ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at:www.ijdsir.com
Volume – 8, Issue – 4, August – 2025, Page No. : 121 - 149

Comparative Evaluation of Five Alternative Methods for Estimation of Point A with Different Maxillary Incisor Inclinations: A Cephalometric Study

[1]Dr. Mehak, PG 3rd Year, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

[2]Dr. Parul Jain, Professor and HOD, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

[3]Dr. Abhishek Sharma, Professor, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

[4]Dr. Atul Jindal, Reader, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

[5]Dr. Ushmita Mehta, Senior Lecturer, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

[6]Dr. Mohammed Ismail, Postgraduate, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

Corresponding Author: Dr. Mehak, PG 3rd Year, Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab.

Citation of this Article: Dr. Mehak, Dr. Parul Jain, Dr. Abhishek Sharma, Dr. Atul Jindal, Dr. Ushmita Mehta, Dr. Mohammed Ismail, "Comparative Evaluation of Five Alternative Methods for Estimation of Point A with Different Maxillary Incisor Inclinations: A Cephalometric Study", IJDSIR- August – 2025, Volume – 8, Issue – 4, P. No. 121 – 149.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Objective: This study aimed to evaluate the reliability of five alternative cephalometric landmarks (A1–A5) as substitutes for Point A across varying maxillary incisor inclinations—normally inclined, proclined, and retroclined—using angular and linear cephalometric parameters.

Materials and Methods: A total of 120 pretreatment lateral cephalograms were analyzed and divided into three groups (40 each) based on U1-PP angulation. Point A (Downs) and five alternatives—A1 (Jacobson), A2 (Tindlund), A3 (Prosthion projection), A4 (Labial lamella), and A5 (2 mm anterior to apex)—were identified on each radiograph. Angular (SNA, U1–NA, N–A–Pog) and linear (NA–P, U1–NA) measurements

were recorded. Intra- and intergroup comparisons were made using ANOVA, post hoc Bonferroni tests, and Pearson correlation analysis.

Results: Points A1 and A2 showed minimal variation from Point A across all groups and had the highest correlation coefficients, indicating strong reliability. Point A3 demonstrated the greatest variability, particularly in proclined incisors, while A4 and A5 were moderately reliable in retroclined cases but inconsistent elsewhere.

Conclusion: Point A1 emerged as the most consistent and reliable alternative to Point A, regardless of incisor inclination. Point A2 serves as a viable secondary landmark. A3, A4, and A5 should be used with caution due to positional variability influenced by incisor angulation.

Keywords: Cephalometric Analysis Maxillary Alveolar Process, SNA Angle

Introduction

Cephalometric analysis is an indispensable tool in orthodontic diagnosis, treatment planning, and the evaluation of growth and treatment-related changes. It allows for the quantitative assessment of skeletal, dental, and soft tissue relationships through standardized radiographic landmarks. Among the various skeletal landmarks, Point A (subspinale) plays a pivotal role. It is defined as the most concave point on the anterior contour of the maxillary alveolar process, located between the anterior nasal spine and the crest of the maxillary alveolar ridge. Point A is integral to several cephalometric parameters such as the SNA angle, which denotes maxillary position in relation to the cranial base, and the ANB angle, a fundamental indicator of sagittal skeletal discrepancies between the maxilla and mandible. Additionally, it contributes to Wits appraisal and other skeletal evaluations used to diagnose Class I, II, and III malocclusions.[1]

Despite its importance, the accurate identification of Point A can often be challenging. One of the key variables that affect its localization is the inclination of the maxillary incisors. In clinical orthodontics, maxillary incisors are frequently subjected to various movements, including proclination, retroclination, or vertical repositioning. Such movements may significantly influence the shape and position of the surrounding alveolar bone, thereby altering the concavity that defines Point A. These changes can result in variations in landmark identification, leading to potential inaccuracies in diagnostic measurements and treatment planning.[2]

This challenge has prompted researchers and clinicians to explore alternative strategies for more reliable and reproducible localization of Point A, particularly in cases with altered maxillary incisor inclinations. Various geometrically derived methods and anatomical surrogate approaches have been proposed in the literature to address this issue. These alternative methods attempt to identify Point A based on relatively stable skeletal or dental landmarks, thereby reducing the dependency on variable soft tissue or alveolar contours that may be affected by orthodontic treatment.[3]

However, the comparative validity and reliability of these alternative methods—especially across a range of maxillary incisor inclinations—have not been thoroughly investigated. Variability in cephalometric tracing and landmark identification can compromise the reproducibility of orthodontic assessments, especially in growing patients or cases involving significant dental compensation. Hence, it becomes essential to systematically evaluate these methods under controlled parameters to determine their clinical utility.[3]

The present study aims to conduct a comparative cephalometric evaluation of five alternative methods for estimating Point A under varying maxillary incisor inclinations. By analyzing a sample of lateral cephalograms with different incisor angulations, the study will assess the consistency, accuracy, and reliability of each method in relation to a gold standard reference. This investigation seeks to identify the method least influenced by incisor inclination, thereby offering clinicians a more dependable approach for cephalometric analysis in both diagnosis and treatment monitoring.

Ultimately, the findings of this study could contribute to improved diagnostic precision, better treatment planning, and enhanced inter-examiner reproducibility in cephalometric assessments, especially in cases where dental-alveolar changes are expected or have already occurred.

Material and Methodology

The study was conducted on 120 lateral cephalograms of patients reporting to the Department of Orthodontics and Dentofacial Orthopaedics at Guru Nanak Dev Dental College and Research Institute, Sunam.

Lateral Cephalogram (figure 1) was traced using 3H lead pencil on acetate tracing paper under X ray viewer box and then sample was divided into 3 groups based on the maxillary incisor inclination (U1-PP angle).

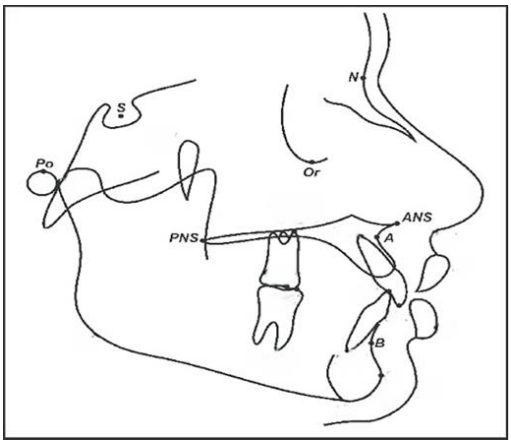


Figure 1: Cephalometric Landmarks

- Group A – 40 participants with normally inclined incisors.
- Group B – 40 participants with proclined incisors.
- Group C – 40 participants with retroclined incisors.

Point A as suggested by Downs and five alternative points for estimation of point A suggested in the literature was marked and evaluated in all the three groups.

