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Dental and skeletal characteristics and growth in Class III malocclusion between skeletal ages of 10 and 14

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The purpose of this study was to evaluate growth changes and skeletal characteristics of Korean children with Class III malocclusions from 10 to 14 years of skeletal age. Radiographs of 60 children with Class III malocclusion and 60 normal controls were assessed. Both groups were subdivided into 6 samples according to sex and skeletal age. Skeletal age was assessed using handwrist X-rays using the Greulich and Pyle norms. The Krogman-Walker plane (occipitale-maxillon) through Sella was used as a reference plane in this study with y-axis perpendicular to the x-axis. Six Student t-tests were conducted to compare the control group with the Class III group according to each gender and age.

The characteristics of Class III malocclusion group compared to the control group included shorter anterior and posterior cranial base, shorter and retrusive maxilla, longer mandible, increased molar-incisor distance, retroclined lower incisors, labially proclined upper incisors, and anteriorly located mandibular molar, smaller upper and middle facial depth, and larger lower facial depth.

Landmarks representing facial depth, size of maxilla and mandible, and their AP relationship including anterior facial height indicate that growth characteristic was determined early in life. But growth pattern of cranial base and some of the dental landmarks showed progressive divergence between Control and Class III groups with age. The position of the posterior border of the mandible was found to be significantly forward in both females and males by the age of 14 and at the anterior border in males and females at all ages. Hyperdivergent mandibular plane, changes in anterior segment of mandible, small anterior cranial base, and decrease in cranial base flexure was also noted.

Key words : Korean, Class III malocclusion, Cephalometry, Krogman-Walker plane.

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Discrepancies in size, form, or the position of the jaw can result in Class II or Class III malocclusions.[1] Correction of Class III malocclusions has been a common problem faced by orthodontists in Asia. To a limited extent, clinicians can promote maxillary growth as well as retard mandibular growth.[2] A particular situation may warrant the use of a specific treatment, or mandate surgical intervention to produce ideal results. The objective of this study is to characterize

the dento-facial skeletal patterns of Class III malocclusions in the Korean population between the ages of 10 and 14, selected on the basis of their skeletal age rather than their actual age.

Cases with Class III malocclusions are frequently observed. Statistics from clinicians' offices show that these cases account for 2.3% to 13% of the patient population in Asia.[3] Studies on the distribution of Class III patients in Korea have been done by many resea-rchers. A sample from university students shows the normal distribution range to be from 9 to 10 percent,[4,5] while the portion of patients treated in universityaffiliated orthodontic clinics is between 23 to 35 percent.[6,7] Almost two-third of the patients with Class III malocclusions are estimated to have associated skeletal dysplasia to a significant degree.[8]

Class III malocclusion was first characterized by Edward Angle,[9] whose classification was based on the mandibular position as defined by the position of the lower first permanent molar with respect to the upper first permanent molar, assuming that the maxillary first permanent molar was stable in the antero-posterior relationship with respect to the cranium. In a Class III molar relationship, the lower first permanent molar is further forward than the upper first permanent molar. Various characteristics have been attributed to Class III malocclusions, such as a shorter anterior and posterior cranial base, a shorter maxilla, a longer mandible, and excessive lower facial height. These factors contribute to the characteristics of Class III malocclusions. However, the mandibular protrusion has been reported to be the primary factor.[10] A group of researchers identified mandibular prognathism on the basis of measurements of the angles that characterize the size and position of the jaws, such as facial angle, angle of convexity, SNA, SNB, and SN-Pog.[11] In this study, an antero-posterior dental discrepancy greater than 4 mm is defined as a Class III malocclusion, i.e. the lower molar is at least 4 mm more anterior than a Class I position.

Changes in growing children have been studied using various methods. Lee described normal Craniofacial growth changes in the Korean youth population.[12] Kim and Lee observed the distribution of various facial types in Class III malocclusions and characterized the crani-facial features of a growing Class III population.[13] They concluded in their article that Class III malocclusions could be characterized by a shorter cranial base, a smaller saddle angle, maxillary defici-ency, mandibular excess, and excessive vertical growth of the lower anterior face. Baik noted the cephalometric differences between normal subjects and Class III patients.[10] These studies commonly revealed a shorter cranial base with a smaller saddle angle, a small maxilla, a longer mandible, and excessive lower facial height with a greater gonial angle.

MATERIALS AND METHODS

This is a retrospective study designed to evaluate cephalometrically the skeletal and dentoalveolar characteristics of Class III Korean children. Samples for this study were collected from the patients of the Department of Orthodontics at Kyung Hee Medical Center in Seoul. This study utilized the methods established by Walker, Kerr and Rothstein for taking skull measurements of sample groups by skeletal age and gender.[14-17] The Class I normal control group was composed of children with Class I molar and canine relationships, overjets and overbites between 2 and 4 mm, less than 3 mm of crowding, less than 1 mm of spacing, and no missing teeth other than third molars. They were typical representatives of Korean children in the city of Seoul from the 1990s to the early 2000s. All radiographs were assessed for skeletal age by the author using hand-wrist plates and the methodology of Greulich and Pyle.[18] Ages of 10, 12, and 14 were arbitrarily chosen by the author.

The Class III samples were selected from the children who visited the Department of Orthodontics Kyunghee Medical Center for orthodontic evaluation. The inclusion criteria for this sample were as follows: (1) Class III malocclusion as assessed from dental casts showing dental discrepancy greater than 4 mm; (2) no prior

Table 1. Sample selection: 6 control samples and 6 Class III samples. Sampled according to the skeletal age appropriate to the limits of the study regardless of chronological age. Skeletal age was assessed using handwrist X-rays using the Greulich and Pyle norms. The standards categorize age group by whole year or year and 6 months.

Control Samples					
Male			Female		
10 year group	n=10	10 years 6 months	10 year group	n=10	10 years 6 months
12 year group	n=10	12 years 6 months	12 year group	n=10	12 years 6 months
14 year group	n=10	14 years 6 months	14 year group	n=10	14 years 6 months
Class III Samples					
Male			Female		
10 year group	n=8	10 years 6 months	10 year group	n=9	10 years 6 months
12 year group	n=10	12 years 6 months	12 year group	n=10	12 years 6 months
14 year group	n=12	14 years 6 months	14 year group	n=11	14 years 6 months

orthodontic treatment; (3) no history of severe medical illness; (4) all first permanent molars were present; (5) radiographs of high quality were taken; and (6) skeletal age appropriate to the limits of the study regardless of actual age. Table I lists the characteristics of the control and the Class III group. The control and Class III group each had six subgroups : 3 groups of males and 3 groups of females. This model is the most accurate way of classifying and describing the dentition and the skeletal relationship of the lower jaw to the upper face. ANB and all the angles using N can be misleading and should be used only to help corroborate measurements, such as Wits.

Lateral cephalograms were scanned using UMAX Powerlook 1100 and UTA-1100 Transparency Adapter connected to a Windows Environment. Anatomical landmarks were identified using Adobe Photoshop 5.0, and measurements taken using Grab It from Datatrend. The Krogman-Walker plane (occipitale-maxillon) was used as the horizontal plane of orientation in this study with the y-axis perpendicular to the x-axis passing through Sella. The Krogman-Walker horizontal plane, as shown in Fig. 1, is defined by two highly reproducible endpoints, maxillon and occipitale, which are located in the mid-sagittal plane. Each landmark from the control and the Class III samples was sequentially located in a predefined sequence (Fig. 2). Twelve sets of landmark means, consisting of 3 groups of males and 3 groups of females, were constructed so that any statistical differences between the control and Class III groups could be verified.

