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Predictability of Wits appraisal, ANB, Beta, Yen, W, μ and Pi angle as indicators of anteroposterior dysplasia in Jharkhand population

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ABSTRACT

Objectives: The measurements for assessing the antero-posterior discrepancy between the apical bases are many with their individual benefits and shortcomings. So, it is very important to categorize the reliability of the major diagnostic criteria for successful planning of treatment and to fore see the outcome. The present study assesses the predictability of Wits appraisal, ANB, Beta, Yen, W, μ and Pi angles as an indicators of anteroposterior dysplasia.

Materials and Methods: A total of 120 lateral cephalograms of skeletal Class I, II and III patients were selected based on Down's facial angle and then tracing was carried out manually to measure Wits appraisal, ANB, Beta, Yen, W, μ and Pi angles. Analysis of variance and correlation coefficient analysis were done to assess the significance of association between these variables.

Results: Yen angle is highly predictable and a homogenously distributed angular parameter used to assess sagittal discrepancy. The most desirable differentiation results among the three skeletal relationship were represented by Beta angle followed by Yen angle. Statistically significant correlation among the seven parameters for skeletal Class I relationship were shown by Yen and W angle, for skeletal Class II relationship by Beta angle and μ angle and for skeletal Class III relationship by Beta angle and W angle. No statistically significant correlation existed between Yen Angle and Beta Angle in all the three groups.

Conclusion: Yen angle was found to have the most homogenous and predictable parameter. A statistically significant correlation for skeletal Class I relationship were observed between Yen and W angle, for skeletal Class II relationship between Beta and μ angle and for skeletal Class III relationship between Beta angle and W angle and they can be used interchangeably in assessing skeletal jaw relationship.

1. Introduction

The evaluation of sagittal jaw relationship between maxilla and mandible has been one of the major problems in the field of Orthodontics, which is of primary importance in diagnosis and treatment planning.[1] Even before Edward H. Angle introduced his classification of malocclusion to the profession in the early 1900s, the antero-posterior relationship of mandible to maxilla was the most important diagnostic criterion. This relationship can be determined from clinical observation to some degree, but it can be much more accurately evaluated from a lateral cephalogram.[2]

In 1931 the introduction of radiographic cephalometry by Broadbent in the United States and Hofrath in Germany, has become one of the most important tool of clinical and research orthodontics.[3,4] In orthodontics, discrepancies

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are described in three planes of space namely, transverse, sagittal and vertical. Of these, the sagittal discrepancies are most commonly encountered in day to day practice.

Various angular and linear measurements have also been incorporated into cephalometric analyses to help the clinician for diagnosing these sagittal discrepancies.[5] The first step in evaluating antero-posterior jaw relationship cephalometrically was Down's description of points A and B.[6] A few years later, Reidel[7] used angle ANB angle, which later on became an important part of many analysis.[5]

However, it has been claimed that ANB angle is affected by a number of misleading factors and may give false results; therefore, number of new measurements have been developed to determine the skeletal discrepancy. Jacobson in 1975 eliminated the cranial reference points and used occlusal plane as reference base. It was referred to as Wits appraisal.[6]

Baik and Ververidou in 2004 introduced a new measurement "Beta (β) angle". It uses three skeletal landmarks that does not depend on any cranial landmarks or dental occlusion to determine the sagittal jaw relationship.[8]

Another cephalometric measurement parameter μ angle was given by Fattahi et al. in 2006. This angle uses anatomic landmarks: point A, point B and mandibular plane. The angle formed is independent of cranial and dental landmarks and it is not affected by mandibular rotation.[9] Yen angle measures an angle formed between line Sella to midpoint of the premaxillae (M) and midpoint of the premaxillae (M) to centre of mandibular symphysis (G). But rotation of jaw because of growth or orthodontic treatment can mask true basal dysplasia, similar to ANB angle.[10]

W angle also uses skeletal landmarks same as Yen angle, which indicates the severity and the type of skeletal dysplasia. One of its shortcoming is that it does not indicate which jaw is at fault. It simply shows the relationship between maxilla and mandible.[11] In 2012 Pi angle was introduced by Kumar et al., points were constructed: M point, G' point, (G point perpendicular projected on to the true horizontal) and M' point (M point perpendicular projected on to the true horizontal). The Pi analysis then consists of constructing the Pi angle (GG'M) and Pi linear (G'–M').[12]

All the above mentioned parameters to assess the sagittal jaw discrepancies uses either the cranial reference plane or the dental occlusion. Each of the reference planes has their own limitations. It was necessary to assess the validity and predictability of Wits appraisal, ANB, Beta, Yen, W, μ and Pi angle as indicators of anteroposterior dysplasia.

2. Materials and Methods

2.1. Source of data

Study was conducted on patients visiting the Department of Orthodontics and Dentofacial Orthopaedics, Hazaribag College of Dental Sciences and Hospital, Hazaribag, Jharkhand. Ethical approval was obtained (EC/NEW/INST/2020/799). A total of 120 pretreatment lateral cephalograms of individuals, who had never undergone any orthodontic treatment were obtained. Based on Down's facial angle[6] samples were categorized into skeletal pattern group pattern. A total of 40 patients were included in each group of which 20 were males and 20 females.

