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Craniofacial Growth Differences in Individuals with Skeletal Class III and Class I During Different Growth Periods

İskeletsel Sınıf III ve Sınıf I bireylerin Farklı Büyüme Dönemlerindeki Kraniofasiyal Büyüme Farklılıklari

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ABSTRACT

Objective: The purpose of this study is to compare the craniofacial growth of individuals with skeletal class III and class I structure at different stages of growth periods.

Methods: The study includes 266 untreated individuals with class I and class III malocclusion admitted for orthodontic treatment. The individuals were divided according to their genders—male and female—and growth periods based on the hand–wrist films. The differences between the growth periods and sex groups of class I and class III individuals were statistically evaluated.

Results: In the study, there was no difference between class I and class III in terms of anterior and posterior cranial base length. The cranial base angle was shown to be lower in class III individuals than in class I individuals. Effective maxillary length (Co-A) is significantly lower in class III patients than in class I individuals. Mandibular growth dimensions of the class III and class I groups are similar in the early period however, differences between the two groups increase in later periods. Craniofacial and mandibular sizes were larger in class I and class III males than females. We found that protrusion of the maxillary incisor and retrusion of the mandibular incisor become increasingly evident as development progresses.

Conclusion: In class III and class I individuals, the amount of maxillary and mandibular growth is similar in the early stages of development, whereas in class III individuals the skeletal discrepancy is intensified in the later stages of development.

Keywords: Malocclusion, Angle class III, cephalometry, pubertal growth

ÖZ

Amaç: Bu çalışmanın amacı, iskeletsel sınıf III ve sınıf I yapıya sahip bireylerin farklı büyüme dönemlerindeki kraniyofasiyal büyümelerini karşılaştırmaktır.

Yöntemler: Çalışmaya ortodontik tedavi için başvuran sınıf I ve sınıf III maloklüzyona sahip 266 tedavi edilmemiş hasta dahil edilmiştir. Bireyler cinsiyetlerine (kadın ve erkek) ve el-bilek filmlerine göre büyüme dönemlerine göre ayrılmıştır. Sınıf I ve sınıf III hastaların büyüme dönemleri ve cinsiyet grupları arasındaki farklar istatistiksel olarak değerlendirilmiştir.

Bulgular: Çalışmada ön ve arka kranial kaide uzunluğu açısından sınıf I ve sınıf III arasında fark bulunamamıştır. Kranial kaide açısının sınıf III hastalarda sınıf I hastalara göre daha düşük olduğu gösterilmiştir. Efektif maksiller uzunluk (Co-A) sınıf III bireylerde sınıf I bireylere göre anlamlı derecede düşüktür. Sınıf III ve sınıf I gruplarının mandibular büyüme miktarları erken dönemde benzerdir, ancak daha sonraki dönemlerde iki grup arasındaki farklar artmaktadır. Kraniyofasiyal ve mandibular boyutlar sınıf I ve sınıf III erkeklerde kadınlara göre daha büyük bulunmuştur. Gelişim ilerledikçe maksiller kesici dişin protrüzyonunun ve mandibular kesici dişin retrüzyonunun giderek belirginleştiği bulunmuştur.

Sonuç: Sınıf III ve sınıf I bireylerde maksilla ve mandibulanın büyüme miktarları gelişimin erken safhalarında benzerken sınıf III bireylerde gelişimin ilerleyen safhalarında iskeletsel uyumsuzluk şiddetlenmektedir.

Anahtar Kelimeler: Maloklüzyon, Angle sınıf III, sefalometri, pubertal büyüme

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INTRODUCTION

Class III anomalies may arise from the interrelationships of dentoalveolar and craniofacial structures and their combinations.[1,2] Spalj et al reported that 43% of class III individuals had a mandibular protrusion, 19.6% had maxillary retrusion, and 4.7% had both protrusion and retrusion.[3] Although the prevalence of class III anomalies varies based on ethnicity, it is around 12% in the Asian population [4] and approximately 1% in the European American population.[5]

Genetics, congenital, and environmental factors are among the factors that cause class III anomalies.[6] Class III anomalies may also occur due to environmental factors such as congenital anatomical defects, syndromes, nasal congestion (nasal obstruction), sinusitis, septum deviation, mouth breathing due to hypertrophic tonsils and adenoids, tongue size, and position, and forced anterior positioning of the mandible due to premature contacts.[7,8]

Class III cases typically have a negative ANB (A point, nasion, B point) angle,[2,9] increased posterior cranial base (S-Ba) length, decreased anterior cranial base (SN) length[2,10] and cranial base angle (SNBa),[10,11] increased face height, increased mandibular length (Co-Gn), corpus (Go-Gn) and ramus (Ar-Go) size,[2] a glenoid fossa more anteriorly located,[9,12] protrusive maxillary incisors, and retrusive mandibular incisors.[2,10,13,14] In individuals with class III skeletal structure, Wits values decrease over time, and there is an increase in maxillomandibular difference and lower face height.[15]

The growth and development characteristics of craniofacial structures may show different trends in different malocclusions. In studies with class III individuals, the SNBa is smaller, S-Ba increased, maxillary SNA and Co-A dimensions decreased, whereas mandibular dimensions (Co-Gn), gonial angle, and lower face height increased, with protruded maxillary incisors and retrusive mandibular incisors.[2,14,16]

The cranial base, especially the anterior skull base, which forms the ethmoid–maxillary complex with the upper midface, has great importance in craniofacial growth and development. It is said that a disorder in SN growth will often be coupled by midfacial insufficiency.[17] In individuals with class III malocclusions, the posterior cranial base (S-Ba) horizontal growth is insufficient due to early fused synostosis, and thus the condyles and glenoid fossa are located more anteriorly with a smaller SNBa angle.[12,17,18] In the study of Reyes et al, the SNBa angle was reported to be smaller in class III individuals, while the lower anterior face height was found to be higher in advanced stages of development.[11]

According to Ochoa and Nanda,[19] changes in growth and development in boys take approximately 2 years longer than in girls. Maxillary growth slows down after 12 years of age in girls, and mandibular growth slows down after 14 years of age. In males, growth continues until the age of 16 years.[19] Mitani et al[20] compared class III individuals with prognathic mandibles with class I individuals, and their growth rates were found to be similar until puberty but changed in later periods.

In class III individuals, growth potential and shape are important in the decision and success of orthodontic treatment. Considering that the majority of orthodontic treatments are performed during the growth period, identification of the craniofacial growth behavior will be helpful in choosing the right mechanics and timing of treatment in class III patients, especially in terms of the intermaxillary relationship.[21] The H0 hypothesis of this study was determined that there is no difference in the dimensional and angular values of craniofacial structures between class I and class III individuals and genders at different growth periods. This study aims to compare the craniofacial growth of individuals with skeletal class III and class I at different growth periods.

MATERIAL AND METHODS

This retrospective and cross-sectional study was conducted on lateral cephalometric and hand–wrist films of 266 applicants for orthodontic treatment. Individuals were chosen from the orthodontics department's archive using the patient registration program (FileMaker Pro11). This study was approved by Gazi University Clinical Research and Ethics Committee (Date: 26.10.2011, Number: 318).

The following criteria were taken into account in the selection of individuals included in the study, who have not received orthodontic treatment, have no congenital tooth deficiency, skeletal class I (ANB: 0-4°) and class III (ANB < 0°)[22] have an anomaly class I individuals with a balanced facial structure and class III individuals with concave facial structure, individuals without any syndrome, craniofacial anomaly, and cleft lip–palate.

In this study, the individuals were first divided into 2 main groups, skeletal class III (n = 133) and class I (n = 133). Then, these groups were also classified according to their genders as male and female. These groups were divided into 4 subgroups based on the growth periods (prepubertal, pubertal, postpubertal, and adult) determined based on the hand–wrist films[23] (Table 1). The Δ values are the amount of the difference values between the 2 periods (Δ1: difference value between pubertal and prepubertal periods, Δ2: difference value between postpubertal and pubertal periods, Δ3: difference value between adult and postpubertal periods).