Fig. 4 illustrates cephalometric measurements used in this study following the method of Rothstein. To measure errors of measurement, one lateral headfilm from each group was randomly selected and redigitized 3 times. The means of the differences between the landmarks in locating a single point relative to Sella was less than 0.7 mm. For each of the variables listed, descriptive statistics, including mean and standard deviation, were calculated for each subgroup in the control and Class III groups. 6 Student t-tests were conducted to compare the control sample with the Class III sample according to the each gender and age.

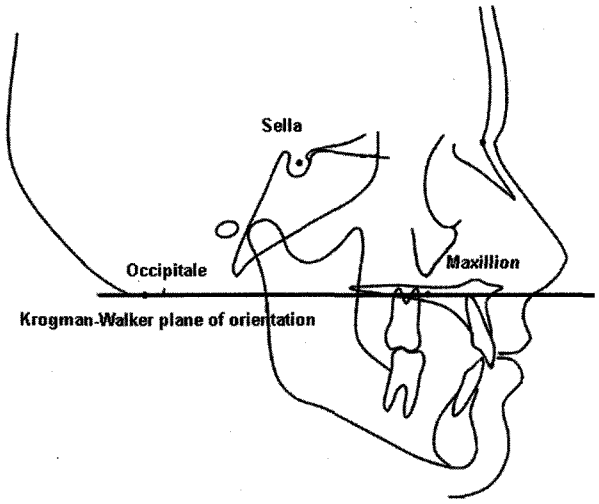

Fig. 1. The plane of orientation. Maxillion is a point below the Key Ridge, midway between the upper and lower border of the palate. Occipitale is the lowest point on the occipital bone.

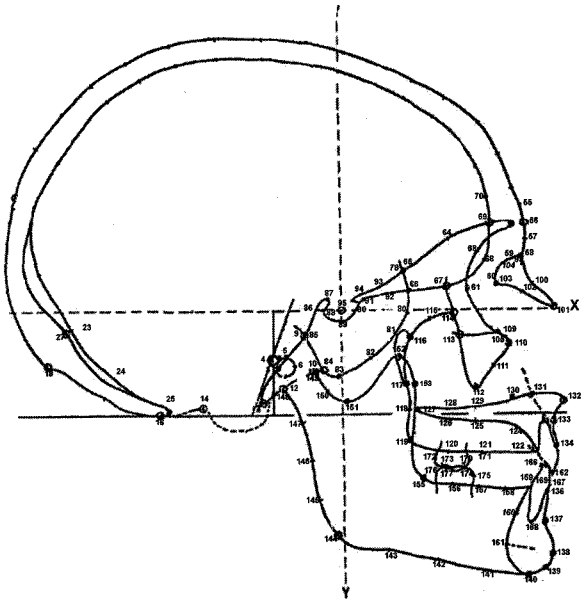

Fig. 2. Landmarks identified (after Rothstein, 2000. Edited with permission).

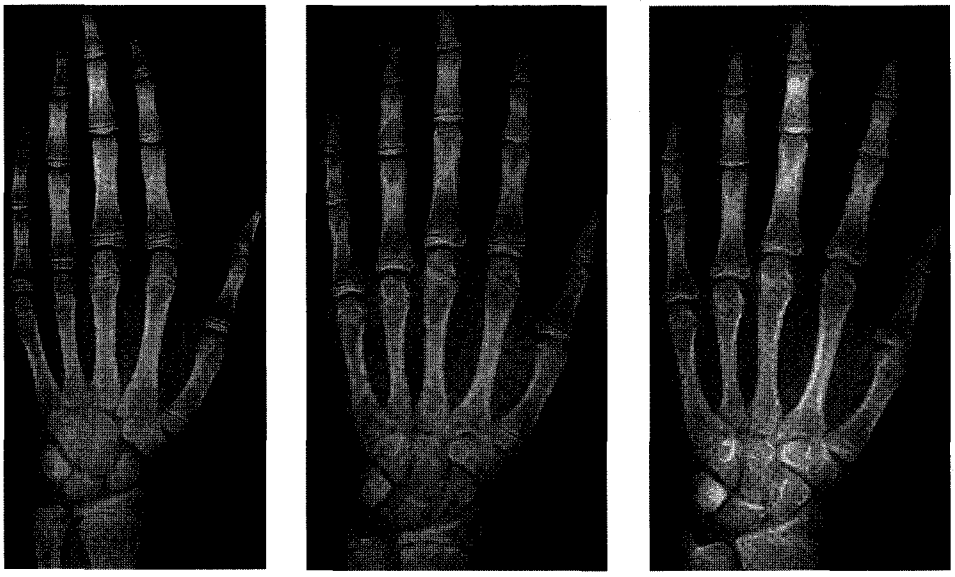

Fig. 3. Skeletal Ages from left to right 10 years 6 months, 12 years 6 months, and 14 years 6 months (after Greulisch and Pyle, 1959).

Table 3 lists the means and standard deviations for each of the subgroups in the female sample. Table 4 lists the means and standard deviations for each of the subgroups in the male sample. Each table lists all the variables and their definitions.

