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A Cephalometric Study for Comparative Assessment, Interchangeability and Accuracy of Sagittal Maxillo: Mandibular Jaw Relationships

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Abstract

Introduction: In this retrospective study, we evaluated different methods for assessing skeletal class I, class II and class III relationships in the sagittal plane with twenty-two parameters, comprising of thirteen angular and nine linear measurements and later determined the level of agreement between them.

Methods: Pre-treatment Lateral Cephalogram of 100 patients, both male and female, 11-25 years of age group, were taken. Measurements pertaining to various sagittal maxillo-mandibular jaw relationships were assessed manually and compared for interchangeability and accuracy.

Results: Among all the angular parameters, YEN angle was found to be homogenously distributed as well as highly reliable in all the three groups. The strongest correlation was found between FABA angle and AF-BF distance, thus high interchangeability among the parameters.

Limitations: For standardising norms, further investigation must be conducted in different populations for assessing different parameters of the sagittal discrepancy.

Conclusions: All the parameters assessed in this study shared statistically significant correlation amongst themselves. Therefore, conjunctive use of at least three analysis should be done rather than relying on one single parameter and relate them with clinical findings.

Keywords: Sagittal discrepancy; Antero-posterior jaw relationship; Cephalometric parameters

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Introduction

In orthodontics, sagittal discrepancies are more frequently confronted in day to day practice. The first jaw based relationship assessment on the first permanent molars was provided by Angle. A new era of orthodontics began after the introduction of Broadbent's cephalometer [1]. After Wylie's descrfibed effort to define anteroposterior jaw relationship, several other cephalometric parameters have been proposed [2]. Downs's A-B plane angle used positive and negative signs to signify retrusion and protrusion of mandible [3]. Riedel introduced ANB angle, and it became the most regularly used measurement [4]. However, these methods are subjected to error as any displacement of nasion point, will directly affect them [3,4]. Later, to eliminate cranial reference points and to reduce the rotational effects of jaw growth; Jacobson used the occlusal plane as a reference, named it as the Wits appraisal. But he described skeletal discrepancies using dental parameter [5]. Thus, these two most commonly used measurements have flaws.

Readings were not affected by the facial degree measure angle of divergence, as he also eliminated point N Chang employed a linear measurement for the perpendiculars distance from points A and B onto the FH plane [7,8]. Yang and Suhr also used the FH

plane by drawing a perpendicular from point A [6,7,9]. Studies have reported that the Frankfurt plane is not a true horizontal. Still, it remains to be the most commonly used plane for facial typing. Nanda and Merrill, used the palatal plane as a reference based and suggested angles and linear measurements. After a decade, the Beta angle was proposed by Baik and Ververidou [8-11]. Here, the problem lies with point A, as it is considered to be changed by alveolar bone remodelling; and the point condylion and its reproducibility. Proposed the sagittal dysplasia measure indicator, known as YEN angle [12].
Proposed W angle as a modification of YEN angle with a benefit of remaining relatively stable on jaws rotation or its vertical growth. The parameter named Pi angle also defies ease of application but does not seem to offer significant advantages [13].

The literature revealed several angular measurements and linear measurements to define the sagittal skeletal discrepancy such as AXD, JYD, MM bisector, FABA, Beta angles, AF-BF and App-Bpp, but none has been authenticated universally [14]. Therefore, it's essential for the orthodontist to understand, merits and demerits of each parameter. In the absence of clear indications of these parameters, the conjunctive use of different parameters is recommended. The purpose of our study was to evaluate different methods for assessing skeletal class I, class II and class III relationships in the sagittal plane with twenty-two parameters, comprising of thirteen angular and nine linear measurements and to determine the level of agreement between them [15-17]. The study was focused on their reliability and variability with the interchangeability or the redundancy in assessing the AP jaw relationship for young adults of North India population.

Materials and Methods

The material of this retrospective study is based on existed diagnostic records of patients visited between 2011-2013 to the Department of Orthodontics and Dentofacial Orthopedics, M. M. College of Dental Sciences and Research, Mullana, Haryana, India. The retrieved records from the archives of the Department of Orthodontics were good quality and evaluated anonymously, therefore, no requirement existed for ethical approval [18]. The pre-treatment Lateral Cephalogram of a minimum of 100 patients, both male and female were taken [19]. The pre-treatment radiograph selected as patients of 11-25 years age group; patients with permanent dentition only; no impacted or missing teeth except for third molars; no craniofacial deformity or asymmetry; no excess soft tissue (to avoid the interference with the identification of cephalometric points); and no previous orthodontic treatment record [20].

