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Displacement of Cephalometric Points A and B with Changes in Maxillary and Mandibular Incisor Inclination

Maksiller ve Mandibular Keser Eğimlerindeki Değişikliklere Bağlı Olarak 'A' ve 'B' Noktalarının Konum Değişiklikleri

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ABSTRACT

Objectives: This study aimed to evaluate whether treatment-induced changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B in skeletally mature, non-extraction patients.

Materials and Methods: Pre- (T0) and post-treatment (T1) lateral cephalograms of 90 skeletally mature patients (45 female, 45 male) were retrospectively analyzed. Inclusion required a complete incisor complement and a minimum 4° change in both UI-SN and IMPA. Tracings were performed with NemoCeph 2025; T0 and T1 cephalograms were superimposed on S-N, with a horizontal reference at 7° to S-N and a vertical reference through Sella. Method error was assessed by remeasuring 30 patients four weeks after the initial measurements, and intra-observer reliability was calculated using a two-way mixed-effects, absolute-agreement, single-measurement model- ICC(A,1). The threshold for statistical significance was set at $p < 0.05$.

Results: Linear regression analysis demonstrated that incisor inclination significantly influenced the sagittal positional change of both landmarks. A 1° increase in the UI-SN angle corresponded to approximately 0.043 mm of posterior displacement of point A, while a 1° increase in IMPA was associated with approximately 0.055 mm of posterior displacement of point B. Vertical changes were largely independent of incisor inclination, except for a statistically significant but clinically negligible association between IMPA and the vertical position of point B. The UI-SN–point A association was stronger in males.

Conclusion: Points A and B are not positionally stable during orthodontic treatment; both undergo sagittal displacement proportional to incisor inclination change, with measurable effects on SNA and SNB.

Keywords: *Anatomic landmarks, Cephalometry, Incisor, Tooth movement techniques.*

ÖZET

Amaç: Bu çalışmanın amacı, iskeletsel gelişimini tamamlamış ve çekimsiz tedavi gören hastalarda maksiller ve mandibular keser eğimindeki tedaviye bağlı değişikliklerin, sefalometrik A ve B noktalarının sagital ve vertikal yöndeki konum değişiklikleri ile ilişkili olup olmadığını değerlendirmektir.

Gereç ve Yöntemler: İskeletsel gelişimini tamamlamış 90 hastanın (45 kadın, 45 erkek) tedavi öncesi (T0) ve tedavi sonrası (T1) lateral sefalometrik radyografları retrospektif olarak incelendi. Çalışmaya dahil edilme kriteri olarak keserlerin tam bulunması ve hem UI-SN hem de IMPA değerlerinde en az 4°'lik değişim arandı. Çizimler NemoCeph 2025 yazılımı ile gerçekleştirildi; T0 ve T1 radyografları S-N düzlemi üzerine süperpoze edildi, S-N'ye 7° açıyla yatay referans ve Sella noktasından geçen dikey referans kullanıldı. Ölçüm hatası, 30 hastada dört hafta sonra tekrar ölçüm yapılarak gözlemci içi güvenirlik, iki yönlü karma etkiler, mutlak uyum ve tekli ölçüm modeli kullanılarak hesaplanmıştır. İstatistiksel anlamlılık düzeyi $p <0,05$ olarak kabul edilmiştir.

Bulgular: Doğrusal regresyon analizinde keser eğiminin her iki noktanın sagital konum değişimini anlamlı düzeyde etkilediği görüldü. UI-SN açısındaki 1°'lik artış A noktası için yaklaşık 0,043 mm posterior hareket ile ilişkili bulundu. IMPA açısındaki 1°'lik artış B noktası için yaklaşık 0,055 mm posterior hareket ile ilişkili bulundu. Vertikal yöndeki konum değişimi çoğunlukla keser eğiminden bağımsızdı; yalnızca IMPA ile B noktasının vertikal konumu arasında istatistiksel olarak anlamlı ancak klinik olarak ihmal edilebilir düzeyde bir ilişki saptandı. UI-SN ile A noktası arasındaki ilişkinin erkeklerde kadınlara kıyasla anlamlı derecede daha güçlü olduğu görüldü.

Sonuç: A ve B noktaları ortodontik tedavi sırasında sabit kalmamakta; her iki nokta da keser eğimindeki değişimle orantılı olarak sagital yönde yer değiştirmekte ve bu durum SNA ile SNB ölçümlerine yansımaktadır.

