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Diagnostic value of five cephalometric analysis in recognition of class I, II, and III sagittal patterns

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ABSTRACT

Background and Objective: Controversy exists over superiority of cephalometric analyses in diagnosis of skeletal classes. The aim of the present study was to compare diagnostic value of cephalometric analyses of class I, II, III anteroposterior jaw discrepancies. *Materials and methods*: A total of 90 cephalographs (n=90×3) were retrieved from the database of radiological clinic and classified into three study groups: Group I (Class I, n=30), Group II (Class II, n=30), and Group III (Class III, n=30). The cephalographs were traced manually. A-B plane, ANB angle, Wits appraisal, AF-BF, and cephalometric indices in McNamara's anteroposterior measurements, including maxillary (Co–A) and mandibular (Co–Gn) unit length and their difference were analyzed. Diagnostic values of these analyses were measured; statistics were analyzed using McNemar, correlation, and Kappa coefficients (α=0.05). *Results*: In the Class I group, A-B plane angle showed the highest sensitivity (90%) and accuracy (76.7%), In the Class II group, ANB angle showed the highest sensitivity (86.7%) and accuracy (85.5%). In the Class III group, Wits appraisal showed the highest sensitivity (90%) and accuracy (96.7%). *Conclusion*: Downs, Downs/Steiner, and Downs/AF-BF analyses can be more reliably used for assessment of class I, II, and III sagittal patterns, respectively.

Keywords: Diagnostic value, cephalometric analyses, sagittal pattern, malocclusion

1. INTRODUCTION

Abnormality in craniofacial development (sagittal, vertical, transverse planes) may lead to different malocclusions (Proffit et al., 2014). Malocclusions in the sagittal plane are considered as the most common orthodontic problems (Azuma et al., 2008; Bernabé et al., 2008; Javadpour, 2019). The skeletal discrepancies in the sagittal plane are clearly assessed on radiographs. Standardized lateral cephalograph has recognized as the classical tool for diagnosis of the sagittal discrepancies in the skeletal, dental, and soft tissues (Proffit et al., 2014; Devereux et al., 2011; Mishra & Pandey, 2017; Ahmed et al., 2018; Qamaruddin et al., 2018; Taha Mahmood & Fida, 2018). Cephalometric analysis is the clinical practice of cephalometry. It is the analysis of skeletal and dental relationships which indicates the anteroposterior positioning of the teeth in relation to their basal bones. The initial purpose of cephalometric analyses was to research the growth and development of skeletal structures and to establish a quantitative method for obtaining descriptive information about dentofacial patterns. Unlike the Angle's Class I/II/III molar relationships, the classification of sagittal jaw relationships into three skeletal classes I/II/III is still unclear (Hurmerinta et al., 1997). Numerous cephalometric analyses have been proposed for sagittal skeletal relationships. However, the validity and reliability of these assessments can be easily affected by anatomical variations, skull developmental disorders, changes in reference plans, and anatomic location points which may lead to incorrect conclusions. Precise identification of the landmarks has a direct impact on the results of the cephalometric analyses and treatment decisions; however, labeling the cephalometric landmarks in lateral cephalographs is problematic. Therefore, due to diagnostic limitations of cephalometric analyses in orthodontics, supplementary diagnostic tools should be considered (Jacobson, 1975; Jenkins, 1955; Riedel, 1952).

Since Downs (1956) introduced the A-B plane angle, numerous cephalometric parameters have been proposed to evaluate anteroposterior jaw relationships, the most commonly used are ANB angle and Wits appraisal (Jacobson, 1975; Jenkins, 1955; Riedel, 1952). Subsequent geometry studies have shown that some cephalometric parameters are sensitive to small position changes and can be influenced by changes in other parameters. ANB angle can be influenced by the length of cranial base (anterior edge of the foramen magnum (basion) to the fronto-nasal suture (nasion)) and vertical growth pattern (Jacobson, 1975; Jacobson, 1976; Beatty, 1975). The Wits appraisal analysis (using the occlusal plane as the reference) was introduced to overcome the limitation of ANB angle; however, the Wits analysis can be affected by a change in inclination of its reference plane or vertical development of the alveolar process (Rotberg et al., 1980; Chang, 1987; Williams et al., 1985). To alleviate these problems, some researchers have suggested true horizontal plane instead of occlusal plane (Rotberg et al., 1980; Chang, 1987; Williams et al., 1985; Bishara et al., 1983). There is no consensus on the best or most accurate cephalometric plane for analyzing Class I, II, III sagittal patterns. Moreover, diagnostic value of these analyses has not been assessed adequately in an Iranian population. Therefore, the aim of the present study was to evaluate the cephalometric analysis of Class I, II, III anteroposterior jaw discrepancies.

