.
Keywords: cephalometric analysis, anteroposterior, skeletal relation

Introduction

Modern orthodontics increasingly incorporates cone beam computed tomography (CBCT) imaging in the diagnosis of dental problems. However, due to the substantial body of scientific literature supporting 2D cephalometric analyses and the critical importance of radiological protection for patients, 2D lateral cephalograms remain the primary diagnostic modality for orthodontic assessment and treatment plans [1]. Cephalometric analysis investigates the origin of differences in the sagittal and horizontal planes regarding the relationship of both jaws to identify anterior-posterior and vertical malocclusions [1].

After age seven, the anterior cranial base usually stays consistent, making it a trustworthy benchmark for comparing facial features [2]. The anteroposterior plane, which is a plane that runs parallel to the sagittal suture, separates into the left and right halves of the head and neck. The maxilla and mandible expand forward in what is known as the anteroposterior (AP) or saggital dimensions. This plane allows us to evaluate the relationship between the mandible and maxilla and their general alignment concerning the face structure. This evaluation is crucial to classify a patient as skeletal class I, II, or III [3].

Classification of anteroposterior skeletal relationship

1. Skeletal class I (Straight): In this classification, the mandible is positioned 2 to 3 millimeters posterior to the maxilla. A harmonious anteroposterior relationship exists between the maxilla and mandible [3]. The Skeletal class I relationship is assessed clinically using the two-finger method and radiographically by measuring the ANB angle [4].

2. Skeletal class III (Concave): In this scenario, the mandible protrudes to the maxilla. This condition may result from maxillary retrusion, mandibular protrusion, or a combination of both factors. Research conducted by Ellis and McNamara indicates that the combination of maxillary retrusion and mandibular protrusion is the most prevalent skeletal relationship, observed in 30% of class III patients. Isolated occurrences of maxillary retrusion (follow this 19.5%) and mandibular protrusion (19.1%) [3].

3. Skeletal class II (Convex): In this classification, the mandible is retruded relative to the maxilla. This phenomenon may arise from either underdevelopment of the mandible or excessive growth of the maxilla, contributing to a convex facial profile [3].

Lateral Cephalometric radiograph

This method plays a pivotal role in orthodontic treatment planning by providing a two-dimensional image. The sagittal relationship is particularly significant to patients and necessitates thorough examination. To determine whether the underlying skeletal components are harmonious or if there are significant deviations that need more attention, lateral cephalometric radiographs are used [5]. In cephalometrics, sagittal jaw relationships and positions are analyzed using linear and angular variables. The left side of the patient is usually oriented toward the film, and the midsagittal plane of the subject's head is often placed 60 inches (152.4 cm) from the X-ray tube target [5]. The ear rods of the cephalostat line up with the X-ray's central beam. The midsagittal plane and the film are typically kept at a distance of 7 inches (18 cm) [5]. The patient's head is held such that their lips are relaxed, their teeth are in the typical occlusal position, and the Frankfort plane is parallel to the floor [2].

Cephalometric tracing process

A cephalometric tracing is an overlay drawing derived from a cephalometric radiograph, which may be produced either manually by transferring specific outlines onto acetate paper with a lead pencil or by digital methods utilizing a computer program [6]. These tracings are essential tools for facilitating cephalometric analysis, enabling precise measurements via digital tracing techniques and traditional manual methods [6-7].

1) Manual Tracing

In manual tracing, digital images are initially printed on radiographic films [6]. Subsequently, acetate cellulose paper is applied atop each radiograph, and the tracing is executed with an HB pencil. At the same time, the images are viewed on a tracing megascope within a darkened environment [6]. Although this method is widely used in orthodontics and research, it is quite time-consuming. It has several drawbacks, such as a significant chance of error when tracing landmarks and when identifying and measuring them [7].

2) Digital Tracing

The implementation of digital methods is anticipated to diminish the occurrence of personal errors resulting from operator fatigue while facilitating standardized, rapid, and effective evaluations characterized by a high degree of reproducibility [7]. Digital approaches offer significant advantages over traditional methods, as they are user-friendly and time-efficient, thereby rendering them the preferred choice [7]. While software programs are available for cephalometric tracing of digital radiographs, it remains essential for clinicians to possess the requisite knowledge to accurately identify anatomical structures and the cephalometric points within digital images [6].

Cephalometric analysis

The cephalometric study is an essential tool for assessing the axial inclination of the incisors, the development of the facial skeleton, the relationship between the jaw bases, soft tissue morphology, growth patterns, the location of malocclusion, and the limitations of available treatment choices [2].

1. Down's Analysis

By 1948, Down had created one of the first and most popular analyses. Down's analysis, which uses the "Nasion" as a reference point, primarily sheds light on a subject's skeletal profile [8].

