Original Article

Cephalometric Evaluation of Maxillary Incisors Inclination, Facial, and Growth Axes in Different Vertical and Sagittal Patterns: An Original Study

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ABSTRACT

Aim: The aim of this study was to evaluate the inclination of the maxillary incisors (I), facial axis (FA), and growth axis (GA) in different vertical and sagittal patterns. **Materials and Methods:** A total of 498 consecutive orthodontic patients, with an average age of 18.87 years (range = 5–63 years), were grouped based on their vertical and sagittal patterns. Maxillary incisors, FA, and GA axes were traced and their corresponding angles to nasion-basion and true horizontal lines were measured. The sample was divided into three groups based on the mandibular divergence (mandibular plane-MP/sella-nasion [SN]): Group 1—hypodivergent pattern (MP/SN ≤ 27; $n = 30$), Group 2—normodivergent pattern (27 < MP/SN <37; $n = 254$), and Group 3—hyperdivergent pattern (MP/SN ≥ 37; $n = 214$); the sample was then divided into three groups based on the sagittal pattern (ANB, angle between points A, Nasion and B): Group I—skeletal CLI (Class I) (0 <ANB <4; $n = 228$), Group II—skeletal CLII (ANB ≥ 4; $n = 216$), and Group III—skeletal CLIII (ANB ≤ 0; $n = 54$). Group differences were evaluated using the analysis of variance and *post hoc* tests. Chi-square tests were used for testing relationships between categorical variables. **Results:** FA/nasion-basion (NBa) and GA/NBa were different among the vertical groups ($P < 0.001$). FA/NBa was found significantly different in the sagittal groups, whereas GA/NBa was only different between CLII and CLIII groups. Compensation in maxillary incisors' inclination was present in the sagittal groups, but not in the vertical ones. CLI patients when stratified in vertical groups showed FA/NBa and GA/NBa to be different across the three vertical groups. **Conclusion:** FA/NBa was found different in the vertical and the sagittal groups. Maxillary incisors compensation was only found in the sagittal and not in the vertical groups.

Keywords: *Cephalometry, facial axis, growth axis, maxillary incisors, sagittal, vertical dimension*

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Introduction

Orthodontists have always highlighted the importance of the maxillary incisors' (I) position as one of the pillars of smile and facial aesthetics.[1,2] Cephalometric and clinical evaluation of maxillary incisors' axial inclination during orthodontic treatment is a routine practice to ascertain an adequate positioning with regard to both bony and soft tissues structures. Therefore, orthodontists have always considered locating the maxillary incisors in an ideal position as a main objective of treatment planning. Accordingly, assessment of maxillary incisors' position during and at the end of treatment remains a key factor in orthodontic treatment success.[3]

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Contrary to conventional thought, the optimal position of the teeth in the face should be determined by the position of the maxillary incisors, rather than the mandibular ones. Furthermore, Creekmore[4] recommends using the simplified Radney analysis, the modified Steiner analysis, or the modified Ricketts analysis when positioning the teeth in the face as it should be predicated on the position of the maxillary incisors.

Concordantly, Schudy[5] stated that in producing functional harmony, the maxillary incisors should be first positioned in correct axial inclination from the standpoint of aesthetics and then the mandibular incisors position should be adjusted to produce the correct interincisal angle.

Furthermore, the orthodontic treatment should aim to optimize tooth positions within the existing skeletal pattern, taking into consideration the vertical and the sagittal pattern of the patient.

The axial inclination of the maxillary incisors is usually evaluated on the conventional lateral cephalograph and/or the articulated dental casts.[3,6,7]

This inclination is assessed according to the different reference lines and planes at the beginning of treatment, throughout treatment, and after placing the maxillary incisors in an inclination that is judged optimal for the patient.