Anahtar Kelimeler: *Anatomik işaretler, Dişleri hareketlendirme teknikleri, Kesici diş, Sefalometri.*

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Introduction

Lateral cephalometric radiography is the principal two-dimensional record used in orthodontic diagnosis and treatment planning, and most quantitative assessments of skeletal, dental, and soft-tissue relationships still rely on it.[1,2] Among the landmarks used in routine analysis, points A and B occupy a uniquely influential position: they define the anterior limits of the maxillary and mandibular skeletal bases and form the basis of the SNA, SNB, and ANB angles that drive sagittal skeletal classification.[3,4]

Point A, originally described by Downs, lies at the deepest concavity of the anterior maxillary alveolar process, between the anterior nasal spine and the cervical region of the maxillary central incisor.[3] Point B occupies the analogous concavity on the anterior mandibular alveolus, between the lower incisor apex and pogonion.[4] Because both landmarks lie on alveolar bone directly overlying the incisor root apices, their reliability as skeletal reference points has been debated in the cephalometric literature for decades.[5]

The angels derived from these landmarks also have well-documented limitations. Jacobson[6] introduced the Wits appraisal to circumvent the dependence of ANB on cranial-base orientation, Hussels and Nanda[7] demonstrated that ANB can vary substantially even when the underlying sagittal jaw relationship is unchanged, Taylor[8] showed that mandibular rotation alone produces clinically meaningful shifts in ANB, and Bishara et al.[9] documented longitudinal growth-related changes in ANB not paralleled by Wits. Any displacement of A or B itself would therefore propagate directly into the most widely used indices of skeletal discrepancy.

Landmark identification adds a further layer of variability. Although Zamora et al.[10] reported high observer agreement for major points on CBCT-derived images, two-dimensional studies have repeatedly identified point A as among the least reproducible landmarks; Grogger et al.[11] found its x-coordinate to be the dominant source of error variance in nearly every angular measurement examined. Comparative 2D/3D studies report improved reliability for point A on CBCT, and computer-assisted edge detection improves the reproducibility of point B but not point A.[12]

The central clinical question is whether incisor inclination changes during treatment actively displace these landmarks. Erverdi[13] was among the first to formalize a regression relationship between maxillary incisor inclination and the sagittal position of point A. Studies on Class II Division 2 proclination have since reported posterior displacement of A by 1–2 mm, with measurable effects on SNA.[14–16] Comparable findings emerge for incisor retraction following premolar extraction, where point A shifts in the direction of the retracted apex, while Class II Division 2 and Class III patients show markedly different A-point movement per degree of inclination change.[17] For point B, Al-Abdwani et al.[18] found only borderline associations with lower incisor inclination, whereas Neani et al.[19] reported approximately 0.17 mm of B-point retraction per millimeter of lower-incisor retraction in bimaxillary protrusion cases.

Despite this accumulated evidence, the literature remains inconsistent. Discrepancies have been attributed to residual craniofacial growth, differences between 2D and 3D imaging, variation in the type and magnitude of incisor movement, and heterogeneity of malocclusion samples. Few studies have simultaneously controlled for skeletal maturity, restricted treatment to non-extraction mechanics, and quantified the contribution of incisor inclination change using hierarchical statistical models.

The aim of this retrospective study was therefore to evaluate, in skeletally mature individuals treated without premolar extraction, whether changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B, and to quantify the variance attributable to incisor inclination versus the corresponding skeletal angles (SNA, SNB).

Materials and Methods

This retrospective study was conducted on pre-treatment (T0) and post-treatment (T1) lateral cephalometric radiographs of 90 patients (45 female, 45 male) selected from the archive of the Department of Orthodontics, Faculty of Dentistry, Istanbul Okan University. The required sample size was estimated as a priori for the study's primary analysis — a two-tailed bivariate correlation between treatment-induced incisor inclination change and the sagittal displacement of points A and B. Based on the moderate-to-strong associations reported in previous cephalometric studies, an expected correlation of $\rho = 0.48$ was assumed. At $\alpha = 0.05$ and 90% statistical power, a minimum of 42 patients was required. The final sample of 90 patients (180 cephalograms) comfortably exceeded this requirement. Ethical approval for the study was granted by the Istanbul Okan University Ethics Committee on 15 September 2025 (Decision no. 28).

Inclusion criteria were: (i) completed skeletal growth, defined as Cervical Vertebral Maturation stage CS 5 or CS 6; (ii) a full complement of maxillary and mandibular incisors; (iii) a treatment-induced change of at least 4°, in absolute terms and irrespective of direction (proclination or retroclination), in each of UI-SN and IMPA; and (iv) cephalograms of diagnostic quality. The 4° threshold was applied to the absolute magnitude of change in each angle so that both proclination and retroclination cases were represented and was chosen to ensure that only clinically meaningful inclination changes exceeding the intra-observer method error of the angular measurements were analysed, thereby minimizing the influence of measurement variability. Patients were excluded if they had a cleft lip or palate, any craniofacial syndrome, a history of premolar extraction or orthognathic surgery, prior orthodontic treatment, or evidence of marked root resorption during treatment.

