Original Research Article

Cephalometric analysis for assessing sagittal jaw relationship- A comparative study

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ABSTRACT

The successful treatment of Orthodontic patient is dependent on careful diagnosis. Three planes of discrepancies are commonly described in orthodontics namely, transverse, sagittal and vertical. Of these, the sagittal discrepancies are most commonly encountered in day to day practice. This study was aimed to compare various methods of cephalometric analysis for assessing sagittal jaw relationship.

Materials and Methods: There were total of 180 lateral cephalograms used and each samples were divided into 2 groups based on their skeletal relationship according to ANB angle. i.e Class I and Class II. Class I and Class II were again divided into average, horizontal and vertical group. Pretreatment records were taken and tracing were performed on the lateral cephalogram and measured values were recorded and subjected to statistical analysis.

Results: In class I, the highest frequency was seen in A-B plane angle and FABA angle and in class II the highest frequency found in K angle followed by A-B plane angle. In class I horizontal group, a strong level of agreement was found between AXB angle with AF-BF distance while in class II average group, A-B plane angle shows strong level of agreement with WITS and FABA angle. In terms of reliability, all the ten parameters (A-B plane angle, WITS, AF-BF distance, APP-BPP distance, FABA angle, BETA angle, YEN angle, W angle and K angle) show good reliability in class II average and vertical group.

Conclusion: No single measurement is perfect in all the cases. A combination of different measurements should be used to have a true assessment of sagittal jaw relationship.

1. Introduction

In orthodontic diagnosis and treatment planning, cephalometric radiograph is considered to be a valuable tool. Three planes of discrepancies are commonly described in orthodontics namely, transverse, sagittal and vertical. Of these, the sagittal discrepancies are most commonly encountered in day to day practice. Angular and linear measurements have been incorporated into various cephalometric analyses to help the clinician for diagnosing these antero-posterior discrepancies.[1] Assessing these sagittal relationship is a challenging issue in orthodontics.

The evaluation of sagittal jaw relationship between maxilla and mandible has been one of the major problem in the field of orthodontics, which is of prime importance in diagnosis and treatment planning. This is because influence of growth at point A and B, rotations of jaws during growth, vertical relationships between the jaws and reference planes, and a lack of validity of the various methods proposed for their evaluation and appropriate treatment plan.[2] The sagittal relationship is usually of utmost concern to the patient and needs a critical evaluation.

Clinicians with increasing frequency are treating malocclusions in conjunction with orthognathic surgery. With Broadbent's introduction of the cephalometer in 1931, a new era of cephalometrics began in orthodontics with numerous cephalometric measurements been devised.[3]

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Cephalometrics has been adapted as an important clinical tool for assessment of jaw relationship in all the three planes-antroposterior, transverse and vertical being an integral part of orthodontic treatment plan.

2. Aim & Objectives of the study

1. To compare the various methods of cephalometric analysis for assessing sagittal jaw relationship.
2. To determine the level of agreement between these methods.
3. To evaluate which of the criteria is more reliable for clinicians.

2.1. Source of the data

The study was carried out in the Department of Orthodontics &DentofacialOrthopedics, Kothiwal Dental College & Research Centre, Moradabad, UP and a total of 180 lateral cephalograms used for the study. The study samples were divided into 2 groups based on their skeletal relationship according to ANB angle. i.e Class I and Class II.
Class I and II was further divided into three groups on the basis of their growth pattern.

Table 1:

ANB Angle	Groups	Number of Patients (n)	Sella Nasion-Mandibular plane Angle (SN-GoGn angle)[4]	Growth pattern
0^0-4^0	Class I	90	$<31^0$= Horizontal	Horizontal=30
			31^0-34^0= Average	Average=30
			$>34^0$= Vertical	Vertical=30
4^0-8^0	Class II	90	$<31^0$= Horizontal	Horizontal =30
			31^0-34^0= Average	Average =30
			$>34^0$= Vertical	Vertical=30

2.2. Eligibility criteria

2.2.1. Inclusion criteria
1. Class I and Class II patients.
2. For Class I, ANB angle should be 0^0 to $4^0$and for class II ANB angle should be a range of 4^0-8^0
3. Age group of 13-30 years.
4. No previous orthodontic treatment.