The deepest midline point on the premaxilla between the anterior nasal spine and prosthion taken as point A (Downs).[4] A point plotted 3 mm labial to a point between the upper third and lower two third of the long axis of the root of the maxillary central incisor taken as point A1.[1] (figure 2) Point formed by the intersection of a line parallel to the palatal plane, 7mm below, and the anterior contour of maxilla as the replacement for point A, taken as point A2.[5] (figure 3) Point at the intersection of projection of point prosthion on a line parallel to the palatal plane, 7 mm below the palatal plane taken as point A3.[3] (figure 4) Point which is located on the anterior surface of the image of the labial lamella at the region of the apex of the maxillary incisors taken as point A4.[6] (figure 5). Point which is 2 mm ahead of the root apex of maxillary incisors taken as point A5. (figure 6)

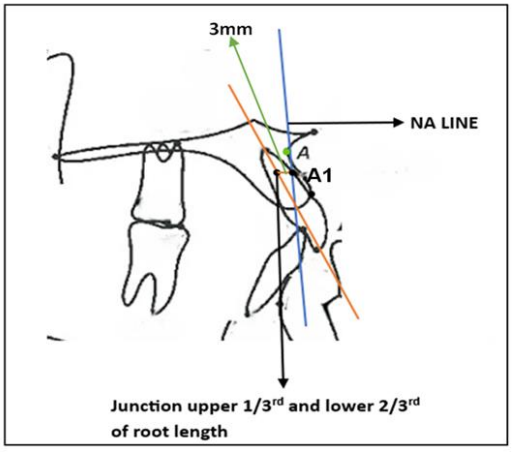


Figure 2: Point A1

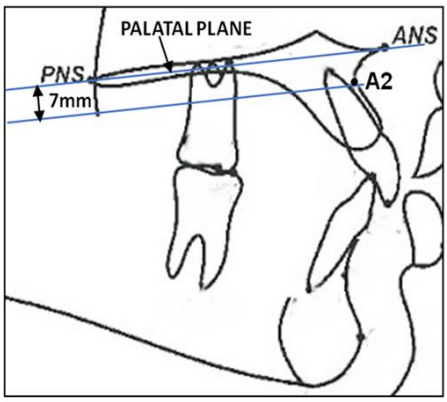


Figure 3: Point A2

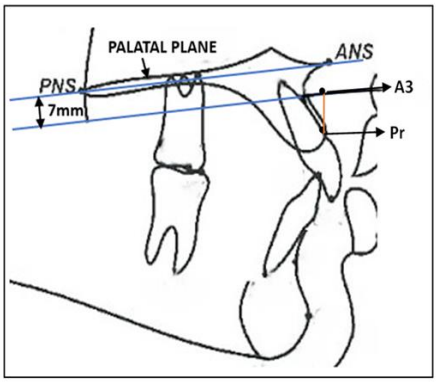


Figure 4: Point A3

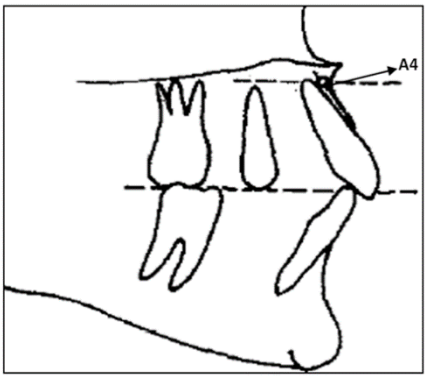


Figure 5: Point A4

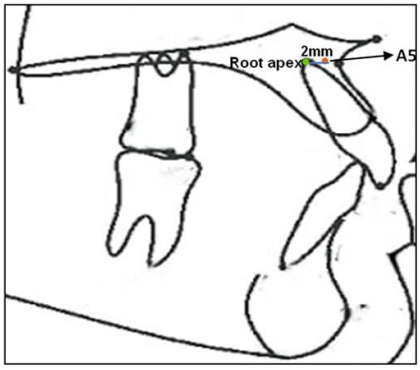


Figure 6: Point A5

Various angular and linear parameters were evaluated to check the reliability of five alternative methods for estimation of point A.

1. Angular measurements –

- SNA, SNA1, SNA2, SNA3, SNA4, SNA5.
- U1-NA, U1-NA1, U1-NA2, U1-NA3, U1-NA4, U1-NA5.
- N-A-Pog, N-A1-Pog, N-A2-Pog, N-A3-Pog, N-A4-Pog, N-A5-Pog.

2. Linear measurements – (figure 7)

- U1-NA, U1-NA1, U1-NA2, U1-NA3, U1-NA4, U1-NA5.
- NA-P, NA1-P, NA2-P, NA3-P, NA4-P, NA5-P.

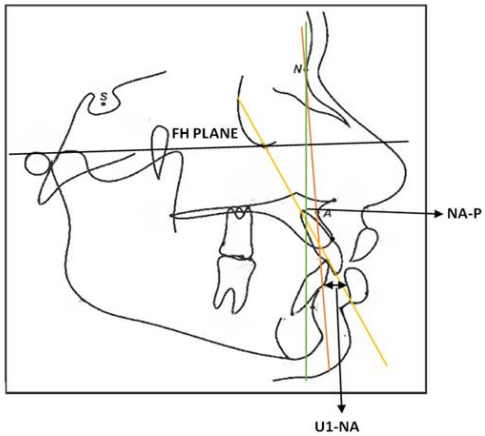


Figure 7: Lateral cephalogram tracing showing various linear parameters (NA-P, U1-NA)

Results

Mean Values of Various Angular And Linear Cephalometric Parameters for Group A, Group B, and Group C (GRAPH 1, 2 and 3)

The linear and angular cephalometric parameters were evaluated across the 3 groups. The results were presented as mean and standard deviation of the entire sample among each group.

Comparison of All the Angular And Linear Cephalometric Parameters Using One-Way Anova For Group A, B and C (Table 1, 2 And 3)

One-way ANOVA was used to compare the mean values of angular and linear cephalometric parameters. The interpretation disclosed highly statistically significant differences between groups for all angular and linear parameters in Groups A and B. In Group C, all linear variables showed statistically significant differences amongst groups, whereas the angular parameters did not, with the exception of N-A-Pog which showed a significant difference between groups.

Table 1: Comparison of All The Angular And Linear Cephalometric Parameters Using One-Way Anova

Group A – Normally Inclined Maxillary Incisors

Parameter Type	Cephalometric Parameter		Sum of Squares	df	Mean Square	F	p value
Angular Parameter (Degree)	SNA	Between Groups	967.338	5	193.468	13.322	**
		Within Groups	3398.125	234	14.522		
		Total	4365.463	239			
	U1-NA	Between Groups	885.671	5	177.134	5.302	**
		Within Groups	7818.125	234	33.411		
		Total	8703.796	239			
	N-A-Pog	Between Groups	4667.450	5	933.490	24.771	**
		Within Groups	8818.400	234	37.685		
		Total	13485.850	239			
Linear Parameter (mm)	NA-P	Between Groups	921.600	5	184.320	14.780	**
		Within Groups	2918.250	234	12.471		
		Total	3839.850	239			
	U1-NA	Between Groups	1727.971	5	345.594	24.389	**
		Within Groups	3315.825	234	14.170		
		Total	5043.796	239			

$p \leq 0.001$ highly significant (**)

Table 2: Comparison of All the Angular and Linear Cephalometric Parameters Using One-Way Anova

Group B - Proclined Maxillary Incisors

Parameter Type	Cephalometric Parameter		Sum of Squares	df	Mean Square	F	p value
	SNA	Between Groups	1346.683	5	269.337	15.541	**
		Within Groups	4055.300	234	17.356		
		Total	5401.983	239			
	U1-NA	Between Groups	1431.633	5	286.327	5.197	**
		Within Groups	12891.550	234	55.092		
		Total	14323.183	239			