All lateral cephalograms were obtained under standardized conditions with each patient's Frankfort horizontal plane parallel to the floor, the teeth in centric occlusion, and the lips at rest. Digital tracing and measurement were performed with NemoCeph 2025 software (Nemotec S.L., Madrid, Spain), a computer-assisted cephalometric program whose accuracy is comparable to manual tracing and to other widely used digital platforms.[20]

For each patient, T0 and T1 radiographs were superimposed on the anterior cranial base using the S–N line, an approach selected for its stability in skeletally mature individuals and its extensive use in the literature. An individualized coordinate system was then constructed from the S–N line. The horizontal reference axis (Hor.Ref.) was defined at 7° to S–N to approximate the Frankfort horizontal plane, and the vertical reference axis (Ver.Ref.) was drawn perpendicular to Hor. Ref. through Sella. This system allowed the sagittal and vertical components of landmark displacement to be evaluated independently: the perpendicular distance from a landmark to the vertical reference axis represents its sagittal (anteroposterior) position, whereas the perpendicular distance to the horizontal reference axis represents its vertical position. Accordingly, treatment-induced changes in A-Ver.Ref. and B-Ver.Ref. quantify sagittal displacement, while changes in A-Hor.Ref. and B-Hor.Ref. quantify vertical displacement.

The following angular measurements were recorded at T0 and T1: UI-SN, IMPA, SNA and SNB. Linear distances to the horizontal and vertical reference axes were measured in millimeters for the maxillary incisor edge (UI) and apex (UI-Apex), the mandibular incisor edge (LI) and apex (LI-Apex), and points A and B. For every parameter, the treatment-induced change was calculated as T1 − T0.

Statistical Analysis

Method error was assessed by remeasuring 30 patients four weeks after the initial measurements, and intra-observer reliability was calculated using a two-way mixed-effects, absolute-agreement, single-measurement model — ICC(A,1). The threshold for statistical significance was set at $p < 0.05$. Because the correlational analyses were exploratory and hypothesis-generating, no formal correction for multiple comparisons (e.g., Bonferroni) was applied; instead, exact p-values are reported throughout, and the results are interpreted with corresponding caution. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 27 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were reported as mean, standard deviation, median, minimum–maximum, and 25th–75th percentile values for continuous variables, and as frequencies and percentages for categorical variables. The normality of distribution was evaluated with the Shapiro–Wilk test. Relationships between non-normally distributed continuous variables were examined using Spearman's rank correlation analysis. For the mathematical modelling of a dependent continuous variable in relation to its independent predictors, hierarchical linear regression analysis was applied using a block-entry design.

Results

The study sample comprised 90 skeletally mature patients (45 female, 45 male; mean age 26.0 ± 6.2 years). Descriptive statistics for all principal cephalometric variables at T0 and T1, together with the corresponding treatment-induced changes, are presented in Table 1. Method-error analysis demonstrated excellent intra-observer reliability, with ICC(A,1) values ranging from 0.95 to 1.00 across all variables (Table 2); no systematic difference was observed between repeat tracings. Spearman correlations between treatment-induced changes and the displacement of points A and B are summarized in Table 3. The sagittal displacement of point A (Δ A-Ver. Ref.) was moderately negatively associated with the change in UI-SN ($r = -0.608$, $p < 0.001$), indicating that proclination of the upper incisor was accompanied by posterior movement of point A. The same outcome correlated positively with the changes in SNA ($r = 0.393$, $p < 0.001$) and strongly with the sagittal displacement of the maxillary incisor apex ($r = 0.668$, $p < 0.001$). The vertical displacement of point A (Δ A-Hor.Ref.) was related only to the vertical movement of the upper incisor apex ($r = 0.423$, $p < 0.001$). The scatter plot in Figure 1 illustrates the negative linear trend between Δ UI-SN and the sagittal displacement of point A.

