Original article

Diagnostic indices using multivariate analysis to evaluate skeletal and soft tissue problems of orthodontic patients

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Key words : Severity indices, Cluster analysis, Discriminant analysis, Soft tissue

Abstract : The purpose of this cephalometric investigation was undertaken to develop a severity index of hard tissue (SIH) and severity index of soft tissue (SIS). The subjects were 482 Japanese female patients of the permanent dentition. All the data were derived from initial lateral cephalometric radiographs. From the many skeletal measurements currently used widely, we narrowed down this list to select the main measurements that characterize both skeletal and soft tissue problems using multivariate analysis.

When SIH and SIS were formulated, distribution of discriminant scores of SIH and SIS for normal, Class II groups were drawn for clinical use. Decision for orthognathic surgery in skeletal Class III patients was also applied with these SIH and SIS. As a result, SIH=0.61 (Wits appraisal) −0.42 (APDI) +37.52 and SIS=1.41 (upper E-line) −0.26 (cant of upper lip) −0.12 (nasolabial angle) +1.54 (labiomenetal sulcus) +11.02. These indicies were found to be useful for diagnosing, making treatment plan and evaluating treatment result.

Two treated cases were presented as examples to show how these indices should be applied.

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多変量解析を用いた硬・軟組織の診断指標

抄録：硬•軟組織の難易度のインデックス（SIH と SIS）を作成するための側方頭部X線規格写真を用いた研究を行った．SIH と SIS の作成に際して，臨床応用を目的に正常咬合とII級咬合群の判別分析を行った．III級患者に対しては，外科手術の適応を判別するために，SIH と SIS を使用した．資料は 482 名の永久歯列の日本人女子である．すべてのデータは，初診時の側方頭部X線規格写真を用いた．今日広く使用されている骨格的計測項目の内から，多変量解析を用いて硬・軟組織の問題となる特徴を選定した．その結果，SIH＝0.61 (Wits appraisal) −0.42 (APDI) +37.52，軟組織の評価 SIS＝1.41 (upper E-line) −0.26 (cant of upper lip) −0.12 (nasolabial angle) +1.54 (labiomenetal sulcus) +11.02 であった．これらのインデックスは，診断，治療計画の立案および治療結果の評価に有用であることが判った．

（日矯正歯誌　54(6)：385～396, 1995）

Introduction

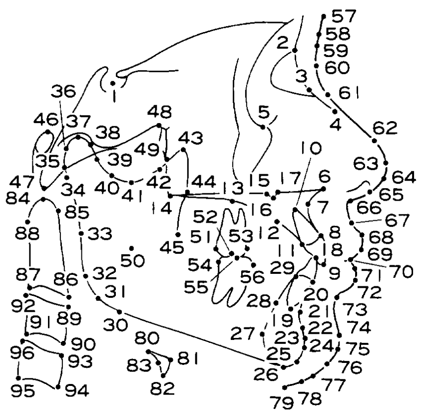
Antero-posterior skeletal discrepancy has been evaluated by several cephalometric measurements such as ANB angle[1], A-B plane angle[2], A to N-Po[3], archial concept[4], Harvold's triangle[5], Wits appraisal[6], APDI[7], and nasion perpendicular to A & P[8]. These analyses have been clinically useful and widely accepted for years. However, except for APDI, the measurements were not devised statistically but simply determined geometrically. For example, ANB angle was determined as a measurement for assessing the antero-posterior jaw relationship because points A and B are geometrically anterior limits of the upper and lower denture base, although no statistically proof has been given.

The APDI (Antero-posterior dysplasia indicator), on the other hand, was derived from the correlation coefficient to molar displacement and its value was the sum of the facial angle, A-B plane angle and palatal plane angle. A combination of such statistically significant measurements should provide a better differential diagnosis. However, the parent group age to devise APDI was from 8 to 14 years in both sexes that included growth differences.

Sassouni and Nanda[9] reported that young people have smaller morphological differences than adults because the differences are exaggerated with growth. Therefore, sample age should be unified and adult must show the group characteristics clearly. Moreover, the initially listed cephalometric measurements of the APDI study were only 13 variables that seemed to be selected basically from authors clinical experience. Furthermore, although correlation coefficient values and the statistical power of each measurement were different, resultant formula was simply sum of those measurement value.

Therefore, probably, there has been no cephalometric method derived pure statistically except our previous study[10]. We have developed severity indices for Class II and Class III malocclusions separately and found to be effective. In that study, however, dental as well as skeletal variables were included for deciding treatment method. As a result, the most major variable to discriminate the severity was overjet, which was clinically a matter of course.

The purpose of this cephalometric investigation is to understand the skeletal factors which cause antero-posterior problems to devise a severity indices both in hard (SIH) and soft (SIS) tissues. When SIH and SIS will be formulated, distribution of discriminant scores of SIH and SIS for Normal occlusion, Class II and Class III groups will be drawn for clinical use. In order to test if SIH can be applied for a decision to take orthognathic surgery instead of orthodontic treatment in Class III cases, discriminant scores and frequency of those treatment selection will be drawn.