All the lateral cephalometric radiographs were taken using the same digital cephalometer. Manual tracings were performed on clear acetate placed over the digitally printed cephalometric film. All the tracings and measurements were performed by the same investigator. The sample of 100 pre-treatment lateral cephalograms was divided into three groups as skeletal class I, class II and class III based on ANB and Wits appraisal; with a minimum of 15 lateral cephalograms in each group [21]. Male and female were considered separately. Subsequently, angles and linear measurements were measured. The coefficient of variability was calculated between all the measurements of sagittal maxilla-mandibular jaw relationships, and thus, their accuracy and interchangeability were assessed [22].

Statistical analysis

The data was collected and tabulated using spreadsheet software. SPSS 21 software was used for statistical analysis. Ten radiographs were randomly selected to determine radiographic measurements errors. Paired 't' test was used for comparing the repeated measurements with the first one [23]. Appropriate statistical methods were employed to calculate minimum/maximum values, range, mean ± SD. Independent 't' test was applied, to find the differences between males and females. Pearson's coefficient was used to determine the level of correlation among all parameters.

Results

The mean age was 16.5 years (class I, n=38), 16.2 years (class II, n=43) and 21.2 years (class III, n=19) of 100 patients. Of all, 51 patients were male. Both showed no statistically significant differences (p>0.05). Range, mean, Standard Deviation (SD), and Coefficient of Variability (CV) were tabulated (**Table 1**).

The assessment of sagittal jaw relationship by thirteen angular and nine linear parameters; and measurement of agreement with ANB angle and Wits appraisal (on BOP) were tabulated among all three groups (**Table 2**). All the angular measurements are statistically significant with ANB angle. YEN angle (n=41) showed the highest frequency in Class III malocclusion cases, and; S-Gn/AB angle (n=65) showed the highest frequency in Class II malocclusion cases [24].

The coefficients of variability (**Table 1**) and correlation matrixes (**Table 3**) of all parameters were calculated in all three groups. According to these coefficients, YEN (CV=4.94, 4.74 and 3.01) and FABA (CV=4.58, 4.88 and 7.50) angles were the most homogenous distributed; least homogenous was the Wits appraisal, in all three groups. ANB angle had statistically significant positive correlation with JYD angle (r=0.502, 0.499 and 0.766; p<0.01) and AXD angle (r=0.556, 0.572 and 0.631; p<0.01) in all three groups, (**Table 4**); whereas Wits appraisal on BOP had correlation with Wits appraisal on FOP (r=0.812, 0.969, 0.984; p<0.01) and MM bisector (r=0.348, 0.729, 0.718) and App-Bpp distance (r=0.339, 0.588, 0.745). The positive correlation was quite strong between A'B' distance and AXD angle (r=0.794, 0.804, 0.677; p<0.01); negative correlation was strong between AFB angle and FABA angle [r=(-0.734), (-0.805) and (-0.617); p<0.01] and; FABA and AF-BF distance [r=(-0.788), (-0.847) and (-0.716); p<0.01] among all three groups (**Table 5**).

Table 1: Range, mean, Standard Deviation (SD), and Coefficient of Variability (CV).