Table 1. Descriptive statistics of the principal cephalometric variables (n = 90)

Variable	T0 (mean ± SD)	T1(mean ± SD)	ΔT (T1 − T0) (mean ± SD)
Angular measurements (°)			
UI-SN	101.86±9.56	104.6±11.91	4.02±13.29
IMPA	98.37±10.37	100.69±10.6	4.32±7.91
SNA	79.87±4.15	79.16±3.82	-0.71±1.83
SNB	77.7±4.63	77.66±4.47	-0.03±1.33
Linear measurements (mm)			
A – Hor.Ref. (vertical position of A)	47.51±3.96	47.81±3.92	0.3±1.52
A – Ver.Ref. (sagittal position of A)	63.11±5.11	62.6±5.34	-0.5±1.38
B – Hor.Ref. (vertical position of B)	90.8±6.75	90.55±6.61	-0.25 ±1.4
B – Ver.Ref. (sagittal position of B)	56.99±8.99	57.16±8.88	-0.17±0.94

Table 2. Method-error analyses results

		ICC	%95 CI		p
UI-SN (°)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	1.000	1.000	<0.001*
IMPA (°)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	1.000	1.000	<0.001*
HOR.REF-UI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.999	1.000	<0.001*
HOR.REF-LI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.999	1.000	<0.001*
VER.REF-UI APEKS (mm)	t0	0.999	0.999	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
VER.REF-LI APEKS (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	1.000	0.999	1.000	<0.001*
SNA (°)	t0	1.000	1.000	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
SNB (°)	t0	0.999	0.998	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
A-HOR.REF. (mm)	t0	0.999	0.998	1.000	<0.001*
	t1	0.998	0.997	0.999	<0.001*
A-VER.REF. (mm)	t0	0.999	0.998	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
B-HOR.REF. (mm)	t0	1.000	0.999	1.000	<0.001*
	t1	0.999	0.998	1.000	<0.001*
B-VER.REF. (mm)	t0	1.000	1.000	1.000	<0.001*
	t1	1.000	0.999	1.000	<0.001*

*p<0.05

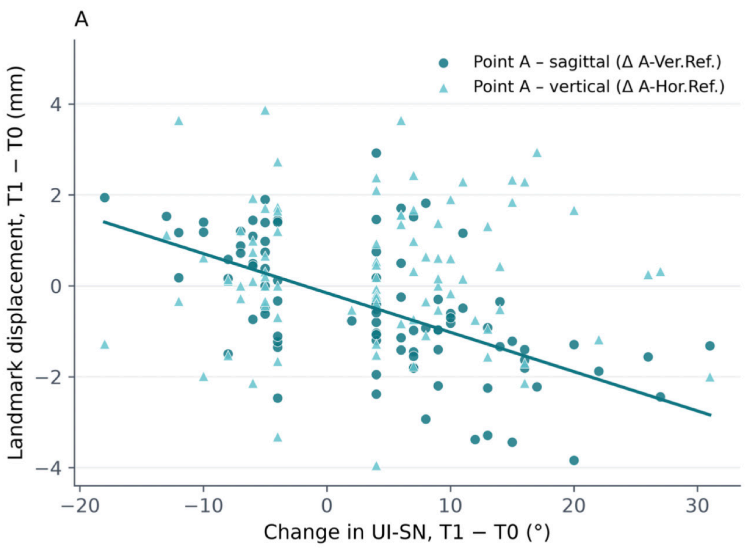

Figure 1. Scatter plot of the relationships between the changes in A-Hor. Ref. (Vertical Position) and A-Ver. Ref. (Sagittal Position) and the changes in UI-SN (T1−T0)

The sagittal displacement of point B (Δ B-Ver. Ref.) correlated negatively with the change in IMPA ($r = -0.488$, $p < 0.01$) and positively with the change in SNB ($r = 0.407$) and with the sagittal displacement of the lower incisor apex ($r = 0.653$, $p < 0.001$) (Table 3). The vertical displacement of point B (Δ B-Hor.Ref.) showed a moderate positive correlation with the vertical movement of the lower incisor apex ($r = 0.530$, $p < 0.001$). In correlation analysis it was not meaningfully associated with IMPA; however, in the hierarchical regression model IMPA reached statistical significance as a predictor of the vertical position of point B, while explaining only a negligible fraction of its variance (adjusted $R^2 \approx 4\%$, $p = 0.014$). The negative linear trend between Δ IMPA and the sagittal displacement of point B is shown in Figure 2.

Table 3. Spearman correlations between treatment-induced cephalometric changes and the displacement of points A and B.