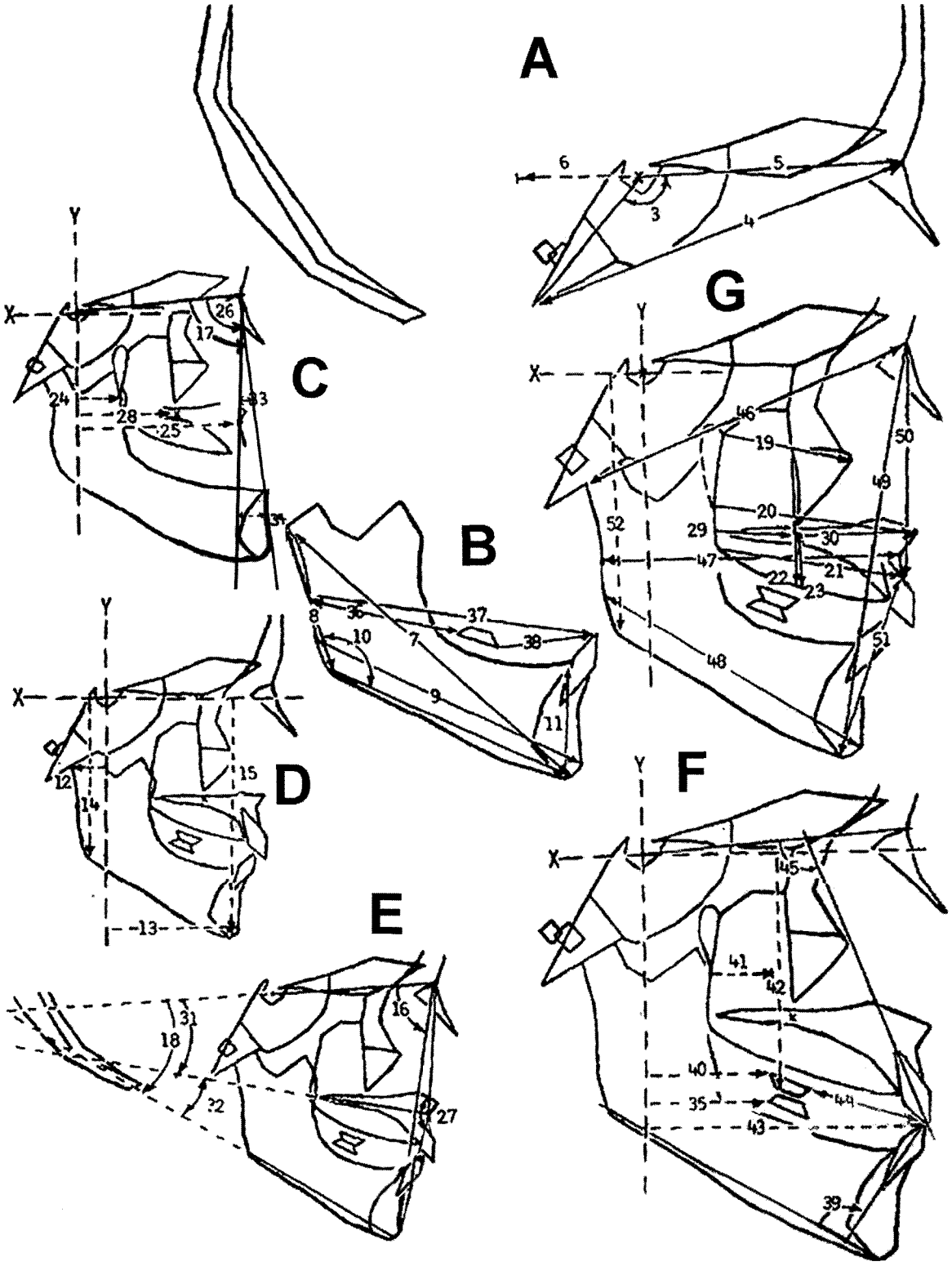

Fig. 4. Measurements used to describe size, form, and position of skeletal and dental anatomy in children with Class III malocclusion as compared with normal control group (after Rothstein, 2000. Edited with permission).

Table 2. Legends

Variable	Definition	Diagram
Cranial base		
Flexure (angle)	Ba-S-N	A 3
Total length	Ba-N	A 4
Anterior length	S-N	A 5
Posterior length	Ba-S	A 6
Mandible		
Overall length	Ar-Gn	B 7
Ramal height	Ar-Go	B 8
Corporal length	145-Pog	B 9
Ramo-corporal angle	Ar-Go-Gn	B 10
Symphyseal height	159-Me	B 11
159: infradentale posterior where the posterior symphysis and the superior border of the corpus meet at the lingual of Lower 1		
A-P relationship to Sella:		
Posterior mandible	Ar-S	D 12
Anterior mandible	S-Pog	D 13
Vertical relationship to Sella		
Posterior mandible	S-Go	D 14
Anterior mandible	S-Gn	D 15
A-P relationship of Pog to ACB (Anterior Cranial Base)	S-N-Pog	E 16
A-P relationship of point B to ACB	S-N-B	C 17
Slope in relation to ACB	[S-N]-[Go-Gn]	E 18
Maxilla		
Overall length at the level of:		
Orbit	Ptm-Malar	G 19
Palate	Ptm-ANS	G 20
Alveolus	Max. tuberosity-Pr	G 21
Overall mid-maxilla vertical height 114: supra-antral point where the line drawn from the superior part of the Ptm fissure intersects with the orbit of the eye. 121: midpoint between point maxillary tuberosity and orale (the point where palate and maxilla meet at the lingual of upper 1.	114-121	G 22
Palato-alveolar height	Max-121	G 23
Sella to posterior margin of maxilla	S-Ptm	C 24
Sella to anterior margin at midface	S-A	C 25
A-P relation off midface to ACB	S-N-A	C 26
Midfacial convexity	N-A-Pog	E 27
A-P relationship of key ridge to sella	S-Max	C 28
A-P rel. of key ridge to post max margin	PNS-Max	G 29
Length of anterior moiety of palate	Max-ANS	G 30
Slope of palate in relation to ACB	[S-N]-[PNS-A]	E 31
Palato-mandibular plane angle	[PNS-A]-[Go-Gn]	E 32
Maxilla-mandible		
AP alveolar discrepancy	A-N-B	C 33
Magnitude of discrepancy	B-A	C 34
Dentition		
Mandible to Mandibular molar		
AP relationship to Sella, from Sella to Distal of Lower 6	S-DL6	F 35
AP relationship to mid-ramal margin Mid-ramal margin: point midway between Articulare and Gonion	Mid RmPt-DL6	B 36
Mandible to mandibular incisor		
AP relationship to Sella	MidRmPt-L1	B 37
Molar/incisor separation	ML6-L1	B 38
Inclination	[L1-168]-[Go-Me]	F 39
Maxilla to Maxillary molar		
AP relationship to Sella	S-DU6	F 40
AP rel to post. max margin	Ptm-DU6	F 41
Vertical height from Sella	S-DCU6	F 42
Maxilla to Maxillary incisor		
AP relationship to Sella	S-U1	F 43
Molar/incisor separation	MU6-U1	F 44
Inclination in relation to ACB	[U1-164]-[S-N]	F 45
Facial depth		
Upper	Ar-N	G 46
Middle	MidRmPt-A	G 47
Lower 145: Ar-Go being divided into 4 equal parts, 145 is the point 3/4 the way inferior from Ar or 1/4 the way superior from Gonion.	145-Pog	G 48
Total anterior height	N-Me	G 49
Upper anterior height	N-Pr	G 50
Lower anterior height	Pr-Me	G 51
Total posterior height	S-Go	G 52

RESULTS

Results showing significantly different measurements that were identified in either all six inter-subgroup comparisons, or in at least five of the six comparisons between control and Class III population are mentioned in this section. A few cases indicated significant differences for either all three female or male subgroups. Fig. 5 shows measurements that were significantly different in at least five of the six inter-subgroup comparisons between the control and Class III malocclusion groups.

Cranial Base: The flexure of the cranial base and total length (A3 and A4) were smaller in Class III populations. Total length was smaller in all three female and male samples. Posterior cranial base (A6) was also smaller.

Mandible: In Class III, overall length of the mandible was greater (B7), largely due to differences in corporal length (B9). Ramo-corporal angle (B10) was significantly greater in all samples, and symphyseal height (B11) was significantly greater as well. Vertical height of the chin area was also greater in Class III (D15, E18). SNB (C17) and SNPog. (E16) was significantly larger for all six inter-subgroup comparisons. A large mandibular body in Class III populations is one of the causes of the increased SNB (B9) value.

Antero-posterior positioning of the mandible relative to Sella was not significant for the controls (D12).

Maxilla: Overall length of the maxilla was less (G20-22). The maxillary bone itself seems to be in stable position relative to the anterior cranial base (C24). However, results from G23 through G30 indicate a small maxillary complex in Class III populations. SNA (C26) was significantly less in all Class III subgroups.

Maxilla/Palate: The slope of the palate relative to the cranial base was significantly different only in males aged 12 and 14 (E31).