The lateral cephalometric and hand–wrist films belonging to the groups were taken in x-ray machines (MORITA, J. Morita MFG. CORP., Kyoto, Japan) under standard conditions with a magnification difference of 1.1 mm. Lateral cephalometric films were first scanned with a scanner (EPSON Scanner PerfectionV700) at 300 dpi resolution and transferred to the computer. Later the measurements were done with the digital cephalometric analysis program of Dolphin Imaging Software (version 11.0, Dolphin Imaging and Management Solutions, Calif, USA). 188 lateral cephalometric radiographs belonging to 96 individuals randomly selected from both groups were measured using intraclass correlation coefficient (ICC) for a second time after 3 weeks from the completion of the measurements, to evaluate individual error control and intraexaminer reliability.

In this study, 25 cephalometric parameters, 13 angular, 11 linear, and 1 proportional, were evaluated. SN, S-Ba, Wits, Co-A, Co-Gn, N-ANS, ANS-Me, N-Me, S-Go, U1-NA, L1-NB length measurements, BaSN, NSAr, SArGo, ArGoMe, SNArGoMe, SNA, SNB, ANB, SN/GoGn, U1/SN, U1/NA, IMPA, L1/NB angular measurements, and SGo/NMe proportional measurements were carried out (Figure 1).

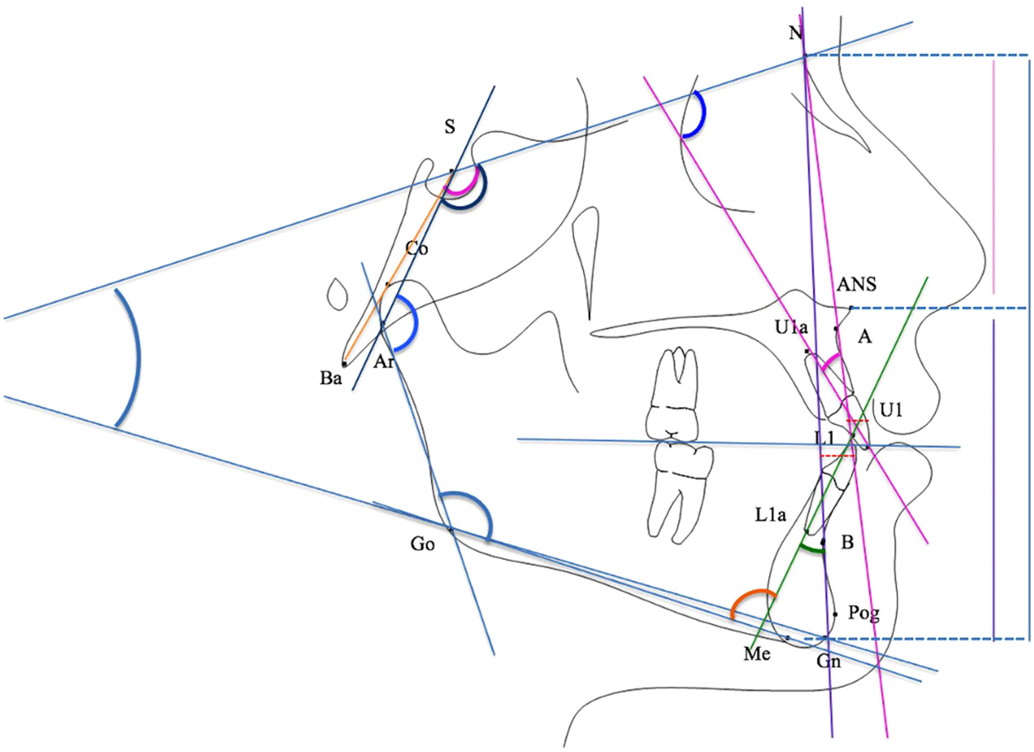
Statistical Analysis

The Statistical Package for the Social Sciences version 15.0 software (SPSS Inc.; Chicago, IL, USA) was used to analyze the study's data. The NCSS PASS 2008 software program was used to do a power analysis on the study's sample size was analyzed. For this purpose, information about the variables of interest (SNB, ANB) from other similar studies was used as a reference.[11] As a result

Table 1. Chronological and Skeletal Age Range and SD Values According to Growth Period and Genders

				Chronological Age				Skeletal Age			
			n	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Class III	M	Prepubertal	18	10.40	1.42	8.08	12.83	9.98	1.62	7.00	12.50
		Pubertal	16	12.84	1.32	11.00	16.25	13.47	0.43	13.00	14.00
		Postpubertal	16	15.53	1.00	14.08	17.17	16.06	0.98	14.25	17.00
		Adult	16	20.65	3.40	16.00	30.00	18.69	0.48	18.00	19.00
	F	Prepubertal	16	9.64	1.33	7.33	11.50	9.30	1.34	6.83	11.00
		Pubertal	17	12.04	0.81	10.25	13.25	12.47	0.80	11.00	13.00
		Postpubertal	16	13.64	0.86	12.42	15.25	14.69	0.75	13.50	16.00
		Adult	16	17.59	2.24	13.50	21.83	17.56	0.73	16.00	18.00
Class I	M	Prepubertal	16	10.96	1.51	8.08	13.25	10.67	1.82	7.83	12.67
		Pubertal	19	13.76	0.94	12.17	15.33	13.61	0.43	13.00	14.00
		Postpubertal	16	15.70	1.19	14.00	18.25	15.97	1.87	10.00	17.00
		Adult	16	17.98	1.59	15.92	20.67	18.31	0.48	18.00	19.00
	F	Prepubertal	17	9.42	1.52	7.08	12.42	8.85	1.27	6.83	10.00
		Pubertal	16	11.98	0.81	10.42	13.50	12.06	0.85	11.00	13.00
		Postpubertal	16	13.31	0.98	11.50	14.75	14.66	0.72	13.50	16.00
		Adult	19	17.57	4.39	14.17	31.33	17.21	0.71	16.00	18.00

F, female; M, male.



Sella (S): Geometric midpoint of the sella turcica, *Nasion (N):* The most anterior point of the frontonasal suture, *Ba (Ba):* The lowest and most posterior point in norma lateralis at the junction of the endocranial surfaces of the basis occipitalis, *Point A (Subspinal point) (A):* The deepest point of the concavity on the middle contour of the alveolar process, between the spinal nasalis anterior and the prosthion, *B point (Supramental point) (B):* Deep point on the alveolar process between the infradentale and pogonion in the mandibular symphysis, *Spina Nazalis Anterior (ANS):* The most extreme point of the maxillary bony prominence at the anterior base of the nose, *Condyle (Co):* The highest and most posterior point of the mandibular condyle, *Articulare (Ar):* The point where the posterior border of the mandibular condyle intersects with the skull base bone base image, *Gonion (Go):* The point where the bisector of the angle between the mandibular and ramal planes intersects the mandible, *Menton (Me):* The lowest point of the lower border of the mandibular symphysis, *Gnathion (Gn):* Midpoint of Menton and pogonion points, *Pogonion (Pg):* The most anterior point of the mandibular symphysis in the sagittal direction, *U1:* The apex of the cutting edge of the upper most anterior central incisor, *U1a:* Root tip of the upper most anterior central incisor, *L1:* The apex of the cutting edge of the lower most anterior central incisor, *L1a:* Root tip of mandibular most anterior central incisor

Figure 1. Reference points and measurements used in cephalometric analysis.

