치의과학박사 학위논문

Differences in Heritability of the Skeletodental Characteristics in Face Between Twin Subjects with Skeletal Class I and II Patterns

골격성 I급과 II급 유형을 가지는 쌍둥이의 얼굴 골격과 치열 특징의 유전율 차이에 관한 연구

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서울대학교 대학원

치의과학과 치과교정학 전공

박헌묵

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이 논문을 치의학박사 학위논문으로 제출함

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박 헌 묵

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Abstract

Differences in Heritability of the Skeletodental Characteristics in Face Between Twin Subjects with Skeletal Class I and II Patterns

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Objective: To investigate differences in the heritability of skeletodental characteristics between skeletal Class I and Class II twin pairs.

Methods: Forty Korean adult twin pairs were divided into Class I group (0°≤ANB≤4°; mean age, 40.7 years-old) and Class II group (ANB>4°; mean age, 43.0 years-old). Each group comprised 14 monozygotic and 6 dizygotic pairs. 33 cephalometric variables were measured using lateral cephalograms. Craniofacial structures were divided into the anteroposterior, vertical, dental, mandible, and cranial base characteristics. The ACE model was used to calculate heritability (A>0.7 indicates high heritability). Then, principal components analysis (PCA) was performed.

Results: In the anteroposterior characteristics, high A values were observed for numerous variables in Class I group and for SNB and facial angle in Class II group. In the vertical characteristics, high A values were observed for FH−PP and PP−MP in Class I group and PP−MP, anterior and posterior facial height in Class II group. In the dental characteristics, high A values were observed only in Class I group. In the mandibular characteristics, CD−Gn and Ar−Go showed high A values in Class II group. The cranial base length variables (S−N, S−Ar, Ar−N) showed high A values in Class II group. The PCA demonstrated that Class I and Class II groups derived eight components with 88.3% cumulative explanation and seven components with 91.0% cumulative explanation, respectively.

Conclusion: These results provide valuable information for growth prediction and planning of orthodontic and/or orthopedic treatment for Class I and Class II patients.

Keywords : heritability; twins; ACE model; principal components analysis

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(지도교수 : 백승학)

박 헌 묵

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I. Introduction

When predicting the growth and planning of the orthodontic and/or orthopedic treatments for growing patients, it is necessary to consider diverse craniofacial skeletal and dental characteristics. Therefore, several growth prediction methods have provided information about whether orthodontic and/or orthopedic treatment can be applied or should be delayed until completion of growth using patient or population-based cephalometric data.[1-8] Especially, Ricketts studied several cephalometric growth prediction methods to determine the mandibular growth.[1,2,4] Barbosa et al[8] also compared longitudinal growth changes between Class I and Class II div 2 subjects using lateral cephalograms. However, influences of the genetic and environmental factors on the characteristics of skeletal, dental, and soft tissues cannot be completely investigated using simple cephalometric analysis. Therefore, genetic studies have been performed using a parent-offspring correlation study, model fitting, a questionnaire with a pedigree chart, and a twin model.[2-7]

Since genetic information of monozygotic (MZ) twins is identical and those of dizygotic twins (DZ) share on half of their alleles and a testable assumption of equal environments for identical and fraternal twins, twin study design creates the basis for exploring the effects of genetic and environmental variance on a phenotype. Therefore, both MZ twins and DZ twins would be included in twin study design.

Since twin studies can accurately analyze the effects of genetic and environmental factors on the sizes and shapes of craniofacial structures, there have been numerous previous studies.[9-19] There are several considerations in the design of twin studies. First, the degree of heritability estimates can be influenced by the age of subjects. If the subjects are in the adolescent period, the mandibular growth will continue until completion of growth. Therefore, twin subjects under the age of 19 should be excluded to minimize the influence of age. Second, the sex of dizygotic twin pairs should be matched to minimize errors from the differences in cephalometric linear and angular variables between male and female.[17−19]

Although there are some studies that have investigated the influences of genetic and environmental factors on craniofacial morphology using adult twins,[17−19] there is no twin study that compared the craniofacial skeletal and dental characteristics between skeletal Class I and Class II twin pairs. Therefore, the purpose of this study was to investigate the differences in heritability of craniofacial skeletal and dental characteristics between skeletal Class I and Class II subjects using monozygotic (MZ) and dizygotic (DZ) twin pairs.

II. Review of Literature

1. Heritability

Heritability can be defined as the proportion of phenotypic variability that is attributable to genetic factors; higher estimates suggest that genetic variability has a large influence on the variability of a given trait in the population.[13,20] The calculation of heritability provides a means of quantifying the extent of the genetic contribution to phenotypic variation.[21]
Two types of heritability can be distinguished: 'narrow type heritability' refers to the contribution of additive genetic variance to observed phenotype variance, whereas 'broad type heritability' refers to total contribution of genetic factors (additive and non-additive) to observes variation.[16]

2. Study design for estimation of heritability using the twins

The twin study is one of the most effective methods available for investigating genetically determined variables in orthodontics, as well as in other medical fields.[4] Many polygenic craniofacial traits are susceptible to environmental modification and can be difficult to study with conventional methods.[5]
Therefore, the vast of study has employed the twin and their family to estimate the relative genetic and environmental influences on the craniofacial morphology.[6]

Classical methods of twin study have been based on comparisons of the differences within pairs of monozygotic twins and dizygotic twins.[5] As monozygotic (identical) twins develop from a single egg fertilized by a single sperm, which splits after the egg starts to develop, they are expected to share all of their genes, whereas dizygotic (fraternal) twins share only about half of them, which is the same as non−twin siblings.[5,7] Therefore, by assuming that both types of twins have been sampled from the same gene pool and that similar environmental factors act upon them, one can estimate the relative contributions of genetic and environmental influences.[5]

In the classical twin study, path analysis and Dahlberg' s analysis were used to examine the heritability.[11] The path analysis allows a separation of genetic and environmental influences for a given trait using the path diagram and calculates the genetic heritability and cultural inheritance based on the intra−class correlation coefficient of MZ and DZ pairs.[6] Dahlberg' s analysis utilizes the intra−pair variances for MZ and DZ twins to calculate the quotient between genetic and environmental standard deviations.[11]

Recently, model−fitting methods have been used to calculate the proportion of the total variance explained by additive/dominant genes and common/specific environment.[12,16] Genetic analysis of model fitting allows estimation of the significance of the different components of variance: the additive genetic factor (A), the shared environment (C), or the non−additive genetic factor (D), and the unique environment (E) using maximum likelihood genetic structural equation modeling.[16]

3. ACE model

The ACE model is one of the statistical methods commonly used to analyze the results of twin studies. It aims to decompose sources of phenotypic variation into three categories: additive genetic variance (A), common (or shared) environmental factors (C), and specific (or nonshared) environmental factors plus measurement error (E).[20]