	Range	Mean ± SD	Coefficient of variability	Range	Mean ± SD	Coefficient of variability	Range	Mean ± SD	Coefficient of variability
ANB	0-4	2.79 ± 1.14	40.97	05-Nov	6.81 ± 1.76	25.87	(-10)-0	(-2.42) ± 2.7	(-113.80)
AXD	Feb-13	8.92 ± 2.70	30.21	Jul-16	12.0 ± 2.27	18.9	(-4)-9	3.68 ± 3.53	95.77
Convexity	(-5)-16	6.45 ± 4.10	63.56	Apr-30	15.3 ± 5.24	34.27	(-22)-3	(-5.9) ± 6.78	(-114.49)
JYD	0-18	7.6 ± 3.44	45.13	May-18	10.0 ± 2.42	24.1	(-3)-8	2.68 ± 3.15	117.19
W	47-66	54.9 ± 3.98	7.25	32-61	50.0 ± 5.17	10.34	58-69	62.5 ± 3.10	4.95
BETA	20-38	30.9 ± 3.54	11.42	13-44	25.09 ± 6.41	25.56	Jul-56	41.7 ± 9.80	23.49
YEN	105-141	123.6 ± 6.1	4.94	102-130	117.2 ± 5.5	4.74	128-146	133.7 ± 4.03	3.01
FABA	73-89	82.0 ± 3.76	4.58	67-81	74.0 ± 3.62	4.88	81-105	91.8 ± 6.89	7.5
AFB	0-9	4.74 ± 2.04	42.98	May-14	9.28 ± 2.28	24.59	(-9)-6	(-1.2) ± 3.72	(-294.85)
S-Gn/AB	28-47	38.5 ± 3.62	9.4	39-60	46.2 ± 4.91	10.61	18-39	29.7 ± 5.19	17.47
A-B Plane	(-10)-2	(-5.3) ± 2.5	(-46.72)	(-17)-(-6)	(-11.3) ± 2.9	(-25.87)	(-3)-12	2.9 ± 3.67	124.65
APDI	74-92	81.7 ± 4.6	5.65	66-93	74.45 ± 5.53	7.43	86-107	94.1 ± 5.9	6.28
SN-AB	21-85	73.6 ± 10.1	13.73	59-75	67.05 ± 4.29	6.39	72-98	86.1 ± 7.18	8.34
WITS(BOP)	(-3)-2	0.33 ± 1.04	314.65	02-Nov	6.37 ± 2.38	37.36	(-21)-0	(-6.5) ± 4.9	(-74.52)
WITS(FOP)	(-2)-2	0.54 ± 0.93	172.9	02-Nov	6.53 ± 2.48	37.98	(-19)-(-1)	(-6.2) ± 4.3	(-69.48)
WITS(MM)	(-7)-3	(-2.0) ± 2.2	(-106.47)	(-2)-7	3.14 ± 2.49	79.43	(-23)-(-4)	(-10.6) ± 5.6	(-52.40)
D.OVERJET	0-8	3.97 ± 2.07	52.16	Mar-14	8.8 ± 2.48	28.04	(-7)-1	(-2.37) ± 2.5	(-108.30)
APP-BPP	(-1)-10	5.21 ± 2.95	56.64	Feb-17	10.0 ± 3.21	32.15	(-17)-6	(-2.7) ± 5.67	(-205.11)
AB'	Feb-15	9.16 ± 3.66	39.94	Jul-20	14.2 ± 3.28	23.06	(-10)-10	1.7 ± 5.62	314.24
AF-BF	0-15	5.63 ± 2.91	51.63	Jun-16	10.4 ± 2.54	24.4	(-13)-6	(-1.9) ± 5.39	(-276.79)
AD'	Mar-24	16.1 ± 4.9	30.91	Jun-30	21.05 ± 5.04	23.94	(-5)-18	6.8 ± 6.69	97.04
MM.DIFF	15-34	24.1 ± 4.1	17.3	Oct-28	19.63 ± 4.26	21.7	22-49	35.8 ± 6.95	19.4

Table 2: Measurement of agreement with ANB angle and Wits appraisal (on BOP) were tabulated among all three groups.

Method of analysis	Number of cases in each category			Measurement of agreement	
	Class I	Class II	Class III	Kappa value	P-value
ANB	38	43	19		
AXD	39	33	28	0.467	<0.001
Convexity	53	41	6	0.591	<0.001
JYD	26	60	14	0.303	<0.001
W	41	27	32	0.52	<0.001
BETA	47	32	21	0.596	<0.001
YEN	38	21	41	0.345	<0.001
FABA	28	44	28	0.57	<0.001
AFB	27	59	14	0.627	<0.001
S-Gn/AB	17	65	18	0.55	<0.001
AB PLANE	53	32	15	0.668	<0.001
APDI	13	44	43	0.485	<0.001
SN-AB	43	28	29	0.501	<0.001
WITS (BOP)	38	43	19		
WITS (FOP)	47	38	15	0.857	<0.001
WITS (MM)	51	38	11	0.694	<0.001
D.OVERJET	19	71	10	0.387	<0.001
App-Bpp	43	38	19	0.576	<0.001
A’B’	30	15	55	0.247	<0.001
AF-BF	33	53	14	0.597	<0.001
A’D’	32	44	24	0.41	<0.001
MM DIFF.	31	42	27	0.493	<0.001
Mar-24	Mar-24	Mar-24	Mar-24	Mar-24	Mar-24
15-34	15-34	15-34	15-34	15-34	15-34

Table 3: Correlation matrixes in class I group.