Traditionally, the inclination of the maxillary incisors is evaluated using cephalometric measurements of the long axis of the incisor (joining incisal tip to apex) and planes: sella-nasion (SN), the Frankfort horizontal (FH) plane, the palatal plane (PP), A-pogonion (A-Pog), N-pogonion (N-Pog), nasion-A point (NA) line, the line parallel to N-perpendicular passing through point A, to the maxillary occlusal plane, to the bony orbit, to the forehead, and glabella as well as the interincisal angle.[8-13] Variables that affect these measurements are taken into consideration.[8]

Naini *et al.*[14] found that the ideal inclination of the maxillary incisor in profile view is approximately parallel to the true vertical line, and thereby perpendicular to the true horizontal (H) line.

However, association between the maxillary incisors' inclination and the patient's facial pattern has not been thoroughly investigated, especially the facial axis (FA). In Ricketts' analysis,[9,15] the FA angle (mean 90° ± 3.5°) is the angle formed between nasion-basion (NBa) plane and the line extending from foramen rotundum (Pt) to constructed gnathion (Gn'). The smaller the FA angle the more retrusive the chin, whereas an angle greater than 90° suggests a protrusive or forward growing chin.[9,15] According to Ricketts, FA to NBa angle does not change with growth, and it indicates the direction of growth and varies among vertical and horizontal growers. Similarly, the growth axis (GA) (described by Downs as the angle between sella turcica [S] to gnathion [Gn] line and FH line),[9,16] ranges from a minimum of 53° to a maximum of 66°, with a mean reading of 59.4° ± 3.8°. This angle also indicates the growth pattern of the mandible. Furthermore, Brodie's longitudinal studies[17,18] showed that the morphogenetic pattern of the human head is established by age 3 months and follows a determined course from infant to childhood, and that the vertical growth pattern is constant throughout the development from ages 8 to 19 years, keeping the lower face height increases at a similar rate with a ratio of 55% to total facial height stable during the growth period.[17,18]

Thus, the objectives of this study were to determine if there is an association between the inclination of the maxillary incisors and FA and GA in different vertical patterns (hypodivergent, normodivergent, and hyperdivergent), and to determine if there is an association between the inclination of the maxillary incisors and FA and GA in different sagittal dimensions (CLI, CLII, and CLIII). The null hypothesis was that there is no association between FA, GA and maxillary incisors' inclination with vertical divergence on one hand and with sagittal classification on the other hand.

Materials and Methods

Setting and design

This was a retrospective study.

Sampling criteria

Before data collection, we calculated the optimal sample size for our study design. Using an anticipated effect size (f2) of 0.02 (large) and a power level of 0.8 with three main predictors and a probability level of 0.05, the ideal sample size was calculated to be 543.

Patients with craniofacial anomalies were excluded.

Study method and observational parameters

A total of 498 consecutive lateral cephalograms, who had an average age of 18.87 years (range = 5–63 years), were selected from patients' data at the Department of Orthodontics and Dentofacial Orthopedics at the American University of Beirut, Beirut, Lebanon. Available lateral cephalometric radiographs of growing (*n* = 307) and adult (*n* = 183) patients (306 females, 192 males) taken before or at the end of orthodontic treatment (after removal of appliances) placed according to the natural head position at an appropriate distance (sagittal plane–film distance of 13 cm) and all taken in one machine were studied. Consent from the institutional review board at the American University of Beirut, Beirut, Lebanon, was granted (OTO.AM.01).

The 498 lateral cephalograms were digitized using the Dolphin Orthodontic software (Dolphin Imaging and Management Solutions, La Jolla, California). Angular measurements were computed to determine the inclination of maxillary incisor to SN, PP, and NA, as well as FA, GA, and maxillary incisor to NBa and true horizontal (H). MP/SN and ANB angles were also measured. Measurements of different variables were carried out on the digitized lateral cephalograms [Figure 1].

