ORIGINAL ARTICLE
KOREA. J. ORTHOD.
2003 : 33(3) : 141-50

Classification of the skeletal variation in the normal occlusion

Ji-Young Kim[1], Tae-Woo Kim[2], Dong-Seok Nahm[3], Young-Il Chang[4]

The purposes of this study were to classify the anteroposterior and vertical skeletal pattern of normal occlusion samples into specific types with factor and hierarchical cluster analysis, and to evaluate the range and limit of skeletal relationships that permit the establishment of normal occlusion via natural dentoalveolar compensation.

Lateral cephalograms of 294 normal occlusion samples were measured, as selected from 15,836 persons through a community dental health survey who cooperated in record taking. Using a factor analysis, two factors representing anteroposterior and vertical skeletal relationships were extracted from 18 skeletal measurements. Then cluster analysis classified the skeletal patterns into nine types. The means and the standard deviations of 8 anteroposterior skeletal measurements and 10 vertical skeletal measurements were determined and comparisons of these measurements among the types were performed. The results obtained in this study showed that the range of normal occlusion included very diverse anteroposterior and vertical skeletal relationships.

Key words : Skeletal Variation, Skeletal Pattern, Cluster Analysis, Normal Occlusion

Relatively good occlusion with skeletal discrepancy is not uncommon. This confirms that significant anatomical variation exists even within so-called normal occlusion samples of persons, and to a greater degree in the malocclusion group.[1] Therefore, simple cephalometric analysis for a patient by means of numerical standards derived from other persons with an average skeletal relationship would be scientifically flawed. Thus, it could be suggested that patients with malocclusion should not be treated by standardized cephalometric analysis, but rather by the individual norm of cephalometric analysis.[1,2]

For the purpose of clinical diagnosis and treatment planning, it is important to present a new direction toward the individualized evaluation of facial form. Even though previous studies[3,4] have considered the anteroposterior or vertical relationships separately, only a little information was available on classifying skeletal types by antero-posterior and vertical variables at the same time.[5]

The purpose of this study was to classify the antero-

Former graduate student[1], Associate professor and Chairman[2], Professor[3], Professor[4]
Department of Orthodontics, College of Dentistry, Seoul National University

Reprint requests to : **Young-Il Chang**
28-2 Yoenkun-dong, Chongno-Ku, Seoul 110-749, Korea
Department of Orthodontics, College of Dentistry, Seoul National University
82-2-760-2600 / dmajor@empal.com

posterior and vertical skeletal patterns of those subjects with normal occlusion into specific types by factor and hierarchical cluster analysis and to evaluate the ranges and limitation of skeletal variations that could permit the establishment of normal occlusion.

MATERIALS AND METHODS

Selection of normal occlusion samples

This study was based on the lateral cephalograms of subjects with normal occlusion selected through a community dental health survey in Seoul, Korea. The 1,543 persons who met the criteria of normal occlusion samples were selected from 15,836 persons and 294 subjects acceded to participate. Complete orthodontic records were made, including cephalometric and panoramic radiographs, diagnostic casts and intraoral and the facial photographs. The 294 subjects consisted of 177 males and 117 females and their age ranged from 15.1 to 30.5 years with a mean age of 20.2 years.

Selection criteria of normal occlusion samples

1) Class I molar and canine relationship with normal occlusal interdigitation
2) Fully erupted permanent dentition except third molars
3) Normal overjet and overbite (2~4mm)
4) Minimal crowding (arch-length/tooth material discrepancy less than 3mm) and spacing (less than 1mm)
5) No history of previous orthodontic or prosthodontic treatment

Cephalometric analysis

Lateral cephalograms were taken by the Cranex 3+ (Orion Corporation Soredex, Helsinki, Finland) machine, with a target-source distance of 150 cm, target-film distance of 20 cm, 75KVp, 10mA, exposure time of 1.2 seconds. The subject's head was placed in a standardized position with cephalostat. Magnification rate was 14%.

Each lateral cephalogram was originally traced on frosted acetate film (3M Unitek, Monrovia, CA, USA) with 0.3 mm pencil by one investigator. The tracings were digitized with a digital converter (Intuos 2 Graphic Tablet, Wacom Co., Japan) and analyzed by Visual C++ (Microsoft, Redmond, WA, USA) software designed for this study. The values were measured in the units of 0.1 degree and 0.1mm.