1	S	25	Gn	49	Ptm	73	SLI
2	Na	26	Me	50	Xi	74	Ps'
3	Rhi	27	L-Pog	51	D-U6	75	Ps
4	Rhi	28	L-B	52	U6	76	Ps''
5	Or	29	Inf'	53	M-U6	77	U-MeS
6	ANS	30	L-Go	54	D-L6	78	GnS
7	A	31	Go	55	L6	79	L-MeS
8	Pr	32	P-Go	56	M-L6	80	Hyo1
9	U-1	33	R2	57	Gla	81	Hyo2
10	U-1R	34	DC1	58	Gla'	82	Hyo3
11	Pr'	35	Ar	59	NS	83	Hyo4
12	P3	36	P-Cd	60	In	84	C2-1
13	P6	37	Cd	61	NTd	85	C2-2
14	PNS	38	A-Cd	62	NT	86	C2-3
15	DCl	39	DC2	63	Prn	87	C2-4
16	Cl	40	P-R3	64	Prn'	88	C2-5
17	MCl	41	R3	65	Cm	89	C3-1
18	L-1	42	A-R3	66	Sub	90	C3-2
19	L-1R	43	Cr	67	SLS	91	C3-3
20	Inf	44	L-Cr	68	LS	92	C3-4
21	B	45	R1	69	LS'	93	C4-1
22	Pm	46	Po	70	Stom	94	C4-2
23	R-Pog	47	Ba	71	LI'	95	C4-3
24	Pog	48	Pt	72	LI	96	C4-4

Fig. 1 Cephalometric landmarks

Subjects and Methods

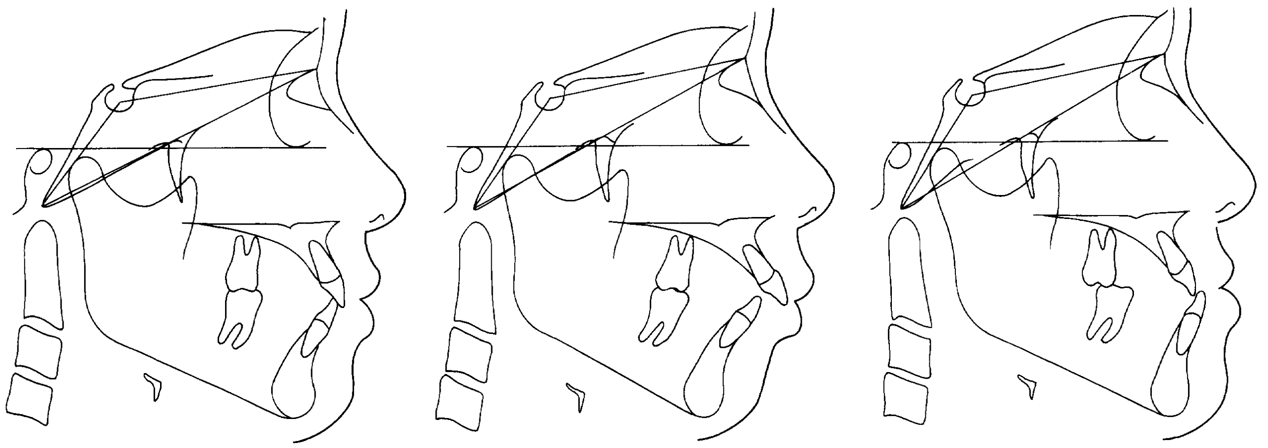
I. Subjects

The subjects for this investigation were 482 female patients who visited the Department of Orthodontics, School of Dentistry, Aichi-Gakuin University and other related orthodontic clinics in Nagoya. Fifty patients were diagnosed with Normal occlusion, 216 patients were diagnosed with Angle's Class II division 1 malocclusion with more than 6 mm of overjet and the same size of 216 patients with Angle's Class III in which overjet was negative. We defined normal occlusion as subjects which show Angle's Class I molar relation with minimum crowding or rotation and 2-3 mm of overjet and overbite. Age of the subjects were between 18 and 30 years old. All the data were derived from initial lateral cephalometric radiographs. Characteristics of the 3 groups are first of all, described then, 2 opposite groups, that are Class II and III groups will be compared to obtain the effective variables to differentiate antero-posterior discrepancy. Normal occlusion individuals will be used to test if those individuals distributed in the middle with the average being 0.

II. Cephalometric analysis

Ninety-six landmarks were plotted on each tracing to find average tracing of the 3 groups (Fig. 1, 2-a, 2-b and 2-c). Fifty-four cephalometric measurements of the skeletal pattern were selected from the following methods ;

1) 8 values from Wylie[10]
2) 12 values from Coben[11]



a. An average tracing of adult female Normal occlusion group (N=50)

b. An average tracing of adult female Class II group (N=216)

c. An average tracing of adult female Class III group (N=216)

Fig. 2

3) 10 values from Graber[12]
4) 14 values from Ricketts[13]
5) N-S-Ar from Björk[14]
6) 3 values from Kim[15]
7) 2 values from Kamiyama and Takiguchi[16]
8) 3 values from McNamara[8]
9) the Wits appraisal from Jacobson[6]

Twenty-nine cephalometric measurements of the soft tissue were selected from the following methods ;

1) 7 values from Kimura *et al.*[17]
2) 13 values from Legan and Burstone[18]
3) 2 values from Ricketts[13]
4) 1 value from McNamara[8]
5) 1 value from Merrifield[19]
6) 3 values from Powell & Humphrey[20]
7) other two values.

After landmarks and reference planes were drawn, the data were inputted to a personal computer (PC-486, EPSONT™ with the use of a digitizer, KD3200™, Graphtec). The location of each landmark on the x- and y-axes was calculated with a cephalometric analyzing program (Versa-STAT. Yasunaga Laboratory Co., Ltd) and statistical program (HALBOU, Gendaisugakusha).

Three step statistical mode was applied to select significant variables to making simple formulae (Fig. 3).

