RESEARCH ARTICLE

Predicting the sagittal skeletal pattern using dental cast and facial profile photographs in children aged 9 to 14 years

Rashna Hoshang Sukhia[1], Rozina Nuruddin[2], Syed Iqbal Azam[3], Mubassar Fida[4]

Abstract

Objective: To quantify prediction of sagittal skeletal pattern using anteroposterior dental relationships on dental casts and facial profile photograph.

Method: The cross-sectional study was conducted at the Aga Khan University Hospital, Karachi, from December 2016 to July 2017, and comprised orthodontic patients of either gender aged 9-14 years who attended the outpatient dental clinic. The sagittal skeletal relationship assessed on cephalometric radiographs was compared with anteroposterior dental and facial measurements on their dental cast and facial profile photographs. A prediction model was developed using multiple linear regression. The applicability of the prediction model was checked on an independent sample. Data was analysed using STATA 12.

Results: Of the 76 patients, about two-third (n=47) were females. The overall median age was 12.3 years (inter-quartile range: 1.8), with majority (60.5%) aged 12-14 years. The proportion of Class I, II and III malocclusion was 25 (32.9%), 50 (65.8%) and 1 (1.3%) respectively. Highest percentage of variability 47.4% in ANB angle was determined by the soft tissue ANB angle. 54.9% of the variability in the ANB angle could be explained by overjet, soft tissue ANB' angle, lower lip to E-line distance, Class II incisor relationship, history of malocclusion and thumb sucking, interaction terms between Class II incisor relationship and history of malocclusion, and history of thumb sucking and soft tissue ANB' angle.

Conclusion: Sagittal skeletal relationship in an individual can be predicted with moderate accuracy using the prediction equation incorporating dental and facial variables along with history of malocclusion and thumb-sucking without potentially harmful exposure to cephalometric radiographs.

Keywords: Cephalometry, Clinical prediction, Dental cast, Facial photographs, Skeletal pattern. (JPMA 72: 2198; 2022)

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Introduction

Malocclusion in growing children may present as a discrepancy in the sagittal, vertical or transverse dimension of the maxilla or mandible and therefore may require growth modification in any of these planes of space.[1] In the sagittal plane, management of an orthodontic patient as the decision regarding growth appliance therapy is predominantly based on sagittal skeletal relationship.[1] Sagittal skeletal malocclusion is a commonly encountered defect due to disturbances in the development of maxilla and mandible which can impact the alignment, positioning and the health of the dentition.[2]

In the United States, the skeletal Class I relationship is highly prevalent (80-85%), followed by skeletal Class II (15%) and Class III relationship (1%).[3] However in orthodontic patients reporting to Aga Khan University Hospital (AKUH) dental clinics, Class II relationship is reported to be 48.1%, indicating a higher burden of this malocclusion in local population.[4]

Skeletal sagittal relationship is traditionally assessed by a cephalometricradiograph.[1] Cephalomeric radiographs are potentially cytotoxic,[5-7] particularly to radiosensitive tissues in the neck region, such as thyroid gland, vertebral bone marrow and oesophagus.[6] Such cytotoxic effects accumulate over the lifetime of an individual.[7,8] Also, availability of fully functioning cephalometric radiographic equipment in many areas of developing countries like Pakistan may be questionable.

[1,4]Department of Surgery, The Aga Khan University and Hospital, Karachi, Pakistan; [2,3]Department of Community Health Sciences, The Aga Khan University and Hospital, Karachi, Pakistan.

Correspondence: Rashna Hoshang Sukhia. e-mail: rashna.aga@aku.edu

Clinical, photographic or cast evaluations provide possible ways to determine incisor, canine and molar classification, and overjet measurement. Studies have shown that overjet alone is not a very reliable indicator of skeletal sagittal relationships.[9,10] Some authors have reported it to be a good predictor for Class II Division 1 cases.[11,12] A statistically significant, though weak correlation (r= 0.336, p<0.01), between Angle's Classification and skeletal sagittal relationship has been reported.[4] Moderate correlations among facial profile measurements on photographs with cephalometric radiographs, ranging between 0.356 and 0.643 have been reported.[13,14]

The burden of skeletal malocclusion and its impact on a child's self-esteem cannot be ignored. Given the cost, availability and potential harmful effects of cephalometric radiation exposure, there is a need to explore non radiological methods to arrive at a diagnosis. Thus if dental relationships and facial soft tissue analyses (low cost, easily available methods with no harmful effects) can predict the sagittal skeletal relationship of an orthodontic patient, this non-radiological method can prove to be a helpful diagnostic tool.