2.2.2. Exclusion criteria
1. Subjects with congenital anomalies/syndromes.
2. Subjects with marked asymmetries.
3. History of facial trauma.

2.3. Tracing of lateral cephalograms

All the cephalograms were traced on a standard acetate paper of 8"x10" size and 0.003" thickness by a standard technique using a soft 3H pencil using a view box. Tracings were done in a darkened room with no additional light. On the tracing sheets the cephalometric analysis of all the ten parameters were performed and each measured values were recorded. All the tracings were done by a single observer.
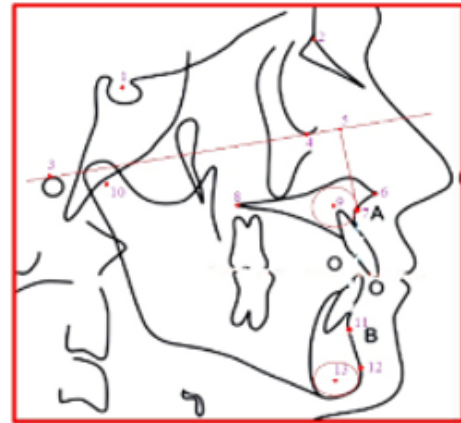
Fig. 1: Showing various landmarks
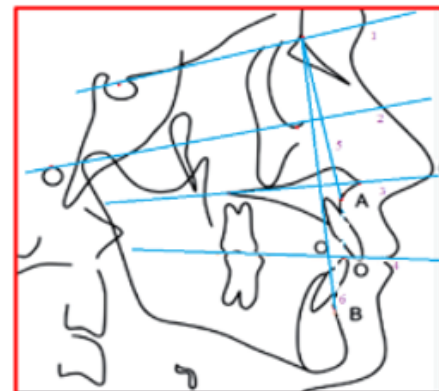
Fig. 2: Showing various planes and lines in the study

2.3.1. Landmarks
1. **S: Sella**[4] Geometric center of the pituitary fossa located by visual inspection
2. **N: Nasion**[4] Most anterior point on the frontonasal suture in the midsagittal plane
3. **Po: Porion.** [4]Most superiorly positioned point of the external auditory meatus located by using the ear rods of the cephalostat (mechanical porion).
4. **Or: Orbitale.** [4]Lowest point on the inferior rim of the orbit.
5. **Point X:** [5]A perpendicular is constructed from point A to FH plane.

6. **ANS: Anterior nasal spine.** [4]The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.
7. **Point A: Subspinale.** [4] Most posterior midline point in the concavity between the anterior nasal-spine and the prosthion.
8. **PNS: Posterior nasal spine** [4] Posterior spine of the palatine bone constituting the hard palate
9. **Point M:** [6] Mid-point of anterior maxilla
10. **Point C:** [7] Apparent axis of the condyle
11. **Point B: Suprarnentale.** [4]Most posterior midline point in the concavity of the mandible between the most superior point on the alveolar hone overlying the lower incisors (infradentale) and pogonion.
12. **Pog:** Pogonion [4] Point on the bony symphysis tangent to the facial plane
13. **Point G:** [8]Centre of largest circle placed at tangent to the internal anterior, inferior and posterior surface of mandibular symphysis.
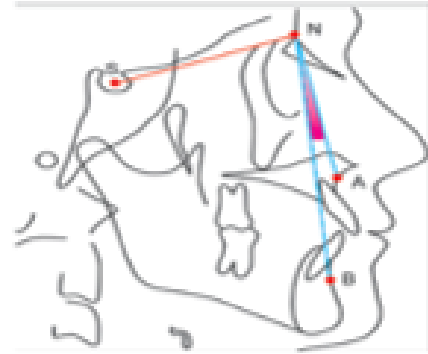
2.3.2. Planes and lines