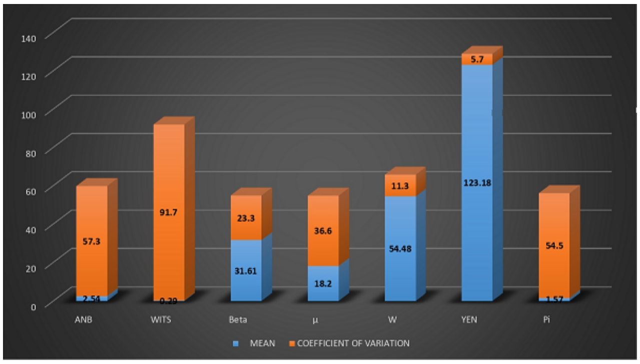

Figure 1: Coefficient of variation for pooled group

2.2. Subjects were selected under the following

2.2.1. Inclusion criteria

1. Down's facial angle between 82° and 95° for Class I, less than 82° for Class II, and more than 95° for Class III skeletal pattern.
2. Age group: 18 to 25 years.
3. Permanent dentition with no missing teeth.
4. No previous history of orthodontic treatment.
5. No craniofacial malformations or facial disfigurement.
6. High quality pretreatment cephalometric radiograph.

2.2.2. Exclusion criteria

1. Previous orthodontic and orthognathic surgical treatment.
2. Congenital defects and any marked facial deformity.
3. Medical history.

2.3. Methods of analyzing lateral cephalograms

All the tracings were made on 0.002" acetate tracing papers (Captain Ortho) using a 3H pencil. A single operator performed all the tracings in a standardized manner to avoid inter-operator errors. Samples were assigned to Class I, II, and III skeletal groups according to the above-mentioned criteria of selection. The Wits appraisal, ANB, Beta, Yen, W, μ and Pi angle were measured for each patient in all the three groups. In order to check the intra-operator reliability, a total of 20 cephalograms were selected randomly and traced for both angular and linear measurements by the same operator twice to eliminate memory bias. Cephalometric points and reference planes were used in the study.

2.4. Landmarks used commonly in this study were as follows

Skeletal, Dental and Soft tissue structures were then traced and landmarks were taken and identified as defined by Alexander Jacobson [12] and Thomas Rakosi. [13]

1. *Point A:* The deepest midline point on the premaxillae between the ANS and prosthion.
2. *Point B:* The most posterior point in the concavity between infradentale and pogonion.
3. *Point C:* The center of the condyle, found by tracing the head of the condyle and approximating its center.
4. *Point G:* The center of the largest circle that is tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphysis.
5. *Point M:* Midpoint of the premaxillae.
6. *Point S:* Midpoint of the Sella turcica.
7. *Point N:* Most anterior point of the frontonasal suture in the median plane.
8. *Sella Nasion plane (SN plane):* Line extending from sella to nasion.
9. *Functional occlusal plane:* Line extending through the first molars and premolars.

ANB angle utilizes skeletal landmarks Nasion, Point A (maxilla) and Point B (mandible). The angle formed by lines connecting between them are measured. [7] Beta angle uses 3 skeletal landmarks - point A, point B, and the apparent axis of the condyle (C). Three lines drawn are connected: C point and B point, A and B points and a line perpendicular to the C-B line. Finally, the β angle is measured between the perpendicular line and the A-B line. It indicates the severity and the type of skeletal dysplasia in the sagittal dimension. [8] μ angle uses three anatomic landmarks: point A, point B and mandibular plane. The angle is formed between AB line and perpendicular line from point A to mandibular plane is measured. [9] Pi angle utilizes the skeletal landmarks G and M points to represent the mandible and maxilla, respectively. The reference plane utilized in measuring the Pi angle is the true horizontal, a line perpendicular to the true vertical obtained in natural head position (NHP). The Pi angle is constructed in the following manner: A perpendicular line is drawn from G point to intersect the true horizontal at G', with a further line constructed from G' to M point. Connecting the points G'G and G'M forms the angle GG'M, or Pi angle. The name is chosen because the angle resembles the symbol Pi (π) in geometry. [12]

Yen angle utilizes skeletal landmarks - point S, point M, and point G. The angle formed between, the S-M line and the M–G line is measured. The angle indicates the severity and the type of skeletal dysplasia in the sagittal dimension. [10] W angle is measured between the perpendicular line drawn from point M to S–G line and the M–G line. It indicates the severity and the type of skeletal dysplasia in the sagittal dimension. [11] Wits appraisal is 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 occlusal plane which is drawn through the region of maximum cuspal interdigitation. The points of contact on the occlusal plane from points A and B are labeled AO and BO, respectively. [14]

3. Statistical Analysis

The data were collected, tabulated, and statistically analyzed using as follows:

1. One-way analysis of variance to determine whether there was any statistically significant difference between the mean values of all the seven parameters.
2. Post hoc assessment.
3. Chi-square test.
4. Correlation coefficients between the 7 parameters were calculated using Pearson correlation to determine which combination would produce a higher value.

