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Regional Variations in Craniofacial Morphology in the Edo Period

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Abstract Previous studies have found that the craniofacial morphology of people during the Edo period was affected by one's social class, and that secular changes in cranial morphology occurred during the Edo period in the mandible. The purpose of this study was to investigate the regional differences in craniofacial morphology between the Hayaoke and Kamekan groups who were buried within the city of Edo and the people who died in six other regions in the Edo period.
A total of 541 individuals were examined, including 63 males excavated from 20 sites in six regions, 38 females from 17 sites in six regions. In addition, 66 individuals (44 males and 22 females) of the early Edo period and 54 individuals (30 males and 24 females) from the medieval period were examined for comparison.
This study reveals that the secular changes in cranial morphology occurred between the medieval period and the late Edo period because the medieval group had statistical differences in many variables, which indicated the breadth and flatness of faces in the Hayaoke group. Although the craniofacial morphologies of the regional groups of the Edo period are basically similar to those of the Hayaoke group, there are same tendencies in both sexes, as individuals of the Tohoku group tend to be scattered near the medieval group and the Kyusyu and Kansai groups tend to be near the Kamekan group. These results can be regarded as the relatively weak regional difference in craniofacial morphology that tends to exist among the people in the Edo period.

Introduction

In the previous studies, the author investigated the craniofacial morphology of human skeletal remains of the Edo period and discovered that were generally two findings. (1) Craniofacial morphology was affected by one's social class among the people in the Edo period because there were statistical significant differences in many variables of both sexes between the skeletal remains buried in circular wooden coffins called as "Hayaoke" and those buried in ceramic coffins called as "Kamekan" during the middle to late Edo period (Sakaue, 2012). (2) Secular changes in cranial morphology occurred during the Edo period because the human skeletal remains of the early Edo period had relatively larger skulls and somewhat stouter mandibles than those of the middle-late Edo period male townsmen (Sakaue, 2013).

In order to answer the question of why these morphological changes occurred, it will be helpful to know the regional variations in the Edo period. Thus, the purpose of this study was to investigate the regional differences in craniofacial morphology between the people who died within the city of Edo and the people who died in other region during the Edo period. For comparison, the human skeletal remains of the medieval period and early Edo period (Sakaue 2013) were also investigated.

Material and methods

The materials of this study are listed in Table 1 (Figure 1). The criteria for selecting the samples and sexual assessment were followed as Sakaue (2013). A total of 541 individuals were examined (Table 2), including 63 males excavated from 20 sites in six regions and 38 females from 17 sites

Table 1. Sites and sample sizes used in this study.

Region	Site	Prefecture	Stored	Male		Female	
				Hayaoke	Kamekan	Hayaoke	Kamekan
Edo	Ikenohata shichikencho	Tokyo	NMNS	61	9	37	9
	Sugenji	Tokyo	NMNS	28	20	9	16
	Shyokenji	Tokyo	NMNS	15	4	12	10
	Hoxtushyoji I and II	Tokyo	NMNS	6	6	2	4
	Enouji	Tokyo	NMNS	4	0	1	2
	Houkouji II	Tokyo	NMNS	1	0	1	0
	Shyugyoji	Tokyo	NMNS	0	1	0	0
	Hosenji I	Tokyo	NMNS	0	1	0	0
	Ikenohata shichikencho minami	Tokyo	NMNS	16	7	8	5
	Jishouin	Tokyo	NMNS	0	2	0	2
	Kotobuki	Tokyo	NMNS	16	6	3	4
	Ryukouji	Tokyo	NMNS	0	2	0	4
	Total			147	58	73	46
Kyushu	Tenpukuji	Fukuoka	KUM		14		5
	Kyomachi	Fukuoka	KUM		1		0
	Harada	Fukuoka	KUM		3		4
	Inaridani	Fukuoka	KUM		3		2
	Total				21		11
Chugoku	Jougahaji	Okayama	Kurashiki Arcaheological Museum		3		3
	Shimizudainichido	Shimane	the Yasugi city Broad education		2		0
	Monzen	Tottori	the Torroti prefecture Center of Archaeological operations		5		1
	Total				10		4
Kansai	Fushimijo ato	Kyoto	Kyoto City Archaeological Research Institute		4		3
	Total				4		3
Chubu	Nagoyashinai	Aichi	UMT		3		1
	Komoro-hurahara	Nagano	Privately owned (Teacher Tanaka)		2		1
	Komoro-mikage	Nagano	Privately owned (Teacher Tanaka)		0		1
	Komoro-tenjinmae	Nagano	Privately owned (Teacher Tanaka)		2		0
	Siokawa	Yamanashi	STM		3		4
	Sunahara	Nagano	Nagano Prefectural Museum of History		0		2
	Total				10		9
Kanto	Totukatateyama	Saitama	NMNS		8		3
	Sawada	Ibaraki	NMNS		1		0
	Total				9		3
Tohoku	Iwaya	Aomori	UMT		2		0
	Nigarui	Aomori	TUM		1		0
	Shibanaidate	Akita	TUM		2		1
	Takanosu-bosawa	Akita	TUM		1		2
	Tamukai	Aomori	TUM		1		2
	Uwano	Aomori	TUM		2		0
	Hatanai	Aomori	TUM		0		1
	Hachinohe	Aomori	UMT		0		2
	Total				9		8
Early Edo	Hatchobori-Sanchyome (1st)	Tokyo	NMNS		2		2
	Hatchobori-Sanchyome (2nd)	Tokyo	NMNS		15		9
	Shitaya-Dohochyo	Tokyo	NMNS		1		4
	Hitotsubashi Senior High School	Tokyo	STM		26		7
	Total				44		22
Medieval	Haseyaji	Kanagawa	STM		1		0
	Yuigahama	Kanagawa	STM		10		8
	Yoshimohama	Fukuoka	KUM		6		8
	Yurakucho	Tokyo	UMT		1		0
	Ootemachi	Tokyo	UMT		2		1
	Kajibashi	Tokyo	UMT		1		0
	Marunouchi	Tokyo	NMNS		4		2
	Zaimokuza	Kanagawa	UMT		5		5
	Kokutetu	Tokyo	NMNS		0		1
	Total				30		25