MZ twins have identical genotypes and DZ twins share, on average, 50% of their gene variants, which leads to the assumption of

differential levels of sharing of additive genetic effects (A).[22]
Even in the absence of genetic influences on a phenotype, twins are phenotypically more similar than unrelated individuals since they have been raised in the same family environment.[23] Common environmental factor (C) represents variance due to the environmental influences that make siblings similar but cannot be attributed to their genetic resemblance.[22]

Finally, there is an independent unique error, corresponding to the usual independent and identically distributed noise corrupting the measurements plus actual unique environmental influences, for example, trauma and illness.[23] Specific environmental factor (E) refers to variance explained by non−genetic influences that render siblings different.[22]

The phenotypic variance within the population is assumed to be the same and can be divided into additive genetic (*A*), common environmental (*C*), and unique environmental (*E*) components, written as

Total phenotype variance = A+C+E

Narrow-sense heritability is denoted by

$$h^2 = \frac{A}{A + C + E}$$

and similarly, the contribution of common environmental factor can be defined as

$$C^2 = \frac{C}{A + C + E}$$

which describes the relative variance attributable to common environmental causes. The estimation of heritability and common environmental variance constitutes the analysis of variance components.[23]

The basic ACE model relies on several assumptions, including the absence of assortative mating that there is no genetic dominance or epistasis, that all genetic effects are additive, and the absence of gene−environment interactions.[24] In order to address these limitations, several variants of the ACE model have been developed, including an ACE−β model, which emphasizes the identification of causal effects, and the ACDE model, which accounts for the presence of dominant genetic effects.[20,24,25]

4. Heritability of the vertical and horizontal craniofacial characteristics

Since the interpretation of the results of previous twin studies is difficult because of the differences in zygosity determination, sample size, age of samples, and statistical methods used, there has been inconsistency in heritability of the vertical and horizontal craniofacial traits among previous studies.[16,17] In particular, the difference in genetic heritability between vertical and horizontal cephalometric measurements show different results among previous twin studies.

Manfredi et al.[11] reported the heritability of 39 lateral cephalometric parameters using the Wright’s path analysis and Dahlberg' analysis in MZ and DZ twins and their siblings. They reported that higher heritability values were observed among vertical variables compared with horizontal variables. Among the vertical skeletal parameters, high h^2 values were found at the total anterior facial height (h^2 =1.5) and the lower anterior facial height (h^2 =1.56) compared with the posterior facial height. In addition, the shape of the mandible was more genetically determined than the size of the mandible.

Savoye el al[12] reported that high genetic determination was found for the vertical proportions and the lowest heritability values were found for sella−upper incisal edge to sella−lower incisal edge in the twin study using the model fitting method. The genetic component was 71% for the upper−to−lower facial height, 66% for the anterior−to−posterior facial height, 62% for the total facial height, and 66% for the sella−A−point to sella−B−point and the sella−upper incisal edge to sella−lower incisal edge.

Carels et al.[13] also investigated the relative genetic and environmental impact on the cephalometric variables in twins using the model fitting and path analysis. They found that the genetic determination is significantly higher for the vertical variables (72%) than the horizontal variables (61%). In addition, the linear craniofacial and dental measurements showed the highest genetic determination (68.2-85.8%). However, most angular measurements showed no significant genetic determination. Only the gonial angle was explained by genes for 45.3%.
Kim et al.[17] reported the heritability of the facial skeletal and dental characteristics in Korean adult MZ and DZ twins using Falconer' s method. They reported that among the variables of facial horizontal and vertical structures, the angular relationships between the maxilla, mandible and anterior cranial base had a strong genetic influence. In addition, overall mean h2 values of the facial horizontal structures were higher than that of the facial vertical structures (1.10 versus 0.71).

However, Lundström and McWilliam[16] reported no significant differences in the heritability between the horizontal and vertical measurements based on the path analysis. On average, the genetic heritability (h2) was 0.6 for both horizontal and vertical variables, while the cultural heritability (c2) was lower, 0.1 for the horizontal measurements and 0.2 for the vertical measurements.

5. Heritability of dentoalveolar characteristics

Many previous studies have been reported on the genetic heritability of dentoalveolar characteristics. Šidlauskas et al.[16] reported that variables describing sagittal position of lower incisors and chin protrusion showed high heritability (lower incisor tip to NB, A=0.84; Pog to NB, A=0.83;). Lundström et al.[6] investigated the relationship between genetic and non-genetic factors for six incisal position variables using the path analysis. The results were that the anteroposterior apical base relationship (h^2 =0.8) and lower incisor inclination (h^2 =0.7) were showed high heritability compared with overjet (h^2 =0.5) and upper incisor inclination (h^2 =0.4).

Kim et al.[19] reported that maxillary incisor inclination in the hypodivergent group and mandibular incisor inclination in the hyperdivergent group exhibited high heritability. Also, occlusal plane inclination showed high heritability in both groups. Amini et al.[15] reported low-to-moderate heritability for the dental variables except for vertical dentoalveolar height of the upper molar (h^2 =0.8) and lower incisor inclination (h^2 =0.96).

6. The growth pattern of Class I and II subjects

Previous studies on the horizontal and vertical growth patterns of skeletal Class I and Class II malocclusions have reported different results. Jacob et al.[23] compared longitudinal mandibular growth between Class I and Class II division 1 patients. They investigated that ANB differences between Class I and Class II patients were mainly due to mandibular retrusion in Class II patients. Ngan el al.[26] also reported that no significant difference was found in cranial base dimension between the Class I and Class II subjects. However, Riesmeijer et al.[27] investigated that the maxilla (SNA) was found to be more protrusive in the Class II groups and mandibular position (SNB) was more retrusive in Class II patients in their longitudinal study.

Also, Ngan el al.[26] reported that mandibular plane angle of both Class I and Class II subjects were similar, as were the decreases in the mandibular plane angles over time. They insisted that if the Class II problem is primarily mandibular and retrusion is not due to vertical discrepancies, then there must either be mandibular growth deficiencies or differences in cranial base morphology. However, Riesmeijer et al.[27] investigated that Class II group had a more vertical growth pattern, with a larger SN−GoMe angle in the Class II patients. They reported that the mandibular plane angle closed less in the Class II group that in the Class I group.

7. Principal component analysis

Principal component analysis (PCA) is a technique for reducing the dimensionality of such datasets, increasing interpretability but at the same time minimizing information loss. Its idea is that PCA reduce the dimensionality of a dataset, while preserving as much 'variability' as possible.[28,29]

This means that 'preserving as much variability as possible' translates into finding new variables that are linear functions of those in the original dataset, that successively maximize variance and that are uncorrelated with each other.[26,27] Finding such new variables, the principal components (PCs), reduces to solving an eigenvalue/eigenvector problem.[28,29]

To facilitate the interpretation of principal components, PCA often involves a rotation of the components.[28,29] This simplifies the interpretation because, after a varimax rotation, each original variable tends to be associated with a small number of the components, and each component represents only a small number of variables.[28,29]

There have been several previous twin studies using PCA to investigate the heritability of the craniofacial skeletal and dental characteristics. Šidlauskas et al.[16] investigated that six principal components were determined by PCA explaining 83% of total variance on the mandibular cephalometric variables. Carels et al.[13] found five independent factors explaining 81% of total variance. Kim et al.[19] also investigated that PCA derived 10 components with 91.2 and 92.7% of cumulative explanation.