1. **Sella-Nasionplane:** It is the anteroposterior extent of anterior cranial base.
2. **FH plane:** Extends from porion to orbitale.
3. **Palatal plane (ANS-PNS)** - It is a linear measurement from point ANS to point PNS.
4. **Occlusal plane:** It is formed by joining mid points of overlap of M-B cusps of first molars and the buccal cusps of the first premolars.
5. **N-A line**: line extends from nasion to point A.
6. **N-B lin**e: line extends from nasion to point B.
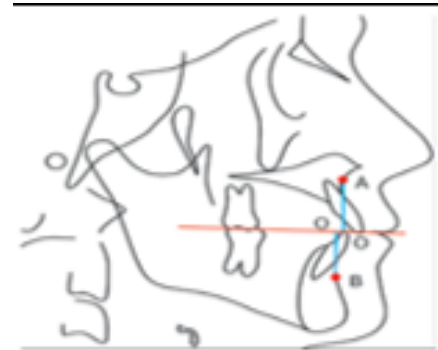
2.4. Parameters used in the study
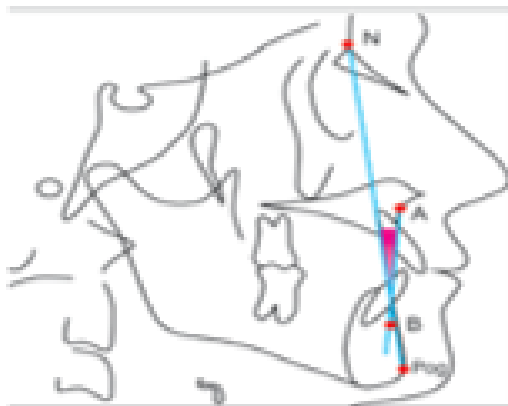
Fig. 3: A-B PLANE [9]

2.5. Statistical analysis

The data of the study was subjected to Comparative test, Cohen's Kappa coefficient and Cornbach's alpha test.

Fig. 4: ANB ANGLE [10]

Fig. 5: WITS APPRASIAL [11]

Fig. 6: AXB ANGEL [5]

Fig. 7: AF-BF DISTANCE [12]
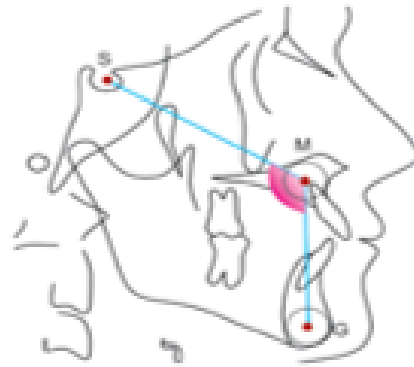
Fig. 10: YEN ANGEL [6]

Fig. 8: FABA ANGLE [13]
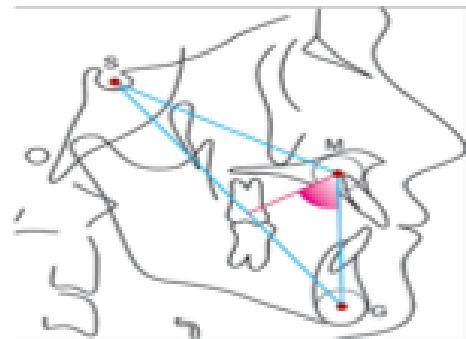
Fig. 11: W-ANGEL [8]
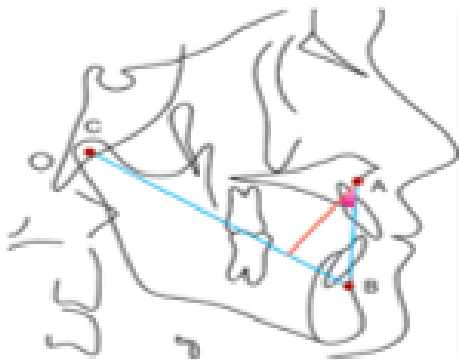
Fig. 9: BETA ANGELS [7]

Fig. 12: APP-BPP DISTANCE [14]
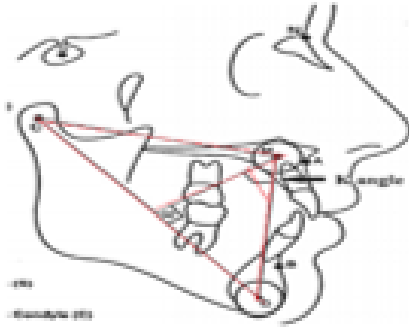
Fig. 13: K-ANGEL [15]

Before conducting a study, the examiner were trained and calibrated, a pilot study was performed by using intra examiner reliability (kappa) formula on 10 patients and the reliability was found to be 0.80-0.90 which is satisfactory.

