Reliability of Beta angle in assessing true anteroposterior apical base discrepancy in different growth patterns

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Abstract

Introduction: Beta angle as a skeletal anteroposterior dysplasia indicator is known to be useful in evaluating normodivergent growth patterns. Hence, we compared and verified the accuracy of Beta angle in predicting sagittal jaw discrepancy among subjects with hyperdivergent, hypodivergent and normodivergent growth patterns. **Materials and Methods:** Lateral cephalometric radiographs of 179 patients belonging to skeletal Classes I, II, and III were further divided into normodivergent, hyperdivergent, and hypodivergent groups based on their vertical growth patterns. Sagittal dysplasia indicators - angle ANB, Wits appraisal, and Beta angle values were measured and tabulated. The perpendicular point of intersection on line CB (Condylion-Point B) in Beta angle was designated as 'X' and linear dimension XB was evaluated. **Results:** Statistically significant increase was observed in the mean values of Beta angle and XB distance in the vertical growth pattern groups of both skeletal Class I and Class II patients thus pushing them toward Class III and Class I, respectively. **Conclusions:** Beta angle is a reliable indicator of sagittal dysplasia in normal and horizontal patterns of growth. However, vertical growth patterns significantly increased Beta angle values, thus affecting their reliability as a sagittal discrepancy assessment tool. Hence, Beta angle may not be a valid tool for assessment of sagittal jaw discrepancy in patients exhibiting vertical growth patterns with skeletal Class I and Class II malocclusions. Nevertheless, Class III malocclusions having the highest Beta angle values were unaffected.

Key words: Beta angle, sagittal dysplasia, vertical growers

INTRODUCTION

Assessment of jaw relationship in all three planes (anteroposterior, transverse, and vertical) is an integral part of orthodontic treatment planning. Of the several analyses attempted to assess the anteroposterior discrepancy with numerous angular and linear measurements,[1-12] the ANB angle,[3,13] Wits appraisal[4] and Beta angle[10] are commonly used. However, the validity of ANB angle and Wits appraisal is questionable due to a number of distorting factors such as rotation of jaws,[4] variation in the position of nasion,[14-18] length of cranial base[15] and vertical distance of points A and B from the cranial base.[15] Although the Wits appraisal, overcomes some of these limitations,[4] it is affected by tooth eruption,[19,20] Curve of Spee, open bite and is not easily identifiable or reproducible.[21]

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Beta angle is yet another method for determining true sagittal apical base relationships independent of cranial reference planes or functional occlusal plane. It uses three skeletal landmarks-point A, point B and apparent axis of the condyle-point C. Angle formed between A-B line and point A perpendicular to C-B line (Condylion-B point) is the Beta angle.[10] The sample used for development of this new parameter comprised of cases with normal vertical components, based on mandibular occipital (MOCC) angle and hypothesize that the Beta angle would remain relatively stable even when the jaws are rotated downward and backward.[10] When point B is rotated backwards, the C-B line is also rotated in the same direction carrying the perpendicular from point A with it. The Beta angle is presumed to remain relatively stable because the A-B line is also rotating in the same direction. Hence, it is believed that Beta angle would accurately assess the sagittal relationship in skeletal patterns even if clockwise or counter-clockwise rotation of the jaws tended to camouflage it. This would be geometrically true if the mandible were to rotate like a steering wheel with every point on it being displaced to the same extent and same direction. However, internal rotation of the mandible is different and has two components i.e., (a) matrix rotation centered around the condyle, (b) intra-matrix rotation centered within the body of the mandible.[22] Hence, it is essential to understand and investigate the degree to which vertical dysplasia can affect the Beta angle. Moreover, projection of perpendicular from point A to C-B line (named Point X) results in the formation of a right angle triangle, AXB. Angle XAB forms the Beta angle under consideration. Since in any right angled triangle, each side is proportional to the angle diametrically opposite to it, we also decided to evaluate the linear dimension of mandible pertaining to line XB to assess its effect on Beta angle.

MATERIALS AND METHODS

This cross-sectional study was based on departmental pretreatment records containing high definition lateral cephalometric radiographs of only those patients who had no previous history of trauma, orthodontic treatment or orthognathic surgery and no missing teeth, functional mandibular shifts or congenital defects.

Sample size was determined using a power calculation based on mean Beta angle value of Class I occlusion (31.1° ± 2°).[10] To detect a change of 2° from this mean value with 95% confidence and 80% power, we required a sample size of 16 in each group.