Table 2. The Significance of the Differences Between the Measurement Values Belonging to the Class I, Class III Groups and Genders

		Prepubertal					Pubertal					Postpubertal					Adult				
		Class III n = 34		Class I n = 33			Class III n = 33		Class I n = 35			Class III n = 32		Class I n = 32			Class III n = 32		Class I n = 35		
		$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*
S-N (mm)	M	68.9	2.8	71.2	3.9	.056[a]	71.6	3.1	73.1	4.8	.302[a]	74.7	3.6	75.8	3.7	.395[a]	74.0	3.8	73.5	4.8	.724[a]
	F	67.0	3.0	68.7	3.6	.160[b]	69.3	3.3	69.8	2.4	.643[a]	69.7	4.0	71.2	3.0	.127[b]	70.4	3.3	71.7	3.3	.263[a]
	P	.061[a]		.031[b]			.046[a]		.018[a]			.000[b]		.000[a]			.007[a]		.190[a]		
S-Ba (mm)	M	44.8	2.6	45.4	3.8	.576[a]	48.4	3.2	48.5	4.1	.956[a]	48.7	3.6	48.7	3.6	.954[a]	50.1	2.9	47.5	3.8	.033[a]
	F	43.5	3.2	44.3	3.3	.496	43.9	3.8	46.1	2.9	.077[a]	46.8	2.9	47.5	3.5	.539[a]	45.9	3.5	45.6	3.2	.804[a]
	P	.219[a]		.380[a]			.001[a]		.059[a]			.110[a]		.315[a]			.001[a]		.132[a]		
BaSN (°)	M	125.6	4.5	129.9	3.9	.005[a]	127.7	6.0	130.6	6.0	.171[a]	126.6	6.5	127.6	5.9	.676[a]	125.2	6.4	128.1	7.7	.269[a]
	F	127.0	3.7	129.8	3.9	.042	129.1	5.0	130.7	4.7	.347[a]	128.6	3.1	130.8	5.5	.181[a]	130.2	6.2	131.0	4.7	.666[a]
	P	.319[a]		.944[a]			.484[a]		.952[a]			.272[a]		.119[a]			.036[a]		.182[a]		
NSAr (°)	M	120.2	5.3	123.8	4.6	.040[a]	122.1	5.3	126.2	5.8	.040[a]	122.4	6.4	122.8	5.1	.865[a]	119.9	6.2	123.8	8.3	.144[a]
	F	119.5	4.6	124.1	4.1	.018[b]	122.7	5.2	124.2	3.9	.352[a]	122.0	4.3	124.5	5.3	.157[a]	122.1	7.1	126.0	4.5	.058[a]
	P	.783[b]		.860[a]			.775[a]		.246[a]			.831[a]		.359[a]			.361[a]		.321[a]		
SArGo (°)	M	147.8	8.2	144.1	5.8	.139[a]	142.3	5.8	142.1	7.8	.909[a]	144.0	6.5	148.1	7.6	.111[a]	144.7	5.0	143.5	9.4	.654
	F	143.4	6.5	142.0	7.4	.587[a]	144.4	6.3	142.0	3.8	.023[b]	143.8	4.0	143.8	8.1	.440[b]	141.5	6.9	143.5	5.4	.351[a]
	P	.090[a]		.388[a]			.242[b]		.986[a]			.915[a]		.127[b]			.147[a]		.997[a]		
ArGoMe (°)	M	128.1	6.4	128.0	6.2	.943[a]	131.9	5.6	128.5	6.3	.102[b]	127.3	7.6	124.5	6.2	.257[a]	127.7	7.7	125.9	7.8	.516[a]
	F	130.1	5.2	130.5	6.3	.845[a]	130.4	6.8	130.5	5.7	.948[a]	129.2	6.1	126.2	6.6	.201[a]	133.1	7.6	126.0	5.7	.003[a]
	P	.340[a]		.261[a]			.497[a]		.319[a]			.463[a]		.458[a]			.054[a]		.977[a]		
SNArGoMe (°)	M	396.1	4.8	395.9	4.6	.891[a]	396.4	3.6	396.7	5.8	.819[a]	393.8	6.0	395.4	6.5	.467[a]	392.3	4.5	393.2	7.3	.683[a]
	F	393.0	4.5	396.6	4.5	.028[a]	397.4	5.0	396.7	4.9	.693[a]	395.0	4.6	394.5	4.9	.775[a]	396.8	5.1	395.5	5.3	.475[a]
	P	.060[a]		.656[a]			.488[a]		.998[a]			.536[a]		.652[a]			.014[a]		.296[a]		
SNA (°)	M	78.2	2.6	79.6	2.8	.166[a]	78.9	3.7	80.3	2.9	.217[a]	78.3	3.3	80.0	4.5	.233[a]	81.5	4.5	81.2	4.5	.888[a]
	F	80.5	2.6	79.3	3.5	.254[a]	78.0	4.4	80.1	3.5	.145[a]	80.0	3.8	81.5	3.1	.232[a]	79.1	4.1	80.7	1.9	.133[a]
	P	.014[a]		.812[a]			.525[a]		.820[a]			.210[a]		.302[a]			.128[a]		.631[a]		
SNB (°)	M	80.4	2.9	77.2	2.9	.004[a]	81.3	3.1	77.9	2.9	.002[a]	80.4	3.4	77.9	4.4	.076[a]	85.0	4.3	78.6	4.2	.000[a]
	F	82.8	3.2	76.9	4.2	.000[a]	80.1	3.8	77.9	4.0	.114[a]	82.0	4.4	79.1	3.6	.052[a]	82.8	3.9	78.1	1.9	.000[a]
	P	.029[a]		.782[a]			.325[a]		.993[a]			.275[a]		.404[a]			.147[a]		.646[a]		
ANB (°)	M	−2.1	1.8	2.3	1.3	.000[a]	−2.4	1.6	2.4	0.9	.000[a]	−2.1	1.5	2.1	1.0	.000[a]	−3.5	2.8	2.6	1.3	.000[a]
	F	−2.3	1.6	2.4	1.4	.000[a]	−2.1	1.8	2.2	1.2	.000[a]	−2.0	1.5	2.4	1.1	.000[a]	−3.7	2.4	2.6	1.2	.000[a]
	P	.717[b]		.588[b]			.387[b]		.581[a]			.910[b]		.459[a]			.792[b]		.753[b]		
Wits (mm)	M	−6.8	2.6	−1.6	2.9	.000[a]	−8.3	3.1	−0.1	3.2	.000[a]	−6.1	3.1	0.5	3.4	.000[a]	−10.1	5.4	0.3	2.0	.000[a]
	F	−7.5	2.6	−1.3	3.1	.000[a]	−7.6	2.8	−2.0	3.0	.000[a]	−7.6	3.6	−1.5	2.9	.000[a]	−10.5	4.7	−0.6	2.4	.000[a]
	P	.398[a]		.784[a]			.519[a]		.053[b]			.193[b]		.080[b]			.838[a]		.265[a]		
Co-A (mm)	M	78.7	3.1	83.7	4.6	.002[b]	84.9	4.9	89.7	5.5	.011[a]	86.1	4.9	90.2	5.6	.034[a]	88.1	4.1	89.1	6.2	.564[a]
	F	77.8	4.3	81.1	5.2	.060[a]	79.9	4.6	83.3	3.0	.020[a]	83.2	5.3	87.3	4.1	.020[a]	83.2	3.1	88.7	5.8	.002[a]
	P	.482[a]		.155[b]			.005[a]		.000[a]			.110[a]		.080[a]			.001[a]		.846[a]		
Co-Gn (mm)	M	110.4	4.6	110.3	5.9	.944[a]	120.8	6.1	121.2	7.1	.868[a]	125.0	5.9	125.5	7.5	.831[a]	132.3	6.3	121.2	7.4	.000[a]
	F	106.8	5.0	106.0	6.0	.704[a]	114.1	5.6	110.0	5.6	.043[a]	118.7	6.9	115.6	5.7	.168[a]	125.3	5.9	118.3	6.0	.002[a]
	P	.032[a]		.046[a]			.002[a]		.000[a]			.010[a]		.000[a]			.003[a]		.079[b]		
SN/GoGn (°)	M	34.1	5.0	33.9	4.5	.902[a]	34.2	3.8	34.4	5.5	.883[a]	31.3	6.3	32.9	7.0	.507[a]	30.1	4.7	30.9	7.7	.742[a]
	F	31.2	4.4	35.0	4.6	.023[a]	35.2	4.8	34.8	5.0	.848[a]	32.8	4.5	32.4	5.2	.845[a]	34.5	5.0	33.2	5.5	.470[a]
	P	.089[a]		.492[a]			.528[a]		.827[a]			.447[a]		.845[a]			.017[a]		.311[a]		
N-ANS (mm)	M	52.5	2.7	53.0	3.7	.661[a]	55.5	3.1	56.2	3.0	.506[a]	56.8	4.6	58.6	3.3	.212[a]	59.7	4.3	57.6	4.5	.188
	F	49.5	2.1	49.9	3.8	.708[a]	52.8	3.0	52.6	3.5	.897[a]	54.9	2.6	55.3	3.5	.653[a]	55.3	3.3	56.7	3.9	.389[b]
	P	.001[a]		.024[a]			.015[a]		.003[a]			.149[a]		.011[a]			.003[a]		.185[b]		
ANS-Me (mm)	M	62.5	5.3	65.5	4.8	.096[a]	69.7	6.5	72.8	5.8	.148[a]	74.3	5.4	76.5	5.7	.256[a]	75.1	7.6	72.4	8.1	.347[a]
	F	57.4	4.8	63.0	3.9	.001[a]	66.2	4.5	66.1	4.2	.929[a]	67.6	5.4	66.6	3.6	.525[a]	71.7	6.7	68.9	5.2	.167[a]
	P	.006[a]		.100[a]			.078[a]		.000[a]			.002[a]		.000[a]			.190[a]		.127[a]		
N-Me (mm)	M	114.5	5.7	117.2	7.6	.252[a]	124.7	8.5	127.7	7.7	.276[a]	130.7	7.0	134.2	7.7	.105[b]	134.3	7.8	128.7	11.0	.105[a]
	F	106.2	5.9	111.7	5.8	.011[a]	118.4	6.6	117.2	5.1	.563[a]	121.9	6.2	120.3	5.0	.450[a]	126.7	8.0	124.3	6.9	.340[a]
	P	.000[a]		.024[a]			.023[a]		.000[a]			.001[a]		.000[a]			.011[b]		.160[a]		
S-Go (mm)	M	71.0	4.0	74.1	5.4	.068[a]	78.9	7.0	80.4	6.2	.515[a]	86.7	6.8	86.4	6.3	.906[a]	90.5	7.2	86.9	8.0	.200[a]
	F	68.5	3.9	69.9	5.5	.412[a]	73.7	4.6	73.8	4.9	.944[a]	78.8	5.0	77.8	5.4	.591[a]	79.9	4.0	79.5	5.0	.824[a]
	P	.068[a]		.033[a]			.016[a]		.002[a]			.001[a]		.000[a]			.000[a]		.002[a]		

