

Orthodontic Treatment Effect on Inclination of Maxillary Incisors and Growth Axes in Adult Patients with Various Mandibular Divergent Patterns

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ABSTRACT

Aim: To evaluate, in an adult population, the effect of orthodontic treatment on the inclination of maxillary incisors, facial, and growth axes in different mandibular divergence pattern. In addition, we aimed to determine if there is an association between the inclination of the maxillary incisors and facial and growth axes and if this association will change after orthodontic treatment.

Materials and methods: Two-hundred and thirty-eight consecutive lateral cephalograms (119 at T1 and 119 at T2) of adult patients with an average age of 26.45 ± 9.11 years at T1 and 29.58 ± 9.36 at T2 were selected and digitized. Cephalometric maxillary incisors (I) inclination was measured to cranial base (SN), palatal plane (PP), nasion-A point (NA), nasion-basion (NBa), and true horizontal (H). Facial (FA) and growth (GA) axes' inclinations were measured relative to NBa and H. The sample was stratified in three subgroups based on cephalometric mandibular divergence to anterior SN (MP/SN). A—Hypodivergent = $MP/SN \leq 27^\circ$ ($n = 28$); B—Normodivergent = $27 < MP/SN < 37^\circ$ ($n = 49$); C—Hyperdivergent = $MP/SN \geq 37^\circ$ ($n = 42$). Associations were tested using Chi-square tests for categorical data. Paired sample *t*-tests and Pearson's correlation were computed for continuous data.

Results: At T1, there was a tendency to have more proclined I in group A ($I/SN = 105.59 \pm 10.8^\circ$) and more retroclined in group C ($I/SN = 99.06 \pm 12.04^\circ$) with no statistical significance. However, at T2, maxillary incisors were statistically significant different between groups A and C ($p = 0.002$). Pre-treatment FA and GA were statistically significantly different among the three divergence groups ($p < 0.0001$) with more increased angles in the group A ($FA/NBa = 92.77 \pm 5.07^\circ$) vs group C ($FA/NBa = 86.28 \pm 5.08^\circ$). This angle increases around 2° on average at posttreatment assessment (group A— $p = 0.033$; group B— $p = 0.002$). Correlations between I and facial/growth axes were not statistically significant at T1, whereas at T2 those correlations were higher and statistically significant between I/PP to FA/NBa ($r = 0.408$; $p \leq 0.0001$).

Conclusion: Correlations between the maxillary incisors' inclination and the facial/growth axes were not statistically significant initially whereas after orthodontic treatment, those correlations were higher and statistically significant. Differences in FA existed between pre- and postorthodontic groups in all divergence groups.

Clinical significance: Orthodontists should assess the inclination of the maxillary incisors, not only to the maxilla and anterior SN but also to FA and take it into consideration in their treatment objectives.

Keywords: Facial axis, Growth axis, Incisors, Mandibular divergence, Posttreatment.

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INTRODUCTION

The maxillary incisors' inclination (I) is a major component of smile and facial esthetics.^{1,2} Therefore, it must be assessed during treatment planning, when judging treatment progress and in assessing treatment outcome.³ Achieving an optimal I of the maxillary incisors after orthodontic treatment should be an objective to ensure facial harmony and constitutes a primary goal to attain.¹

To improve the prediction of the optimal I of the maxillary incisors, many cephalometric and profilometric measurements have been suggested.^{4–8} While the cephalometric I of the maxillary incisors has been extensively studied, its potential association with the facial pattern, namely the facial axis (FA) and growth axis (GA), has not been thoroughly investigated.

The facial axis (FA), as initially described by Ricketts, is the angle between NBa plane and the line extending from foramen rotundum (Pt) to constructed gnathion (Fig. 1). It has a mean of $90 \pm 3.5^\circ$ and is indicative of the facial type. Therefore, it indicates the direction of growth and varies among vertical and horizontal patterns.^{4,9} In hypodivergent patients, the FA is increased, and the face grows down and forward, as opposed to hyperdivergent patients who

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Associations were evaluated using Chi-square tests for categorical data. Paired sample *t*-tests and Pearson's correlation were computed for continuous data. For all parameters, two-sided *p*-values were reported. $p < 0.05$ was considered as statistically significant. All analyses were completed using IBM SPSS Statistics

show a decreased FA measurement and a downward and backward direction of growth.

