Research paper

Facial average soft tissue depth variation based on skeletal classes in Indonesian adult population: a retrospective lateral cephalometric study

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Highlights

- Database of 10 midline facial landmarks average soft tissue thickness grouped into 3 skeletal classes in Indonesian adult population is presented in this study.
- Significant difference among skeletal classes occurred in male lower lip.
- Significant differences among skeletal classes occurred in female subnasale, upper lip, stomion, lower lip and labiomentale.
- A generic pattern of deeper upper lip than lower lip in class III compared to class II and conversely, deeper lower lip than upper lip in class II compared to class III, was visible in both male and female groups.

Abstract

Objective: To understand the influence of three types of skeletal classes (Class I, Class II and Class III) on midline average soft tissue depth (ASTD).

Methods: Lateral cephalograms of 335 pre-treatment orthodontic patients were obtained from the archive of Radiology Clinic Universitas Padjadjaran Dental Hospital Bandung Indonesia. The linear measurements of 10 midline facial landmarks ASTD and angular measurement of ANB were extracted and analysed statistically.

Results: A database of ASTD grouped by skeletal classes, specific for the Indonesian population, within the South East Asian ancestry group was obtained.

Conclusions: A generic pattern of deeper upper lip than lower lip in class III compared to class II and conversely, deeper lower lip than upper lip in class II compared to class III, was visible in both male and female groups.

Keywords: average soft tissue depths, facial soft tissue thickness, skeletal classes, craniofacial reconstruction, Indonesia

Introduction

Craniofacial reconstruction (CFR) is a method used to estimate and depict a face based on the morphology and morphometry of the underlying skull. The reconstructive method is predominantly employed for archaeological purposes to reconstruct the face of a person long dead or in forensic investigations to assist with the identification process [1,2]. The nomenclature and techniques for CFR vary depending on the practitioners' preferences. There are three primary techniques mentioned in the literature:

- the application of Average Soft Tissue Depths (ASTD) pins on the craniofacial landmarks based on the sex, age and ancestry estimation of the skull [3];
- (ii) masticatory and neck muscles sculpting followed by limited ASTD application [4];
- (iii) a combination technique of ASTD, anatomical structure modelling and facial feature estimation [1,2,5].

There are numerous studies providing ASTD data based on sex, age, ancestral origin and body mass index (BMI) which are derived from various sample sources for instance cadavers [6-10], ultrasound [11-17], magnetic resonance imaging scans [18-21], computed tomography scans [22-31], cone beam computed tomography [32-34], and lateral cephalograms [35-47]. Interestingly, some papers have found that skeletal classes influences the ASTD pattern in the oral area, both in subadult [35-37,39-40,42,48] and adult [38,41,43-46] populations.

In the field of orthodontics, skeletal class has been used widely to quantify the relationship between the maxilla and mandible. The skeletal class system is divided into three classes based on the ANB angle between landmarks [43,45,49 -50].

The aim of this study was to understand the effect of skeletal classes on facial ASTD pattern in the Indonesian adult population. This is important to provide evidence as to whether skeletal class should be considered as one of the ASTD assessment criteria in addition to (or instead of) sex, age, and/or ancestry groups during the process of CFR.

Materials and methods

Three hundred and thirty-five (335) lateral cephalogram x-ray image files were collected from the archive of Radiology Clinic Universitas Padjadjaran Dental Hospital Bandung Indonesia, which were ethically approved for research by The Health Research Ethics

Committee Universitas Padjadjaran. The samples were derived from a clinical population of pre-treatment orthodontic archives (83 males and 252 females; age range 17 to 51 years; average age 24.1 ± 5.8 years old). Patients with craniofacial syndromes were excluded from the sample. Lateral cephalograms were used for diagnosis and treatment evaluation of orthodontic treatment; widely available in the archive and taken in a standardised head position by setting the orbitale to porion line (Frankfurt Horizontal Plane) parallel to the floor. In addition, the soft tissue outline along with the underlying skeletal profile is visible in a single image which allows the measurement of the ASTD and skeletal class analysis simultaneously [41-42].