(*Continued*)

Table 2. The Significance of the Differences Between the Measurement Values Belonging to the Class I, Class III Groups and Genders (*Continued*)

		Prepubertal					Pubertal					Postpubertal					Adult				
		Class III n = 34		Class I n = 33			Class III n = 33		Class I n = 35			Class III n = 32		Class I n = 32			Class III n = 32		Class I n = 35		
		$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*	$\bar{X}$	SD	$\bar{X}$	SD	*P*
SGo/NMe (%)	M	62.1	3.4	63.2	2.9	.310[a]	63.3	3.4	63.0	4.0	.827[a]	66.4	4.3	64.5	5.0	.270[a]	67.3	3.4	67.8	5.5	.734[b]
	F	64.5	3.6	62.5	3.1	.090[a]	62.3	3.4	63.0	3.5	.572[a]	64.7	3.4	64.7	3.9	.989[a]	63.2	3.8	64.1	3.7	.495
	P	.049[a]		.509[a]			.412[a]		.990[a]			.226[a]		.926[a]			.003[a]		.053[b]		
U1/SN (°)	M	104.1	5.2	101.5	5.9	.174[a]	103.9	6.9	105.3	5.3	.500[a]	107.4	8.2	106.1	7.0	.617[a]	108.4	7.5	105.5	9.1	.334[a]
	F	106.4	5.5	104.0	7.9	.321[a]	107.3	6.8	105.2	10.1	.486[a]	106.9	6.9	102.0	5.5	.036[a]	110.1	8.2	103.1	6.8	.010[a]
	P	.224[a]		.311[a]			.163[a]		.973[a]			.836[a]		.078[a]			.543[a]		.383[a]		
U1/NA (°)	M	25.9	5.5	21.9	7.5	.085[a]	25.0	5.1	25.0	3.7	.996[a]	29.1	7.9	26.0	5.9	.985[b]	26.9	7.7	24.2	7.4	.326[a]
	F	25.8	5.0	24.7	6.8	.592[a]	29.3	8.2	25.1	7.8	.142[a]	26.9	6.1	20.5	4.2	.002[a]	30.9	6.0	22.4	6.9	.000[a]
	P	.975[a]		.275[a]			.080[a]		.951[a]			.497[b]		.000[b]			.105[a]		.449[a]		
U1-NA (mm)	M	4.0	2.1	3.4	3.1	.544[a]	5.2	2.3	5.4	2.5	.837[a]	7.5	3.2	5.5	2.4	.117[b]	6.6	3.6	5.6	2.8	.318[b]
	F	3.2	1.5	3.4	1.9	.552[b]	6.5	2.8	4.7	2.6	.069[a]	5.7	2.4	3.3	1.6	.003[a]	7.3	2.5	4.3	2.4	.001[a]
	P	.244[a]		.732[b]			.157[a]		.466[a]			.052[b]		.006[a]			.865[a]		.138[a]		
IMPA (°)	M	82.3	5.0	91.3	6.3	.000[a]	79.7	6.1	90.8	6.8	.000[a]	85.6	5.9	89.0	6.6	.130[a]	78.4	10.5	91.4	7.8	.000[a]
	F	83.6	5.7	86.1	6.4	.259[a]	83.2	5.3	87.6	6.5	.043[a]	82.6	5.4	87.7	7.4	.031[a]	78.9	10.9	90.9	8.1	.001[a]
	P	.465[a]		.023[a]			.085[a]		.362[b]			.142[a]		.606[a]			.902		.860[a]		
L1/NB (°)	M	18.8	6.5	24.5	5.6	.010[a]	17.4	5.8	25.5	6.0	.000[a]	19.8	5.3	22.3	6.2	.221[a]	15.7	8.2	23.2	7.5	.011[a]
	F	19.4	6.4	19.5	6.8	.951[a]	20.7	5.8	22.2	7.2	.515[a]	19.6	5.7	21.3	6.2	.420[a]	18.5	7.7	24.5	5.9	.012[a]
	P	.783[a]		.031[a]			.105[a]		.151[a]			.901[a]		.633[a]			.337[a]		.566[a]		
L1-NB (mm)	M	3.1	2.3	4.7	2.1	.037[a]	2.7	1.9	5.5	2.5	.001[a]	4.2	2.0	5.0	2.8	.375[a]	3.2	2.8	5.2	2.9	.056[a]
	F	2.5	1.9	3.0	2.1	.470[a]	3.6	1.9	4.1	2.5	.971[b]	3.3	1.9	3.8	1.8	.439[b]	3.3	2.1	4.6	1.8	.054[a]
	P	.429[a]		.023[a]			.183[a]		.038[b]			.201[a]		.101[b]			.895[a]		.473[a]		

$P < .05$, $P < .01$, $P < .001$.
F, female; M, male.
[a]Independent sample *t*-test.[b]Mann–Whitney *U*-test.

of the analysis carried out by taking alpha (α) = 0.05 and power ($1-\beta$) = 0.90, it was calculated that there should be at least 15 individuals in each group, for a total sample size of 240 individuals. In the power analysis performed after the study for $\alpha = 0.05$ and considering the number of individuals in each group, the power was found to be between 0.87 and 1.00 for the SNB variable and between 0.99 and 1.00 for the ANB in 4 different periods.

The conformity of the quantitative variables considered in the study to the normal distribution was examined using the Shapiro–Wilk test and graphical methods. For statistical comparison of 2 independent groups (the comparison of class III and class I in each period and in each gender group, the comparison of males and females in each period and in each class), "Independent sample *t*-test" was used for normally distributed variables and the "Mann–Whitney *U*-test" was used for non-normally distributed variables. The difference between 2 independent groups and the previous growth period and the next growth period (Δ) in each gender group in each class showing the difference between periods was evaluated with the "Independent sample *t*-test" for variables that normally distributed, and with the "Mann–Whitney *U*-test" for variables that do the non-normally distributed. For all statistical analyses, a value of $P < .05$ was accepted as the level of statistical significance.