Angular Parameter (Degree)	N-A-Pog	Between Groups	6868.971	5	1373.794	21.139	**
		Within Groups	15207.025	234	64.987		
		Total	22075.996	239			
Linear Parameter (mm)	NA-P	Between Groups	1322.238	5	264.448	21.193	**
		Within Groups	2919.925	234	12.478		
		Total	4242.163	239			
	U1-NA	Between Groups	2187.321	5	437.464	70.019	**
		Within Groups	1461.975	234	6.248		
		Total	3649.296	239			

p≤0.001 highly significant (**)

Table 3: Comparison of All The Angular And Linear Cephalometric Parameters Using One-Way Anova

Group C - Retroclined Maxillary Incisors

Parameter Type	Cephalometric Parameter		Sum of Squares	df	Mean Square	F	p value
Angular Parameter (Degree)	SNA	Between Groups	230.383	5	46.077	2.256	NS
		Within Groups	4779.600	234	20.426		
		Total	5009.983	239			
	U1-NA	Between Groups	154.021	5	30.804	0.731	NS
		Within Groups	9866.775	234	42.166		
		Total	10020.796	239			
	N-A-Pog	Between Groups	1400.883	5	280.177	3.751	**
		Within Groups	17479.100	234	74.697		
		Total	18879.983	239			
Linear Parameter (mm)	NA-P	Between Groups	224.600	5	44.920	2.498	*
		Within Groups	4207.250	234	17.980		
		Total	4431.850	239			
	U1-NA	Between Groups	482.433	5	96.487	6.957	**
		Within Groups	3245.300	234	13.869		
		Total	3727.733	239			

p≤0.001 highly significant (**), p≤0.05 significant (*), p≥0.05 non-significant (NS)

Intragroup Comparison Of Various Angular And Linear Parameters Using Post Hoc Test For Group A, B and C (Table 4, 5 And 6)

Post hoc (Bonferroni) test was used to determine the specific parameters that deferred from each other.

Table 4: Intragroup Comparison of Various Angular and Linear Cephalometric Parameters Using Post Hoc (Bonferroni) Test

Group A – Normally Inclined Maxillary Incisors

Angular Parameters (Degree)

A. SNA

Parameter		Mean Difference	p-value
SNA	SNA1	-0.425	NS
	SNA2	-0.850	NS
	SNA3	-3.850	**
	SNA4	2.125	NS
	SNA5	2.025	NS
SNA1	SNA	0.425	NS
	SNA2	-0.425	NS
	SNA3	-3.425	**
	SNA4	2.550	*
	SNA5	2.450	NS
SNA2	SNA	0.850	NS
	SNA1	0.425	NS
	SNA3	-3.000	*
	SNA4	2.975	*
	SNA5	2.875	*
SNA3	SNA	3.850	**
	SNA1	3.425	**
	SNA2	3.000	*
	SNA4	5.975	**
	SNA5	5.875	**
SNA4	SNA	-2.125	NS
	SNA1	-2.550	*
	SNA2	-2.975	*
	SNA3	-5.975	**
	SNA5	-0.100	NS
SNA5	SNA	-2.025	NS
	SNA1	-2.450	NS
	SNA2	-2.875	*
	SNA3	-5.875	**
	SNA4	0.100	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

B. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	0.175	NS
	U1-NA2	0.700	NS
	U1-NA3	3.175	NS
	U1-NA4	-2.425	NS
	U1-NA5	-2.400	NS
U1-NA1	U1-NA	-0.175	NS
	U1-NA2	0.525	NS
	U1-NA3	3.000	NS
	U1-NA4	-2.600	NS
	U1-NA5	-2.575	NS
U1-NA2	U1-NA	-0.700	NS
	U1-NA1	-0.525	NS
	U1-NA3	2.475	NS
	U1-NA4	-3.125	NS
	U1-NA5	-3.100	NS
U1-NA3	U1-NA	-3.175	NS
	U1-NA1	-3.000	NS
	U1-NA2	-2.475	NS
	U1-NA4	-5.600	**
	U1-NA5	-5.575	**
U1-NA4	U1-NA	2.425	NS
	U1-NA1	2.600	NS
	U1-NA2	3.125	NS
	U1-NA3	5.600	**
	U1-NA5	0.025	NS
U1-NA5	U1-NA	2.400	NS
	U1-NA1	2.575	NS
	U1-NA2	3.100	NS
	U1-NA3	5.575	**
	U1-NA4	-0.025	NS

$p \leq 0.001$ highly significant (**), $p \geq 0.05$ non-significant (NS)

C. N-A-Pog

Parameter		Mean Difference	p-value
N-A-Pog	N-A1-Pog	-1.200	NS
	N-A2-Pog	-2.050	NS
	N-A3-Pog	-7.875	**
	N-A4-Pog	5.050	*
	N-A5-Pog	4.875	*
N-A1-Pog	N-A-Pog	1.200	NS
	N-A2-Pog	-0.850	NS
	N-A3-Pog	-6.675	**
	N-A4-Pog	6.250	**
	N-A5-Pog	6.075	**
N-A2-Pog	N-A-Pog	2.050	NS
	N-A1-Pog	0.850	NS
	N-A3-Pog	-5.825	**
	N-A4-Pog	7.100	**
	N-A5-Pog	6.925	**
N-A3-Pog	N-A-Pog	7.875	**
	N-A1-Pog	6.675	**
	N-A2-Pog	5.825	**
	N-A4-Pog	12.925	**
	N-A5-Pog	12.750	**
N-A4-Pog	N-A-Pog	-5.050	*
	N-A1-Pog	-6.250	**
	N-A2-Pog	-7.100	**
	N-A3-Pog	-12.925	**
	N-A5-Pog	-0.175	NS
N-A5-Pog	N-A-Pog	-4.875	*
	N-A1-Pog	-6.075	**
	N-A2-Pog	-6.925	**
	N-A3-Pog	-12.750	**
	N-A4-Pog	0.175	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

Linear Parameters (mm)

D. NA-P

Parameter		Mean Difference	p-value
NA-P	NA1-P	-0.300	NS
	NA2-P	-0.750	NS
	NA3-P	-3.300	**
	NA4-P	2.475	*
	NA5-P	2.325	NS
NA1-P	NA-P	0.300	NS
	NA2-P	-0.450	NS
	NA3-P	-3.000	*
	NA4-P	2.775	*
	NA5-P	2.625	*
NA2-P	NA-P	0.750	NS
	NA1-P	0.450	NS
	NA3-P	-2.550	*
	NA4-P	3.225	**
	NA5-P	3.075	*
NA3-P	NA-P	3.300	**
	NA1-P	3.000	*
	NA2-P	2.550	*
	NA4-P	5.775	**
	NA5-P	5.625	**
NA4-P	NA-P	-2.475	*
	NA1-P	-2.775	*
	NA2-P	-3.225	**
	NA3-P	-5.775	**
	NA5-P	-0.150	NS
NA5-P	NA-P	-2.325	NS
	NA1-P	-2.625	*
	NA2-P	-3.075	*
	NA3-P	-5.625	**
	NA4-P	0.150	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

E. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	0.525	NS
	U1-NA2	0.950	NS
	U1-NA3	4.625	**
	U1-NA4	-3.275	**
	U1-NA5	-3.150	**
U1-NA1	U1-NA	-0.525	NS
	U1-NA2	0.425	NS
	U1-NA3	4.100	**
	U1-NA4	-3.800	**
	U1-NA5	-3.675	**
U1-NA2	U1-NA	-0.950	NS
	U1-NA1	-0.425	NS
	U1-NA3	3.675	**
	U1-NA4	-4.225	**
	U1-NA5	-4.100	**
U1-NA3	U1-NA	-4.625	**
	U1-NA1	-4.100	**
	U1-NA2	-3.675	**
	U1-NA4	-7.900	**
	U1-NA5	-7.775	**
U1-NA4	U1-NA	3.275	*
	U1-NA1	3.800	**
	U1-NA2	4.225	**
	U1-NA3	7.900	**
	U1-NA5	0.125	NS
U1-NA5	U1-NA	3.150	*
	U1-NA1	3.675	**
	U1-NA2	4.100	**
	U1-NA3	7.775	**
	U1-NA4	-0.125	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

Table 5: Intragroup Comparison of Various Angular And Linear Cephalometric Parameters Using Post Hoc (Bonferroni) Test

Group B – Proclined Maxillary Incisors , Angular Parameters (Degree)

A. SNA

Parameter		Mean Difference	p-value
SNA	SNA1	-0.725	NS
	SNA2	-0.700	NS
	SNA3	-5.000	**
	SNA4	1.950	NS
	SNA5	2.175	NS
SNA1	SNA	0.725	NS
	SNA2	0.025	NS
	SNA3	-4.275	**
	SNA4	2.675	NS
	SNA5	2.900	*
SNA2	SNA	0.700	NS
	SNA1	-0.025	NS
	SNA3	-4.300	**
	SNA4	2.650	NS
	SNA5	2.875	*
SNA3	SNA	5.000	**
	SNA1	4.275	**
	SNA2	4.300	**
	SNA4	6.950	**
	SNA5	7.175	**
SNA4	SNA	-1.950	NS
	SNA1	-2.675	NS
	SNA2	-2.650	NS
	SNA3	-6.950	**
	SNA5	0.225	NS
SNA5	SNA	-2.175	NS
	SNA1	-2.900	*
	SNA2	-2.875	*
	SNA3	-7.175	**
	SNA4	-0.225	NS

p≤0.001 highly significant (**), p≤0.05 significant (*), p≥0.05 non-significant (NS

B. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	0.925	NS
	U1-NA2	0.800	NS
	U1-NA3	4.825	NS
	U1-NA4	-2.350	NS
	U1-NA5	-2.450	NS
U1-NA1	U1-NA	-0.925	NS
	U1-NA2	-0.125	NS
	U1-NA3	3.900	NS
	U1-NA4	-3.275	NS
	U1-NA5	-3.375	NS
U1-NA2	U1-NA	-0.800	NS
	U1-NA1	0.125	NS
	U1-NA3	4.025	NS
	U1-NA4	-3.150	NS
	U1-NA5	-3.250	NS
U1-NA3	U1-NA	-4.825	NS
	U1-NA1	-3.900	NS
	U1-NA2	-4.025	NS
	U1-NA4	-7.175	**
	U1-NA5	-7.275	**
U1-NA4	U1-NA	2.350	NS
	U1-NA1	3.275	NS
	U1-NA2	3.150	NS
	U1-NA3	7.175	**
	U1-NA5	-0.100	NS
U1-NA5	U1-NA	2.450	NS
	U1-NA1	3.375	NS
	U1-NA2	3.250	NS
	U1-NA3	7.275	**
	U1-NA4	0.100	NS

p≤0.001 highly significant (**), p≥0.05 non-significant (NS)

C. N-A-Pog

Parameter		Mean Difference	p-value
N-A-Pog	N-A1-Pog	-2.475	NS
	N-A2-Pog	-2.175	NS
	N-A3-Pog	-10.875	**
	N-A4-Pog	4.750	NS
	N-A5-Pog	5.050	NS
N-A1-Pog	N-A-Pog	2.475	NS
	N-A2-Pog	0.300	NS
	N-A3-Pog	-8.400	**
	N-A4-Pog	7.225	**
	N-A5-Pog	7.525	**
N-A2-Pog	N-A-Pog	2.175	NS
	N-A1-Pog	-0.300	NS
	N-A3-Pog	-8.700	**
	N-A4-Pog	6.925	*
	N-A5-Pog	7.225	**
N-A3-Pog	N-A-Pog	10.875	**
	N-A1-Pog	8.400	**
	N-A2-Pog	8.700	**
	N-A4-Pog	15.625	**
	N-A5-Pog	15.925	**
N-A4-Pog	N-A-Pog	-4.750	NS
	N-A1-Pog	-7.225	**
	N-A2-Pog	-6.925	*
	N-A3-Pog	-15.625	**
	N-A5-Pog	0.300	NS
N-A5-Pog	N-A-Pog	-5.050	NS
	N-A1-Pog	-7.525	**
	N-A2-Pog	-7.225	**
	N-A3-Pog	-15.925	**
	N-A4-Pog	-0.300	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

Linear Parameters (mm)

D. NA-P

Parameter		Mean Difference	p-value
NA-P	NA1-P	-0.925	NS
	NA2-P	-0.875	NS
	NA3-P	-4.700	**
	NA4-P	2.150	NS
	NA5-P	2.325	NS
NA1-P	NA-P	0.925	NS
	NA2-P	0.050	NS
	NA3-P	-3.775	**
	NA4-P	3.075	*
	NA5-P	3.250	**
NA2-P	NA-P	0.875	NS
	NA1-P	-0.050	NS
	NA3-P	-3.825	**
	NA4-P	3.025	*
	NA5-P	3.200	**
NA3-P	NA-P	4.700	**
	NA1-P	3.775	**
	NA2-P	3.825	**
	NA4-P	6.850	**
	NA5-P	7.025	**
NA4-P	NA-P	-2.150	NS
	NA1-P	-3.075	*
	NA2-P	-3.025	*
	NA3-P	-6.850	**
	NA5-P	0.175	NS
NA5-P	NA-P	-2.325	NS
	NA1-P	-3.250	**
	NA2-P	-3.200	**
	NA3-P	-7.025	**
	NA4-P	-0.175	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

E. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	1.000	NS
	U1-NA2	0.850	NS
	U1-NA3	5.625	**
	U1-NA4	-3.200	**
	U1-NA5	-3.350	**
U1-NA1	U1-NA	-1.000	NS
	U1-NA2	-0.150	NS
	U1-NA3	4.625	**
	U1-NA4	-4.200	**
	U1-NA5	-4.350	**
U1-NA2	U1-NA	-0.850	NS
	U1-NA1	0.150	NS
	U1-NA3	4.775	**
	U1-NA4	-4.050	**
	U1-NA5	-4.200	**
U1-NA3	U1-NA	-5.625	**
	U1-NA1	-4.625	**
	U1-NA2	-4.775	**
	U1-NA4	-8.825	**
	U1-NA5	-8.975	**
U1-NA4	U1-NA	3.200	**
	U1-NA1	4.200	**
	U1-NA2	4.050	**
	U1-NA3	8.825	**
	U1-NA5	-0.150	NS
U1-NA5	U1-NA	3.350	**
	U1-NA1	4.350	**
	U1-NA2	4.200	**
	U1-NA3	8.975	**
	U1-NA4	0.150	NS