Down categorized facial structures into four primary types [5]**:**

1. Retrognathic: Characterized by a regressive or retruded lower jaw.
2. Mesognathic: Representing an "ideal" or average position of the lower jaw.
3. Prognathic: Defined by a protrusive lower jaw.
4. True Prognathism: Noted for a pronounced protrusion of the lower face.

Down's skeletal parameters:

1. Facial angle: The facial angle is formed by the intersection of the Nasion-Pogonion plane and the Frankfort horizontal plane (Figure 1). It shows how much the jaw is set back or sticks out compared to the upper face. The angle typically measures 87.8°, ranging from 82° to 95° according to Phulari (2011) [9]. A heightened facial angle typically accompanies class III malocclusion of the structure. Class II malocclusion of the skeletal type is defined by the mandible being positioned further back, typically resulting in lower facial angle measurements [5].

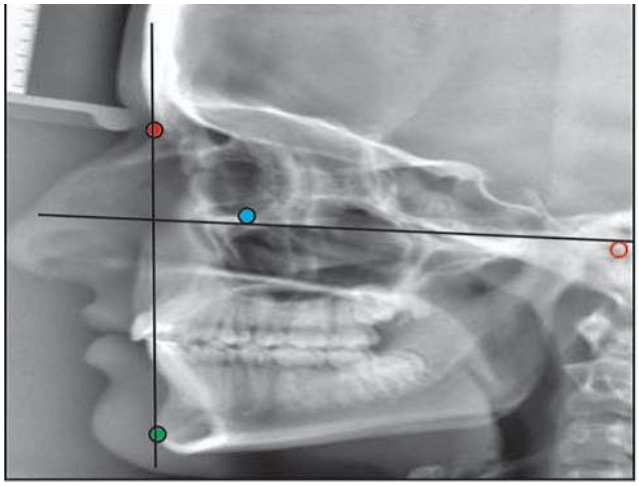

Figure 1: Facial angle [5]

2. Angle of Convexity: The A point-Pogonion line and the angle of convexity are defined by the intersection of the Nasion-A point line (Figure 2). This measurement assesses the degree of maxillary protrusion with the overall facial profile. Specifically, the angle is determined between the maxillary base at its most anterior point (designated as A point) and the total facial profile, represented by the N-Pog [10]. The measurement is recorded in degrees, commencing from zero. If the Pogonion-A point line extends anteriorly beyond the Nasion, the angle is classified as positive [9]. A positive angle indicates a greater prominence of the maxillary denture base in comparison to the mandible [9]. Conversely, when the Pogonion-A point line extends posteriorly behind the Nasion, the angle is categorized as negative [10]. A negative angle implies that the mandibular dental base exhibits greater prominence relative to the maxilla [10]. The established range for this angle is from -8.5° to +10°, with a mean value of 0° [5].

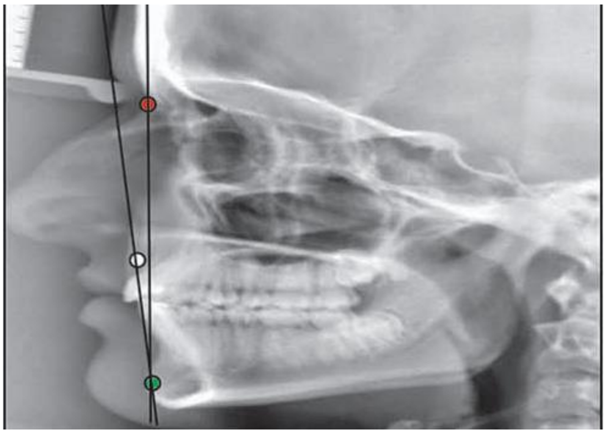

Figure 2: Angle of convexity [5]

3-A-B Angle: The facial line, also known as the Nasion-Pogonion line, is a line that, when stretched, forms an angle with the line connecting points A and B (Figure 3). A-B plane angle is the name given to this angle [6]. The A-B plane serves as an indication of the maxillomandibular relationship in relation to the facial line [9]. Generally, point B is situated posterior to point A, resulting in the A-B angle typically being negative, except for class III malocclusions [11]. A substantial negative value often indicates a class II facial pattern, which may arise from a retropositioned chin or mandible, an underdeveloped chin point, or a prominent maxilla (with point B located posterior to point A). The angle measurement ranges from a maximum of 0° to a minimum of -9°, with an average measurement of -4.6° [11].

4) The Y-(Growth) axis: It constitutes an essential element in the assessment of skeletal patterns within Down's analysis. A line that runs from Sella turcica to Gnathion intersects the Frankfort horizontal plane (porion-orbitale) to make an acute angle, which is how this axis is represented (Figure 4). This angle has an average value of 59.4°.

It indicates whether the chin is positioned forward, backward, or downward about the upper facial anatomy in both anteroposterior and vertical dimensions [12]. This angle is typically greater in class II face patterns than in individuals with class III characteristics [12].