Table 2: Interpretation of Cohen's kappa.

Value of Kappa	Level of Agreement
0–.20	None
.21–.39	Minimal
.40–.59	Weak
.60–.79	Moderate
.80–.90	Strong
Above.90	Almost Perfect

Table 3: Interpretation of Cornbach's alpha.

Cornbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3. Results

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Table 11 describes the Cornbach's alpha value for Class I average, horizontal and vertical group among different parameters in which AF-BF distance is the most reliable parameter with highest cornbach's alpha value (0.609) in class 1 average, however the internal consistency is questionable.

Table 12 Class II average group, YEN∠ shows the highest alpha value (0.849) along with W ∠ (0.841) and K ∠ (0.816) with good reliability.

4. Discussion

In orthodontic diagnosis both angular and linear cephalometric variables have been proposed to analyse sagittal jaw relationship and jaw position. This study attempted to analyse different cephalometric parameters which were used to indicate the sagittal jaw relationship in Class I, and II malocclusions and also to find the reliability and level of agreement between these parameters in assessment of sagittal jaw discrepancy. These variables can be erroneous as the angular variables can be affected by changes in facial height, jaw inclination, and total jaw prognathism, whereas linear variables can be affected by the inclination of the reference line. In the current study, seven angular and three linear variables had been used to assess the antero-posterior jaw relationship. AB plane ∠ , AXB ∠, FABA ∠, YEN ∠, K ∠, Beta ∠, W ∠ were the angular variables and Wits appraisal AF-BF distance, APP-BPP distance were the three linear variables. All the parameters were found to be equally significant in assessing the antero-posterior discrepancy like previous studies. [16,17] However, each of the parameters had their own merits and demerits; hence, it becomes important to find which one is more reliable for the clinician.

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. Taylor and Nanda [18,19] have shown that position of nasion is not fixed during growth, and any displacement of nasion directly affects ANB angle. Furthermore, rotation of the jaws by either growth or orthodontic treatment can also change the ANB. To overcome this, the Wits appraisal was introduced which 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. Occlusal plane can be easily affected by tooth eruption and dental development as well as by orthodontic treatment. [20]

Nanda [19] in 1994 said that linear measurements has distinct advantages over angular measurements in that there are fewer variables to affect the accuracy of the linear measurement, and there is less error of measurement. Angular changes are complex measurements because in any angular measurement the position of three points is involved. The effect of angular changes also becomes larger as you move away from the vertex of the angle being measured. For these reasons it was decided to use linear measurements in his study and he used palatal plane and found it stable.

A popular recent alternative, Beta angle avoided use of functional plane and is not affected by jaw rotations. But it uses points A and B, which can be remodelled by orthodontic treatment and growth. [21,22] Furthermore, as shown by various studies, the reproducibility of the location of condylion on closed-mouth lateral head films is limited. [23] Instead of condylion, centre of condyle could be used, but

Table 4: Comparison of ten parameters in Class I and Class II

	Class I			Class II		
	Average %	Horizontal %	Vertical %	Average %	Horizontal %	Vertical %
A-B PLANE ∠	100	100	96.6	53.3	83.33	80
WITS apprasial	96.6	93.3	100	53.33	66.66	46.6
AXB ∠	90	90	86.6	53.3	50	100
AF-BF Distance	73.3	86.6	70	66.6	56.6	86.6
APPP-BPP distance	90	93.3	93.3	53.33	50	86.6
FABA ∠	100	96.6	100	53.33	26.6	66.6
BETA ∠	76.6	63.33	66.6	26.6	76.6	46.6
YEN ∠	66.6	60	73.3	63.33	50	73.3
W ∠	73.3	56.6	90	60	56.6	73.3
K ∠	73.3	63.33	60	77.6	86.66	80

Table 5: Class I average with Cohen's Kappa values

	WITS apprasial	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN ∠	W ∠	K ∠
A-B PLANE ∠	.000	.000	.000	.000	.000	.000	.000	.000	.000
WITS apprasial		-.053	.173	-.053	.000	-.039	-.031	-.040	-.051
AXB ∠			.255	-.111	.000	-.099	-.083	.037	.072
AF-BF distance				.255	.000	-.190	-.174	-.125	-.277
APP-BPP distance					.000	-.099	.000	.111	-.134
FABA ∠						.000	.000	.000	.000
BETA ∠							.385	.448	.350
YEN ∠								.467	.163
W ∠									.481

