Original Article

Comparison between Pre and Posttreatment Inclination of Maxillary Incisors in Adults: Association with Facial and Growth Axes

Abstract

Objective: The objective of the study is to evaluate the orthodontic treatment effect on maxillary incisors' inclination relative to facial and growth axes in adult subjects. **Materials and Methods:** Hundred consecutive nongrowing orthodontic patients with an average age of 26.24 ± 9.29 years were selected, and their T1 (initial) and T2 (final) lateral cephalograms were digitized. Cephalometric maxillary incisors' (I) inclination was measured to SN, PP, NA, NBa, and true horizontal (H). Facial and growth axes' inclinations were measured relative to NBa and H. Associations were tested using Chi-square tests for categorical data. Paired sample *t*-tests and Pearson's correlation were computed for continuous data. **Results:** Maxillary incisors' inclination, MP/SN, and ANB angle did not show statistically significant differences between T1 and T2, while mandibular incisors' inclination and interincisal angle increased significantly ($P = 0.01$ and $P = 0.02$, respectively). Facial and growth axes increased at T2 but changes were not statistically significant among the two groups. At T1, correlations between maxillary incisors' inclination and facial/growth axes were not statistically significant. Similarly, correlations between MP/SN and ANB angles on the one hand and facial/growth axes on the another hand were not statistically significant. At T2, I/PP correlated significantly with facial axis (FA)/NBa ($r = 0.308$; $P = 0.002$) and with FA/H ($r = 0.268$; $P = 0.007$). Similarly, I/SN and I/NBa correlated significantly with FA/NBa ($r = 0.399$; $P < 0.0001$ and $r = 0.422$; $P < 0.0001$ correspondingly) and with FA/H ($r = 0.305$; $P = 0.002$ and $r = 0.325$; $P = 0.001$ correspondingly). Statistically significant negative correlations existed between MP/SN angle and facial/growth axes at T2 (r values ranging −0.704 to −0.409 at $P < 0.0001$). **Conclusions:** While there was no correlation between I and facial/growth axes at pretreatment, significant and higher correlations existed at the end of the orthodontic treatment. This association reflects the connection between the corrected posttreatment position of maxillary incisors relative to the corresponding vertical pattern. Therefore, orthodontists should evaluate the position of the maxillary incisors to FA and may consider it in their treatment objectives.

Keywords: *Facial axis, growth axis, incisors, inclination*

Samar Bou Assi[1,2], Anthony Macari[1], Antoine Hanna[1], Josephine Aybout[1], Ziad Salameh[3]

[1]Division of Orthodontics and Dentofacial Orthopedics, American University of Beirut, Beirut, Lebanon, [2]Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon, [3]Department of Research Center, Faculty of Dental Medicine, Lebanese University, Beirut, Lebanon

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Address for correspondence:
Dr. Samar Bou Assi,
Division of Orthodontics and Dentofacial Orthopedics,
American University of Beirut,
Beirut, Lebanon.
E-mail: sbouassi@ul.edu.lb

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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 inclination of the maxillary incisors after orthodontic treatment should be an objective to ensure facial harmony.[1]

To improve the prediction of the optimal inclination of the maxillary incisors, many cephalometric and profilometric measurements have been suggested.[4-8]

While the cephalometric inclination of the maxillary incisors has been extensively studied, its potential association with the facial pattern, namely the facial and growth axes, 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 (Gn') [Figure 1]. It has a mean of 90° ± 3.5° and is indicative of the facial type. Therefore, it indicates the direction of growth and varies among vertical and horizontal patterns.[4,9]

Similarly, the growth axis (GA) as described by Downs is the angle between sella turcica (S) to gnathion (Gn) line and Frankfort horizontal line [Figure 1]. It ranges from a 53° to 66°, with a mean reading of 59.4° ±3.8°. This angle indicates the growth pattern of the mandible.[4,10]