The definitions of the cephalometric landmarks and measurements used were previously described by Ku et al.[4]

Statistical analysis

1) Reliability test

To test the reliability of landmark identification, tracing methods and the measurement technique, 30 lateral cephalograms were randomly selected and were traced and digitized again on separate days, two months after the initial tracing. The resultant measurements were compared with the original data and Dahlberg's formula was used to calculate the error of estimation :

$S_e=\sqrt{\frac{\Sigma D^2}{2n}}$, where D is the difference between two measurements of a pair and n is the number of subjects. The combined tracing and digitizing errors of angular measurements ranged from 0.00° to 0.17° with mean of 0.05°, while that of linear measurements ranged from 0.00 mm to 0.12 mm with a mean of 0.03 mm.

2) Factor analysis

Principal component analysis (factor analysis) was used to summarize 18 skeletal variables. Two sets of factors for anteroposterior and vertical skeletal variability of normal occlusion subjects were extracted and interpreted after a varimax rotation of the factor loadings. The factor scores were calculated for each individual, and these factor scores were used as new variables in the following procedures.

3) Cluster analysis

The Ward method of hierarchical cluster analysis was applied to classify the skeletal pattern anteroposteriorly as well as vertically by using scores for two factors identified in the principal component analysis. The number of

Table 1. Result of principal component analysis

Factor	Rotation sums of squared loadings		
	Eigenvalue	Variance (%)	Cumulative proportion (%)
Anteroposterior variables	4.637	46.368	46.368
Vertical variables	3.732	37.318	83.686

Table 2. Rotated component matrix

	Component	
	1	2
FH−AB	−0.928	−0.222
ANB	0.878	0.102
SN−AB	−0.856	−0.327
APDI	−0.827	−0.272
Wits appraisal	0.770	−0.216
ODI	0.665	−0.614
PMA	0.109	0.943
SN−MP	0.239	0.907
FMA	0.284	0.893
AB−MP	0.636	0.748

skeletal patterns was decided by a dendrogram.

4) One way analysis of variance (ANOVA) and *post hoc* test

One way analysis of variance (ANOVA) was used to compare the groups and Duncan's multiple range tests were used to determine which groups were significantly different.

RESULTS

1. Classification of normal occlusion

Two factors with an eigenvalue greater than 1.0 were extracted after the principal component analysis (factor

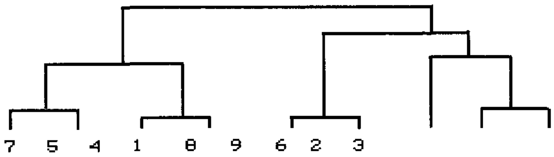

Fig. 1. Tree dendrogram of cluster analysis derived from 294 lateral cephalograms.

analysis). The accumulated proportion of these two factors was 83.7%; in other words, two factors could account for 83.7% of the normal samples on the skeletal pattern. These were interpreted after a varimax rotation of the factor loadings. Table 1 shows the results of principal component analysis after varimax rotation – converged in 3 iterations – with Kaiser Normalization.

These two factors were identified as anteroposterior and vertical variables as shown in Table 2. The anteroposterior variables were mainly composed of FH−AB, ANB, SN−AB, APDI, and Wits appraisal in the descending order of factor loading. The vertical variables were mainly composed of PMA, SN−MP, FMA, AB−MP, and ODI in the descending order of factor loading.

A hierarchical cluster analysis by Ward method, based on two factor scores, was carried out to classify the skeletal patterns of normal occlusion samples anteroposteriorly as well as vertically. The tree dendrogram obtained from cluster analysis is shown in Figure 1. It apparently expresses nine skeletal patterns. As an analysis of lineage in the dendrogram, Type 7 and Type 5, Type 4 and Type 1, Type 8 and Type 9, and Type 2 and Type 3 were in close relation with each other. Type 6 was somewhat apart from the other types.

	Class II tendency	Class I	Class III tendency
Hyper-divergent	**Type 1** 52(17.7%)	**Type 2** 48(16.3%)	**Type 3** 8(2.7%)
Normo-divergent	**Type 4** 19(6.5%)	**Type 5** 41(19.3%)	**Type 6** 75(25.5%)
Hypo-divergent	**Type 7** 7(2.4%)	**Type 8** 26(8.8%)	**Type 1** 18(6.1%)

Fig. 2. Topographic diagram of nomination and frequency of each type membership.