Maxilla-Mandible: The maxilla of the Class III subgroups was less prominent when compared to the controls ($p < 0.01$). The ANB angle (C33) and the distance from point A to point B as measured along the x-axis (C34) were significantly different when compared to the controls.

Mandibular Dentition : Significant differences were identified with regards to angular measurements (F35, B36-38, F39). The mandibular molar was located anterior relative to the mandible while the lower incisors were retroclined. The molar-incisor distances (B38) were greater in all age groups. The lower incisor inclination (F39) was significantly less in all 6 subgroups.

Maxillary Dentition: Significant differences were detected antero-posteriorly in all 6 inter-subgroup comparisons. The incisors were more anterior and more labially proclined (F43-45), while the molars were mesially positioned (F40-41).

Facial Depth and Height: The upper and middle facial depth (G46-47) was significantly less, while the lower facial depth was significantly greater. No significant difference was noted in upper anterior height, but lower facial height was greater (G49-52).

DISCUSSION

Cranial-facial complex growth is analyzed by antero-posterior and vertical direction relative to the cranial base. The growth of individual bones results in differences in facial forms, thus creating individuality.[19] Various methods have been proposed to evaluate or predict the growth of cranial-facial structures. But whether growth after adolescence can affect an individual, or if an individual's cranial-facial patterns are fixed early in life is in question. This is especially a big concern when dealing with Class II or Class III patients near their growth spurt. Should we start the treatment, or postpone it until we are sure that the patient's growth pattern can be categorized?

Mitani's study[20,21] showed that an individual's cranio-facial form is determined relatively early in life, and that after this an individual will show additive growth comparable to that seen in normal individuals. This study uses linear measurements without much consideration of the growth in the posterior cranial region.

Class III malocclusions can occur as a result of dental and/or skeletal configurations such as a small maxilla, a prognathic mandible, or an obtuse mandibular plane

Table 3. The measurements of each of the 50 variables for the control and Class III female samples. (Significantly different measurement is indicated by asterisks. Levels of significance: * P < 0.05, ** P < 0.01.)

Females			Class I						Class III					
	Definition	Diagram	Age 10		Age 12		Age 14		Age 10		Age 12		Age 14	
			mean	s.d.	mean	s.d.	mean	s.d.	Mean	s.d.	Mean	s.d.	mean	s.d.
Cranial base														
Flexure (angle)	Ba-S-N	A 3	131.4	5.7	133	5.3	134.3	5.9	127.9	6.6*	128.2	7.1*	128.7	6.0*
Total length	Ba-N	A 4	99.2	5.1	100.1	4.7	101.4	4.8	97.3	5.8*	98.0	4.6*	98.7	4.8**
Anterior length	S-N	A 5	63.1	3.3	63.6	3.3	64.5	2.1	62.8	3.2	62.7	3.2	63.6	4.2
Posterior length	Ba-S	A 6	23.2	3.1	23.9	2.8	24.5	2.8	22.7	3.2	22.1	2.7*	23.2	3.0*
Mandible														
Overall length	Ar-Gn	B 7	107.7	6.2	109.7	5.6	110.7	5.1	118.6	6.3**	118.7	5.4**	122.5	5.5**
Ramal height	Ar-Go	B 8	47.6	3.7	46.8	3.2	47.5	3.8	48.1	3.6	47.6	3.2	48.1	3.7
Corporal length	145-Pog	B 9	75.8	5.8	75.1	4.9	76.1	5.5	77.1	5.6**	77.3	4.5**	77.9	5.6**
Ramo-corporal angle	Ar-Go-Gn	B 10	125	5.8	124.4	6.6	125.4	5.8	129.7	6.6**	128.8	6.7**	129	5.7*
Symphyseal height	159-Me	B 11	30.9	3.0	31.9	3.0	34.8	3.2	31.9	2.9	32.1	2.8	35.9	3.3*
A-P relationship to sella:														
Posterior mandible	Ar-S	D 12	14.0	2.9	14.3	2.6	15.1	2.6	14.5	2.6	15.8	2.2	16.7	2.4*
Anterior mandible	S-Pog	D 13	55.9	7.1	57.9	6.5	61.2	6.6	58.7	6.5*	59.4	6.7*	64.0	7.1**
Vertical relationship to Sella														
Posterior mandible	S-Go	D 14	70.7	4.8	71.6	3.1	71.6	4.8	71.2	4.3	71.6	3.1	74.6	4.6
Anterior mandible	S-Gn	D 15	99.1	5.7	100.2	4.9	103.5	6.2	100.9	5.9	102.8	4.5*	105.2	6.5**
A-P relationship of Pog to ACB	S-N-Pog	E 16	77.0	3.1	78.1	3.9	78.3	4.3	84.3	3.2**	83.7	4.1**	82.1	3.7**
A-P relationship of point B to ACB	S-N-B	C 17	76.0	3.1	77.0	3.5	77.7	3.9	82.1	3.2**	81.9	3.5**	81.0	4.0**
Slope in relation to ACB	[S-N]-[Go-Gn]	E 18	33.9	5.2	34.8	7.4	34.2	5.8	35.2	5.8*	36.3	5.8*	37.7	6.1**
Maxilla														
Overall length at the level of:														
Orbit	Ptm-Mal	G 19	34.2	2.3	34.7	2.9	34.1	2.8	35.4	2.5	33.5	2.6	35.9	2.6
Palate	Ptm-ANS	G 20	48.5	3.4	49.5	3.6	52.3	3.5	46.1	3.2	48.0	3.6*	49.8	3.8*
Alveolus	Max. tuberosity-Pr	G 21	49.4	3.5	52.7	4.2	52.4	6.2	48.1	3.5*	48.0	3.7**	48.5	6.5**
Overall mid-maxilla vertical height	114-121	G 22	45.6	4.6	48.5	4.1	49.5	4.1	45.1	4.6	46.3	4.1*	47.9	4.1*
Palato-alveolar height	Max-121	G 23	10.6	1.6	12.7	2.3	13.0	2.5	10.1	1.9	13.2	2.2	12.5	2.3
Sella to posterior margin of maxilla	S-Ptm	C 24	17.4	2.4	18.0	2.4	17.9	2.8	17.1	2.5	17.5	2.4	18.1	2.9
Sella to anterior margin at midface	S-A	C 25	65.4	4.4	66.0	4.6	68.8	3.9	63.1	4.4*	64.1	4.3**	65.2	4.4**
A-P relation off midface to ACB	S-N-A	C 26	79.9	4.0	80.5	3.4	80.9	3.9	77.9	3.6**	78.5	3.6**	78.1	3.6**
Midfacial convexity	N-A-Pog	E 27	170.5	6.9	170.8	4.8	172.6	5.1	177.9	5.1**	179.6	5.4**	182.5	3.8**
A-P relationship of key ridge to Sella	S-Max	C 28	39.5	3.2	39.7	3.6	41.8	3.2	40.2	3.4	38.3	3.5	39.8	2.9*
A-P rel. of key ridge to post max margin	PNS-Max	G 29	22.1	5.2	22.5	4.1	23.5	3.5	21.1	2.5	22.4	2.3	21.1	2.6
Length of anterior moiety of palate	Max-ANS	G 30	25.6	2.8	26.7	2.9	27.2	3.6	24.6	2.8	25.7	3.2*	23.5	3.8**

Table 3. The measurements of each of the 50 variables for the control and Class III female samples. (Significantly different measurement is indicated by asterisks. Levels of significance: * P < 0.05, ** P < 0.01.)