Table 6: Class I horizontal group Cohen's Kappa values

	WITS apprasial	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN ∠	W ∠	K ∠
A-BPLANE ∠	.000	.000	.000	.000	.000	.000	.000	.000	.000
WITS apprasial		.783	.634	-.053	.651	.068	.077	-.087	.220
AXB ∠			.839	.362	.474	.016	.037	-.056	.322
AF-BF distance				.286	.366	.127	.000	-.096	.420
APP-BPP distance					-.034	-.092	.063	.124	.076
FABA ∠						-.053	-.040	-.045	.112
BETA ∠							.341	.412	.091
YEN ∠								.467	.086
W ∠									.138

Table 7: Class I vertical group with Cohen's Kappa values

	WITS apprasial	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN ∠	W ∠	K ∠
A-B PLANE ∠	.000	-.061	-.065	-.047	.000	.046	-.049	-.034	-.054
WITS apprasial		.000	.000	.000	.000	.000	.000	.000	.000
AXB ∠			.667	.444	.000	-.056	-.066	.146	.143
AF-BF distance				.250	.000	-.163	-.186	.057	.022
APP-BPP distance					.000	-.077	.106	.366	.053
FABA ∠						.000	.000	.000	.000
BETA ∠							.075	.022	.104
YEN ∠								.250	.292
W ∠									.171

Table 8: Class II average group with Cohen's Kappa values.

	WITS appraisal	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN ∠	W ∠	K ∠
AB PLANE ∠	.865	.732	.727	.732	.867	.483	.118	.118	.359
WITS		.595	.571	.595	.737	.390	.103	.231	.459
AXB ∠			.455	.464	.602	.483	.118	.118	.359
AFBF distance				.727	.609	.308	.087	.087	.286
APP-BPP distance					.602	.224	.370	.370	.359
FABA ∠						.587	.008	.008	.268
BETA ∠							.173	.173	.255
YEN ∠								.395	.375
W ∠									.750

Table 9: Class II horizontal group with Cohen's Kappa values.

	WITS appraisal	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN ∠	W ∠	K ∠
AB plane ∠	.016	.267	.39	.00	0.07	.108	.034	.097	.135
WITS appraisal		.161	.195	.290	.091	.329	.017	-.097	.426
AXB ∠			.733	.600	.400	.125	.273	.484	.267
AFBF				.733	.435	.022	.222	.346	187
APP-BPP distance					.400	.125	.333	.097	.133
FABA ∠						.073	.367	.321	007
BETA ∠							-.017	-.069	.108
YEN ∠								.412	.034
W ∠									.167

Table 10: Class II Vertical group with Cohen's kappa values.

	WITS Appraisal	AXB ∠	AF-BF distance	APP-BPP distance	FABA ∠	BETA ∠	YEN V	W ∠	K ∠
AB PLANE ∠	.103	000	-.190	-.190	-.333	.359	-.296	.074	.167
WITS Appraisal		.000	.237	.237	.609	.464	.483	.224	.103
AXB ∠			.000	.000	.000	.000	.000	.000	.000
AFBF				.000	.471	.237	.595	.595	.286
APP-BPP distance					.471	.237	.595	.595	.286
FABA ∠						.087	.526	.526	.333
BETA ∠							.483	.483	.359
YEN ∠								.659	.444
W ∠									.815

Table 11: Cronbach's Alpha valuein Class I

Parameters	Average group	Horizontal group	Vertical group
AB PLANE ∠			
WITS	.447	.343	.375
Appraisal	.537	.514	.486
AXB ∠	.557	.495	.487
AF-BF Distance	.609	.502	.370
APP-BPP DISTANCE	.512	.511	.337
FABA ∠	.423	.531	.432
BETA ∠	.354	.485	.421
YEN ∠	.396	.461	.330
W ∠	.158	.375	.236
K ∠	.433	.560	.274

