Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning

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The interaction of the muscles of mastication and the craniofacial skeleton plays an important role in the control of craniofacial growth. The literature contains many reports on the relationship between the masseter muscle and craniofacial morphology.[1-7] Among the characteristics of facial morphology, facial type—such as short, average, and long—is an important factor in orthodontic treatment, mainly because facial type influences the anchorage system, growth prediction of the maxillofacial structures, and goals of orthodontic treatment, along with bite force and masticatory function.

Ricketts et al.[8] described the long-face pattern as being long and narrow with dental arches that are frequently crowded and have weak musculature and an obtuse mandibular gonial angle. In contrast, the short face pattern is short and wide, with a strong, square mandible and broad dental arches. However, the relationship between mandibular structures and facial type is not yet fully understood. The purpose of this study was to evaluate the relationship between these structures, including cortical bone thickness, tooth inclination, mandibular body inclination, and facial type.

Materials and methods

The material for this study consisted of 39 dry skulls of male Asiatic Indians from the Department of Anatomy, Nihon University School of Dentistry at Matsudo, Japan. All occlusions were

Abstract

The purpose of this study was to evaluate relationships between morphological characteristics of vertical sections of the mandibular body and facial type. Of the correlation coefficients between tooth and bone inclination and facial type parameters, facial height index (FHI) was negatively associated with second premolar (P2), first molar (M1), and second molar (M2) inclinations. The angle represented by Frankfort horizontal plane to mandibular plane (FMA) was negatively associated with bone inclination of the M2 section. The buccal cortical bone was thicker in short-faced individuals than in the average and long-faced groups, while lingual cortical bone thickness of the M1 and M2 sections was greater. The basal cortical bone thickness of the L1 section was greater in the short-faced group, and the inclinations of the P2, M1, and M2 axes were significantly smaller. Teeth in the short-faced group inclined more lingually than in the average- and long-faced groups. The results of this study provide evidence that a significant but complex relationship exists between structures of the mandibular body and facial types. The morphological features that relate to masticatory function and facial types are associated with cortical bone thickness of the mandibular body and the buccolingual inclination of the first and second molars.

Key Words

Facial type • Mandibular body • CT • Mandibular structure

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Figure 1

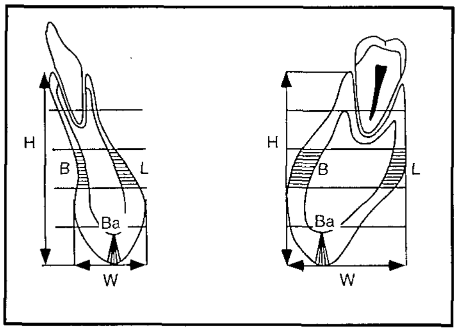

Figure 2

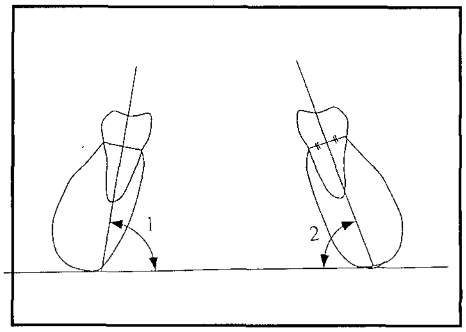

Figure 3

Figure 1
Computer tomograph of M2 section

Figure 2
Definitions of variables H: height; W: width; L: lingual cortical bone (mean thickness of 10 points in middle region); B: buccal cortical bone (mean thickness of 10 points in middle region); Ba: basal cortical bone (mean thickness of 5 points in basal region)

Figure 3
Definitions of variables 1. Tooth inclination; 2. Bone inclination

Figure 4
Cephalogram variables
1. FMA; 2. Palatal to mandibular plane angle; 3. Gonial angle; 4. Posterior facial height; 5. Anterior facial height