Females			Class I						Class III					
	Definition	Diagram	Age 10		Age 12		Age 14		Age 10		Age 12		Age 14	
			mean	s.d.	mean	s.d.	mean	s.d.	Mean	s.d.	Mean	s.d.	mean	s.d.
Slope of palate in relation to ACB	[S-N]-[PNS-A]	E 31	13.4	3.8	13.2	4.9	12.1	4.6	13.9	3.5	14.7	4.8	13.2	4.3
Palato-mandibular plane angle	[PNS-A]-[Go-Gn]	E 32	17.6	5.8	18.6	8.6	17.0	5.5	18.0	5.5	19.2	5.8	18.6	4.1*
Maxilla-mandible														
AP alveolar discrepancy	A-N-B	C 33	3.9	1.1	3.5	1.5	3.2	1.6	0.8	2.0**	-1.4	1.6**	-2.9	2.1**
Magnitude of discrepancy	B-A	C 34	5.8	3.0	5.6	2.7	5.2	2.0	1.3	4.3**	-3.6	3.4**	-6.8	4.0**
Dentition														
Mandible to Mandibular molar:														
AP relationship to SellaSella	S-DL6	F 35	29.9	4.0	30.5	4.9	36.1	4.5	30.8	4.5	33.1	4.9*	38.8	4.1*
AP relationship to mid-ramal margin	Mid RmPt-DL6	B 36	39.5	3.3	41.8	4.3	44.7	3.4	41.7	3.5*	43.2	4.7*	46.9	3.9**
Mandible to mandibular incisor:														
AP relationship to Sella	MidRmPt-L1	B 37	76.4	5.1	77.6	4.3	79.4	4.9	77.9	5.0*	79.1	4.4**	81.9	5.3**
Molar/incisor separation	ML6-L1	B 38	26.9	3.6	26.6	2.7	26.9	2.3	28.8	3.6*	28.1	2.7*	30.0	2.2**
Inclination	[L1-168]-[Go-Me]	F 39	95.6	8.9	97.0	8.6	99.5	7.9	88.8	7.9**	84.8	8.8**	79.4	8.0**
Maxilla to Maxillary molar:														
AP relationship to Sella	S-DU6	F 40	27.7	4.1	28.6	4.2	32.6	3.9	25.8	4.5*	27.5	4.6	30.1	4.1*
AP rel to post. max margin	Ptm-DU6	F 41	9.3	3.2	10.8	3.4	12.5	2.5	8.3	3.2	10.5	3.5*	10.5	2.4*
Vertical height from Sella	S-DCU6	F 42	57.1	3.5	58.5	4.0	59.2	4.0	55.9	3.2	56.2	3.9*	58.1	4.1*
Maxilla to Maxillary incisor:														
AP relationship to Sella	S-U1	F 43	68.2	7.6	70.0	6.5	71.8	4.8	64.8	8.1*	65.3	7.1**	66.6	5.4**
Molar/incisor separation	MU6-U1	F 44	31.3	3.2	30.8	3.0	31.4	2.2	26.2	3.2	28.0	2.7*	28.6	2.4*
Inclination in rel to ACB	[U1-164]-[S-N]	F 45	101.3	6.9	101.2	7.0	100.7	7.8	107.6	7.1**	106.3	7.3**	107.6	7.8**
Facial depth														
Upper	Ar-N	G 46	93.4	4.8	92.8	4.8	94.0	4.8	90.5	5.0*	89.8	4.7**	91.9	4.7**
Middle	MidRmPt-A	G 47	75.2	5.4	76.4	4.0	78.0	4.3	73.0	5.6*	74.1	4.2**	75.4	5.2**
Lower	145-Pog	G 48	65.8	5.3	67.1	5.2	67.1	5.3	67.4	5.3**	69.5	4.8**	69.9	5.1**
Total anterior height	N-Me	G 49	108.9	6.7	111.1	5.8	114.4	7.2	113.7	7.6**	115.5	6.4**	119.6	6.7**
Upper anterior height	N-Pr	G 50	65.5	4.9	65.8	5.1	67.4	5.0	66.1	5.1	67.0	4.5	68.5	5.5
Lower anterior height	Pr-Me	G 51	48.5	4.2	48.6	3.2	51.3	5.1	50.1	3.7*	50.5	3.7*	53.7	5.0*
Total posterior height	S-Go	G 52	67.7	4.3	68.1	3.6	69.6	4.6	69.8	4.5*	68.6	3.3	71.2	4.8

Table 4. The measurements for each of the 50 variables for the control and Class III male samples. (Significantly different measurement is dicated by asterisks. Levels of significance: * P < 0.05, ** P < 0.01.)