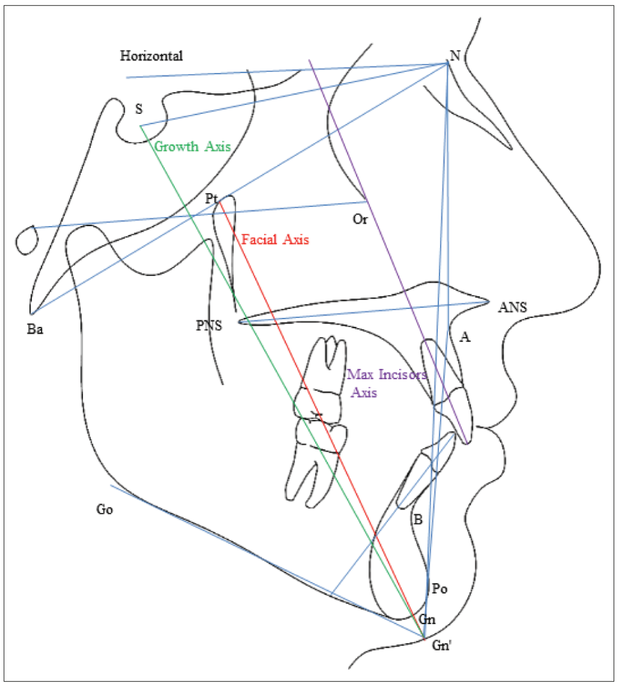

Figure 1: Landmarks and planes on a lateral cephalometric tracing as used in the study showing maxillary incisors axis and facial and growth axes

The sample was divided into three groups based on the vertical pattern (MP/SN) [Table 1]:

- Normodivergent group (27° <MP/SN <37°; $n = 254$)
- Hypodivergent group (MP/SN ≤ 27°; $n = 30$)
- Hyperdivergent group (MP/SN ≥ 37°; $n = 214$)

It was also stratified into three other groups based on the sagittal pattern (ANB) [Table 2]:

- Skeletal CLI (0° <ANB < 4°; $n = 228$)
- Skeletal CLII (ANB ≥ 4°; $n = 216$)
- Skeletal CLIII (ANB ≤ 0°; $n = 54$)

The maxillary incisors' inclination was measured relative to NA, PP, and SN.

Also, the angles between the long axis of maxillary incisors/FA/GA, and NBa line were measured. The maxillary incisors/FA/GA were also measured relative to the true horizontal [Figure 1].

Statistical analyses

Data cleaning was performed on all entered data to check for potential errors carried out during data entry. An initial frequency distribution was generated for all variables to check for any potential outliers.

When groups were stratified based on the vertical MP/SN and sagittal planes (ANB), the one-way analysis of variance (ANOVA) was used to test differences in variables between these groups followed by the *post hoc* Bonferroni test. The chi-square test was used to

Table 1: Means of selected cephalometric measurements in groups stratified on vertical pattern MP/SN

Groups (n = 498)	1 (n = 30) Hypodivergent		2 (n = 254) Normodivergent		3 (n = 214) Hyperdivergent		ANOVA (P)	Comparisons among groups		
	Mean	SD	Mean	SD	Mean	SD		1–2	1–3	2–3
Age (years)	*23.32*	*11.54*	*17.99*	*9.81*	*18.18*	*10.99*	*0.00*	*0.00*	*0.00*	*NS*
Cephalometric measurements										
Facial axis/NBa	94.25	5.14	89.98	4.98	85.65	4.98	*0.00*	*0.00*	*0.00*	*0.00*
Facial axis/horizontal	119.15	6.77	117.51	9.87	115.76	3.48	*0.01*	*NS*	*NS*	*0.04*
Growth axis/NBa	99.33	7.40	94.56	4.80	90.05	7.40	*0.00*	*0.00*	*0.00*	*0.00*
Growth axis/horizontal	124.45	3.11	122.36	7.03	125.60	71.45	*0.75*	*NS*	*NS*	*NS*
I–NBa	84.63	13.23	84.41	10.57	82.96	9.57	*0.28*	*NS*	*NS*	*NS*
I–Horizontal	110.96	11.42	112.63	10.06	113.07	8.79	*0.52*	*NS*	*NS*	*NS*
I–NA	17.66	11.06	21.92	10.07	22.07	8.20	*0.00*	*0.00*	*0.00*	*NS*
I/PP	109.22	11.54	111.39	11.95	109.25	11.01	*NS*	*NS*	*NS*	*NS*
I/SN	98.81	12.23	102.29	12.21	102.14	9.17	*0.04*	*NS*	*NS*	*NS*