The cephalogram examinations were conducted using Picasso Trio device (Vatech/E.WOO, Gyeonggi-Do, South Korea). The standard protocol was applied to all adult patients with 40-90 KV and maximum 2-10 mA. The fixed film-to-tube distance was 180 cm. The digital cephalograms were analysed using Adobe Photoshop CS5.1 (Adobe Systems, San Jose, CA, USA) by the first author (ES). All cephalograms were rescaled following the mm scale bar displayed on each image, using the ruler tool and image size option [51]. The enlargement was less than 10% according to the scale bar, which corresponds to the expected radiographic correction factor. Image size adjustment did not alter the image quality nor the landmark identification process as the images were not resampled as they were resized, in order to avoid blurring or distortion. The soft tissue depth on 10 landmarks were measured in millimetres (Fig. 1):

Glabella: The most anterior point on midline of frontal bone at eyebrow level

Nasion: The most anterior point on midline of frontonasal suture

Rhinion: The most anterior point of the nasal bones

Subnasale (A): The deepest point on the curvature between the anterior nasal spine (ANS) and the prosthion on the anterior surface of the maxilla

Upper lip (prosthion): the most anterior and inferior point of the of the alveolar process at midline between the maxillary central incisors

Stomion: The junction of upper lip and lower lip at midline

Lower lip (infradentale): the highest and most anterior point of the alveolar process at midline between the mandibular central incisors

Labiomentale (B): the deepest point on the curvature between the infradentale and pogonion on the anterior surface of the mandible

Pogonion: The most anterior point of the mandibular symphysis

Gnathion: The most inferior point of the mandibular symphysis

Next, ANB angle (point A to Nasion to point B) was also noted to determine the skeletal class: class I ANB 2°-4°; class II ANB >4°; class III ANB <2°[38,41,43,45,49 -50] (Fig. 1). A negative ANB angle value occurred when point B was located more anteriorly than point A. Intra-observer error analysis was performed by the author (ES) twice in between period at least a month. Inter-observer variation was also assessed by comparing values obtained by the author (ES) and another observer with cephalometric analysis experience. Both the intra and inter observer studies was employed on 10% of randomly selected images. The statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS) for Windows (version 22.0; IBM Corp., Armonk, NY, USA).

Results

Strong Intraclass Correlation Coefficient (ICC) values were presented in intra-observer measurements which inferred that the variables were repeatable (0.822 to 0.997). In addition, high levels of agreement between the two observers were seen, which implied that these parameters were reproducible (0.935 to 0.994).

Table 1 Independent *t* test of midline ASTD between male and female groups (*significant $p < 0.05$).

Landmarks	Male (n=83)		Female (n=252)		Total (n=335)			t-test
	Mean	SD	Mean	SD	Mean	SD	Sig.	Mean Diff
Glabella	5.13	0.87	4.97	0.74	5.01	0.78	NS	0.16
Nasion	6.04	1.06	5.50	1.04	5.63	1.07	*.000	0.54
Rhinion	3.00	0.59	2.45	0.50	2.58	0.58	*.000	0.55
Subnasale	14.06	1.70	12.01	1.58	12.52	1.83	*.000	2.05
Upper lip	14.21	2.28	11.96	1.74	12.51	2.12	*.000	2.26
Stomion	5.13	2.31	3.89	1.56	4.20	1.85	*.000	1.24
Lower lip	14.36	2.12	12.94	1.91	13.30	2.05	*.000	1.42
Labiomentale	12.67	1.94	12.41	1.84	12.48	1.87	NS	0.26
Pogonion	11.46	2.48	11.77	1.84	11.69	2.01	NS	-0.30
Gnathion	8.12	4.65	7.17	1.72	7.40	2.78	NS	0.95

Independent *t*-test confirmed that midline ASTD was significantly deeper in males than females at 6 landmarks: nasion, rhinion, subnasale, upper lip, stomion and lower lip ($p < .05$)

(Table 1). The mean differences were relatively small for the nasion (0.54 mm) and rhinion (0.556 mm); medium for stomion (1.24 mm) and lower lip (1.42 mm), and considerably larger in the subnasale (2.05 mm) and upper lip (2.26 mm). All midline landmarks were larger in males than in females by 0.3 mm, except for the pogonion. Due to the presence of sexual dimorphism in most landmarks, the following statistical analysis was divided by sex. One-way analysis of variance (ANOVA) along with homogeneity of variance test and Welch ANOVA were computed simultaneously to investigate whether there is a significant difference between the three skeletal classes for ASTD. When significant Levene's test of homogeneity was detected, then Welch ANOVA *p*-value was chosen over the regular one-way ANOVA. Additionally, Tukey's post hoc test was used for one-way ANOVA, while Games-Howell's post hoc was used for Welch ANOVA.