		ANB	AXD	Convexity	JYD	W	BETA	YEN	FABA	AFB	S-Gn/AB	A-B Plane	APDI	SN-AB				MM.DIFF	AD'	AF-BF	A'B'	APP-BPP	D.OVER-JET	WITS (MM)	WITS (FOP)	WITS (BOP)	
ANB	r	0.3	0.09	0.08	0.005	-0.33	-0.42	-0.22	-0.16	0.19	0.36	-0.13	-0.33	-0.008	r WITS (BOP)	ANB	r	-0.3	0.59	0.44	0.57	0.59	0.71	0.138	0.122		r WITS (BOP)
	p	0.067	0.58	0.62	0.978	0.03	0.008	0.18	0.34	0.25	0.026	0.41	0.03	0.96	p		p	0.06	0	0.006	0	0	0	0.41	0.465		p
AXD	r	0.556	0.09	-0.04	0.08	-0.32	-0.21	-0.31	0.11	-0.02	0.12	0.09	-0.18	0.004	r WITS (FOP)	AXD	r	-0.21	0.87	0.45	0.79	0.66	0.27	0.171		0.81	r WITS (FOP)
	p	0	0.55	0.77	0.631	0.05	0.19	0.05	0.5	0.89	0.46	0.57	0.28	0.97	p		p	0.18	0	0.004	0	0	0.09	0.304		0	p
Convexity	r	0.66	0.67	0.12	0.074	-0.27	0	-0.13	-0.4	0.4	0.57	-0.27	-0.4	-0.12	r WITS (MM)	Convexity	r	-0.21	0.74	0.32	0.68	0.58	0.42		0.32	0.34	r WITS (MM)
	p	0	0	0.44	0.65	0.093	0	0.43	0.012	0.01	0	0.09	0.003	0.47	p		p	0.206	0	0.04	0	0	0.008		0.04	0.032	p
JYD	r	0.5	0.78	0.56	0.211	-0.18	-0.29	-0.17	-0.5	0.29	0.36	-0.64	-0.44	-0.05	r D. OVERJET	JYD	r	-0.28	0.69	0.26	0.26	0.49		0.194	0.056	0.26	r D. OVERJET
	p	0.001	0	0	0.204	0.27	0.07	0.3	0.001	0.07	0.02	0	0.005	0.75	p		p	0.084	0	0.102	0.1	0.001		0.243	0.73	0.11	p
W	r	-0.39	-0.58	-0.47	-0.63	-0.49	-0.23	-0.63	-0.5	0.57	0.12	-0.38	-0.8	-0.18	r APP -BPP	W	r	0.39	-0.56	-0.27	-0.43		0.42	.408*	0.19	0.33	r APP -BPP
	p	0.01	0	0.003	0	0.002	0.16	0	0	0	0.45	0.01	0	0.26	p		p	0.01	0	0.1	0.006		0.007	0.011	0.24	0.037	p
BETA	r	-0.14	0.02	-0.07	0.163	0.119	0.08	-0.61	-0.32	0.33	-0.17	-0.36	-0.8	-0.25	r A'B'	BETA	r	0.27	0.15	-0.24		0.67	0.289	0.219	0.12	0.136	r A'B'
	p	0.41	0.89	0.67	0.327	0.47	0.6	0	0.04	0.04	0.3	0.02	0	0.12	p		p	0.09	0.37	0.14		0	0.078	0.187	0.44	0.416	p
YEN	r	-0.41	-0.73	-0.52	-0.66	0.64	-0.11	-0.37	-0.78	0.67	0.22	-0.25	-0.49	0.004	r AF-BF	YEN	r	0.2	-0.7		0.4	0.66	0.33	0.304	-0.03	0.131	r AF-BF
	p	0.09	0	0.001	0	0	0.49	0.02	0	0	0.17	0.12	0.002	0.98	p		p	0.23	0		0.01	0	0.043	0.064	0.83	0.433	p
FABA	r	-0.52	-0.29	-0.34	-0.12	0.13	0.51	0.17	-0.3	0.03	-0.26	-0.2	-0.47	-0.31	r AD'	FABA	r	0.13		0.5	0.85	0.68	0.303	0.121	0.05	0.029	r AD'
	p	0.01	0.07	0.033	0.44	0.43	0.001	0.28	0.06	0.02	0.11	0.21	0.003	0.05	p		p	0.4		0.001	0	0	0.064	0.469	0.74	0.86	p
AFB	r	0.31	0.42	0.21	0.22	-0.31	-0.29	-0.47	-0.73	-0.2	-0.45	0.19	0.24	0.24	r MM. DIFF	AFB	r		-0.07	0	-0.1	-0.19	-0.32	-0.52	-0.37	-0.45	r MM .DIFF
	p	0.56	0.009	0.201	0.16	0.05	0.07	0.003	0	0.17	0.004	0.23	0.14	0.13	p		p		0.68	0.99	0.56	0.26	0.05	0.001	0.02	0.004	p
S-Gn/AB	r	0.16	-0.09	-0.09	-0.06	-0.13	-0.66	0.09	-0.53	0.49																	
	p	0.32	0.59	0.57	0.721	0.41	0	0.57	0.001	0.002																	
A-B Plane	r	-0.66	-0.22	-0.44	-0.07	-0.004	0.43	0.03	0.57	-0.2	-0.36																
	p	0	0.17	0.005	0.635	0.98	0.006	0.83	0	0.22	0.02																
APDI	r	-0.52	-0.46	-0.49	-0.296	0.2	.330*	0.41	0.5	-0.44	-0.2	0.61															
	p	0.001	0.004	0.001	0.071	0.21	0.043	0.01	0	0.005	0.22	0															
SN-AB	r	-0.14	-0.35	-0.279	-0.19	0.45	0.082	0.31	-0.01	-0.07	-0.05	0.15	0.096														
	p	0.38	0.027	0.09	0.23	0.004	0.62	0.05	0.96	0.65	0.77	0.35	0.56														

Table 4: Correlation matrixes in class II group.