4. Results

The most homogenously distributed and variable parameter was observed by Yen angle (5.7%) followed by W angle (11.3%), Beta angle (23.3%), μ angle (36.6%), Pi angle (54.5) and the least homogenous was ANB angle (57.3%). The linear parameter Wits Appraisal (91.7) showed the least homogenous distribution. (Table 1) (Figure 1)

When sexual dimorphism was compared for all the seven parameters using multivariate analysis, no statistically significant result (P>0.05) were observed in all the three skeletal groups. A statistically significant differences (P<0.01) were found for each parameter when comparison of each parameter were done of the total sample for the three skeletal patterns using ANOVA analysis (Table 2)

4.1. The mean value and standard of deviation of all the three skeletal groups for the 7 parameters are as follows:

4.1.1. ANB angle

1. *In Class I skeletal pattern group:* The mean value for ANB angle in Class I skeletal pattern group was 2.78° with a standard deviation of 0.83°
2. *In Class II skeletal pattern group:* The mean value for ANB angle in Class II skeletal pattern group was 6.18° with a standard deviation of 1.45°
3. *In Class III skeletal pattern group:* The mean value for ANB angle in Class III skeletal pattern group was -1.33° with a standard deviation of 1.80°

Table 1: Range of measurements for pooled group

Parameters	N	Min	Max	Mean	SE	SD	Coefficient of variation
ANB	120	-5	10	2.54	30	3.38	57.3
WITS	120	-6	8	0.29	.30	3.37	91.7
Beta	120	16	48	31.61	.67	7.36	23.3
μ	120	0	31	18.20	.60	6.6	36.6
W	120	33	67	54.48	.56	6.16	11.3
YEN	120	102	140	123.18	.63	6.99	5.7
Pi	120	-5	6	1.57	.71	2.75	54.5

Table 2: Descriptive and comparative statistics using ANOVA among the threeskeletal relations for the total sample

Variables	Class	N	Mean	Std. Deviation	F-test	Sig. (P-value)
	Class I	40	2.78	0.83	280.240	0.001*
ANB	Class II	40	6.18	1.45		
	Class III	40	-1.33	1.80		
	Class I	40	-0.15	0.66	238.905	0.001*
Wits	Class II	40	4.33	2.04		
	Class III	40	-2.95	1.47		
	Class I	40	31.50	3.80	69.876	0.001*
ß	Class II	40	25.05	4.96		
	Class III	40	38.30	6.03		
	Class I	40	18.05	4.90	39.973	0.001*
μ	Class II	40	13.10	5.41		
	Class III	40	23.45	5.22		
	Class I	40	54.35	3.49	72.900	0.001*
W	Class II	40	48.95	5.19		
	Class III	40	60.15	3.53		
	Class I	40	122.68	4.62	59.417	0.001*
YEN	Class II	40	117.40	4.60		
	Class III	40	129.48	5.62		
	Class I	40	2.93	1.35	383.698	0.001*
Pi	Class II	40	7.48	1.63		
	Class III	40	-1.93	1.56		

4.1.2. Beta angle

1. In Class I skeletal pattern group: The mean value for Beta angle in Class I skeletal pattern group was 31.50° with a standard deviation of 3.80°
2. In Class II skeletal pattern group: The mean value for Beta angle in Class II skeletal pattern group was 25.05° with a standard deviation of 4.96°
3. In Class III skeletal pattern group: The mean value for Beta angle in Class III skeletal pattern group was -1.33° with a standard deviation of 1.80°

4.1.3. Pi angle

In Class I skeletal pattern group: The mean value for Pi angle in Class I skeletal pattern group was 2.93 ° with a standard deviation of 1.35°

In Class II skeletal pattern group: The mean value for Pi angle in Class II skeletal pattern group was 7.48° with a standard deviation of 1.63°

In Class III skeletal pattern group: The mean value for Pi angle in Class III skeletal pattern group was -1.93° with a standard deviation of -1.93°

4.1.4. μ angle

1. In Class I skeletal pattern group: The mean value for μ angle in Class I skeletal pattern group was 18.05° with a standard deviation of 4.90°
2. In Class II skeletal pattern group: The mean value for μ angle in Class II skeletal pattern group was 13.10° with a standard deviation of 5.41°
3. In Class III skeletal pattern group: The mean value for μ angle in Class III skeletal pattern group was 23.45° with a standard deviation of 5.22°

4.1.5. Yen angle

1. *In Class I skeletal pattern group:* The mean value for Yen angle in Class I skeletal pattern group was 122.68 ° with a standard deviation of 4.62°

