ABSTRACT

The anteroposterior discrepancy is usually of utmost concern to patients and parents and hence has received maximum attention in orthodontics. A number of analyses have been proposed over the years with varying degrees of reliability and success in assessing sagittal jaw relationships. It is absolutely essential that a clinician be aware of a range of analyses to be used in different situations. This review provides an insight into the various cephalometric methods used for evaluation of the anteroposterior jaw relationship in chronologic order and their clinical implications in contemporary orthodontics.

Keywords: Sagittal dysplasia, Anteroposterior discrepancy, Cephalometric analysis.


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INTRODUCTION

After the discovery of cephalometrics in 1931, it has been adapted as an important clinical tool for assessment of jaw relationship in all three planes–anteroposterior, transverse and vertical being an integral part of orthodontic treatment planning. The sagittal relationship is usually of utmost concern to the patient and needs a critical evaluation. Previously established parameters such as the ANB angle,1 Wits analysis,2 AF-BF,3 APDI,4 Beta angle,5 Yen angle,6 W angle,7 and the recently introduced Pi analysis8 have been defined and used effectively for the evaluation of anteroposterior (AP) discrepancies affecting the apical bases of the jaws. These analyses have both advantages and inaccuracies associated with their use which needs to be understood.

There are obvious shortcomings for both angular and linear measurements, which have been comprehensively discussed in the literature.9,10 Cranial reference planes such as the Frankfort horizontal and Sella-Nasion line have been used in the determination of jaw dysplasia. Extracranial measurements, independent of cranial reference planes or dental occlusion reflecting true sagittal relationship have also been used. The purpose of this review is to discuss various angular and linear geometric parameters for assessment of sagittal jaw relationship in chronologic order and their clinical implications in contemporary orthodontics.

The Assessment of Anteroposterior Dysplasia by Wendell L Wylie

Wylie11 (1947) was the first to evaluate anteroposterior apical base relationship cephalometrically. He proposed an analysis where perpendiculars from glenoid fossa, sella turcica, pterygomaxillary fissure, buccal groove of maxillary first molar and anterior nasal spine are projected to the FH plane and horizontal distances measured and entered on a form where the standard values are printed. Any increase or decrease in patient values are designated as orthognathic and prognathic respectively. Mandibular length is assessed by projecting perpendiculars from pogonion and posterior surface of condyle to a tangent drawn to lower border of mandible. Maxillary values below the norm and mandibular values above the norm are considered Class III, prognathic (positive sign). Vice versa to this situation are considered Class II, orthognathic (negative sign) (Table 1).

A disadvantage here is that linear measurements are more prone to errors than angular.

Down’s AB Plane Angle and Angle of Convexity

The very next year in 1948, WB Downs12 in his cephalometric analysis described the A-B plane angle, as a means to assess anteroposterior apical dysplasia. Location of this plane in relation to facial plane is the measure of the anterior limit of the denture bases to each other and to the profile. It permits estimation of the difficulty the operator will meet in gaining correct incisal relationships and satisfactory axial inclinations of these teeth. In the control group the relation of this plane to the facial plane was found to range from 0° to a posterior position of B which could be read as −9°. The mean was −4.8° (Fig. 1A).
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Table 1: Wylies method to assess AP dysplasia

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Standard</th>
<th>Patients value</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Orthognathic</td>
</tr>
<tr>
<td>Glenoid fossa to sella</td>
<td>18</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Sella to Ptm</td>
<td>18</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Maxillary length</td>
<td>52</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Ptm to upper 6</td>
<td>15</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Mandibular length</td>
<td>103</td>
<td>101</td>
<td></td>
</tr>
</tbody>
</table>

The angle of convexity\(^1\) also proposed by Downs (Nasion-Point A-Pogonion) is yet another measure of the protrusion of the face in profile. If Point A fell posterior to the facial plane, the angle formed is read in minus degrees, and if anterior, in plus degrees. The normal range is +10° to –8.5° (Fig. 1B).

Being angular measurements, these were more advantageous as it eliminated differences due to absolute size.