III. Materials and Methods

The initial samples were 126 Korean adult twins (48 MZ and 15 DZ twin pairs) whose lateral cephalograms were available at the Samsung Medical Center, Seoul, Republic of Korea. This study protocol was reviewed and approved by the Institutional Review Board of the School of Public Health, Seoul National University, Seoul, Republic of Korea (IRB 2005-08-113-027). Informed consent was obtained from all subjects.

The inclusion criteria were (1) MZ or DZ twin pairs; (2) the same sex in DZ twin pairs; (3) age was over 19 years; and (4) skeletal Class I or Class II pattern (ANB > 0°). The reasons for employing these criteria were to avoid bias from age and sex.[17-19]

The exclusion criteria were (1) an edentulous area of the anterior teeth, (2) use of a removable prosthesis, and (3) a history of orthodontic treatment or orthognathic surgery. The reasons for employing these criteria were to avoid influences of these conditions on the profile and vertical dimension of the face.[17-19]

As the final sample, 40 Korean adult MZ and DZ twin pairs (mean age, 41.9± 8.3 years-old; 40 males and 40 females) were selected. They were divided into the Class I group (n=20 twin pairs, 0° ≤ ANB ≤ 4° ; mean age, 40.7 ± 7.4 years-old) and Class II group (n=20 twin pairs, ANB > 4° ; mean age, 43.0 ± 9.0 years-old). Each group comprised 14 MZ and 6 DZ twin pairs with the same sex (20 males and 20 females per group, Table 1).

The landmarks and reference lines used for cephalometric analysis are illustrated in Figure 1.The craniofacial structures were divided into the anteroposterior (AP), vertical, dental, mandible and cranial base for investigating which areas were influenced by heredity.[17-19] The linear, angular, and ratio variables, which could describe the sizes and shapes of these structures (Figure 2), were measured by a single operator (EMK) using the V-Ceph 6.0 program (Cybermed, Seoul, Republic of Korea). Since ODI showed significant differences between the MZ and DZ twin subgroups ($P < 0.01$ in Class I group, $P < 0.05$ in Class II group) and lower gonial angle showed significant differences between the MZ and DZ twin subgroups ($P < 0.05$ in Class I group; Table 2), these variables were excluded. As a result, 33 cephalometric variables were selected for further investigation (Table 2).

All variables from 20 randomly selected subjects were remeasured by the same operator (EMK) at 2-week intervals. The intra-operator measurement error was assessed using the intraclass correlation coefficient (ICC). Since there were no significant differences between the first and second measurements, the first set of measurements was used.

Although the genetic effect (A) on MZ twins is equal, DZ twins with the same sex share half of their DNA information. In addition, both MZ and DZ twins are assumed to have the same environmental effect (E).[17,18,30,31] Therefore, Pearson's correlation coefficient (r_{mz}, r_{dz}), sum of the genetic and environmental effects on the phenotype, was calculated as $r_{mz} = A + E$ in MZ twin pair and $r_{dz} = \frac{1}{2}A + E$ in DZ twin pair (Table 3).

Based on the difference between the correlation coefficients for MZ twin pairs and DZ twin pairs with the same sex, the ACE model was used to calculate the additive genetic effects (A), common environmental effects (C), and specific environmental effects (E).[28] It allows knowing the heritability (A) of twins.[20] In the present study, an A value above 0.7 was considered as high heritability and an A value between 0.4 and 0.7 was considered as moderate heritability.[33]

The principal components analysis (PCA) with Kaiser normalization varimax rotation was used to extract components by grouping the cephalometric variables in Class I group and Class II group, respectively.[18,19,32] The components with an eigenvalue higher than 1 were chosen.[18,19] After the mean ICC values of each component were calculated, the A value was also calculated for Class I group and Class II group, respectively.[18,19]

All statistical analyses were performed using SPSS program version 21, (IBM Corp., Armonk, NY, USA). A *p*−value less than 0.05 was considered statistically significant.

IV. Results

Genetic heritability (A) in Class I group (Table 4)

In the AP characteristics, the maxilla, mandible, and intermaxillary relationship showed high A values (SNA 0.80; SNB, 0.86; facial convexity angle, 0.74; facial angle, 0.74; Pog to N perp, 0.84; Go-Me/S-N,0.70). In the angular characteristics, two angular variables showed high A values (FH-PP, 0.74; PP-MP, 0.74). In the dental characteristics, inclination of the maxillary and mandibular incisors and interincisal angle showed high A values (U1-FH, 0.82; U1-PP, 0.73; IMPA, 0.87; interincisal angle,0.75). In the mandibular characteristics, only mandibular body length showed high A value (Go-Me, 0.75). In the cranial base characteristics, cranial base angle showed high A value (N-S-Ba,0.86)

Genetic heritability (A) in Class II group (Table 4)

In the AP characteristics, only two variables showed high A values (SNB, 0.89; facial angle, 0.80). In the angular characteristics, PP-MP and facial height variables showed high A values (PP-MP, 0.84; anterior facial height,0.93; posterior facial height, 0.92). In the mandibular characteristics, two variables showed high A values (CD-Gn, 0.74; Ar-Go, 0.81). In the cranial base characteristics, three variables showed high A values (S-N, 0.84; S-Ar, 0.80; and Ar-N, 0.90). However, none of the dental variables showed high A values.

Comparison of the A values between Class I group and Class II group (Table 4)

For AP and vertical characteristics, SNB, facial angle, and PP-MP showed high heritability in both groups. However, there was no common variable in the dental, mandible, and cranial base characteristics, which showed high heritability in the two groups.

PCA in Class I group (Table 5)

The PCA derived eight components with 88.3% cumulative explanation. Among eight components, PCA2 and PCA6 components had three variables with high A values (U1-PP, U1-FH and facial angle in PCA2; Go-Me/S-N, Go-Me and Pog-N perp in PCA6). In addition, PCA4 and PCA5 components had two variables with high A values (cranial base angle and SNB in PCA4; IMPA and interincisal angle in PCA5).

PCA in Class II group (Table 6)

The PCA derived seven components with 91.0% cumulative explanation. Among seven components, PCA1 had seven variables with high A values (anterior facial height, S-N, S-Ar, Ar-Go, CD-Gn, posterior facial height, and Ar-N). PCA2 had two variables with high A values (facial angle and PP-MP).

V. Discussion

This twin study was the first to compare the heritability of the craniofacial skeletal and dental characteristics between skeletal Class I and Class II twin pairs. In previous studies, craniofacial skeletal and dental characteristics were analyzed without considering differences in the AP skeletal growth patterns.[6,9,11,16]

In terms of the AP characteristics, the finding that the heritability values for SNB and facial angle were high in both Class I and Class II groups (SNB, 0.86 and 0.89; facial angle, 0.74 and 0.80; Table 4) was similar to the results of previous studies,[15,16] which reported that SNB was under strong genetic influence.