2. Steiner Analysis

The Steiner analysis, a cephalometric technique developed by Cecil C. Steiner in 1953, offers substantial clinical insights while requiring a limited number of measurements [12].

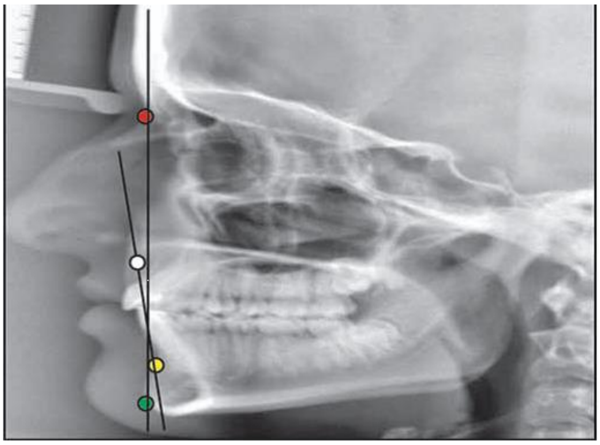

Figure 3: A-B angle [5]

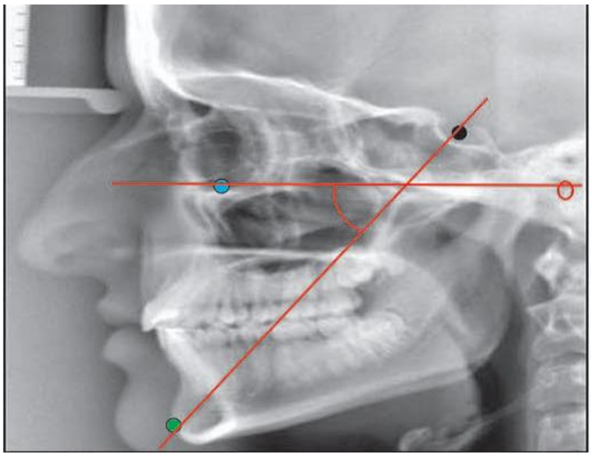

Figure 4: The Y- axis [5]

Skeletal Parameters:

1. SNA Angle: The SNA angle reflects the anterior cranial base placement of the maxilla. It is established at the point where the Sella-Nasion line intersects the line that connects the Nasion and A-point (Figure 5). At 82°, the SNA angle's mean value is determined. A reading exceeding 82° indicates a relative protrusion of the maxilla. If the measurement is below 82°, it suggests a relative retrusion or recessive positioning of the maxilla [12].

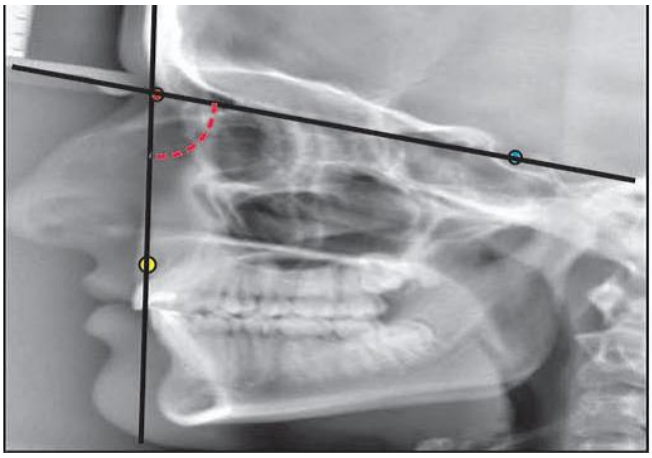

Figure 5: SNA Angle [5]

2. The SNB angle: One important metric that shows the connection between the mandible and the anterior cranial base is the SNB angle. The Sella-Nasion line and a line that connects the Nasion to the B-point intersect to form this angle (Figure 6). The mean value for the SNB angle is 80 degrees. An SNB angle measuring less than 80 degrees suggests a retruded position of the mandible, while an angle exceeding 80 degrees indicates a prognathic or forwardly positioned mandible [12].

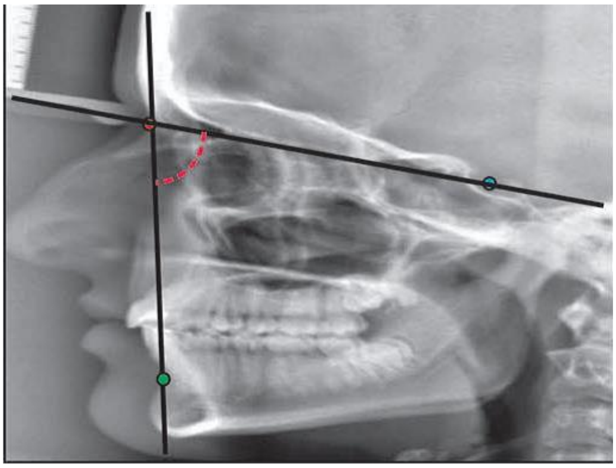

Figure 6: SNB angle [5]

3. ANB angle: The lines joining the Nasion to the A-point and the Nasion to the B-point establish the ANB angle (Figure 7). An essential determinant of the relative locations of the mandibular and maxillary jaws is this angle [12]. The average reading for the ANB angle ranges from 2° to 4°, giving a broad measurement of the anteroposterior disparity between the maxillary and mandibular apical bases [12].