UMT: University Museum, University of Tokyo, NMNS: National Museum of Nature and Science, Tokyo, TUM:The Tohoku University Museum, STM: St Marianna University, KUM: The Kyushu University Museum,

Figure 1. Male and female examples of each regional group.

in six regions. In addition, 66 individuals (44 males and 22 females) of the early Edo period and 54 (30 males and 24 females) of the medieval period were examined for comparison. The definitions followed those of Martin's measurements (Baba, 1991). When both sides were available, the left side was basically measured. The samples of the Kanto region in this study were excavated from the Kanto plain, except for those excavated from the Tokyo metropolitan area. All materials of each region, except for the city of Edo and the Inaridani burial site of the Kyusyu region, had no positive proof of social class. The Inaridani burial site was thought to be for family burials of the samurai class (Okazaki *et al.*, 2004).

Statistical analyses were performed as follows: 1) The Shapiro-Wilk test was conducted for all variables in each group in order to test for any deviations from a normal distribution; 2) In order to compare the relative significant differences between the Hayaoke group, which has the largest sample size in this study, and the other regional groups, Dunnett's tests were conducted for variables of normal distributions, or Steel's tests were

Table 2. Summary statistics of all measurements and Indexes in males

		Hayaoke (N = 147)			Kamekan (N = 58)			Kyusyu (N = 21)			Chugoku (N = 10)			Kansai (N = 4)			Chubu (N = 9)			Kanto (N = 10)			Tohoku (N = 9)			Early Edo (N = 44)			Medieval (N = 30)	
		Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.
1	Maximum length	181.4	6.5	>	177.8	6.2		181.6	5.8		182.9	6.0		184.4	7.8		174.2	5.5		183.9	5.7		182.5	8.2		181.8	6.7		183.3	6.4
8	Maximum breadth	138.3	4.6	<	141.0	5.0		138.2	5.3		135.8	5.8		140.7	8.2		138.6	3.9		140.7	5.3		142.2	4.6		138.3	5.1		138.1	4.0
17	Basion-Bregma height	136.1	4.7		138.1	5.6	<	139.9	4.2		139.8	7.4		141.2	4.0		131.9	5.1		140.3	4.0		132.3	7.2		137.1	4.9		138.1	5.7
9	Least frontal breadth	93.4	4.3		94.2	4.9		93.0	4.7		94.5	3.6		95.3	3.2		89.8	3.0		95.3	4.1		94.7	5.3		93.4	4.7		93.3	4.1
10	Maximum frontal breadth	114.6	4.2	<	116.9	5.5		114.3	4.7		115.6	3.6		115.6	5.6		112.8	5.6		118.2	5.7	<	119.2	7.1		115.4	3.9		114.9	4.1
5	Basion-Nasion length	101.7	4.5		100.0	4.1		101.8	3.3		102.4	4.7		104.5	4.1	>	96.0	4.6		102.4	2.9		101.6	5.8		101.9	3.5		103.2	5.0
11	Biauricular breadth	125.9	4.4		125.0	4.3		124.5	4.8		124.8	3.2		129.4	3.2		122.4	5.3		127.4	5.0		126.9	3.2		125.3	4.4		126.9	4.4
12	Biasterionic breadth	108.5	4.6		108.3	5.1		109.9	6.1		110.1	4.2		108.6	5.5		105.2	5.0		111.0	6.8		112.5	4.5		108.9	3.9		110.0	5.3
40	Basion-Prosthion length	99.2	5.0	>	96.3	5.8		98.5	3.5		101.0	3.7		98.9	8.2		93.7	6.2		97.2	6.1		101.7	7.1		98.7	4.6		101.3	4.6
14	Minimum cranial breadth	68.6	3.5		69.5	4.1		67.1	2.8		66.8	4.0		69.8	2.9		64.7	3.6		69.3	4.9		68.6	3.6		67.9	3.0		67.5	3.4
7	Foramen magnum length	35.8	2.2		35.4	2.4		35.7	1.9		35.4	1.4		36.7	3.3		33.6	2.5		35.5	2.4		35.4	1.2		35.6	2.1		35.6	2.1
16	Foramen magnum breadth	29.5	1.9		29.8	2.2		29.7	1.5		30.1	2.6		30.5	0.6		28.7	2.2		29.4	2.1		30.6	1.8		29.2	1.6		29.2	1.8
23	Horizontal circumference	518.2	14.3		514.5	13.6		515.0	11.2		514.4	13.2		515.9	17.6		501.6	13.5		523.1	15.9		525.8	18.0		516.5	16.6		517.2	18.1