The current study was planned to quantify prediction of sagittal skeletal pattern (ANB angle – angle measured between maxillary base, nasion and mandibular base) by developing a prediction equation, using dental casts and facial profile photograph soft tissue analyses.

Materials and Methods

The cross-sectional analytical study was conducted at the (The Aga Khan University Hospital) AKUH Orthodontic clinics, Karachi, from December 2016 to July 2017. After approval from the institutional ethics review committee, the sample size was calculated using Power Analysis and Sample Size software program licensed by Number Cruncher Statistical System (NCSS PASS), version 2008, to achieve 90% power to detect an R^2 of 0.05 with a significance level of 0.05. The variables tested were adjusted for an additional 5 independent variables with an R^2 of 0.6.[12]

The sample was raised using simple random sampling technique. Those included were orthodontic patients of Pakistani origin aged 9-14 years regardless of gender who attended the dental clinics. Their cephalograms were taken on a standardized machine and standardised photographs were taken in the natural head position. Subjects with craniofacial syndromes, patients having prior history of tooth extractions, orthodontic treatment, prosthodontic treatment, maxillofacial or plastic surgery and patients having history of previous trauma to the face and dentition were excluded.

The patient's demographic factors, history of respiratory illness, malocclusion and habits were collected from the medical records. The outcome variable i.e. the ANB angle was traced from the patients' cephalogram on a tracing paper (lead acetate paper) using a 0.5 mm lead pencil and an X-ray illuminator in a dark room, and was measured using the cephalometric ruler in degrees (±0.1).The main exposure variable was the overjet measured as the horizontal distance in millimeters (±0.1) from the labial surface of the lower incisor to the incisal edge of the upper incisor on the dental cast. Overjet was measured on both central incisors, and the highest overjet was recorded. Data was collected by a single operator.

Molar relationship was assessed using Angle's classification1 and incisor relationship was noted using British Standards Institute classification.[15] Facial profile photograph soft tissue analysis [measuring Tragus, nasion and maxillary position, (TNA angle - relative maxillary position), Soft tissue maxillo-mandibular angular discrepancy measured between soft tissue maxillary point on upper lip, nasion and soft tissue mandibular point between lower lip and chin (ANB' angle), upper lip to E-line [line from tip of nose to tip of chin], lower lip to E-line, upper lip to S-line [line from tip of chin to mid of base of nose] and lower lip to S-line, angle of convexity, Tragus, nasion and mandibular position, (TNB angle - relative mandibular position), soft tissue nasion, soft tissue sella and soft tissue pogonion, N'-S'-Pog' and soft tissue nasion, soft tissue sella and soft tissue point on mandibular position, N'-S'-B' (soft tissue angles of facial convexity) was carried out on standardised lateral profile photographs taken in the natural head position, with the patient looking at a far object at eye level (Figure).

The relationship of the dependent variable, ANB angle, was studied with the main independent variable, overjet, along with the dental and facial soft tissue relationships which were assessed using the dental cast (incisor and molar relationships) and facial profile photographs. The demographic factors, including age and gender, behavioural factors, including thumb sucking habit and swallowing habit, illnesses, like history of respiratory illness such as tonsils and adenoids, and familial factors, including history of malocclusion in the family, which may influence the sagittal skeletal, dental and facial soft tissue relationships, were studied as confounders and adjusted for in the prediction equation.

Data were analysed using STATA 12. Descriptive statistics, means and standard errors (SE) / median and interquartile range (IQR) were reported for normally distributed and non-normally distributed quantitative data, respectively. For qualitative variables, frequencies and percentages were calculated.

Simple linear regression was then carried out using ANB angle as the dependent variable and different demographic, history, antero-posterior dental relationships and facial profile photograph analyses as independent variables individually. Variables with $p \leq 0.25$ were considered eligible for multivariable analysis. Multi-collinearity, confounding and interaction were also assessed. Multivariable analysis using multiple linear regression was used to identify the final parsimonious model and to develop a prediction equation for the ANB angle. The overall significance of the model was kept at $p<0.05$. During post-estimation Z residuals, deviance residuals and Cooks residuals and normal probability plots were examined to assess model adequacy.

Figure: Facial profile photograph for soft tissue analyses.