Table 3: Post hoc assessment

Dependent Variable	Class (A)	Class (B)	Mean	Sig. (P- value)
	Class I	Class II	-3.40	0.001*
ANB	Class I	Class III	4.10	0.001*
	Class II	Class III	7.50	0.001*
	Class I	Class II	-4.48	0.001*
WITS	Class I	Class III	2.80	0.001*
	Class II	Class III	7.28	0.001*
	Class I	Class II	6.45	0.001*
ß	Class I	Class III	-6.80	0.001*
	Class II	Class III	-13.25	0.001*
	Class I	Class II	4.95	0.001*
μ	Class I	Class III	-5.40	0.001*
	Class II	Class III	-10.35	0.001*
	Class I	Class II	5.40	0.001*
W	Class I	Class III	-5.80	0.001*
	Class II	Class III	-11.20	0.001*
	Class I	Class II	5.28	0.001*
YEN	Class I	Class III	-6.80	0.001*
	Class II	Class III	-12.08	0.001*
	Class I	Class II	-4.55	0.001*
Pi	Class I	Class III	4.85	0.001*
	Class II	Class III	9.40	0.001*

2. *In Class II skeletal pattern group:* The mean value for Yen angle in Class II skeletal pattern group was 117.40° with a standard deviation of 4.60°
3. In Class III skeletal pattern group: The mean value for Yen angle in Class III skeletal pattern group was 129.48° with a standard deviation of 5.62°

4.1.6. W angle

1. In Class I skeletal pattern group: The mean value for W angle in Class I skeletal pattern group was 54.35° with a standard deviation of 3.49°
2. In Class II skeletal pattern group: The mean value for W angle in Class II skeletal pattern group was 48.95° with a standard deviation of 5.19°
3. In Class III skeletal pattern group: The mean value for W angle in Class III skeletal pattern group was 60.15° with a standard deviation of 3.53°

4.1.7. Wits appraisal

1. *In Class I skeletal pattern group:* The mean value for WITS in Class I skeletal pattern group was -0.15 ° with a standard deviation of 0.66°
2. *In Class II skeletal pattern group:* The mean value for WITS in Class II skeletal pattern group was 4.33° with a standard deviation of 2.04°
3. *In Class III skeletal pattern group:* The mean value for WITS in Class III skeletal pattern group was -2.95° with a standard deviation of 1.47° (Table 2)

The post hoc assessment showed all the parameters could differentiate among Class I, Class II and Class III skeletal pattern. But, Beta angle was found to be a good determinant to differentiate between the three groups followed by Yen angle. (Table 3)

The Chi-square test indicated Pi and ANB angle to be the most predictable with 100% accuracy and μ angle less predictable by giving only 47.5% accuracy for differentiating Class I cases. In Class II cases, the most predictable results were shown by Yen angle with 40.0% accuracy and ANB angle to be less predictable showing 0.0% result. In Class III cases 35.5% accuracy was shown by μ angle giving the most predictable result and ANB angle showed less accuracy by 0.0%. (Table 4)

Pearson's correlation test was done to determine statistically significant correlation (P<0.001) among the seven sagittal parameters for Class I, Class II and Class III skeletal relationship.

1. *Class I skeletal relationship*: A statistically significant positive correlation was observed between ANB angle and Pi angle (r=0.740), Yen angle and W angle (r=0.897). The strongest correlation result was seen between Yen and W angle.
2. *Class II skeletal relationship:* A statistically significant positive and negative correlation were observed among the parameters. Positive correlation was observed between ANB angle and Pi angle (r=0.593); Beta angle and μ angle(r=0.659). A significant negative correlation was observed only between ANB angle and Yen angle (r= -0.543). Among all the above mentioned statistically significant groups strong correlation in Class II was observed between

Table 4: Chi Square test for ANB, BETA, YEN, μ, W, Pi angle and wits appraisal

Parameters	Type of Malocclusion	Below Normal	Normal	Above Normal	χ^2 value
ANB	Class I	0 0.0%	40 100.0%	0 0.0%	139.130, p-value = 0.001*
	Class II	0 0.0%	0 0.0%	40 100.0%	
	Class III	11 27.5%	0 0.0%	29 72.5%	
Total		11 9.2%	40 33.3%	69 57.5%	
Beta	Class I	3 7.5%	35 87.5%	2 5.0%	113.358, p-value = 0.001*
	Class II	29 72.5%	10 25.0%	1 2.5%	
	Class III	0 0.0%	12 30.0%	28 70.0%	
Total		32 26.7%	57 47.5%	31 25.8%	
YEN	Class I	1 2.5%	23 57.5%	16 40.0%	67.752, p-value = 0.001*
	Class II	18 45.0%	16 40.0%	6 15.0%	
	Class III	1 2.5%	3 7.5%	36 90.0%	
Total		20 16.7%	42 35.0%	58 48.3%	
μ	Class I	17 42.5%	19 47.5%	4 10.0%	54.842, p-value = 0.001*
	Class II	32 80.0%	6 15.0%	2 5.0%	
	Class III	0 0.0%	12 30.0%	28 70.0%	
Total		32 26.7%	57 47.5%	31 25.8%	
W	Class I	3 7.5%	28 70.0%	9 22.5%	107.619, p-value = 0.001*
	Class II	26 65.0%	14 35.0%	0 0.0%	
	Class III	0 0.0%	12 30.0%	28 70.0%	
WITS	Class I	34 85.0%		6 15.0%	70.318, p-value = 0.001*
	Class II	1 2.5%		39 97.5%	
	Class III	0 0.0%		12 30.0%	
Total		32 26.7%		57 47.5%	
Pi	Class I	40 100.0%		0 0.0%	64.338, p-value = 0.001*
	Class II	10 25.0%		30 75.0%	
	Class III	0 0.0%		12 30.0%	
Total		32 26.7%		57 47.5%	