In terms of the vertical characteristics, the number of cephalometric variables showing high A value for AP characteristics was more than that for vertical characteristics in Class I group (6 variables: SNA, SNB, facial convexity angle, facial angle, Pog−N perpendicular, mandibular body length to anterior cranial base vs. 2 variables: : FH−PP, PP−MP; Table 4), which was in accordance with Sidlauskas et al.[16] However, other studies suggested that the vertical variables showed higher heritability than the AP variables.[6,13] This difference might have originated from twin samples with different ages or ethnic background.

In terms of the dental characteristics, the heritability values for the inclination of the maxillary incisors, mandibular incisors and interincisal angle were higher in Class I group than those in Class II group (U1−FH, 0.82 vs. 0.56; U1−PP, 0.73 vs. 0.59; IMPA, 0.87 vs. 0.58; IIA, 0.75 vs. 0.12; Table 4).On the contrary, the angle between the occlusal plane and the maxillary or mandibular incisors exhibited a low−to−moderate heritability in both Class I group and Class II group (U1−OP, 0.20 and 0.00; L1−OP, 0.21 and 0.43;

Table 4). These findings indicated that it is necessary to consider the differences in the pattern of dental compensation of the maxillary and mandibular incisors between Class I and Class II subjects.

In terms of the mandibular characteristics, the finding that the mandibular body length (Go-Me) had a high A value in Class I group (0.75, Table 4) was similar to the results of previous studies.[13,15] However, Class II group showed different pattern as follows: (1) The A value of Go-Me was moderate in Class II group (0.55, Table 4); and (2) the heritability values for effective mandibular length and ramus height were higher in Class II group compared to those in Class I group (CD-Gn, 0.74 vs 0.00; Ar-Go, 0.81 vs. 0.00; Table 4). These findings implied that skeletal Class I and Class II subjects might have different genetic influences on the size and shape of the mandible; for example, there was a strong genetic influence on the mandibular body length in skeletal Class I subjects and on the overall shape of the mandible and the ramus height in skeletal Class II subjects.

In terms of the cranial base characteristics, the saddle angle showed a moderate A value and a low C value in Class I group (0.68 and 0, respectively; Table 4) and a low A value and a moderate C value in Class II group (0 and 0.68, respectively; Table 4), which were similar to the results of previous studies. [11,14] Since those studies included younger twins before completion of growth, [11,14] the heritability estimates of the saddle angle might be low-to-moderate in both younger and adult twins in Class I and Class II subjects.

In the present study, the PCA derived eight and seven components with 88.3% and 91.0% cumulative explanation in Class I and Class II groups, respectively (Tables 5 and 6). However, previous twin studies reported lower explanation power compared to this study (range: 81.0%–83.0%; number of components: five to nine components).[5,13,16] The differences between the present study and previous studies might be due to variations in study designs and statistical criteria for determining the principal components.[18,19]

Although this study reported the differences in heritability of the skeletodental characteristics between skeletal Class I and Class II subjects, there are several considerations to confirm the results of this study as follows: (1) it is necessary to perform the prospective study with increase in the number of twins and more sophisticated statistical analysis method; (2) It is also necessary to investigate the longitudinal growth patterns from childhood, and young adults, to middle–aged adults; and 3) It is also necessary to examine history of temporomandibular disorders especially in Class II subjects and to analyze to its effects on the skeletodental characteristics. In addition, it would be better to investigate the heritability of the skeletodental characteristics in skeletal Class III subjects even though it is difficult to gather skeletal Class III twin samples. In future studies, three–dimensional analysis using CBCT would be necessary to examine characteristics of transverse growth pattern.

VI. Conclusion

The main findings of this study could be summarized as follows.

1. In the anteroposterior characteristics, high A values were observed for numerous variables in Class I group and for SNB and facial angle in Class II group.
2. In the vertical characteristics, high A values were observed for FH−PP and PP−MP in Class I group and PP−MP, anterior facial height and posterior facial height in Class II group.
3. In the dental characteristics, high A values were observed only in Class I group.
4. In the mandibular characteristics, CD−Gn and Ar−Go showed high A values in Class II group.
5. The cranial base length variables (S−N, S−Ar, and Ar−N) showed high A values in Class II group.
6. The PCA demonstrated that Class I and Class II groups derived eight components with 88.3% cumulative explanation and seven components with 91.0% cumulative explanation, respectively.

Since the results from this study exhibited differences in the heritability of skeletodental characteristics between twin subjects with skeletal Class I and Class II patterns, this study might provide valuable information for growth prediction and planning of orthodontic and/or orthopedic treatment for patients with Class I and Class II malocclusion.

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Table 1. Demographic data of samples.

	Class I group	Class II group	Significance
Distribution of pairs	14 MZ pairs and 6 DZ pairs	14 MZ pairs and 6 DZ pairs	1.0000
Gender	20 males and 20 females	20 males and 20 females	1.0000
Age (years)	40.71 ± 7.36	43.02 ± 9.03	0.2582
ANB (°)	2.10 ± 1.26	5.04 ± 1.47	0.0001***

MZ, monozygotic twin; DZ, dizygotic twin

Mean and standard deviation of age and ANB angle were calculated in the Class I and Class II group.

Mann Whitney U test was performed. ***, $P<0.001$

Table 2. Comparison of cephalometric variables measured between the monozygotic (MZ) and dizygotic (DZ) twin subgroups within Class I and Class II groups

		Class I group					Class II group				
		Class I-DZ (n=6 pairs)		Class I-MZ (n=14 pairs)		p-value	Class II-DZ (n=6 pairs)		Class II-MZ (n=14 pairs)		p-value
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Antero-posterior	SNA (°)	80.43	2.52	81.16	3.91	0.5354	83.96	4.4	81.45	3	0.1023
	SNB (°)	78.51	3.01	78.99	3.7	0.6687	78.81	4.47	76.47	2.89	0.1365
	ANB (°)	1.94	1.57	2.17	1.13	0.7454	5.16	1.4	4.99	1.51	0.5710
	Facial convexity angle (NA-Pog, °)	177.86	6.74	177.4	3.68	0.9647	170.16	3.85	170.67	3.42	0.6542
	Facial angle (FH-NPog, °)	89.25	3.14	88.56	2.71	0.3301	87.21	2.1	86.66	2.33	0.1200
	A-N Perpendicular (mm)	0.36	2.54	-0.2	3.01	0.3525	2.01	1.63	1.18	2.45	0.1023
	Pog-N Perpendicular (mm)	4.45	4.73	5.09	3.3	0.2814	6.34	2.92	7.21	3.71	0.1509
	mandibular body length / anterior cranial base (Go-Me/S-N)	1.16	0.09	1.13	0.08	0.4517	1.1	0.1	1.1	0.06	0.8536
Vertical	ODI	67.02	6.76	73.14	3.59	**0.0048****	74.71	5.96	77.17	5.32	**0.0362***
	FH-PP (°)	0.07	3.46	1.08	2.58	0.4517	1.28	3.74	1.59	2.31	0.6829
	FMA (°)	27.11	3.82	23.62	4.97	0.0570	27.06	5.49	25.82	5.66	0.3917
	PP-MP (°)	25.36	4.91	22.55	4.41	0.1213	25.78	5.54	24.22	6.42	0.2204
	Bjork Sum (°)	395.33	2.56	392.27	5.62	0.0954	395.07	6.8	395.43	5.99	0.7419
	Ant. Facial Height (AFH, N-Me, mm)	122.34	4.9	120.66	6.21	0.3375	120.53	5.9	121.61	7.18	0.5532
	Post. Facial Height (PFH, S-Go, mm)	80.52	4.76	82.59	8.47	0.6263	80.8	6.16	80.73	7.87	0.6637
	N-ANS/ANS-Me	0.78	0.07	0.81	0.05	0.1481	0.79	0.06	0.85	0.09	0.0561