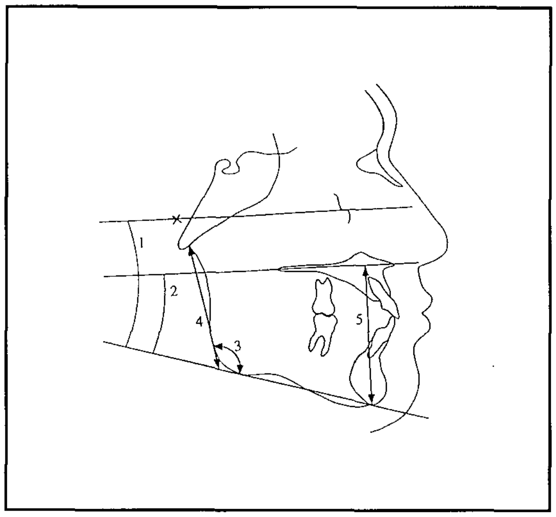

Figure 4

Class I or Class II with minimal dental crowding. Lower third molars were present in all the skulls, and three showed impacted third molars.

For each subject, a lateral radiograph of the skull and four sections of CT scans (GE Yokogawa Medical System Co, CT Verterx 3000) of the mandibular body were available. These CT scans (slice thickness 1 mm; scan time 3 sec; 120 kV) were made in the high-precision mode. The standard plane for positioning consisted of the midpoint of the left central incisor and the distobuccal cusp of both second molars. The standard plane was positioned perpendicular to the vertical line of the X-ray beam. The guideline of the lower incisor (L1) section was defined through the center of the left incisor in occlusal view. The guidelines of the second premolar (P2), first molar (M1), and second molar (M2) sections were defined through the center of each tooth in the lateral view. Sections in M1 and M2 were made parallel to their axes in the 2-mm mesial position for taking photographs of the mesial root[9] (Figure 1).

The following seven measurements of each section were made: height, width, buccal cortical bone thickness, lingual cortical bone thickness, basal cortical bone thickness, tooth inclination, and bone inclination. Reference points and variables are defined in Figures 2 and 3. Landmarks were traced from each film, digitized, and scaled to allow for radiographic enlargement. The mean and standard deviation were estimated for each of the variables assessed from the CT scans.

The maxillofacial morphology of subjects was assessed by measurements recorded indirectly from standardized radiographs. The radiographic reference points and methods closely followed those defined by Kasai et al.[10] Reference points and variables are defined in Figure 4. Radiographs were traced on acetate drafting film, digitized, and scaled to allow for radiographic enlargement.

A number of parameters have been used to categorize vertical facial type, including cant of the mandibular plane,[11] cant of the palatal plane,[12] gonial angle,[13] and ratios of anterior and posterior facial heights,[14] as well as the structural morphology of the mandible. The subjects were divided into three groups according to facial pattern:[15] short, average, and long facial types. Assignments were based on an evaluation of the following facial parameters: (1) FMA (inclination of the mandibular plane relative to Frankfort horizontal plane); (2) Palatal to mandibular plane angle (inclination of the mandibular plane relative to the palatal plane); (3) Gonial angle (inclination of the mandibular plane relative to the ramus plane); and (4) FHI (ratio of posterior facial height to anterior facial height). Subjects were rank-ordered for each facial parameter and divided into three groups. Concordance in the ranking was determined. The 39 subjects were divided into the following subgroups: 9 short facial type (SFT), 23 average facial type (AFT), and 7 long facial type (LFT).

To assess the significance of the error involved in the radiographic measurement methods, the authors reassessed a series of 20 subjects 2 months after the initial measurements. The mean difference between the first and second measurements, the standard error of a single measure, and the percentage of total variance attributable to measurement errors were calculated for each variable. The error variance (*Ve*) was calculated using the following formula:

$$Ve = \Sigma(x_1-x_2)^2 / 2n ,$$

where x_1 and x_2 are the measurements repeated and n is the sample size. The mean differences were less than 1.0 mm or 1.0 degree. A small number of significant mean differences between the first and second measurements of some variables reflected difficulties in the identification of some reference points, especially tooth axis. In general, the contributions of errors to the total variance were small, ranging from 2.4% to 7.2%.