$p \leq 0.001$ highly significant (**), $p \geq 0.05$ non-significant (NS)

Table 6: Intragroup Comparison of Various Angular and Linear Cephalometric Parameters Using Post Hoc (Bonferroni) Test

Group C – Retroclined Maxillary Incisors, Angular Parameters (Degree)

A. SNA

Parameter		Mean Difference	p-value
SNA	SNA1	-0.375	NS
	SNA2	-0.350	NS
	SNA3	-1.800	NS
	SNA4	1.175	NS
	SNA5	0.950	NS
SNA1	SNA	0.375	NS
	SNA2	0.025	NS
	SNA3	-1.425	NS
	SNA4	1.550	NS
	SNA5	1.325	NS
SNA2	SNA	0.350	NS
	SNA1	-0.025	NS
	SNA3	-1.450	NS
	SNA4	1.525	NS
	SNA5	1.300	NS
SNA3	SNA	1.800	NS
	SNA1	1.425	NS
	SNA2	1.450	NS
	SNA4	2.975	NS
	SNA5	2.750	NS
SNA4	SNA	-1.175	NS
	SNA1	-1.550	NS
	SNA2	-1.525	NS
	SNA3	-2.975	NS
	SNA5	-0.225	NS
SNA5	SNA	-0.950	NS
	SNA1	-1.325	NS
	SNA2	-1.300	NS
	SNA3	-2.750	NS
	SNA4	0.225	NS

p≥0.05 non-significant (NS)

B. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	0.350	NS
	U1-NA2	0.250	NS
	U1-NA3	1.450	NS
	U1-NA4	-0.900	NS
	U1-NA5	-0.875	NS
U1-NA1	U1-NA	-0.350	NS
	U1-NA2	-0.100	NS
	U1-NA3	1.100	NS
	U1-NA4	-1.250	NS
	U1-NA5	-1.225	NS
U1-NA2	U1-NA	-0.250	NS
	U1-NA1	0.100	NS
	U1-NA3	1.200	NS
	U1-NA4	-1.150	NS
	U1-NA5	-1.125	NS
U1-NA3	U1-NA	-1.450	NS
	U1-NA1	-1.100	NS
	U1-NA2	-1.200	NS
	U1-NA4	-2.350	NS
	U1-NA5	-2.325	NS
U1-NA4	U1-NA	0.900	NS
	U1-NA1	1.250	NS
	U1-NA2	1.150	NS
	U1-NA3	2.350	NS
	U1-NA5	0.025	NS
U1-NA5	U1-NA	0.875	NS
	U1-NA1	1.225	NS
	U1-NA2	1.125	NS
	U1-NA3	2.325	NS
	U1-NA4	-0.025	NS

p≥0.05 non-significant (NS)

C. N-A-Pog

Parameter		Mean Difference	p-value
N-A-Pog	N-A1-Pog	-1.025	NS
	N-A2-Pog	-1.000	NS
	N-A3-Pog	-3.600	NS
	N-A4-Pog	3.375	NS
	N-A5-Pog	2.950	NS
N-A1-Pog	N-A-Pog	1.025	NS
	N-A2-Pog	0.025	NS
	N-A3-Pog	-2.575	NS
	N-A4-Pog	4.400	NS
	N-A5-Pog	3.975	NS
N-A2-Pog	N-A-Pog	1.000	NS
	N-A1-Pog	-0.025	NS
	N-A3-Pog	-2.600	NS
	N-A4-Pog	4.375	NS
	N-A5-Pog	3.950	NS
N-A3-Pog	N-A-Pog	3.600	NS
	N-A1-Pog	2.575	NS
	N-A2-Pog	2.600	NS
	N-A4-Pog	6.975	*
	N-A5-Pog	6.550	*
N-A4-Pog	N-A-Pog	-3.375	NS
	N-A1-Pog	-4.400	NS
	N-A2-Pog	-4.375	NS
	N-A3-Pog	-6.975	*
	N-A5-Pog	-0.425	NS
N-A5-Pog	N-A-Pog	-2.950	NS
	N-A1-Pog	-3.975	NS
	N-A2-Pog	-3.950	NS
	N-A3-Pog	-6.550	*
	N-A4-Pog	0.425	NS

Linear Parameters (mm)

NA-P

Parameter		Mean Difference	p-value
NA-P	NA1-P	-0.425	NS
	NA2-P	-0.375	NS
	NA3-P	-1.425	NS
	NA4-P	1.475	NS
	NA5-P	1.050	NS
NA1-P	NA-P	0.425	NS
	NA2-P	0.050	NS
	NA3-P	-1.000	NS
	NA4-P	1.900	NS
	NA5-P	1.475	NS
NA2-P	NA-P	0.375	NS
	NA1-P	-0.050	NS
	NA3-P	-1.050	NS
	NA4-P	1.850	NS
	NA5-P	1.425	NS
NA3-P	NA-P	1.425	NS
	NA1-P	1.000	NS
	NA2-P	1.050	NS
	NA4-P	2.900	*
	NA5-P	2.475	NS
NA4-P	NA-P	-1.475	NS
	NA1-P	-1.900	NS
	NA2-P	-1.850	NS
	NA3-P	-2.900	*
	NA5-P	-0.425	NS
NA5-P	NA-P	-1.050	NS
	NA1-P	-1.475	NS
	NA2-P	-1.425	NS
	NA3-P	-2.475	NS
	NA4-P	0.425	NS

$p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

D. U1-NA

Parameter		Mean Difference	p-value
U1-NA	U1-NA1	0.450	NS
	U1-NA2	0.325	NS
	U1-NA3	1.850	NS
	U1-NA4	-2.175	NS
	U1-NA5	-2.000	NS
U1-NA1	U1-NA	-0.450	NS
	U1-NA2	-0.125	NS
	U1-NA3	1.400	NS
	U1-NA4	-2.625	*
	U1-NA5	-2.450	NS
U1-NA2	U1-NA	-0.325	NS
	U1-NA1	0.125	NS
	U1-NA3	1.525	NS
	U1-NA4	-2.500	*
	U1-NA5	-2.325	NS
U1-NA3	U1-NA	-1.850	NS
	U1-NA1	-1.400	NS
	U1-NA2	-1.525	NS
	U1-NA4	-4.025	**
	U1-NA5	-3.850	**
U1-NA4	U1-NA	2.175	NS
	U1-NA1	2.625	*
	U1-NA2	2.500	*
	U1-NA3	4.025	**
	U1-NA5	0.175	NS
U1-NA5	U1-NA	2.000	NS
	U1-NA1	2.450	NS
	U1-NA2	2.325	NS
	U1-NA3	3.850	**
	U1-NA4	-0.175	NS

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

Group A – Normally Inclined Maxillary Incisors

Angular Parameters

SNA1 differed significantly from SNA4. SNA2 revealed statistically significant difference from SNA4 and SNA5.