The italic values in this table represent P-value < 0.05

SN = sella-nasion, NBa = nasion-basion, SD = standard deviation, PP = palatal plane, ANOVA = analysis of variance, I = maxillary incisor, NS = P-value > 0.05

gauge bivariate associations between malocclusion and vertical patterns. *Post hoc* results for the chi-square test were calculated by extracting the adjusted residuals. Chi-square values were calculated by multiplying each adjusted residual by itself. *P* values were obtained by transforming the chi-square numbers through the Statistical Package for the Social Sciences (SPSS) software. For all parameters, two-sided *P* values were reported. *P* value < 0.05 was considered as statistically significant. All analyses were completed using IBM SPSS (IBM, released 2016, IBM SPSS Statistics for Windows, version 24.0, Armonk, New York).

Results

Interrater reliability was calculated on all variables of randomly chosen cephalograms (*n* = 50). Intraclass correlation coefficients were high (>0.9).

Although age was statistically significantly different between the vertical groups, no gender differences existed. The distribution of females and males between the groups was not statistically significantly different (*P* value= 0.343).

The total sample was then subdivided into three groups based on the vertical pattern MP/SN: Group 1—hypodivergent pattern (MP/SN ≤ 27°; *n* = 30), Group 2—normodivergent pattern (27° < MP/SN < 37°; *n* = 254), and Group 3—hyperdivergent pattern (MP/SN ≥ 37°; *n* = 214) [Figure 2]. The age of Group 1 (hypodivergent) was different from the age of Groups 2 (normodivergent) and 3 (hyperdivergent). The mean of FA for each group was as follows: hypodivergent (mean FA = 94.25°), normodivergent (mean FA = 89.98°), and hyperdivergent (mean FA= 85.65°). ANOVA showed that FA/NBa was different across the three groups (*P* < 0.00) as well as FA/H (*P* = 0.01). The *post hoc* analysis showed that there was a significant difference in FA/NBa between normodivergent and hypodivergent, hypodivergent and hyperdivergent, and hyperdivergent and normodivergent, whereas FA/H showed only differences between normodivergent and hyperdivergent groups (*P* value = 0.04). GA/NBa was

Table 2: Means of selected cephalometric measurements in groups stratified on sagittal pattern (ANB)

Groups (*n* = 498)	I (*n* = 228) Class I		II (*n* = 216) Class II		III (*n* = 54) Class III		ANOVA (*P*)	Comparisons among groups		
	Mean	SD	Mean	SD	Mean	SD		I–II	I–III	II–III
Age (years)	*17.69*	*9.09*	*20.01*	*12.02*	*19.21*	*11.17*	*NS*	*NS*	*NS*	*NS*
Cephalometric measurements										
Facial axis/NBa	89.48	5.36	86.69	5.09	90.46	6.70	*0.00*	*0.00*	*NS*	*0.00*
Facial axis/horizontal	117.05	10.32	116.15	3.98	118.85	4.74	*0.06*	*NS*	*NS*	*NS*
Growth axis/NBa	95.35	7.72	91.90	5.84	95.09	5.11	*0.00*	*NS*	*NS*	*0.00*
Growth axis/horizontal	126.90	69.13	120.96	7.51	122.76	3.05	*0.40*	*NS*	*NS*	*NS*
I–NBa	85.16	8.89	80.88	11.32	89.75	8.05	*0.00*	*0.00*	*0.00*	*0.00*
I–Horizontal	113.55	8.19	110.70	10.91	117.31	7.47	*0.00*	*0.00*	*0.02*	*0.00*
I–NA	23.08	7.61	17.51	10.32	29.22	7.31	*<0.001*	*<0.001*	*<0.001*	*<0.001*
I/PP	110.74	12.44	108.01	10.80	116.56	7.17	*<0.001*	*0.033*	*0.002*	*<0.001*
I/SN	103.47	8.55	98.15	12.88	108.42	7.94	*<0.001*	*<0.001*	*0.006*	*<0.001*

The italic values in this table represent *P*-value < 0.05.