Cephalometric landmarks used in this study included Sella(S), Nasion(N), Point A(A), Point B(B), Gnathion(Gn), Menton(Me), Gonion(Go), Articulare(Ar), and projection of perpendicular from point A to C-B line (X).

Linear and angular measurements used

- Wits appraisal
- Angle ANB
- XB distance — the linear distance between point X and B point
- Beta angle — the angle between the perpendicular from point A to C-B line and the A-B line
- Angle Go-Gn (Gonion-Gnathion) to SN plane.

All radiographs were traced by a single investigator and Sagittal dysplasia indicators — angle ANB, Wits appraisal, and Beta angle values were measured and tabulated. Vertical growth pattern was assessed using angles Go-Gn to SN plane[23] and MOCC as used by Margolis.[24] The point of intersection obtained by the perpendicular drawn from point A to the C-B line (condylion to point B) was designated as 'X' and linear distance XB measured and recorded [Figure 1].

Angular and linear measurements were obtained nearest to 0.01 mm and 0.5° using digital Vernier caliper (Hangzhou United Bridge Tools Co., Ltd.) and semicircular protractor respectively. From a total of 264 patients initially selected, 179 radiographs were included in the study based on specific inclusion criteria. Age range was between 15 and 25 years.

Criteria for a patient to be included in Class I skeletal pattern:

1. Angle ANB of 1-3°,[10]
2. Wits appraisal of 0 to −3 mm,[10]
3. Angle's Class I molar relationship,
4. Orthognathic, Class I profile.

Criteria for Class II group:

1. Angle ANB was above 4°,[10]
2. Wits appraisal greater than 0 mm,[10]
3. Molar relationship was Angle's Class II and
4. Retrognathic, Class II profile.

Criteria for Class III group:

1. Angle ANB was lesser than 1°,[10]
2. Wits reading equal to or lesser than −4 mm,[10]
3. Molar relationship Angle's Class III and
4. Prognathic, Class III profile.

Based on vertical growth pattern as evidenced by MOCC angle[24] and angle Go-Gn to SN,[23] each skeletal class was further divided into three groups.

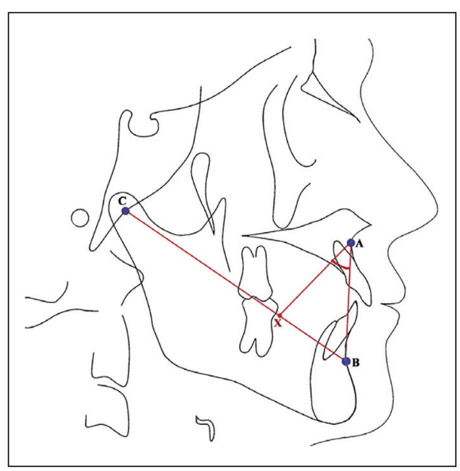

Figure 1: Cephalometric parameters analyzed in study – Beta angle (XAB) and XB distance

- Normodivergent/normal growth pattern — MOCC between −4 and +4°; Go-Gn-28-36°
- Hyperdivergent/vertical growth pattern — MOCC >4°; Go-Gn >36°
- Hypodivergent/horizontal growth pattern — MOCC <4°; Go-Gn –<28°

The final sample distribution is shown in Table 1.

After an interval of 2 weeks, 20 randomly selected radiographs were retraced by the same investigator and repeatability of Beta angle and XB distance was measured by intra-class correlation coefficient (ICC) as shown in Table 2, indicating a good agreement between two different time interval observations.

Statistical analysis

The measured values of Beta angle and XB distance in each group were evaluated for statistical significance using Statistical Package for Social Sciences (SPSS version 16, IBM). Data are represented as means ± standard deviations (SD). One-way analysis of variance was used to identify overall differences in mean values of Beta angle and XB distance in each group. The level of significance was set at $P < 0.05$. When differences between groups were found to be significant, the Bonferroni test for multiple comparisons was applied. Receiver operating characteristics (ROC) curves were run to examine the sensitivity and specificity of XB linear distance as a test to discriminate between the three different skeletal pattern groups. Kappa statistics were used to measure the agreement between skeletal classes and Beta angle category in different growth patterns, and ICC was used to measure repeatability of quantitative variables (Beta angle and XB distance) to examine intra-examiner bias.