		ANB	AXD	Convexity	JYD	W	BETA	YEN	FABA	AFB	S-Gn/AB	A-B Plane	APDI	SN-AB				MM.DIFF	AD'	AF-BF	A'B'	APP-BPP	D.OVER-JET	WITS (MM)	WITS (FOP)	WITS (BOP)	
ANB	r	0.56	0.43	0.57	0.37	-0.29	-0.5	-0.34	-0.65	0.56	0.42	-0.55	-0.47	-0.56	r WITS (BOP)	ANB	r	-0.5	0.51	0.55	0.54	0.52	0.82	0.56	0.54		r WITS (BOP)
	p	0	0.004	0	0.01	0.052	0.001	0.022	0	0	0.004	0	0.001	0	p		p	0.001	0	0	0	0	0	0	0		p
AXD	r	0.57	0.41	0.55	0.3	-0.27	-0.52	-0.32	-0.62	0.52	0.36	-0.51	-0.53	-0.49	r WITS (FOP)	AXD	r	-0.205	0.79	0.69	0.8	0.65	0.6	0.299		0.96	r WITS (FOP)
	p	0	0.006	0	0.04	0.072	0	0.034	0	0	0.018	0	0	0.001	p		p	0.188	0	0	0	0	0	0.052		0	p
Convexity	r	0.85	0.62	0.61	0.17	-0.34	-0.6	-0.36	-0.59	0.49	0.48	-0.6	-0.43	-0.53	r WITS (MM)	Convexity	r	-0.47	0.61	0.57	0.6	0.57	0.77		0.74	0.72	r WITS (MM)
	p	0	0	0	0.26	0.024	0	0.017	0	0.001	0.001	0	0.004	0	p		p	0.001	0	0	0	0	0		0	0	p
JYD	r	0.49	0.79	0.54	0.47	-0.51	-0.33	-0.64	-0.56	0.71	0.22	-0.52	-0.56	-0.43	r D. OVER-JET	JYD	r	-0.078	0.73	0.62	0.75	0.55		0.41	0.53	0.52	r D. OVER-JET
	p	0.001	0	0	0.001	0	0.03	0	0	0	0.153	0	0	0.004	p		p	0.62	0	0	0	0		0.006	0	0	p
W	r	-0.58	-0.51	-0.67	-0.43	-0.43	-0.2	-0.62	-0.55	0.56	0.23	-0.07	-0.46	-0.47	r APP-BPP	W	r	0.36	-0.41	-0.3	-0.43		0.42	0.4	0.56	0.58	r APP-BPP
	p	0	0	0	0.004	0.004	0.17	0	0	0	0.13	0.64	0.002	0.001	p		p	0.017	0.01	0.018	0.004		0.004	0.008	0	0	p
BETA	r	-0.4	-0.17	-0.46	0.006	0.29	-0.08	-0.67	-0.63	0.74	0.17	-0.16	-0.54	-0.64	r A'B'	BETA	r	0.52	0	-0.23		0.73	0.52	0.29	0.44	0.46	r A'B'
	p	0.007	0.252	0.002	0.97	0.055	0.594	0	0	0	0.256	0.306	0	0	p		p	0	0.99	0.147		0	0	0.059	0.003	0.002	p
YEN	r	-0.68	-0.78	-0.77	-0.65	0.78	0.26	-0.58	-0.84	0.77	0.35	-0.27	-0.53	-0.61	r AF-BF	YEN	r	0.4	-0.67		0.78	0.72	0.57	0.36	0.49	0.51	r AF-BF
	p	0	0	0	0	0	0.086	0	0	0	0.02	0.07	0	0	p		p	0.008	0		0	0	0	0.017	0.001	0	p
FABA	r	-0.61	-0.55	-0.65	-0.43	0.33	0.4	0.46	-0.55	0.66	0.12	-0.08	-0.53	-0.57	r AD'	FABA	r	0.296		0.69	0.92	0.64	0.49	0.25	0.34	0.37	r AD'
	p	0	0	0	0.003	0.031	0.006	0.002	0	0	0.437	0.604	0	0	p		p	0.054		0	0	0	0.001	0.101	0.024	0.015	p
AFB	r	0.74	0.73	0.74	0.7	-0.55	-0.22	-0.66	-0.8	-0.34	-0.45	0.49	0.21	0.21	r MM. DIFF	AFB	r		0.09	-0.19	0.038	-0.11	-0.39	-0.5	-0.27	-0.26	r MM. DIFF
	p	0	0	0	0	0	0.157	0	0	0.025	0.002	0.001	0.164	0.175	p		p		0.58	0.215	0.808	0.471	0.009	0.001	0.087	0.088	p
S-Gn/AB	r	0.46	0.17	0.5	0.07	-0.25	-0.56	-0.29	-0.59	0.39																	
	p	0.002	0.26	0.001	0.63	0.106	0	0.059	0	0.01																	
A-B Plane	r	-0.63	-0.2	-0.55	-0.1	0.28	0.58	0.27	0.58	-0.46	-0.7																
	p	0	0.18	0	0.495	0.063	0	0.071	0	0.002	0																
APDI	r	-0.52	-0.63	-0.53	-0.45	0 .41	0.35	0.51	0.58	-0.52	-0.14	0.46															
	p	0	0	0	0.002	0.006	0.019	0	0	0	0.383	0.002															
SN-AB	r	-0.47	-0.63	-0.61	-0.52	0.37	0.21	0.46	0.74	-0.71	-0.42	0.53	0.54														
	p	0.001	0	0	0	0.014	0.158	0.002	0	0	0.004	0	0														