Interpretation for the readings:

A reading exceeding 4° suggests a class II skeletal tendency, conversely a reading below 2° or any negative reading indicates that the mandible is positioned anterior to the maxilla, signifying a class III skeletal relationship [6].

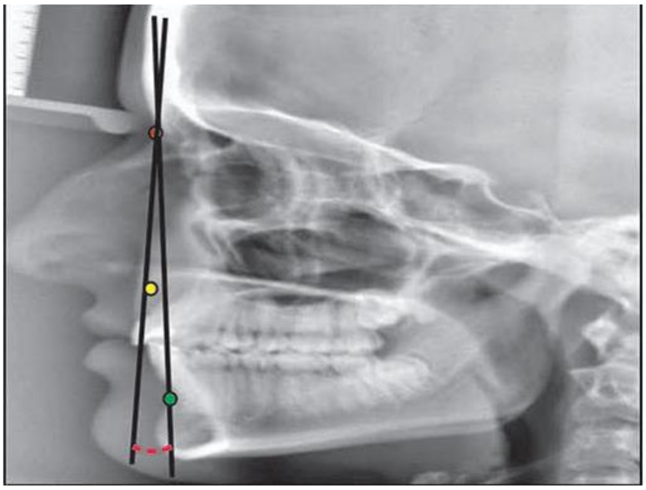

Figure 7: The ANB angle [5]

Although the ANB angle remains a widely utilized metric, existing literature highlights the potential discrepancies between angular measurements and actual discrepancies between the apical bases [13]. Notably, various studies have indicated that the position of the Nasion is dynamic and may change by approximately 1 mm per year. Any displacement of the Nasion will have a direct impact on the ANB angle [13]. Moreover, rotational changes in the jaws induced by growth or orthodontic intervention may also affect ANB readings [13]. Additional factors influencing the ANB angle include the length of the cranial base, its inclination, and the height of the anterior face. As individuals age, the ANB angle generally experiences a decline due to the counterclockwise rotational growth of the jaws [14].

The drawbacks of Steiner Analysis:

The ANB angle is subject to variation based on both jaw rotation and the length of the cranial base. Specifically, clockwise rotation of the jaw base can lead to an increase in the ANB angulation, while counterclockwise rotation tends to decrease it. Furthermore, a short cranial base may result in a posterior positioning of the Nasion relative to the jaws, thereby increasing the ANB angulation. In contrast, a longer cranial base is associated with a reduction in the ANB angulation [12].

3. Wits Appraisal/Analysis

The anteroposterior relationship between the jaws is determined by using the occlusal plane [11] (Figures 8 and 9). This method is not an independent analysis; rather, it is a linear measurement [15]. It is used in conjunction with other analyses, mostly to confirm their conclusions. Wits evaluation involves tracing a lateral cephalometric head film from points A and B to the occlusal plane, which is determined by the area of greatest cuspal interdigitation. By using perpendicular lines, AO and BO, respectively are the locations where these perpendiculars cross the occlusal plane. Point BO is usually placed posterior to point AO in cases with skeletal class II jaw malocclusion, producing a positive signal. On the other hand, when skeletal class III jaw malocclusion occurs, point BO is situated much anterior to point AO, and the Wits reading is negative [6]. For male participants, the space between BO and AO is usually measured to be 1 mm, while for female patients, BO is exactly in line with AO [12].

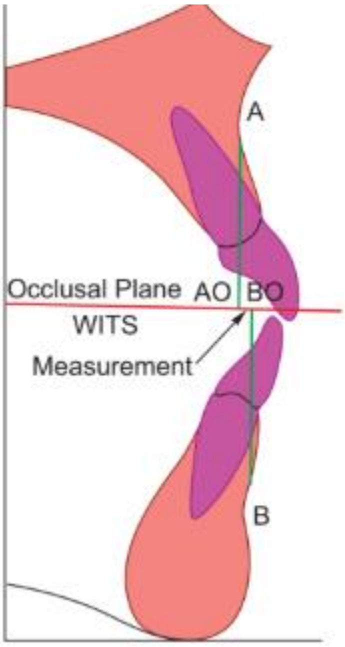

Figure 8: Wits Appraisal [12]