Angle of Convexity	Angle formed between soft tissue nasion, soft tissue pronasale and soft tissue pogonion
Nasolabial angle	Angle formed by a line tangent to the upper lip and a line tangent to the columella of the nose
TNA' Angle - Relative Maxillary Position	Angle between soft tissue tragus, nasion and maxillary base
TNB' Angle - Relative Mandibular Position	Angle between soft tissue tragus, nasion and mandibular base
ANB' Angle – Soft Tissue Maxillomandibular Angular Discrepancy	Angle between soft tissue maxillary base, nasion and mandibular base
N'.Sn.Pog'- Soft tissue angles of facial convexity	Angle between soft tissue nasion, subnasale and pogonion
N'.Sn.B'- Soft tissue angles of facial convexity	Angle between soft tissue nasion, subnasale and mandibular base
Upper and Lower Lip Distance to E Line	Distance in millimeter from the E line to the most prominent point on the upper and lower lip
Upper and Lower Lip Distance to S Line	Distance in millimeter from the S line to the most prominent point on the upper and lower lip

Soft tissue tragus (T), Soft tissue nasion (N), Maxillary base (A), Mandibular base (B), Subnasale (Sn), Soft tissue pogonion (Pog'), E line (line drawn from nose tip to soft tissue pogonion), S line (line drawn from mid of nasal base {Sn to tip of nose} to soft tissue pogonion).

To check the applicability of the prediction equation, a separate random sample of 30 subjects aged 9-14 years was used. Paired t test and Bland Altman plot were used to check the difference between the actual ANB angle and the predicted ANB angle.

Results

Of the 76 patients, about two-third (n=47) were females. The overall median age was 12.3 years (IQR: 1.8), with majority 46 (60.5%) aged 12-14 years. Skeletal Class II malocclusion was the most frequent malocclusion as 50

(65.8%) subjects had ANB angle >4 degrees. An increased overjet was also a frequent finding, with 62 (81.6%) subjects showing overjet >4mm.

The most frequent incisor relationship was found to be Class II incisor relationship 65 (85.6%) and 50 (65.8%) showed a Class II molar relationship.

Scatter plots of ANB angle with overjet, TNA angle (relative maxillary position), ANB′ angle (Soft tissue maxillo-mandibular angular discrepancy), upper lip to E-line, lower lip to E-line, upper lip to S-line and lower lip to S-line showed a positive linear relationship, indicating that an increase in the value of each of these independent variables led to an increase in the value of the dependent variable. A negative linear relationship was seen for angle of convexity, TNB angle (relative mandibular position), N′-S′-Pog′ and N′-S′-B′ (soft tissue angles of facial convexity), indicating that an increase in each of these independent variables led to a decrease in the ANB angle.

Table-1: Univariate analysis of ANB angle with demographic, skeletal, dental, facial soft tissue analyses, history and behavioural factors (n=76).

Variable	Crude Beta coefficient	95% Confidence Interval	R^2
Age (years)	-0.13	-0.63, 0.37	0.004
Gender (Female)	-0.19	-1.41, 1.03	0.001
Overjet (mm) **	0.33	0.80, 0.47	0.240
Angle of Convexity (degrees) **	-0.08	-0.16, 0.004	0.046
Nasolabial Angle (degrees)	0.002	-0.05, 0.05	0.0001
TNA′ Angle - Relative Maxillary Position (degrees)	0.08	-0.07, 0.22	0.014
TNB′ Angle - Relative Mandibular Position (degrees) **	-0.23	-0.37, -0.08	0.119
ANB′ Angle-Soft tissue maxillomandibular angular discrepancy (degrees) **	0.67	0.51, 0.84	0.474
N′.Sn.Pog′- Soft tissue facial convexity angle (degrees) **	-0.32	-0.40, -0.24	0.455
N′.Sn.B′ - Soft tissue facial convexity angle (degrees) **	-0.29	-0.37, -0.20	0.382
Upper Lip distance to E Line (mm) **	1.03	0.74, 1.32	0.403
Lower Lip distance to E Line (mm) **	0.42	0.12, 0.72	0.094
Upper Lip distance to S Line (mm) **	1.09	0.71, 1.46	0.309
Lower Lip distance to S Line (mm) **	0.36	0.03, 0.70	0.060
Class II Incisor relationship **	2.21	0.61, 3.81	0.210
Right Molar Class II **	1.65	0.47, 2.84	0.095
Left Molar Class II **	1.60	0.41, 2.79	0.092
History of Tonsils	1.28	-1.74, 4.31	0.010
History of Adenoids	0.07	-3.63, 3.76	<0.001
History of Malocclusion	0.02	-1.16, 1.21	<0.001
History of Thumbsucking	1.02	-0.59, 2.62	0.021
Immature Swallowing Pattern	-1.15	-4.17, 1.88	0.008