2. MATERIALS AND METHODS

This study was conducted on 270 observations of 90 cephalographs (n=90) in 2018. Cephalographs without any artifacts were retrieved from the database of three radiological clinics and classified into three study groups: Group I (Class I) included 30 subjects with normal skeletal relationship (Figure 1). Group II (Class II) with 30 subjects having retrognathic profiles (Figure 2). Group III (Class III) included 30 subjects with prognathic profiles (Figure 3). All the selected cephalographs were carefully hand-traced in a similar manner and by the same observer under the same illumination and magnification using single matte lacquered polyester acetate tracing paper (Dentaurum, Germany) and 3H lead pencil. The linear and angular measurements were recorded using scale and protractor. Since the cephalographs had been obtained retrospectively, no patients were harmed due to this study. The ethics of the study were approved by the university committee, according to the Helsinki declaration.

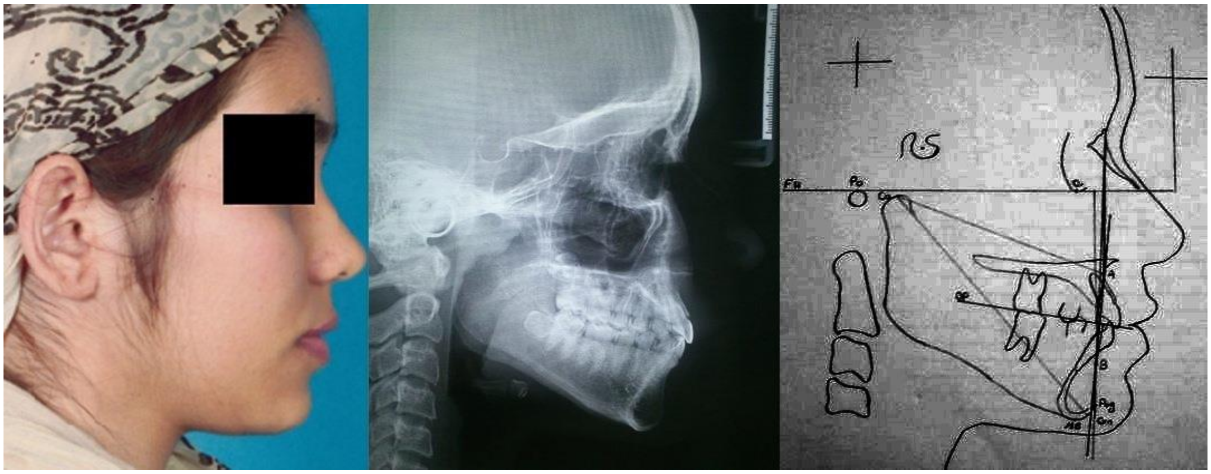

Figure 1 A Class I case.

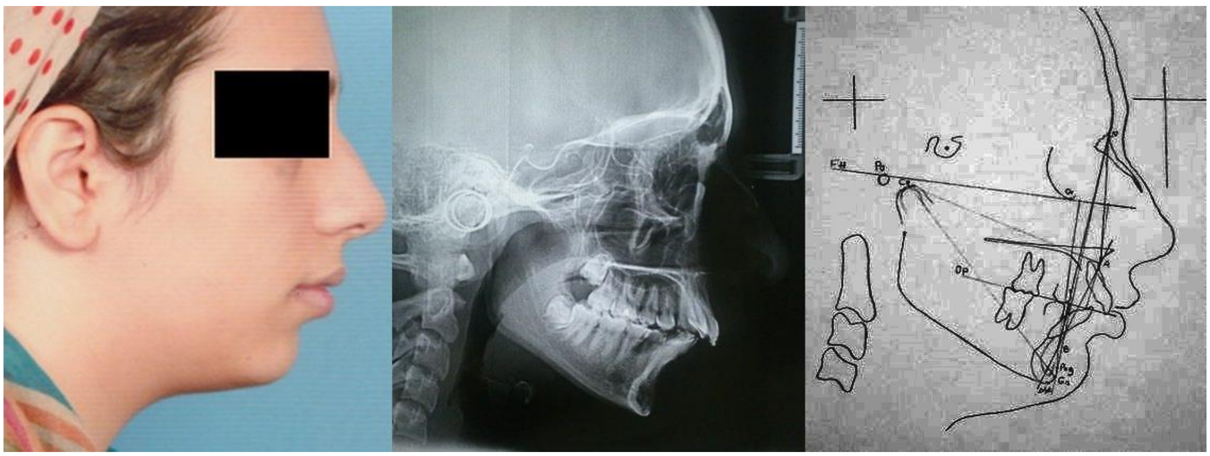

Figure 2 A case of Class II.