Predictor (ΔT1 − T0)	Outcome	r
Δ UI-SN	Δ A-Ver.Ref. (sagittal A)	−0.608* p<001*
Δ SNA	Δ A-Ver.Ref. (sagittal A)	0.393* p<001*
Δ Ver.Ref. – UI Apex	Δ A-Ver.Ref. (sagittal A)	0.668* p<001*
Δ Hor.Ref. – UI Apex	Δ A-Hor.Ref. (vertical A)	0.423* p<001*
Δ IMPA	Δ B-Ver.Ref. (sagittal B)	−0.488* p<001*
Δ SNB	Δ B-Ver.Ref. (sagittal B)	0.407* p<001*
Δ Ver.Ref. – LI Apex	Δ B-Ver.Ref. (sagittal B)	0.653* p<001*
Δ Hor.Ref. – LI Apex	Δ B-Hor.Ref. (vertical B)	0.530* p<001*

r values; * p < 0.05, Δ A-Ver.Ref. and Δ B-Ver.Ref. = sagittal displacement; Δ A-Hor.Ref. and Δ B-Hor.Ref. = vertical displacement.

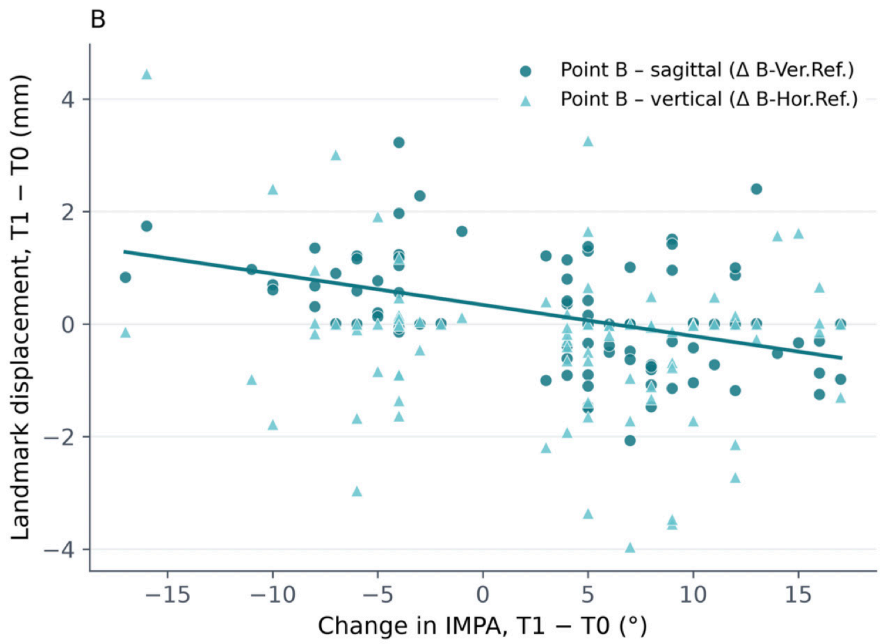

Figure 2. Scatter plot of the relationships between the changes in B-Hor. Ref. (Vertical Position) and B-Ver. Ref. (Sagittal Position) and the changes in IMPA (T1−T0)

As shown in Table 4, the change in UI-SN was strongly and inversely related to the sagittal displacement of the maxillary incisor apex ($r = -0.716$, $p < 0.01$), and the change in IMPA was inversely related to that of the mandibular incisor apex ($r = -0.674$, $p < 0.01$), that incisor inclination change was driven predominantly by apical movement in the opposite direction.

Table 4. Spearman correlations among incisor inclination, apex displacement, and skeletal angle changes.

Variable pair (ΔT1 − T0)	r
ΔUI-SN ↔ Δ Ver.Ref. – UI Apex	−0.716* p<0.001*
Δ IMPA ↔ Δ Ver.Ref. – LI Apex	−0.674* p<0.001?

* p < 0.05.

When the analysis was stratified by sex (Table 5), the negative association between Δ UI-SN and the sagittal displacement of point A was substantially stronger in males (r = −0.792) than in females (r = −0.454); this difference between the two correlations was statistically significant (Fisher r-to-z, z = 2.69, p = 0.007). The corresponding IMPA–point-B relationship was similar in both sexes (males r = −0.497; females r = −0.439; Fisher r-to-z, z = 0.34, p = 0.73, not significant).

Hierarchical linear regression models are presented in Table 6. For the sagittal displacement of point A, UI-SN alone explained 16.9% of the variance (Model 1: $R^2 = 0.169$, p < 0.001); adding age, sex and SNA in Block 2 significantly increased the explained variance to 40.1% (p < 0.001). The sagittal displacement of point B, IMPA alone explained 21.5% of the variance (Model 1: $R^2 = 0.215$, p < 0.001), rising to 42.8% after Block 2 (p< 0.001). In contrast, the vertical displacement of point A was not significantly explained by either model and the vertical displacement of point B was only marginally related to IMPA (Model 1: $R^2 = 0.052$, adjusted $R^2 = 0.044$, p = 0.014), with no significant improvement after Block 2.

Table 5. Sex-stratified Spearman correlations between incisor inclination change and the sagittal displacement of points A and B.