Significant differences of lower lip ASTD among three skeletal classes in the male group was detected by one-way ANOVA (Table 2). The male lower lip ASTD was significantly thicker by 1.9 mm in class II than class III (Table 3). Significant differences occurred by one-way ANOVA in subnasale, upper lip, stomion, lower lip, and labiomentale ASTD in the female (Table 2). The female subnasale ASTD was significantly deeper in class III than class II by 0.81 mm. The upper lip ASTD was significantly deeper in class III than class I and II by 0.80 mm and 1.28 mm, respectively. The stomion ASTD was significantly deeper in class III than class I and II by 0.77 mm and 1.21 mm, respectively. The lower lip ASTD was significantly deeper in class II than class I and III by 0.92 mm and 0.92 mm, respectively. The labiomentale ASTD was significantly deeper in class II than class I and III by 1.19 mm and 1.63 mm, respectively (Table 3). The ASTD of each skeletal class pooled by sex groups were plotted into line charts for easy comprehensionof the pattern (Fig. 2-3).

Table 2 Descriptive statistics and one-way ANOVA test of midline ASTD among three skeletal classes in males and females (*$p < 0.05$; NS: non-significant; [a]Welch ANOVA).

Landmarks	Mean	SD	Mean	SD	Mean	SD	Sig.
Males	**Class I (n=19)**		**Class II (n=33)**		**Class III (n=31)**		
Glabella	5.35	0.88	5.04	0.97	5.10	0.77	NS
Nasion	6.31	1.10	6.07	1.13	5.84	0.94	NS
Rhinion	2.89	0.66	2.97	0.52	3.09	0.63	NS
Subnasale	13.79	1.86	13.68	1.19	14.63	1.95	NS
Upper lip	14.05	2.23	13.72	1.90	14.83	2.58	NS
Stomion	5.48	1.74	4.44	2.04	5.66	2.71	NS
Lower lip	14.17	2.15	15.34	1.71	13.44	2.11	*.001
Labiomentale	12.13	1.73	13.28	2.24	12.36	1.58	NS
Pogonion	11.60	1.88	11.67	2.94	11.16	2.31	NS
Gnathion	7.69	1.67	7.61	2.04	8.91	7.21	NS
Females	**Class I (n=68)**		**Class II (n=111)**		**Class III (n=73)**		
Glabella	4.96	0.73	4.97	0.75	5.00	0.75	NS
Nasion	5.49	1.11	5.58	1.05	5.38	0.96	NS
Rhinion	2.37	0.45	2.41	0.47	2.57	0.58	NS
Subnasale	12.05	1.33	11.67	1.71	12.48	1.47	*.003
Upper lip	11.94	1.70	11.45	1.66	12.73	1.62	*.000
Stomion	3.87	1.50	3.42	1.34	4.63	1.66	*.000
Lower lip	12.54	1.91	13.46	2.02	12.54	1.53	*.001
Labiomentale[a]	12.01	1.34	13.21	1.95	11.58	1.59	*.000
Pogonion	11.57	1.68	12.04	1.92	11.54	1.81	NS
Gnathion	7.34	1.86	6.94	1.57	7.36	1.80	NS

Table 3 Post hoc pairwise following one-way ANOVA comparison of midline ASTD among skeletal classes (*$p < 0.05$, **Tukey, ***Games-Howell).