24	Transverse arc	312.5	9.4	<	320.5	11.6		315.5	10.5		311.3	10.1		320.5	8.7		306.2	9.5		317.8	7.2		309.8	16.9		313.1	9.5		309.6	9.1
26	Frontal sagittal arc	126.1	5.7		126.4	5.9		127.8	7.9		126.9	6.6		126.0	3.9		120.9	8.0		126.8	3.0		123.6	8.1		127.5	5.6		125.0	6.5
27	Parietal sagittal arc	126.2	8.0		125.9	8.6		125.7	9.5		130.9	7.9		126.9	7.8		122.3	1.1		126.9	7.6		126.9	7.7		126.2	6.9		129.6	6.0
28	Occipital sagittal arc	118.0	8.3		118.0	5.3		122.6	11.9		117.0	5.5		123.9	6.6		112.3	6.1		122.8	9.3		114.6	6.3		116.6	6.1		117.9	7.3
25	Total sagittal arc	370.3	13.4		370.3	12.4		376.1	16.7		374.9	14.4		376.8	13.0		355.4	8.8		376.4	9.8		365.2	18.3		370.3	12.2		372.4	12.9
29	Frontal sagittal chord	110.7	4.4		110.5	4.7		113.0	5.4		112.4	5.7		112.8	3.3		107.5	4.3		112.0	2.7		109.0	6.1		111.7	4.3		111.3	4.8
30	Parietal sagittal chord	112.7	6.2		112.4	7.2		113.1	6.9		117.1	5.7		114.7	5.5		110.1	5.1		114.6	5.8		114.8	6.4		113.2	5.5		115.9	4.0
31	Occipital sagittal chord	98.3	5.3		99.5	3.9		101.5	6.5		100.9	6.4		104.0	5.0		96.0	4.2	<	103.5	5.9		95.6	5.6		98.3	4.2		98.7	4.0
43	Outer biorbital breadth	104.6	4.0		104.0	4.2		103.2	4.3		104.0	4.1		107.6	3.3		103.2	1.7		106.8	3.9		104.3	5.0		104.6	3.6		105.1	4.1
43a	Bifrontal breadth	97.3	3.9		96.9	4.0		96.2	3.5		99.1	5.3		100.8	4.8		94.9	1.7		98.8	4.7		97.3	4.5		97.5	3.8		97.3	3.8
	Nasion subtence (calculated)	14.1	2.4		14.4	3.0		14.7	2.6		14.3	3.1		16.1	1.4		12.4	0.9		14.3	2.0		13.9	3.6		14.5	2.1		14.7	2.3
44	Biorbital breadth	97.9	3.7		97.2	4.1		96.9	3.4		94.0	4.0		101.8	5.4		96.8	1.4		99.9	4.4		98.8	4.6		98.5	3.7		98.8	3.9
45	Bizygomatic breadth	135.0	4.5	>	133.0	5.2	>	133.3	4.0		132.2	4.1		137.6	3.4		131.7	3.8		136.1	4.1		136.0	3.2		134.8	4.3	<	136.8	4.9
46	Bimaxillary breadth (zm)	100.0	4.8	>	97.6	4.9		98.8	4.7		98.8	5.1		102.0	5.6		98.1	2.8		99.4	5.3		100.3	3.5		99.8	5.2	<	102.9	5.2
46b	Bimaxillary breadth (zm:a)	100.2	4.8	>	98.0	4.8	>	97.9	5.0		98.6	4.7		101.6	7.5		97.0	2.4		99.9	3.5		98.9	4.6		100.3	5.4	<	102.9	5.2
	Subspinale subtence (calculated)	22.6	3.3		23.8	3.0		24.2	3.5		23.8	3.2		25.9	2.2		21.2	2.2		22.2	3.2		21.0	3.2		22.3	2.9		22.7	3.6
48	Upper facial height	72.2	4.2	<	73.9	3.6		72.7	4.3		71.4	3.5		74.9	4.6		68.8	6.1		73.4	5.1		70.9	4.2		71.9	3.8		70.0	3.8
48H	Upper facial height (Howells)	68.3	4.0	<	70.2	3.3		69.1	4.4		68.6	3.4		71.7	4.0		65.8	5.4		69.5	5.2		67.1	4.0		68.1	3.5		66.6	3.8
48d	Malar height	24.3	2.5		23.8	2.5		24.4	1.9		24.5	2.4		24.4	2.0		21.8	1.4		25.1	2.0		23.9	2.2		23.7	2.4		24.1	2.1
49a	Interorbital breadth	21.1	2.0		20.6	2.1		20.9	1.6		22.0	3.5		21.4	1.4		21.7	2.5		22.0	3.0		23.2	4.2		21.2	1.8	≪	22.7	2.3
50	Anterior interorbital breadth	17.0	2.0		16.9	2.1		18.0	1.4		18.2	2.4		18.2	1.7		18.3	1.8		17.9	2.3		19.0	2.6		16.9	2.1	≪	18.5	2.3
51	Orbital breadth	43.3	1.9		43.3	1.9	≫	41.5	1.6		41.6	1.5		44.9	2.6	>	40.7	0.9		43.3	2.2	>	41.3	2.2		43.0	1.9		42.4	2.1
52	Orbital height	34.2	1.9	<	35.6	1.8		34.1	1.7		34.4	2.3		36.4	2.8		32.7	1.8		35.0	2.1		33.2	2.3		33.9	1.9		33.8	1.5
54	nasal breadth	25.5	1.9	≫	24.5	1.7	>	24.9	1.9		25.7	1.8		25.5	1.1		25.7	2.0		26.3	1.8		25.0	2.0		24.9	1.6		26.0	1.8
55	nasal height	52.3	3.0	>	53.7	2.6	>	54.0	3.0		52.1	2.5		55.9	2.5		51.4	2.9		52.8	3.1		50.5	3.5		51.9	2.8		51.9	2.8
57	Least nasal breadth	7.2	1.6		7.0	2.0		6.4	1.5		7.3	2.0		6.2	1.2		7.4	1.9		7.6	2.2		7.5	1.4		7.1	1.9	<	8.3	2.1