Statistically significant variations were noticed amongst SNA3 and all other SNA measurements (SNA, SNA1, SNA2, SNA4, SNA5). U1-NA3 showed significant differences, specifically from U1-NA4 and U1-NA5. All other angular measurements were statistically similar. N-A-Pog, N-A1-Pog, N-A2-Pog showed statistically significant difference from N-A4-Pog and N-A5-Pog. N-A3-Pog significantly differed from all other N-A-Pog variants.

Linear Parameters

Post hoc analysis revealed that NA-P showed statistically significant differences from NA4-P. NA1-P and NA2-P showed notable difference from NA4-P and NA5-P. NA3-P was statistically significantly different from all other variants (NA-P, NA1-P, NA2-P, NA4-P, and NA5-P). U1-NA, U1-NA1, U1-NA2 exhibited a statistically highly significant variation among U1-NA4, U1-NA5. U1-NA3 was statistically significantly different from all other variants (U1-NA, U1-NA1, U1-NA2, U1-NA4, and U1-NA5).

Group B – Proclined Maxillary Incisors

Angular Parameters

Analysis revealed that SNA1 and SNA2 was statistically different from SNA5. SNA3 was statistically distinct from all other SNA variants (SNA, SNA1, SNA2, SNA4, SNA5). U1-NA3 displayed a statistically highly significant variation compared to U1-NA4 and U1-NA5. N-A1-Pog and N-A2-Pog showed statistically significant differences with N-A4-Pog and N-A5-Pog. N-A3-Pog differed significantly from all other variants (N-A-Pog, N-A1-Pog, N-A2-Pog, N-A4-Pog, N-A5-Pog).

Linear Parameters

Both NA1-P and NA2-P differed statistically from NA4-P and NA5-P. NA3-P showed statistically significant differences from all other variants (NA-P, NA1-P, NA2-P, NA4-P, and NA5-P). U1-NA, U1-NA1 and U1-NA2 showed highly statistically significant differences when compared to U1-NA4 and U1-NA5. Additionally, U1-NA3 exhibited a statistically highly significant difference among all other variations (U1-NA, U1-NA1, U1-NA2, U1-NA4, and U1-NA5).

Group C – Retroclined Maxillary Incisors

Angular Parameters

No statistically significant differences were found between SNA, U1-NA, and their alternative parameters. N-A3-Pog displayed a statistically significant variation from both N-A4-Pog and N-A5-Pog.

Linear Parameters

NA3-P presented a statistically significant variation from NA4-P. U1-NA1 and U1-NA2 also demonstrated statistically relevant disparities when compared to U1-NA4. U1-NA3 exhibited a highly statistically notable contrast with both U1-NA4 and U1-NA5.

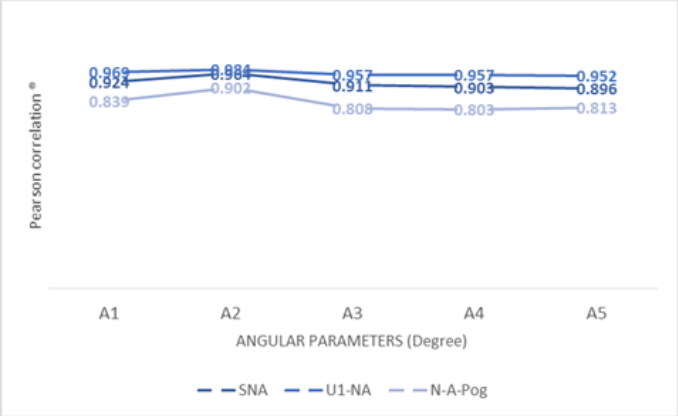
Correlation Coefficient for Comparison of All Five Alternative Points To Original Parameter For All The Three Groups (Graph 1, 2, 3)

The Pearson correlation coefficient revealed a highly significant positive correlation between all alternative angular and linear parameters and the original parameters across all three groups.

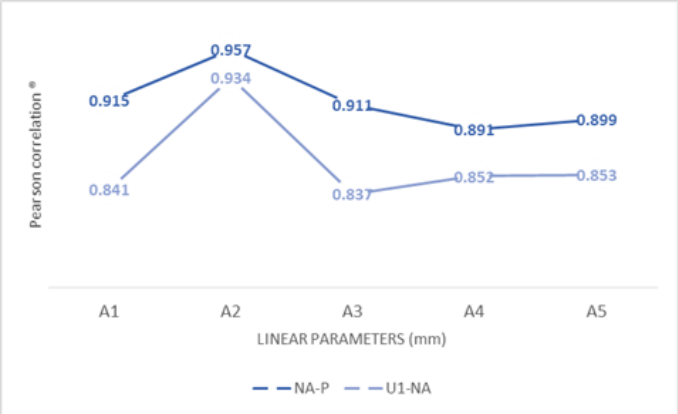
Graph 1: Correlation Coefficient for Comparison of All Five Alternative Parameters To Original Parameter

Group A – Normally Inclined Maxillary Incisors

Angular Parameters (Degree)



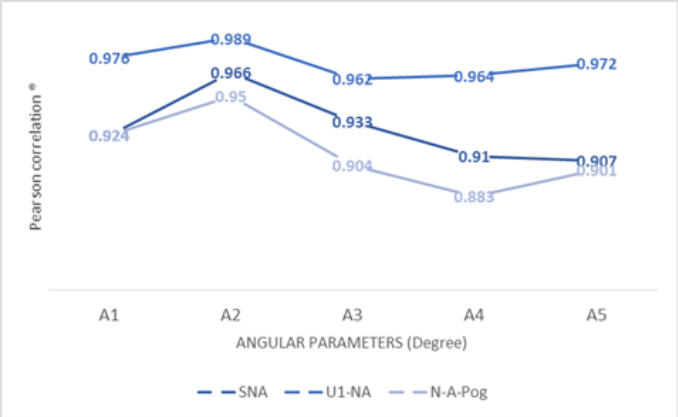
Linear Parameters (mm)

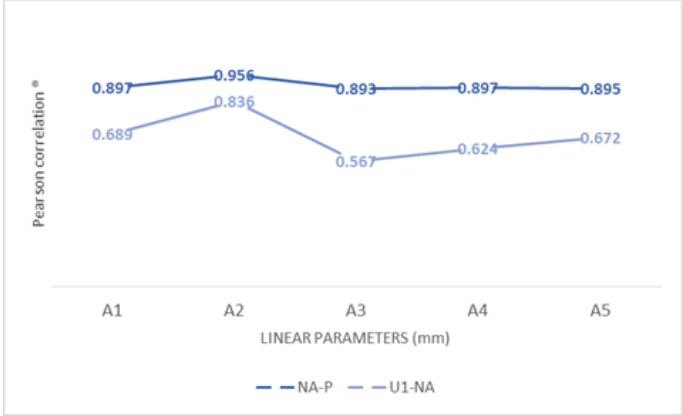


Graph 2: Correlation Coefficient for Comparison Of All Five Alternative Parameters To Original Parameter

Group B – Proclined Maxillary Incisors

Angular Parameters (Degree)