Group	Landmarks	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.
Male	Lower lip**	Class II	Class III	1.90	0.49	*.001
Females	Subnasale**	Class II	Class III	-0.81	0.23	*.002
	Upper lip**	Class I	Class III	-0.80	0.28	*.013
		Class II	Class III	-1.28	0.25	*.000
	Stomion**	Class I	Class III	-0.77	0.25	*.007
		Class II	Class III	-1.21	0.22	*.000
	Lower lip**	Class I	Class II	-0.92	0.29	*.004
		Class II	Class III	0.92	0.28	*.003
	Labiomentale***	Class I	Class II	-1.19	0.25	*.000
		Class II	Class III	1.63	0.26	*.000

Discussion

The female sample was larger than the male sample in this study, which was extracted from the clinical population of the pre-treatment orthodontic archive. This is due to the market

targeting of female adults for orthodontic intervention in Indonesia [51]. The Indonesian archipelago is inhabited mostly by East Asian ancestry groups and the eastern islands of Indonesia including Papua island which is inhabited by the Australasian ancestry group [51]. The sample of this study was obtained from West Java region which allowed all sub-ancestral groups within the East Asian cluster to be represented in this study.

The influence of skeletal class on ASTD has been explored from lateral cephalograms in numerous ways, including manual acetate sheet tracing [35-39,41,44,45,47], digital measurement using iTEM Analyses imaging program [42], DentaPacs 8.1 [43], Sidexis Xg [40], NemoCeph NS[46], and Adobe Photoshop CS5.1 (this study). Nevertheless, the ASTD among three skeletal classes of the Indonesian adult population was found comparable with the previous studies from other ancestral groups (Table 4). This may indicate that the different method of cephalometric analysis did not affect the results. However, different ancestry groups showed similar peri-oral ASTD patterns which suggested that skeletal classes may play an important role in ASTD application.

Table 4 Midline facial adult ASTD database among skeletal classes from various geographical regions: Japanese [38], Japanese [41], Turkish [43], Pakistani [44], Sudanese [45], Chinese [46], and Indonesian (this study).