Females			Class I						Class III					
	Definition	Diagram	Age 10		Age 12		Age 14		Age 10		Age 12		Age 14	
			mean	s.d.	mean	s.d.	mean	s.d.	Mean	s.d.	Mean	s.d.	mean	s.d.
Cranial base														
Flexure (angle)	Ba-S-N	A 3	130.7	4.7	131.5	7.2	131.1	4.8	128.3	4.9*	127.4	5.9**	127.2	4.9**
Total length	Ba-N	A 4	99.7	3.4	101.8	4.9	103.7	5.5	97.9	3.6*	99.6	4.2**	101.0	5.0**
Anterior length	S-N	A 5	64.4	2.6	64.8	2.6	67.0	3.8	63.0	2.7	63.0	3.4*	65.7	3.3*
Posterior length	Ba-S	A 6	23.0	2.4	24.3	2.7	25.2	2.9	22.7	2.2	22.5	2.9*	23.1	3.0**
Mandible														
Overall length	Ar-Gn	B 7	107.5	4.5	110.9	3.7	111.8	3.0	121.1	5.8**	122.5	3.6**	125.4	3.2**
Ramal height	Ar-Go	B 8	47.1	3.3	47.3	3.0	47.0	3.9	48.9	3.1	46.8	3.1	48.6	4.9
Corporal length	145-Pog	B 9	74.4	4.0	76.7	3.0	77.7	4.9	75.9	4.3*	78.9	5.2**	79.9	4.9**
Ramo-corporal angle	Ar-Go-Gn	B 10	124.1	4.8	123.8	4.4	123.6	4.9	129.6	4.9**	127.9	4.2**	128.5	5.4**
Symphyseal height	159-Me	B 11	32.3	2.8	34.0	2.8	35.5	3.8	34.0	2.9*	36.0	3.0	37.3	3.9*
A-P relationship to sella														
Posterior mandible	Ar-S	D 12	13.8	2.2	14.0	2.0	14.9	2.3	14.3	2.0	15.3	2.4	16.1	2.4*
Anterior mandible	S-Pog	D 13	57.4	5.9	59.8	5.5	62.7	7.0	62.7	5.5**	64.7	5.5**	66.9	6.9**
Vertical relationship to Sella														
Posterior mandible	S-Go	D 14	70.5	3.9	72.5	5.0	75.7	6.2	70.5	3.9	73.1	4.3	77.3	5.9
Anterior mandible	S-Gn	D 15	100.5	4.1	107.5	7.2	110	6.7	101.7	4.2	109.0	7.1*	113.1	7.4*
A-P relationship of Pog to ACB	S-N-Pog	E 16	77.6	3.6	78.3	3.6	79.4	3.5	83.9	3.3**	84.8	3.8**	85.5	3.4**
A-P relationship of point B to ACB	S-N-B	C 17	77.0	3.1	77.5	3.5	78.7	3.2	80.7	3.1**	81.4	4.1**	83.1	3.6**
Slope in relation to ACB	[S-N]-[Go-Gn]	E 18	34.4	5.2	34.8	5.4	35.1	5.0	36.1	5.1*	36.4	4.9**	38.1	4.3**
Maxilla														
Overall length at the level of														
Orbit	Ptm-Mal	G 19	34.5	2.8	36.4	2.8	36.9	3.2	33.9	2.7	37.6	2.8	37.1	3.1
Palate	Ptm-ANS	G 20	49.8	3.2	51.0	3.7	54.1	3.8	47.8	3.3*	45.9	3.6**	49.4	3.8**
Alveolus	Max. tuberosity-Pr	G 21	50.2	4.2	53.4	3.6	54.5	4.4	45.9	4.6**	46.5	4.0**	50.6	3.7**
Overall mid-maxilla vertical height	114-121	G 22	46.7	2.0	50.5	3.4	54.4	4.6	45.0	2.3	48.8	3.6*	52.2	4.2*
Palato-alveolar height	Max-121	G 23	13.5	1.5	14.6	2.2	14.7	2.2	12.4	1.5	13.7	1.9	13.1	2.2*
Sella to posterior margin of maxilla	S-Ptm	C 24	17.4	1.9	17.5	2.4	18.4	2.6	16.8	2.0	17.3	2.6	17.9	2.5
SellaSella to anterior margin at midface	S-A	C 25	67.8	4.2	68.5	4.3	70.1	4.6	61.3	4.1**	63.3	4.1**	65.1	4.7**
A-P relation off midface to ACB	S-N-A	C 26	80.2	3.2	81.8	3.9	81.2	3.1	78.1	3.0**	78.1	3.7**	78.2	3.0**
Midfacial convexity	N-A-Pog	E 27	170.9	4.2	172.5	4.7	174.1	4.5	179.5	4.5**	183.8	4.7**	185.2	4.8**
A-P relationship of key ridge to sella	S-Max	C 28	42.0	2.7	43.6	2.8	43.7	3.5	40.3	2.5*	41.3	2.9	39.2	3.1**
A-P rel. of key ridge to post max margin	PNS-Max	G 29	20.4	4.3	24.8	5.2	22.9	4.5	21.2	2.1	23.1	2.3	20.1	2.4**

Table 4. The measurements for each of the 50 variables for the control and Class III male samples. (Significantly different measurement is dicated by asterisks. Levels of significance: * P < 0.05, ** P < 0.01.)

Females			Class I						Class III					
	Definition	Diagram	Age 10		Age 12		Age 14		Age 10		Age 12		Age 14	
			mean	s.d.	mean	s.d.	mean	s.d.	Mean	s.d.	Mean	s.d.	mean	s.d.
Length of anterior moiety of palate	Max-ANS	G 30	24.9	2.2	25.6	2.7	26.5	3.1	22.5	2.5*	22.4	3.1**	23.8	3.0**
Slope of palate in relation to ACB	[S-N]-[PNS-A]	E 31	13.5	4.5	14.9	4.1	13.4	4.3	14.1	4.2	13.4	4.2*	12.2	4.8*
Palato-mandibular plane angle	[PNS-A]-[Go-Gn]	E 32	17.1	4.1	16.7	3.6	17.6	4.7	18.2	3.6	17.5	4.4**	19.0	4.1*
Maxillamandible														
AP alveolar discrepancy	A-N-B	C 33	3.2	2.0	3.5	1.4	2.5	1.2	-2.6	1.9**	-3.3	2.3**	-5.7	2.0**
Magnitude of discrepancy	B-A	C 34	5.5	2.9	5.7	2.6	6.0	3.2	-6.1	2.8**	-7.1	2.1**	-11.9	3.3**
Dentition														
Mandible to Mandibular molar														
AP relationship to Sella	S-DL6	F 35	29.0	3.3	32.8	3.7	37.8	4.9	30.6	3.7	33.1	4.2*	37.2	4.9*
AP relationship to mid-ramal margin	Mid RmPt-DL6	B 36	39.3	3.2	43.2	3.2	45.0	4.5	42.7	3.4*	47.1	3.5**	49.9	4.2**
Mandible to mandibular incisor														
AP relationship to Sella	MidRmPt-L1	B 37	75.0	4.6	78.9	3.5	81.8	4.6	79.2	4.9**	82.3	3.5**	85.3	4.6**
Molar/incisor separation	ML6-L1	B 38	26.3	2.4	27.0	2.3	27.5	2.8	28.1	2.1*	29.1	2.1*	30.7	3.0**
Inclination	[L1-168]-[Go-Me]	F 39	95.9	5.7	97.6	6.4	98.4	4.3	82.2	5.8**	79.7	7.0**	78.3	4.6**
Maxilla to Maxillary molar														
AP relationship to Sella	S-DU6	F 40	27.4	3.4	30.8	3.7	34.3	4.2	25.9	3.2*	28.8	3.9*	32.0	4.0*
AP rel to post. max margin	Ptm-DU6	F 41	10.9	2.9	11.9	2.9	12.8	3.6	9.9	3.2	10.0	2.9*	9.6	3.4**
Vertical height from SellaSella	S-DCU6	F 42	57.4	2.7	60.7	4.4	63.3	4.8	58.0	3.1	61.1	4.3	63.7	4.5
Maxilla to Maxillary incisor														
AP relationship to Sella	S-U1	F 43	69.5	5.2	71.7	4.3	73.5	3.5	63.0	5.4**	64.6	4.3**	67.1	2.1**
Molar/incisor separation	MU6-U1	F 44	30.2	3.0	31.3	3.2	32.6	4.1	27.1	3.2**	28.6	3.2*	28.2	3.4**
Inclination in rel to ACB	[U1-164]-[S-N]	F 45	101.6	6.7	101.5	8.0	102.2	7.9	108.0	6.7**	107.0	9.0**	109.2	8.3**
Facial depth														
Upper	Ar-N	G 46	92.8	3.8	93.2	4.2	93.0	5.1	89.9	3.6*	88.0	4.1**	88.3	5.1**
Middle	MidRmPt-A	G 47	75.7	3.9	77.0	3.7	80.5	4.9	72.4	4.0**	74.0	4.1**	74.1	4.6**
Lower	145-Pog	G 48	72.4	4.4	73.7	3.0	75.7	5.1	74.9	4.0**	75.8	3.2**	78.4	4.1**
Total anterior height	N-Me	G 49	111.7	4.6	114.2	6.6	119.1	6.5	115.1	4.1**	118.5	6.5*	124.4	7.0**
Upper anterior height	N-Pr	G 50	65.9	2.9	67.4	4.2	70.2	4.3	67.0	3.0*	67.9	3.8	71.4	4.1
Lower anterior height	Pr-Me	G 51	50.8	2.8	50.6	4.0	53.8	3.6	52.7	3.1*	51.3	4.1	55.4	3.6*
Total posterior height	S-Go	G 52	67.5	3.7	70.5	4.6	75.7	5.6	67.6	4.0	71.8	4.6	76.3	5.5