**Angle ANB**

Riedel\(^1\) (1952) introduced the ANB angle for evaluating the anteroposterior relationship of the maxilla to the mandible. However, it was Cecil C Steiner\(^1\) who popularized this angle (mean value of 2° in adults and 2.8° in children, range 2-4°) in 1953 in his classic article, ‘Cephalometrics for you and me’ (Fig. 2A). This has been widely accepted as the principal method of evaluating anteroposterior jaw relationship. Although the ANB angle is still very popular and useful, it has been demonstrated in the literature\(^1\) that there is often a difference between the interpretation of this angle and the actual discrepancy between the apical bases. Several authors\(^1,14,17,18\) have shown that the position of nasion is not fixed during growth (nasion grows 1 mm per year), and any displacement of nasion will directly affect the ANB angle.\(^1\) Furthermore, rotation of the jaws by either growth or orthodontic treatment can also change the ANB reading.\(^2\) The length of the cranial base, its inclination and anterior face height are the other factors affecting ANB. With advancing age, ANB decreases due to counterclockwise growth rotation of jaws.

Binder\(^1\) recognized the geometric effects at work in the ANB angle. He showed that for every 5 mm of anterior displacement of Nasion horizontally, the ANB angle reduces by 2.5°. A 5 mm upward displacement of Nasion decreases the ANB angle by 0.5° and 5 mm downward displacement increases ANB angle by 1°.

**Jenkin’s ‘a’ Plane**

Jenkins\(^2\) in 1955 established the ‘a’ plane, a perpendicular dropped from point A to occlusal plane. Linear distances from ‘a’ plane to point B [+3 mm], Gnathion [+5 mm], and mandibular incisors [+2 mm] are computed for dysplasia identification.

**Taylor’s AB’ Linear Distance**

Taylor\(^1\) (1969) introduced new parameter, the linear distance between Point A and B’. B’ is the perpendicular from point B to the sella-nasion plane (Fig. 2B). Its mean value was 13.2 mm. This study concluded that there was 1 mm of change from point A to the perpendicular B’ for each degree of change in ANB.
AXD Angle and A-D’ Distance

To counter the disadvantages of angle ANB, Beatty\textsuperscript{21} (1975) introduced the AXD angle—the interior angle formed by the intersection of the lines extending from points A and D at point X (X is point of intersection of perpendicular from point A to SN plane). Instead of point B, point D is taken as it is center of bony symphysis and not affected by changes in incisor position or chin prominence. Beatty\textsuperscript{21} also introduced the linear measurement A-D’, the distance from point A to line DD’ (Perpendicular from D to sella-nasion plane) (Fig. 2C). Mean value for AXD angle and A-D’ distance was 9.3º and 15.5 mm respectively. Advantage here is that two variables, N and point B are eliminated.

Wits Appraisal of Jaw Disharmony

Jacobson\textsuperscript{2} (1975) in order to overcome the inaccuracies of ANB angle devised ‘Wits’ Appraisal (Wits stands for University of the Witswatersrand, Johannesburg, South Africa) which was intended as a diagnostic aid whereby the severity or degree of anteroposterior jaw disharmony can be measured, independent of cranial landmarks, on a lateral cephalometric head film. The method of assessing the degree or extent of the jaw disharmony entails drawing perpendiculars on a lateral cephalometric head film tracing from points A and B on the maxilla and mandible, respectively, onto the functional occlusal plane denoted as AO and BO respectively and measuring the distance between them (Fig. 2D). According to Jacobson, in a skeletal Class I relationship, in females, AO and BO should coincide whereas in males, BO is ahead of AO by 1 mm. Study by Bishara\textsuperscript{22} et al showed that Wits appraisal does not change significantly with age.

Limitations of Wits Appraisal

The Wits appraisal avoids the use of nasion and reduces the rotational effects of jaw growth, but it uses the occlusal plane, which is a dental parameter,\textsuperscript{2} to describe the skeletal discrepancies. Occlusal plane can be easily affected by tooth eruption and dental development as well as by orthodontic treatment.\textsuperscript{23-25} This can profoundly influence the Wits appraisal. Furthermore, accurate identification of the occlusal plane is not always easy or accurately reproducible.\textsuperscript{26,27}
especially in mixed dentition patients or patients with open bite, canted occlusal plane, multiple impactions, missing teeth, skeletal asymmetries, or steep curve of Spee.