Male	Articles	g	n	rhi	sn	ls	sto	li	lbm	pog	gn
Class I	[41]	6.06	7.59	2.88	14.51	15.88	6.31	16.19	14.15	14.07	8.95
	[43]	5.62	6.59	2.11	17.04	16.09	6.43	17.07	11.47	10.55	8.52
	[44]	5.36	5.67	3.60	17.83	16.86	6.93	17.73	12.33	10.66	7.03
	[45]	5.77	6.94	4.00	17.57	17.34	5.49	19.54	15.46	14.09	8.89
	[46]	5.32	6.32	2.84	16.68	18.13	6.21	18.73	13.80	11.91	7.00
	This study	5.35	6.31	2.89	13.79	14.05	5.48	14.17	12.13	11.60	7.69
Class II	[41]	5.64	7.08	2.64	14.45	15.27	6.01	17.12	14.58	13.85	8.73
	[43]	5.59	6.42	2.51	17.03	15.25	6.26	17.21	11.62	9.66	8.28
	[44]	5.66	5.40	3.53	17.86	12.30	6.53	19.73	13.80	12.46	7.86
	[45]	5.87	6.26	3.87	15.84	15.26	4.13	19.47	14.63	12.61	7.74
	[46]	5.68	6.30	3.21	16.37	18.50	4.92	19.50	13.62	11.32	6.24
	This study	5.04	6.07	2.97	13.68	13.72	4.44	15.34	13.28	11.67	7.61
Class III	[41]	5.84	7.38	2.61	15.54	16.15	7.16	15.48	13.11	13.06	9.56
	[43]	5.85	6.17	2.50	17.38	16.72	7.32	15.95	10.89	10.64	8.02
	[44]	6.08	6.56	3.69	18.52	19.00	8.26	18.26	14.30	11.95	7.78
	[45]	5.94	6.16	3.97	18.38	16.88	6.41	18.19	13.31	11.91	8.56
	[46]	5.22	5.86	4.25	17.18	17.91	9.00	16.93	12.79	12.44	7.03
	This study	5.10	5.84	3.09	14.63	14.83	5.66	13.44	12.36	11.16	8.91
Female	**Articles**	**g**	**n**	**rhi**	**sn**	**ls**	**sto**	**li**	**lbm**	**pog**	**gn**
Class I	[38]	5.60	6.55	2.45	12.86	12.38	4.35	15.24	13.53	13.86	7.23
	[41]	5.43	6.45	2.44	13.00	12.53	4.27	15.00	13.39	13.77	6.93
	[43]	5.14	5.17	2.18	15.56	13.69	5.15	15.24	10.30	9.91	6.94
	[44]	5.06	5.13	3.10	14.26	12.70	5.86	16.70	13.13	12.60	6.73
	[45]	5.78	5.80	3.47	15.73	14.38	4.44	17.00	12.87	13.44	8.67
	[46]	5.36	5.53	2.56	14.11	15.08	4.11	16.95	12.66	12.26	6.54
	This study	4.96	5.49	2.37	12.05	11.94	3.87	12.54	12.01	11.57	7.34
Class II	[38]	5.43	6.42	3.45	12.75	12.07	3.72	15.88	15.99	16.28	6.19
	[41]	5.45	6.38	2.47	12.69	11.88	3.45	15.40	15.68	15.47	6.27
	[43]	5.24	6.12	1.98	15.72	13.75	5.34	16.04	10.86	9.62	6.43
	[44]	4.96	5.33	3.00	14.33	10.86	6.00	18.00	13.50	11.46	6.66
	[45]	5.56	5.84	3.36	14.29	13.44	3.33	17.91	14.16	12.44	7.67
	[46]	5.49	5.62	2.38	14.56	14.70	3.85	18.07	12.30	12.11	6.81
	This study	4.97	5.58	2.41	11.67	11.45	3.42	13.46	13.21	12.04	6.94
Class III	[38]	5.63	6.36	2.58	14.11	14.37	4.56	14.85	12.70	12.51	6.84
	[41]	5.65	6.23	2.68	13.96	14.03	4.65	14.77	12.79	12.64	6.89
	[43]	5.63	6.36	2.58	14.11	14.37	4.56	14.85	12.70	12.51	6.84
	[44]	5.08	4.95	3.30	15.95	15.82	7.13	14.21	11.21	10.73	-
	[45]	5.97	5.53	3.21	16.47	15.37	5.58	16.39	12.95	11.87	7.89
	[46]	5.12	5.11	2.74	14.51	16.75	8.30	13.98	12.54	11.54	6.38
	This study	5.00	5.38	2.57	12.48	12.73	4.63	12.54	11.58	11.54	7.36

Comparison among three skeletal classes using one-way ANOVA yielded significant differences which were more frequent in the female group than in the male group (Table 2). However, the difference in sample size between male and female groups must be considered [38].

The largest significant mean difference in ASTD occurred in the lower lip of the male group, where class II was deeper by 1.9 mm than class III (Table 3). Irrespective of the statistical significances, the common pattern of peri-oral ASTD appeared in both male and female groups (Fig. 2-3). Subnasale and upper lip ASTD were deeper in class III than class II. In contrast, the ASTD of labiomentale, upper lip and pogonion were deeper in class II than class III. This pattern corroborated the earlier studies which supported the idea that skeletal classes influences the peri-oral ASTD, in which at least one upper lip landmark (sn/ls) were deeper in class III than class II and at least one lower lip landmark (li/lbm) were deeper in class II than class III (see Table 4 for references). Lip incompetence was not present in this study. Nevertheless, cases with lip strain might be existed in this study and play role as the confounding factor of the upper lip, stomion, and lower lip measurements.

This study improved the scientific basis of CFR which is often regarded as more of an art than a science. In the past, ASTD was used as CFR guidelines irrespective of the underlying skeletal pattern. Based on this study, there might be possibilities to develop an algorithm for ASTD tailored to the skeletal pattern. In addition, the skeletal pattern largely genetically determined. Therefore, genetics could be predictive of this including a range of other important features in CFR. Moreover, within the skeletal class II pattern, there are 2 sub-division (II division 1 and II division 2) defined by dental pattern and occlusion. Further research may discover significant effect on nasolabial soft tissue features.

Conclusions

The midline ASTD study of an Indonesian adult population indicated several findings:

1. Sexual dimorphism of Indonesian adult midline ASTD was detected at the nasion, rhinion, subnasale, upper lip, stomion and lower lip in which the largest mean difference was 2.26 mm.