Results

Table 1 shows correlation coefficients between cortical bone thickness of each section and facial type parameters. Significant correlation coefficients were found in buccal cortical bone thickness of L1, P2, and M1 sections. Table 2 shows the correlation coefficients between tooth and bone inclination and facial type parameters. In tooth inclination, FHI was negatively associated with P2, M1, and M2 inclination. In bone inclination, FMA was negatively associated with the bone inclination of the M2 section. The definitions of facial type groups in cephalometry are shown in Table 3. Table 4 shows the differences among facial types in height and width of mandibular sections. The P2 width of the long-faced group was significantly smaller than that of the average group. The M1 width of the short-faced group was significantly larger than that of the average- and long-faced groups.

Table 5 shows the differences in cortical bone thickness among facial types. In the buccal cortical bone thickness, there were significant differences in all sections. The buccal cortical bone of the short-faced group was thicker than that of the average- and long-faced groups. The lingual cortical bone thickness of the M1 and M2 sections of the short-faced group was greater than that of the average- and long-face groups. The basal cortical bone thickness of the L1 section of the short-faced group was greater than that of the long-faced group. In summary, the buccal and lingual cortical bone thicknesses of the short-faced group were greater than those of the average- and long-faced groups. However, the basal cortical bone thicknesses of premolar and molar sections showed almost the same values among three groups.

Table 6 shows the differences in tooth and bone inclinations in each section. In tooth inclination, P2, M1, and M2 were significantly smaller in the short-faced group than in the average- and long-faced groups. This indicated that these teeth inclined more lingually in the short-faced group than they did in other groups. Regarding bone inclination, the M1 section of the short-faced group was significantly smaller than that of the other groups.

Table 1
Correlation coefficients for facial measurements and cortical bone thickness of each section

	FMA	Palatal to mandibular angle	Gonial angle	FHI
Buccal cortical bone				
L1	0.03	-0.32*	-0.22	0.41**
P2	-0.15	-0.42**	-0.56**	0.40*
M1	-0.21	-0.40	-0.45**	0.29
M2	0.08	-0.31	-0.21	0.25
Lingual cortical bone				
L1	-0.01	0.01	-0.06	0.14
P2	-0.29	-0.06	-0.25	0.04
M1	-0.11	-0.17	-0.17	0.19
M2	-0.15	-0.09	-0.05	0.26
Basal cortical bone				
L1	-0.15	-0.15	-0.09	0.14
P2	-0.08	-0.28	-0.27	0.29
M1	-0.15	-0.21	-0.11	0.17
M2	-0.16	-0.13	0.05	0.15

* significant level of *t* value of correlation coefficient $p < 0.05$
** significant level of *t* value of correlation coefficient $p < 0.01$
L1: left central incisor, P2: second premolar, M1 : first molar, M2 : second molar
FHI: ratio of posterior facial height to anterior facial height

Table 2
Correlation coefficients for facial measurements and tooth and bone axes of each section

	FMA	Palatal to mandibular angle	Gonial angle	FHI
Tooth inclination				
L1	0.22	-0.14	-0.17	-0.04
P2	0.00	0.26	0.04	-0.36*
M1	-0.27	0.26	-0.05	-0.35*
M2	-0.24	0.37	-0.02	-0.36*
Bone inclination				
L1	-0.07	-0.14	-0.02	0.14
P2	-0.16	0.09	0.23	-0.06
M1	-0.31	0.25	0.06	-0.27
M2	-0.35*	0.30	0.06	-0.24