**Anteroposterior Dysplasia Indicator (APDI)**

Kim and Vieta⁴ (1978), proposed APDI to assess sagittal dysplasia. The APDI reading is obtained by tabulating the facial angle (FH to Npog) ± the A-B plane angle (AB to Npog) ± the palatal plane angle (ANS-PNS to FH plane) (Fig. 3A). The mean value of the anteroposterior dysplasia indicator (APDI) in the normal group was 81.4º, with a standard deviation of 3.79. Lesser values indicate disto-occlusion and greater indicates mesio-occlusion.

**Freeman’s AXB Angle (1981)**

In 1981, Freeman¹⁴ described a method eliminating point N, so that the degree of divergence of the face does not affect the readings. A perpendicular is constructed from point A to Frankfort Horizontal, establishing point X. A line from points X to B forms angle A-X-B (Fig. 3B). The mean for the A-X-B measurement in normal occlusion cases was approximately 4º. A variation of this is to draw perpendicular from point A to SN plane (X-point), giving an angle of 6.5º.

Freeman¹⁴ also proposed a simple method of correction of ANB angle by adjusting or modifying the measurements by merely subtracting 1º from the A-N-B measurement for every 2º that the S-N-A reading exceeds 81.5º. Conversely, add 1º to the A-N-B measurement for every 2º that the S-N-A reading is under 81.5º. This modification over-corrects slightly, so with cases that are more than 10º above or below, the total adjustment should be reduced by 1º; a 1/2º adjustment may be made for 5º difference if desired.

**JYD Angle (1982)**

Seppo Jarvinen²⁸ proposed JYD angle to measure sagittal apical base relationship, formed by the intersection of the lines extending from points J and D to point Y (Fig. 3C). Point J is the center of the cross-section of the anterior body of the maxilla, and point Y is the point of intersection of the SN plane and the perpendicular to the SN plane from point J. Mean value for this angle is 5.25 ± 1.97º. An advantage of this method is that it eliminates use of point A. But, disadvantage is that it is affected by jaw rotation and vertical facial growth.

Figs 3A to C: (A) APDI angle, (B) angle AXB and (C) JYD angle
Quadrilateral Analysis or Proportional Analysis

In 1983, Rocco di Paolo proposed quadrilateral analysis\textsuperscript{29} based on theorem in Euclidean geometry that determines the direction, extent and location of the skeletal dysplasia in millimeter measurement which is more understandable in surgical orthodontics than angular measurements. The analysis is based on the concept of lower facial proportionality which states that in a balanced facial pattern there is a 1:1 proportionality that exists between the maxillary base length and mandibular base length; also that the average of the anterior lower facial height (ALFH) and posterior lower facial height (PLFH) equals these denture base lengths (Fig. 4A).

Maxillary length = mandibular length = ALFH + PLFH/2

Clinically, the biggest advantage of quadrilateral analysis is that it offers an individualized cephalometric diagnosis (not dependent on established angular or linear norms) on patients with or without skeletal dysplasias. Author claims that it is a reliable and accurate method of assessing whether orthodontic treatment, surgical treatment, or a combination of both is required to achieve a satisfactory result.\textsuperscript{29}

McNamara’s Maxillomandibular Differential (1984)

McNamara\textsuperscript{30} derived a method for cephalometric evaluation from the analysis of Rickett’s and Harvold. This analysis is useful in the diagnosis and treatment planning of the individual patient when the values derived from the tracing of the patient’s initial head film are compared to established norms from Bolton, Burlington and Ann Arbor samples. Maxillomandibular differential was calculated by subtracting effective midfacial length from effective mandibular length. First the effective midfacial length, not the actual anatomic length of the maxilla, is determined by measuring a line from condyion (the most posterosuperior point on the outline of the mandibular condyle, to point A. Then, the effective mandibular length is derived by constructing a line from condyion to anatomic gnathion (Fig. 4B). A geometric relationship exists between the effective length of the midface and that of the mandible. Any given effective midfacial length corresponds to a given effective mandibular length.\textsuperscript{30} Ideal maxillomandibular differentials are: small, 20 mm; medium, 25 to 27 mm and large, 30 to 33 mm.