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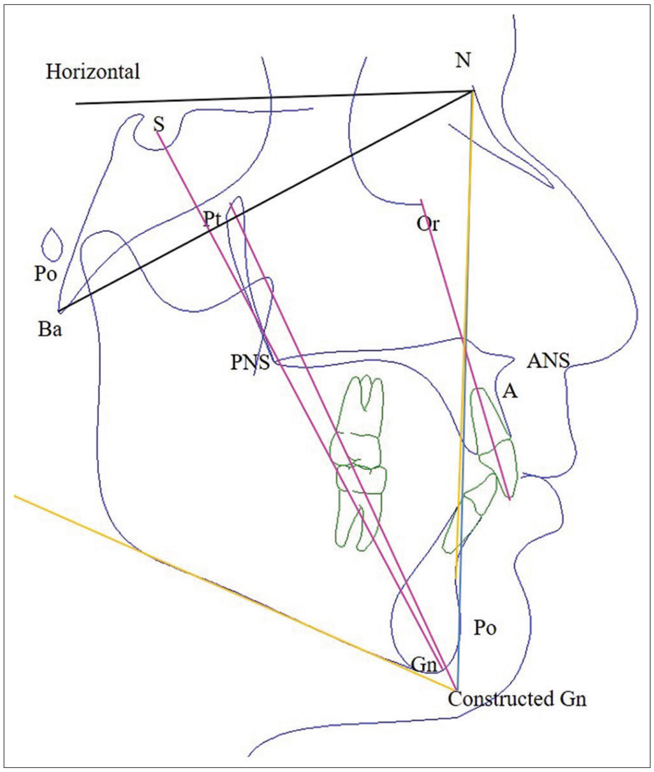

Figure 1: Lateral cephalometric tracing with landmarks and planes used in the study including facial and growth axes and maxillary incisor's long axis

In the literature, there is a lack of categorical assessment of the inclination of the maxillary incisors after orthodontic treatment; although there are numerous reports on different facial patterns and malocclusions, not all malocclusions were considered. Chirivella *et al*. found the inclination of the maxillary incisors to differ among different facial types,[11] Mollabashi *et al*. concluded that this inclination was similar in CLII div 1 cases treated with different mechanics,[12] Burns *et al*. showed significant changes in this inclination in CLIII patients treated with camouflage orthodontic tooth movement,[13] Troy *et al*. found no difference in maxillary incisors' inclination between CLIII surgical and camouflage groups after treatment[14] while Zou *et al*. found significant changes in this inclination in CLIII cases after surgery;[15] thus, our aim was to assess pre and posttreatment maxillary incisors' inclination relative to facial and growth axes as both axes are reflective of the vertical and sagittal discrepancies and the facial type of the patient.

The purposes of this study were two fold:

1. To determine if there is an association between the inclination of the maxillary incisors and facial and growth axes in an orthodontic population
2. To compare changes in pre versus posttreatment inclination of the maxillary incisors relative to the facial and growth axes' inclination after orthodontic treatment.

The null hypothesis was that there is no association between the maxillary incisors inclination and the facial and growth axes before and after orthodontic treatment.

Materials and Methods

This study was approved by the Institutional Review Board at the American University of Beirut, Beirut, Lebanon (OTO. AM.01).

Study design

This study was designed as a retrospective correlative comparative study.

Subjects

Hundred consecutive nongrowing orthodontic patients who had an average age of 26.24 ± 9.29 years were selected from patients' data at the Department of Orthodontics and Dentofacial Orthopedics at the American University of Beirut, Beirut, Lebanon.

Inclusion criteria

The following inclusion criteria were used.

- Chronological age above 16 years for girls and 18 years for boys
- Available lateral cephalometric radiographs taken before and at the end of orthodontic treatment (after removal of appliances).

Exclusion criteria

The following exclusion criteria were used.

- Craniofacial anomalies
- Orthognathic surgeries.

Methods

Available lateral cephalometric radiographs taken before 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.