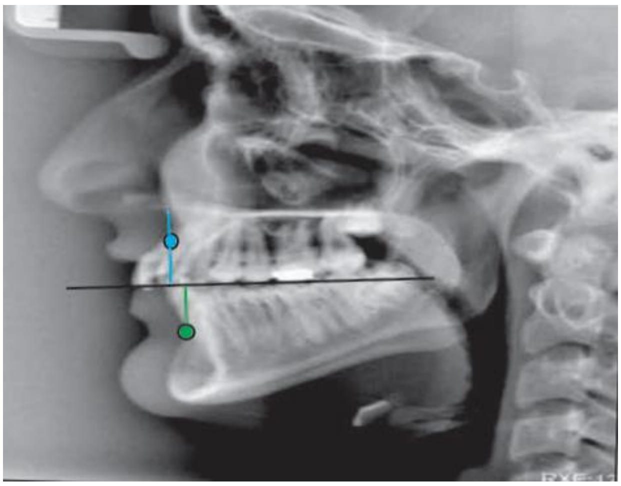

Figure 9: Skeletal class II malocclusion [5]

4. AXD Angle and A-D Distance

The internal angle at point X is the AXD angle, which was initially proposed by Edward Beatty in 1975. The point D is located at the bone symphysis, and this point is determined by projecting. A point A onto a line that is perpendicular to the Sella-Nasion (SN) line (Figure 10). The 9.3° is the average value of the AXD angle. The linear distance between points A and D' is known as the A distance. Here, D' stands for the foot of the line drawn perpendicularly from point D to the Sella-Nasion plane. It has been shown that the average A-D distance is 15.5 mm [12].

Advantages: With this method, point D is used, which is not impacted by modifications to incisor location or chin prominence. Additionally, it eliminates the necessity of utilizing the Nasion point [16].

Disadvantages: However, point A remains part of the framework, which is susceptible to displacement due to orthodontic tooth movement [16].

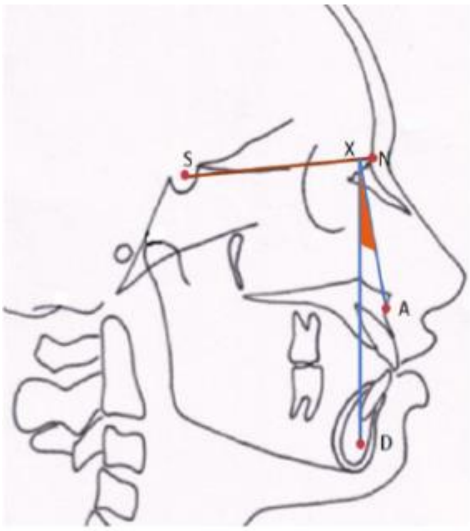

Figure 10: The AXD angle [16]

5. Taylor's AB' linear distance

This concept was first introduced by Taylor in 1969. Here, point B' is the point at which a line drawn perpendicularly from point B intersects the Sella-Nasion plane, and the measurement between point A and point B' is the linear distance in issue (Figure 11). This linear distance has an average value of 13.2 mm. For every degree of shift in the ANB angle, the distance from point B' to point A changes by 1 mm, according to research by Daokar and Rajput (2018)[16].

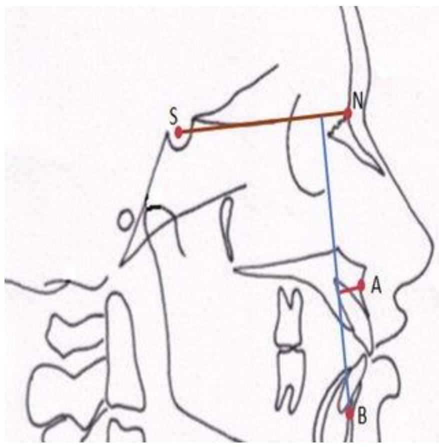

Figure 11: Taylor's AB' linear distance [16]

6. McNamara's Analysis

The analysis formulated by James McNamara at the University of Michigan in 1984 serves as a significant tool for diagnosis, evaluation, and treatment planning [16]

Skeletal Parameters of McNamara's analysis:

1. Point A to Nasion perpendicular: This parameter connects the maxilla to the cranial base by measuring the linear distance between the Nasion and Point A [12].

A positive measurement suggests a prognathic maxilla, indicating that point A is located anterior to the Nasion perpendicular. On the other hand, a negative measurement indicates a retrognathic maxilla, where point A is positioned posterior to the Nasion perpendicular. In adults, the value is typically 1 mm, while the normative value in mixed dentition is 0 mm [12].