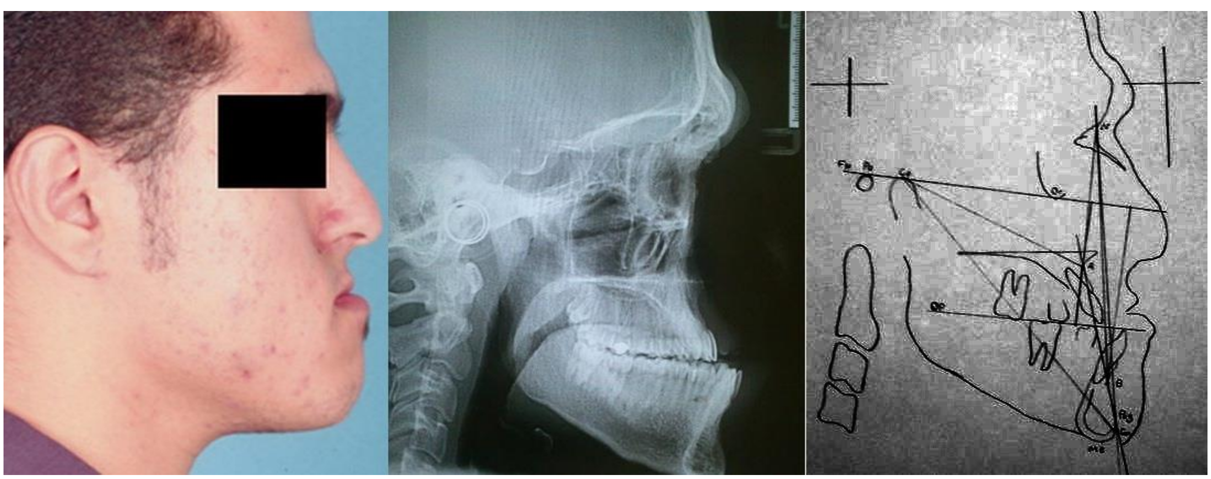

Figure 3 A Class III example.

The inclusion criteria were as follow: (1) individuals with all completely erupted permanent teeth, (2) no history of previous orthodontic treatment, (3) non-extraction treatment plan, (4) moderate to severe skeletal malocclusion class II/ III, (5) age range 12-17 years for Class I and II malocclusions and 12-28 years for Class III malocclusions, (6) no history of syndrome, developmental dental anomaly, and oral habit. All cephalographs for malocclusions I and II were retrieved from the database of a radiology center and class III malocclusion cephalographs were selected from two centers of radiology. The magnification factors were measured for all cephalographs. The lateral cephalometry in which Frankfurt plane was parallel to the true horizontal plane was traced and the following cephalometric landmarks were determined: Point A (Subspinale), the deepest point in the midsagittal plane between the anterior nasal spine and prosthion; Point B (Supramentale), the deepest point in the midsagittal plane between infradentale and Pg;N (Nasion), the most anterior point of nasofrontal suture in the midsagittal plane, Po (Porion), the midpoint on the upper edge of the external auditory meatus; Pg (Pogonion), the most anterior point on the symphysis of the mandible constructional points; Go (Gonion), the junction of the ramus with the lower border of the mandibular body on its posteroinferior aspect; Co (Condylion), the most superior posterior point on the outline of the mandibular condyle.

The cephalometric planes were drawn: Frankfurt Plan (FH), occlusal functional plane (Occ.plane), A-B plane, N-Pog (facial) plane. Angular measurements of ANB and A-B planes and linear measurement AF-BF, Wits (AO-BO) measurements were performed, and McNamara (the difference between Co-A and Co-Gn) were measured, accordingly. In the ANB (Steiner) analysis, the result of 2° with a standard deviation of ±2 was considered as CLI and less than 2° CLIII and greater than 2° was considered as CLII, (CLII > CLI (ANB of 2 ± 2°) > CLIII). In A-B plane angle (Downs) analysis the results of 4.6 ° with a standard deviation of ±3.7 was considered as CLI and less than this value CLIII and more than 4.6 ° was considered as CLII (CLII > CLI (A-B plane angle of 4.6 ± 3.7°) > CLIII). In the Wits appraisal the following ranges of the malocclusion classes were defined: malocclusion Class I: 0±1mm; malocclusion Class II: > 0±1mm; malocclusion Class III: < 0±1mm. In the McNamara Analysis, the range value of 25 to 28 mm for females (medium size) and 29 to 33 mm for males (coarse size) were considered as CLI and less than these values CLII and greater than these values was considered as CLIII malocclusion. In the AF-BF analysis, the results of 1 to 6 mm were considered as CLI and less than this value CLIII and more than that of CLII.