Table 5: Correlation matrixes in class III group.

		ANB	AXD	Convexity	JYD	W	BETA	YEN	FABA	AFB	S-Gn/AB	A-B Plane	APDI	SN-AB				MM. DIFF	AD'	AF-BF	A’B’	APP-BPP	D. OVER--JET	WITS (MM)	WITS (FOP)	WITS (BOP)	
ANB	r	0.74	0.43	0.54	0.58	-0.11	-0.45	-0.15	-0.58	0.69	0.77	-0.57	-0.72	-0.44	r WITS(BOP)	ANB	r	-0.415	0.69	0.75	0.7	0.85	0.39	0.42	0.74		r WITS (BOP)
	p	0	0.06	0.015	0.009	0.626	0.051	0.528	0.008	0.001	0	0.01	0	0.058	p		p	0.077	0	0	0.001	0	0.096	0.074	0		p
AXD	r	0.63	0.46	0.56	0.63	-0.08	-0.51	-0.14	-0.58	0.7	0.78	-0.5	-0.75	-0.75	r WITS(FOP)	AXD	r	-0.12	0.76	0.65	0.67	0.66	0.3	0.343		0.98	r WITS (FOP)
	p	0.004	0.044	0.012	0.004	0.739	0.024	0.54	0.009	0.001	0	0.008	0	0	p		p	0.625	0	0.002	0.001	0.002	0.203	0.15		0	p
Convexity	r	0.9	0.51	0.3	0.45	-0.02	-0.37	0.105	-0.63	0.64	0.44	-0.37	-0.46	-0.2	r WITS(MM)	Convexity	r	-0.32	0.54	0.57	0.59	0.66	0.39		0.71	0.71	r WITS (MM)
	p	0	0.025	0.208	0.051	0.912	0.109	0.669	0.003	0.003	0.054	0.117	0.043	0.392	p		p	0.173	0.02	0.009	0.008	0.002	0.096		0.001	0.001	p
JYD	r	0.76	0.77	0.65	0.26	-0.33	-0.09	-0.5	-0.21	0.46	0.34	-0.59	-0.51	-0.52	r D.OVER-JET	JYD	r	-0.39	0.81	0.67	0.67	0.8		0.16	0.14	0.14	r D. OVER-JET
	p	0	0	0.002	0.269	0.16	0.69	0.029	0.39	0.044	0.14	0.008	0.024	0.021	p		p	0.096	0	0.001	0.002	0		0.49	0.545	0.552	p
W	r	-0.34	-0.22	-0.41	-0.39	-0.23	-0.43	-0.36	-0.66	0.76	0.78	-0.62	-0.88	-0.6	r APP-BPP	W	r	-0.019	-0.14	-0.28	-0.11		0.314	0.55	0.74	0.74	r APP -BPP
	p	0.153	0.351	0.08	0.098	0.324	0.06	0.129	0.002	0	0	0.004	0	0.006	p		p	0.93	0.58	0.243	0.661		0.191	0.013	0	0	p
BETA	r	-0.48	-0.56	-0.39	-0.55	0.062	-0.65	-0.33	-0.55	0.65	0.51	-0.58	-0.76	-0.71	r A’B'	BETA	r	0.421	-0.52	-0.49		0.72	0.21	0.38	0.71	0.69	r A’B'
	p	0.034	0.013	0.094	0.014	0.801	0.003	0.159	0.013	0.002	0.024	0.009	0	0.001	p		p	0.072	0.02	0.033		0	0.388	0.105	0.001	0.001	p
YEN	r	-0.37	-0.4	-0.32	-0.5	0.74	0.26	-0.42	-0.71	0.74	0.83	-0.56	-0.81	0.61	r AF-BF	YEN	r	-0.01	-0.36		0.68	0.86	0.363	0.53	0.76	0.77	r AF -BF
	p	0.118	0.085	0.172	0.027	0	0.282	0.068	0.001	0	0	0.012	0	0.005	p		p	0.969	0.13		0.001	0	0.126	0.019	0	0	p
FABA	r	-0.39	-0.58	-0.18	-0.46	-0.07	0.45	-0.008	-0.65	0.65	0.59	-0.53	-0.77	-0.75	r AD'	FABA	r	0.367		0.59	0.8	0.77	0.36	0.45	0.6	0.57	r AD'
	p	0.099	0.009	0.461	0.044	0.757	0.052	0.975	0.003	0.002	0.008	0.019	0	0	P		p	0.122		0.007	0	0	0.13	0.05	0.006	0.01	p
AFB	r	0.752	0.61	0.57	0.65	-0.1	-0.72	-0.28	-0.61	-0.54	-0.56	0.33	0.48	0.2	r MM.DIFF	AFB	r		-0.23	-0.53	-0.29	-0.44	-0.03	-0.71	-0.75	-0.71	r MM .DIFF
	p	0	0.005	0.011	0.002	0.679	0	0.241	0.005	0.017	0.012	0.156	0.034	0.408	p		p		0.34	0.019	0.225	0.06	0.908	0.001	0	0.001	p
S-Gn/AB	r	0.78	0.59	0.61	0.74	-0.24	-0.43	-0.37	-0.56	0.71																	
	p	0	0.008	0.005	0	0.311	0.064	0.116	0.011	0.001																	
A-B Plane	r	-0.83	-0.4	-0.88	-0.58	0.26	0.28	0.31	0.17	-0.63	-0.58																
	p	0	0.082	0	0.009	0.279	0.237	0.195	0.484	0.003	0.009																
APDI	r	-0.88	-0.61	-0.74	-0.75	0.11	0.57	0.4	0.53	-0.86	-0.78	0.8															
	p	0	0.005	0	0	0.636	0.011	0.087	0.019	0	0	0															
SN-AB	r	-0.62	-0.6	-0.55	-0.71	0.24	0.64	0.54	0.49	-0.63	-0.652	0.56	0.74														
	p	0.004	0.006	0.014	0.001	0.318	0.003	0.015	0.031	0.004	0.003	0.013	0														