2. Pogonion to Nasion perpendicular: This measurement pertains to the linear distance between the Pogonion and the Nasion perpendicular, linking the mandible to the cranial base. A positive value indicates that the Pogonion is situated anterior to the Nasion perpendicular, which is indicative of a prognathic mandible. Conversely, a negative value indicates a posterior positioning, signifying a retrognathic mandible. The normal range during mixed dentition is from -8 mm to -6 mm, whereas in adult individuals, it extends from -4 mm to 0 mm, with a maximum of +2 mm observed in males. Values falling below this normative range suggest a retrognathic mandible, whereas those exceeding the norm suggest a prognathic mandible [12].

3. Maxillo-mandibular differential method: In 1984, McNamara outlined a method informed by the works of Ricketts and Harvold to assess maxillo-mandibular differentials. By using this procedure, the effective mandibular length is subtracted from the effective midfacial length (effective maxillary length) [14]. The distance between the Condylion and point A is used to calculate the effective midfacial length, while the distance between the Condylion and Gnathion is used to calculate the effective mandibular length (Figure 12). The ideal maxillo-mandibular differentials are categorized as follows [14]:

- Small-sized individuals: 20 mm
- Medium-sized individuals: 25-27 mm
- Large-sized individuals: 30-33 mm

This analytical framework offers vital insights into the dimensional variations of both the midface and mandible [14].

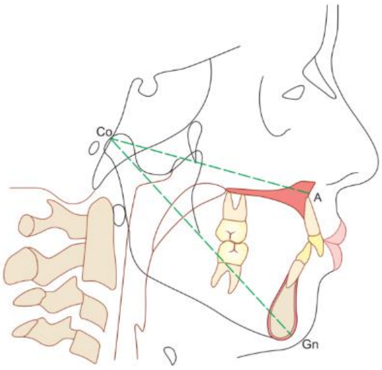

Figure 12: Measurements of maxillary and mandibular length [12]

7. The AXB Angle

In 1981, Freeman characterized the AXB angle by omitting point N, thereby ensuring that variations in the degree of facial divergence do not impact the readings [7]. Instead of utilizing point N, a perpendicular line is established from point A to the Frankfurt Horizontal plane, resulting in the designation of a new point, X. The line that extends from point X to point B delineates the AXB angle (Figure 13), the average measurement of the AXB angle is 4 degrees [7].

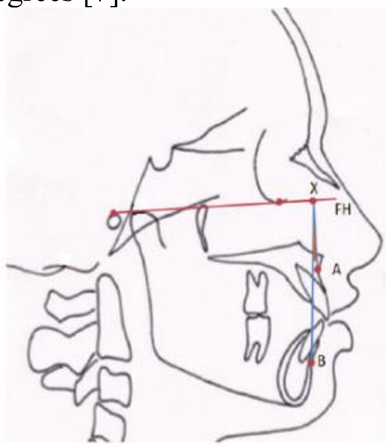

Figure 13: The AXB Angle [16]

8. The JYD Angle

Järvinen presented the JYD angle in 1982 as a way to assess the sagittal apical base connection. Lines that extend from points J and D to point Y connect to form this angle. In particular, the Sella-Nasion (SN) plane and a line drawn perpendicularly from point J to the SN plane intersect at point Y, whereas point J is the center of the cross-section of the maxilla's anterior body, Point D is situated inside the symphysis of the bones (Figure 14). The average value of the JYD angle is reported to be 5.25 ± 1.97° [11].

Advantages: The JYD angle eliminates the necessity of identifying point A.

Disadvantages: It is important to note that the JYD angle can be influenced by factors such as jaw rotation and vertical facial growth [16].

9. AF-BF distance

This distance was introduced in 1987 by Hong Pu Chang. When perpendicular lines are projected from points A and B onto the Frankfort Horizontal (FH) plane, the result is known as the AF-BF distance (Figure 15) [7]. The AF and BF are the designations for the sites on the FH plane where these perpendicular lines connect, respectively. The typical AF-BF distance for males is 3.43 ± 2.93 mm, and for females, it is 3.87 ± 2.63 mm, according to Darkwah *et al.* (2018)[7]. Point AF is considered to be in front of point BF when this distance is positive. The measurement, on the other hand, is categorized as negative if point AF is situated after point BF [16].

10. The APP-BPP distance

Based on the palatal plane, Nanda and Merrill (1994) developed a linear distance measurement method. Building perpendicular lines from points A and B to the palatal plane is the method used in this method (Figure 16). The mean measurement for white women was recorded at 5.2 ± 2.9 mm, while for white men it was noted at 4.8 ± 3.6 mm. Elevations in these values are indicative of class II skeletal patterns, whereas reductions correspond to class III skeletal patterns [11].

Advantage: This analytical method is not influenced by variations in the Nasion point, thereby rendering the palatal plane more stable [16].