Statistical analysis

While assessing each skeletal class, the other two classes were re-assessed as control. The sample size was determined as 30 cephalographs, in order to obtain test powers above 80% according to the relative sampling error of 0.13 of population variance. Therefore, 30 cephalographs were obtained for each group. The accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. Data were analyzed using McNemar, correlation coefficient, and Kappa coefficient of SPSS software (version 21.0, IBM, Armonk, NY, USA). The level of significance was $P \leq 0.05$.

3. RESULTS

The results are presented as Tables 1 to 4 and Figures 1 to 3. In the Class I group, the highest accuracy (76.7%) and sensitivity (90%) were related to the A-B plane angle analysis. The sensitivity of A-B plane angle was much higher than all other 4 methods, and stands out. However, accuracies were at the same (strong) level for all 5 screening approaches. The order of accuracy in CLI analysis was as follow: AF-BF < McNamara < Wits < ANB angle < A-B plane angle. As well, the sequence of sensitivity in CLI analysis was as follow: McNamara < Wits < AF-BF < ANB angle < A-B plane angle. Specificity values were all rather similar and strong. The order of specificity was: A-B plane angle<AF-BF<ANB angle<Wits appraisal = McNamara. The order of PPV was: McNamara (which was considerably smaller than others) < Wits <AF-BF<A-B plane < ANB. The four superior tests had rather similar PPVs. The order of NPV was: McNamara < Wits < AF-BF < ANB angle < A-B plane angle. The NPV of A-B plane angle was excellent and stands out among other tests that had moderate to strong NPVs. The highest reliability was seen in the case of A-B plane angle and ANB angle which had reliabilities considerably higher than the rest (Tables 1 and 2). The analysis A-B plane angle had the highest sum of sensitivity + specificity, sum of PPV + NPV, and accuracy. Therefore, it seems the best analysis for detection of Class I malocclusions. According to the McNemar test, all tests were acceptable except McNamara (Table 2 and Figure 1). There was a significant correlation between Downs and Steiner analyses ($r = 0.471$, $P < 0.05$); however, there was no significant correlation between the rest of analyses ($P > 0.05$).

Table 1 The results of each test while assessing each class.

Target	Assessments	A-B plane angle	AF-BF	ANB angle	Wits	McNamara
Cl I	Cl I	27	18	20	13	5
	Cl II	2	11	9	7	20
	Cl III	1	1	1	10	5
Cl II	Cl I	12	8	4	8	5
	Cl II	18	22	26	22	23
	Cl III	0	0	0	0	2
Cl III	Cl I	6	5	8	2	2
	Cl II	0	1	0	1	3
	Cl III	24	24	22	27	25

Table 2 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class I sagittal discrepancy

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	McNemar	K	Correlation
A-B plane angle	90	70	60	93.3	76.7	1	0.533	0.566
AF-BF	60	74	58.1	75.5	61.1	1	0.338	0.380
ANB angle	66.7	80	62.5	82.8	75.5	0.832	0.459	0.460
Wits appraisal	43.3	83.3	56.5	74.6	70	0.248	0.283	0.288
McNamara	16.7	88.3	41.7	67.9	64.4	0.002	–	0.069