RESULTS

A total of 266 individuals were included in this study. The growth periods, genders, chronological and skeletal age range values of the groups, and sample size of individuals in the groups are shown in Table 1. The intraexaminer reliability levels of the measurements for each selected parameter were assessed by using intraclass correlation coefficient (ICC). These values were close to the exact value of 1.00 (0.813-0.993) for the measurement repetition coefficients (*r*) calculated.

The S-N and S-Ba dimensions were found to be larger in class III males than females in the pubertal and adult periods, and the S-N size in the postpubertal period. S-N dimensions were found to be larger in class I males than females in the prepubertal, pubertal, and postpubertal periods. Statistically significant increases were observed in the S-N dimensions (Δ1 and Δ2) in class III males and (Δ2) in class I males, as well as in the S-Ba dimensions (Δ1 and Δ2) in class III females. Cranial base angle (BaSN) and saddle angle (NSAr) were found significantly smaller in prepubertal class III males than class I males, and in class III females compared to class I females. BaSN was observed to be significantly smaller in males in the class III group in adults than in females (Table 2 and 3, Figure 2).

The SArGo in the pubertal period, and the ArGoMe in the adult period were found to be larger in class III females than in class I females. While a significant decrease was observed in the SArGo value in the Δ1 and the ArGoMe value in the Δ2 in the class III males, a significant increase in the SArGo value in the Δ2 was observed in the class I males. The SNArGoMe was found to be smaller in prepubertal period class III females than in class I females and in adult period class III males than in females. When the amount of change between the periods was compared, a significant increase was observed in the Δ1 in class III females (Table 2 and 3, Figure 3).

The SNA angle was found to be smaller in prepubertal class III males than females. In terms of SNA, a significant decrease was observed in class III females in the Δ1, while a significant increase was observed in the Δ3. The SNB angle for males and females in the class III group was found to be larger in the prepubertal and adult periods compared with the class I males and females. While a significant decrease was observed in class III females in the Δ1, a significant increase was observed in class III males in the Δ3.

The ANB and Wits values were found to be smaller in prepubertal, pubertal, postpubertal, and adult periods for class III females and males than for class I females and males. When the amount of change in ANB and Wits values between the periods were compared, significant decreases were observed in class III males and females in the Δ3 (Table 2 and 3, Figure 4).

The Co-A dimension was determined to be smaller in class III males and females than in class I males and females in the growth periods. A significant increase was observed for class III and class I males in the Δ1, for class I females in the Δ2. The Co-Gn dimension of the adult females and males in the class III group was found to be larger than the females and males in the class I group. Besides, it was found that Co-A and Co-Gn dimension was larger in class III males than females in all growth periods. Significant increases were observed in Co-Gn size for class III males in the Δ1, Δ3, for class III girls in the Δ1, Δ2, Δ3, and for class I males and class I females in Δ1 and Δ2 (Table 2 and 3, Figure 4).

Table 3. Changes of Measurements According to Class I, Class III Groups and Genders Between Growth Periods

		Δ 1 (Pubertal–Prepubertal)		Δ2 (Postpubertal–Pubertal)		Δ3 (Adult–Postpubertal)	
		Class III	Class I	Class III	Class I	Class III	Class I
		$\bar{D}$	$\bar{D}$	$\bar{D}$	$\bar{D}$	$\bar{D}$	$\bar{D}$
S-N (mm)	M	**2.7***	1.9	**3.1***	**2.8***	−0.7	−2.3
	F	2.3	1.1	0.4	1.4	0.6	0.5
S-Ba (mm)	M	**3.6****	**3.0****	0.3	0.3	1.5	−1.3
	F	0.4	1.7	**2.8***	1.4	−0.8	−1.8
BaSN (°)	M	2.1	0.7	−1.1	−3.0	−1.4	0.5
	F	2.1	0.9	−0.5	0.1	1.5	0.2
NSAr (°)	M	2.0	2.4	0.3	−3.4	−2.5	1.0
	F	3.2	0.1	−0.6	0.3	0.1	1.5
SArGo (°)	M	**−5.5***	−2.0	1.7	**6.1****	0.7	−4.7
	F	1.0	0.0	−0.6	1.7	−2.3	−0.3
ArGoMe (°)	M	3.7	0.5	**−4.5***	−4.0	0.4	1.4
	F	0.3	0.1	−1.2	−4.3	4.0	−0.2
SNArGoMe (°)	M	0.2	0.9	−2.6	−1.3	−1.5	−2.2
	F	**4.4****	0.1	−2.4	−2.2	1.8	1.0
SNA (°)	M	0.7	0.8	−0.6	−0.3	**3.1***	1.2
	F	**−2.5***	0.8	2.0	1.4	−0.9	−0.8
SNB (°)	M	0.9	0.7	−0.9	0.0	**4.5*****	0.7
	F	**−2.7***	1.0	1.9	1.2	0.8	−1.0
ANB (°)	M	−0.2	0.1	0.3	−0.3	**−1.4***	0.5
	F	0.2	−0.2	0.1	0.2	**−1.7****	0.2
Wits (mm)	M	−1.5	1.5	2.1	0.6	**−4.0****	−0.2
	F	0.0	−0.6	0.0	0.4	**−2.9***	0.9
Co-A (mm)	M	**6.2*****	**6.0*****	1.2	0.5	1.9	−1.1
	F	2.1	2.2	3.2	**4.0***	0.1	1.5
Co-Gn (mm)	M	**10.4*****	**10.9*****	4.2	**4.3***	**7.3****	−4.3
	F	**7.4*****	**4.0****	**4.6***	**5.6***	**6.5****	2.7
SN/GoGn (°)	M	0.1	0.6	−2.9	−1.6	−1.2	−2.0
	F	**3.9***	−0.1	−2.4	−2.4	1.7	0.8
N-ANS (mm)	M	**3.0****	**3.2****	1.4	**2.5***	**2.9***	−1.0
	F	**3.2****	**2.7***	2.1	**2.7***	0.4	1.4
ANS-Me (mm)	M	**7.2*****	**7.3*****	**4.5***	**3.7***	0.9	−4.1
	F	**8.9*****	3.1	1.4	0.5	4.1	2.3
N-Me (mm)	M	**10.1*****	**10.5*****	**6.0***	**6.5****	3.6	**−5.5***
	F	**12.2*****	**5.5***	3.5	3.2	4.8	3.9
S-Go (mm)	M	**7.9*****	**6.3*****	**7.8*****	**6.1****	3.8	0.5
	F	**5.2****	**3.9***	**5.2***	4.0	1.0	1.7
SGo/NMe (%)	M	1.2	−0.2	**3.1***	1.6	0.9	**3.2***
	F	−2.2	0.5	2.4	1.7	−1.5	−0.6
U1/SN (°)	M	−0.2	3.8	3.5	0.8	0.9	−0.6
	F	0.9	1.2	−0.5	−3.2	3.2	1.1
U1/NA (°)	M	−0.9	3.1	4.1	1.0	−2.2	−1.8
	F	3.5	0.4	−2.4	**−4.6***	4.1	1.9
U1-NA (mm)	M	1.2	**1.9***	**2.3***	0.1	−0.8	0.1
	F	**3.3*****	1.3	−0.8	−1.4	1.6	0.9
IMPA (°)	M	−2.5	−0.5	**5.8****	−1.9	**−7.1***	2.4
	F	−0.4	1.5	−0.7	0.1	−3.7	3.2
L1/NB (°)	M	−1.4	1.0	2.4	−3.2	−4.1	0.9
	F	1.4	2.7	−1.2	−1.0	−1.1	3.3
L1-NB (mm)	M	−0.4	0.8	**1.5***	−0.6	−1.0	0.3
	F	1.1	1.1	−0.3	−0.3	0.0	0.9

F, female; M, male.
*P < .05, **P < .01, ***P < .001. Δ1: difference value between pubertal-prepubertal period, Δ2: difference value between postpubertal-pubertal period, Δ3: difference value between adult-postpubertal period.