Similarly, the GA, as described by Downs, is the angle between sella turcica (S) to gnathion (Gn) line and Frankfort horizontal line (Fig. 1). It ranges from 53 to 66°, with a mean reading of $59.4 \pm 3.8^\circ$. This angle indicates the growth pattern of the mandible.^{4,10}

In the literature, there is a lack of categorical assessment of the I of the maxillary incisors after orthodontic treatment; although there are numerous reports on different facial patterns and malocclusions, not all malocclusions were considered. Chrivella et al. found the I of the maxillary incisors to differ among different facial types.¹¹ Mollabashi et al. concluded that this I was similar in class (CLII) div 1 cases treated with different mechanics.¹² Burns et al. showed significant changes in this I in CLIII patients treated with camouflage orthodontic tooth movement.¹³ Troy et al. found no difference in maxillary incisors' I between CLIII surgical and camouflage groups after treatment,¹⁴ while Zou et al. found significant changes in this I in CLIII cases after surgery;¹⁵ thus, our aim was to assess pre- and posttreatment maxillary incisors' I relative to FA and GA as both axes are reflective of the vertical and sagittal discrepancies and the facial type of the patient. To the best of our knowledge, this is the first attempt to assess such a potential association at pre- and postorthodontic treatments.

Accordingly, the main objective of this study was to compare the changes in pre- vs posttreatment I of the maxillary incisors and I of FA and GA after orthodontic treatment in different mandibular divergence patterns. The secondary aim was to determine the potential association between the I of the maxillary incisors and FA and GA in an adult orthodontic population, if this association will change after orthodontic treatment.

MATERIALS AND METHODS

This is a retrospective cohort study. The study duration was 1 year. The material was comprised of 119 pre- and 119 posttreatment lateral cephalograms of Caucasian adult subjects (85 females and 34 males) selected from patients' data at the department (name of the institution). Their mean age was 26.45 ± 9.11 (Table 1). Prior to the conduct of the study, signed consent to use the radiographs was obtained from the patients. The inclusion criteria were Caucasian

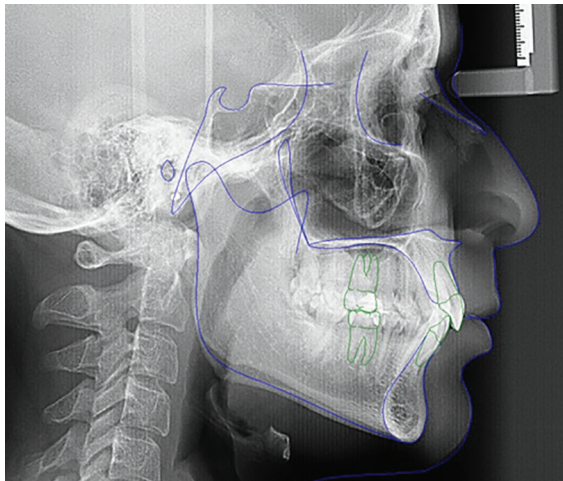


Fig. 1: Digitized lateral cephalogram

patients, nongrowing (chronological age above 16 years for girls and 18 years for boys), with available lateral cephalometric radiographs taken prior to and at the end of orthodontic treatment (after the removal of appliances). The following conditions were the basis for exclusion: previous orthodontic and/or orthognathic surgery treatment; the presence of any craniofacial anomaly; and this retrospective study was approved by the Institutional Review Board at the American University of Beirut, Beirut, Lebanon (OTO. AM.01). The study duration was 6 months.

Sample size calculation was performed before initiating data collection. With an anticipated effect size of 0.5, a power level of 0.8, a probability level of 0.05, and with the number of observed and unobserved variables used in the structural equation model of this study, a minimum sample size of 89 subjects was required.

Available lateral cephalometric radiographs taken prior to and at the end of orthodontic treatment placed according to the natural head position at an appropriate distance (sagittal plane—film distance of 13 cm), all with the same machine, were studied.