Table 5: Pearson's correlation analysis assessment for skeletal Class I, II, III

Variable		**ANB**	**WITS**	**ß**	μ	**W**	**YEN**	**Pi**
Class I								
ANB	Pearson Correlation	1.000	-0.249	-0.328	-0.192	-0.131	-0.213	0.740
	p-value		0.121	0.039	0.235	0.420	0.186	0.001*
WITS	Pearson Correlation	-0.249	1.000	0.305	0.216	0.134	0.109	-0.042
	p-value	0.121		0.055	0.181	0.409	0.501	0.798
BETA	Pearson Correlation	-0.328	0.305	1.000	0.478	0.437	0.290	0.038
	p-value	0.039	0.055		0.002	0.005	0.070	0.818
μ	Pearson Correlation	-0.192	0.216	0.478	1.000	0.207	0.002	-0.054
	p-value	0.235	0.181	0.002		0.199	0.991	0.742
W	Pearson Correlation	-0.131	0.134	0.437	0.207	1.000	0.897	0.028
	p-value	0.420	0.409	0.005	0.199		0.001*	0.866
YEN	Pearson Correlation	-0.213	0.109	0.290	0.002	0.897	1.000	-0.111
	p-value	0.186	0.501	0.070	0.991	0.001*		0.494
Pi	Pearson Correlation	0.740	-0.042	0.038	-0.054	0.028	-0.111	1.000
	p-value	0.001*	0.798	0.818	0.742	0.866	0.494	
				Class II				
ANB	Pearson Correlation	1.000	0.443	-0.479	-0.398	-0.495	-0.417	0.511
	p-value		0.004*	0.002*	0.011*	0.001*	0.007*	0.001*
WITS	Pearson Correlation	0.443	1.000	-0.446	-0.452	-0.531	-0.476	0.133
	p-value	0.004*		0.004*	0.003*	0.001*	0.002*	0.414
BETA	Pearson Correlation	-0.479	-0.446	1.000	0.588	0.703	0.439	-0.264
	p-value	0.002*	0.004*		0.001*	0.001*	0.005	0.099
μ	Pearson Correlation	-0.398	-0.452	0.588	1.000	0.487	0.285	-0.130
	p-value	0.011*	0.003*	0.001*		0.001	0.074	0.423
W	Pearson Correlation	-0.495	-0.531	0.703	0.487	1.000	0.677	-0.384
	p-value	0.001*	0.001*	0.001*	0.001*		0.001*	0.015
YEN	Pearson Correlation	-0.417	-0.476	0.439	0.285	0.677	1.000	-0.408
	p-value	0.007*	0.002*	0.005*	0.074	0.001*		0.009*
Pi	Pearson Correlation	0.511	0.133	-0.264	-0.130	-0.384	-0.408	1.000
	p-value	0.001*	0.414	0.099	0.423	0.015	0.009*	
				Class III				
ANB	Pearson Correlation	1.000	0.292	-0.187	-0.192	-0.098	-0.543	0.593
	p-value		0.067	0.248	0.235	0.549	0.001*	0.001*
WITS	Pearson Correlation	0.292	1.000	-0.325	-0.407	0.084	-0.014	0.475
	p-value	0.067		0.040	0.009*	0.607	0.931	0.002*
BETA	Pearson Correlation	-0.187	-0.325	1.000	0.659	0.332	0.267	-0.266
	p-value	0.248	0.040*		0.001*	0.036*	0.096	0.097
μ	Pearson Correlation	-0.192	-0.407	0.659	1.000	0.163	0.197	-0.122
	p-value	0.235	0.009*	0.001*		0.316	0.224	0.454
W	Pearson Correlation	-0.098	0.084	0.332	0.163	1.000	0.340	-0.027
	p-value	0.549	0.607	0.036*	0.316		0.032*	0.867
YEN	Pearson Correlation	-0.543	-0.014	0.267	0.197	0.340	1.000	-0.176
	p-value	0.001*	0.931	0.096	0.224	0.032*		0.276
Pi	Pearson Correlation	0.593	0.475	-0.266	-0.122	-0.027	-0.176	
	p-value	0.001*	0.002*	0.097	0.454	0.867	0.276	

Beta angle and μ angle.