Discussion

Orthodontic diagnosis and treatment planning provided great significance to the maxilla-mandibular relationship evaluation [25]. The most popular parameters, ANB angle and Wits appraisal, are affected by numerous factors and can often be inaccurate. Still, they are in use for an absolute determination for assessing sagittal skeletal disharmony. Methods for geometric correction in both parameters had been proposed to eliminate these distorting effects [26]. In cephalometrics, both angular and linear variables should be used simultaneously, as individually they are erroneous. Linear measurement has a distinct advantage over angular measurement because fewer variables can affect their accuracy [27,28].

A'-B' distance is a linear measurement, introduced by Taylor, to establish few degree changes in ANB angle accomplished through the linear measurements [18]. Approximately 1 mm per degree of change was noted in this study, whereas the actual values ranging from 0.7 mm per degree to 0.8 mm per degree. Taylor also stated that nasion is moving away from Sella approximately 1 mm per year [29]. Therefore, an alternative to ANB angle, AXD angle was devised [19]. In this study, the AXD angle's mean value accuracy (12.0°) was relatively close to the pre-treatment mean (12.7°) reported in the original study for Class II malocclusion. He also used A'-D' distance as a linear measurement to eliminate the inter-individual variation due to the effect of anterior cranial base length and anterior facial height, arising in assessing AXD angle [30]. AXD angle also showed a statistically significant positive correlation with ANB angle in all the three groups; and strong correlation especially with JYD angle and A'-B' distance, which was in agreement [31].

Brought JYD angle, which showed a statistically assessing AXD's significant strong positive correlation with ANB angle, AXD angle and A'-D' distance. This might be due to the use of SN plane as a reference plane in all the above three parameters. The rotation of the jaws can influence these parameters, whereas actual anterior face height can affect AXD and JYD angles. The JYD angle usually increases with steepening of the mandibular plane angle [32]. Though, PABA (palatal plane to AB plane) or APDI (Anteroposterior Dysplasia Indicator) angle was introduced by Kim and Vietas as a combination of the facial angle, A-B plane angle and palatal plane angle; but this geometric summation is less liable for interchangeability [22,33]. The mean value for Class II malocclusion group was 74.45° for APDI angles; in agreement with the earlier study. APDI was the most homogenously distributed parameter and showed a strong correlation with ANB angle and Wits appraisal in all groups, which was further supported by Oktay and Yang Suhr [23,34].

Ift was recommended the conjunctive use of APDI with ANB angle and Wits appraisal. Also, due to their different geometric basis, these three parameters would complement each other, especially in geometrically distorting figures as they have low interchangeability [35,36].