Table 2. Cont'd

Dental	U1-FH (°)	116.64	6.63	113.25	6.35	0.0570	114.19	5.51	111.79	6.81	0.2012
	U1-PP (°)	118.38	7.91	114.33	6.42	0.0742	115.47	5.87	113.4	6.49	0.3991
	U1-OP (°)	54.2	3.94	55.74	4.99	0.1793	54.26	6.75	56.3	6.02	0.2517
	IMPA (°)	92.98	7.57	97.02	7.59	0.1213	100.19	5.98	100.57	5.92	0.4686
	L1-OP (°)	67.91	6.34	68.25	8.51	0.5257	61.65	5.66	63.03	7.6	0.8228
	Interincisal angle (°)	121.6	10.05	126.11	11.05	0.1891	118.57	10.02	121.81	11.43	0.5016
	FH-OP (°)	9.16	4.83	11.01	3.09	0.0514	11.56	4.3	11.9	5.15	0.7419
	OP-MP (°)	16.83	4.16	13.77	5.16	0.0742	16.2	3.39	14.29	5.27	0.1665
Mandible	Gonial angle (Ar-Go-Gn, °)	122.38	8.79	118.45	7.51	0.2097	121.11	8.02	119.33	5.59	0.2409
	Upper gonial angle (Ar-Go-N, °)	44.46	4.26	44.91	3.9	0.8943	43.87	4.61	44.06	2.31	0.6829
	Lower gonial angle	77.92	5.00	73.54	4.43	**0.0126***	77.23	5.80	75.26	4.85	0.1232
	CD-Gn (mm)	108.62	8.34	107.44	8.53	0.7566	103.28	8.43	104.89	9.45	0.4768
	Go-Me (mm)	73.74	3.96	72.98	5.61	0.5851	69.23	5.67	70.8	4.65	0.4850
	Ar-Go (mm)	48.01	5.2	50.67	7.06	0.1992	47.44	4.78	48.56	6.36	0.2979
Cranial Base	Saddle angle (N-S-Ar, °)	126.95	4.13	127.34	5.32	0.8479	123.72	3.16	125.89	4.14	0.0820
	Cranial base angle (N-S-Ba, °)	133.64	4.03	133.56	4.78	0.7343	131.58	5.1	133.07	3.57	0.4216
	S-N (mm)	62.23	3.37	64.61	2.45	0.1523	62.97	3.35	64.25	3.37	0.1547
	S-Ar (mm)	35.91	2.99	35.74	3.26	0.6159	35.98	2.98	35.41	3.41	0.8023
	Ar-N (mm)	89.22	4.5	90.8	4.55	0.2097	87.7	4.39	90.44	5.15	0.0546

Mann-Whitney U test was performed to compare the variables between MZ and DZ subgroups within Class I and Class II groups.
(*, $P<0.05$; **, $P<0.01$)

Table 3. The effect of genetic and environmental factors on the facial anteroposterior, facial vertical, dental, mandible, and cranial base variables measured in the Class I and Class II groups

		Class I group		Class II group	
		r_{mz}	r_{dz}	r_{mz}	r_{dz}
facial anteroposterior	SNA (°)	0.8734	0.2669	0.7971	0.7297
	SNB (°)	0.9093	0.1711	0.8475	0.5774
	ANB (°)	0.3208	-0.3771	0.5265	0.0237
	Facial convexity angle (NA-Pog, °)	0.6272	-0.5416	0.5662	0.5351
	Facial angle (FH-NPog, °)	0.8499	0.5911	0.8230	0.1797
	A-N Perpendicular (mm)	0.7177	0.3745	0.6063	-0.2908
	Pog-N Perpendicular (mm)	0.7767	0.2050	0.7055	0.2208
	mandibular body length / anterior cranial base (Go-Me/S-N)	0.8140	0.0793	0.6307	0.9211
facial vertical	FH-PP (°)	0.7236	-0.2690	0.5624	0.8477
	FMA (°)	0.7737	0.6259	0.8516	0.6647
	PP-MP (°)	0.7947	-0.4834	0.8705	0.5104
	Bjork Sum (°)	0.8367	-0.2503	0.8772	0.7987
	Ant. Facial Height (AFH, N-Me, mm)	0.9343	0.8561	0.9386	0.0557
	Post. Facial Height (PFH, S-Go, mm)	0.8937	0.8670	0.9459	0.5514
	N-ANS/ANS-Me	0.6224	0.4323	0.8858	0.5315
Dental	U1-FH (°)	0.8424	-0.5742	0.6243	-0.0880
	U1-PP (°)	0.7284	-0.5928	0.6274	0.0784
	U1-OP (°)	0.6576	0.2775	0.5073	0.7615
	IMPA (°)	0.8583	-0.0917	0.6892	0.2079
	L1-OP (°)	0.7144	0.6386	0.5480	-0.6280
	Interincisal angle (°)	0.7618	0.1741	0.7709	0.7106
	FH-OP (°)	0.5391	-0.2724	0.8685	0.5846
	OP-MP (°)	0.2113	0.5529	0.6989	-0.1669
Mandible	Gonial angle (Ar-Go-Gn, °)	0.7241	0.6508	0.5764	0.3033
	Upper gonial angle (Ar-Go-N, °)	0.4816	0.6336	0.2193	-0.1697
	CD-Gn (mm)	0.2279	0.6605	0.8234	0.3373
	Go-Me (mm)	0.8756	-0.5329	0.7662	0.8101
	Ar-Go (mm)	0.8455	0.8664	0.9072	0.5218
Cranial Base	Saddle angle (N-S-Ar, °)	0.7366	0.0286	0.7372	0.7375
	Cranial base angle (N-S-Ba, °)	0.9093	-0.1470	0.7255	0.9811
	S-N (mm)	0.9184	0.9953	0.8933	0.4504
	S-Ar (mm)	0.9351	0.7824	0.8194	0.6911
	Ar-N (mm)	0.9241	0.7717	0.9635	0.5517

r_{dz}, Pearson's correlation coefficients of the DZ group; r_{mz}, Pearson's correlation coefficients of the MZ group.