A total of 238 lateral cephalograms (119 at T1 and 119 at T2) were digitized using the Dolphin orthodontic software (Dolphin Imaging and Management Solutions, La Jolla, California, United States) (Fig. 1). Different variables were measured on the digitized lateral cephalograms, and angular measurements were computed to determine the I of maxillary incisors to cranial base (SN), palatal plane (PP), nasion-A point (NA), NBa, and true horizontal (H), and facial and growth axes' I were measured relative to NBa and H (Fig. 2).

The sample was then stratified into three groups depending on the divergence based on MP/SN angle: A—hypodivergent = $MP/SN \leq 27^\circ$ ($n = 28$); B—normodivergent = $27 < MP/SN < 37^\circ$ ($n = 49$); and C—hyperdivergent = $MP/SN \geq 37^\circ$ ($n = 42$). To determine the intra-observer reliability, a single investigator repeated all angular and linear cephalometric measurements on 30 randomly selected cephalograms (nearly 20% of the sample).

Statistical Analyses

After conducting data cleaning for any potential errors, an initial frequency distribution was generated for all variables to check for any potential outliers. The intraclass correlation coefficient was computed for all quantitative measures to assess inter-rater reliability.

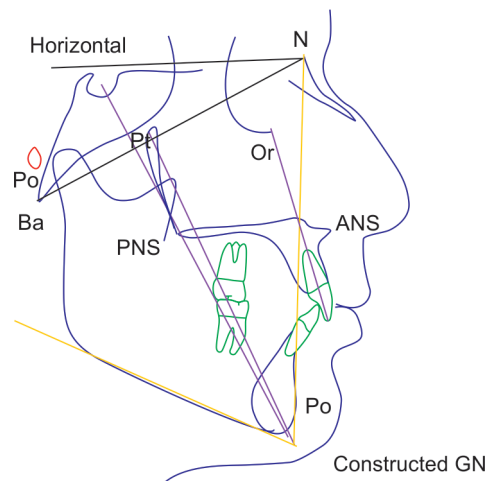


Fig. 2: Lateral cephalometric tracing with landmarks and planes used in the study including facial and growth axes and maxillary incisor's long axis

Table 1: Means of age and selected cephalometric measurements in groups T1 and T2 for the whole sample and groups A/B and C