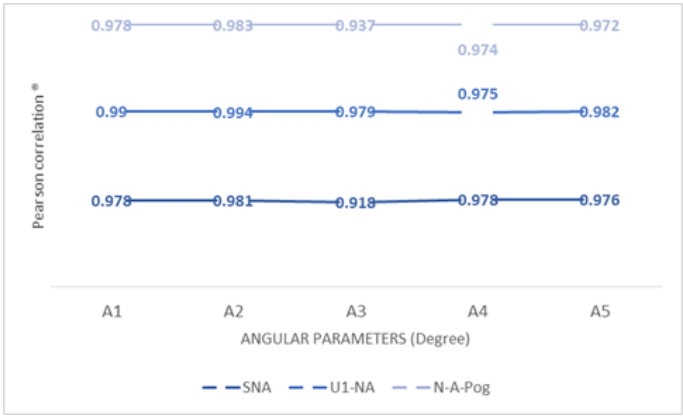




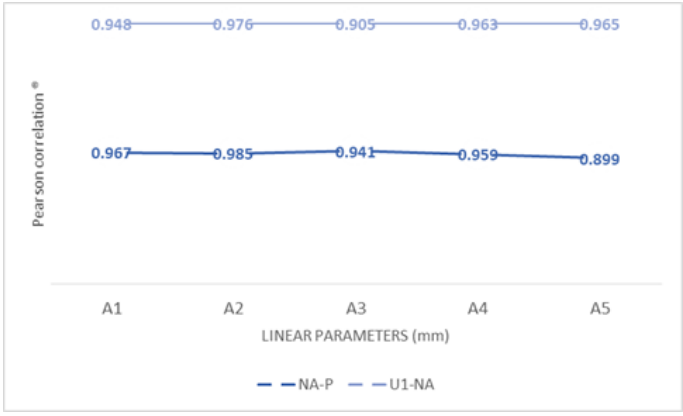
Graph 3: Correlation Coeeficient For Comparison Of All Five Alternative Parameters To Orignial Parameter

Group C – Retroclined Maxillary Incisors

Angular Parameters (Degree)



Linear Parameters (mm)



Intergroup Comparison Using One – Way Anova (Table 7)

Angular Parameters

Statistically significant intergroup differences were observed for SNA–SNA3, SNA–SNA4, and SNA–SNA5. U1–NA differed statistically from all its alternative

parameters. N-A-Pog also showed statistically significant variation across all groups when compared with N-A2-Pog, N-A3-Pog, and N-A5-Pog.

Table 7: Intergroup Comparison Using One- Way Anova And Independent T-Test Angular Parameters (Degree)

Parameter	Mean difference			p-value			
	Group A	Group B	Group C	Overall	A vs B	A vs C	B vs C
SNA -SNA1	0.425	0.725	0.375	NS	NS	NS	NS
SNA -SNA2	0.850	0.700	0.350	NS	NS	*	NS
SNA-SNA3	3.850	5.000	1.800	**	*	**	**
SNA-SNA4	2.125	1.950	1.175	*	NS	*	*
SNA-SNA5	2.025	2.175	0.950	**	NS	*	**
U1-NA-U1-NA1	0.175	0.925	0.350	*	*	NS	NS
U1-NA-U1-NA2	0.700	0.800	0.250	*	NS	*	*
U1-NA-U1-NA3	3.175	4.825	1.450	**	**	**	**
U1-NA-U1-NA4	2.425	2.350	0.900	**	NS	**	**
U1-NA-U1-NA5	2.400	2.450	0.875	**	NS	**	**
N-A-Pog-N-A1-Pog	1.200	2.475	1.025	NS	NS	NS	*
N-A-Pog-N-A2-Pog	2.050	2.175	1.000	*	NS	*	*
N-A-Pog-N-A3-Pog	7.875	10.875	3.600	**	**	**	**
N-A-Pog-N-A4-Pog	5.050	4.750	3.375	NS	NS	*	NS
N-A-Pog-N-A5-Pog	4.875	5.050	2.950	*	NS	*	*

$p \leq 0.001$ highly significant (**), $p \leq 0.05$ significant (*), $p \geq 0.05$ non-significant (NS)

Linear Parameters (mm)

Parameter	Mean difference			p-value			
	Group A	Group B	Group C	Overall	A vs B	A vs C	B vs C
NA-P-NA1-P	0.300	0.925	0.425	NS	NS	NS	NS
NA-P-NA2-P	0.750	0.875	0.375	NS	NS	NS	*
NA-P-NA3-P	3.300	4.700	1.425	**	**	**	**
NA-P-NA4-P	2.475	2.150	1.475	*	NS	*	*
NA-P-NA5-P	2.325	2.325	1.050	**	NS	*	*
U1-NA-U1-NA1	0.525	1.000	0.450	NS	NS	NS	NS
U1-NA-U1-NA2	0.950	0.850	0.325	NS	NS	*	NS
U1-NA-U1-NA3	4.625	5.625	1.850	**	NS	**	**
U1-NA-U1-NA4	3.275	3.200	2.175	*	NS	*	*
U1-NA-U1-NA5	3.150	3.350	2.000	*	NS	*	*

p≤0.001 highly significant (**), p≤0.05 significant (*), p≥0.05 non-significant (NS)

Linear Parameters

Statistically significant differences were observed for NA-P compared to NA3-P, NA4-P, and NA5-P. U1–NA also differed significantly from U1–NA3, U1–NA4, and U1–NA5.

Intergroup Comparison Using Independent T-Test (Table 7)

Angular Parameters

SNA2 displayed a statistically significant variation amongst Groups A and C, while SNA3, U1–NA3, and N-A3-Pog showed statistically significant differences across all groups. SNA4, SNA5, U1–NA2, U1–NA4, U1–NA5, and N-A2-Pog differed statistically between Group C and the other groups. U1–NA1 and N-A1-Pog exhibited statistically significant variations amongst Groups A and B, and Groups B and C, respectively. N-A4-Pog differed statistically between Groups B and C.

Linear Parameters

NA3-P showed statistically significant differences across all groups. NA4-P differed statistically between Group C and the others. U1–NA2 displayed statistically significant variations amongst Groups A and C, while U1–NA3, U1–NA4, and U1–NA5 differed statistically between Group C and the others.

Discussion

In this investigation, the reliability of five alternative landmarks to Point A was assessed across 120 subjects. The primary goal was to determine how consistently these alternative points could be identified, particularly in clinical scenarios where Point A is challenging to locate due to anatomical variation or image quality. To explore the effect of upper incisor inclination on landmark visibility and reproducibility, subjects were categorized into three groups: normally inclined, proclined, and retroclined maxillary incisors.

A sample size of 120 was selected based on a power analysis conducted using G*Power 3.1.9.7 software (Heinrich Heine University. Düsseldorf, Germany), ensuring adequate power (95%) and a low probability of type I error ($\alpha = 0.05$). This sample size was sufficient to detect significant differences among the groups and support robust comparisons based on incisor inclination.

Previous studies, such as those by Patel et al. (2014) and Singh & Shivaprakash (2018),[7,8] have addressed the difficulty of accurately locating Point A and suggested alternative landmarks. Building on this, the present study evaluates five alternatives (A1–A5) across a wider range of maxillary incisor inclinations. Unlike Singh & Shivaprakash's two-group approach, this study includes a third group with normally inclined incisors, enhancing clinical relevance. Subjects were stratified into three groups—normally inclined, proclined, and retroclined—to assess the influence of incisor angulation on the reliability of alternative landmarks. Standardized cephalograms using the same X-ray unit minimized magnification errors, ensuring consistent measurements.