Table 1: Distribution of the sample based on growth pattern and skeletal classification

Growth pattern	Skeletal class		
	I	II	III
Normodivergent	20 (9 male, 11 female)	26 (14 male, 12 female)	25 (12 male, 13 female)
Hyperdivergent	17 (8 male, 9 female)	19 (9 male, 10 female)	18 (8 male, 10 female)
Hypodivergent	18 (9 male, 9 female)	19 (8 male, 11 female)	17 (9 male, 8 female)

Table 2: ICC for Beta angle and XB distance

Variable	ICC	α value	*P* value
Beta angle	0.894	0.894	<0.001
XB distance	0.973	0.986	<0.001

ICC: Intra-class correlation coefficient

Table 3: Descriptive statistics for mean value of Beta angle and XB distance in all skeletal class groups

Skeletal class	Parameters	Growth pattern	Mean	SD	*P* value
I	Beta angle (°)	Normal	31.9	2.5	0.004*
		Horizontal	31.1	2.5	
		Vertical	34.4	3.5	
	XB distance (mm)	Normal	21.9	1.5	<0.001*
		Horizontal	19.5	2.4	
		Vertical	24.5	3.2	
II	Beta angle (°)	Normal	24.5	3.6	0.002*
		Horizontal	22.4	5.6	
		Vertical	27.7	4.4	
	XB distance (mm)	Normal	17.3	3.7	<0.001*
		Horizontal	14.3	4.5	
		Vertical	20.5	3.6	
III	Beta angle (°)	Normal	43.2	5.4	0.521
		Horizontal	42.1	7.6	
		Vertical	41.0	5.3	
	XB distance (mm)	Normal	30.5	6.6	0.228
		Horizontal	27.0	6.8	
		Vertical	29.4	5.3	

*Values showed statistically significant difference between the groups using ANOVA ($P < 0.05$). ANOVA: Analysis of variance, SD: Standard deviation

RESULTS

Mean (±SD) values for Beta angle and XB distance for Class I and Class II but not Class III with normal, horizontal, and vertical growth patterns were significantly different ($P < 0.05$) [Table 3].

Significant ($P < 0.05$) increase in Beta angle values in vertical growth patterns of both Class I and II cases [Table 4] was observed. The XB distance also showed significant differences among the various groups for both Class I and Class II cases. Skeletal Class III cases however showed no statistical difference among the three growth patterns.

Horizontal growth pattern showed maximum agreement for Beta angle with 100% reliability in Class III, 83.3% in Class I and 73.7% in Class II ($K = 0.778$, $P < 0.001$) [Tables 5 and 6]. Normal growth patterns were also found to be 100% reliable in Class III and 80% in Class I but only 69.2% in Class II ($K = 0.747$, $P < 0.001$). Vertical growth patterns on the other hand showed only 47.4% reliability of Beta angle as a sagittal parameter in Class II cases and 47% in Class I cases ($K = 0.474$, $P < 0.001$). However, Class III showed 100% reliability [Tables 5 and 6].

Average XB value in skeletal Class II was 17.4 mm (±4.5). It increases to 21.9 mm (±3.1) in Class I and further to 29.2 mm (±6.4) in Class III [Table 7].

ROC curve analysis for XB distance to identify the cut-off to differentiate Class II from the other classes is

Table 4: Bonferroni test for multiple comparisons among three different growth patterns

Class	Dependent variable	Growth pattern (I)	Growth pattern (J)	*P* value
I	Beta angle	Normal	Horizontal	1.000
			Vertical	0.034*
		Horizontal	Normal	1.000
			Vertical	0.005**
		Vertical	Normal	0.034*
			Horizontal	0.005**
	XB distance	Normal	Horizontal	0.015*
			Vertical	0.006**
		Horizontal	Normal	0.015*
			Vertical	<0.001**
		Vertical	Normal	0.006**
			Horizontal	<0.001**
II	Beta angle	Normal	Horizontal	0.428
			Vertical	0.058
		Horizontal	Normal	0.428
			Vertical	0.002**
		Vertical	Normal	0.058
			Horizontal	0.002**
	XB distance	Normal	Horizontal	0.048*
			Vertical	0.030*
		Horizontal	Normal	0.048*
			Vertical	<0.001**
		Vertical	Normal	0.030*
			Horizontal	<0.001**

*Statistically significant at $P < 0.05$, **Statistically significant at $P < 0.01$

Table 5: Agreement between skeletal class and Beta angle category in different growth patterns