Variable		HYPO		NORMO		HYPER		Total		ANOVA	A-B	A-C	B-C
		Mean	SD	Mean	SD	Mean	SD	Mean	SD				
Age	T1	26.93	8.44	25.75	8.89	26.94	9.91	26.45	9.11	0.79	NS	NS	NS
	T2	29.38	8.40	29.09	9.23	30.29	10.24	29.58	9.36	0.83	NS	NS	NS
	<i>p</i>	<0.0001		<0.0001		<0.0001		<0.0001					
I/NA	T2-T1	2.44	2.82	3.24	2.13	3.35	1.46	3.09	2.13	0.18	0.35	0.24	NS
	T1	23.6	9.3	19.35	10.46	20.51	10.01	20.76	10.1	0.20	0.23	0.63	NS
	T2	22.76	6.68	20.22	7.82	19.18	8.98	20.45	8.06	0.19	0.55	0.21	NS
I/PP	<i>p</i>	0.633		0.502		0.236		0.694					
	T2-T1	-0.84	9.18	0.88	9.08	-1.33	7.18	-0.31	8.47	0.43	NS	NS	0.653
	T1	109.15	22.28	109.39	10.21	108.7	10.35	109.09	13.9	0.97	NS	NS	NS
I/SN	T2	112.94	7.89	110.29	5.91	107.64	9.09	109.98	7.82	0.02	0.44	0.02	0.31
	<i>p</i>	0.351		<0.0001		0.399		0.450					
	T2-T1	3.79	21.14	0.9	9.33	-1.06	8.08	0.89	12.79	0.30	NS	0.37	NS
ANB	T1	105.59	10.8	101.59	10.68	99.06	12.04	101.64	11.38	0.06	0.40	0.06	0.86
	T2	106.26	7.54	103.36	6.17	99.62	9.23	102.72	8.04	0.002	0.34	0.002	0.07
	<i>p</i>	0.698		<0.0001		0.707		0.204					
FA/Nba	T2-T1	0.66	8.95	1.77	9.31	0.56	9.55	1.08	9.25	0.8	NS	NS	NS
	T1	3.41	2.39	3.03	3.3	4.44	2.87	3.62	2.3	0.075	NS	0.48	0.08
	T2	3.33	2.37	3.44	2.8	5.13	3.76	4.01	3.17	0.016	NS	0.06	0.03
FA/ Horiz	<i>p</i>	0.682		0.078		0.263		0.105					
	T2-T1	-0.09	1.1	0.40	1.57	0.69	3.95	0.39	2.61	0.48	NS	0.67	NS
	T1	92.77	5.07	89.96	4.03	86.28	5.084	89.32	5.27	<0.0001	0.04	<0.0001	0.001
GA/Nba	T2	93.42	4.66	91.35	3.4	85.93	3.72	89.93	4.89	<0.0001	0.07	<0.0001	<0.0001
	<i>p</i>	0.033		0.002		0.624		0.061					
	T2-T1	0.65	1.53	1.39	2.98	-0.35	4.59	0.6	3.47	0.06	NS	0.7	0.05
GA/ Horiz	T1	119.07	7.49	118.34	3.24	115.47	4.24	117.5	5.07	0.004	NS	0.009	0.02
	T2	121.84	8.161	123.1	7.94	110.28	10.33	118.28	10.65	<0.0001	NS	<0.0001	<0.0001
	<i>p</i>	0.099		<0.0001		0.002		0.377					
I/Nba	T2-T1	2.78	8.59	4.76	6.91	-5.19	10.04	0.78	9.57	<0.0001	0.98	0.001	<0.0001
	T1	92.01	11.4	94.13	3.89	90.93	5.54	92.50	6.97	0.08	0.59	NS	0.09
	T2	90.07	10.19	93.58	3.14	89.44	3.85	91.29	6.06	0.002	0.04	NS	0.003
I/ Horiz	<i>p</i>	0.059		0.218		0.068		0.004					
	T2-T1	-1.94	5.21	-0.55	3.11	-1.5	5.17	-1.21	4.45	0.37	0.57	NS	0.95
	T1	128.41	13.26	120.98	14.5	120.6	3.88	122.6	11.9	0.01	0.02	0.02	NS
MP/SN	T2	128.32	13.33	123.67	5.18	120.66	3.79	123.7	8.06	<0.0001	0.03	<0.0001	0.19
	<i>p</i>	0.805		0.207		0.930		0.223					
	T2-T1	-0.1	2.04	2.69	14.73	0.06	4.18	1.11	9.85	0.34	0.70	NS	0.62
I/Nba	T1	107.86	26.59	83.33	12.6	82.35	10.18	88.76	19.39	<0.0001	<0.0001	<0.0001	NS
	T2	109.51	24.02	84.77	9.17	81.23	9.01	89.34	17.97	<0.0001	<0.0001	<0.0001	0.7
	<i>p</i>	0.169		0.277		0.391		0.444					
I/ Horiz	T2-T1	1.64	6.16	1.43	9.13	-1.12	8.35	0.58	8.27	0.25	NS	0.52	0.43
	T1	112.38	9.56	108.62	17.57	111.74	10.12	110.61	13.6	0.41	0.74	NS	0.84
	T2	114.02	7.29	108.33	15.43	106.63	9.24	109.07	12.12	0.04	0.14	0.04	NS
MP/SN	<i>p</i>	0.158		0.821		<0.0001		0.051					
	T2-T1	1.64	5.97	-0.29	9.05	-5.11	8.19	-1.54	8.5	0.002	0.95	0.003	0.017
	T1	23.09	2.65	32.16	2.84	44.63	16.15	34.43	12.85	<0.0001	0.001	<0.0001	0.001
MP/SN	T2	23.69	3.52	30.93	3.51	40.59	4.74	32.64	7.64	<0.0001	<0.0001	<0.0001	<0.0001
	<i>p</i>	0.198		0.008		0.116		0.054					
	T2-T1	0.6	2.40	-1.23	3.1	-4.04	16.3	-1.79	10.04	0.15	N.S	0.18	0.55