3. *Class III skeletal relationship:* A statistically significant positive and negative correlation was observed among the parameters. Positive correlation were observed between ANB angle and Pi angle (r= 0.511); Beta angle and μ angle (r= 0.588); Beta angle and W angle (r= 0.703); W angle and Yen angle (r= 0.677). A significant negative correlation was observed among ANB angle and W angle (r= -0.495); Wits and W angle (r = -0.531). Among all the above mentioned statistically significant groups, strong correlation in Class III was observed between Beta angle and W angle. (Table 5)

An Intra-observer reliability test was done by using a total of 20 cephalograms which were selected randomly. These were traced and both angular and linear measurements were evaluated by the same operator twice with an interval of 4 weeks between tracing to eliminate memory bias. Dahlberg's error test was carried out to check the error between repeated measurements which suggested no statistically significant difference between the first and second radiographic measurements showing intra-observer reliability (P>0.05). The values varied from 0.874-0.932 showing good to excellent reliability.

5. Discussion

An accurate antero-posterior measurement of jaw relationship is critically important in orthodontic treatment planning.[15] Numerous factors other than the skeletal pattern influence the facial profile: size and shape of the nose, thickness and posture of the lips, the morphology of tissues over the symphysis and the inclination of incisors are some of the factors that contribute to the soft tissue profile.[16] Nevertheless, the sagittal apical base relationship of the jaws is the most significant factors.[17]

Lateral cephalometric radiograph is an extremely useful diagnostic tool in orthodontic practice which was introduced in the year 1931 by Broadbent.[3] Wylie was the first to assess the jaws in AP plane, then number of angular and linear measurements were introduced. In cephalometrics, both angular and linear variables have been proposed to analyze sagittal jaw relationship and jaw position.[15] Angular measurements can be erroneous as a result of changes in facial height, jaw inclination, and total jaw prognathism; linear variables can be affected by the inclination of the reference line. However, each of the methods exhibits its own inherent weakness, based on variability of factors other than the jaw relationship itself.[18]

Various angular parameters have been formulated to assess jaw discrepancies in the sagittal plane. Riedel's[7,18] ANB angle formed between SNA and SNB angles is the most frequently used cephalometric parameter for representing the sagittal skeletal inter- maxillary discrepancy, there are numerous studies that suggest that this angle is not sufficiently reliable enough in the diagnosis of skeletal classification.[19,20] In an attempt to overcome the limitations of ANB angle, a need for other indicators has emerged.

To overcome problems related to the ANB angle in 1975, Wits appraisal was introduced by Jacobson.[14] It is a simple method whereby the severity or degree of anteroposterior jaw dysplasia may be measured on a lateral cephalometric head film. The method entails drawing perpendicular from points A and B on the maxilla and mandible, respectively, onto the occlusal plane. The points of contact of the perpendiculars onto the occlusal plane are labeled AO and BO, respectively. The sample selected were adults and on the basis of excellence of occlusion, it was found, on the average, that in females points A0 and BO coincided and in males point BO was located 1 mm ahead of point AO.

There are studies which suggested, Wits appraisal has apparent drawbacks in the diagnosis of skeletal classification as it relates with points A and B to the functional occlusal plane; this generates 2 major problems. First, accurate identification of the occlusal plane is not always easy or accurately reproducible, especially in mixed dentition patients or patients with openbite, severe cant of the occlusal plane, multiple impactions, missing teeth, skeletal asymmetries, or steep curve of Spee. Second, any change in the angulation of the functional occlusal plane, caused by either normal development of the dentition or orthodontic intervention, can profoundly influence the Wits appraisal.[8,20]

The Beta angle, a new measurement for assessing the skeletal discrepancy between the maxilla and the mandible in the sagittal plane, was introduced by Baik et al.[8] in 2004. It uses 3 skeletal landmarks—point A, point 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.

5.1. Lines were defined

1. Line connecting the center of the condyle C with B point (C-B line).
2. Line connecting A and B points.
3. Line from point A perpendicular to the C-B line.

Finally, the Beta angle measured between the perpendicular line and the A-B line.

The reproducibility of condyle is questionable this led to the development of new angles, i.e., W and Yen angle. Both the measurements utilize stable landmarks such as Sella, M point, and G point. Yen angle introduced by Neela et al.[10] in 2009 which was developed in the Department of Orthodontics and Dentofacial Orthopaedics, Yenepoya Dental College, Mangalore, Karnataka, India, and hence its name. The advantage of Yen angle, it is not influenced by growth changes and can be easily used in mixed dentition. 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. Yen angle is also found to be reliable in the assessment of anteroposterior discrepancies of jaws.