Comparative Evaluation of Angular and Linear Parameters in Group A (Normally Inclined Maxillary Incisors)

In individuals with normally inclined maxillary incisors, significant variation ($p \leq 0.001$) was observed across all six reference points (A, A1–A5) in both angular and linear parameters. Among angular measurements, SNA showed the most variation. Points A1 and A2 exhibited minimal deviation from Point A, confirming their reliability—findings consistent with Patel et al. (2014) and Poudel et al. (2021).[7,9] A3 showed higher SNA values due to its anterior position, echoing Singh and Shivaprakash (2018),[8] who deemed it the least reliable.

A4 and A5 showed slightly lower SNA values, indicating posterior positioning.

For the U1-NA angle, A1 and A2 again demonstrated close agreement with Point A, reinforcing their anatomical proximity and stability. A3 showed reduced values due to its anterior bias, while A4 and A5 remained comparable to Point A. All alternatives had strong correlation values, though A3's absolute deviations limit its clinical use.

N-A-Pog angles also confirmed the reliability of A1 and A2 in sagittal skeletal assessment. Linear parameters like NA-P and U1-NA followed a similar pattern, with A1 and A2 showing minimal deviation, A3 yielding higher/lower extremes, and A4/A5 remaining slightly posterior but statistically consistent.

Overall, A1 and A2 demonstrated the best agreement with Point A across all measures, validating their use in normally inclined incisors—a group previously underrepresented in literature.

Group B – Proclined Maxillary Incisors: Comparative Evaluation

In cases with proclined maxillary incisors, significant differences ($p \leq 0.001$) were observed across all reference points (A, A1–A5) for both angular and linear cephalometric parameters.

Angular Parameters: SNA values showed that A1 and A2 closely approximated Point A with non-significant differences, confirming their reliability—consistent with findings by Singh & Shivaprakash (2018) and Poudel et al. (2021).[8,9] In contrast, A3 significantly overestimated maxillary position due to its anterior location, reducing its diagnostic value. A4 and A5 yielded slightly lower SNA values, aligning with Patel et al. (2014), but with greater variability in pronounced proclination cases.

For U1–NA angles, A1 and A2 again showed minimal variation, affirming their stability. A3 underestimated incisor inclination, likely due to its anterior displacement, while A4 and A5 showed slightly elevated values but within acceptable clinical limits.

In N–A–Pog angles, A1 and A2 remained dependable for convexity assessment. A3 significantly exaggerated facial convexity, while A4 and A5 slightly underestimated it without statistical significance.

Linear Parameters: NA–P distances for A1 and A2 were slightly elevated but non-significant, confirming their diagnostic reliability. A3 showed significantly higher values, exaggerating maxillary prominence, while A4 and A5 slightly underestimated maxillary position but remained acceptable substitutes.

For linear U1–NA measurements, A1 and A2 showed minimal deviation. A3 significantly underestimated incisor protrusion, while A4 and A5 showed lower scores with statistical significance but retained strong correlation.

A1 and A2 consistently showed the highest agreement with Point A across angular and linear parameters, making them the most reliable alternatives. A3, despite high correlation, showed significant deviations and should be avoided. A4 and A5, though slightly less accurate, remain acceptable secondary options when Point A is obscured in proclined cases.

Group C – Retroclined Maxillary Incisors: Comparative Evaluation

Angular Parameters: In retroclined cases, SNA values across all points (A, A1–A5) showed minimal variation and were not statistically significant ($p = 0.089$), with A1 and A2 displaying the closest agreement with Point A and strongest correlations. A3 remained the most anterior and least reliable, consistent with prior studies.[8,10] U1–NA angular values also showed no significant differences ($p = 0.602$), reaffirming that angular assessments are relatively unaffected by retroclination. A1 and A2 again

showed the best agreement, while A3 and A4/A5 remained within acceptable limits. For N–A–Pog, ANOVA revealed significance (p = 0.003), with A3 significantly overestimating convexity and A4/A5 underestimating it. A1 and A2 showed minimal deviation and are preferred for assessing sagittal facial convexity.

Linear Parameters: For NA–P, significant differences were noted (p = 0.032), with A1 and A2 closely approximating Point A. A3 showed forward displacement, while A4 and A5 were posteriorly positioned. Similarly, U1–NA values were lowest for A3 and highest for A4/A5 (p = 0.000). A1 and A2 demonstrated the highest accuracy and correlation, making them the most stable and clinically reliable alternatives.[11]

In retroclined profiles, A1 and A2 remain the most dependable substitutes for Point A across angular and linear parameters due to their anatomical stability and strong correlation. A3 should be avoided due to consistent overestimation, while A4 and A5 may serve as secondary options when visibility is limited.

Intergroup Comparison of Cephalometric Parameters – Concise Summary

This study compared Point A with five alternative cephalometric landmarks (A1–A5) across three maxillary incisor inclination groups—normally inclined, proclined, and retroclined—to evaluate their diagnostic reliability. Among the angular parameters, Point A1 exhibited minimal variation across all groups, establishing it as the most stable and reliable substitute. A2 also performed well, particularly in retroclined cases, though it displayed slight variability in proclined profiles. In contrast, A3 consistently overestimated maxillary prominence and incisor inclination across all groups due to its anterior location, rendering it the least dependable. Points A4 and A5 showed greater stability in retroclined subjects but were less reliable in proclined cases, likely due to positional changes from incisor root torque. Linear measurements followed a similar pattern: A1 maintained strong consistency across all groups for both NA–P and U1–NA measurements, reaffirming its clinical value.[12] A2 remained stable in retroclined and normally inclined groups, with only minor deviation in proclined cases. A3 showed the highest deviations—especially among proclined subjects—making it unsuitable as a substitute. A4 and A5, while reliable in retroclined cases, demonstrated greater variability in proclined profiles. Overall, the study confirmed that alternative landmarks, especially A1 and A2, are most reliable in retroclined cases, with A1 serving as the preferred substitute when Point A is indistinct, and A2 as a viable secondary option. By including a normally inclined group, this study extends previous research (Singh & Shivaprakash, 2018),[8] offering broader clinical applicability for assessing sagittal jaw relationships when Point A is compromised.[13,14]

Conclusion

The present study, conducted on 120 pretreatment lateral cephalograms at the Department of Orthodontics and Dentofacial Orthopaedics, GNDDC, Sunam, aimed to evaluate the reliability of five alternative cephalometric landmarks (A1 to A5) as substitutes for Point A across varying maxillary incisor inclinations—normally inclined, proclined, and retroclined. The findings revealed that Point A1 was the most consistent and reliable alternative to Point A across all three groups, showing minimal variation irrespective of incisor inclination. Point A2 also demonstrated high reliability, especially in retroclined and proclined cases, and can serve as a dependable substitute when A1 is difficult to locate. In contrast, Points A4 and A5 were found to be

less reliable due to their proximity to the root apex, making them susceptible to changes in tooth inclination. Point A3 showed the greatest variability and was consistently the least dependable across all groups, as its anterior location (prosthion) is highly influenced by incisor proclination or retroclination. Overall, A1 and A2 can be considered valid and clinically acceptable alternatives when Point A is radiographically unclear or anatomically obscured, such as in cases with cleft lip and palate, excessive soft tissue overlap, or in young children. Points A3, A4, and A5, however, should be used with caution due to their susceptibility to positional distortion.

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