Nine types were arranged into a 3×3 contingency table with the X-axis representing the anteroposterior skeletal relationship and the Y-axis representing the vertical skeletal relationship. This table represents skeletal Class III tendency on the right part, skeletal class II tendency on the left part, hyper-divergent facial pattern on the upper part, and hypo-divergent facial pattern on the lower part. The nomination and frequency of each group are shown in Figure 2. The largest group was Type 6 with 75 samples (25.5%) followed by Type 1 with 52 samples (17.7%). The smallest group was Type 7 with 7 samples (2.4%) followed by Type 3 with 8 samples (2.7%). Types 1, 3, 7, and 9 represented extremes of characteristic skeletal pattern that could form normal occlusion. Type 1 (N=52) and Type 9 (N=18) had relatively more samples than Type 7 (N=7) and Type 3 (N=8).

In the subgrouping of the sample according to anteroposterior skeletal pattern, Class I (39.1%), II (34.3%), and III (26.5%) skeletal patterns showed relatively similar distribution and among them, the largest percentage of samples were in the Class I pattern. It was found that a hyperdivergent pattern was dominant in Class II and Class I skeletal patterns (66.7% and 41.7%, respectively), whereas normodivergent pattern was dominant in the Class III skeletal pattern (74.2%). It was also found that a small percentage (9.0%) of the Class II skeletal pattern had a hypodivergent pattern and a small percentage (7.9%) of Class III skeletal pattern had a hyperdivergent pattern.

To obtain information about the frequency distributions of the three types of anteroposterior skeletal classification within vertical skeletal patterns, further categorization was performed. From this study, it was found that a large number of samples were distributed among normodivergent (45.9%) and hyperdivergent (36.7%) patterns. The other small percentage was 17.3% in a hypodivergent pattern. Hyperdivergent

Table 3. Means and standard deviations for anteroposterior skeletal measurements of the nine types

	Type 1 N=52	Type 2 N=48	Type 3 N=8	Type 4 N=19	Type 5 N=41	Type 6 N=75	Type 7 N=7	Type 8 N=26	Type 9 N=18	p-value*
FH-AB	80.8 ± 2.5	84.7 ± 2.1	90.8 ± 2.0	77.6 ± 1.9	82.8 ± 2.1	87.9 ± 2.6	77.5 ± 2.8	86.2 ± 1.8	91.2 ± 2.8	0.000
ANB	4.2 ± 2.1	2.5 ± 1.2	−0.8 ± 1.4	5.0 ± 1.0	3.5 ± 1.1	1.3 ± 1.2	6.0 ± 1.4	2.1 ± 1.1	0.2 ± 0.9	0.000
APDI	81.0 ± 12.7	83.7 ± 2.2	90.1 ± 1.7	78.6 ± 2.2	83.2 ± 2.1	87.3 ± 2.6	79.2 ± 3.2	85.9 ± 2.4	88.9 ± 2.7	0.000
SN-AB	72.0 ± 2.4	75.2 ± 2.2	82.1 ± 2.1	68.3 ± 2.0	74.3 ± 2.1	79.8 ± 2.9	70.8 ± 3.5	79.1 ± 2.1	82.7 ± 2.6	0.000
Wits appraisal	−0.8 ± 1.7	−2.8 ± 1.8	−7.3 ± 1.2	1.2 ± 2.0	−0.2 ± 1.6	−3.1 ± 1.9	4.2 ± 2.4	−1.0 ± 2.3	−3.2 ± 1.7	0.000
AF-BF	7.6 ± 2.1	4.3 ± 1.8	−0.7 ± 1.7	9.9 ± 1.8	5.7 ± 1.6	1.7 ± 2.1	10.0 ± 2.6	3.1 ± 1.5	−1.0 ± 2.3	0.000
AFB	5.2 ± 1.4	3.0 ± 1.2	−0.5 ± 1.2	6.8 ± 0.9	4.0 ± 1.1	1.2 ± 1.5	6.8 ± 1.6	2.1 ± 1.0	−0.7 ± 1.6	0.000
ABPA	−6.0 ± 1.6	−3.6 ± 1.5	1.0 ± 2.1	−7.9 ± 1.5	−5.8 ± 1.7	−2.6 ± 1.7	−9.7 ± 1.4	−4.1 ± 1.6	−1.4 ± 1.4	0.000

* Calculated by ANOVA test.