The 200 lateral cephalograms (100 at T1 and 100 at T2) were digitized using the Dolphin Orthodontic software (Dolphin Imaging and Management Solutions, La Jolla, CA) [Figure 2]. Different variables were measured on the digitized lateral cephalograms, and angular measurements were computed to determine the inclination of maxillary incisors to SN, PP, NA, NBa, and true horizontal (H), and facial and growth axes' inclinations were measured relative to NBa and true horizontal [Figure 1].

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. Intraclass correlation coefficient was computed for all quantitative measures to assess interrater reliability.

Associations were tested 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. $P < 0.05$

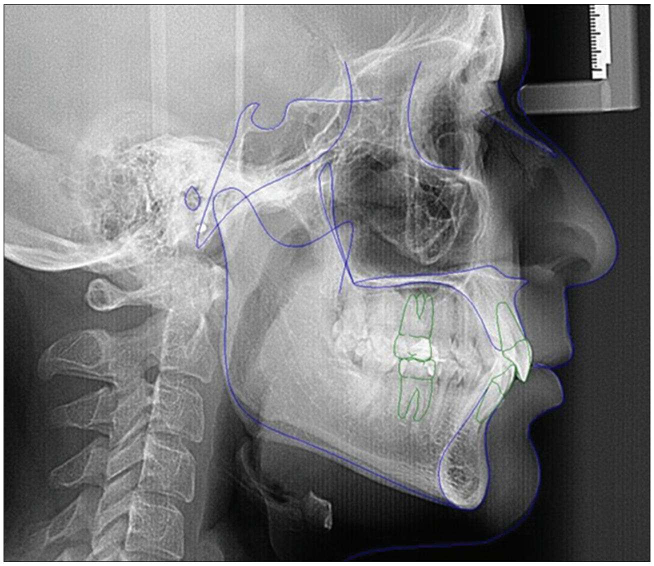

Figure 2: Digitized lateral cephalogram

was considered as statistically significant. All analyses were completed using IBM SPSS Statistics version 27 (IBM, released 2020, IBM SPSS Statistics for Windows, version 27.0, Armonk, New York).

Results

We repeated measures on 30 randomly chosen lateral cephalograms. The intraclass correlation coefficients were high (>0.9).

The sample included 72 female and 28 male subjects. When classified on gender, no statistically significant differences were present at initial or posttreatment timepoints for all measured variables. Thus, statistical analyses were applied on the whole sample as one entity irrespective of gender. At T1, the average age for the whole sample was 26.24 ± 9.29 years, and at T2, it was 29.067 ± 9.577 years.

On average, maxillary incisors' inclination slightly increased by around 1° at T2. However, no statistically significant differences existed [Table 1]. MP/SN angle decreased by around 2° (T1 = 36.61°; T2 = 34.61°) but was not statistically significantly different. ANB angle increased only 0.5° (T1 = 3.70°; T2 = 4.18°). On the other hand, mandibular incisors inclination increased more than 2° (IMPA: T1 = 92.16°; T2 = 94.47°) at a statistically significant difference (P = 0.001). The interincisal angle was also different (T1 = 132.96°; T2 = 128.98°; P = 0.002) [Table 1].

Facial and growth axes increased at T2, but changes were not statistically significant among the two groups, except for GA to NBa which decreased by around 1° (T1 = 93.32°; T2: 92.08°; P = 0.01) [Table 1].

Correlations

At T1, correlations between maxillary incisors' inclination and facial/growth axes were not statistically significant.