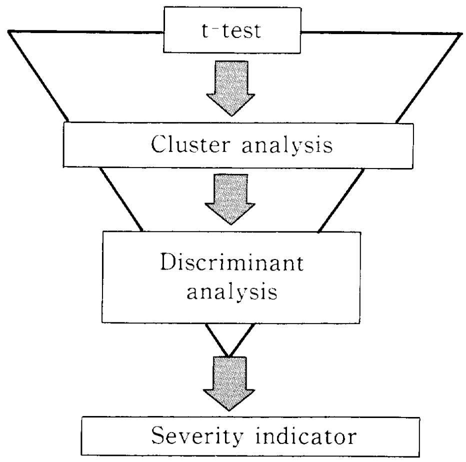


Fig. 3 Three step mode statistical selection of variables

III. Statistical analysis

Because most major above measurements were first of all listed in order to avoid personal thinkings or clinical experiences and to make this study been more scientific, three step statistical mode was applied. This procedure may select significant diagnostic measurements that distinguish Class II and Class III skeletal characteristics. Normal occlusion samples were excluded in this procedure to make it easy to identify the characteristics that differentiate the antero-posterior skeletal problems.

IV. T-statistics

The mean differences between Class II and Class III groups in each measurements were calculated using t-tests. We then selected variables to discriminate the Class II and Class III groups using significant values ($p<0.001$) from the t-test. There should be many variables that have similar biological meanings in the variables that were selected with t-test. Therefore, clustering similar variables to one group is required for the next step.

V. Cluster analysis

The object of this analysis[21] is to see whether the individuals or variables can be formed into any natural system of groups. The number of groups may not be specified in advance. The individuals or variables can be grouped in an entirely arbitrary way, but the investigator seeks a system such that the individuals within a group resemble each other more than do individuals in different groups. Six-clustering methods have been tried first for grouping multivariate data in this study. Among the results of the 6 different cluster analyses, the dendrogram of group average method was found to be the most reasonable in cephalometrically biological meanings.

Measurements within each cluster with the highest t-value were selected as representative variables of the clusters.

VI. Discriminant analysis

Explanatory variables were selected with partial F-statistic values more than 10.0 by using stepwise modes. The coefficients of the formula to calculate SIH and SIS were determined by this analysis.

Finally, ranges of clinical norms for SIH and SIS were determined ; if the discriminant score of a certain patient was outside of one standard deviation of Class II or Class III group toward normal side (zero), the individual would be classified as normal.

VII. Application of SIH and SIS for Class II and Class III cases

Case 1 was a female patient who was at the initial visit. Conventional cephalometric evaluation revealed skeletal Class III and diagnosed as Angle's Class III malocclusion. Two jaw surgery with non-extraction orthodontic treatment was planned.

Case 2 was a female patient who was at the initial visit. Conventional cephalometric evaluation revealed skeletal Class II and diagnosed as Angle's Class II division 1 malocclusion. Extraction of four first bicuspids followed by edgewise appliance with Head gear and Class II elastic use were planned.

Results

I. T-statistics

The t-tests revealed 39 significant measurements out of the initial 54 ($p<0.001$) for skeletal measurements (Table 1) and 20 out of 29 measurements for soft tissue evaluation (Table 2).

II. Cluster analysis

Sixteen clusters were selected by means of cluster analysis (group average method) for skeletal measurements (Table 3) and 8 clusters for soft tissue measurements (Table 4). The skeletal measurements with the highest t-values were selected from each cluster as follows ; APDI, Ramus position, Corpus length, Ar-Go, Wits appraisal, Ramus to SN, Mandibular arc, Ptm-A, N-S, Ba-N, Porion location, S-Ar, Y-axis to SN, Ans-Me, Gonial angle, and Cranial deflection. The soft tissue measurement with the highest t-values, on the other hand, were selected as follows ; Merrifield's Z angle, Cant of Upper Lip,Stom-Ms, Upper E-line, Nasofacial angle, Verti. lip-chin ratio, Labiomental sulcus, and Nasolabial angle.

III. Discriminant analysis

Results of discriminant analysis for skeletal and soft tissue measurements are shown in Tables 5 and 6. The explanatory variables derived through the above 3 stepwise statistical analyses were finally the following cephalometric measurements ; for skeletal measurements, APDI and Wits appraisal ; and for soft tissue measurements ; Upper E-line, Cant of Upper Lip, Nasolabial angle, and Labiomentalsulcus. For skeletal measurement, the estimated discriminant error rate was 2.06%, the apparent error rate was 98.15%, which indicated high rate of discrimination between Class II and Class III from the confusion matrix[25]. Mahalanobis generalized distance between Class II and Class III was 16.69. For soft tissue measurements, the estimated discriminant error rate was 4.10%, the apparent error rate was 96.53%, and Mahalanobis generalized distance between Class II and Class III was 12.10. These numbers are the mean differences between the two groups, and is called Mahalanobis' generalized distance. Large apparent error rate indicates that this formula can be reliable.

Table 1 Parent groups : descriptive and inferential statistics for skeletal measurements