	Nasal subtense (calculated)	2.4	1.0		2.6	1.0		2.0	0.8		2.1	0.9		2.3	1.3		2.2	1.2		2.2	0.8	>	1.4	0.8		2.2	0.9		2.5	1.0
60	External palate length	52.2	3.2	>	50.6	3.6	>	50.0	3.7		51.6	1.5		51.9	5.4	>	47.9	3.6		50.5	2.5		52.3	4.0		51.6	3.7		52.6	3.0
61	External palate breadth	65.7	3.8		65.6	3.9		67.5	4.1		64.2	4.3		65.9	8.7		63.6	2.5		66.6	4.5		64.3	3.9		64.9	3.8		66.1	3.1
62	Internal palate length	45.4	2.8		44.8	3.0		43.2	3.5		43.6	3.0		44.5	4.8		40.1	3.4		43.3	3.3		45.6	3.7		44.6	2.7		45.1	3.1
63	Internal palate breadth	40.7	3.3		40.1	5.5		41.5	2.6		41.2	3.4		40.5	5.5		40.5	1.8		40.2	4.1		41.2	0.7		40.7	2.7		42.4	2.5
66	Bigonial breadth	100.8	6.0		98.7	5.8		101.6	5.2		100.3	4.1		99.5	3.8		99.5	6.0		100.4	6.8		101.9	6.1		102.6	5.8	<	104.7	4.8
68	Projective length of mandible	70.6	5.0		69.8	4.8		71.6	5.3		68.3	8.1		74.6	10.8		65.6	2.7		70.0	3.6		66.8	5.9		72.1	4.9		72.9	3.8
65	Bicondylar breadth	121.5	5.7		120.6	6.0		120.0	6.5		123.2	6.7		124.9	2.4		117.4	4.0		124.0	6.1		120.2	6.0		120.7	5.5	<	123.7	5.4
65(1)	Bicoronoid breadth	97.4	5.0		97.8	5.4		97.9	5.8		98.5	4.0		98.2	1.9		94.5	3.7		100.0	7.1		100.1	8.7		97.3	5.5	<	100.8	4.7
67	Bimental breadth	47.5	2.5		47.5	2.5		47.4	2.6		47.6	1.9		49.2	3.2		46.3	3.6		47.6	2.7		48.2	3.6		47.7	3.0		48.0	3.0
69	Height of mandibular symphysis	35.5	3.2		36.2	2.9		34.9	3.6		36.0	4.3		36.7	2.7	>	31.3	4.4		36.8	3.1		33.1	4.2		35.0	3.6		34.0	2.8
69(1)	Mandibular body height	31.6	2.6		32.2	2.6		30.7	2.6		32.7	4.1		33.0	2.4		28.9	2.9		33.5	4.0		30.3	3.8		31.4	2.3		30.5	2.5
69(2)	Mandibular body height at M2	26.8	2.5		26.6	2.7		26.0	2.4		25.8	3.3		27.3	2.0		23.5	3.1		28.4	3.2		27.3	3.3		27.0	2.0		27.1	2.3
69(3)	Mandibular body breadth	13.3	1.3	>	12.6	1.3		13.4	1.6		14.1	1.7		13.3	0.5		12.6	0.9		13.1	1.2		14.5	1.9		13.8	1.5	≪	14.3	1.3
69b	Mandibular body breadth at M2	17.1	1.6		16.6	1.4		17.7	1.3		18.0	2.0		18.3	1.7		16.6	1.3		17.2	1.5		18.9	2.0	<	18.0	1.5		18.4	1.6
70	Height of mandibular ramus	64.9	4.4		65.0	4.6		64.1	4.6		64.2	4.8		70.8	3.4		63.2	4.4		67.3	6.3		63.6	4.9		63.6	4.9		64.2	4.0
71a	Minimum width of ramus	34.7	3.2	≫	32.7	2.7		33.5	3.3		32.8	3.1		35.5	1.9		33.1	3.9		34.6	1.8		34.8	4.3		34.7	2.9	<	36.2	2.6
71(1)	Condylo-cornoid breadth	36.3	3.3	≫	33.8	3.9		35.3	3.0		35.1	2.9		37.0	3.9		35.8	2.5		36.0	2.6		35.3	3.3		35.5	3.9		34.7	3.1
	Mandibular condyle breadth (left)	20.8	1.9		20.6	2.0		20.1	2.2		20.4	2.4		20.9	2.8		19.2	2.1		20.9	1.5		19.5	1.9		20.2	1.8		20.8	1.7
8/1	Cranial index	76.3	3.5	≪	79.4	3.8		76.2	3.9		74.3	4.0		76.4	5.1		79.6	3.1		76.6	3.8		78.0	3.4		76.2	3.9		75.4	2.7
17/1	Index	75.1	3.2	≪	77.7	3.2	<	77.1	2.8		76.4	3.0		76.6	1.1		75.8	4.2		76.4	3.8		72.5	3.4		75.5	3.4		75.4	3.8
17/8	Index	98.5	4.3		98.0	4.3		101.3	3.9	<	103.1	7.3		100.6	6.1		95.2	3.2		99.9	4.6	≫	93.0	4.7		99.2	4.4		100.1	5.4
9/10	Index	81.5	3.3	>	80.6	3.2		81.3	3.1		81.8	2.4		82.5	1.3		79.6	3.0		80.7	3.4		79.6	4.7		81.0	4.3		81.2	3.3
9/8	Index	67.6	3.4		66.8	3.4		67.3	3.1		69.7	3.1		67.8	2.7		64.8	2.5		67.8	3.3		66.5	2.4		67.6	4.3		67.6	3.3
8/12	Index	127.6	5.5	<	130.4	6.0		126.2	8.5		123.5	6.8		129.6	3.6		132.0	7.6		127.1	7.8		126.6	4.5		127.2	5.6		125.7	5.9
40/5	Index	97.6	4.3		96.3	4.8		96.8	3.2		98.8	4.0		94.6	5.4		97.6	6.1		94.9	5.2		100.1	2.8		96.9	3.6		98.2	3.9
16/7	Index	82.7	5.6		84.3	6.3		83.3	6.1		85.0	6.4		83.7	7.0		85.7	7.9		83.1	5.1		86.4	4.7		82.2	5.9		82.1	5.1