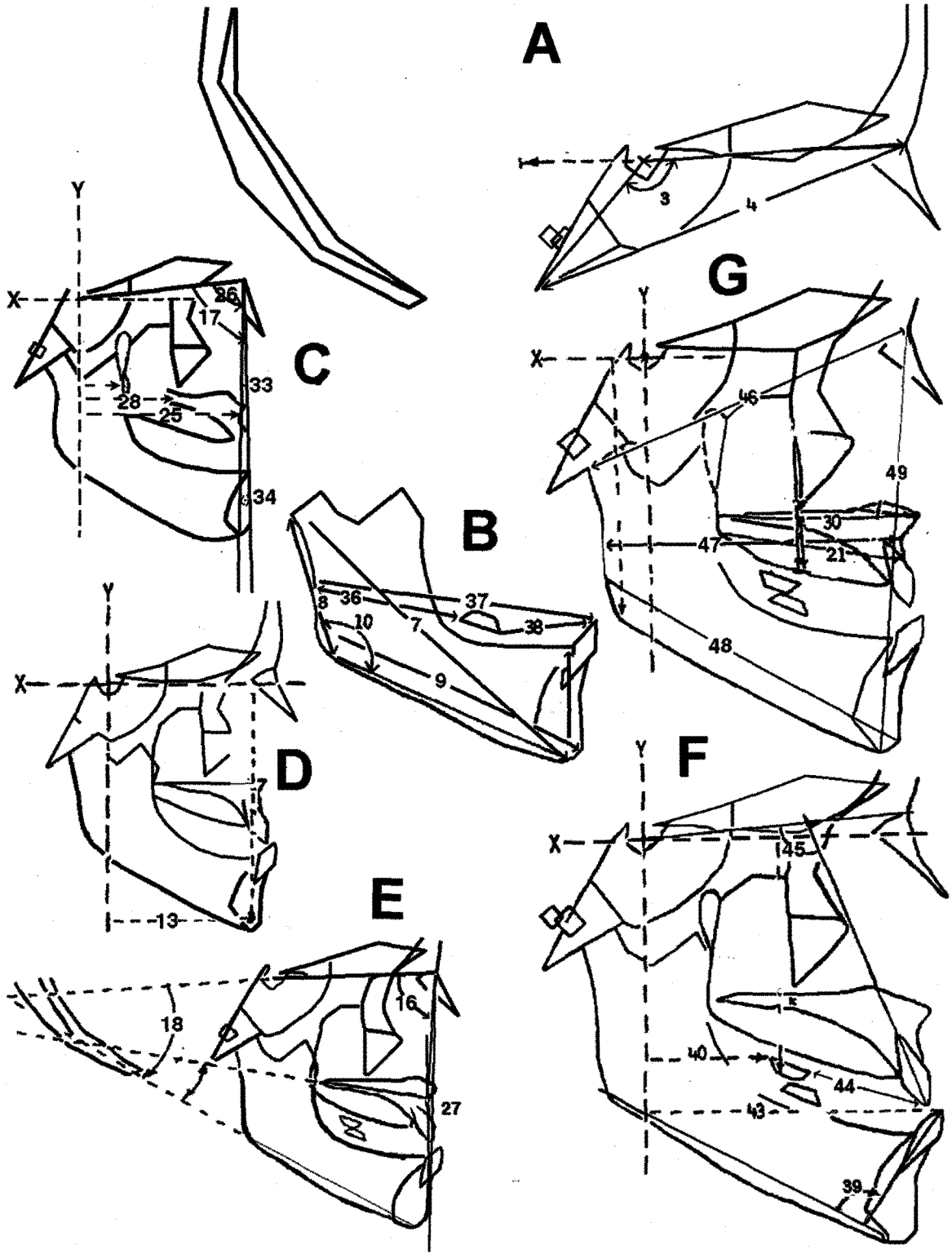

Fig. 5. Significantly different measurements identified in the Class Ⅲ sample.

angle. Moorrees observed that the degree of variation increased with the distance of the landmarks from the basic orientation axis in both vertical and horizontal distances.[22,23] The Krogman-Walker plane was used in this study because this plane passes through the mid-face, which reduced the variability of endpoints in the middle and lower face. The Krogman-Walker plane also closely approximated the natural position of the head, making it more reliable in the assessment of antero-posterior deviations.

The N-A-Pog (E27) angle indicated that the Class III population had significant mid-facial concavity with a retrusive maxilla (C26, E26). This finding was present in all six inter-subgroup comparisons between normal and Class III malocclusions. Frontal bone thickness was not assessed in this study due to difficulties in identifying the landmarks. The author found less than 1 mm S-N horizontal growth change in Class III females between age 10 and 14 (A5). S-N-Pog (E16) difference between Class I and Class III is significant in the $P<0.001$ level. However, this value decreases from age 10 (84.3) to age 14 (82.1) in the female Class III group. This tendency is also found in S-N-B (C17).

The maxillary retrusion found in the 10-year-old Class III males may be due to the fact that growth is not complete at this age. Moss considers the form and spatial position of the bony elements to be a direct response to the primary growth of the functioning soft tissues and the spaces that they protect and support.[24] The maxilla, for instance, is viewed as a conglomerate of relatively independent bony components, and its form is related to the teeth, the orbital contents, the respiratory function, and the muscle attachments. We found that S-DU6 (F40) values show upper molar forward movement with age in both the male and female Class I and Class III groups. This coincides with the findings regarding the overall length of the maxilla. Length of the maxillary bone is significantly smaller at the alveolar level. The length differences between control and Class III populations are insignificant at the orbital level (G19, G20, G21).

The maxilla is known to maintain a retruded relationship to the cranial base and does not become more prominent with time. In contrast, the mandible is protrusive even in the late deciduous dentition, and becomes more protrusive with time, making the discrepancy between the upper and lower jaws increasingly severe.[25] Anterior positioning of mandibular ramus and clockwise rotation of the mandibular chin area are some of the characteristics found in Class III patients.

Landmarks representing facial depth, the size of the maxilla and the mandible, and the AP relationship of the maxilla and the mandible (including anterior facial height) indicate that growth characteristics are determined early in life (B7 thru B11, G46 thru G50). But the growth pattern of the cranial base and some of the dental landmarks show progressive divergence between Class I and Class III populations with age (A3 thru A6, F35, B36, B38, F40, F41). This need to be verified in future studies with more samples and more indicators of growth, such as biologic markers of bone metabolism in urine or the growth hormone receptor gene. N-A-Pog (E 27) increases from 178 to 183. This does not mean facial convexity is diminishing with growth; an E27 value larger than 180 means that the value is negative and that mandibular growth excels maxillary growth.

In one measurement growth change with age showed contradictory results. The S-N-Pog mean value was found to decrease with age in females, while the value increases with age in males. The same phenomenon is found with S-N-B. However, in both of the cases the difference from the control sample is significant in 0.01 level. Anterior-posterior discrepancy of the A-N-B shows a decrease with aging in both males and females. The value is negative except in the 10-year-old female group. S-Pog (D13) increases 5 mm in the Class III female population from 10 to 14 years old. The lower incisor angle (F39) gets almost 10 mm more lingually inclined in the 10 to 14 year old Class III female population, while the control female group gets 4 degrees greater.