Valuable		Class II (N=216) Mean	S. D.	Class III (N=216) Mean	S. D.	t-value	Sig.
Wylie							
N-S	(mm)	69.4	3.0	67.6	3.0	6.4	***
N-Me	(mm)	131.8	6.2	131.4	7.1	0.6	
N-Ans	(mm)	59.5	2.9	58.6	3.2	3.0	**
Ans-Me	(mm)	76.5	5.8	74.1	5.8	4.3	***
A'-Ptm'	(mm)	49.7	2.9	47.5	3.3	7.7	***
Cn-Cd	(mm)	115.6	5.4	125.5	6.1	17.7	***
Pog'-Go	(mm)	76.2	4.4	81.6	4.4	12.7	***
Cd-Go	(mm)	58.1	5.3	61.6	3.8	7.8	***
Coben							
Bk-N	(mm)	109.2	4.0	106.6	4.4	6.6	***
Ba-S	(mm)	48.6	2.7	48.1	3.1	1.8	
Ar-Po	(mm)	108.5	5.6	119.0	6.0	18.7	***
Ar-Go	(mm)	46.7	5.6	51.2	4.0	9.5	***
Go-Po	(mm)	77.4	4.6	82.6	4.4	11.8	***
Ptm-A	(mm)	50.0	2.8	47.7	3.3	7.9	***
N-M	(mm)	130.4	5.8	131.1	7.1	1.2	
N-Ans	(mm)	58.8	2.9	57.9	3.1	3.0	**
Ans-M	(mm)	71.6	5.1	73.2	5.6	3.2	**
S-Ar	(mm)	32.6	2.9	31.6	3.0	3.6	***
S-Go	(mm)	79.0	6.4	81.5	4.9	4.6	***
S-Gn	(mm)	127.3	5.6	135.1	6.6	13.2	***
Northwestern							
SNA	(°)	79.2	3.4	79.0	3.6	0.7	
SNB	(°)	73.3	3.5	80.8	3.7	21.5	***
SNP	(°)	72.8	3.8	80.1	3.8	19.8	***
ANB	(°)	5.9	2.4	−1.8	2.8	30.9	***
FH to SN	(°)	12.5	2.8	12.8	3.2	0.8	
NF to SN	(°)	11.4	3.1	11.8	3.6	1.3	
Y-axis to SN	(°)	77.8	4.3	72.3	4.2	13.4	***
Mp to SN	(°)	43.1	7.5	39.8	6.4	4.9	***
Gonial angle	(°)	124.8	7.4	128.7	7.6	5.4	***
Ramus to SN	(°)	98.2	5.6	91.1	5.7	13.2	***
Jacobson							
Wits appraisal	(mm)	4.7	3.3	−9.7	4.5	38.2	***
Kim							
A-B to Mp	(°)	72.1	5.9	57.0	6.4	25.6	***
ODI	(°)	71.0	7.1	56.0	7.4	21.4	***
APDI	(°)	76.2	4.9	95.0	5.5	37.4	***
Ricketts							
Facial axis	(°)	80.2	4.6	86.6	4.5	14.6	***
Facial depth	(°)	85.8	3.3	93.4	3.3	23.9	***
Mandibular plane	(°)	30.6	6.9	27.0	5.7	5.8	***
Lower facial height	(°)	51.4	5.3	50.5	4.9	1.9	
Mandibular arc	(°)	29.8	5.7	27.5	5.6	4.3	***
Total facial height	(°)	66.9	6.2	65.2	5.7	3.0	**
Convexity	(mm)	6.7	3.3	−1.8	3.5	26.1	***
Cranial deflection	(°)	30.8	2.2	31.7	2.7	3.7	***
Cranial length anterior	(mm)	58.7	2.6	57.5	2.7	4.7	***
Cranial length posterior	(mm)	50.6	2.9	49.1	3.3	4.9	***
Posterior facial height	(mm)	68.3	5.7	67.3	4.7	2.0	*
Ramus position	(°)	74.4	3.2	81.3	4.0	19.9	***
Porion location	(mm)	42.2	3.1	40.0	2.9	7.5	***
Corpus length	(mm)	67.3	3.8	76.6	4.3	23.8	***
McNamara							
Nasion perp. point A	(mm)	2.0	3.4	2.0	3.8	0.0	
Co-Point A	(mm)	86.3	4.3	84.2	4.6	4.9	***
Pog to Nasion Per.	(mm)	−9.2	7.4	7.4	7.2	23.7	***
Bjork							
N-S-Ar	(°)	127.9	5.1	126.5	5.4	2.7	**
Kamiyama							
SN. Ar-Gn	(°)	62.9	5.3	58.6	4.7	8.8	***
FH to NF	(°)	−1.2	2.8	−1.0	3.1	0.6	

*: $P<0.05$, **: $P<0.01$, ***: $P<0.001$

Table 2 Parent groups : descriptive and inferential statistics for soft tissue measurements

Valuable		Class II (N=216)		Class III (N=216)		t-value	Sig.
		Mean	S. D.	Mean	S. D.		
Soft tissue (Horizontal)							
Na perp. Gla	(mm)	8.7	1.6	9.0	1.7	1.8	
Gla perp. SN	(mm)	−1.6	1.0	−1.5	1.1	1.6	
Gla perp. In	(mm)	−2.6	1.5	−2.3	1.7	1.4	
Gla perp. Pn	(mm)	20.9	3.3	21.7	3.9	2.1	*
Gla perp. LS	(mm)	13.5	4.4	14.0	4.9	1.1	
Gla pep. LI	(mm)	8.4	5.4	16.4	6.0	14.5	***
Subna perp. Pn	(mm)	13.4	1.7	13.9	1.8	3.1	**
Legan & Burstone							
Facial convexity angle	(°)	18.1	5.8	2.2	6.0	27.8	***
Maxillary prognathism	(mm)	7.6	3.7	7.8	4.4	0.6	
Mandibular prognathism	(mm)	−6.4	8.1	11.4	7.5	23.5	***
Gla-Sub	(mm)	76.5	5.1	77.2	5.2	1.3	
Sub-Ms	(mm)	75.8	5.1	77.5	5.2	3.6	***
Vert. H. rat		1.0	0.1	1.0	0.1	1.7	
Nasolabial angle	(°)	91.4	11.3	87.3	11.1	3.8	***
Upper lip protrusion	(mm)	9.1	1.8	5.4	1.7	21.9	***
Lower lip protrusion	(mm)	8.9	3.2	6.7	2.3	8.4	***
Labiomental sulcus	(mm)	5.2	1.3	3.5	1.1	15.3	***
Sub-Stom	(mm)	25.5	2.4	23.1	2.8	9.4	***
Stom-Ms	(mm)	48.9	4.2	54.3	4.0	13.4	***
Vertical lip-chin ratio		0.5	0.1	0.4	0.1	17.0	***
Ricketts							
Upper E-line	(mm)	2.5	2.4	−3.9	2.2	28.3	***
Lower E-line	(mm)	5.3	3.4	1.2	2.7	13.6	***
McNamara							
Cant of Upper Lip	(°)	21.5	7.9	24.8	8.5	4.2	***
Merrifield							
Merrifield's Z angle	(°)	60.2	8.8	79.3	7.8	24.1	***
Powell & Humphreys							
Nasofrontal angle	(°)	142.9	6.2	142.5	6.3	0.6	
Nasofacial angle	(°)	32.1	3.7	26.2	3.9	16.3	***
Nasomental angle	(°)	130.5	4.9	141.0	5.1	21.7	***
Gla-Subna to FH	(°)	95.7	2.9	95.8	3.4	0.3	
Gla-Spog to FH	(°)	87.5	3.2	94.8	3.2	23.6	***