Growth pattern	Beta angle category			Total
	<27°	27°-34°	>34°	
Normal growth pattern				
Class II				
Count	18	8		26
Percentage within class	69.2	30.8		100
Class I				
Count		16	4	20
Percentage within class		80	20	100
Class III				
Count			25	25
Percentage within class			100	100
Horizontal growth pattern				
Class II				
Count	14	5		19
Percentage within class	73.7	26.3		100
Class I				
Count	1	15	2	18
Percentage within class	5.6	83.3	11.1	100
Class III				
Count			17	17
Percentage within class			100	100
Vertical growth pattern				
Class II				
Count	9	9	1	19
Percentage within class	47.4	47.4	5.3	100
Class I				
Count		8	9	17
Percentage within class		47	53	100
Class III				
Count			18	18
Percentage within class			100	100

represented in Figure 2. Similarly, ROC curve for XB distance to discriminate skeletal Class III from the other groups is presented in Figure 3. The optimum cut-off with corresponding sensitivity and specificity are presented in Table 8. A cut-off of 20.75 will delineate Class II from Class I and Class III together. Similarly, a cut-off of 22.25 will delineate Class III from Class I and Class II together.

DISCUSSION

Accurate anteroposterior analysis of jaw relationships is critically important in planning orthodontic treatment. Many linear and angular measurements are proposed in cephalometrics for this purpose. It is important that vertical growth patterns do not affect such parameters as it could mislead the clinician and make interpretation very complex. The Beta angle purports to be unaffected by vertical growth patterns. Verification of the accuracy of this parameter in different growth patterns, is therefore necessary.

Subjects with horizontal and normal growth patterns showed good adherence to Beta angle values. However, individuals with vertical growth patterns and skeletal Class I relationship exhibited only 47% reliability with respect to Beta angle values. A similar lack of reliability was observed in skeletal Class II vertical growth patterns (47.4%) as well. Hence, use of Beta angle as a true indicator of sagittal

Table 6: Kappa statistics to measure the agreement of Beta angle in different growth patterns with the original study

Growth pattern	*K* value	*P* value
Normal	0.747	<0.001*
Horizontal	0.778	<0.001*
Vertical	0.474	<0.001*

*$P < 0.001$

Table 7: Descriptive statistics of XB distance (mm) for different skeletal groups

Skeletal class	N	Mean	SD
I	55	21.9	3.1
II	64	17.4	4.5
III	60	29.2	6.4
Total	179	22.7	6.9

SD: Standard deviation

Table 8: Validity and optimum cut-off value for XB distance by ROC curve

Discriminating skeletal class	Value more than (mm)	Sensitivity %	Specificity %
Skeletal Class II to others	20.75	83.5	81.2
Skeletal Class III to others	22.25	90	73.1

ROC: Receiver operating characteristics

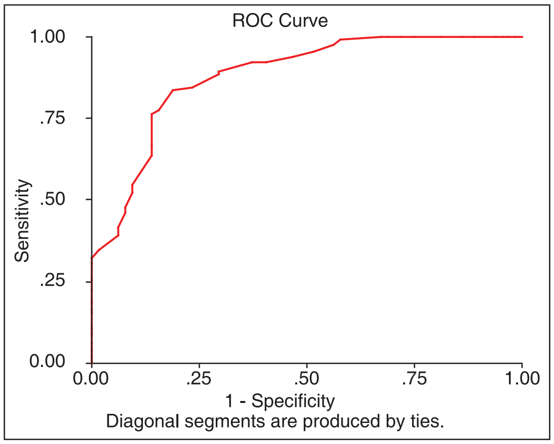

Figure 2: Receiver operating characteristics curve for XB distance to discriminate skeletal Class II group from other groups

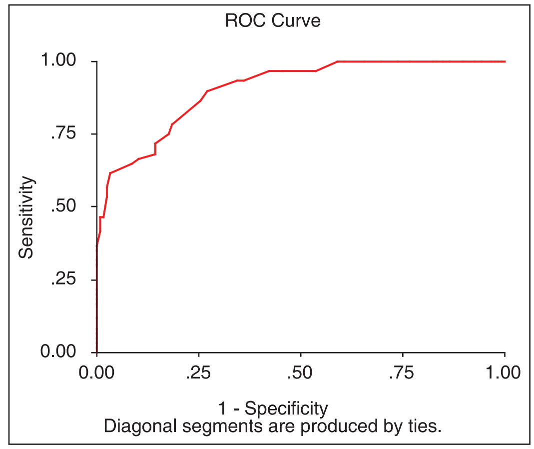

Figure 3: Receiver operating characteristic curve for XB distance to discriminate skeletal Class III from other groups

dysplasia is reliable only in individuals with horizontal to normal growth patterns. Only 47% of vertical growers in both Class I and Class II exhibited true sagittal discrepancy, which may be because steep mandibular planes had a strong tendency to increase the Beta angle values. This finding is however not in agreement with a previous report[10] in patients with normal growth patterns (evidenced by Margolis MOCC angle)[24] and had a cut-off point between Class I and Class II of 27.5° and between Class I and Class III of 35.5° with 95% sensitivity.