Figs 4A to D: (A) Maxillomandibular differential, (B) AF-BF distance, (C) quadrilateral analysis and (D) APP-BPP distance
From a clinical standpoint, this analysis is very useful in determining actual dimensional variations of midface/mandible, thus giving the orthodontist an idea as to whether a skeletal Class II or III problem is positional or dimensional.

**AF-BF Distance (1987)**

Chang\(^3\) reported a study conducted on 80 young Chinese and described the AF-BF distance obtained by projecting perpendiculars from points A and B to the FH plane. (Fig. 4C), giving us yet another assessment tool to measure sagittal jaw dysplasia. The mean value for male was 3.43 ± 2.93 mm, whereas for female, it was 3.87 ± 2.63 mm. The AF-BF distance would be positive when point AF was ahead of point BF; and negative if point AF was located behind point BF. An extension of this analysis is to draw perpendiculars from N to FH plane and measure distances from points A and B to N vertical. The difference between the two values should be equal to the AF-BF distance. One disadvantage of this method is that it can be affected by inclination of FH plane.

**APP-BPP Distance**

Nanda and Merrill\(^3^1\) in 1994, proposed APP-BPP linear distance measurement based on claimed advantages of palatal plane (Fig. 4D). This perpendicular projection of points A and B to palatal plane (APP-BPP) averaged 5.2 ± 2.9 mm in white women with normal occlusions compared with 4.8 ± 3.6 mm for white men. It increases in Class II and decreases in Class III.

The advantage of this analysis is that it is not dependent on variations of nasion point. The palatal plane is claimed to be more stable by the authors.

**FH to AB Plane Angle (FABA)**

Sang and Suhr\(^3^2\) (1995) proposed FH to AB angle (Fig. 5A) to measure sagittal dysplasia. This study was conducted on 110 Korean children with normal occlusion. Mean value for this was 80.91 ± 2.53° with range of 10.5°. There was no statistically significant difference between males and females. However, from a clinical standpoint, when FABA was compared with Freeman’s AXB angle\(^1^4\) and AF-BF, it shows more sensitivity to the vertical relationship between points A and B.\(^3^2\)
Beta Angle (2004)

Baik and Ververidou\(^5\) proposed the Beta angle as a new measurement for assessing the skeletal discrepancy between the maxilla and the mandible in the sagittal plane. It uses 3 skeletal landmarks—points A, B, and the apparent axis of the condyle C—to measure an angle that indicates the severity and the type of skeletal dysplasia in the sagittal dimension (Fig. 5B). Beta angle between 27° and 35° have a Class I skeletal pattern; a Beta angle less than 27° indicates a Class II skeletal pattern, and a Beta angle greater than 34° indicates a Class III skeletal pattern. Authors claim that the advantage of Beta angle over ANB and Wits appraisal is that (1) it remains relatively stable even if the jaws are rotated clockwise or counterclockwise and (2) it can be used in consecutive comparisons throughout orthodontic treatment because it reflects true changes of the sagittal relationship of the jaws, which might be due to growth or orthodontic/orthognathic intervention.

Overjet as Predictor of Sagittal Dysplasia (2008)

Zupancic et al\(^33\) reported a study to determine whether any correlation exists between overjet value, as measured on study casts, and cephalometric parameters, which evaluate the craniofacial complex in the sagittal plane. Authors concluded that for Class I and III malocclusion, overjet is not a good predictor of sagittal dysplasia; however, for Class II division 1 malocclusion, overjet is a statistically significant predictor.

Yen Angle (2009)

Neela et al\(^6\) reported the Yen angle which was developed in the Department of Orthodontics and Dentofacial Orthopaedics, Yenepoya Dental College, Mangalore, Karnataka, India, and hence its name. It uses the following three reference points: S, midpoint of the sella turcica; M, midpoint of the premaxilla; and G, center of the largest circle that is tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphysis (Fig. 5C). Mean value of 117 to 123º can be considered a skeletal Class I, less than 117º for skeletal Class II, and greater than 123º as a skeletal Class III. The advantage here is that it eliminates the difficulty in locating points A and B, or the functional occlusal plane used in Wits and condyle axis in Beta angle analyses. As it is not influenced by growth changes, it can be used in mixed dentition as well. But, rotation of jaws can mask true sagittal dysplasia here also.
Dentoskeletal Overjet (2011)

AL-Hammadi\textsuperscript{34} reported a study conducted on 250 Yemeni population, to develop a new linear measurement method and named it Dentoskeletal overjet (Fig. 6A). This depends on two basic principles; the first is the dentoalveolar compensation for underlying skeletal base relation; and the second is the overjet that remains due to incomplete dentoalveolar compensation as a result of large skeletal discrepancy. Mean value of –1 to +2.5 mm, classified as skeletal Class I, skeletal Class II when this measurement is more than 2.5 mm, and skeletal Class III when it is less than –1 mm.