* : $P<0.05$, ** : $P<0.01$, *** : $P<0.001$

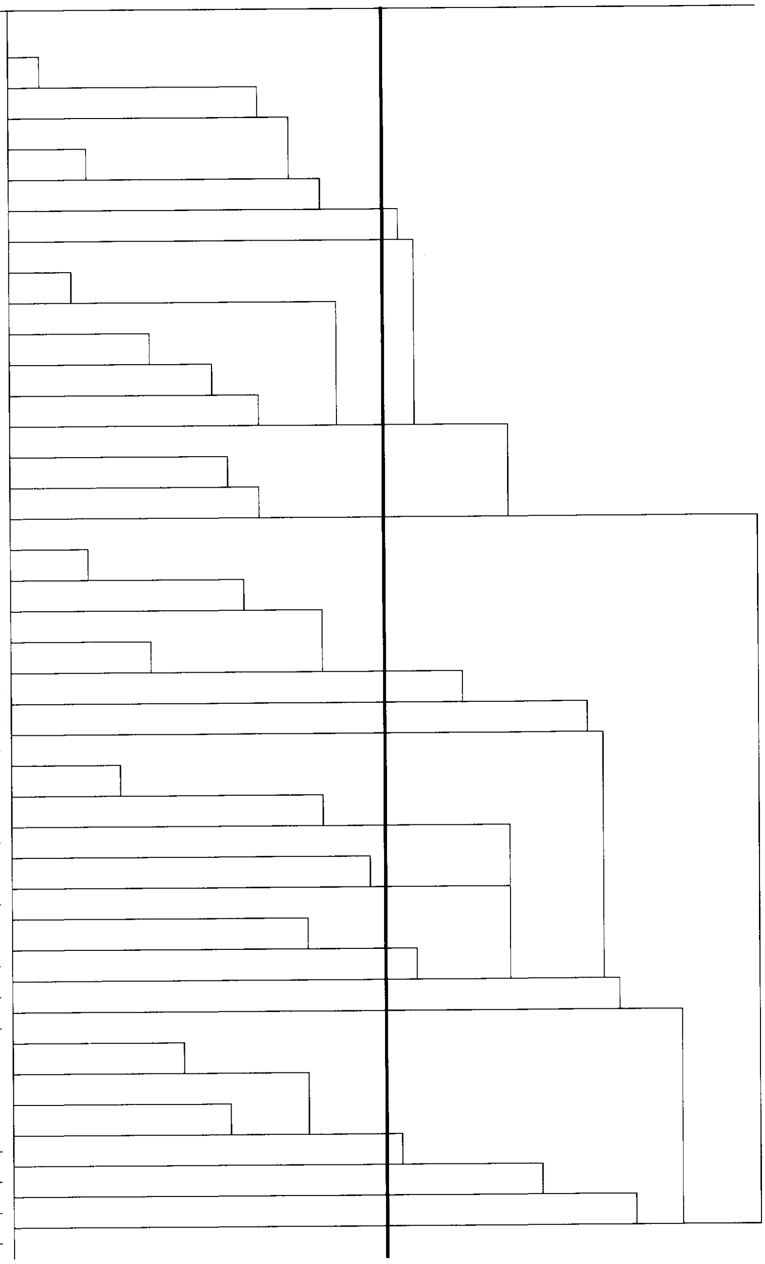
IV. Severity indices

Explanatory variables were selected to develop indices to describe antero-posterior problems of skeletal and soft tissues. The procedure was, first of all, to conduct discriminant analysis.

The resulting formula for SIH is as follows ; SIH=0.61 (Wits appraisal) −0.42 (APDI) +37.52 and that for soft tissue ; SIS=1.41 (Upper E-line) −0.26 (Cant of Upper Lip) −0.12 (Nasolabial angle) +1.54 (Labiomental sulcus) +11.02. Furthermore, the possibility of clinical application for these indices was investigated by using the present samples. As shown in Figures 4 and 5, the frequencies of Class II cases are located in the right hand side, where discriminant score is positive, and those of Class III cases are located in the negative score side, and Normal occlusion individuals distributed in the middle with the average being zero. Moreover, as shown in Figure 6, the frequency of orthognathic surgery increased as discriminant score decreased. Means and standard deviations of discriminant scores in Class III and Class II samples for SIH were −8.34±4.49 and 8.34±3.61 respectively. Those for SIS were −6.05±3.39 and 6.05±3.55 respectively. Therefore, ranges of clinical norms for SIH and SIS may be determined as discriminant scores

Table 3 Cluster analysis of skeletal measurements (group average method)