Table 4. Means and standard deviations for vertical skeletal measurements of nine types

	Type 1 N=52	Type 2 N=48	Type 3 N=8	Type 4 N=19	Type 5 N=41	Type 6 N=75	Type 7 N=7	Type 8 N=26	Type 9 N=18	p-value*
PMA	27.0 ± 2.9	28.4 ± 2.6	27.5 ± 3.1	25.0 ± 2.7	21.4 ± 1.8	22.9 ± 2.3	17.8 ± 3.2	16.5 ± 2.9	17.7 ± 2.2	0.000
SN-MP	36.1 ± 3.1	36.9 ± 2.5	35.5 ± 3.5	35.3 ± 2.8	30.3 ± 2.5	30.4 ± 2.5	26.2 ± 3.3	23.3 ± 2.9	24.0 ± 1.5	0.000
FMA	27.3 ± 3.1	27.5 ± 2.5	26.7 ± 1.6	26.0 ± 2.7	21.8 ± 2.6	22.3 ± 2.1	19.6 ± 3.4	16.2 ± 2.8	15.4 ± 2.8	0.000
AB-MP	71.9 ± 1.6	67.9 ± 1.8	62.4 ± 3.0	76.5 ± 1.6	75.4 ± 1.9	69.8 ± 2.0	83.0 ± 1.5	77.6 ± 2.4	73.4 ± 1.4	0.000
ODI	72.1 ± 2.8	66.9 ± 3.0	61.6 ± 4.5	77.4 ± 3.5	75.8 ± 3.0	69.2 ± 3.5	84.7 ± 2.0	77.3 ± 3.2	71.1 ± 2.9	0.000
Björk sum	396.1 ± 3.1	396.9 ± 2.5	395.5 ± 3.5	395.3 ± 2.8	390.3 ± 2.5	390.4 ± 2.5	386.2 ± 3.3	383.3 ± 2.9	384.0 ± 2.5	0.000
Gonial angle	120.4 ± 5.0	121.2 ± 3.9	121.9 ± 5.8	117.2 ± 3.9	115.4 ± 4.8	117.1 ± 4.6	111.8 ± 5.5	110.6 ± 5.3	110.5 ± 5.6	0.000
AP FHR	65.7 ± 2.7	63.8 ± 2.4	65.3 ± 2.9	66.2 ± 2.2	70.3 ± 2.6	69.6 ± 2.5	73.8 ± 3.3	76.5 ± 3.0	75.4 ± 2.4	0.000
AL FHR	55.8 ± 1.5	55.9 ± 1.6	56.9 ± 1.7	54.5 ± 1.3	55.1 ± 2.0	55.7 ± 1.7	53.9 ± 1.4	55.5 ± 1.3	56.0 ± 1.6	0.000
Y axis angle	63.7 ± 2.5	61.9 ± 2.5	61.5 ± 1.1	64.1 ± 2.5	61.6 ± 1.8	60.3 ± 2.2	62.2 ± 1.7	59.7 ± 2.2	57.7 ± 2.9	0.000

* Calculated by ANOVA test.

patterns consisted of 48.1% of the Class II skeletal pattern and 7.8% of the Class III skeletal pattern. On the other hand, the Class II skeletal pattern showed the lowest percentage (13.7%) in the hypodivergent pattern.

2. Means and standard deviations for each measurement of nine types

Variables which included two factors (the result of principal component analysis) with means and standard deviations for the nine different types are listed in Table 3 and 4. The significance level was predetermined at

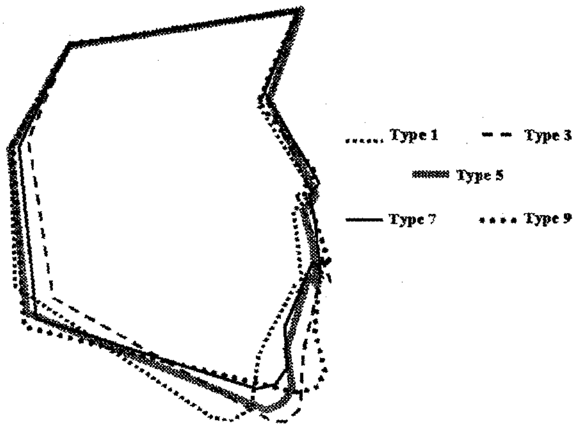

Fig. 3. Superimposition of profilogram for each characteristic type

0.05 and there were significant differences between nine types. To compare the differences of each measurement between types, Duncan's multiple range test was performed and this *post hoc* treatment showed that each variable has been relatively well stratified according to the nine types (*post hoc* data not shown).