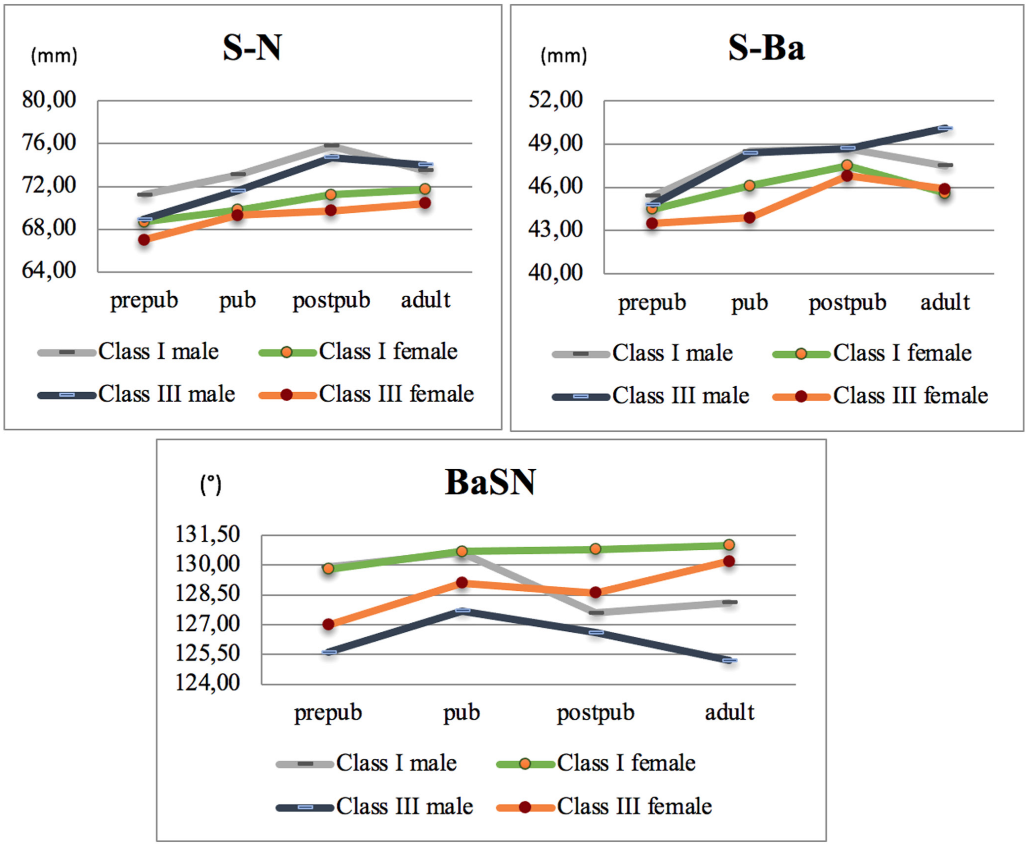


Figure 2. SN, SBa, and BaSN changes of class III and class I individuals according to growth periods.

Furthermore, the SN/GoGn angle was observed to be smaller in class III females than in class I females in the prepubertal period, and class III males were significantly smaller than females in the adult period. It was found that there was a significant increase in class III males in the Δ1. While the ratio of SGo/NMe was found to be smaller in class III males in the prepubertal period than in females, it was found to be larger in the adult period. Furthermore, there were significant increases in class III males in the Δ2 and in class I females in the Δ3.

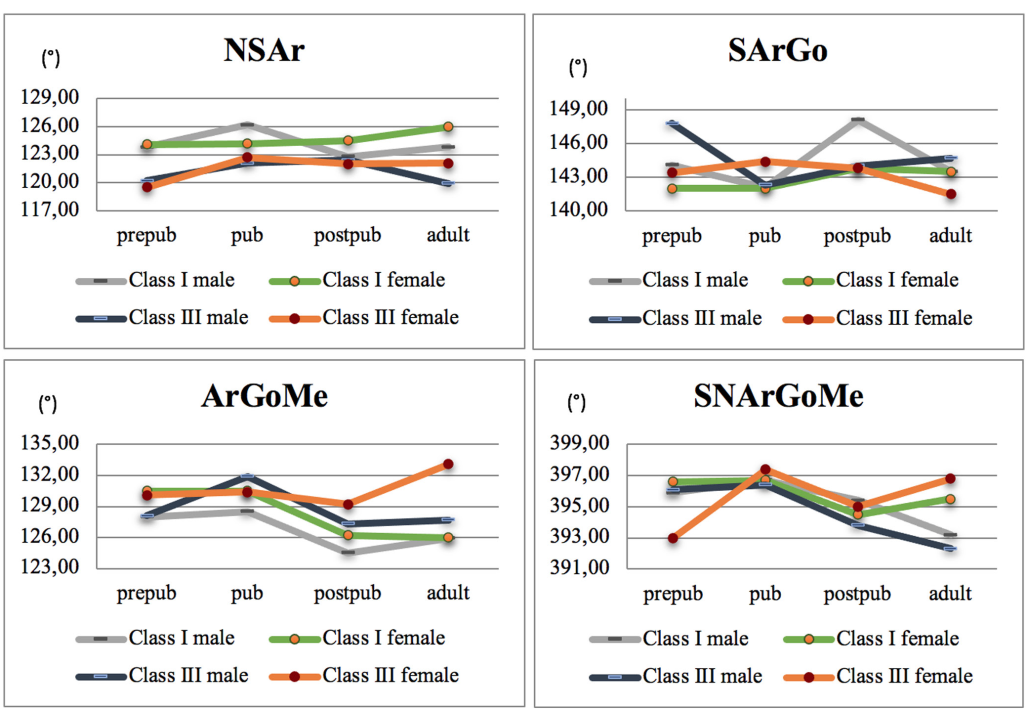


Figure 3. NSAr, SArGo, ArGoMe, SNArGoMe changes in class III and class I individuals according to growth periods.

