European Journal of Orthodontics 35 (2013) 66–70
doi:10.1093/ejo/cjr001
Advance Access publication 8 February 2011

A new approach of assessing sagittal dysplasia: the W angle

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SUMMARY In orthodontic diagnosis and treatment planning, an accurate antero-posterior measurement of jaw relationships is critically important. Previously described angular and linear measurements can be inaccurate because of their dependency on various factors. The purpose of this study was to introduce a new cephalometric measurement, named the W angle, to assess the sagittal relationship between maxilla and mandible with accuracy and reproducibility. This angle uses three skeletal landmarks—point S, point M, and point G—to measure an angle that indicates the severity and the type of skeletal dysplasia in the sagittal dimension. One hundred and forty-two pre-treatment cephalometric radiographs of patients between the age of 15 and 25 years were selected. They were again subdivided into Classes I, II, and III groups on the basis of Beta angle, Wits appraisal, and ANB angle. The W angle was measured between the perpendicular from point M on S–G line and the M–G line. The mean and the standard deviation for the W angle were calculated. After using the one-way analysis of variance and the Newman–Keuls test, receiver operating characteristics curves were obtained. Results showed that a 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 relationship.

Introduction

In diagnosis and treatment planning of skeletal malocclusions, the evaluation of the antero-posterior (AP) jaw relationship is an indispensable step, and this relationship is generally determined by cephalometric analysis. Since Wylie's (1947) first attempt to describe AP jaw relationship, various other cephalometric parameters have been proposed. Of these parameters, the ANB angle (Riedel, 1952), the Wits appraisal (Jacobson, 1975), and recently Beta angle (Baik and Ververidou, 2004) are the commonly used parameters. Still, sagittal jaw relationships are difficult to evaluate because of rotations of the jaws during growth, vertical relationships between the jaws and the reference planes, and a lack of validity of the various methods proposed for their evaluation (Jacobson, 1975; Moyers *et al.*, 1979; Baik and Ververidou, 2004; Nanda, 2005).

With regard to the validity of the ANB angle and Wits appraisal, various studies have pointed out a number of distorting factors. Number of studies have questioned stability of nasion (N; Nanda, 1955; Moore, 1959; Enlow, 1966; Binder, 1979).

During shooting of cephalogram, rotation of head side wards or upwards can affect the ANB reading. Furthermore, rotation of the jaws by either growth or orthodontic treatment can also change the ANB reading. The ANB angle can also differ because of variance in the length of the cranial base (Jacobson, 1975).

Wits appraisal was projected to overcome the existing limitations of angle ANB (Jacobson, 1975). 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, to describe the skeletal discrepancies. The occlusal plane can be easily affected by tooth eruption and dental development as well as by orthodontic treatment (Richardson, 1982; Frank, 1983; Sherman *et al.*, 1988). This can profoundly influence the Wits appraisal. Furthermore, accurate identification of the occlusal plane is not always easy or accurately reproducible (Rushton *et al.*, 1991; Haynes and Chau, 1995), especially in mixed dentition patients or patients with open bite, canted occlusal plane, multiple impactions, missing teeth, skeletal asymmetries, or steep curve of Spee.

Because of these geometric effects, a conjunctive use of the ANB angle and the Wits appraisal has been recommended (Moyers *et al.*, 1979; Nanda, 2005). However, when there is a difference in the jaw relationship assessment between the two parameters, it is difficult to know on which parameter to base a selection.

Some authors have suggested angles or linear measurements based on the palatal plane (Nanda and Merrill, 1994). Although palatal plane is stable with age, its inclination is highly variable, requiring additional cephalometric data to ensure a more accurate diagnosis (Nanda and Merrill, 1994).

To determine true apical base relationship independent of the cranial reference planes or dental occlusion, Beta angle was developed (Baik and Ververidou, 2004). Although it gives fair idea of true apical elation, it still uses point A as a reference point for the AP position of the maxilla. The position of point A is believed to be affected by alveolar bone remodelling associated with orthodontic tooth movement of the upper incisors (Arvysts, 1990; Erverdi, 1991; Nanda, 2005). The other problem is locating point condylion. The reproducibility of the location of condylion on mouth-closed lateral head films is limited (Adenwalla *et al.*, 1988; Moore *et al.*, 1989; Ghafari *et al.*, 1998).

Most recently introduced sagittal dysplasia indicator is YEN angle (Neela *et al.*, 2009). But since it measures an angle between line SM and MG, rotation of jaw because of growth or orthodontic treatment can mask true basal dysplasia, similar to ANB angle.