27/26	Index	100.2	6.6		99.8	8.6		98.6	8.2		103.4	8.2		100.8	8.0		101.4	6.1		100.2	7.0		102.9	5.6		99.1	5.8		103.9	7.0
28/26	Index	93.8	7.3		93.5	6.4		96.2	10.1		92.3	4.6		98.3	4.7		93.3	9.6		96.9	7.8		92.9	6.1		91.6	5.5		94.4	5.5
29/26	Index	87.8	1.8		87.4	1.9		88.5	1.7		88.6	1.9		89.5	1.5		89.0	2.4		88.3	1.6		88.2	2.2		87.6	1.5	≪	89.1	1.7
30/27	Index	89.3	1.8		89.4	2.6		90.0	2.1		89.6	2.5		90.5	2.0		90.1	3.7		90.4	2.4		90.4	0.6		89.7	1.7		89.5	1.9
31/28	Index	83.4	2.8		84.4	2.4		83.1	4.1	<	86.2	3.5		84.0	1.7		85.6	3.8		84.5	3.5		83.4	2.7		84.4	2.1		83.9	3.0
(1 + 8 + 17)/3	Modulus	151.9	3.6		152.3	4.0		153.2	3.5		152.8	4.4		155.5	5.1		148.2	3.1		154.9	2.5		152.3	5.4		152.4	3.7		153.2	3.6
	Frontal index of flatness	14.5	2.3		14.8	3.2		15.3	2.4		14.5	1.5		16.0	1.2		13.1	1.0		14.4	1.7		14.2	3.3		14.8	2.1		15.1	2.4
	Zygomatic index of flatness	22.6	3.4	≪	24.3	3.0	<	24.8	3.7		24.2	3.6		25.5	2.4		21.9	2.2		22.2	3.0		21.3	3.5		22.3	3.0		22.3	3.4
	Simotic index of flatness	33.5	11.8		37.4	12.8		31.3	11.5		29.8	12.9		36.1	19.3		28.5	17.0		30.1	10.1		18.7	11.6		31.6	12.8		30.7	11.6
43/8	Index	75.7	3.5	>	73.8	3.2		74.7	3.2		76.7	4.7		76.7	4.8		74.5	2.9		76.0	3.6		73.3	2.7		75.7	3.8		76.2	3.3
46/45	Index	74.1	3.0		73.4	3.0		74.1	2.5		74.8	3.1		74.1	2.5		74.5	1.4		73.1	3.6		73.8	2.2		74.1	2.9		74.5	3.3
48/45	Index	53.5	3.0	≪	55.6	2.8		54.5	2.8		54.1	3.7		54.4	3.1		52.3	5.6		53.9	2.8		52.1	3.6		53.4	2.8	≫	51.2	3.4
48/46	Index	72.2	4.0	≪	75.8	4.2		73.6	3.9		72.5	6.1		73.5	3.6		70.2	6.4		74.1	6.2		70.7	3.6		72.1	4.1	≫	68.8	4.0
9/45	Index	69.2	3.2	<	70.8	3.2		69.8	3.6		71.5	2.6		69.3	2.6		68.1	1.7		70.1	3.4		69.6	3.1		69.4	3.5		68.2	2.8
45/8	Index	97.7	3.8	≫	94.3	3.6		96.6	3.5		97.4	3.5		98.1	7.0		95.1	3.2		96.8	3.9		95.6	2.3		97.5	3.9		99.1	4.1
50/44	Index	17.3	1.9		17.3	1.8		18.6	1.2	≫	20.3	7.2		17.9	1.4		18.9	1.7		17.8	1.9		19.2	2.1		17.2	1.9	<	18.8	2.1
52/51	Index	79.1	4.4	≪	82.2	4.4	<	82.4	4.0		82.6	5.5		81.0	5.0		80.5	4.2		80.9	3.4		80.7	7.0		79.0	5.4		80.0	4.6
54/55	Index	49.0	4.2	≫	45.7	3.1	>	46.2	3.1		49.4	4.1		45.5	1.5		50.1	5.8		49.9	3.5		49.6	4.5		48.1	3.7		50.2	4.2
61/60	Index	126.2	8.3		130.2	10.7	≪	135.5	8.9		124.7	11.1		126.5	3.9		133.4	10.0		131.9	9.4		123.2	7.0		126.4	11.1		125.9	6.7
63/62	Index	89.9	8.4		89.7	12.8	<	96.5	7.8		94.9	9.8		91.7	15.2		101.3	7.0		92.9	7.1		91.0	7.1		91.6	8.4		94.3	7.4
68/65	Index	58.2	4.4		58.0	4.8		60.4	9.6		55.6	7.7		59.8	9.1		55.9	2.9		56.6	4.4		60.3	15.5		59.8	4.6		59.0	4.6
69(3)/69(1)	Index	42.3	5.3	≫	39.2	4.4		43.9	5.9		43.8	8.6		40.5	1.4		43.6	3.4		39.4	4.4		48.3	8.5	<	44.1	5.9	≪	47.1	5.7
69b/69(2)	Index	64.3	6.6		63.1	7.6		68.4	5.2		70.6	9.9		66.8	1.8		71.3	9.3		61.0	6.5		69.9	10.0	<	67.0	6.4		68.3	8.3
71/70	Index	53.6	5.3	≫	50.6	4.9		52.4	5.1		51.2	5.1		50.2	1.2		52.4	6.2		51.8	5.1		54.8	7.3	<	54.9	6.1		56.6	5.0
72	Total profile angle	83.3	3.1		84.3	3.6		82.3	3.0		81.8	4.4		85.1	3.9		82.6	3.7		84.2	3.5		81.9	2.9		83.6	3.2		81.7	3.7
74	Alveolar profile angle	64.7	6.4	<	67.1	6.7	≪	73.0	6.8	≪	71.5	8.3		79.5	9.5		67.9	6.6	<	69.8	5.7		64.3	7.0		66.4	5.1		65.4	6.5
75	Profile angle of nasal bone	63.3	6.2		61.9	5.7		62.0	4.4	>	57.6	6.5		63.3	10.2		61.7	7.0		64.5	5.9		68.4	8.7		64.8	5.7		64.8	7.6
79	Mandibular angle	124.5	6.7	<	126.6	6.7		124.5	6.5		127.2	5.6		117.9	2.7		126.8	3.5		122.6	5.6		122.1	9.2		124.0	6.2	≫	119.5	3.9