Table 1: Means of age and selected cephalometric measurements in Groups T1 and T2

Groups	Mean±SD		*P*
	T1 (*n*=100)	T2 (*n*=100)	
Age (year)	26.24±9.29	29.067±9.577	0.001
Maxillary incisors/NA	19.477±10.0407	19.800±8.028	0.706
Maxillary incisors/PP	108.611±10.5604	109.181±7.487	0.538
Maxillary incisors/SN	100.157±11.2680	101.901±7.719	0.070
ANB	3.705±3.0825	4.188±3.275	0.088
Facial axis/NBa	88.609±4.918	89.187±4.527	0.125
Facial axis/H	116.938±4.572	117.893±11.173	0.361
Growth axis/NBa	93.326±5.590	92.084±4.126	0.010
Growth axis/H	120.934±10.337	122.364±4.524	0.185
Maxillary incisors/NBa	82.121±10.626	82.828±7.795	0.435
Maxillary incisors/H	110.741±10.246	108.909±7.724	0.051
MP/SN	36.613±12.793	34.6073±6.619	0.068
IMPA	92.162±7.757	94.476±7.991	0.001
Interincisal angle	132.968±13.747	128.988±10.483	0.002

SD: Standard deviation

R values were low for I/PP, I/SN, I/NBa, and I/H ranging from 0.01 to 0.3 [Table 2]. Similarly, correlations between MP/SN and ANB angles on the one hand and facial/growth axes on the another hand were not statistically significant.

On the opposite and at T2, higher and statistically significant positive correlations existed between maxillary incisors inclination and facial/growth axes [Table 2]. At T2, I/PP correlated significantly with FA/NBa (r = 0.308; P = 0.02), and with FA/H (r = 0.268; P = 0.007). Similarly, I/SN and I/NBa correlated significantly with FA/NBa (r = 0.39; P < 0.0001 and r = 0.422; P < 0.0001 correspondingly) and with FA/H (r = 0.305; P = 0.002 and r = 0.325; P = 0.001 correspondingly) [Table 2]. In addition, strong and statistically significant negative correlations existed between MP/SN angle and facial/growth axes at posttreatment assessment with r values ranging from −0.409 to −0.704 at P < 0.0001.

While ANB angle negatively correlated with facial/growth axes at T1, these correlations became stronger at T2 at statistically significant differences. At T1, ANB angle correlated with FA/NBa at r = −0.375; P < 0.0001, which increased to r = −0.465; P < 0.0001 [Table 2].

Discussion

The aim of this study was to evaluate changes in maxillary incisors' inclination relative to facial and growth axes in an adult orthodontic population. The main outcome was the fact that posttreatment maxillary incisors' inclination had significant positive correlations with facial and growth axes while there were no correlations in the pretreatment assessment. To the best of our knowledge, this was the first time that such an association was evaluated on adult subjects.

Facial and growth axes reflect the position of the mandible in the vertical and sagittal planes. When those

Table 2: Correlations between I inclination, MP/SN, ANB, and facial and growth axes at T1 and T2

n=100	Facial axis/NBa		Facial axis/H		G axis/NBa		G axis/H		MP/SN		ANB	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
I/PP												
r	0.189	0.308**	0.021	0.268**	0.133	0.322**	-0.036	0.110	0.039	-0.157	-0.382**	-0.486**
P	0.060	0.002	0.833	0.007	0.188	0.001	0.721	0.274	0.703	0.118	0.000	0.000
I/SN												
r	0.226*	0.399**	0.045	0.305**	0.153	0.381**	-0.022	0.055	0.030	-0.284**	-0.395**	-0.466**
P	0.024	0.000	0.659	0.002	0.130	0.000	0.828	0.586	0.769	0.004	0.000	0.000
I/NBa												
r	0.295**	0.422**	0.041	0.325**	0.225*	0.439**	-0.023	0.070	0.066	-0.196	-0.361**	-0.459**
P	0.003	0.000	0.686	0.001	0.025	0.000	0.822	0.492	0.512	0.050	0.000	0.000
I/H												
r	0.076	0.399**	0.016	0.305**	0.030	0.381**	-0.036	0.055	0.088	-0.283**	-0.333**	-0.466**
P	0.451	0.000	0.872	0.002	0.767	0.000	0.725	0.589	0.384	0.004	0.001	0.000
I/NA												
r	0.151	0.235*	-0.001	0.186	0.092	0.218*	-0.023	0.046	0.047	-0.067	-0.475**	-0.508**
P	0.134	0.019	0.994	0.064	0.365	0.030	0.817	0.652	0.640	0.505	0.000	0.000
MP/SN												
r	-0.278**	-0.704**	-0.242*	-0.657**	-0.238*	-0.692**	-0.046	-0.409**			0.170	0.244*
P	0.005	0.000	0.015	0.000	0.017	0.000	0.649	0.000			0.090	0.015
ANB												
r	-0.375**	-0.465**	-0.275**	-0.392**	-0.206*	-0.384**	-0.117	-0.186	0.170	0.244*		
P	0.000	0.000	0.006	0.000	0.039	0.000	0.247	0.064	0.090	0.015		