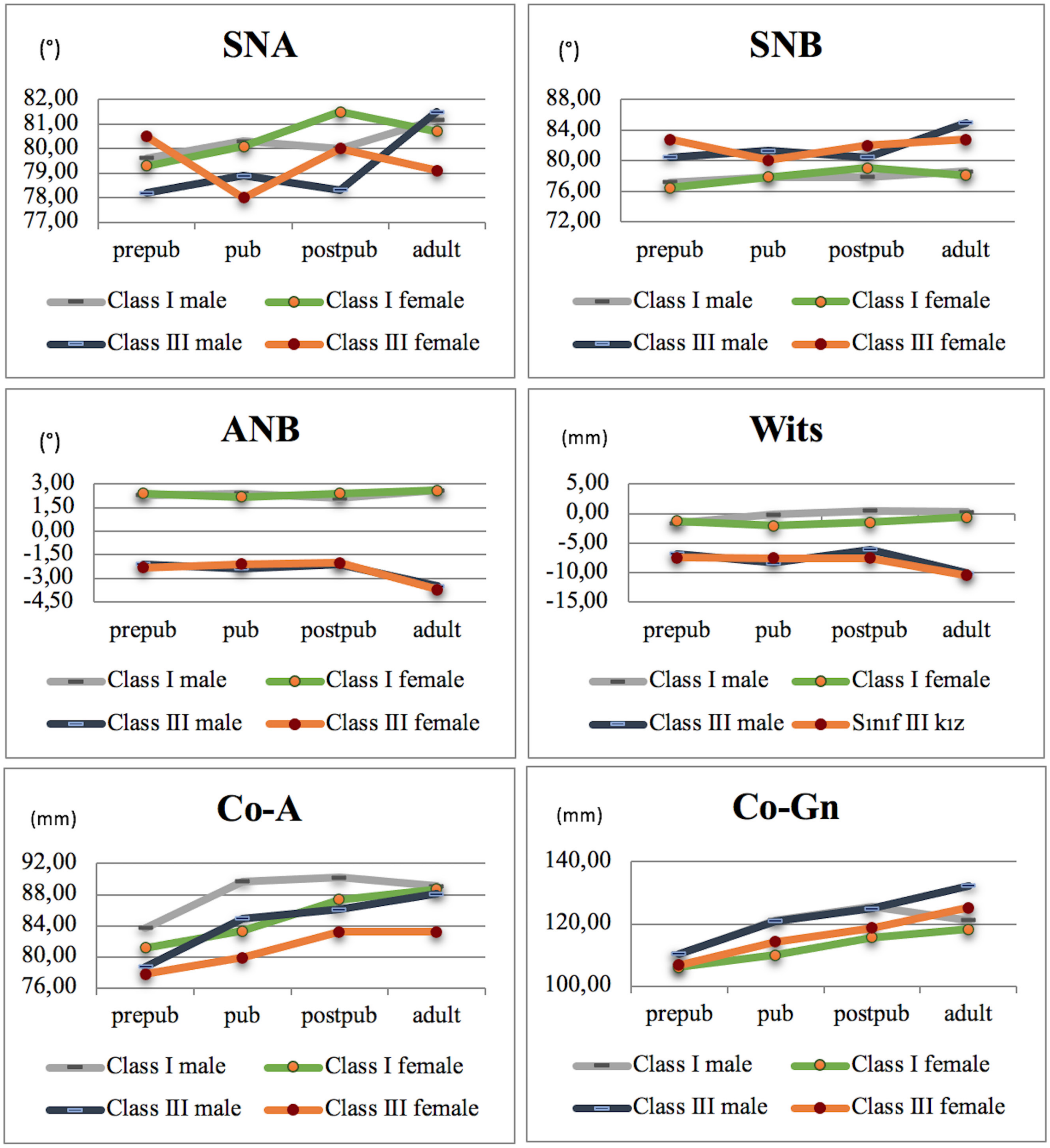


Figure 4. SNA, SNB, ANB, Wits, Co-A, and Co-Gn changes of class III and class I individuals according to their growth periods.

The N-ANS, ANS-Me and N-Me dimension was found to be greater in class III and class I males than females in the growth periods. The ANS-Me and N-Me dimensions were found to be smaller in the prepubertal period in class III females compared to class I females. Besides, there was a significant increase in class III and class I males, females in the Δ1. There was also a significant decrease in N-Me in class I females and males in the Δ1, in the class III females in the Δ2, and in the class I males in the Δ3 (Table 2 and 3, Figure 5).

The U1/SN, U1/NA angles and U1-NA length were found to be greater in class III females than in class I females in the postpubertal, and in adult periods. U1-NA length showed a significant increase in class III males in Δ2, in females in Δ1, and in class I males in Δ1. The IMPA, L1/NB angles and L1-NB length were significantly smaller in class III males than in class I males in the prepubertal, pubertal. The IMPA angle was also significantly smaller in class III females than class I females in the pubertal, postpubertal, and adult periods, while the L1/NB angle was significantly smaller in adult periods. In addition, U1/NA angle and U1-NA length, IMPA, L1/NB angles, and L1-NB length were found to be greater in class I males than females. In terms of IMPA, a significant increase was observed in class III males in the Δ2, while there was a significant decrease in the Δ3 (Table 2 and 3, Figure 6).

DISCUSSION

Chronological or bone age is used in studies related to growth and development. While there are studies based on chronological age when creating age groups,[2,11,14,24] there are also studies based on bone age[20] or using other methods.[16] Besides the chronological ages of all individuals included in this study, maturation periods were determined by looking at the left hand–wrist radiographs and the Greulich–Pyle atlas,[25] and groups were formed according

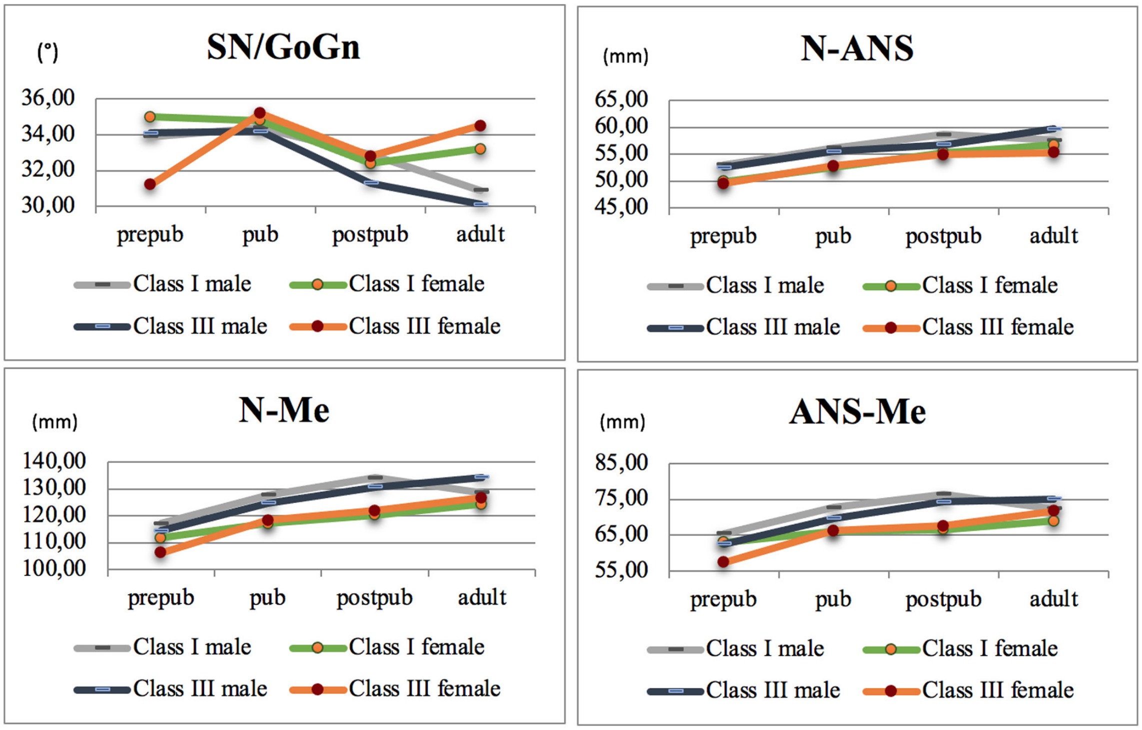


Figure 5. SN/GoGn, N-ANS, ANS-Me, N-Me changes in class III and class I individuals according to growth periods.

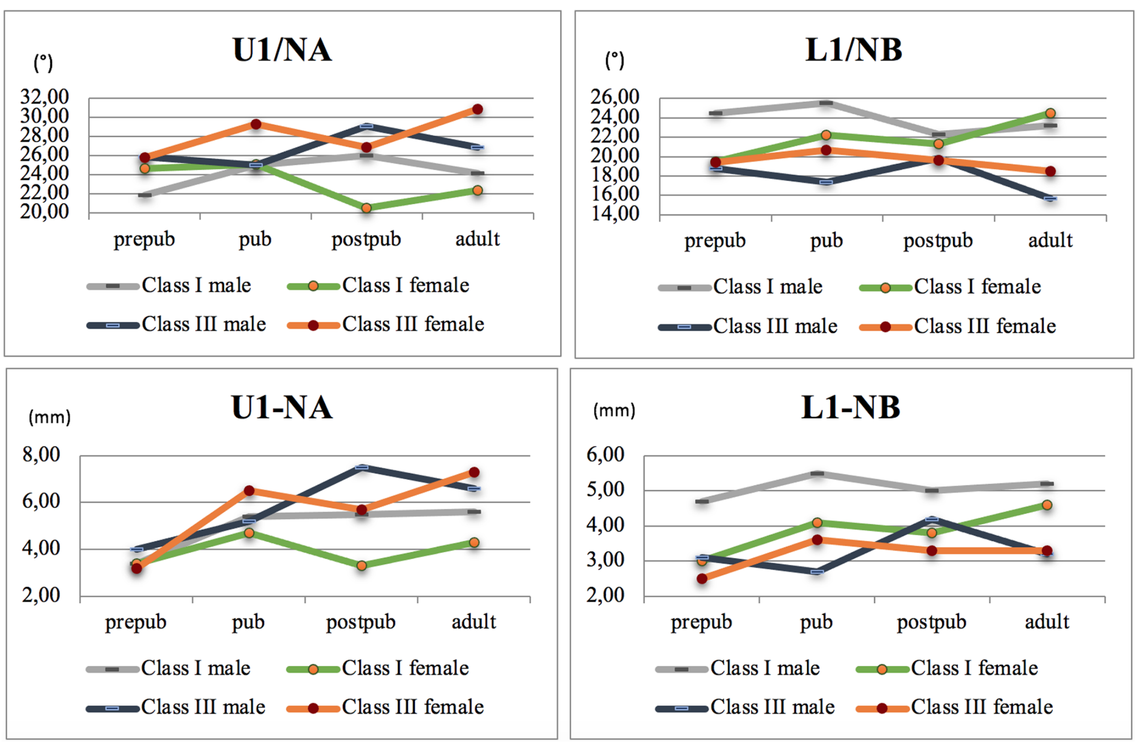


Figure 6. U1/NA, U1-NA, L1/NB, L1-NB changes in class III and class I individuals according to growth periods.