SN = sella-nasion, NBa = nasion-basion, SD = standard deviation, PP = palatal plane, ANOVA = analysis of variance, NA = nasion-A point, I = maxillary incisor, NS = *P*-value > 0.05

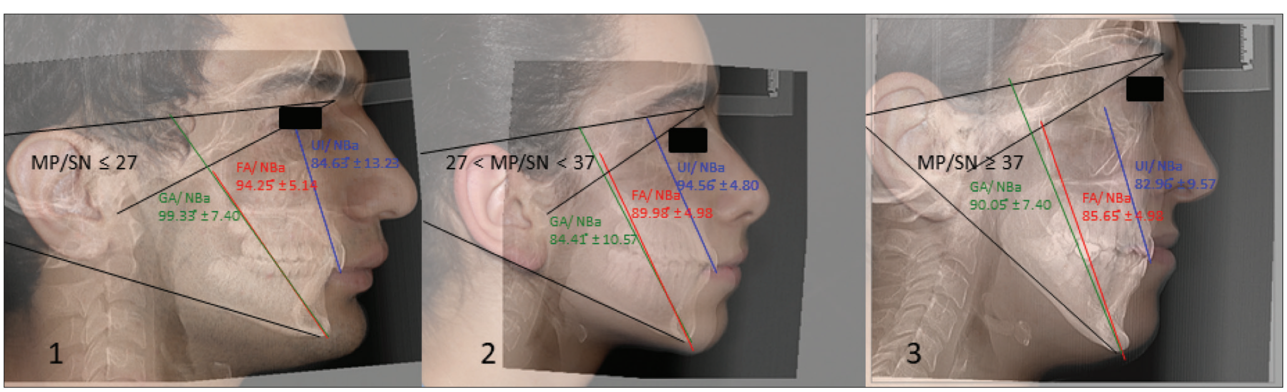

Figure 2: Maxillary incisors, facial and growth axes in the three vertical Groups 1, 2, and 3 stratified on MP/SN: Group 1 (hypodivergent pattern), Group 2 (normodivergent pattern), and Group 3 (hyperdivergent pattern)

also found different among the three groups (P <0.00), and *post hoc* analysis showed that there was a significant difference across the three groups. There was no difference in GA/H, I/NBa, and I/H, I/PP, and I/SN. Only I/NA was different between Groups 1 and 2 and Groups 1 and 3 with more retroclined incisors in the hypodivergent group [Table 1].

Categorizing in the sagittal dimension, we subgrouped the sample according to ANB angle into: skeletal CLI (0° <ANB <4°; n = 228), skeletal CLII (ANB ≥ 4°; n = 216), and skeletal CLIII (ANB ≤ 0°; n = 54) [Figure 3]. No statistically significant difference was observed in age among the three sagittal groups. FA/NBa was found significantly different in the three skeletal groups (P value = 0.00) with Groups I and II being different as well as Groups II and III. GA/NBa was also found different (P value = 0.00) with differences only between Groups II and III. FA/H and GA/H were not found different. I/NBa, I/H, I/NA, I/PP, and I/SN were all found different across the three groups; the maxillary incisors being more proclined in CLIII and more retroclined in CLII [Table 2].

The sample was then divided into groups according to the vertical (MP/SN) and the sagittal (ANB) patterns [Table 3]. When classified on the sagittal dimension, hypodivergent pattern had the highest percentage of incidence in CLI (53.3%), hyperdivergent in CLII (50.9%), and normodivergent in CLIII (66.7%). Chi-square test revealed that the contingency table was statistically significantly different (P = 0.005). *Post hoc* tests showed that the differences were mainly in the normodivergent to hyperdivergent patterns in CLII and CLIII (0.0017 < P < 0.0173).