Yang Suhr introduced a parameter on FH plane fthaft named FABA; which showed highest negative statistically significant correlation with AFB angle and AF-BF distance means, the smaller the FABA, larger the AF-BF distance and AFB angle values and vice-versa; similar to the results of Doshi et al. [24,37]. Therefore, showed a good interchangeability with FABA angle and AF-BF distance, this result was in par with results of Gul and Fida's study [25,38]. Since, FH plane is known for its uncertainty of accurately locating porion in cephalometrics; natural head position had been used as reference plane due to its high reproducibility. We had also studied dependability on three different sagittal reference planes, and the results indicated that Wits appraisal on MM Bisector was less correlated with ANB angle; unlike correlation studies done [28]. MM bisector's normal occlusion measurement mean values were numerically dissimilar with Jacobson's original values [39]. The most homogenously distributed parameter, Maxillo-mandibular differential is a subtractive result of effective midfacial length and effective mandibular length. This analysis is very suitable in myofunctional therapy. In contrast, S-Gn/AB angle did not show any overlap between values in different classes [40].

AF-BF distance also did not take into account point A and B vertical relationship, which seems to affect anteroposterior jaw dysplasia as well as the facial profile. Its mean values were higher when compared with Chang's AF-BF values, unlike the study, done by Judy et al. where the AF-BF values were lower [31,41]. also proved that AF-BF distance showed.

The highest correlation coefficient with App-Bpp distance; but, a statistically significant correlation with SN-AB angle, unlike earlier study. App-Bpp linear distance was averaged as 4.8 mm ± 6.9 mm 6.6 ± 4.5 mm in Indian males and females, respectively. Though the palatal plane is stable, but its inclination remains highly variable with age, thus it's difficult to gain mean values around the norms. But, App-Bpp distance was positively correlated with Wits appraisal and ANB angle, similar to the previous study [42].

Similar to study on Indian population, the mean measurements value for Beta angle were 30.49° ± 8.7°; having a high standard deviation, thus conveyed more severe malocclusion among Indian population [33]. Positive correlation results of Beta angle with AB plane angle, FABA and APDI angles, were also dictated [43].

Comparisons throughout orthodontic treatments and during the planning of orthognathic surgery. It helps in deciding between orthodontic camouflage and surgery; but not in determining which jaw is prognathic or retrognathic. In this study, YEN angle was found to be homogenously distributed, similar to the study [44]. It showed a statistically significant positive angle has been correlation only with the W angle. In W angle's geometry, a perpendicular from point M on S-G line rotates along with jaw rotation, thus recommended parameter in a clockwise or counterclockwise rotation. Many studies had already proved the reliability and validity of these angles in different populations. Still, the mean values of these angles were found to be higher when compared with the study [45]. Another linear measurement parameter, dentoskeletal overjet depends on dentoalveolar compensation and overjet. However, for skeletal discrepancy overjet didn't found to be a good predictor in the sagittal plane, but it acted as a significant predictor in Class II division 1 malocclusion subjects. also compared these angles were with Pi analysis and predicted their corrections.

The quadrilateral analysis being individualised, and not dependent on established norms, would be an excellent tool in cases with underlying skeletal discrepancies. In orthodontics, conventional cephalometrics is incapable of delineating shape and size as it relies on linear and angular measurements [46]. Therefore, there is a requirement for a better comparative method w.r.t biological variability. Therefore, Procrustes analysis can be used for direct comparison of patient's tracing to the size and position corrected template. Due to the large variability in the human population, a single cephalometric analysis may not provide an accurate diagnosis. Moreover, cephalometrics is not an exact diagnostic tool and analysis, which are based on angular and linear parameters, have evident limitations. Hence, it is imperative that a clinician be aware of a range of cephalometric analysis to be used appropriately as the need arises. Again, the best solution would be to apply at least three analysis in each case [47]. Thorough knowledge of the various analysis at hand will help the astute clinician in choosing the most appropriate ones for each case. Predictability and variability of each parameter must be considered when assessing individuals' skeletal discrepancy. For standardising norms, further investigation must be conducted in different populations for assessing different parameters of the sagittal discrepancy. Further reliability, validity and correlation studies are required to evaluate latest developed parameters like E analysis, SAR angle and HBN angle for assessing sagittal maxilla-mandibular jaw relationships in different populations.

Conclusion

Despite numerous cephalometric sagittal dysplasia indicators, ANB angle remains the most widely used due to its simplicity and global acceptability. However, total reliability on ANB angle cannot be recommended. The Wits appraisal of jaw disharmony is also popular. Being a linear parameter dependent on the occlusal plane, again has obvious limitations. Many studies have been published in comparisons, but none exit on comparing thirteen angular and nine linear parameters altogether. The present study concluded that: Among the angular parameters, the YEN angle was found to be homogenously distributed as well as highly reliable. High interchangeability among FABA angle and AF-BF distance due to their strongest correlation. The conjunctive use APDI with ANB angle and the Wits appraisal is recommended for assessing AP jaw relationship.

Conflict of Interest

None.

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