* significant level of *t* value of correlation coefficient $p < 0.05$

Discussion

Among cortical bone thicknesses in these four sections, the thickness of the buccal cortical bone was strongly associated with facial type. The thicker the buccal cortical bone, the smaller the

Table 3
Definitions of facial types

	SFT (n=9)		AFT (n=23)		LFT (n=7)		ANOVA Sig.of F		
	Mean	SD	Mean	SD	Mean	SD	SFT-AFT	AFT-LFT	SFT-LFT
FMA	18.3	6.2	22.9	5.7	26.6	5.7			*
Palatal to mandibular angle	18.7	4.5	23.9	6.0	29.1	4.5	*	*	**
Gonial angle	116.4	6.2	121.1	7.2	125.9	6.5			*
FHI (PFH / AFH)	0.82	0.04	0.75	0.09	0.71	0.05	*		**

SFT=short-faced type, AFT=average-faced type, LFT=long-faced type
* sig. of $F < 0.05$, ** sig. of $F < 0.01$
ANOVA: analysis of variance

Table 4
Height and width of mandibular sections among facial types

	SFT (n=9)		AFT (n=23)		LFT (n=7)		ANOVA Sig.of F		
	Mean	SD	Mean	SD	Mean	SD	SFT-AFT	AFT-LFT	SFT-LFT
Section height									
L1	29.4	3.8	31.6	2.8	31.4	3.1			
P2	28.6	4.2	30.3	2.5	30.5	3.2			
M1	27.3	4.3	28.4	2.3	28.7	3.2			
M2	25.8	3.7	25.4	2.5	24.5	2.2			
Section width									
L1	13.1	2.2	13.3	1.4	12.5	1.4			
P2	16.2	2.3	16.3	2.0	14.5	1.1		*	
M1	18.1	2.1	17.5	2.1	15.4	0.5		*	*
M2	19.5	2.3	19.5	1.9	19.4	1.2			

* sig. of $F < 0.05$, ** sig. of $F < 0.01$

gonial and mandibular plane angles and the larger the posterior facial height. Regarding tooth and bone inclinations, subjects with the above-mentioned features turned out to have more lingually inclined tooth and bone axes.

Certain malocclusions are associated with specific facial types, and it is important for the clinician to identify each patient's facial characteristics. This task is important not only for initial classification, but also in planning treatment of existing problems, and in the early determination of the prognosis of the treatment. Ricketts et al. described the long-face pattern as being long and narrow with weak musculature, frequently crowded dental arches, and an obtuse mandibular gonial angle. The short-face pattern is short and wide, with a strong, square mandible and broad dental arches.

To classify facial types, we selected four variables from many cephalometric measurement variables. FMA and palatal-to-mandibular angle indicate the variation of mandibular plane. FHI (facial height index),[16] which is calculated by posterior facial height/anterior facial height, indicates facial pattern, such as long or short face. The gonial angle has been shown to be associated with facial morphology[17,18] and masticatory function.[2,3,18,19] Kasai et al.[13] found that the gonial angle was associated with buccal and lingual cortical bone thickness in the second molar section. The results of this study agreed with Kasai et al.

From the view of functional anatomy, the buccal and lingual structures of second molar sections seemed to be influenced by masticatory function. This is not unexpected because the second molar section is closer to the ramus and the area of attachment of the masticatory muscles. Jaw-closing muscle activity is said to be greatest in subjects with a large posterior facial height, a small anterior facial height, a long mandible, a flat mandibular plane, and a small gonial