11. The FH to AB Plane Angle (FABA)

In 1995, Sang D. Yang and Cheong H. Suhr introduced the FH to AB Plane Angle (FABA). By drawing lines from points A and B to the FH plane, this angle is determined, creating the inner angle known as FABA (Figure 17). The mean value of this angle has been reported to be 80.91 ± 2.53° [11]. Angles that exceed the normal range suggest a tendency toward Class III malocclusion, whereas angles below 81° indicate a propensity toward class II malocclusion. One significant benefit of the FABA is that, in comparison to the AF-BF or AFB angles, it is more accurate at predicting anteroposterior (AP) skeletal dysplasia and/or facial profiles [16].

12. Beta Angle

Baik and Maria Ververidou developed the Beta Angle in 2004 as a method for assessing sagittal jaw connections. Points A, B, and C, the apparent axis of the condyle are the three skeletal landmarks used in this angle (Figure 18). The sagittal dimension measures an angle that corresponds to the degree and category of skeletal dysplasia [7]. A patient is considered to have a class I skeletal pattern if their β angle falls between 27° and 35°. When the Beta angle is measured to be less than 27°, the case is classified as class II. Conversely, a Beta angle measurement exceeding 38° indicates a class III classification. It is important to note that there are no gender-related differences concerning the Beta angle [7, 18].

13. U angle

A cephalometric measurement called the μ angle was introduced by Fattahi *et al.* in 2006. Points A, and B, and a line drawn perpendicularly from point A to the mandibular plane are the three skeletal landmarks used to determine this measurement (Figure 19). Class I skeletal patterns are identified in patients with a μ angle between 16.1° and 23.9°. When the μ angle is more acute, it indicates a class II skeletal pattern. When it is more obtuse, it indicates a class III pattern [9]. The authors concluded that the μ angle demonstrates acceptable specificity and sensitivity in evaluating the anteroposterior relationship of the jaws. Consequently, it can be employed to assess the severity of jaw discrepancies in conjunction with other diagnostic parameters [9].

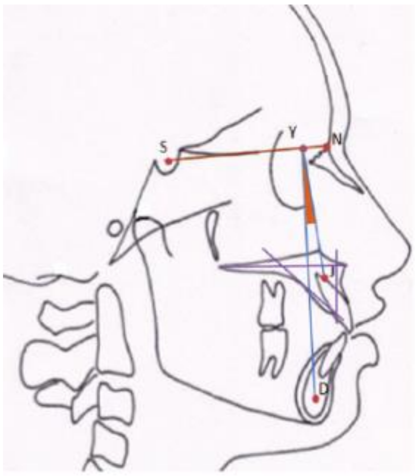

Figure 14: The JYD angle [16]

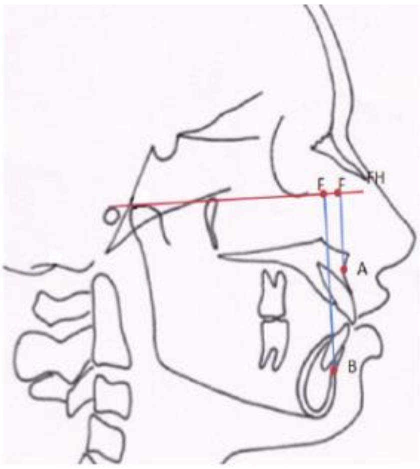

Figure 15: The AF – BF distance [16]

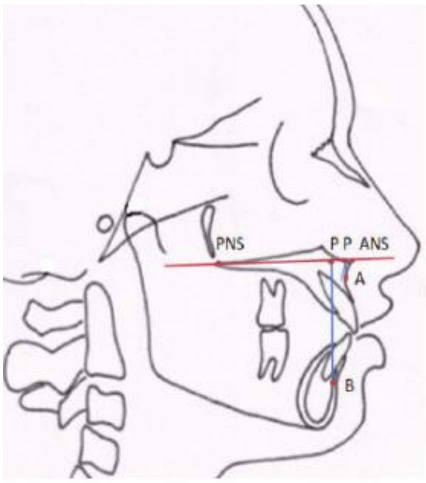

Figure 16: APP-BPP distance [16]

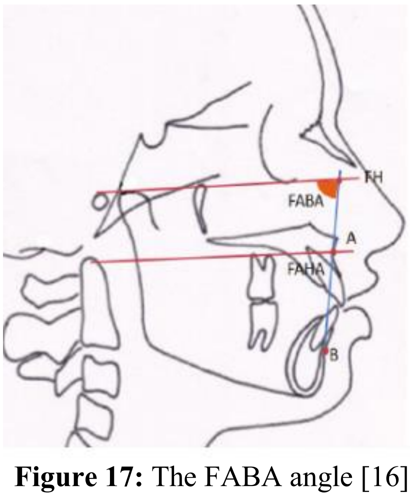

Figure 17: The FABA angle [16]