"＜" and "≪" mean the results of the Dunnett's test or the Steel's test for multiple comparison between "Hayaoke" group and each groups.
"＜" means $P<0.05$ and "≪" means $P<0.01$ respectively.

Table 3. Summary statistics of all measurements and Indexes in males

		Hayaoke (N = 73)		Kamekan (N = 46)		Kyusyu (N = 11)		Chugoku (N = 4)		Kansai (N = 3)		Chubu (N = 9)		Kanto (N = 3)		Tohoku (N = 8)		Early Edo (N = 22)		Medieval (N = 25)	
		Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.	Test	Mean	S.D.
1	Maximum length	171.9	6.5		169.0	5.4		172.0	6.7		179.5	3.5		176.3	8.4		171.7	11.3		172.6	7.3		176.0	3.9		174.5	4.7		175.7	8.2
8	Maximum breadth	133.5	5.5	<	135.0	4.8		132.8	4.5		136.5	4.1		133.2	3.6		138.0	5.0		136.4	4.8		137.1	4.4		135.0	5.8		133.8	3.8
17	Basion-Bregma height	130.7	3.9		132.1	4.0		132.3	2.5		133.8	4.0		134.8	3.9		128.4	6.5		130.5	2.4		129.0	4.6		129.5	4.3		131.9	5.2
9	Least frontal breadth	89.3	4.7		89.5	3.2		90.8	3.0		91.5	1.3	<	96.4	4.0		90.5	4.6		90.3	6.4		91.0	5.5		90.5	3.8		91.5	3.7
10	Maximum frontal breadth	109.4	4.7		109.9	3.8		110.5	4.1		113.0	5.7		115.1	1.9		112.4	6.2		110.3	4.7		111.9	5.1	<	111.8	4.7		110.6	4.1
5	Basion-Nasion length	94.8	3.7		95.0	3.5		95.3	3.7	<	100.3	3.8		99.3	2.3		92.6	5.3		94.8	4.7		96.4	1.8		95.3	3.0	≪	98.4	4.8
11	Biauricular breadth	119.4	4.5		118.7	4.7		116.4	3.0		122.5	3.4		119.0	0.5		121.7	6.3		121.0	5.5		121.4	4.4		120.2	4.7		120.7	4.6
12	Biasterionic breadth	104.4	4.0		103.9	3.9		104.3	4.0		107.6	1.6		108.3	4.0		108.0	6.1		107.7	4.0		105.6	3.5	<	106.7	4.0	<	107.2	4.4
40	Basion-Prosthion length	94.2	5.5	>	92.7	3.8		95.0	5.3		97.6	2.5		95.7	4.6		89.7	7.0		90.6	7.4		97.8	3.6		93.8	4.2	<	97.6	5.8
14	Minimum cranial breadth	64.1	3.4	<	65.1	3.6		64.4	3.5		65.0	4.6		64.9	4.0		62.1	3.0		63.5	2.7		65.1	3.0		65.0	2.5		64.2	3.4
7	Foramen magnum length	33.9	2.0		33.8	2.1		33.6	1.7		32.6	1.0		33.6	1.2		32.3	1.9		32.6	2.8		34.6	1.2		33.7	1.9		34.1	2.5
16	Foramen magnum breadth	28.4	1.7		28.2	1.9		29.0	1.6		28.3	1.5		28.5	1.4		27.3	1.7		28.5	2.0		28.6	1.4		28.5	2.0		28.5	1.8
23	Horizontal circumference	493.9	12.8		490.6	11.8		481.7	31.6		506.6	7.8		499.2	15.5		496.9	27.0		497.9	21.9		503.2	10.7		502.7	12.8		495.8	23.6
24	Transverse arc	302.4	11.2		304.6	9.8		304.6	7.1		309.3	11.0		308.0	6.6		299.7	15.1		302.4	4.9		298.9	9.7		301.8	10.7		301.0	8.6
26	Frontal sagittal arc	121.4	5.9		120.1	5.6		122.9	6.2		124.3	6.0		124.3	1.2		120.6	9.0		121.0	6.0		118.6	4.0		121.6	5.0		120.8	5.7
27	Parietal sagittal arc	120.8	7.0		119.9	10.8		122.3	9.1		124.3	5.5		126.8	6.0		117.5	5.2		120.6	5.4		116.8	4.9		120.6	8.6		123.8	8.1
28	Occipital sagittal arc	114.9	8.2		113.5	6.6		112.5	7.7		122.8	5.7		109.5	3.0		114.4	8.1		113.6	8.1		115.1	4.0		116.4	8.5		115.2	10.1
25	Total sagittal arc	357.1	12.5		353.5	12.7		357.7	15.5		371.3	10.1		360.7	5.3		352.5	18.3		355.3	15.4		350.4	9.2		358.6	12.3		359.8	15.8
29	Frontal sagittal chord	106.3	4.2		105.8	4.2		107.8	4.2		108.0	6.5		108.2	1.6		106.4	9.1		106.9	4.6		105.9	2.9		106.6	3.4		106.7	4.8
30	Parietal sagittal chord	108.7	5.6		106.6	6.8		110.0	7.3		111.7	4.5		113.8	5.2		107.1	4.1		108.5	4.5		106.4	3.9		109.9	6.0		110.9	6.5