** p≤0.25; ANB: Point A on maxilla, nasion, point B on mandible; ANB′: Soft tissue point A, soft tissue nasion, soft tissue point B; TNA′: Trgaus, soft tissue nasion, soft tissue point A on maxilla; TNB′: Trgaus, soft tissue nasion, soft tissue point B on mandible; N′.Sn.Pog′: Soft tissue nasion, subnasale, soft tissue pogonion; N′.Sn,B′ Soft tissue nasion, subnasale, soft tissue point B on mandible; Class II incisor and molar relationship: Yes (Class II) / No (Class I and III).

Table-2: Multivariable analysis of ANB angle with independent variables with interaction.

Variables	Adjusted Beta Coefficient	95% Confidence Interval	R^2 Adjusted
Overjet (mm)	0.09	-0.05, 0.24	0.5487
ANB′ (Soft Tissue) (degrees)	0.50	0.28, 0.71	
Lower Lip distance to E Line (mm)	0.28	0.06, 0.51	
Class II Incisor Relationship	1.48	-0.17, 3.13	
History of Malocclusion	2.51	0.34, 4.67	
History of Thumb Sucking	-4.67	-9.65, 0.31	
Class II Incisor Relationship # History of Malocclusion	-3.25	-5.59, -0.90	
History of Thumb Sucking # ANB′ (Soft Tissue)	0.36	-0.04, 0.77	
Constant	-1.60	-3.75, 0.56	

Simple linear regression showed that the estimated ANB angle increased by 0.33 degrees when the overjet increased by 1 mm. The estimated mean ANB angle of patients having an overjet of 0 mm was 2.94 degrees. This model gave an R^2 value of 0.24, meaning that 24% of the variation in ANB angle was explained by overjet (Table 1).

The highest percentage of variability in ANB angle using simple linear regression was explained by the soft tissue ANB angle at 47.4%. However, using multivariable linear regression analysis, the variability in the ANB angle can be explained by about 54.9% (Table 2).

The estimated model can be written as follows:

ANB angle= -1.60+ 0.09 (Overjet)+0.50 (ANB' softtissue)
+0.28 (Lower lip Eline)+ 1.48 (Class II Incisor Relationship)
+2.51 (History of Malocclusion)
-4.67 (History of thumbsucking)
-3.25 (Class II Malocclusion*History of Malocclusion)
+0.36(History of thumbsucking*ANB' softtissue)

ANB angle= β_0+ β_1 (Overjet)+ β_2 (ANB' soft tissue)
+ β_3 (Lower lip E line)+ β_4 (Class II Incisor Relationship)
+ β_5 (History of Malocclusion)+ β_6 (History of thumb sucking)
+ β_7 (Class II Malocclusion *History of Malocclusion)
+ β_8 (History of thumb sucking*ANB' soft tissue)

Where β_0 is the constant and β_1 to β_8 are the coefficients for the independent variables in the predicted equation.

The mean predicted ANB angle using this equation was 5.43±0.228 degrees (range: 4.98-5.89 degrees). The narrow confidence interval (CI) for the predicted mean ANB angle indicated that it was a precise estimate.

Age and gender were the demographic factors studied as confounders and assessed for in the univariate analysis. However, since they were not significantly associated, they were excluded from multivariable analysis.

Intra-examiner reliability was assessed using intra-class correlation (ICC) analysis using two-way mixed effect model. A random sample of 20 subjects was selected from the original sample after one month and the linear and angular measurements of the facial profile were repeated by the principal examiner. Very strong correlation was observed between the two readings (ICC >0.8).

During post-estimation, the predicted ANB angle and the residuals were calculated using the final model with interaction terms. The fit of the model was then checked by Shapiro-Wilk test for normality of the standardized Z residuals which indicated normal distribution(p=0.687), thus the model was a good fit.

For example, a 10-year-old child presented with an overjet of 10mm and a Class II incisor relationship with his mother having a history of malocclusion. His soft tissue ANB angle was 12 degrees and he had no thumb sucking habit. Using the above equation:

ANBangle= -1.60+ 0.09 (10)+ 0.50 (12)+ 0.28 (2)+ 1.48 (1)+ 2.51 (1) - 4.67 (0)-3.25 (1*1)+ 0.36(0*12)

ANB angle was found to be 6.6 degrees.

Therefore, this child would have an ANB angle of 6.6 degrees and would be a likely candidate for growth modification treatment.