Table 12: 1Cronbach's Alpha value in Class II

	Average group	Horizontal group	Vertical group
AB PLANE ∠	.770	.658	.879
WITS appraisal	.772	.628	.828
AXB ∠	.793	.520	.818
AF-BF Distance	.796	.513	.818
APP-BPP distance	.782	.547	.818
FABA ∠	.783	.555	.830
BETA ∠	.795	.666	.820
YEN ∠	.849	.691	.809
W ∠	.841	.590	.800
K ∠	.816	.611	.827

approximation of center of condyle is difficult.[24]

Yen angle[25] was introduced to overcome few of these deficits. This does not utilize A and B points as skeletal landmarks, which are affected by local remodelling due to orthodontic treatment or occlusal plane as in Wits. Instead it utilizes points M and G which are not affected by local remodelling, and they approximate to being centroid points similar to sella. 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 too.[25]

To overcome these existing problems, a new study was thus required. Since this is a novel study and to the best of our knowledge, the only of its kind, where different sagittal parameter were compared to assess the level of agreement and reliability, a direct comparison cannot be made with any other study or studies.

In the past various studies were done by using the cephalometric parameters to assess sagittal jaw relationship but none had provide the level of agreement between these parameters and reliability of these parameters in day to day clinical practice. Nadia et al[26] had done a study where they had taken 155 lateral cephalograms for the assessment of sagittal jaw relationship with a mean age of 10.5 years ± 1.39 years. Six linear and angular measurements were taken. No sex or age differences were detected in all parameters. Roy P et al.[27] had compared the credibility of five cephalometric measurements in assessing the antero-posterior jaw relationship and to assess the correlation between various measurements used for antero-posterior discrepancy, including ANB, Yen angle, Beta angle, Wits appraisal, and horizontal appraisal. A total of 99 patients aged 16 years and above patients were subdivided into skeletal Classes I, II, and III groups of 33, each based upon the ANB angle derived from the pre-treatment cephalogram and showed that ANB angle had very high sensitivity and specificity to discriminate a Class II from Class I and Class III from Class I.

5. Interpretation of Results

5.1. A-B plane angle

In this study Table 4 shows that A-B Plane angle has the highest frequency in Class I average and horizontal group (100%) and in class II horizontal group (83.3%). This shows that while doing cephalometric analysis the maximum number of cases were found with almost same AB plane ∠ values. However, this plane doesn't show any reliability (Tables 11 and 12) in all groups but have a strong level of agreement with FABA ∠ (0.867) and WITS (0.865) in Class II average group (Table 8) whereas Ahmed[28] et al in 2018 said that ANB has a strong level of agreement with A-B Plane angle i.e 0.802 for all classes of malocclusion.

5.2. WITS appraisal

Highest frequency was seen in class I vertical (100%) and class II horizontal (66.66%) group (Table 4). Oliver et al. found poor agreement between both WITS and ANB ∠ with AF-BF distance but in class III cases and they concluded that variation in vertical skeletal measurements affect the strength of agreement. In this study a strong level of agreement was found between WITS and AB plane ∠ (0.865) in class II average group (Table 8), and moderate level of agreement was with AF-BF distance(0.634) in class I horizontal group (Table 6) and also with FABA ∠ (0.737) in class II average (Table 8) and class II vertical group (0.609) (Table 10).

Reliability is good in class II vertical group (0.818) followed by class II average group (Table 12), which is acceptable (0.772).

Sang and Suhr[13] concluded that APDI and WITS appraisal are the parameters for the evaluation of AP relationship of dentition rather than the jaws.

5.3. AXB angle

Highest frequency was seen in class II (100%) vertical followed by class I average and vertical (90%) group. (Table 4)

AXB angle has strong level of agreement with AF-BF distance in class I horizontal group (0.839) (Table 6) and moderate level of agreement in vertical group (0.667) (Table 4).

However AXB ∠ was much more reliable in Class II vertical 0.818 (Table 12) followed by class II average (0.793) (Table 12). A study conducted by Music et al[29] showed that the frequency distribution of classes I, II and III were similar coincident with the one given by the cephalometric clinical diagnosis. The most valid method was the AXB bearing with the cephalometric clinical diagnosis a 90.91% concordance.

5.4. AF-BF distance

Highest frequency was seen in class I horizontal and class II vertical groups (86.66%) (Table 4).