Group	Measurement	t-value
G1	Facial depth	23.9
	Pog to Nasion Per.	23.7
	*APDI	37.4
	SNB	21.5
	SNP	19.8
	Facial axis	14.6
G2	*Ramus Position	19.9
G3	Pog'-Go	12.7
	Go-Po	11.8
	Gn-Cd	17.7
	Ar-Po	18.7
	S-Gn	13.2
	*Corpus length	23.8
G4	Cd-Go	7.8
	*Ar-Go	9.5
	S-Go	4.6
G5	ANB	30.9
	Convexity	26.1
	*Wits appraisal	66.6
	A-B to Mp	38.0
	ODI	25.6
G6	*Ramus to SN	13.2
G7	*Mandibular arc	4.3
G8	A'-Ptm'	7.7
	*Ptm-A	7.9
	Co-Point A	4.9
G9	*N-S	6.4
	Cranial length anterior	4.7
G10	*Ba-N	6.6
	Cranial length posterior	4.9
G11	*Porion location	7.5
G12	*S-Ar	3.6
G13	*Y-axis to SN	13.4
	SN. Ar-Gn	8.8
	Mp to SN	4.9
	Mandibular plane	5.8
G14	*Ans-Me	4.3
G15	*Gonial angle	5.4
G16	*Cranial deflection	3.7



* : Measurements within each cluster with the hightest *t-value*

toward normal side from Class III and Class II by one standard deviation. Discriminant score outside of one standard deviation toward zero (normal side) for Class III and Class II groups were larger than −3.9 and smaller than 4.73, which would be clinical norm of discriminant score for SIH. For SIS, clinical norm of discriminant score would be larger than −2.7 and smaller than 2.5 as a clinical norm.

V. Examples to evaluate treatment changes using SIH and SIS

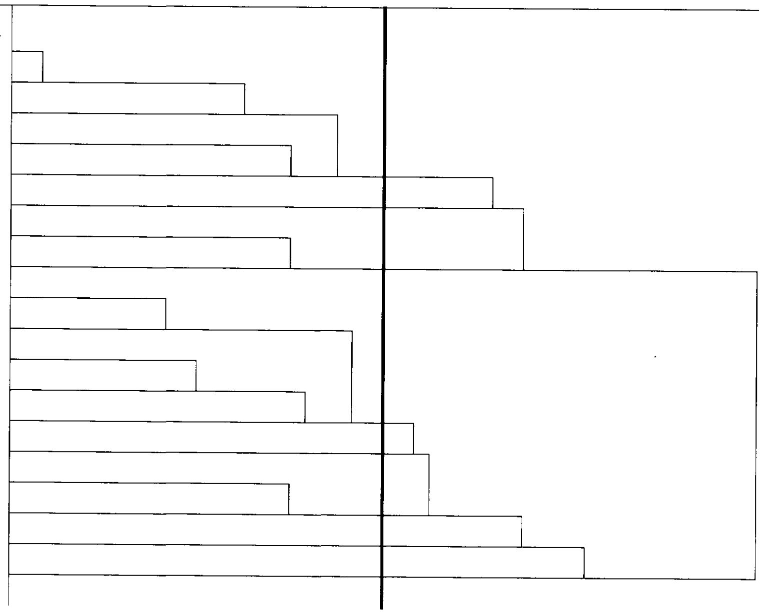
Case 1 received two jaw surgery with non-extracted orthodontic treatment. Treatment period was 2 years 5 months. Fig. 7 shows cephalometric changes during the treatment. Table 7 shows SIH and SIS scores at the initial visit, just before surgery, and at the end of the treatment.

SIH and SIS scores at the initial visit was −19.5 and −8.2 which indicated severe skeletal Class III, whereas SIH after the orthodontic treatment combined with surgery was −9.5 which still indicated skeletal Class III. However, SIS after the treatment was −1.9 which is within a normal range.

There was a big skeletal improvement because of orthognathic change.

Table 4 Cluster analysis of soft tissue (group average method)

		t-value
G1	Mandibular prognathism	23.5
	Gla-SPog to FH	23.6
	Gla perp. Li	14.5
	*Memmifield's Z angle	24.1
	Nasomental angle	21.7
G2	*Cant of Upper Lip	4.2
G3	Sub-Ms	3.6
	*Stom-Ms	13.4
G4	Lower lip protrusion	8.4
	Lower E-line	13.6
	Upper lip protrusion	21.9
	*Upper E-line	28.3
	Facial convexity angle	27.8
G5	*Nasofacial angle	16.3
G6	Sub-Stom	9.4
	*Verti. lip-chin ratio	17.0
G7	*Labiomental sulcus	15.3
G8	*Nasolabial angle	3.8



* : Measurements within each cluster with the hightest t-value

Table 5 Discriminant analysis of skeletal measurements

Measurement	Discriminant coefficient	F-value
APDI	−0.42	77.22
Wits appraisal	0.61	93.97
Constant	37.52	
Mahalanobis' generalized distance		16.69
Class I group		8.34±3.61
Class III group		−8.34±4.49
Estimated discriminant error rate		2.06%
Apprent error rate		98.15%

Table 6 Discriminant analysis of soft tissue

Measurement	Discriminant coefficient	F-value
Upper E-line	1.41	609.83
Cant of Upper Lip	−0.26	69.64
Nasolabial angle	−0.12	26.84
Labiomental sulcus	1.54	110.10
Constant	11.02	
Mahalanobis' generalized distance		12.10
Class I group		6.05±3.55
Class III group		−6.05±3.39
Estimated discriminant error rate		4.10%
Apprent error rate		96.53%

Case 2 was diagnosed as Angle's Class II division 1 malocclusion. Four first bicuspids were extracted to start with edgewise appliances. Treatment period was 3 years. Fig. 8 shows cephalometric changes during the treatment. Table 8 shows SIH and SIS scores before and after the treatment.