To check the applicability of the prediction equation, the predicted ANB angle was calculated using the prediction equation in a random sample of 30 subjects. The mean actual ANB angle of the sample was 5.63±0.433 (range: 4.77-6.50) and the mean predicted ANB angle was 5.55±0.430 (range: 4.69, 6.41) with a mean difference of 0.08±0.448 (range: -0.81-0.98) which was statistically non-significant (p=0.852).

Discussion

Class II malocclusion is a common malocclusion, especially in the subcontinent and neighbouring countries.[16-18] About two-thirds 50 (65.8%) of the study sample comprised children having a skeletal Class II malocclusion assessed using the ANB angle, which has also been reported to be the most prevalent amongst Pakistani orthodontic patients.[4,18] The proportion of Class II malocclusion was 50 (65.8%), with Class II incisor relationship being 65 (85.6%), and 62 (81.6%) showed an overjet>4 mm.

A positive history of thumb sucking habit was found in 12 (15.8%), and an immature swallowing pattern with a tongue thrust in 3 (4%). Prevalence of abnormal oral habits among children, mainly thumb sucking and tongue thrusting, has been reported to be around 3% which increases to around 10.3% amongst children with malocclusion.[19]

The Overjet explained about 24% of the variability in the ANB angle in the current study. Overjet has been reported to have a strong correlation with ANB angle (r=0.69), explaining about 28.8% in the ANB angle.[11] This was, however, reported using simple linear regression, with overjet as independent variable and ANB angle as dependent variable. Lombardo et al.[12] reported a significant correlation of overjet with ANB angle (r= 0.4872, p=0.001) with an R^2 value of 0.319 for right overjet and 0.313 for left overjet. They used multiple regression analysis to predict right and left overjet using ANB angle, incisor mandibular plane angle (IMPA) and Upper incisor to anterior nasal spine to posterior nasal spine (ANS-PNS)angle.

The current study found that incisor relationship could predict about 21% of the variability in ANB angle, whereas right and left molar relationship can predict about 9.5% and 9.2% of the variability in ANB angle using simple linear regression analysis. Incisor relationship in the current study was also found to significantly interact with history of malocclusion in multivariable analysis, which indicates a genetic component of aetiology of malocclusion.

Al-Hamlan et al.[20] reported a significant association of incisor relationship with ANB angle using Chi square test (p=0.05). No significant association was reported between molar relationship and ANB angle (p=0.21). This may be due to the fact that molar relationship might be affected by local dental factors, like carious lesions and early exfoliation of deciduous molars.

The highest percentage of variability (47.4%) in the ANB angle was explained by soft tissue ANB angle (soft tissue maxilla-mandibular angular discrepancy), assessed using simple linear regression in the current sample. A strong positive correlation between skeletal ANB angle measured on cephalometric radiograph and the soft tissue ANB angle measured using three-dimensional (3D) facial imaging (r=0.74, p<0.05) has been reported in the literature.[21] Their analysis, however, was not adjusted for other factors which might explain the variability in the skeletal ANB angle.

The current study is the first where a prediction model using multiple linear regression incorporating anteroposterior dental relationships and facial soft tissue profile analyses have been used to predict the ANB angle for the assessment of the skeletal pattern of a patient without using the cephalometric radiograph, thus preventing the patient from radiation exposure and minimising the cost of diagnosis. The internal validity of the study was one of its strengths as standardized cephalograms from one radiographic machine and standardised photographs taken in the natural head position were used for the study. Very strong ICC coefficients amongst the two sets of facial profile photograph measurements, done one month apart by the same examiner, indicated excellent reliability.

In terms of limitations, the study was done at a single centre. The prediction equation needs to be tested at other centres. The cross-sectional study was done using pre-existing records and casts were used to measure overjet and molar relationship. However in clinical practice, overjet and molar relationship can be measured clinically on the patient. Also some variables like history of tonsils, adenoids, malocclusion, thumb sucking etc were collected from the records and therefore may have been subjective. It is therefore recommended to conduct a prospective study whereby these cofounders can be assessed more objectively.

Conclusions

The mean predicted ANB angle using multiple linear regression equation was 5.43±0.228 degrees, indicating a trend towards skeletal Class II malocclusion. The model built could be used to explain about 54.9% variability in the ANB angle and can thus be used to predict and diagnose the sagittal skeletal relationship among Pakistani children aged 9-14 years in places where cephalometric facility may not be available.

Disclaimer: The Abstract has been previously presented in conferences, and the text is based on an academic thesis project.

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