Moderate level of agreement was seen with APP-BPP distance (0.727) in class II average group (Table 8) and horizontal group (0.733) (Table 9) followed by FABA ∠ in class II average group (0.609) (Table 8) but no agreement was seen with any vertical group.

Reliability was good in class II vertical (0.818) and acceptable in average (0.796) group (Table 12).

Judy Farman et al in 1995[30] found no significant difference in AF-BFdistance between males and females in class I group.

5.5. APP-BPP distance

Highest frequency was seen in class I horizontal and vertical groups (93.3%) and in class II the highest frequency was seen in vertical group (86.6%) (Table 4).

Nanda et al in 1994[14] said that palatal plane is the most stable plane and have good reliability in class I malocclusion. In this study, APP-BPP distance showed a moderate level of agreement with FABA ∠ (0.602) in class II average group (Table 8) and weak level of agreement in class II horizontal group (0.400) (Table 9).

Reliability was good only in class II vertical group (0.818) and acceptable in class II average (0.782) group (Figure 12).

5.6. FABA angle

Highest frequency was seen in Class I average and vertical group (100%) (Table 4).

A Weak level of agreement found with BETA angle in Class II average group (Table 8) and with YEN and W angle in class II vertical group (0.526) (Table 10).

In class I average group FABA angle shows the weak level of agreement with all the other parameters. (Table 5)

However a good reliability was seen in class II vertical group (0.830) and moderate in class II average group (0.783) (Table 12).

Sang and Suhr[13] concluded that FABA angle may provide not only a reliable cephalometric measurement of AP relationship but also a clue to the facial profile.

5.7. BETA angle

Highest frequency was seen in Class I average and class II horizontal groups (76.66%). (Table 4)

A weak level of agreement was seen with W angle in Class I average group (0.448) (Table 6), class I horizontal group (0.467) (Table 6) and also in class II vertical group (0.483) (Table 10).

Rana et al.,[30] said that clockwise rotation of mandible affected the reliability of BETA angle and thus it is only reliable in class I average, class II average and class II horizontal groups but in this study a good reliability was seen in Class II average and class II vertical groups. Another study conducted by Aparna et al.[17] found a highly significant correlation of ANB angle with BETA angle and between BETA angle and WITS appraisal in class II group.

5.8. YEN angle

Highest frequency was seen in Class I and Class II vertical groups (73.3%) (Table 4).

Moderate level of agreement was seen with W angle (0.659) in class II vertical group (Table 10).

Good reliability was seen in Class II vertical group. (0.809) (Table 12) and in class II average group (0.849) (Table 12). A study conducted by Dr.Surendra and Dr.Lili[31] on Chinese population shows a significant correlation between Yen angle and W angle in all three classes.

5.9. AND K angle

Highest frequency was shown by W angle in class I average and class II vertical groups (73.3%), whereas K angle shows highest frequency in class II horizontal group (86.66%) and in class I average group (73.3%) (Table 4).

There is a strong level of agreement found between W and K angle (0.815) in class II vertical group (Table 10).

W angle shows a good reliability in Class II average group (0.841) and in class II vertical group (0.800) (Table 12). K angle also shows a good reliability in Class II average group (0.816) and in class II vertical group (0.827) (Table 12). This is similar to study conducted by Dr.Surendra and Dr. Lili[31] which shows W angle is the most stable and reliable angle.

6. Conclusion

In this study it has been seen that the most homogenous parameter were AB plane angle and FABA angle.

The strong level of agreement was found between FABA and AB Plane angle, WITS and AB Plane angle in class II average group.

In class II vertical group W and K angle also have strong level of agreement.

In terms of reliability, the most reliable parameter is AB plane angle in class II vertical group (0.879) and in class II average YEN, W and K angle have also shown good reliability (Table 11).

The present study was undertaken to critically evaluate various cephalometric classification methods for sagittal jaw discrepancy.

So it has been concluded that all the sagittal jaw parameters used to assess maxillo-mandibular relationship are affected by change in one or the other parameter. No single measurement is perfect in all the cases. A combination of different measurements should be used to have a true assessment of sagittal jaw relationship.

7. Source of Funding

8. Conflicts of Interest

There are no conflicts of interest.

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