to the skeletal maturation periods as prepubertal, pubertal, postpubertal, and adult periods.[23]

Cranial Base Relationships

Bacetti et al reported that the glenoid fossa is located more anteriorly, with a reduced BaSN in class III individuals.[12] According to Reyes et al,[11] the BaSN in class III cases is smaller than in normal individuals in all age groups. While it was observed to be between 129° and 131° in normal individuals, it was found between 121° and 124° in class III cases.[11] In this study, the BaSN was smaller in class III individuals than in class I individuals, and in males compared to females (Table 2, Figure 2). Therefore, the H0 hypothesis of this study was rejected.

While Guyer et al[2] found the value of the saddle angle to be similar between class I and class III individuals. Ellis and McNamara[1] stated that a decrease in Saddle angle is a class III cranial base feature. In this research, in accordance with other studies, the saddle angle (NSAr) was founded statistically smaller in class III group than class I group especially in the prepubertal and pubertal periods.

In Sanborn's study with class III individuals aged 16–18 years, reported that the Gonion point is located more anteriorly than the skull base and upper face, and the gonial angle (ArGoMe) is greater in class III individuals (133.6˚) than in class I individuals (123˚).[10] Guyer et al stated that the gonial angle is approximately 5˚ larger in class III than class I.[2] Wolfe et al reported that the gonial angle was higher in males than females in the class I and class III groups.[26] Although smaller values of the gonial angle were found in males than females in this study, there were no statistically significant differences. Because the vertical angular dimensions measured in this study are in the optimal angle values (SN/GoGn:30.1-35˚) (Table 2, Figure 3).

Maxillary and Mandibulary Skeletal Relationships

Studies have reported that SNA angle and CoA are smaller in class III individuals.[2,14,16,20,26,27] When we compared the SNA values in this study with Steiner norms,[28] it was found that the SNA values in the class I group were smaller. In this study, SNA values were found to be 79.6˚-81.2˚ in class I males and 79.3˚-81.5˚ in females. This study finding indicate that there is no difference in the SNA angle between class III and class I individuals, except gender variations. Since the SNA value can be affected by the inclination of the SN plane and the degree value is smaller than mm value, no statistical difference was found.

When we compared the SNB values in this study with Steiner norms,[28] it was found that the SNB values were smaller. In this study, SNB values in the class I group were found to be 77.2˚-78.6˚ in class I males and 76.9˚-79.1˚ in females. Miyajima et al reported that the SNB angle in class III females increased by approximately 3˚from early mixed dentition to adulthood.[16] In class III females in this study, the SNB value first decreased by 2.7˚(in the Δ1) and increased in the following periods (in the Δ2 and Δ3). The highest increase was observed in class III males and in Δ3 (4.5˚)(Table 3, Figure 4).

Guyer et al reported that the Co-Gn dimension was 3-6 mm longer in class III individuals than in class I individuals.[2] Reyes et al[11] reported that the amount of growth was higher in class III individuals than in class I individuals. Besides, they reported that the greatest increases in mandibular dimensions occurred in class III individuals approximately 1 year after class I individuals. In males with class III anomalies, the highest increase in Co-Gn dimension occurs between the ages of 12-13 (4.2 mm), with an average increase of 2.9 mm.[11] Similarly, in this study, the highest increase was observed in the Δ1, and this increase was 10.4 mm in males and 7.4 mm in females on average. When the Co-Gn findings of class I individuals were compared with McNamara norms[29] (105-131 mm in class I boys, 103.3-121.6 mm in girls), the Co-Gn sizes in this study were found to be smaller. Considering the Co-Gn averages of this study, it was found between 110.3-125.5 mm in class I males and 106-118.3 mm in females (Table 2, Figure 4).

Intermaxillary Relationships

Wolfe et al stated that ANB and Wits values were smaller in class III individuals and became more severe in the negative direction over time.[26] In this respect, some cases stated that growth can be better evaluated with the Wits measurement, which is measured from the occlusal plane and is not affected by vertical direction changes.[9,26] Chen et al stated that the class III structure was formed before the age of 8 years, and that more vertical and transversal changes were observed in the following period.[27] In the study of Rutili et al, a worsening over time of the skeletal characteristics (ANB, SNB angle, Wits, mandibular length) of class III malocclusion was described.[30] Compatible with these studies, this study also observed that the class III anomaly was exacerbated in both females and males in ANB and Wits measurements in the Δ3. In class 3 individuals, even if the orthodontic treatment is finished in the early growth period, the mandibula will continue to grow in later growth periods and the risk of relapse should be taken into consideration and appropriate clinical measures should be taken (Table 3, Figure 4).

Studies in the literature stated that the morphological characteristics of mandibular prognathism occur before the pubertal growth spurt, and this situation is maintained in the following period.[20,31] Zegan et al in class III individuals found statistically significant differences with several characteristics between the prepubertal (<14 years) and pubertal-postpubertal (>14 years).[31] While there is no difference in mandibular dimensions in the prepubertal and pubertal periods, there are obvious differences in the transition from postpubertal to the adult period. This should be taken into account in treatment planning. In order to prevent the possible risk of relapse due to continued growth until late periods, for example, the duration of treatment can be prolonged, or class 3 elastics can be used to control mandibular growth. Thus, the orthodontist will be able to create a more effective treatment plan by taking some clinical measures.

Vertical Facial Relationships

In the Sanborn study, SN/GoGn values were reported as 33.17˚ in class III individuals and 28.97˚ in class I individuals.[10] On the other hand, Wolfe et al stated that class III individuals have a hyperdivergent growth pattern with increased mandibular plane angle.[26] In this study, the average of SN/GoGn is 30.1˚-34.2˚ in class III males, 31.2˚-35.2˚ in females, 30.9˚-34.4˚ in males in class I group, 32.4˚-35˚ in females. It is seen that they have similar and optimum values (Table 2). According to Ochoa and Nanda, the SN/GoGn angle decreases from 6 to 14 years of age in individuals with class I occlusion.[19] In this study, decreases are observed in the Δ2 (Table 3).

Dentoalveolar Relationships

In individuals with class III malocclusion, the upper incisors are protrusive, and the lower incisors are retrusive as a result of dentoalveolar compensation.[2,10,11,14] In this study, it was observed that proclinations increased in the upper incisors in general during the 4 developmental periods, and there was significant retroclination in the lower incisors in class III cases (Table 2, Figure 6).

In conclusion, we infer the following:

- The craniofacial and especially the mandibular dimensions are larger in class I and class III males than in females.

- The cranial base angle and effective size of the maxilla (Co-A) are smaller in class III individuals than in class I individuals.
- In Class III individuals, maxillary incisors are protrusive, and mandibular incisors are retrusive.
- Although the growth rates between class III and class I individuals in the early period (Δ1) of the maxilla and mandible are similar, these differences intensify in the later periods (Δ3). It was found that the growth rate of the mandible was higher than the growth rate of the maxilla.
- The class III intermaxillary relationship worsened over time. Mandibular growth was found to continue into late growth periods, especially in males.
- In class III individuals, even if orthodontic treatment is completed in the early growth period, the mandible will continue to grow in later growth periods, and the risk of relapse should be considered, and appropriate clinical measures taken. These results reveal the importance of early diagnosis and treatment in class III individuals.

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Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Fikir – N.U.; Tasarım – N.U.; Denetleme – N.U.; Veri Toplanması ve/veya İşlemesi – E.K.; Analiz ve/veya Yorum – E.K.; Literatür Taraması – E.K.; Yazıyı Yazan –E.K.

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