Table 5
Cortical bone thickness among facial types

	SFT (n=9) Mean	SFT SD	AFT (n=23) Mean	AFT SD	LFT (n=7) Mean	LFT SD	ANOVA Sig. of F SFT-AFT	AFT-LFT	SFT-LFT
Buccal cortical bone thickness									
L1	1.5	0.5	1.2	0.4	1.1	0.2			
P2	2.3	0.6	1.9	0.4	1.5	0.3		*	**
M1	3.0	0.4	2.6	0.6	2.0	0.5		*	**
M2	3.7	0.3	3.0	0.5	2.7	0.3	**	**	**
Lingual cortical bone thickness									
L1	4.5	0.6	2.3	0.5	2.0	0.5			
P2	2.6	0.5	2.4	0.6	2.2	0.5			
M1	2.6	0.4	2.2	0.4	2.1	0.4	*		
M2	2.1	0.6	1.6	0.4	1.6	0.4	*		*
Basal cortical bone thickness									
L1	3.3	0.8	3.0	0.5	2.5	0.3			*
P2	4.1	0.6	3.9	0.7	3.9	0.6			
M1	3.7	0.6	3.4	0.6	3.3	0.7			
M2	3.2	0.3	3.3	0.6	3.1	0.5			

* sig. of F < 0.05, ** sig. of F < 0.01

Table 6
Tooth and bone inclination among facial types

	SFT (n=9) Mean	SFT SD	AFT (n=23) Mean	AFT SD	LFT (n=7) Mean	LFT SD	ANOVA Sig of F SFT-AFT	AFT-LFT	SFT-LFT
Tooth inclination									
L1	103.4	7.1	104.0	7.6	104.0	7.2			
P2	81.0	4.1	83.5	3.4	85.3	3.5			*
M1	75.8	3.4	80.2	4.6	82.8	4.2	**		**
M2	65.8	6.1	70.9	5.4	74.3	5.4	*		**
Bone inclination									
L1	85.7	3.0	83.5	5.3	86.1	3.0			
P2	85.6	5.5	88.7	5.0	89.7	5.1			
M1	77.8	3.9	81.9	5.0	84.7	4.7	*		**
M2	68.2	5.7	70.7	6.5	71.1	5.1	*		*

* sig. of F < 0.05, ** sig. of F < 0.01

angle.[17,18,19] These relationships are independent of overall size, and their specificity argues for differences in the tension-generating capacities of muscles according to facial types (long, average, or short).

The long-face pattern includes a narrow dental arch mainly because of its narrow mandible, while the short face pattern is wide. Mandibular molars erupt lingually but then incline buccally. Molars also move buccally because of tongue pressure and masticatory function. Molars are located in a balanced position between tongue and buccal pressure, a position that must also adapt to masticatory function. The dental arch width of long-faced subjects is significantly smaller than that of short-faced subjects. If the volume of tongue is equal, it follows that molars of long-faced subjects receive strong tongue pressure. As a result, the molars are more vertical, despite the narrow dental arch.

The buccal cortical bone of short-faced subjects is thicker than that of long-faced subjects. The molars that receive buccally directed force at mastication should be supported by the strong structure of the buccal cortical bone. Therefore, the bone inclination of short-faced subjects is more lingual than that of long-faced subjects.

Okada et al.[9] found that among the variables of the maxillofacial structure, the mandibular plane angle affected the buccolingual inclination of the mandibular incisor and second molar. The inclination of the second molar might be affected by masticatory function, as has been indicated by previous studies.[17,18,19] In this study, M1 and M2 inclination was associated with facial type, which was related to masticatory function. Therefore, in orthodontic treatment, we should notice whether the arch form consists of a toe-in bend or third-order bend at the first and second molars, which is affected by facial type.

The bite force or masticatory function caused by the masticatory muscles influences not only occlusal variation and dental arch form, but also mandibular shape and structure. When investigating the mandibular structures, it is important to include the teeth to understand the stability of the occlusion and to determine tooth position in orthodontic treatment. The relationship between facial type and structures of the mandibular body would also be interesting to investigate from the point of view of functional anatomy.

Conclusion

The results of this study provide evidence that there is a significant but complex relationship between structures of the mandibular body and facial type. The facial types that relate to masticatory function are associated with the cortical bone thickness of the mandibular body and with the buccolingual inclination of the first and second molars.

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