Male		UI-SN (T1-T0)	Male		IMPA (T1-T0)
A-HOR. REF. (T1-T0) (mm)	r	0.078	B-HOR. REF.(T1-T0)(mm)	r	-0.090
	p	0.552		p	0.494
A-VER. REF. (T1-T0) (mm)	r	-0.792	B-VER. REF.(T1-T0)(mm)	r	-0.497
	p	<0.001*		p	<0.001*
Female		UI-SN (T1-T0)	Female		IMPA (T1-T0)
A-HOR. REF. (T1-T0) (mm)	r	-0.080	B-HOR. REF.(T1-T0)(mm)	r	-0.249
	p	0.563		p	0.067
A-VER. REF. (T1-T0) (mm)	r	-0.454	B-VER. REF.(T1-T0)(mm)	r	-0.439
	p	<0.001*		p	0.001*

Fisher r-to-z comparison of the male vs female correlations: UI-SN/point A z = 2.69, p = 0.007 (significant); IMPA/point B z = 0.34, p = 0.73 (not significant), A-Ver.Ref. and B-Ver.Ref. = sagittal displacement; A-Hor.Ref. and B-Hor.Ref. = vertical displacement.

Table 6. Hierarchical regression analyses

	β	S.E.	St. β	t	p	%95 CI Lower Limit	%95 CI Upper Limit	VIF
1.Model(B-Ver.Ref). (T1-T0)								
Constant	0.300	0.081		3.693	<0.001*	0.139	0.460	
IMPA (T1-T0) (°)	-0.055	0.010	-0.463	-5.558	<0.001*	-0.074	-0.035	1.000
F:30.895 and p<0.001*				R^2:0.215. Adjusted R^2:0.208				
2.Model								
Constant	0.512	0.297		1.725	0.087	-0.076	1.100	
IMPA (T1-T0) (°)	-0.056	0.009	-0.473	-6.519	<0.001*	-0.073	-0.039	1.003
Age at treatment initiation	-0.007	0.012	-0.048	-0.623	0.534	-0.030	0.016	1.129
Sex	0.003	0.141	0.002	0.022	0.983	-0.275	0.282	1.077
SNB (T1-T0) (°)	0.316	0.059	0.449	5.339	<0.001*	0.199	0.434	1.347
F:16.286 and p<0.001*				R^2:0.428. Adjusted R^2:0.401				
1.Model(B-Hor.Ref). (T1-T0)								
Constant	-0.145	0.146		-0.992	0.323	-0.434	0.144	
IMPA (T1-T0) (°)	-0.044	0.018	-0.228	-2.489	0.014*	-0.079	-0.009	1.000
F:6.193 and p=0.014*				R^2:0.052 Adjusted R^2:0.044				
2.Model								
Constant	0.029	0.622		0.047	0.962	-1.204	1.263	
IMPA (T1-T0) (°)	-0.045	0.018	-0.232	-2.494	0.014*	-0.081	-0.009	1.003
Age at treatment initiation	-0.002	0.024	-0.010	-0.101	0.920	-0.051	0.046	1.129
Sex	-0.281	0.295	-0.092	-0.952	0.343	-0.865	0.304	1.077
SNB (T1-T0) (°)	0.017	0.124	0.014	0.133	0.894	-0.230	0.263	1.347
F:1.442 and p=0.215				R^2:0.062. Adjusted R^2:0.019				
1.Model (A-Ver.Ref.) (T1-T0)								
Constant	-0.387	0.121		-3.211	0.002*	-0.626	-0.148	
UI-SN (T1-T0) (°)	-0.043	0.009	-0.411	-4.791	<0.001*	-0.060	-0.025	1.000
F:22.956 and p<0.001*				R^2:0.169. Adjusted R^2:0.161				
2.Model								
Constant	-0.072	0.448		-0.160	0.873	-0.959	0.816	
UI-SN (T1-T0) (°)	-0.018	0.009	-0.176	-2.133	0.035*	-0.035	-0.001	1.245
Age at treatment initiation	-0.009	0.018	-0.038	-0.484	0.629	-0.043	0.026	1.139
Sex	0.267	0.213	0.097	1.249	0.214	-0.156	0.690	1.090
SNA (T1-T0) (°)	0.427	0.071	0.564	6.047	<0.001*	0.287	0.566	1.585
F:14.592 and p<0.001*				R^2:0.401. Adjusted R^2:0.373				
1.Model(A-Hor.Ref.) (T1-T0)								
Constant	0.297	0.146		2.040	0.044*	0.009	0.586	
UI-SN (T1-T0) (°)	-4.321E-08	0.011	0.000	0.000	1.000	-0.021	0.021	1.000
F:0.000 p:1.000								
2.Model								
Constant	1.363	0.627		2.176	0.032*	0.122	2.605	
UI-SN (T1-T0)	0.004	0.012	0.031	0.292	0.771	-0.020	0.027	1.245
Age at treatment initiation	-0.040	0.025	-0.164	-1.631	0.106	-0.089	0.009	1.139
Sex	-0.005	0.299	-0.002	-0.016	0.988	-0.596	0.587	1.090
SNA (T1-T0) (°)	0.037	0.099	0.045	0.378	0.706	-0.158	0.233	1.585
F:0.764 and p=0.578								