When divided into three groups based on the vertical pattern (hypodivergent, normodivergent, and hyperdivergent), CLI patients showed only FA/NBa and GA/NBa to be different across the three groups (P value = 0.00) [Table 4], whereas in CLII patients, FA/NBa and GA/NBa were found different between the hypodivergent and hyperdivergent as well as normodivergent and hyperdivergent, and FA/H was found different only between normodivergent and hyperdivergent [Table 4]. In CLIII patients, FA/NBa was only found significantly different between hypodivergent and hyperdivergent (P value = 0.01), whereas GA/NBa was found

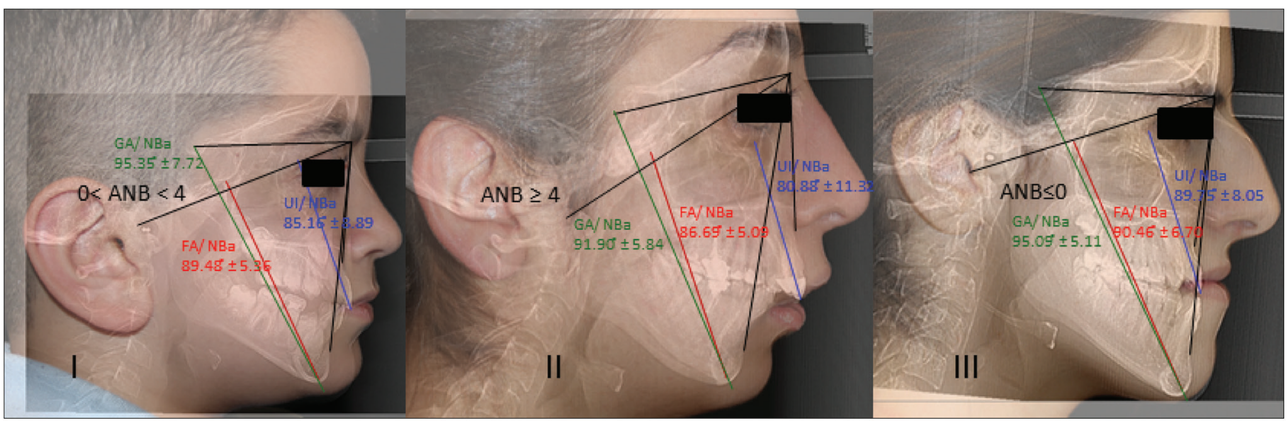

Figure 3: Maxillary incisors, facial and growth axes in the three sagittal Groups I, II, and III stratified on ANB: Group I (Angle CLI), Group II (Angle CLII), and Group III (Angle CLIII)

Table 3: Sample size and distribution in groups stratified on vertical and horizontal patterns (MP/SN and ANB)

Groups (n = 498)	I			II			III			Total		
	Class I			Class II			Class III					
	n	% within DIV MP/SN	% within CL	n	% within DIV MP/SN	% within CL	n	% within DIV MP/SN	% within CL	n	% within DIV MP/SN	% within CL
Group 1 (hypodivergent)	16	53.3	7.0	9	30.0	4.2	5	16.7	9.3	30	100	6.0
Group 2 (normodivergent)	121	47.6	53.1	97	38.2	44.9	36	14.2	66.7	254	%	51.0
Group 3 (hyperdivergent)	91	42.5	39.9	110	51.4	50.9	13	6.1	24.1	214	100	43
Total	228	45.8	100	216	43.4	100	54	10.8	100	498	100	100

SN = sella-nasion, MP = mandibular plane different across the three groups (*P* value = 0.00), and GA/H between hypodivergent and hyperdivergent (*P* value = 0.00) and between hyperdivergent and normodivergent (*P* value = 0.00). No difference was observed across the groups in I/NA, I/PP, and I/SN [Table 4].

FA/NBa was then found different in the vertical as well as the sagittal groups, and maxillary incisors compensation was only found in the sagittal and not in the vertical groups.

Discussion

The main contribution of this study was the association between maxillary incisors and GA and FA inclinations in different vertical and sagittal patterns.