SIH and SIS scores at the initial visit was 15.1 and 8.9 which indicated severe skeletal Class II, whereas those after the orthodontic treatment was 7.9 and 4.8 which still indicated skeletal Class II. Dental compensation to camouflage this skeletal discrepancy was found to be performed.

Discussion

I. Sample distribution

In the present study, the subject size of Class II and Class III were even and 216, so that mean discriminant score became zero. Sample size of each group should be more than 3 times, hopefully 5 times of the number of variables if the parent group would show normal distribution when multivariate analysis would be performed as described by Foley[23]. The resultant numbers of the present three statistical mode analysis for SIH and SIS were 2 and 4, which are small enough not to decrease reliabilities of the analyses.

II. Selection of measurements

From the many skeletal measurements in wide use today, we narrowed down this list to select the main measurements that characterize skeletal prob-

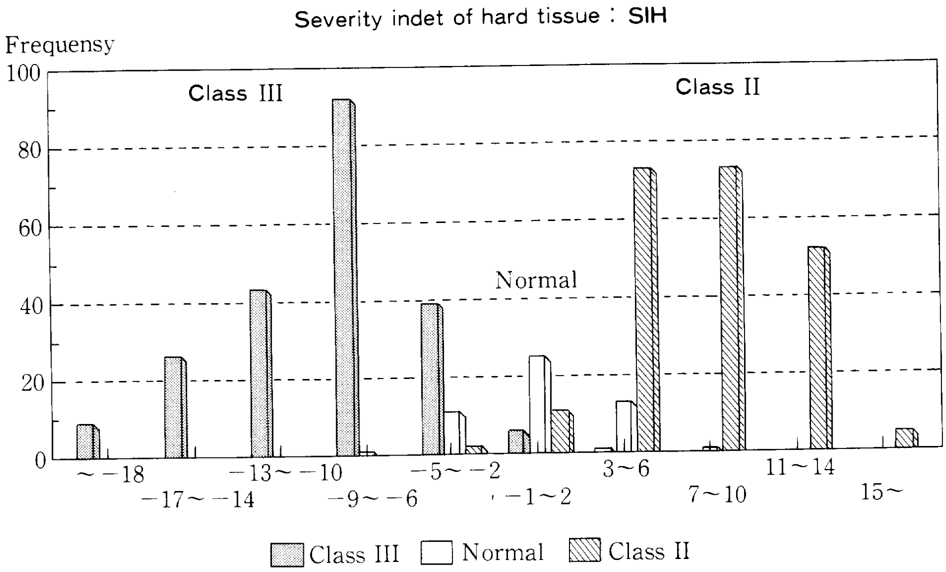


Fig. 4 Distribution of discriminant Scores for Class III, Normal and Class II groups.

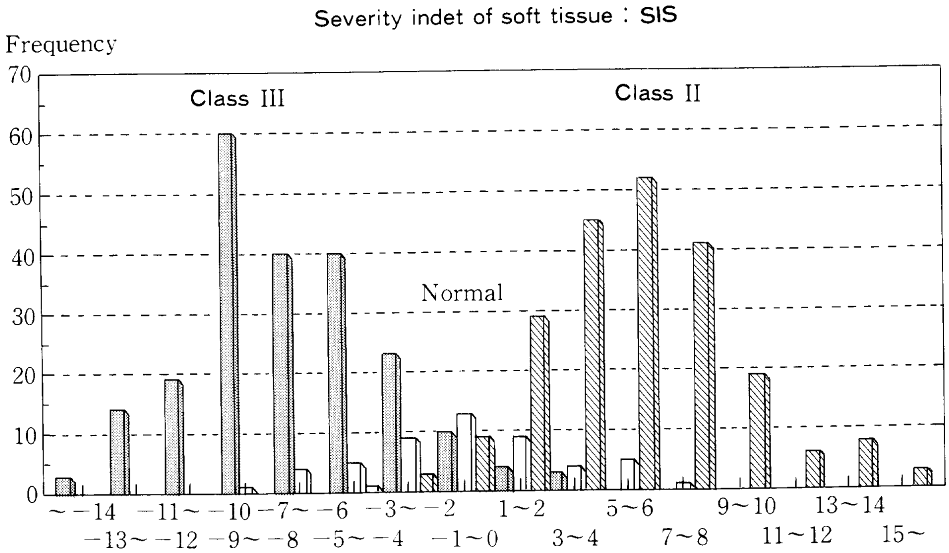
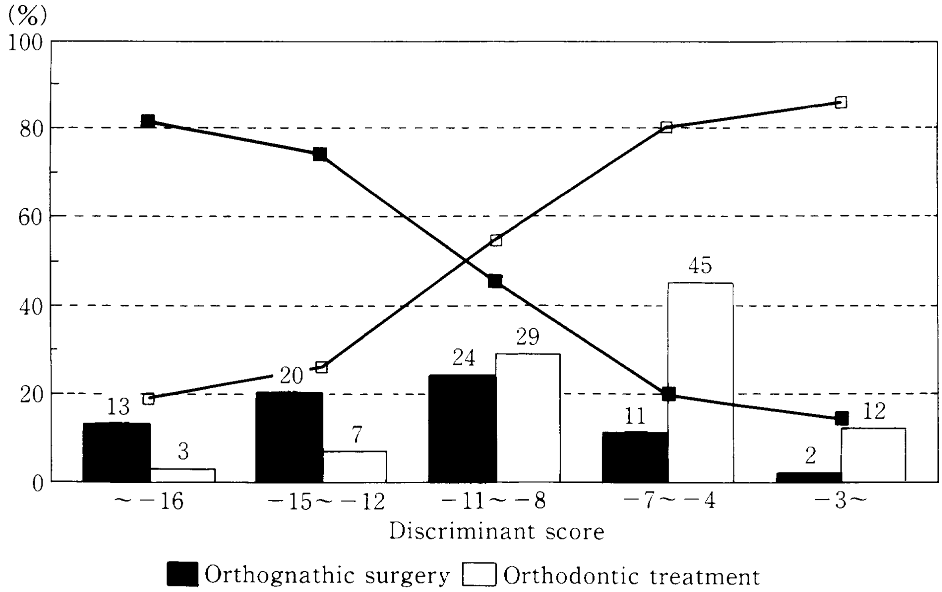