Landmarks located in the lower anterior region of the mandible were all located anteriorly in Class III Landmarks located in the lower anterior region of the mandible were

all located anteriorly in Class III populations. Larger mandibular planes observed in this study coincided with the study done by Sanborn.[26] The Class III Asian population largely results from mandibular prognathism.[27,28] The large vertical height in the lower anterior region coincides with previous findings.[29] Differences in size, form, and the position of the mandible, as well as vertical dysplasia of the maxilla are addressed in this study.

The data from this study indicates that Class III malocclusions in the Korean children compared with Class I control groups are consistent with skeletal dysplasia, in both the size of the maxilla and the size, form and position of the mandible. The Cartesian coordinate system used in the study was essential for interpreting the significance of the angles commonly used to describe the size, form and position of the dental and cranio-facial skeleton.

The maxilla at point A was growth deficient while the maxillary incisors were excessively proclined. Excessive vertical growth of the maxillary molars does not contribute to the vertical dysplasia found in the lower third of the anterior facial height. The corpus of the mandible was decidedly longer and the gonial angle was significantly more obtuse. The mandibular molar was found to be more mesial in relation to the posterior border of the ramus. Ramus height was similar to the Class I controls. The position of the posterior border of the mandible was found to be significantly forward (Ar-S, D12) in both females and males by the age of 14, and at the anterior border in males and females at all ages. The mandibular incisors were significantly more retroclined and with growth became even more so. The significantly larger total facial height was found to be caused exclusively by the excess in the lower third of the total anterior facial height. The vertical excess continues to worsen because of the posterior vertical growth (D14). Ar-Go (B8) shows that there is almost no growth in size in either the control or the Class III groups. Anterior borders of the mandible are more excessive in the Class III group. Even though we found the cranial base angle to be smaller, there is good reason to believe that the combined effects of the maxillary and mandibular attributes are the major etiologic factors for the development of the Class III malocclusion. In addition, Rothstein's study shows that while the cranial base angle in the Class II division 1 was somewhat larger than in the control groups, the size, form and position of the mandible was virtually identical to the controls in Class II samples. The lower molar of Class III females grows significantly more than the control females.

In the Class III female population, the vertical growth (D14) is greater than in the control group, as is the mandibular plane angle in relation to the anterior cranial base (E18). The combined effect of both results is the anterior mandible moving to a more downward and retrusive position (counterclockwise/hyperdivergent growth). This effect is identical in Class III males. However, we do not see negative growth in S-N-Pog. because in the Class III male population corpus length growth (which includes development of the chin button) is so excessive that it overcomes the clockwise rotation. It is therefore important to note that conclusions drawn from angular measurements, especially those using points N, A, B and Pog. must always be used in conjunction with supporting data from the linear coordinates of shape and shape-change studies. The angular measurements can be misleading because we cannot assume that N is located in a position of normalcy. In fact, point N in Class III population may be horizontally deficient and/or vertically higher or lower than the "norm" as well. Consequently, if a sample has a shorter and more superiorly positioned Nasion (i.e shorter anterior cranial base), the SNB angle will suggest a very retrusive mandible, which can be misleading. Likewise, if both N and Pogonion are deficient or excessive and/or vertically higher or lower, this can make it difficult for an orthodontist to understand the morphology of the Class III population.

The method described by Krogman[14] and Rothstein[1] was used in this study to evaluate the characteristics of the Class III Korean population. Class III malocclusions studied here showed that both the maxillary deficiency and the mandibular excess are the primary factors.

However, there is a much higher portion of the population with large mandibles when compared to the Caucasian population.[10]

CONCLUSION

The data in this study supports the following conclusions

1. Class III relationship is caused by a more anteriorly positioned mandible compared to the maxilla. The discrepancy starts early and is partly the result of deficiency and retrusion of the maxillary complex. Another reason is the flexure of the anterior cranial base, the large mandibular corporal length, and vertical height resulting in protrusion of the mandible at an early age. These differences between normal and Class III populations start as early as 10 years of age both in males and females. However, this tendency is greater in males.
2. The hyperdivergency of the mandibular plane becomes more significant when both the male and female populations reach 12 years of age. However, accelerated growth of the mandible itself starts earlier.
3. Maxillary deficiencies in the Class III population become significant at as early as 10 years of age.
4. Excessive anterior vertical growth is mainly due to the change in the anterior segment of the mandible. The mandibular body is more protrusive and inferiorly positioned in the Class III population.
5. Vertical dysplasia is a typical finding in Class III malocclusions. This phenomenon increases when the population reaches the age of 12.
6. Small anterior cranial base length may be one of the factors contributing to the development of Class III malocclusions.
7. This study supports the report of Dibbets regarding the association between the Angle classification and the cranial-facial form.[30] A decrease in cranial base flexure (Ba-S-N, 3A) is found to contribute to a protruded mandibular position, for this angle was found to be significantly smaller in all six inter-sub-group comparisons. However, the combined effects of the maxillary and mandibular attributes are the major etiologic factors for the development of Class III malocclusions.

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국문초록

10세에서 14세 사이 III급부정교합자의 치아안면두개의 형태학적 특성에 대하여

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이 연구는 두부X선 규격사진을 이용하여 III급 부정교합자의 안모를 연령 성별로 분류하고, 각 분류에 대한 두개 안면 형태의 특성을 구명하기 위하여 시행되었다. 정상교합자 60명과 III 급 부정교합자 60명을 표본으로 하였으며 각 군은 10세, 12세, 14세 군 남녀로 구분되었다. 50개의 선 및 각계측치를 Krogman-Walker 의 기준평면을 기준하여 측정하였다

1. III 급 부정교합군은 전방두개저의 길이와 안상각이 정상교합자군에 비하여 작고 하악골체와 하악수직고경이 큰 것으로 나타났으며, 이러한 차이는 남녀 모두 10세부터 유의하게 나타났다. III 급 부정교합군에서의 하악하연각의 유의한 증가는 남녀 모두 12세때 나타났다.
2. III급 부정교합자군에서의 상악골의 후방 위치와 상악골체 크기의 유의한 감소는 남녀 모두 10세부터 나타난다.

3. III급 부정교합자군에서 유의한 하안면부 수직고경의 증가는 주로 하악골체 크기의 변화에 기인하는 것으로 관찰되었다. 하악골체의 경우 III급 부정교합자군에서 더 크고 전하방에 위치하는 것이 관찰되었다. III급 부정교합자군에서의 전체적인 수직고경의 유의한 증가는 12세군에서 유의하게 나타나기 시작한다.
4. 본 연구에서는 III급 부정교합자군에서의 두개저부각의 감소와 (Ba-S-N, 3A) 하악골체의 전방 위치는 남녀 모든 연령층에서 일관되게 관찰되었다. 이 결과는 Rothstein 등에 의해 주장된 II급 부정교합자군에서의 두개저부각의 변화가 하악골체의 전후방 위치에 영향을 주지 못한다는 주장을 부정하며, 디벳 등에 의해 주장된 앵글씨의 부정교합분류와 두개안면형태의 상관성에 대한 연구를 지지한다.

주요 단어 : 한국인, III급 부정교합, 두부X선규격사진, Krogman-Walker 평면.