IMPA	T1	97.35	7.75	93	8.85	90.96	6.93	93.3	8.26	0.005	0.07	0.004	0.68
	T2	96.55	11.14	95.97	8.67	93.39	6.79	95.2	8.77	0.24	NS	0.42	0.49
	<i>p</i>	0.568		0.004		0.010		0.003					
	T2-T1	-0.8	7.28	2.98	6.91	2.44	5.87	1.9	6.77	0.05	0.06	0.15	NS
I/I	T1	131.83	14.96	134.62	14.24	128.58	11.81	131.83	13.75	0.11	NS	0.99	0.11
	T2	130.96	13.82	129.6	9.67	126.37	10.24	128.78	11.03	0.19	NS	0.27	0.49
	<i>p</i>	0.722		0.014		0.134		0.007					
	T2-T1	-0.87	12.83	-5.03	13.71	-2.21	9.39	-3.06	12.16	0.31	0.45	NS	0.82

version 27 (IBM, released 2020, IBM SPSS Statistics for Windows, version 27.0, Armonk, New York).

RESULTS

The intraclass correlation coefficient for intra-examiner reliability was high (>0.9). The sample included 85 female and 34 male subjects. When classified on gender, no statistically significant differences were present at initial or posttreatment time points for all measured variables. Thus, statistical analyses were applied on to the whole sample as one entity irrespective of the gender. At T1, the average age for the whole sample was 26.45 ± 9.11 years, and at T2, 29.58 ± 9.36 years. Upon stratification into divergence groups, group A of hypodivergent pattern included 28 subjects with a mean age of 26.93 ± 8.44 years at T1 and 29.38 ± 8.4 years at T2 (Table 1). Group B of normodivergent pattern had 49 individuals with a mean age of 25.75 ± 8.89 years at T1 and 29.09 ± 9.23 years at T2. Group C of hyperdivergent pattern included 42 patients with a mean age of 26.94 ± 9.91 years at T1 and 30.29 ± 10.24 years at T2. Whether at T1 or at T2, age was not statistically significantly different between groups A, B, and C.

Comparisons of Cephalometric Measurements of the Total Sample between T1 and T2

When the total sample of 119 patients was analyzed, most of the studied parameters were not statistically significantly different between T1 and T2 except for GA/NBa ($p = 0.004$) and mandibular incisors/MP ($p = 0.003$). MP/SN decreased by around 2° (T1 = 34.43° ; T2 = 32.64°) but was not statistically significantly different.

Comparisons of Cephalometric Measurements between Groups A, B, and C at T1

At T1, maxillary incisors' I was not statistically significantly different between the three divergence groups (Table 1), but with a tendency to have more proclined maxillary incisors in group A of hypodivergent (I/SN = $105.59 \pm 10.8^\circ$) and more retroclined in group C of hyperdivergent (I/SN = $99.06 \pm 12.04^\circ$). In addition, ANB angle was not statistically different. However, FA and GA were statistically significantly different among the three divergence groups ($p < 0.0001$) with more increased angles in group A (FA/NBa = $92.77 \pm 5.07^\circ$) vs group C (FA/NBa = $86.28 \pm 5.08^\circ$), i.e., hypodivergent vs hyperdivergent (Table 1). In addition, mandibular incisors to MP were more proclined in group A ($97.35 \pm 7.75^\circ$) than group C ($90.96 \pm 6.93^\circ$) with $p = 0.004$ (Table 1).

Comparisons of Cephalometric Measurements between Groups A, B, and C at T2

At T2, maxillary incisors were statistically significantly different mainly between groups A and C ($p = 0.002$). Significant differences also existed between groups A, B, and C for ANB angle and growth

and facial axes' Is to NBa and H. However, mandibular incisors were not statistically significantly different with IMPA = $96.55 \pm 11.14^\circ$ for group A and $93.39 \pm 6.79^\circ$ for group C (Table 1).