W angle was introduced by Bhad et al.[11] in 2011 and it was measured between the perpendicular from point M on S–G line and the M–G line. W angle is supposed to remain fairly stable even with vertical growth and rotation of jaws as it is not influenced by functional occlusal plane. 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. However, precisely tracing the premaxilla and locating its center is not always easy. To accurately use this angle, the cephalometric X-rays must be high quality. In Class II and Class III skeletal cases, similar to Beta angle, W angle cannot determine which jaw is prognathic or retrognathic.[21]

A new parameter Pi angle was introduced by Kumar et al.[12] in 2012 for the assessment of antero-posterior jaw relationship. Pi angle utilizes extracranial, stable, and relate to the true vertical or a true horizontal perpendicular to it. Pi angle assesses true anteroposterior skeletal patterns even when clockwise or counterclockwise rotation of the jaws would tend to camouflage it. Interpretation of the Pi angle is similar to the ANB angle. The limitation of the Pi angle may include the use of the true horizontal plane passing through nasion. It is evident from literature that during growth, nasion point moves upwards and forward.[21]

However, more recent studies have shown that there is no perfect and absolutely reliable parameter for assessing sagittal skeletal relationship. In this respect, there is a clinical recommendation that several indicators should be used to determine more realistic skeletal diagnosis. However, the interchangeability among various jaw relationship parameters and the underlying factors should be clearly understood. The present study was designed to analyze the angular (ANB angle, Beta angle, μ angle, W angle, and Pi angle, Yen angle) and linear (Wits appraisal) cephalometric measurements used to indicate antero-posterior jaw relationship and assess their reliability.

From this present study, it was found that the value of 7 parameters was significantly ($P < 0.001$) different in all the three skeletal pattern groups. (Table 2)

From this present study, it was found that the mean value of Yen angle recorded in the present study of Yen angle was (Class I= 122.68 ±4.62, Class II= 117.40±4.60, Class III=129.48±5.62). The mean value stated by Neela et al.[10] for Yen Angle in skeletal Class I subject was 120.5 ± 2.9, skeletal Class II was 114 ± 3.6, skeletal Class III was 129 ± 4.6. Thus, the results of this were in accordance with the above study. Yen angle also expressed least coffecient of variation(CV=5.7) and was found to be homogenously distributed as compared to the other six predictors. Similar results were observed in a study conducted by Venkata et al.,[21] Doshi et al.[22] (CV=1.01) T, Katti et al.[23] (CV=1.01), Mittal et al.[24] (0.071) who compared Yen angle with other sagittal jaw parameters and found it to be highly reliable and the most homogenously distributed angular parameter to assess antero-posterior discrepancies.

The mean value of W angle in this study showed were (Class I = 54.35±3.49, Class II=48.95±5.19, Class III= 60.15±3.53). This was in accordance with a study done by Bhad et al.[11] and it is the second most homogenous and reliable angular sagittal discrepancy parameter as the coefficient of variability is (CV=11.3) which were similar to the results observed by Mittal et al.[24] (CV = 0.127) where after Yen angle W angle was the predictable parameter.

The mean value of Beta angle in this study was (Class I =31.50±3.80, Class II= 25.05±4.96, Class III= 38.30±6.03). The mean value result of Beta angle for skeletal Class I subject was 31.1 ± 2, skeletal Class II was 24.5 ± 3, skeletal Class III was 40.0 ± 4.2 as stated by Baik et al.[8] Thus, the results of this study were in accordance with the above study.

Whereas the coefficient of variability (CV=23.3) was lower than that of ANB angle, μ angle and Wits appraisal which was in accordance with the study done by Kannan et al.[25] where Beta angle showed a lower coefficient of variability (CV= 3.58) when compared to ANB angle (CV=11.05). Similar results was also observed by Doshi et al.[22] who found a lower coefficient of variability for Beta angle (CV=5.63) in comparison to ANB angle (CV=22.53).

In the present study the mean value of μ angle was (Class I=18.05±4.90, Class II= 13.10±5.41, Class III= 23.45±5.22) and also showed a coefficient of variability (CV=36.6) lower than that of ANB angle and Wits appraisal. This may be due to the fact that the rotation of lower jaw from temporomandibular joint area or the rotation of mandibular body does not really influence the μ angle as A and B points change their position.[9,25]

From this study the mean value result of Pi angle was (Class I= 2.93±1.35, Class II= 7.48±1.63, Class III= -1.93±1.56). Kumar et al.[12] stated the mean value for Pi angle in his study for skeletal Class I subject was 3.40 ± 2.04, skeletal Class II was 8.94 ± 3.16, skeletal Class III was − 3.57 ± 1.61. Thus, the results of this study were similiar with the study done by Kumar et al.,[12] Bohra et al.,[26] and it also showed the maximum coefficient of variability (CV=0.73) and least homogenous distribution.