Our findings also do not support the theory that Beta angle would remain stable even when jaws are rotated. Clockwise growth rotation significantly increased Beta angle values, thus pushing Class I and Class II subjects toward Class III and Class I, respectively. However, skeletal Class III obviously remained unaffected because the already high Beta angle values were unaffected by vertical growth patterns making it a reliable parameter for such cases.

The linear dimension XB is another variable that showed a statistically significant increase from skeletal Class II (17.4 ± 4.5 mm) through Class I (21.9 ± 3.1 mm) to Class III (29.2 ± 6.4 mm). In Class I and Class II, XB distance was significantly higher in the vertical growers as compared to normal and horizontal groups. No such difference was seen for the three growth patterns in Class III [Table 3].

When a perpendicular is dropped from point A to C-B line intersecting it at 'X', AXB forms a right angled triangle. In a vertical grower, mandibular plane is steep with short ramus height leading to a steep C-B line. Keeping point A constant, to maintain angle AXB at 90°, the point of intersection, X has to move distally to X'. This leads to an increase in the linear dimension X'B and decrease in dimension AX'. In a right angled triangle, each angle is always proportional to the length of the opposite side. Hence, irrespective of the skeletal class, Beta angle values showed an increase in values whenever the XB linear dimension was increased. This is in contrast to previous findings, which state that when mandible rotates, the perpendicular rotates with it leading to stable Beta angle values in the face of clockwise or counter clockwise growth rotations. Hence, Beta angle value is apparently dependent on linear dimension XB. For the same mandibular length, a person with vertical growth pattern and clockwise rotation of the mandible, Beta angle values may become higher because XB distance increases. This might place an individual with Class I anteroposterior discrepancy in skeletal Class III and a Class II discrepancy may be pushed to Class I. This effect will be negated only if point A also moves downwards and forwards to the same extent.

Limitations

The present study was done assuming point A to be constant. When point A varies, Beta angle values are liable to change. This has not been included in this study.

Scope for future studies

Further studies are needed to assess the vertical change in the position of point A and its effect on Beta angle. This can be done by using the simplistic equation of trigonometry as follows:

Angle AXB in Figure 4 is a right angled triangle, and angle XAB represents Beta angle under consideration. Angle XAB or Beta angle can be calculated by the following equation:

$$\tan \theta = \text{Perpendicular/base} = XB/AX$$

Beta angle which is a function of both AX and XB can easily be calculated and the effect of the ratio of XB:AX can be seen in Beta angle value.

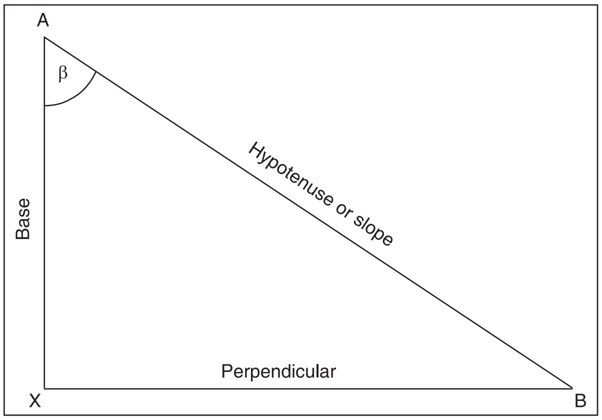

Figure 4: Right angled triangle AXB with beta angle

CONCLUSIONS

Clockwise rotation of the mandible affected the reliability of Beta angle as a sagittal discrepancy assessment tool. Hence, Beta angle may not be a reliable tool for assessment of sagittal jaw discrepancy in patients exhibiting vertical growth patterns with skeletal Class I and Class II malocclusions. However, Beta angle is a reliable indicator of sagittal dysplasia in normal and horizontal patterns of growth. Interestingly, skeletal Class III malocclusions showed 100% adherence to Beta angle values irrespective of the growth pattern.

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