In our study, we found that maxillary incisors' inclination compensates in sagittal discrepancies but not in the vertical ones. Chirivella *et al.*[19] found that the inclination of the maxillary incisors differed among the three vertical types. Arriola-Guillen *et al.*[20] found the maxillary incisors to be more proclined in the skeletal open bite CLIII group when compared to the CLII group, and this was confirmed in our study as the maxillary incisors' inclination was different among CLI, CLII and CLIII, with CLIII showing the most proclination. Bajracharya[21] noted that the maxillary and mandibular incisors of low angle individuals were found to be proclined more than those with high and average angle individuals in a Chinese population, whereas we found no significant difference in maxillary incisors' proclination among hypodivergent, normodivergent, and hyperdivergent groups.

Steiner[22] recommended positions for both maxillary and mandibular incisors in the face that were

Table 4: Mean values of selected cephalometric measurements in CLI, CLII, and CLIII groups stratified on vertical pattern (MP/SN)

Measurement	Sagittal classification	Vertical dimension: 1 (Hypodivergent) Mean	SD	2 (Normodivergent) Mean	SD	3 (Hyperdivergent) Mean	SD	ANOVA (*P*)	Comparisons among groups 1–2	1–3	2–3
Facial axis/NBa	CLI	95.96	4.60	90.51	4.76	86.96	4.83	*0.00*	*0.00*	*0.00*	*0.00*
	CLII	89.77	4.77	89.00	3.98	84.41	4.98	*0.00*	NS	*0.00*	*0.00*
	CLIII	96.80	1.30	90.83	7.31	87.000	3.41	*0.01*	NS	*0.01*	NS
Facial axis/ horizontal	CLI	121.37	3.28	116.88	13.77	116.53	3.21	NS	NS	NS	NS
	CLII	115.16	8.35	117.51	3.45	115.04	3.57	*0.00*	NS	NS	*0.00*
	CLIII	119.20	9.86	119.65	3.96	116.50	3.61	NS	NS	NS	NS
Growth axis/ NBa	CLI	99.37	4.79	94.67	4.95	90.53	9.85	*0.00*	*0.04*	*0.00*	*0.00*
	CLII	96.94	9.76	94.08	5.08	89.57	5.07	*0.00*	NS	*0.00*	*0.00*
	CLIII	103.50	9.24	95.48	3.19	90.76	2.66	*0.00*	*0.00*	*0.00*	*0.00*
Growth axis/ horizontal	CLI	125.12	3.35	122.79	3.35	132.68	109.46	NS	NS	NS	NS
	CLII	122.44	2.42	121.52	10.61	120.34	3.27	NS	NS	NS	NS
	CLIII	125.90	1.74	123.16	2.63	120.46	3.08	*0.00*	NS	*0.00*	*0.00*
I–NBa	CLI	85.28	12.20	85.40	9.20	84.81	7.85	NS	NS	NS	NS
	CLII	78.88	13.88	80.96	11.88	80.96	10.68	NS	NS	NS	NS
	CLIII	92.90	12.82	90.36	7.59	86.84	7.00	NS	NS	NS	NS
I–Horizontal	CLI	110.56	10.91	113.36	8.35	114.31	7.35	NS	NS	NS	NS
	CLII	107.55	11.50	109.91	11.94	111.65	9.87	NS	NS	NS	NS
	CLIII	118.40	11.79	117.51	7.39	116.34	6.27	NS	NS	NS	NS
I–NA	CLI	20.26	10.99	22.63	7.91	24.16	6.29	NS	NS	NS	NS
	CLII	16.26	10.62	16.96	11.18	18.10	9.53	NS	NS	NS	NS
	CLIII	29.70	11.93	29.09	6.89	29.40	7.04	NS	NS	NS	NS
I/PP	CLI	109.76	12.18	110.90	12.42	110.70	12.62	NS	NS	NS	NS
	CLII	106.72	13.31	108.17	11.35	107.98	10.16	NS	NS	NS	NS
	CLIII	117.62	11.30	116.74	6.93	115.64	6.55	NS	NS	NS	NS
I/SN	CLI	103.71	12.43	104.17	8.56	102.50	7.71	NS	NS	NS	NS
	CLII	97.58	11.61	98.05	14.84	98.28	11.10	NS	NS	NS	NS
	CLIII	111.48	13.94	109.17	7.23	105.15	6.67	NS	NS	NS	NS

The italic values in this table represent *P*-value < 0.05.