W-Angle

The W angle was developed by Bhad et al.\textsuperscript{7} The points S, G and M used in Yen angle is utilised here also. Angle between a perpendicular line from point M to the S-G line and the M-G line is measured (Fig. 6B). Findings showed that a patient with a W angle between 51 and 56º has a Class I skeletal pattern. Patient with a W angle less than 51º has a skeletal Class II pattern and one with a W angle greater than 56º has a skeletal Class III pattern. In females with Class III skeletal pattern, W angle has a mean value of 57.4º, while in males, it is 60.4º and this difference was statistically significant. The authors claim that W angle reflects true sagittal dysplasia not affected by growth rotations.

Pi Analysis (2012)

Kumar S et al.\textsuperscript{8} have recently introduced the Pi analysis as a new method of assessing the AP jaw relationship. It consists of two variables, the Pi-angle and the Pi-linear and utilizes the skeletal landmarks G and M points to represent the mandible and maxilla, respectively. M point is the center of the largest circle placed at a tangent to the anterior, superior and palatal surfaces of the premaxilla. G point is the center of the largest circle placed at a tangent to internal anterior, inferior and posterior surfaces at the mandibular symphysis. A true horizontal line is drawn perpendicular to the true vertical, through nasion. Perpendiculars are projected from both points to the true horizontal giving the Pi-angle (GG’M) and Pi-linear (G’–M’) (Fig. 6C). The mean value for the Pi-angle in skeletal Class I, II and III are 3.40 (±2.04), 8.94 (±3.16) and 23.57 (±1.61) degrees respectively. Mean value for the Pi-linear (G’–M’) is 3.40 (±2.20), 8.90 (±3.56) and 23.30 (±2.30) mm, respectively for Class I, II and III groups. The highest level of correlation was obtained for Pi-angle and Pi-linear (0.96).

DISCUSSION

Inspite of so many cephalometric sagittal dysplasia indicators, angle ANB remains the most widely used one due to its simplicity and global acceptability. However, total reliability on angle ANB cannot be recommended for reasons stated above, and corrections need to be applied in specific cases. The Wits appraisal of jaw disharmony is also popular. Being a linear parameter dependent on the occlusal plane, again has obvious limitations. The maxillomandibular differential finds a definite place in cases where myofunctional therapy is contemplated as it helps us to understand whether a skeletal problem is dimensional. The quadrilateral analysis being individualized, and not dependent on established norms, would be an excellent tool in cases with underlying skeletal discrepancies. The Beta angle is claimed to reflect true changes in anteroposterior relationship of the jaws. But it can be affected by errors in locating points A and B, and clockwise rotation of the jaws. Both Yen angle and W angle have eliminated the difficulties in locating points A and B, functional occlusal plane of Wits and condyle axis of Beta angle, thus making it a useful tool in mixed dentition cases also. The most recent Pi analysis defies ease of application and does not seem to offer significant advantages.

The best solution would be to apply at least three analyses in each individual case. A thorough knowledge of the various analyses at hand will help the astute clinician in choosing the most appropriate ones for each case.

CONCLUSION

Literature is replete with attempts to accurately assess anteroposterior discrepancy using different cephalometric analyses with varying degrees of success. Rotational effects of jaws, varying positions of points A and B, nasion, variations in cranial base length, tooth eruption, curve of Spee, etc. seem to have influenced sagittal assessment leading to the use of extracranial reference planes as well. Due to the large variability in human population, a single cephalometric analysis may not provide an accurate diagnosis. Moreover, cephalometrics is not an exact science and the various analyses based on angular and linear parameters have obvious limitations. Hence, it is imperative that a clinician be aware of a range of cephalometric analyses to be used appropriately as the need arises.

REFERENCES