To overcome these existing problems, a measurement was developed and named the W angle. This angle does not depend on any unstable landmarks or dental occlusion and would be especially valuable to assess true sagittal changes because of growth and orthodontic treatment.

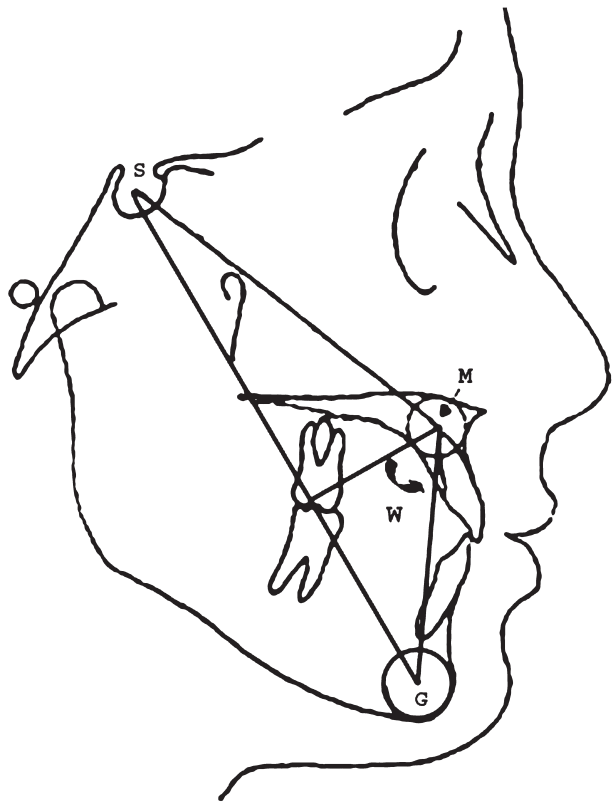

Figure 1 The construction and mode of measuring the W angle.

The W angle

The W angle is a new measurement for assessing the skeletal discrepancy between the maxilla and the mandible in the sagittal plane (Figure 1). It uses three skeletal landmarks—point S, point M, and point G—to measure an angle that indicates the severity and the type of skeletal dysplasia in the sagittal dimension (Figure 1). The W angle can be found by, first, locating three points:

Point S—midpoint of the sella turcica;

Point M—midpoint of the premaxilla;

Point G—centre of the largest circle that is tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphysis.

Next, defining four lines:

Line connecting S and M points.

Line connecting M and G points

Line connecting S and G points.

Line from point M perpendicular to the S–G line.

Finally, measuring the W angle, which is the angle between the perpendicular line from point M to S–G line and the M–G line (Figure 1). The purposes of this study were to define the mean value and the standard deviation for this angle in people with the Classes I, II, and III skeletal pattern.

Materials and methods

To assign samples to the Classes I, II, and III skeletal pattern groups, many files of individuals between 15 and 25 years were screened in the Orthodontic Department of Government Dental College, Nagpur.

After the initial selection, all x-rays were retraced; the ANB and Beta angles and the Wits appraisal were measured by each investigator separately. The mean values of those measurements were calculated. All tracings and measurements were repeated by the same operators at a 2 week interval. The combined error was calculated with the Dahlberg's formula. The mean difference was within 0.7 degrees for angular measurements and was insignificant.

For a patient to be included in the Classes I, II, or III skeletal pattern group, criteria for Beta angle along with one of two (ANB angle and Wits appraisal) had to be met. A skeletal Class I relationship was indicated by an ANB of 2–4 degrees, a Wits coincidence of AO and BO in females or BO 1 mm ahead of AO in males, and a Beta angle of 27–35 degrees. Sixty lateral cephalograms (35 female and 25 male) that met the above criteria comprised the skeletal Class I group.

A skeletal Class II relationship was indicated by an ANB of greater than 4 degrees, a Wits appraisal with AO ahead of BO in females or AO coinciding with or ahead of BO in males, and a Beta angle less than 27 degrees. Forty-six lateral cephalograms (26 female and 20 male) were collected from the screened files that met the above criteria to form the skeletal Class II group.

The skeletal Class III individuals were characterized by an ANB less than 2 degrees, a Wits BO ahead of AO in females or BO ahead of AO by more than 1 mm in males, and a Beta angle greater than 35 degrees. Thirty-six lateral cephalograms (20 female and 16 male) met the required criteria.

To construct the W angle, points S, M, and G were located. To locate points M and G, as suggested by Nanda and Merrill (1994) and Braun *et al.* (2004), a template with concentric circles whose diameters increased in 1 mm increments was used.

After classifying the patients, W angle was measured by two operators and mean value was taken. To measure the method error using Dahlberg's formula, same procedure was repeated after 2 weeks and it was found to be 0.5 degrees.