31	Occipital sagittal chord	96.9	5.5		97.4	4.2		96.4	4.2		103.0	2.8		95.0	3.7		99.0	9.2		97.1	2.1		95.5	4.4		97.5	5.3		97.8	5.7
43	Outer biorbital breadth	99.3	3.6		98.6	3.0		98.5	2.7		101.4	2.5		103.7	4.3		99.2	3.9		99.5	5.4		102.0	3.8		100.5	3.0	<	101.5	4.1
43a	Bifrontal breadth	92.4	3.5		91.9	2.8		92.0	4.1		94.1	2.7		94.8	4.2		95.3	8.5		93.1	5.7		95.6	3.8		93.4	2.8		93.6	3.8
	Nasion subtence (calculated)	12.5	2.3		13.2	2.7		13.4	1.4		11.3	2.1		16.1	3.3		12.3	1.4		14.2	2.2		13.5	2.7		12.7	1.4		12.5	2.4
44	Biorbital breadth	93.6	3.5		92.7	3.1		93.2	3.7		97.0	1.7		96.8	4.4		95.7	3.7		95.6	5.2		95.6	3.6	<	95.3	3.1		96.0	3.8
45	Bizygomatic breadth	125.0	3.8	>	123.8	4.5		123.1	3.8		130.1	8.2		126.7	1.3		124.3	7.5		125.4	6.8		127.5	5.4		126.6	4.2	≪	129.2	4.4
46	Bimaxillary breadth (zm)	93.2	3.7	>	92.2	4.7	>	92.2	3.8		96.9	4.5		95.1	4.2		93.4	5.5		92.7	5.3		95.1	3.3		94.7	4.1	≪	97.4	4.0
46b	Bimaxillary breadth (zm:a)	94.1	4.1	≫	92.7	4.8	≫	92.3	4.4		96.7	4.4		93.7	1.7		92.7	5.9		92.0	5.2		95.4	2.9		95.2	4.7	≪	97.7	4.2
	Subspinale subtence (calculated)	20.6	2.9	<	22.0	2.3		22.3	2.6		18.4	2.6		22.4	1.9		20.3	1.5		21.1	3.4		20.9	2.8		19.5	2.8		20.0	3.6
48	Upper facial height	67.0	4.1	<	68.6	3.3		68.2	1.7		65.2	3.2		65.0	3.2		70.5	4.4		64.2	3.5		68.2	3.4		66.4	4.1		65.8	3.7
48H	Upper facial height (Howells)	63.8	4.3	<	65.1	3.6		64.6	2.6		62.6	3.4		61.9	1.8		67.4	4.5		61.3	3.8		64.5	3.1		62.9	3.9		62.4	3.4
48d	Malar height	22.0	2.0		22.0	1.9		21.8	1.7		23.2	2.4		19.7	2.1		20.1	2.1		20.5	3.2		22.9	1.9		22.1	1.9		22.7	2.5
49a	Interorbital breadth	20.3	2.2		19.7	2.1		20.3	2.3		22.8	1.1		21.7	3.1		22.8	4.2		20.6	2.3		21.3	2.2		20.8	1.7	≪	22.0	2.2
50	Anterior interorbital breadth	16.4	1.9		16.3	1.7		17.1	1.7	<	19.1	1.1		17.3	1.2		18.3	3.3		16.4	1.5		17.0	2.6		16.8	1.7	≪	18.1	2.0
51	Orbital breadth	40.9	1.9		41.1	1.4		39.6	2.1		40.9	0.6		41.8	2.2		39.7	2.3		41.0	2.6		41.2	1.6		41.1	1.8		41.0	2.0
52	Orbital height	33.3	1.8	≪	34.6	1.7	≪	33.9	1.7		32.6	0.7		34.1	1.6		33.5	2.0		34.4	2.0		34.1	2.5		33.1	1.9		33.0	2.1
54	nasal breadth	24.4	1.6		24.5	1.9		23.7	1.6		25.9	1.3		24.9	0.8		24.7	1.7		24.2	1.7		23.9	1.6		24.2	1.3		24.4	1.2
55	nasal height	48.7	2.6		49.4	2.5		49.1	1.4		47.4	3.7		48.3	1.4		49.5	2.4		47.9	2.6		48.5	3.4		47.5	2.9		48.4	3.2
57	Least nasal breadth	6.9	1.9		7.7	1.6		7.3	1.0		7.4	1.4		6.2	2.0		7.3	1.6		8.2	2.7		6.7	1.9		7.6	1.6	≪	8.4	1.8
	Nasal subtense (calculated)	1.7	1.0	≪	2.3	0.9	<	2.0	1.0		1.4	0.9		2.1	1.0		1.5	0.4		2.2	0.8		1.6	1.1		1.7	0.9		1.7	0.8
60	External palate length	50.4	3.6	>	48.8	2.3		49.2	2.8		48.2	4.8		48.9	4.7		47.4	2.7		47.2	2.7		50.7	3.7		49.0	2.5		50.1	2.9
61	External palate breadth	61.3	3.6		61.5	3.5		62.4	3.8		62.3	6.2		60.9	0.5		61.9	2.9		56.1	7.6		61.5	3.2		61.5	3.8		61.1	3.6
62	Internal palate length	44.2	2.7		43.4	2.1		41.7	4.5		43.5	2.3		41.6	3.8	>	40.8	2.5		39.4	2.9		44.2	3.3		42.4	2.5		42.8	3.1
63	Internal palate breadth	37.9	2.7		38.7	3.0		38.1	3.0		38.8	3.5		38.0	2.7		37.6	1.3		37.6	2.4		39.8	2.7		39.4	3.0	<	39.8	2.7
66	Bigonial breadth	93.5	5.5	>	91.1	4.5		93.6	3.5		96.8	3.3		92.4	3.5		95.2	6.9		93.4	7.1		94.8	6.4		95.2	5.4		96.6	4.4