SN = sella-nasion, MP = mandibular plane, NBa = nasion-basion, SD = standard deviation, PP = palatal plane, ANOVA = analysis of variance, NS = *P*-value > 0.05, NA = nasion-A point determined relative to lines NA and NB and to be modified according to the jaw relationships as indicated by the ANB angle. Our findings support Steiner's recommendations and confirm that maxillary incisors' inclination differs according to the sagittal positions of the maxillary bases.

Growth/compensatory issues

The FA is an indicator of the growth pattern of the mandible. Therefore, a FA greater than 90° suggests a forward position of the chin and a horizontal vector of growth (hypodivergent pattern), whereas a FA smaller than 90° suggests a backward position of the chin and a vertical vector of growth (hyperdivergent pattern). When the FA is within normal range, growth occurs along the FA, down and forward (normodivergent pattern).[15] In our study, we rejected the null hypothesis and found that facial and growth axes vary in both vertical and sagittal dimensions, more so in the vertical groups. However, the maxillary incisors showed less compensation in the vertical than that in the sagittal dimensions.

Clinical implications

The findings of this study suggest that the inclination of the maxillary incisors, the FA, and the GA may be cephalometrically evaluated according to the vertical and sagittal pattern of the patient.

Research issues

In our study, the small sample size of hypodivergent group ($n = 30$) might explain some marginal differences that were found among the groups.

It would be interesting to longitudinally follow patients while they are growing to evaluate changes in the association between maxillary incisors inclination and FA and according to the vertical and sagittal patterns. Nevertheless, and considering that mandibular plane rotation to cranial base does not change much throughout growth, our sample of growing and nongrowing individuals stands as a valid one to evaluate the aforementioned association.[17,18] Therefore, the age difference that was found in our study among the different vertical groups is of no relevance, and the results found on growing patients can be considered as stagnant, not likely to undergo future changes. Furthermore, no differences existed between the groups when stratified on gender.

It would also be interesting to assess the FA inclination relative to the maxillary incisors' axis in different soft tissue profiles and to evaluate the parallelism between those two axes in convex, straight, and concave profiles. A pilot study investigating this association was carried out.

Finally, some clinicians evaluate the inclination of the maxillary incisors on dental casts,[3,6] as they consider that the use of the lateral cephalograph for that purpose is sometimes difficult and prone to errors caused by digitization of the radiographs.[23] In our study, dental casts were discarded because of possible inappropriate trimming and because maxillary incisors' proclination or retroclination cannot be assessed properly on study models.

Conclusion

- Facial (FA/NBa) and growth (GA/NBa) axes were different among the various vertical divergence groups, with more forward direction in hypodivergent pattern. However, when groups are stratified on sagittal dimension, facial and growth axes were only different between CLII and CLIII malocclusion groups.
- Maxillary incisors obviously compensated to the discrepancy in the sagittal dimension by retroclining in CLII and proclining in CLIII malocclusions. However, in the vertical pattern, maxillary incisors compensated more significantly in the hypodivergent group, and their inclination was within the normal range in the hyperdivergent group.
- Orthodontists should consider cephalometric evaluation of facial and growth axes as a routine practice and associate maxillary incisor inclination to the vertical direction of growth.

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Conflicts of interest

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Ethical policy and institutional review board statement

Consent from the institutional review board at the American University of Beirut, Beirut, Lebanon, was granted (OTO.AM.01).

Patient declaration of consent

Not applicable.

Data availability statement

Cephalometric records were selected from patients' data at the Department of Orthodontics and Dentofacial Orthopedics at the American University of Beirut, Beirut, Lebanon.

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