3. Pattern analysis

Type 1, 3, 7, and 9 represented extremes of characteristic skeletal patterns that could form normal occlusion and Type 2, 4, 6 and 8 had intermediate characteristics. So it is meaningful to deal with the former types. To characterize and visualize the skeletal distinctions of each type, one representative case per each type that was the closest to the mean value of any variables of the type, was presented as a prototype. Figure 3 superimposes the profilograms for each case. The overall superimposition was done by superimposing on SN plane and registering on Sella.

Type 1 had a Class II skeletal tendency with hyperdivergent facial patterns. The mandible showed clockwise rotation and was relatively more retruded in comparison to Type 5. Type 3 had a Class III skeletal tendency with hyperdivergent facial patterns. The mandible rotated to a clockwise direction and was protruded. Type 7 had a Class II skeletal tendency with hypodivergent facial patterns. The mandible showed a counterclockwise rotation and was retruded. Type 9 had a Class III skeletal tendency with hypodivergent facial patterns. The mandible showed a counterclockwise rotation and was protruded.

Table 5. Variability of skeletal measurements

	Min	Mean ± SD	Max	Range
FH-AB	72.7	84.6 ± 4.4	97.3	24.6
ANB	-3.0	2.6 ± 1.9	8.0	10.9
SN-AB	63.9	76.1 ± 4.7	87.4	12.0
APDI	73.7	84.3 ± 3.9	93.9	20.2
Wits appraisal	-9.0	-1.7 ± 2.6	8.6	17.5
AF-BF	-6.2	4.3 ± 3.6	14.0	20.3
AFB	-4.3	3.0 ± 2.4	9.3	13.6
ABPA	-12.2	-4.3 ± 2.6	4.7	16.9
PMA	11.7	23.6 ± 4.5	35.2	23.5
SN-MP	16.8	31.8 ± 5.2	45.3	28.4
FMA	9.0	23.3 ± 4.7	34.8	25.8
AB-MP	55.4	72.1 ± 4.3	85.3	29.8
ODI	50.9	71.8 ± 5.4	87.3	36.4
Björk sum	376.8	391.8 ± 5.2	405.3	28.4
Gonial angle	94.2	117.1 ± 5.9	135.4	41.2
AP FHR	58.7	68.8 ± 4.7	84.1	25.4
AL FHR	50.9	55.6 ± 1.7	60.2	9.3
Y axis angle	53.1	61.4 ± 2.9	70.8	17.6

4. Variability of skeletal relationship of normal occlusion samples

The means, standard deviations, minimums, maximums and ranges for variability of anteroposterior and vertical skeletal measurements are listed in Table 5. All of the individual cephalometric measurements for normal occlusion samples showed a wide range of variation. Among anteroposterior skeletal measurements, the FH-AB angle ranged from 72.7° to 97.3° with a mean of 84.6° and the ANB angle ranged from −3.0° to 8.0° with a mean of 2.6°. Among vertical skeletal measurements, the PMA angle ranged from 11.7° to 35.2° with a mean of 23.6° and the SN-MP angle ranged from 16.8° to 45.3° with a mean of 31.8°.

DISCUSSION

The results clearly showed a wide range of normal variations in skeletal relationships within normal occlusion samples. The skeletal patterns of these samples were able to be classified into nine groups. As previously defined by Sassouni,[6] *types* are descriptions of skeletal disproportion grouping and such a classification identifies a number of characteristics which, when seen together, present enough similarities to be included in the same group. The nomenclature selected for facial types is parallel to skeletal characteristics of each facial type. There are three basic types with vertical proportions −hyperdivergent, normodivergent and hypodivergent[7] − and three types with anteroposterior proportions − skeletal Class I, II and III. The different skeletal types classified in this study were termed Class II tendency with hyperdivergent, Class I hyperdivergent, Class III tendency with hyperdivergent, Class II tendency with normodivergent, Class I normodivergent, Class III tendency with normodivergent, Class II tendency with hypodivergent, Class I hypodivergent, and Class III tendency with hypodivergent, type 1 to type 9, respectively.