Since the introduction of ANB angle by Riedel,[7] it has been a very popular method to assess the skeletal sagittal jaw relationship. The present study showed the mean value for skeletal (Class I= 2.78±0.83, Class II= 6.18±1.45, Class III= -1.33±1.80), with maximum coefficient of variability (CV=57.3) and least homogenous distribution on comparison to other angular measurements.[24,27,28] This is in accordance to the study done by Kannan et al.[29] where ANB angle showed a high coefficient of variability (CV=11.05) when compared to other angular and linear parameters used for assessing sagittal jaw relationships. Kapoor et al. concluded that ANB angle can be misleading in assessment of antero-posterior discrepancy and this could be attributed to changes in SN plane and rotational effects of jaw which would affect the ANB angle as also observed by Jacobson,[6] Chang[30] andBrown.[31]

Wits appraisal mean value result of this study for skeletal (Class I =-0.15±0.66, Class II= 4.33±2.04, Class III= -2.95±1.47) and also gave the highest coefficient of variation (CV=91.7) indicating that it was the least reliable parameter among the six parameters. This result were in accordance with the study done by Erum et al.[32] (CV=828.1) and Oktay[33] (CV=952.81) where Wits appraisal showed the greatest coefficient of variability when compared to other parameters used for assessing sagittal jaw relationships. The results of the present study showed the following seven sagittal parameters in increasing order of their coefficient of variation (Table 1).

Yen (5.7) > W (11.3) > β (23.3) > μ (36.6) > ANB (57.3) > Wits (91.7)

For skeletal Class I, Class II and Class III, the sexes were combined in the ratio of 1:1 for each group (n=40) and comparison was done for three skeletal pattern using ANOVA analysis, a statistically significant differences were found for each parameter used in this study. The finding were in accordance to the study done by Bohra et al.[26] (Table 2)

The post hoc assessment results showed, all the parameters could differentiate among Class I, Class II and Class III skeletal pattern. However, the most significant values were represented by Beta angle followed by Yen angle, W angle. The result of the present study were not in accordance with the study done by Bohra et al.[26] where Yen angle indicated a very good determinant to differentiate between the three groups. But in this study, Yen angle is the second most predictable parameter after Beta angle. (Table 3)

The Chi-square test indicated Pi and ANB angle to be the most predictable with 100% accuracy and μ angle less predictable by giving only 47.5% accuracy for differentiating skeletal Class I cases. In skeletal Class II cases, the most predictable results were shown by Yen angle with 40.0% accuracy and ANB angle to be less predictable showing 0.0% result. In skeletal Class III cases 35.5% accuracy was shown by μ angle giving most predictable result and ANB angle showed less accuracy by 0.0%. (Table 4)

Pearson's correlation analysis showed significant correlations among the seven sagittal parameters (P<0.001) for Class I, Class II and Class III skeletal relationship.

1. *For Class I skeletal relationship:* A statistically significant positive correlation were observed between ANB angle and Pi angle (r=0.740); Yen angle and W angle(r=0.897). The strongest correlation result was observed between Yen and W angle.
2. *For Class II skeletal relationship:* A statistically significant positive and negative correlation were observed among the parameters. Positive correlation were observed between ANB angle and Pi angle (r=0.593); Beta angle and μ angle(r=0.659). A significant negative correlation were observed only between ANB angle and Yen angle (r= -0.543). Among all the above mentioned statistically significant groups strong correlation in Class II was observed between Beta angle and μ angle.
3. *For Class III skeletal relationship:* A statistically positive and negative correlation was observed among the parameters. Positive correlation were observed between ANB angle Pi angle (r= 0.511); Beta angle and μ angle (r= 0.588); Beta angle and W angle (r= 0.703); W angle and Yen angle (r= 0.677). A significant negative correlation was observed among ANB angle and W angle (r= -0.495); Wits and W angle (r = -0.531). Among all the above mentioned statistically significant groups strong correlation in Class III was observed between Beta angle and W angle. (Table 5)
4. The results of the study show no significant correlation between Yen Angle and Beta angle in all the three skeletal groups and this could be attributed to the difficulty in the approximation of the centre of condyle as stated by Baik and Ververidou[8] and Bohra et al.[26]

6. Conclusion

The following conclusion can be drawn from the study:

1. Amongst the seven sagittal parameters Yen angle was found to have the most homogenous distribution and minimum coefficient of variability to assess the antero-posterior dysplasia
2. Wits appraisal had the least homogenous distribution with maximum coefficient of variability.
3. The most predictable parameter for differentiating skeletal Class I, Class II, Class III cases were Pi and ANB angle, Yen angle and μ angle respectively.
4. Yen angle showed a significant correlation with W angle for skeletal Class I subjects, Beta angle with μ angle for skeletal Class II subjects and Beta angle with W angle for skeletal Class III subjects showing that these sagittal parameters can be equally reliable and therefore, can be used interchangeably in assessing skeletal jaw relationship.

5. No statistically significant correlation existed between Yen angle and Beta angle in all the three skeletal groups.

However, as the above mentioned angular and linear parameters share some degree of correlation amongst them hence, it is suggested that clinician should not rely on a single parameter for diagnosis and treatment planning and verification with other measurements is advisable for better results.

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8. Conflict of Interest

None.

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