2. Significant differences of peri-oral ASTD among three skeletal classes were highlighted in males (lower lip) and females (subnasale; upper lip; stomion; lower lip; labiomentale) which included post hoc differences between class II and III.
3. A generic midline ASTD pattern of class II showing deeper lower lip than class III, and class III showing deeper upper lip than class II, occurred in both male and female groups.
4. It is advisable that practitioners consider applying the upper and lower lip ASTD pattern during CFR practice, possibly by deviating slightly from the existing ASTD pattern with respect to the skeletal class of the individual target skull, at least until more data has been collected to group ASTD accordingly. This study also provided midline ASTD based on skeletal classes in Indonesian adult sample for forensic anthropology population data.

Ethical Statement

The utilisation of the medical imaging in this study has been ethically approved by The Health Research Ethics Committee Universitas Padjadjaran Indonesia (812/UN6.C1.3.2/KEPK/PN/2015).

Competing interests

The authors declare that they have no financial and non-financial competing interest. This study was funded by the Directorate General of Higher Education Ministry of Research, Technology, and Higher Education of the Republic of Indonesia (666/E4.4/K/2014).

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Fig.1. ANB angle measurements and soft tissue depth measurements on midline landmarks: glabella (g), nasion (n), rhinion (rhi), subnasale (sn),upper lip (ls), stomion (sto), lower lip (li), labiomentale (lbm), pogonion (pog), gnathion (gn).

Fig. 2. Difference of ASTD in each skeletal class in males.

Fig. 3. Difference of ASTD in each skeletal class in females.