While previous studies[3,5,8-11] on dentoalveolar compensation have separately analyzed the skeletal patterns of subjects with normal occlusion anteroposteriorly or vertically, the skeletal types were classified on the basis of anteroposterior as well as vertical relationships in this study. For a more accurate identification of facial types, it is important to define the multidimensional combinations.[6] Several investigators[3,4,12,13] reported that the interrelation of anteroposterior and vertical relationship was responsible for various facial types. As described by Schudy,[7] the terms "retrognathic" and "prognathic" are inadequate in describing facial types. The variations in vertical dimensions are also significant in identifying facial types. Considering both anteroposterior and vertical dimensions would lead to a more precise diagnosis from which more specific treatment could be planned. In addition, this study was intended to include as many skeletal variables as possible for objectivity. For example, to evaluate the vertical dysplasia of patients, several cephalometric measurements such as the steepness of mandibular plane, gonial angle, OMA (occlusomandibular plane angle), anteroposterior facial height ratio, ODI (overbite depth indicator) and so forth were evaluated. Opdebeeck[14] reported that reduced lower facial height was not always associated with decreased SN-MP angle, and opposite findings of normal lower facial height combined with reduced SN-MP angle value was not uncommon either. Bishara and Augspurger[15] have suggested that a single parameter would not be sufficient to accurately identify a given facial type. Fields et al.[11] also demonstrated that multiple variables could describe the associated morphology more completely than a single variable. Thus, as many skeletal variables as possible were measured in this study. Reviewing the literature, 18 specific cephalometric measurements were selected which suited the best criteria for identifying subjects with anteroposterior and vertical skeletal variations. 18 variables obtained had some correlation with each other. By using correlation analysis, variables which had a correlation coefficient higher than 0.9 or lower than about 0.4 were excluded because those were not considered to contribute in classifying the characteristic skeletal pattern with consistency. Consequently, 10 variables − SN-AB, FH-AB, APDI, ANB, Wits appraisal, SN-MP, PMA, ODI, FMA, and AB-MP − were selected and principal component analysis was used to summarize these variables into two sets of factors, which were identified as anteroposterior and vertical variables as shown in Table 2. While ODI and AB-MP were regarded as the vertical skeletal variables, they are also estimated to have anteroposterior characteristics. This was inferred from the fact that the factor loading of ODI was higher in factor 1 than in factor 2 and that of AB-MP was relatively high in factor 1. Consequently, ODI decreased according to the anteroposterior relationship in the same vertical skeletal pattern. These findings were consistent with the demonstration of Yang,[16] in which ODI decreased with the increase of APDI in normal overbite samples, reflecting the characteristics of AB to mandibular plane angle.

Class I skeletal pattern and the normodivergent pattern were the most frequent skeletal patterns among the three types of anteroposterior and vertical skeletal relationships. However, Type 6 had the largest number (Figure 2). It could be guessed that the Class I normodivergent pattern was the most common pattern, but the skeletal patterns of normal occlusion samples showed the highest prevalence of Class III tendency with normodivergent pattern (25.5%) in this study sample. The explanation for this result might be that Class III tendency with normodivergent pattern allowed normal occlusion via natural dentoalveolar compensation most frequently. Conversely, it seems that our society accepts more easily the Class III tendency with normdivergent skeletal pattern, even though it is hard to generalize.