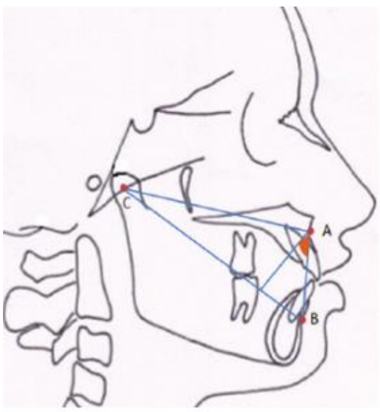

Figure 18: Beta angle [16]

14. The Yen Angle

Three precise anatomical landmarks, point S, the midpoint of the sella turcica; point M, the midpoint of the anterior maxilla; and point G, the center of the bottom of the mandibular symphysis are used to define the YEN angle (Figure 20), which was first proposed by Premkumar (2020) [12]. Skeletal class I patterns are indicated by a YEN angle measurement between 117° and 123°. Skeletal class II pattern is suggested by more acute measures, while class III is indicated by more obtuse data [17].

Advantages: By using reliable landmarks, the YEN angle reduces difficulties in locating points A and B, the condylar axis in beta angle analysis, and the functional occlusal plane as utilized in Wits evaluation. Moreover, it is not impacted by variations in growth [16].

Disadvantages: The rotation of the jaws may obscure the accurate assessment of sagittal dysplasia [16].

15. The W angle

The angle created between the M-G line and the perpendicular line that extends from point M to the S-G line is known as the W angle (Figure 21). This angle was first established by Bhad *et al.* in 2011 [16].

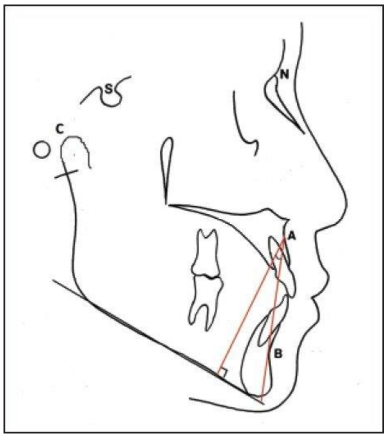

Figure 19: The U angle [11]

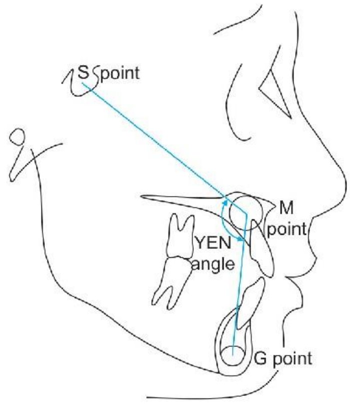

Figure 20: Yen angle [17]

The patient with a W angle between 51 and 56 degrees can be considered to have a class I skeletal pattern. With an angle less than 51 degrees, patients are considered to have a skeletal class II relationship and with an angle greater than 56 degrees, patients have a skeletal class III and there is significant difference in the mean value of W angle among the three skeletal patterns with a no gender difference [19]. One of the main advantages of the W angle, according to, is that it can faithfully represent actual sagittal dysplasia without being influenced by growing rotations [16].

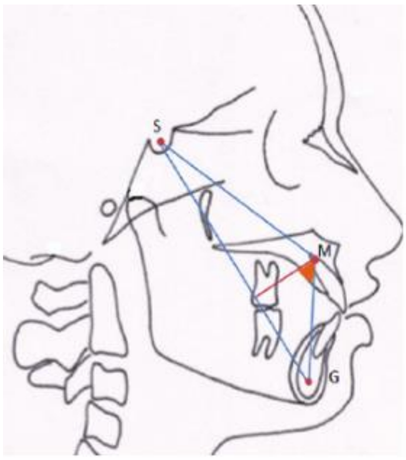

Figure 21: The W angle [16]

16. Ballard Conversion

This analysis utilizes the incisors as indicators of the relative positioning between the maxilla and mandible. The objective is to adjust the teeth to their normative angulation, thereby removing any dento-alveolar compensation. As a result, the residual overjet will provide insights into the relationship between the maxilla and mandible [3].

Conclusions

In cephalometric analysis, it is essential not to rely exclusively on any single parameter or interpret it as an absolute value. Numerous measurements can serve as adjuncts to the ANB angle and Wits appraisal, which are widely recognized as the most effective and useful assessments in this field. To get accurate anteroposterior measures for orthodontic diagnosis and treatment planning, clinicians may use two or more approaches. The ANB angle is still thought to be the most common and extensively applied technique in use today.

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Conceptualization: M.A.J. and S.M.A., Methodology: M.A.J. and S.M.A., Design and data collection: M.A.J. and S.M.A., Formal analysis and investigation: S.M.A. and M.A.J., Writing: S.M.A. and M.A.J., Resource: S.M.A. and M.A.J., Supervision: S.M.A.

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