Fig. 5 Distribution of discriminant Scores for Class III, Normal and Class II groups.

lems. In order words, experimental and subjective factors were eliminated and a three step selection was applied from both statistical and objective and stand points. The first step was a t-test with only significant measurements being selected ($p<0.001$). The second step was cluster analysis (group average method), and with this, measurements with high degrees of similarity were classified in the same group. Then, those with high t-values in each cluster were selected. The third step was discriminant analysis, performed in stepwise mode for each measurement with a significant partial F-value more than 10.0. Morphological factors were described with this analysis.

Two common skeletal measurements were APDI and Wits appraisal. APDI is the sum of facial plane angle, A-B plane angle and palatal plane to F. H. plane angle. However, we found that sum of these angles was actually the same as angle of A-B plane to palatal plane geometrically. Therefore, the resulting formula for SIS is as follows ; SIS=0.61 (Wits appraisal) − 0.42 (A-B plane to palatal plane) + 37.52. On the other hand, Upper E-line, Cant of Upper Lip, Nasolabial angle, and Labiomental sulcus were the significant measurements for soft tissue antero-posterior evaluation.



Number on each bar indicates sample size

Fig. 6 Clinical application of S. I. H. for Class III cases

Fig. 7 Cephalometric superimposition of case 1.

Fig. 8 Cephalometric superimposition of case 2.

Table 7 S. I. H. and S. I. S. scores of case 1 (Class III case)

	Initial	Pre surg.	After Tx.	Clinica Norm
APDI	112.5	111.0	101.0	83.4
Wits appraisal	−16.0	−16.5	−7.5	−1.8
S. I. H.	−19.5	−19.2	−9.5	−3.9~4.7
Upper E-line	−4.5	6.0	−3.0	−2.0
Cant of Upper Lip	53.0	40.0	35.0	17.3
Nasolabial angle	50.0	64.5	67.0	91.4
Labiomental sulcus	4.5	5.0	5.5	4.7
S. I. S.	−8.2	−7.9	−1.9	−2.7~2.5

Severity indices for skeletal and soft tissues as an antero-posterior evaluation

Severity indices were developed using the discriminant coefficients shown in Tables 5 and 6. Therefore, each significant variable can describe its own “weight”. As can be seen in Figures 4 and 5, the function assigned negative scores to most Class III patients and positive scores to most Class II

Table 8 S. I. H. and S. I. S. score of case 2 (Class II case)

	Initial	After Tx.	Clinical Norm
APDI	66.5	69.0	83.4
Wits appraisal	9.0	−1.0	−1.8
S. I. H.	15.1	7.9	−3.9〜4.7
Uppe E-line	6.0	1.5	−2.0
Cant of Upper Lip	20.0	13.0	17.3
Nasolabial angle	103.0	99.0	91.4
Labiomental sulcus	4.5	4.5	4.7
S. I. S.	8.9	4.8	−2.7〜2.5

patients. Moreover, the higher the score goes, the severer the skeletal pattern and/or soft tissue profile go. Because the two opposite parent groups were of equal size and of roughly equal variance, the mean discriminant score was zero. Normal occlusion individuals with intermediate discriminant scores (clustering around zero) indicate the ones who have normal antero-posterior skeletal position for SIH, and for SIS, those scores indicate normal soft tissue profile.

Means and standard deviations of discriminant scores in Class III and Class II samples for SIH were -8.34 ± 4.49 and 8.34 ± 3.61 respectively. Those for SIS were -6.05 ± 3.39 and 6.05 ± 3.55 respectively. The ranges of clinical norms for SIH and SIS were between -3.9 and 4.73 and between -2.7 and 2.5.

Application of SIH and SIS for diagnosing skeletal severity

Case 1 was a skeletal Class III patient who received two jaw surgery, whereas case 2 was skeletal Class II patient who received orthodontic treatment with four bicuspid extraction.

SIH of case 1 at the initial visit was -8.2, where almost half of the present Class III samples received surgical correction (Fig. 6). Surgical correction with some dental compensation was required to camouflage the skeletal discrepancy to improve soft tissue profile. As shown in figure 6, SIH score can predict possibility of surgery.

In Case 2, conventional cephalometric evaluation revealed skeletal Class II and diagnosed as Angle's Class II division 1 malocclusion.

Four first bicuspids were extracted to start with edgewise appliances. Table 8 shows SIH and SIS scores before and after the treatment. SIH and SIS scores at the initial visit was 15.1 and 8.9 which indicated severe skeletal Class II cases, whereas those after the orthodontic treatment was 7.9 and 4.8, which still indicated skeletal Class II. Dental compensation with tooth extraction to camouflage this skeletal discrepancy was performed. Therefore, long term retention may be necessary to prevent relapse.

Discriminant score outside of one standard deviation toward zero (normal side) for Class III and Class II groups would be very difficult for orthodontic treatment. If those scores after the treatment are still deviated side, relapse may tend to occur.

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