Statistical analysis

Data collected by the investigators were first entered to Excel (Microsoft, Redmond, Washington, USA). Collected data were screened for any missing values or outliers and for validity of distribution assumptions. To summarize the data, means and standard deviations of W angle in three groups were calculated. The one-way analysis of variance (ANOVA) was used followed by Newman–Keuls post hoc testing to determine whether there was a statistically significant difference between the mean values W angle of the three groups. A P value ≤0.05 was considered to be statistically significant. Receiver operating characteristics curves were run to examine the sensitivity and specificity of W angle as a test to discriminate between the three different skeletal pattern groups. All statistics were performed in SPSS (SPSS 13, Chicago, Illinois, USA).

Results

The mean value for the W angle in the Class I skeletal pattern group was 53.7 degrees with SD of 2.0, whereas the mean values in the Classes II and III skeletal pattern groups were 48.9 and 58.7 degrees with a SD of 2.1 and 3.2, respectively (Table 1).

The one-way ANOVA followed by Newman–Keuls post hoc testing showed (Table 2) that there was a statistically significant difference between the mean values of W angle of the three groups. Between genders, according to unpaired *t*-test, there was no statistically significant difference except in skeletal Class III group (Table 2).

Receiver operating characteristics curves showed that a W angle less than 51 degrees has 96 per cent sensitivity and 90 per cent specificity for discriminating the Class II group from the Class I group. A W angle greater than 56 degrees has 95 per cent sensitivity and 98 per cent specificity for discriminating the Class III group from the Class I group. Therefore, the receiver operating characteristics curves show that the cut-off point between the Class I and Class II groups could be considered a W angle of approximately 51 degrees, and the cut-off point between the Class I and Class III groups could be considered a W angle of approximately 56 degrees. The results also indicate that a patient with a W angle less than 51 degrees has a Class II skeletal pattern and one with a W angle greater than 56 degrees has a Class III skeletal pattern.

Table 1 Mean (SD) values of W angle in Class I, Class II, and Class III groups. SD, standard deviation.

	Class		
	I	II	III
Female	53.8	48.7	57.4
Male	53.6	49.2	60.4
Mean (SD)	53.7 (2)	48.9 (2.1)	58.7 (3.2)

Table 2 Student-Newman-Keuls testing for pairwise comparisons of group means.

Class	*N*	Subset		
		1	2	3
II	46	48.910		
I	60		53.756	
III	35			59.441
Significance		1.000	1.000	1.000

Discussion

In orthodontic diagnosis and treatment planning, the evaluation of the AP jaw relationship is an indispensable step and this relationship is generally determined by cephalometric analysis. To evaluate this relationship, various angular and linear measurements have been suggested. But these can be erroneous as angular measurements are affected by changes in face height, jaw inclination, and total jaw prognathism; linear variables can be affected by the inclination of the reference line (Williams *et al.*, 1985; Jacobson, 1988).

The most popular parameter for assessing the sagittal jaw relationship remains the ANB angle, but it is affected by various factors and can often be misleading. When using the ANB angle, factors such as the patient's age, growth rotation of the jaws, vertical growth, and the length of the anterior cranial base (AP position of N) should be considered, which makes the interpretation of this angle much more complex (Jacobson, 1975).

To overcome these problems, the Wits appraisal was introduced (Jacobson, 1975). Although not affected by landmarks or jaw rotations, it still has the problem of correctly identifying the functional occlusal plane, which can sometimes be impossible, especially in mixed dentition. Furthermore, changes of the Wits measurement throughout orthodontic treatment might also reflect changes in the functional occlusal plane rather than pure sagittal changes of the jaws (Moore *et al.*, 1989; Ishikawa *et al.*, 2000).

A popular recent alternative Beta angle avoids use of functional plane and is not affected by jaw rotations (Baik and Ververidou, 2004). But it uses point A and point B, which can be remodelled by orthodontic treatment and growth (Richardson, 1982; Frank, 1983; Rushton *et al.*, 1991). Furthermore, as shown by various studies, the reproducibility of the location of condylion on mouth-closed lateral head films is limited (Adenwalla *et al.*, 1988; Moore *et al.*, 1989; Ghafari *et al.*, 1998). Instead of condylion, centre of condyle could be used, but approximation of centre of condyle is difficult (Baik and Ververidou, 2004). This could give a non-significant error of approximately 1 degree.

All other AP parameters introduced over the years are affected by at least one of the factors, namely patient's age, jaw rotations, poor reproducibility of landmarks, growth changes in reference planes, and changes due to orthodontic treatment (Ishikawa *et al.*, 2000).