Figure 1

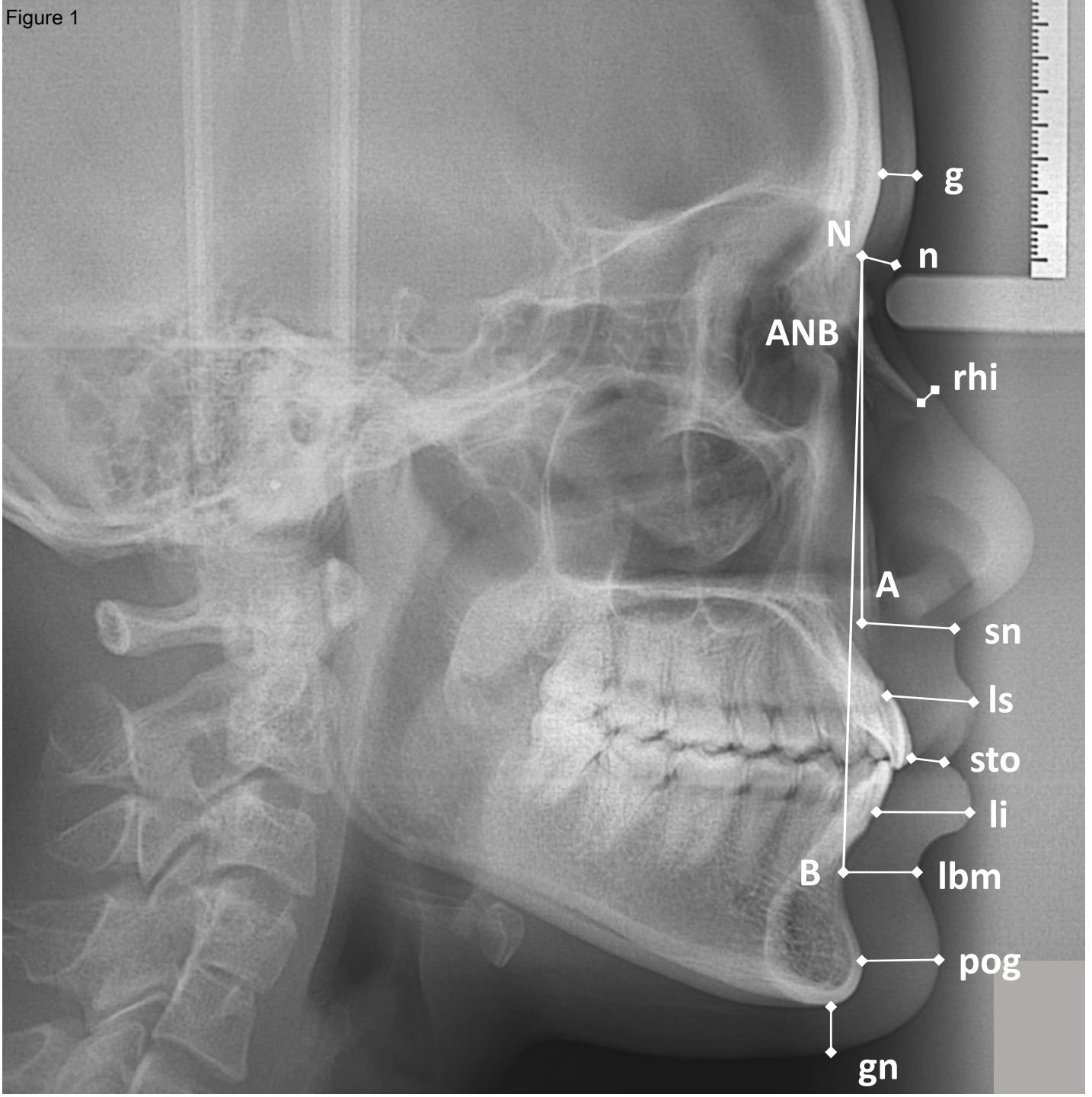

Figure 2

ASTD (mm)	Class I (n=19)	Class II (n=33)	Class III (n=31)
g	5.35	5.04	5.10
n	6.31	6.07	5.84
rhi	2.89	2.97	3.09
sn	13.79	13.68	14.63
ls	14.05	13.72	14.83
sto	5.48	4.44	5.66
li*	14.17	15.34	13.44
lbm	12.13	13.28	12.36
pog	11.60	11.67	11.16
gn	7.69	7.61	8.91

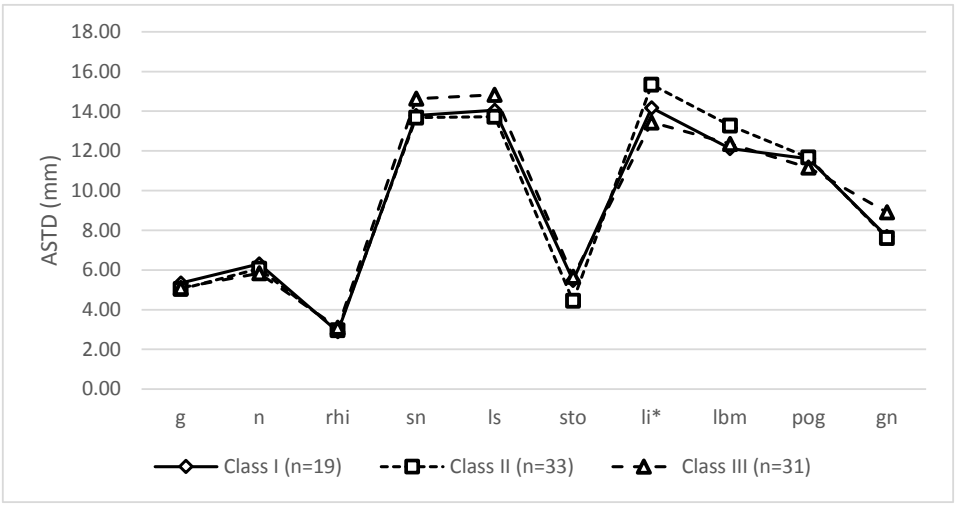

Figure 3

ASTD (mm)	Class I (n=68)	Class II (n=111)	Class III (n=73)
g	4.96	4.97	5
n	5.49	5.58	5.38
rhi	2.37	2.41	2.57
sn*	12.05	11.67	12.48
ls*	11.94	11.45	12.73
sto*	3.87	3.42	4.63
li*	12.54	13.46	12.54
lbm*	12.01	13.21	11.58
pog	11.57	12.04	11.54
gn	7.34	6.94	7.36