Table 4. Genetic effects (A), common (shared) environmental effects (C) and specific (nonshared) environmental effects (E) of the facial anteroposterior, facial vertical, dental, mandible, and cranial base structures in the Class I and Class II groups.

Variables		Class I group			Class II group		
		A	C	E	A	C	E
facial anteroposterior	SNA (°)	**0.7982**	0.0000	0.2018	0.4498	0.3955	0.1547
	SNB (°)	**0.8590**	0.0000	0.1410	**0.8931**	0.0000	0.1069
	ANB (°)	0.1321	0.0000	0.8679	0.4257	0.0000	0.5743
	Facial convexity angle (NA-Pog, °)	**0.7367**	0.0000	0.2633	0.1765	0.3454	0.4781
	Facial angle (FH-NPog, °)	**0.7360**	0.1087	0.1553	**0.8042**	0.0000	0.1958
	A-N Perpendicular (mm)	0.6615	0.0000	0.3385	0.4757	0.0000	0.5243
	Pog-N Perpendicular (mm)	**0.8358**	0.0000	0.1642	0.6434	0.0000	0.3566
	mandibular body length / anterior cranial base (Go-Me/S-N)	**0.7035**	0.0000	0.2965	0.3501	0.3118	0.3380
facial vertical	FH-PP (°)	**0.7401**	0.0000	0.2599	0.0642	0.6035	0.3323
	FMA (°)	0.1165	0.6352	0.2483	0.6195	0.2124	0.1681
	PP-MP (°)	**0.7404**	0.0000	0.2596	**0.8364**	0.0000	0.1636
	Bjork Sum (°)	0.3087	0.4786	0.2128	0.4854	0.3729	0.1417
	Ant. Facial Height (AFH, N-Me, mm)	0.0846	0.8404	0.0751	**0.9324**	0.0000	0.0676
	Post. Facial Height (PFH, S-Go, mm)	0.0000	0.8540	0.1460	**0.9163**	0.0000	0.0837
	N-ANS/ANS-Me	0.4987	0.0768	0.4245	0.1010	0.6641	0.2350
Dental	U1-FH (°)	**0.8151**	0.0000	0.1849	0.5566	0.0000	0.4434
	U1-PP (°)	**0.7293**	0.0000	0.2707	0.5933	0.0000	0.4067
	U1-OP (°)	0.1983	0.3129	0.4889	0.0000	0.5099	0.4901
	IMPA (°)	**0.8714**	0.0000	0.1286	0.5797	0.0000	0.4203
	L1-OP (°)	0.2119	0.4638	0.3243	0.4283	0.0000	0.5717
	Interincisal angle (°)	**0.7493**	0.0000	0.2507	0.1168	0.6150	0.2682
	FH-OP (°)	0.5430	0.0000	0.4570	0.2883	0.5207	0.1909
	OP-MP (°)	0.0000	0.2587	0.7413	0.6122	0.0000	0.3878

Table 4. Continued

Mandible	Gonial angle (Ar-Go-Gn, °)	0.3883	0.3699	0.2418	0.4909	0.0000	0.5091
	Upper gonial angle (Ar-Go-N, °)	0.0000	0.5191	0.4809	0.0000	0.0000	1.0000
	CD-Gn (mm)	0.0000	0.3401	0.6599	**0.7422**	0.0000	0.2578
	Go-Me (mm)	**0.7543**	0.0000	0.2457	0.5460	0.1999	0.2541
	Ar-Go (mm)	0.0000	0.7915	0.2085	**0.8067**	0.0601	0.1332
Cranial Base	Saddle angle (N-S-Ar, °)	0.6756	0.0000	0.3244	0.0000	0.6761	0.3239
	Cranial base angle (N-S-Ba, °)	**0.8640**	0.0000	0.1360	0.2826	0.4946	0.2228
	S-N (mm)	0.0436	0.8224	0.1340	**0.8392**	0.0552	0.1056
	S-Ar (mm)	0.3224	0.6076	0.0700	**0.8025**	0.0000	0.1975
	Ar-N (mm)	0.1854	0.6938	0.1208	**0.9037**	0.0564	0.0398

∫ The A value above 0.7 is considered as high heritability.

Table 5. Principal components analysis (PCA) after varimax rotation in the Class I group with 88.31% explanation

Class I group	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7	PCA8
FMA (°)	0.939	-0.146	-0.025	0.042	0.037	0.225	-0.075	0.024
Bjork Sum (°)	0.848	-0.100	-0.201	0.415	-0.003	0.029	0.022	0.082
PP-MP (°)	0.816	-0.259	-0.178	0.034	-0.024	0.117	-0.027	-0.413
OP-MP (°)	0.788	0.254	-0.139	-0.096	0.003	0.302	-0.105	0.075
U1-PP (°)	0.031	0.930	0.138	0.085	-0.140	-0.049	-0.083	0.152
U1-FH (°)	-0.083	0.927	0.040	0.084	-0.196	-0.137	-0.053	-0.150
FH-OP (°)	0.044	-0.846	-0.050	-0.083	-0.005	-0.093	0.021	-0.163
U1-OP (°)	0.088	-0.712	-0.028	-0.035	0.282	-0.016	0.038	0.342
Facial angle (FH-NPog, °)	-0.481	0.550	0.000	-0.258	0.454	-0.003	0.360	-0.099
Ant. Facial Height (AFH, N-Me, mm)	0.079	0.104	0.946	0.136	0.045	-0.034	-0.037	0.065
Ar-N (mm)	-0.181	0.106	0.832	0.109	-0.373	0.146	-0.074	0.028
S-Ar (mm)	-0.092	-0.079	0.809	-0.273	-0.035	-0.267	0.108	0.117
Post. Facial Height (PFH, S-Go, mm)	-0.560	0.041	0.785	-0.123	0.043	-0.015	-0.030	-0.006
Ar-Go (mm)	-0.604	0.107	0.657	0.087	0.087	0.275	-0.071	-0.073
CD-Gn (mm)	0.095	0.172	0.597	0.108	0.053	0.495	0.265	0.105
Cranial base angle (N-S-Ba, °)	-0.058	0.095	0.078	0.904	-0.071	0.206	0.033	-0.065
Saddle angle (N-S-Ar, °)	0.009	0.187	0.327	0.846	-0.093	0.167	0.050	0.128
SNB (°)	-0.286	0.045	0.365	-0.781	0.147	-0.013	0.251	-0.176
SNA (°)	-0.241	-0.119	0.289	-0.722	0.039	-0.021	0.512	-0.139
IMPA (°)	-0.331	0.059	0.008	0.107	-0.883	-0.048	0.097	-0.016
L1-OP (°)	-0.240	-0.259	-0.029	-0.129	0.856	-0.179	-0.097	0.038
Interincisal angle (°)	-0.176	-0.587	-0.020	-0.148	0.730	-0.021	-0.030	0.130
S-N (mm)	-0.211	0.139	0.424	-0.103	-0.525	0.386	-0.267	-0.133