To overcome some of the limitations of the previously discussed parameters, the W angle was developed. This measurement does not depend on unstable landmarks or the functional occlusal plane. It uses three stable points—point S, point M, and point G. W angle is measured between a perpendicular line from point M to the S–G line and M–G line. Based on statistical analysis, a patient with a W angle between 51 and 56 degrees has a Class I skeletal pattern. Patient with a W angle less than 51 degrees has a skeletal Class II pattern and one with a W angle greater than 56 degrees has a skeletal Class III pattern. In females with class III skeletal pattern, W angle has a mean value of 57.4 degrees, while in males, it is 60.4 degrees.

ANB angle has been shown to be affected by vertical facial growth as well as by jaw rotations (Ishikawa *et al.*, 2000). The geometry of the W angle gives it the advantage to remain relatively stable even when the jaws are rotated or growing vertically (Figure 2). This is a result of rotation of the S–G line along with jaw rotation, which carries the perpendicular from point M with it. Because the M–G line is also rotating in the same direction, the W angle remains relatively stable. Therefore, measurement of W angle is useful sagittal parameter in skeletal patterns with clockwise or counterclockwise rotation of the jaws as well as during transitional period when vertical facial growth is taking place.

Cranial base length (position of point N) can sometimes camouflage true skeletal classes I, II, and III patterns. In this regard, W angle can be a valuable tool for planning orthopaedic or orthognathic procedures as this angle is independent of cranial base length. Another advantage of W angle is that it can be used for evaluation of treatment progress because it reflects true changes of the sagittal relationship of the jaws, which might be due to growth or orthodontic or orthognathic intervention.

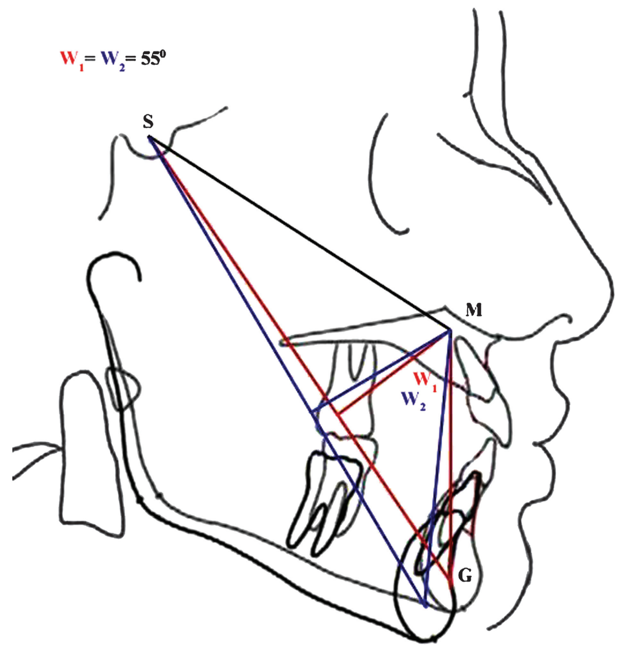

Figure 2 W angle remains relatively stable even when jaws are rotated.

However, precisely tracing the premaxilla and locating its centre is not always easy. To accurately use this angle, the cephalometric x-rays must be high quality. It is then much easier for the clinician to follow the contour of premaxilla and locate its centre.

In Class II and Class III skeletal cases, similar to Beta angle, W angle cannot determine which jaw is prognathic or retrognathic. To clarify this, clinician should be aware of importance of other cephalometric measurements.

Cephalometrics is not an exact science. Cephalometric analyses based on angular and linear measurements have obvious limitations and hence dependency on any one parameter for skeletal assessment is discouraged. W angle adds a valuable tool for assessment of AP jaw relationship. Along with other parameters, it should enable better diagnosis and treatment planning for patients.

Conclusions

1. Previously established measurements for assessing the sagittal jaw relationship can often be misleading.
2. A new angle, the W angle, was developed as a diagnostic tool to evaluate the AP jaw relationship more consistently.
3. Subjects with a W angle between 51 and 56 degrees have a Class I skeletal pattern; a W angle less than 51 degrees indicates a Class II skeletal pattern and a W

angle greater than 56 degrees indicates a Class III skeletal pattern.

4. There is no statistically significant difference between mean W angle values of males and females except for class III malocclusion. In females with Class III skeletal pattern, W angle has a mean value of 57.4 degrees, while in males, it is 60.4 degrees.

Acknowledgement

The authors gratefully acknowledge the support of Dr Vinay Hazare, Dean, Government Dental College, Nagpur, for his valuable support during this study.

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