Comparisons of Cephalometric Measurements at T1 vs T2

The FA/NBa was statistically significantly different in group A (hypodivergent) at T1 vs T2 ($p = 0.033$) and in group B (normodivergent) ($p = 0.002$) with a tendency to increase by around 2° on average. In addition, FA/H was also significantly different in groups B and C between T1 and T2 with corresponding p -values of < 0.0001 and 0.002 , respectively. Maxillary incisors did not show any statistically significant differences in the hypo- and hyperdivergent groups, but only in the normodivergent group with an increase in I/SN by 1.77° at $p < 0.0001$ (Table 1). Mandibular incisors increased significantly in groups B ($+2.98^\circ$; $p = 0.004$) and C ($+2.44^\circ$; $p = 0.01$) but decreased in group A (-0.8°).

Correlations

At T1, correlations between maxillary incisors' I and FA and GA were not statistically significant. R values were low for I/PP, I/SN, I/NBa, and I/H ranging from 0.004 to 0.389 (Table 2). Similarly, correlations between MP/SN and incisors' I were not statistically significant ($p = 0.978$) except for I/NBa: $R = -0.282$ with $p = 0.002$.

On the opposite and at T2, higher and statistically significant positive correlations existed between maxillary incisors' I and FA and GA (Table 2). At T2, I/PP correlated significantly with FA/NBa ($r = 0.408$; $p \leq 0.0001$) and with FA/H ($r = 0.286$; $p = 0.002$). Similarly, I/SN and I/NBa correlated significantly with FA/NBa ($r = 0.491$; $p \leq 0.0001$ and $r = 0.456$; $p \leq 0.0001$ correspondingly) and with FA/H ($r = 0.330$; $p \leq 0.001$ and $r = 0.183$; $p = 0.047$ correspondingly) (Table 2).

In addition, strong and statistically significant negative correlations existed between MP/SN angle and FA and GA at pre- and posttreatment assessment with r values ranging from -0.360 to -0.709 at $p < 0.0001$. The negative correlation increased between T1 and T2.

While ANB angle negatively correlated with FA and GA at T1, these correlations became stronger at statistically significant differences. At T1, ANB angle correlated with FA/NBa at $r = -0.319$; $p \leq 0.001$, which increased to $r = -0.428$; $p \leq 0.0001$ (Table 2).

DISCUSSION

In this study, we evaluated the effect of orthodontic treatment on the I of the maxillary incisors, the FA and GA in different mandibular vertical patterns. The classification of the three divergence groups was based on the angulation of the mandibular plane (MP) to the

Table 2: Correlations between I, MP/SN, ANB, FA, and GA at T1 and T2

N = 119	FA/NBa		FA/H		GA/NBa		GA/H		MP/SN		ANB	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
I/PP	r	0.135	0.408**	0.004	0.286**	0.021	0.012	0.067	-0.003	-0.280**	-0.199*	-0.436**
	p value	0.143	0.000	0.968	0.002	0.818	0.898	0.468	0.978	0.002	0.030	0.000
I/SN	r	0.319**	0.491**	0.133	0.330**	0.100	0.063	0.061	-0.102	-0.369**	-0.361**	-0.424**
	p value	0.000	0.000	0.149	0.000	0.280	0.494	0.511	0.268	0.000	0.000	0.000
I/NBa	r	0.398**	0.456**	0.203*	0.183*	-0.224*	0.256**	0.347**	-0.282**	-0.562**	-0.217*	-0.277**
	p value	0.000	0.000	0.027	0.047	0.036	0.005	0.000	0.002	0.000	0.018	0.002
I/H	r	0.137	0.277**	0.023	0.190*	0.108	-0.080	-0.067	-0.013	-0.175	-0.139	-0.184*
	p value	0.138	0.002	0.803	0.038	0.932	0.387	0.472	0.890	0.057	0.131	0.046
I/NA	r	0.219*	0.317**	0.095	0.220*	0.051	0.081	0.087	-0.074	-0.187*	-0.471**	-0.514**
	p value	0.016	0.000	0.304	0.016	0.550	0.379	0.344	0.427	0.042	0.000	0.000
MP/SN	r	-0.360**	-0.709**	-0.283**	-0.559**	-0.127	-0.139	-0.353**			0.159	0.263**
	p value	0.000	0.000	0.002	0.000	0.693	0.132	0.000			0.084	0.004
ANB	r	-0.319**	-0.428**	-0.253**	-0.378**	-0.162	-0.154	-0.208*	0.159	0.263**		
	p value	0.000	0.000	0.005	0.000	0.078	0.095	0.023	0.084	0.004		

*Correlation is significant at 0.05 level (two-tailed); **Correlation is significant at 0.01 level (two-tailed)

anterior SN. In addition, we aimed to assess the potential correlation between the I of the maxillary incisors and FA and GA in an adult orthodontic population and if this association changes after orthodontic treatment.