Table 5. Continued

Upper gonial angle (Ar-Go-N, °)	0.329	0.023	0.141	0.123	-0.109	0.825	0.033	-0.100
mandibular body length / anterior cranial base (Go-Me/S-N)	-0.071	0.350	0.181	-0.305	0.330	-0.730	0.223	0.026
Gonial angle (Ar-Go-Gn, °)	0.624	0.001	0.140	0.139	0.095	0.717	0.032	-0.074
Go-Me (mm)	-0.245	0.496	0.372	-0.312	0.115	-0.557	0.116	-0.026
Pog-N Perpendicular (mm)	0.245	-0.255	0.209	0.340	-0.225	-0.385	-0.205	0.179
A-N Perpendicular (mm)	-0.269	0.151	0.087	-0.330	0.057	-0.007	0.841	-0.159
ANB (°)	0.111	-0.453	-0.203	0.134	-0.283	-0.025	0.741	0.103
Facial convexity angle (NA-Pog, °)	-0.293	0.518	-0.095	0.077	0.512	0.006	-0.554	0.035
FH-PP (°)	0.123	-0.017	0.243	0.011	0.102	0.055	-0.183	0.863
N-ANS/ANS-Me	-0.169	-0.037	-0.076	0.186	0.009	-0.169	0.073	0.790

Table 6. Principal components analysis (PCA) after varimax rotation in the Class II group with 90.99% explanation

Class II group	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
Bjork Sum (°)	0.977	0.006	-0.069	-0.036	0.036	0.096	0.162
Ant. Facial Height (AFH, N-Me, mm)	-0.968	-0.116	0.114	0.100	-0.071	-0.087	-0.078
Gonial angle (Ar-Go-Gn, °)	0.961	-0.112	0.012	0.015	0.115	0.102	0.076
S-N (mm)	-0.950	-0.116	-0.029	0.041	-0.144	-0.004	-0.021
Saddle angle (N-S-Ar, °)	0.937	0.067	-0.122	-0.096	-0.058	0.023	0.191
Upper gonial angle (Ar-Go-N, °)	-0.933	-0.102	0.082	0.045	-0.048	-0.078	-0.238
FH-PP (°)	-0.926	-0.078	0.105	0.088	-0.039	0.133	-0.136
S-Ar (mm)	-0.921	0.030	-0.149	0.084	0.138	-0.097	0.155
Cranial base angle (N-S-Ba, °)	0.898	0.062	-0.153	-0.115	-0.060	0.076	0.198
Ar-Go (mm)	-0.895	0.125	0.139	0.000	0.129	-0.062	0.154
CD-Gn (mm)	-0.835	0.035	-0.012	-0.055	0.024	-0.077	0.454
Post. Facial Height (PFH, S-Go, mm)	-0.831	0.172	-0.004	0.025	0.249	-0.052	0.347
IMPA (°)	0.828	0.203	-0.074	0.070	-0.006	-0.245	0.203
Ar-N (mm)	0.755	0.073	-0.301	-0.095	0.016	0.139	0.489
FMA (°)	0.729	-0.580	0.224	0.205	0.023	0.042	-0.032
Pog-N Perpendicular (mm)	-0.032	-0.913	-0.036	0.221	-0.096	0.045	-0.002
Facial angle (FH-NPog, °)	-0.009	0.866	0.042	-0.200	0.344	0.002	0.092
PP-MP (°)	-0.090	-0.706	0.329	0.262	-0.097	-0.326	-0.268
A-N Perpendicular (mm)	-0.041	0.671	0.130	0.532	0.396	0.008	0.042
U1-PP (°)	-0.068	0.046	0.930	-0.029	0.231	-0.076	0.121
U1-FH (°)	0.194	0.076	0.871	-0.075	0.202	-0.317	0.118
U1-OP (°)	0.526	0.227	-0.765	-0.192	-0.010	-0.131	0.088
Interincisal angle (°)	0.509	0.209	-0.608	-0.231	0.034	0.467	0.116

Table 6. Continued

ANB (°)	-0.064	-0.162	-0.023	0.957	0.055	-0.067	-0.003
Facial convexity angle (NA-Pog, °)	0.050	0.255	-0.061	-0.944	0.011	-0.034	0.096
SNA (°)	0.009	0.257	0.156	0.253	0.892	-0.032	0.142
SNB (°)	0.036	0.328	0.168	-0.138	0.885	-0.005	0.146
N-ANS/ANS-Me	0.348	0.378	-0.361	-0.032	-0.551	0.404	0.086
L1-OP (°)	0.379	0.046	-0.205	-0.210	0.100	0.784	0.034
FH-OP (°)	-0.359	-0.379	-0.052	0.330	-0.187	0.658	-0.150
OP-MP (°)	-0.034	-0.492	0.164	-0.062	0.188	-0.621	0.135
CD-Gn (mm)	0.621	-0.068	0.210	0.042	0.108	0.055	0.628
mandibular body length / anterior cranial base (Go-Me/S-N)	0.104	0.261	0.135	-0.127	0.310	-0.178	0.594

Figure 1. Landmarks and reference lines used in cephalometric analysis. Landmarks: S, sella; N, nasion; Po, porion; Or, orbitale; CD, condylion; Ar, articulare; Ba, basion; PNS, posterior nasal spine; ANS, anterior nasal spine; A, A point; B, B point; Pog, pogonion; Gn, gnathion; Me, menton; Go, gonion; Reference lines: SN plane; FH (Frankfort Horizontal) plane; Palatal plane(PP); Occlusal plane(OP); Mandibular plane(MP); N perpendicular line; U1, long axis of the upper incisor; L1, long axis of the lower incisor.