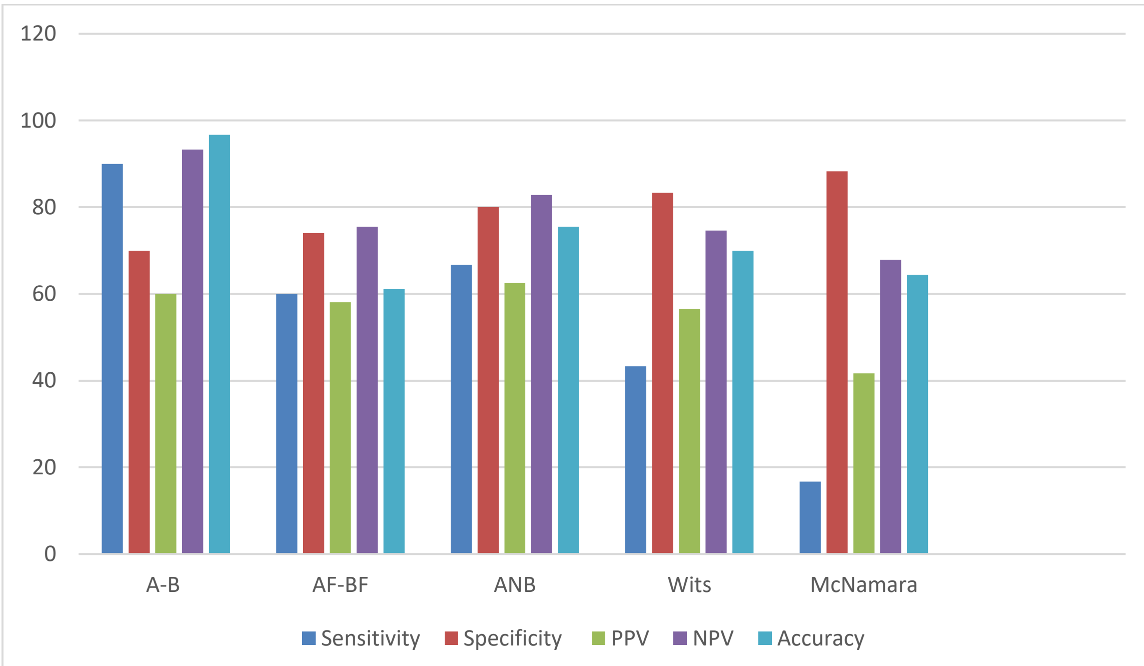

Figure 1 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class I sagittal discrepancy

In the Cl II group, the highest accuracy (85.5%) and sensitivity (86.7%) were related to ANB angle analysis. All accuracies were rather similar and high to moderate, except McNamara which was considerably lower than others. The sequence number of accuracy in CL II analysis was as follow: McNamara < AF-BF < Wits < A-B plane angle < ANB angle. As well, all sensitivities were rather similar. The sequence number of sensitivity in CLII analysis was as follow: A-B plane angle< Wits = AF-AB < McNamara < ANB angle. The order of specificity was: McNamara <AF-BF<ANB angle<Wits appraisal<A-B plane angle. The last one (A-B plane angle) stands out as it had an excellent specificity not present in other approaches. The order of PPV was: McNamara (which was much lower than others) <AF-BF< Wits < ANB < A-B plane angle (which was much higher than others). All NPVs were very high to excellent. The order of NPVs was: A-B plane angle<McNamara < AF-BF < Wits < ANB angle. Reliabilities of all methods except McNamara were similar and at a moderate level. The reliability of McNamara approach was much lower than the rest (Tables 1 and 3). The ANB angle followed by A-B plane angle and Wits appraisal had all accuracies above 80%; of these the Steiner (ANB angle) had the highest accuracy; the same analysis had also the highest sum of sensitivity + specificity; whereas, the highest PPV + NPV sum belonged to the Downs analysis (A-B plane angle). Therefore, these two tests seem to be the best options for detection of Class II cases. According to the McNemar test, the results of the analyses McNamara and Downs were not acceptable, while the rest were (Table 3 and Figure 2). In Cl II group, there were significant correlations between Downs and Steiner (r = 0.480, *P*< 0.05), Downs and AF-BF (r = 0.431, *P*< 0.05), and Downs and Wits (r = 0.431, *P*< 0.05). The rest were non-significant (*P*> 0.05).

In the Cl III group, the highest accuracy (96.7%) and sensitivity (90%) were related to Wits appraisal analysis. The accuracy values were all very high or excellent. Sensitivity values were high or in the case of Wits, excellent. The sequence of accuracy in CL III analysis is as follow: McNamara < ANB angle <AF-BF =A-B plane angle <Wits. As well, the sequence number of sensitivity in CLIII analysis was as follow: ANB angle < A-B plane angle = AF-BF < McNamara < Wits. Specificity values were excellent or very high. The three analyses A-B plane angle, AF-BF, and ANB angle had an extremely high specificity (all 98.3%). The order of specificity was:

McNamara <Wits <AF-BF = ANB angle = A-B plane angle appraisal. Again the same three analyses A-B plane angle, AF-BF, and ANB angle had an extremely high PPV (all above 95%). The order of PPV was: Wits <McNamara<ANB <AF-BF = A-B plane. The NPV values were very close to each other, all being very high to excellent ranging between 86.7% in the case of McNamara to 96.7% in the cases of Wits. All approaches had strong interrater reliability with A-B plane angle and AF-BF having the highest reliabilities (Tables 1 and 4). The highest accuracy belonged to the Wits analysis (96.7%). However, this analysis had a comparatively low PPV + NPV sum. There were other analyses with still high accuracies (92%) besides high PPV + NPV sums and sensitivity + specificity sums. These were A-B plane angle (Downs) and AF-BF analyses. According to the McNemar test, the results of Steiner analysis were not acceptable (Table 4); results of Wits analysis were marginally unacceptable (Table 4and Figure3); the rest of analyses were acceptable. In Class III, all analyses were correlated with each other (all r values > 0.389, all *P*< 0.05), except Wits and McNamara (*P*> 0.05). Strong correlations existed between Downs and Steiner (r = 0.820, *P*< 0.05) and between Downs and AF-BF (r = 0.729, *P*< 0.05).

Table 3 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class II sagittal discrepancy

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	McNemar	K	Correlation
A-B plane angle	60	96.7	90	82.9	84.4	0.013	–	0.643
AF-BF	73.3	80	64.7	85.7	77.7	0.503	0.516	0.519
ANB angle	86.7	85	74.3	92.7	85.5	0.267	0.688	0.693
Wits appraisal	73.3	86.7	73.3	86.7	82.2	1	0.600	0.600
McNamara	76.7	61.7	50	84.1	66.7	0.005	–	0.409

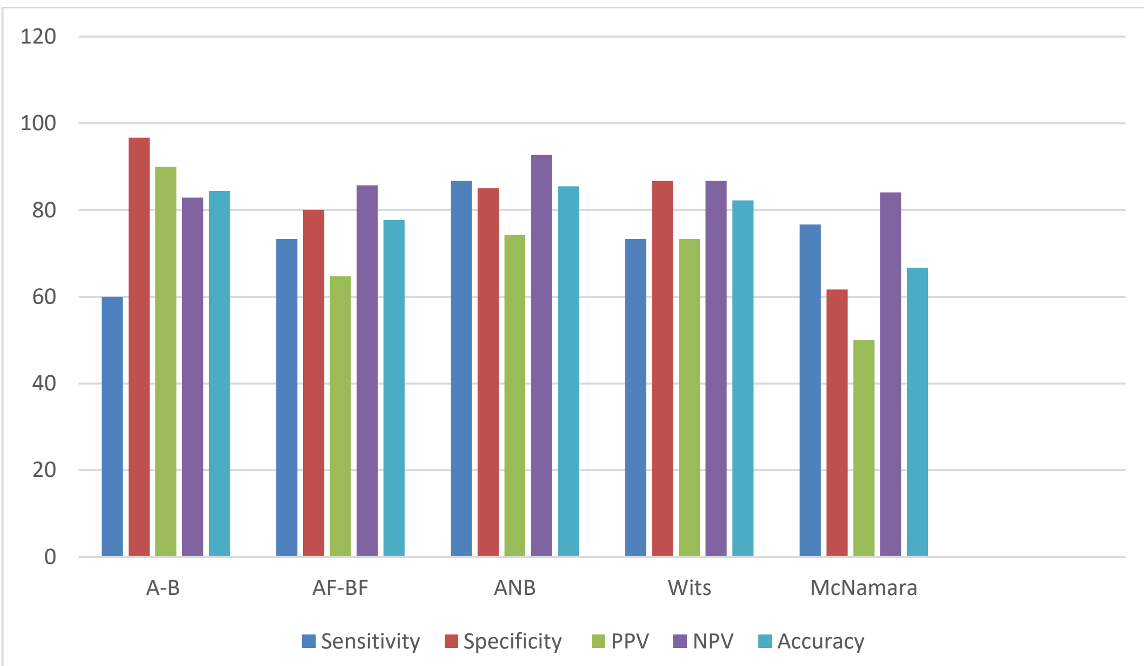

Figure 2 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class II sagittal discrepancy

Table 4 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class III sagittal discrepancy