The main outcomes were that at T1, maxillary incisors' I was not statistically significantly different between the three divergence groups but with a tendency to have more proclined maxillary incisors in the hypodivergent group and more retroclined in the hyperdivergent group; similarly, the mandibular incisors were more proclined in the hypo- than in the hyperdivergent group.

Amjad et al.¹⁶ found in their study on T1 lateral cephalograms that maxillary and mandibular incisors' I was greater in hyperdivergent patients as compared to hypodivergent patients. Their results differ from the findings of the present study as their sample included only CLI patients, whereas our sample included all malocclusions.

In our findings, correlations between the maxillary incisors' I and the FA and GA were not statistically significant in T1, whereas in T2, those correlations were higher and statistically significant. When comparing T1 to T2 measurements, FA/NBa was statistically significantly different in the hypo- and normodivergent groups and FA/H was also significantly different in the normo- and hyperdivergent groups. Maxillary incisors showed statistically significant differences only in the normodivergent group and mandibular incisors increased significantly in the normo- and hyperdivergent groups but decreased in the hypodivergent group.

FA and GA describe the position of the mandible in the vertical and sagittal planes.^{9,10} In growing patients, they indicate the path of growth describing a normal, vertical, or horizontal growth vector of the mandible.^{9,10} However, in nongrowing patients, the FA and GA remain stable and therefore can be used as a reliable cephalometric reference to measure maxillary incisors' I.^{9,10} On the contrary, maxillary incisors' optimal I plays a major role in profile and smile esthetics and is an essential goal to attain in orthodontic treatment and it has not been associated before with the I of FA and GA.^{1,2}

In a previous study, the authors determined that while FA/NBa was different when classified in vertical and sagittal groups, differences in maxillary incisors' I existed only among the different sagittal groups but not among the different vertical groups.¹⁷ Accordingly, in this study, pre- and postorthodontic treatment comparison evaluates the potential changes induced by orthodontic treatment to the association between maxillary incisors' I and FA and GA.

Our sample included adult patients treated only orthodontically with no surgical treatment to exclude any major mandibular repositioning and subsequent changes in FA and GA. In this perspective, changes in FA and GA were considered minor and statistically not significant. However, the correlations of those axes to the maxillary incisors' I increased significantly after treatment. To the best of our knowledge, this was the first time that such an association was evaluated on adult subjects. These significant correlations are essentially the reflection of the optimization of maxillary incisors' I through orthodontic treatment in each individual. Consequently, the cephalometric evaluation of maxillary incisors' I to FA and GA may be an additional valid method to diagnosis and may be sought as a treatment objective.

Research Issues and Limitations

Our sample was consisted of adult patients. It would be interesting to longitudinally follow the growing patients to evaluate the



maxillary incisors' I changes relative to FA and GA. Most clinicians rely on radiographs to evaluate the I of the maxillary incisors; however, study dental casts have been used by some considering that radiographic digitization is difficult and prone to errors.^{18,19} In our study, we used lateral cephalometric radiographs to assess the maxillary incisors' I, and dental casts were discarded as they are considered not valid, especially with inappropriate trimming.

CONCLUSION

Maxillary incisors exhibited different I's in the pretreatment evaluation in correspondence with the divergence patterns. However, these differences were more accentuated after the treatment with more proclination in the hypodivergent group. Similarly, the mandibular incisors were more proclined in the hypodivergent than the hyperdivergent group. The orthodontic treatment induced minor changes in the FA and GA. Nevertheless, significant higher correlations between the Is of the maxillary incisors and the FA existed at the posttreatment time point.

Thus, orthodontists need to highlight the relationship between the maxillary incisors and FA and GA prior to treatment as it may be important in setting the final incisors' I outcome.

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