On the other side, there were many less members in Type 3 (Class III tendency with hyperdivergent pattern) and Type 7 (Class II tendency with hypodivergent pattern) than Type 1 (Class II tendency with hyperdivergent pattern) and Type 9 (Class III tendency with hypodivergent pattern). Although Class III pattern was the least dominant type among the hyperdivergent subjects in this study of normal occlusion sample, it is known to be the predominant type in the malocclusion group.[17] This result indirectly suggested that the Class III hyperdivergent pattern and Class II hypodivergent pattern are difficult to constitute normal occlusions, and the anteroposterior positioning of dental and skeletal components could affect mandibular rotation. This data conformed previous research[15,18] and revealed that the anteroposterior positioning of teeth and skeletal components could logically be anticipated to affect mandibular rotation. As teeth and skeletal parts are located posteriorly, the SN-MP angle is expected to increase. Conversely, low SN-MP angles should be associated with more anterior placement of these component parts. This indicates that the denture, as well as the skeletal base, is in a characteristic anteroposterior position relative to the SN-MP angle or present growth pattern. Forward-rotating (low SN-MP angle) patterns of growth allow the pogonion to move in a relatively forward direction, resulting in a prominent chin point. Conversely, backward-rotating (high SN-MP angle) mandibles move the pogonion backward and downward producing a less prominent chin. Enlow[19] also demonstrated that if the nasomaxillary region is vertically short, a mandibular protrusive effect is produced. In Downs' study[9] of twenty individuals with excellent occlusions, the coefficient of correlation between the mandibular plane angle and the facial angle was found to be −0.726, which is an indication that as the facial angle decreases (chin more posterior) the mandibular plane angle tends to increase (mandibular border becomes steeper).

What is the range of anteroposterior skeletal relationships associated with normal occlusion? About this pursuit, the focus has been largely on mean central values. In this study, the naturally occurring ANB angle in people with normal occlusion ranged from −3.0° to 8.0°. Although Steiner[20] did not report a descriptive statistical measures of dispersion for his ANB angle value, it is interesting that the highest ANB angle in Steiner's system of acceptable compromises was 8°, which was the same as maximum ANB difference recorded in this study. In the vertical skeletal variables, SN-MP ranged from 16.8° to 45.3°. These ranges were similar with the study of Casko and Shepherd,[1] which reported the range from −3° to 8° of the ANB angle and 15° to 41° of the SN-MP angle. Anderson et al.[21] reported the ANB angle ranging from −0.5° to 9.5° in African-American descents with normal occlusion. Oh el al.[13] reported the ANB angle ranged from −2.6° to 6.9°, the SN-MP angle ranged from 17.6° to 43.6°, and that PMA ranged from 12.0° to 35.0°, which showed similar results to this study.

The representative profilograms for each specific type were collectively depicted (Figure 3). The significant amount of variation among those with normal occlusions becomes readily apparent in these superimpositions. Many current systems of cephalometric evaluation simply implicated to the mean values would classify many of these patients as abnormal and in need of correction. However, all these skeletal patterns could permit normal occlusions via natural dentoalveolar compensation without orthodontic treatment. From this viewpoint, it was extremely interesting that the skeletal patterns of normal occlusion samples had a similarity with those of malocclusion patients with skeletal imbalances.

It could be noted that the assessment of individuals with skeletal variability by the mean cephalometric measurements is unreasonable. If the characteristics of the dentoalveolar compensation of extreme skeletal types are carefully studied and the dentoalveolar measurements are investigated, the individual treatment goal for each specific skeletal type can be established. From this aspect, this study is expected to formulate a basis for further study on dentoalveolar compensation and the establishment of individualized treatment goals.

CONCLUSIONS

The purpose of this study was to classify the anteroposterior and the vertical skeletal pattern of normal occlusion into specific types. By using hierarchical cluster analysis, the anteroposterior and vertical skeletal relationships of 294 subjects with normal occlusion were classified into nine types, which could be arranged into 3×3 contingency tables with the X-axis representing the anteroposterior skeletal relationship and the Y-axis representing the vertical relationship. A descriptive feature of the results included :

1. The skeletal patterns of subjects with normal occlusion showed a high prevalence of Class III tendency with a normodivergent pattern (25.5%) and Class II tendency with a hyperdivergent pattern (17.7%).
2. Class II tendency with a hypodivergent pattern (2.4%) and Class III tendency with a hyperdivergent pattern (2.7%) were relatively low in prevalence.
3. In anteroposterior skeletal variables, FH-AB ranged from 72.7 degrees to 97.3 degrees and ANB ranged from −3.0 degrees to 8.0 degrees. In vertical skeletal variables, PMA ranged from 11.7 degrees to 35.2 degrees and SN-MP ranged from 16.8 degrees to 45.3 degrees.

In conclusion, the anteroposterior and vertical skeletal relationships of subjects with normal occlusion were very diverse.