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	McNemar	K	Correlation
A-B plane angle	80	98.3	96	90.8	92.2	0.125	0.817	0.824
AF-BF	80	98.3	96	90.8	92.2	0.125	0.817	0.824
ANB angle	73.3	98.3	95.7	88.1	90	0.039	–	0.775
Wits appraisal	90	85.7	73	95.2	96.7	0.092	0.693	0.703
McNamara	83.3	88.3	78.1	91.4	86.7	0.774	0.705	0.706

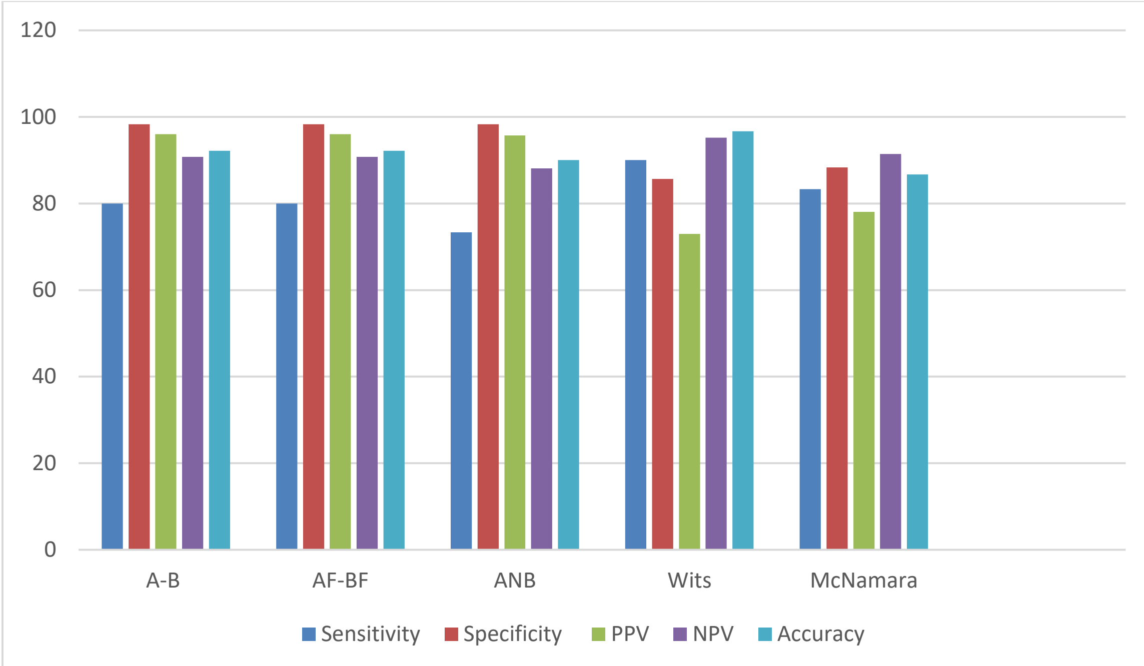

Figure 3 Accuracy, positive predictive value, negative predictive value, sensitivity, and specificity of various parameters in Class III sagittal discrepancy

4. DISCUSSION

Malocclusion is typically classified in sagittal, vertical, and transverse planes. Sagittal plane due to esthetic, psychological, and functional implications is considered as the top of the orthodontic problem list. Cephalometric analysis is routinely used to demonstrate skeletal relationships in the craniofacial complex. In cephalometric analysis, the landmarks display the cranial base and jaw relationship. From the time when the radiographic cephalometry has been introduced, multiple cephalometric analyses with various angular and linear measurements have been suggested. However, the constancy of cephalometric analysis has been questioned by some studies (Taylor, 1969; Nanda, 1994; Oktay, 1991). In the present study, the highest accuracy and sensitivity of the CLI group were related to Downs (A-B plane angle) and Steiner (ANB angle) analysis, respectively, and McNamara's analysis results were not reliable. In class II group, the highest accuracy and sensitivity were related to Steiner (ANB angle) analysis (85.5% and 86.7%, respectively). In this group, the error of McNamara and Downs analysis was statistically significant. Steiner analysis showed to be reliable for CLII assessment. In the CL III group, the highest accuracy (96.7%) and sensitivity (90 %) were related to Wits appraisal analysis and other analyzes were close to one another and less than Wits analysis. ANB angle analysis results were not reliable for CL III assessment.