*p<0.05. S.E.: Standart Error and St.: Standart

Discussion

The present study evaluated whether changes in maxillary and mandibular incisor inclination are associated with sagittal and vertical displacement of cephalometric points A and B in skeletally mature, non-extraction patients. The sagittal displacement of both landmarks correlated negatively with the inclination change of the adjacent incisor: point A moved posteriorly during proclination, and point B behaved similarly in relation to the lower incisor. In both cases the landmark moved almost in parallel with the corresponding incisor root apex. Adding SNA and SNB to the hierarchical regression models roughly doubled the explained variance in landmark displacement, which suggests that incisor-driven movement of A and B is reflected in the skeletal indices derived from them. Points A and B therefore do not appear to be positionally stable during orthodontic treatment; their displacement is predominantly sagittal and is quantitatively linked to incisor mechanics.

The inverse correlation between Δ UI-SN and the sagittal displacement of point A ($r = -0.608$) is consistent with the regression relationship first described by Erverdi[13] and with the proclination studies on Class II Division 2 patients reported by Bicakci et al.[14], Chen et al.[15], Al-Nimri et al.[16], and Prakash et al.[21] The magnitude of A-point retraction observed in our sample falls within the 1–2 mm range described by these authors. Prakash et al.[21] further reported that the SNA reduction following proclination was approximately equal in millimeters to the A-point retraction, a finding that mirrors our regression result in which SNA emerged as a significant Block 2 predictor of A-point displacement. Chen et al.[15] demonstrated this displacement on CBCT and observed a corresponding statistically significant decrease in SNA, whereas Bicakci et al.[14], using lateral cephalograms, did not detect a statistically significant change in SNA or A-point position.

The retraction studies of An et al.[22], Hassan et al.[23], and Amasyalı et al.[24] - the latter using mini-implant-supported torque-arch mechanics in a Turkish cohort - likewise reported posterior movement of point A with a measurable decline in SNA and ANB.

The strong correlation observed in our study between sagittal displacement of point A and that of the upper incisor apex ($r = 0.668$) is therefore consistent with the alveolar remodeling mechanism described by Hong et al.[25], the large-sample analysis of Sun et al.[26], and the systematic CBCT review by Kuc et al.[27]

For point B, the negative association with IMPA ($r = -0.488$) and the strong correlation with the sagittal displacement of the lower incisor apex ($r = 0.653$) align closely with the proportional displacement (approximately 0.17 mm per millimeter of incisor retraction) reported by Neani et al.[19] and with the lingual displacement of point B described by Marques and Siqueira[28] in dolichofacial Class II Division 1 patients. They contrast, however, with the more attenuated effect described by Al-Abdwani et al.[18], whose generalized estimating equation model accounted for skeletal growth and therefore diluted the inclination effect. Because our sample was restricted to skeletally mature individuals (CS 5 or 6), the influence of residual growth was eliminated as a confounder, which may explain why our model yielded a clearer association. Chen et al.[15], using CBCT in Class II Division 2 patients, similarly reported posterior displacement of point B with effects on SNB, and Xu et al.[29] documented buccolingual narrowing of the mandibular alveolar bone proportional to the retraction distance, with cortical resorption exceeding apposition.

In contrast to the sagittal findings, regression models for the vertical displacement of point A were not significant, and the vertical displacement of point B was only weakly related to IMPA — a statistically significant but clinically negligible association (adjusted $R^2 \approx 4\%$, $p = 0.014$). This pattern resembles the asymmetric outcome reported by Hassan et al.[23], who found that incisor inclination changes affected mainly the vertical position of point A in a small, predictable way (≈ 0.6 mm per 10° of retroclination) but contributed to a much larger combined vertical and forward displacement that was not driven by inclination alone. The limited sensitivity of vertical displacement to inclination in our sample may reflect the well-documented difficulties of identifying the vertical coordinate of point A on two-dimensional cephalograms, as well as the contribution of vertical alveolar remodeling mechanisms (extrusion, intrusion, occlusal plane changes) that are not captured by a single angular variable.[11,12,30]