REFERENCES

1. Casko JS, Shepherd WB. Dental and skeletal variation within the range of normal. Angle Orthod 1984 : 54 : 5-17.
2. Moorreess CFA. Normal variation and its bearing on the use of cephalometric radiographs in orthodontic diagnosis. Am J Orthod 1953 : 39 : 942-50.
3. Jeon YM, Park DC, Kim JG. Dentoalveolar compensation of hyperdivergent skeletal pattern in children and adults. Kor J Orthod 1999 : 29 : 197-207.
4. Ku SJ, Lee SJ, Chang YI. Dentoalveolar compensation according to skeletal patterns of normal occlusion. Kor J Orthod 2002 : 32 : 91-105.
5. Fishman LS. Individualized evaluation of facial form. Am J Orthod Dentofac Orthop 1997 : 111 : 510-7.
6. Sassouni V. A classification of skeletal facial types. Am J Orthod 1969 : 55 : 109-23.
7. Schudy FF. Vertical growth versus anteroposterior growth as related to function and treatment. Angle Orthod 1964 : 34 : 75-93.
8. Proffit WR, Henry WF. Contemporary orthodontics 3rd ed. St. Louis : Mosby, 2000 : 2-4, 675-6.
9. Downs WB. Variations in facial relationships : their significance in treatment and prognosis. Am J Orthod 1948 : 34 : 812-40.
10. Jensen E Palling M. The gonial angle. Am J Orthod 1954 : 40 : 120-33.
11. Fields HW, Proffit WR, Nixon WL, Phillips C, Stanek E. Facial pattern difference in long faced children and adults. Am J Orthod 1984 : 85 : 217-23.
12. Steiner CC. Cephalometrics in clinical practice. Angel Orthod 1959 : 29 : 8-29.
13. Oh CK, Yoon YJ, Kim KW. The compensatory adaptation of anterior teeth according to the skeletal relation. Kor J Orthod 2000 : 30 : 175-83.
14. Opdebeeck H, Bell WH. The short face syndrome. Am J Orthod 1978 : 73 : 499-511.
15. Bishara SE, Augspurger EF Jr. The role of the mandibular plane

inclination in orthodontic diagnosis. Angle Orthod 1975 : 45 : 273-81.
16. Yang WS, Chang YI, Kim TW. A new approach to use overbite depth indicator in orthodontic diagnosis. Kor J Orthod 1992 : 22 : 17-30.
17. Siriwat PP, Jarabak JR. Malocclusion and facial morphology : is there a relationship? An epidemiologic study. Angle Orthod 1985 : 55 : 127-38.
18. Isaacson JR, Isaacson RJ, Speidel T, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthod 1971 : 41 : 219-29.
19. Enlow DH, Hans MG. Essentials of facial growth. Philadelphia: Saunders company, 1996 : 166-92.
20. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953 : 39 : 729-55.
21. Anderson AA, Anderson AC, Hornbuckle AC, Hornbuckle K. Biological deviation of a range of cephalometric norms for children of African American descent (after Steiner). Am J Orthod Dentofac Orthop 2000 : 118 : 90-100.

국문초록

정상교합자의 골격 변이의 분류

김지영, 김태우, 남동석, 장영일

서울대학교 치과대학 교정학교실

본 연구의 목적은 정상교합자의 전후방 및 수직적인 골격형을 군집분석을 이용하여 분류하고, 자연적인 치아치조부 보상기전으로 정상교합을 이룰 수 있는 골격의 범위와 한계를 파악하여 교정치료와 수술-교정 복합치료의 경계 증례에서 진단과 치료 계획 수립에 도움이 되고자 하는 것이다. 이를 위하여 대단위 구강 검진 중 15,836명으로부터 선발된 정상교합자 중 검사에 응한 294명의 측모 두부계측방사선사진의 투사도를 작성하여 계측하고, 인자분석을 통하여 18개의 골격 계측항목 중에서 전후방적 골격 관계를 나타내는 인자와 수직적 골격 관계를 나타내는 인자를 추출하였으며, 이를 군집분석에 적용하여 정상교합자의 골격형을 9개의 군으로 분류할 수 있었다. 본문에서는 각 군의 전후방적, 수직적 골격계측 항목의 평균 및 표준편차를 구하고, 각 군 간의 차이를 비교 분석한 결과를 제시하고 있으며, 이를 통하여 정상교합자의 전후방적, 수직적 악골 관계가 매우 다양함을 알 수 있었다.

주요 단어 : 골격 변이, 측모 골격형, 군집분석, 정상교합