Oktay (1991) studied the reliability of ANB, Wits, AF-BF, and APDI measurements and concluded that the Wits, AF-BF, and APDI apical base assessment criteria were not more reliable in clinical diagnosis than the ANB angle. In this study, Wits appraisal was only more reliable in the CLIII group than the ANB angle. The reason could be explained due to differences in the occlusal plane or vertical alveolar height in the studied specimens. Italia and Bhatia (2011) studied the palatal plane and their comparison with ANB angle and Wits appraisal and concluded that all the studied methods ("ANB", "Wits appraisal", "App-Bpp", "App-Pogpp", "Mpp-Dpp" and "MppPogpp" can categorize and differentiate various types of skeletal pattern with great accuracy. In the present study, Wits analysis showed high accuracy for assessing class III and ANB angle displayed high accuracy for class I and II anteroposterior jaw discrepancies. As well as, ANB angle was not reliable for CLIII measurement. This may be due to the fact that the position of point A (ANB angle) and Pog (rotation point at Pogonion) in the CL I and CL II / I groups were more consistent than the CLIII group which had more concave jaw. This may exacerbate the ANB angle error in analysis of the CL III group. Kannan et al. (2012) in a study compared the reliability of sagittal methods for assessing and classifying skeletal Class I, Class II and Class III based on Jaw Relationship. The results of Kannan et al.'s study showed that the ANB and AF-BF showed more variability, but in the present study ANB angle showed the highest accuracy (85.5%) and sensitivity (86.7%) in CLII sagittal pattern. Qamaruddin et al. compared ANB, Wits appraisal, Beta angle, Yen angle, and W angle for their validity and reliability in diagnosis of skeletal Classes I, II, III and suggested that all five-skeletal cephalometric sagittal analyses were reliable and can be used in orthodontic diagnosis as alternative to each other which was inconsistent with the results of the present study. Ahmed et al. evaluated the reliability and validity of different skeletal analyses for identification of sagittal skeletal pattern Classes I, II, III and concluded that the Wits appraisal may be used as valid indicators to assess the Class III sagittal pattern which was consistent with the results of the present study.

In the present study, the accuracy and sensitivity of AF-BF and cephalometric indices in McNamara's anteroposterior measurements were also examined. The results of McNamara's anteroposterior measurement for CLI and CLII were not reliable, and in the CL III pattern its accuracy was lower than other cephalometric indices. Likewise, AF-BF did not show any significant error, but displayed the highest accuracy in the three sagittal patterns compared to other cephalometric indices.

5. CONCLUSION

The A-B plane angle (Downs) had the highest sum of sensitivity + specificity, sum of PPV + NPV, and accuracy in diagnosis of Class I cases. Therefore, it seems the best analysis for detection of Class I malocclusions. The ANB angle followed by A-B plane angle and Wits appraisal had all accuracies above 80% in diagnosis of Class II cases; of these, the Steiner (ANB angle) had the highest accuracy; the same analysis had also the highest sum of sensitivity + specificity; whereas, the highest PPV + NPV sum belonged to the Downs analysis (A-B plane angle). It seems that both Downs and Steiner are the best analyses to be jointly used for Class II diagnosis. The highest accuracy belonged to the Wits analysis (96.7%) while diagnosing Class III. However, this analysis had a comparatively low PPV + NPV sum. There were other analyses with still high accuracies (92%) besides high PPV + NPV sums and sensitivity + specificity sums in detection of Class III cases. These were A-B plane angle (Downs) and AF-BF analyses, which are suggested for the diagnosis of this skeletal malocclusion.

It should be taken into consideration that there were a great diversity between results of different tests, and each of these analyses are more appropriate in the case of a certain diagnostic parameter (e.g., negative predictive value or sensitivity). Therefore, instead of relying on a single analysis for diagnosis, it is better to use a combination of analyses that have the highest PPV, NPV, sensitivity, and specificity for a given classification.

Abbreviation

Point A : subspinale
Point B : supraspinale
N : Nasion
Po : porion
Pg : pogonion
Go: Gonion
Co : condylion
FH : Frankfurt plane
N_pog : faciale plane
Occ.plane : occlusal facial plane
PPV : positive predictive value
NPV : Negative predictive value

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Conflict of Interest
The authors declare that there are no conflicts of interests.

Informed consent
Written & Oral informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this manuscript.

Ethical approval
The study was approved by the Medical Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (ethical approval code: IR.AJUMS.REC.1392.268).

Author Contributions

Abdolmohammad Gachkooban: Concepts, Design, Manuscript editing and review

Mina Moalemnia: Definition of intellectual content, Data acquisition, Data analysis, Statistical analysis, Manuscript preparation.

Data and materials availability

All data associated with this study are available upon request to the corresponding author.

Peer-review

External peer-review was done through double-blind method.

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