**Correlation is significant at the 0.01 level (two tailed), *Correlation is significant at the 0.05 level (two tailed)

axes are within normal range, the mandible is usually in a normal divergent pattern.[4,9,10] However, when these angles deviate from the norm, they indicate a vertical or horizontal growth vector of the mandible toward hypo or hyperdivergent facial pattern.[4,9,10] On the another hand, maxillary incisors' position constitutes a main aspect of facial esthetic evaluation. Changes in the maxillary incisors' inclination and position through orthodontic treatment affect smile esthetics.[2] While the cephalometric evaluation of maxillary incisors is basically performed by assessing the angle between the long axis of the tooth and anterior cranial base (SN) as well as maxillary base (PP),[4] no association was made to the growth pattern of the face through evaluation of the maxillary incisors' inclination relative to facial and growth axes.

In a previous study, the authors determined that while FA/NBa was different when classified in vertical and sagittal groups, differences in maxillary incisors' inclination existed only among the different sagittal groups but not among the different vertical divergence groups.[16] Accordingly, the current pre and postorthodontic treatment comparison stands to evaluate potential changes induced by the orthodontic treatment to the association between maxillary incisors' inclination and facial and growth axes. The correlations, to that end, were low and not significant in the pretreatment assessment [Table 2]. Interestingly, all maxillary incisors measurements, including I/PP, I/SN, I/H, I/NBa, I/NA had significant positive correlations after orthodontic treatment [Table 2], indicating a change into a more harmonious inclination relative to the growth pattern, and thus to facial type.

Our sample included adult patients treated only orthodontically with no surgical treatment to exclude any major effect of mandibular repositioning on facial and growth axes. In this perspective, changes in facial and growth axes were clinically considered minor and statistically not significant [Table 1]. However, the correlations of those axes to the maxillary incisors' inclination increased after treatment. These significant correlations are essentially the reflection of the optimization of maxillary incisors' inclination through orthodontic treatment in each individual. Consequently, the cephalometric evaluation of maxillary incisors' inclination to facial and growth axes may be an additional valid method to diagnosis and may be sought as a treatment objective.

Research issues

Our sample consisted of nongrowing patients. It would be interesting to longitudinally follow patients while they are growing to evaluate maxillary incisors' inclination changes relative to facial and growth axes. Most clinicians use radiographs to evaluate the inclination of the maxillary incisors; however, study dental casts have been used by some considering that radiographs digitization is difficult and prone to errors.[3,17,18] In our study, lateral cephalometric radiographs were used to record maxillary incisors' inclination, and dental casts were discarded as they are considered not valid especially with inappropriate trimming.

Conclusions

Orthodontic evaluation of maxillary incisors' position is mandatory from both functional and esthetical perspectives.

- In an adult population, and before orthodontic treatment, maxillary incisors' inclination did not correlate with facial and growth axes. However, higher correlations existed at posttreatment evaluation
- The orthodontic treatment aiming to optimize the inclination of the maxillary incisors induced a better association with facial and growth axes. This association reflects the connection between an optimal position of maxillary incisors relative to the corresponding vertical pattern of the individual
- Orthodontists should evaluate the position of the maxillary incisors to FA and may consider it in their treatment objectives
- Future research should focus on investigating this association in different groups of sagittal and vertical malocclusions, in growing and adult population.

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Conflicts of interest

There are no conflicts of interest.

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