The substantially stronger UI-SN/A-point correlation in males ($r = -0.792$) than in females ($r = -0.454$) was statistically significant on formal testing (Fisher r-to-z, $z = 2.69$, $p = 0.007$) but remains a tentative observation. Mandibular and maxillary alveolar bone density, cortical thickness, and remodeling capacity have been reported to differ by sex and facial growth pattern in the orthodontic literature; in particular, Kalina et al.[31] showed that the bone-to-tooth (B/T) ratio differs markedly between vertically and sagittally growing individuals, with vertically growing patients exhibiting a substantially lower B/T ratio and therefore a less predictable correspondence between incisor inclination change and overlying alveolar remodeling. Because vertical growth pattern was not stratified in the present study and tends to be unevenly distributed between sexes, part of the observed sex effect may in fact reflect underlying differences in facial divergence rather than sex per se. Because neither age nor sex reached statistical significance in the multivariate regression, this finding should be treated with caution and confirmed in CBCT-based studies on prospectively matched samples before being accepted as a true sex effect.

This study relied exclusively on two-dimensional lateral cephalograms, and small landmark displacements (< 1 mm) may be under- or over-estimated relative to three-dimensional CBCT analysis.[15,30,32] Das et al.[30] specifically showed that point A, which is among the most challenging landmarks to identify on 2D records, is reproduced more reliably on CBCT-derived cephalograms. We did, however, use a digital, computer-assisted workflow (NemoCeph 2025) whose reliability is comparable to manual tracing and to other widely used digital platforms, and we adopted an individualized coordinate system based on S–N superimposition with reference axes constructed at 7° to S–N to minimize the influence of cranial-base orientation.[20] Method-error analysis confirmed acceptable reproducibility. Other limitations include the retrospective design, the restriction to non-extraction treatment, the absence of a control group, and the inability to quantify alveolar remodeling directly; in addition, restricting inclusion to cases with an inclination change of at least 4° may introduce a selection bias toward more pronounced tooth movement, so the associations reported here should not be extrapolated to patients with minimal inclination change. Finally, while we controlled for growth by including only skeletally mature individuals, our findings cannot be extrapolated to growing patients, in whom condylar and sutural changes may independently influence A- and B-point position.[5,18]

The clinical message of these findings is that changes in SNA and SNB observed between pre- and post-treatment cephalograms cannot be interpreted purely as skeletal changes. Soft-tissue outcomes are also affected: Valentim et al.[33] reported a strong correlation between B-point displacement and lower lip position following maxillary incisor retraction, indicating that landmark displacement has both skeletal and aesthetic consequences.

Clinicians should therefore exercise caution when interpreting small post-treatment changes in SNA, SNB, and ANB, particularly when significant proclination or retroclination has been performed. Although the per-degree displacement is small (≈ 0.043–0.055 mm per degree), a clinically common inclination change of 10–15° translates into roughly 0.5–0.8 mm of A- or B-point movement, which is sufficient to shift SNA, SNB and ANB by a few tenths of a degree and thus to affect borderline skeletal classification. The use of additional reference measurements less dependent on incisor-adjacent alveolar landmarks — such as the Wits appraisal or alternative landmarks (the L point, Y point, or related substitutes) — may be considered alongside conventional analyses in cases where substantial incisor inclination change is anticipated.[9,12,34]

Conclusion

In skeletally mature, non-extraction patients, cephalometric points A and B underwent predominantly sagittal displacement proportional to the inclination change of the adjacent incisor. Simple linear regression indicated that point A moved approximately 0.043 mm posteriorly per degree of increase in UI-SN, and point B moved approximately 0.055 mm posteriorly per degree of increase in IMPA. Vertical displacement of both landmarks was largely independent of inclination, with only a weak, clinically negligible association between IMPA and the vertical position of point B. Post-treatment changes in SNA and SNB should therefore be interpreted with caution whenever substantial incisor inclination change has occurred.

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Conflict of Interest

The authors declare that they have no conflict of interest related to this study, including no affiliations with or relationships to any scientific or medical committee members, no consultancy or expert witness roles, no employment in any related company, no shareholdings, or any similar interests.

Authorship Contributions

Idea/Concept: Z.A.A Design: Z.A.A Control/ Supervision: A.E Materials: S.S.Ş.D Data Collection and/ or Processing: S.S.Ş.D Literature Review: S.S.Ş.D Analysis and/or Interpretation: S.S.Ş.D Writing the Article: S.S.Ş.D Critical Review: Z.A.A, A.E

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