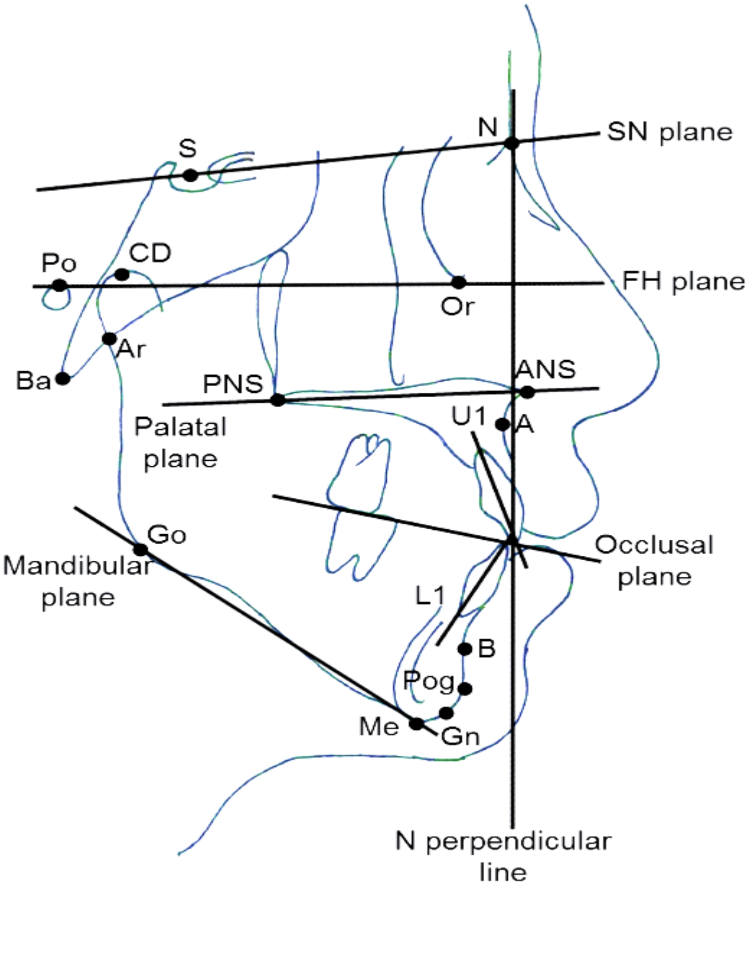
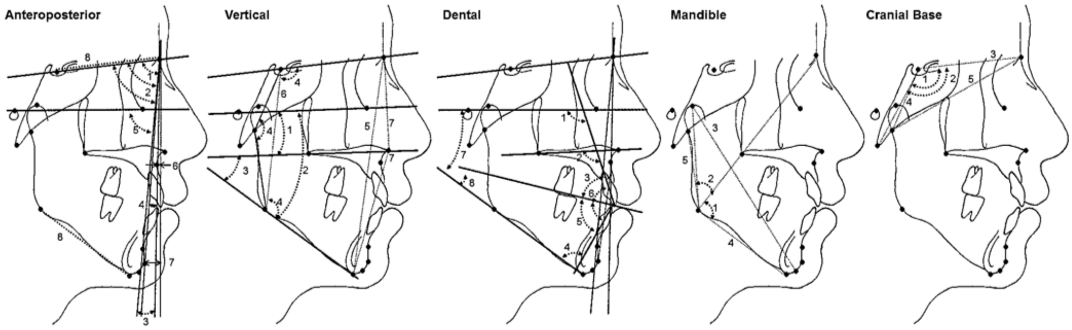


Figure 2. Cephalometric variables. **Anteroposterior characteristics:** 1, SNA(°), 2, SNB(°), 3, ANB(°); 4, NA-Pog(°); 5, FH-NPog(°); 6, A-N perpendicular(mm); 7, Pog-N perpendicular(mm); 8, mandibular body length/anterior cranial base(Go-Me/S-N); **Vertical characteristics:1**, FH-PP(°); 2, FMA(°); 3, PP-MP(°); 4, Bjork Sum(°); 5, N-Me(mm); 6, S-Go(mm); 7, N-ANS/ANS-Me; **Dental characteristics:**1, U1-FH(°); 2, U1-PP(°); 3, U1-OP(°); 4, IMPA(°); 5, L1-OP(°); 6, Interincisal angle(U1-L1, °); 7, FH-OP(°); 8, OP-MP(°); **Mandible characteristics:**1, Gonial angle(Ar-Go-Gn,°); 2, Upper gonial angle(Ar-Go-N)3, CD-Gn(mm); 4, Go-Me(mm); 5, Ar-Go(mm); **Cranial base characteristics:**1,Saddle angle(N-S-Ar,°); 2, Cranial base angle(N-S-Ba,°); 3, S-N(mm); 4, S-Ar(mm); 5, Ar-N(mm)



국문초록

골격성 I급과 II급 유형을 가지는 쌍둥이의 얼굴 골격과 치열 특징의 유전율 차이에 관한 연구

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목적: 본 연구는 골격성 I급 및 II급 환자의 두개안면 골격과 치열 특징의 유전율 차이를 연구하기 위해 시행되었다.

방법: 연구 대상은 한국인 성인 일란성 쌍둥이 (monozygotic twins, MZ) 와 성별이 동일한 이란성 쌍둥이(Dizygotic twins, DZ) 이었으며, 이들을 수평적 골격양상에 따라 골격성 I급 군(Class I group, $0^\circ \leq ANB \leq 4^\circ$, MZ 14쌍, DZ 6쌍)과 골격성 II급 군(Class II group, $ANB > 4^\circ$, MZ 14쌍, DZ 6쌍)으로 분류하였다. 측모두부계측 방사선사진 상에서 총 33개의 변수들을 계측하였고, 두개안면 구조물(craniofacial structures)을 전후방적, 수직적, 치열, 하악골, 두개저로 나누었다. ACE model을 사용하여 각 변수 및 두개안면 구조물의 유전율을 계산하였고, 유전율 값이 0.7을 초과하는 경우 높은 유전율을 갖는 것으로 판단하였다. 변수들에 대한 주성분분석 (principal component analysis)을 통해 각 군의 특성을 나타내는 주성분들을 추출하였고, 이 주성분들의 유전율을 계산하였다.

결과: 이로부터 다음과 같은 결과를 얻었다.

1. 전후방적 변수에서 골격성 I급 군은 대부분의 변수가, 골격성 II급

군에서는 SNB, facial angle이 유전율이 높은 것으로 나타났다.

2. 수직적 변수에서 골격성 I급 군은 Frankfort Horizontal plane-Palatal Plane angle, Palatal Plane angle-Mandibular Plane angle (PP-MP)에서, 골격성 II급 군은 PP-MP, 전안면 및 후안면 고경에서 유전율이 높은 것으로 나타났다.

3. 치열 변수는 골격성 I급 군에서만 높은 유전율을 보이는 계측치가 확인되었다.

4. 하악골 변수에서는 골격성 I급 군은 Condylion-Gnathion, Articulare-Gonion 길이의 유전율이 높았고, 골격성 II급 군에서는 두개저 길이를 나타내는 계측치(Sella-Nasion, Sella-Articulare, Articulare-Nasion)의 유전율이 높은 것으로 나타났다.

5. 주성분분석에서 골격성 I급 군에서는 8개, 골격성 II급 군에서는 7개의 주성분들을 추출하였고, 이 주성분들이 골격성 I급 군 특성의 88.3%, 골격성 II급 군 특성의 91.0%를 설명하는 것으로 나타났다.

결론: 골격성 I급 군과 골격성 II급 군에서 두개안면 골격 및 치열의 유전율이 서로 다르게 나타났으므로, 교정 진단과 치료 계획 수립 시 수평적 골격 양상을 고려하여 성장을 평가하고 예측하는 것이 필요하다.

주요어: 유전율, 쌍둥이, ACE 모델, 주성분 분석

주요어 : heritability; twins; ACE model; principal components analysis

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