68	Projective length of mandible	66.2	4.4		65.7	4.1		66.7	3.6		64.6	2.9		69.1	7.6		64.9	6.7		65.5	7.9		67.9	2.5		67.0	3.5		68.9	4.4
65	Bicondylar breadth	113.7	5.3		110.9	5.8		114.8	6.9		117.7	7.8		117.2	2.3		117.9	9.6		112.4	9.0		117.5	7.1		116.1	5.1		117.0	10.0
65(1)	Bicoronoid breadth	90.3	4.4		90.6	4.9		91.7	4.2		94.4	4.2		96.6	3.7		92.9	7.3		91.5	6.8		90.7	5.7	≪	94.4	4.1	≪	94.6	6.3
67	Bimental breadth	45.6	2.3		45.3	1.9		45.9	2.2		45.2	3.0		44.0	2.5		45.6	4.7		44.8	2.7		45.5	2.3		46.5	2.7	≪	48.9	2.4
69	Height of mandibular symphysis	31.8	3.2		32.2	2.8		33.6	2.1		32.1	3.0		30.8	2.1		31.3	4.3		30.0	4.9		31.8	0.9		30.5	3.4		30.9	3.5
69(1)	Mandibular body height	28.8	2.4		29.0	2.1		29.6	2.6		30.9	2.0		29.1	1.0		29.7	3.0		28.4	3.4		29.5	1.9		28.9	2.8		28.9	2.6
69(2)	Mandibular body height at M2	24.8	2.1		24.3	2.0		24.4	2.4		27.4	1.8		23.8	1.6		25.4	3.8		23.4	3.3		25.9	3.0		25.1	2.3		25.8	2.4
69(3)	Mandibular body breadth	12.6	1.1		12.2	1.2		12.8	1.2		14.3	0.3		11.2	0.3		12.6	1.7		12.8	1.6	≪	14.2	1.2		13.3	1.4		13.3	1.3
69b	Mandibular body breadth at M2	16.9	1.4		16.3	1.5	>	17.0	1.4		17.6	0.4		15.6	1.6		17.3	1.4		16.9	1.6	<	18.6	1.3		17.1	1.1		17.6	1.5
70	Height of mandibular ramus	57.6	3.8		57.8	3.9		58.3	5.1		59.6	2.6		57.0	5.3		57.9	2.7		58.4	3.4	<	61.9	5.7		57.9	3.4		59.9	3.9
71a	Minimum width of ramus	33.1	2.8	≫	31.2	2.3	>	31.5	2.6		33.1	0.8		31.6	1.5		30.3	4.1		30.7	3.3		34.6	1.6		33.2	2.2	<	35.0	1.9
71(1)	Condylo-coronoid breadth	34.3	3.0	>	32.7	3.1	>	32.6	3.3		35.5	4.1		34.5	2.6		32.8	3.3		32.7	2.9		36.4	2.4	>	32.8	2.4		34.9	2.8
	Mandibular condyle breadth (left)	18.5	1.8		18.0	1.5		19.3	2.0		17.5	1.2		18.7	0.7		19.0	3.6		17.7	2.8		20.3	1.3		18.5	1.8		19.4	2.3
8/1	Cranial index	77.8	4.7	<	80.0	3.6		77.3	4.0		76.0	2.3		75.7	4.8		81.5	3.8		79.1	3.2		78.0	2.8		77.4	3.4		76.5	4.4
17/1	Index	76.1	3.1	≪	78.2	2.7		77.0	2.4		74.5	2.7		76.6	5.3		75.7	3.4		75.7	3.3		73.3	2.7	>	74.3	2.9		75.3	2.6
17/8	Index	98.1	4.5		97.9	3.8		99.7	3.6		98.1	3.1		101.3	0.8		93.0	3.3		95.8	4.4		94.1	1.6		96.1	4.3		98.5	4.1
9/10	Index	81.6	3.5		81.4	2.7	>	82.3	2.4		81.1	3.8		83.8	4.9		81.0	2.3		81.9	4.1		81.4	3.3		81.0	2.9		82.8	3.2
9/8	Index	67.0	3.7		66.3	2.9		68.5	3.6		67.1	2.0		72.4	4.8		65.3	3.1		66.2	4.0		66.4	3.2		67.1	2.7		68.3	3.2
8/12	Index	128.0	6.4		130.0	5.2		127.4	5.7		126.8	4.4		123.1	4.7		128.6	6.2		126.7	3.1		129.8	2.6		126.6	6.0		125.2	6.0
40/5	Index	99.4	4.5		97.6	3.2		99.7	3.9		97.3	3.5		96.4	6.0		96.9	5.0		95.6	6.3		101.5	3.6		98.4	3.8		99.1	3.8
16/7	Index	83.9	4.8		83.5	5.2		86.5	6.2		86.8	3.3		84.9	4.7		87.7	4.7		87.6	6.3		82.7	4.6		84.6	5.3		84.0	5.3
27/26	Index	99.6	6.9		99.9	9.1		99.7	7.4		100.1	4.0		102.0	4.0		99.1	6.4		99.8	4.9		98.5	4.5		99.3	8.2		102.7	7.6
28/26	Index	94.8	7.8		94.8	8.4		91.7	7.1		99.1	8.4		88.1	3.2		96.3	7.4		94.0	5.8		97.1	4.8		95.9	7.4		95.5	8.4
29/26	Index	87.6	1.8		88.2	1.7		87.8	1.8		86.9	2.8		87.0	0.9		88.0	3.2		88.4	1.4		89.3	2.0		87.7	1.5		88.3	1.8
30/27	Index	90.0	1.7		89.2	3.9		90.0	1.5		89.9	0.9		89.8	0.2		91.1	1.8		89.9	1.2		91.2	1.5		91.4	4.9		89.7	2.0
31/28	Index	84.4	2.5	<	85.8	1.9		85.8	2.5		83.9	2.2		86.7	1.5		85.1	4.3		85.8	5.0		83.0	2.4		83.8	2.2		85.2	3.4
(1 + 817)/3	Modulus	145.4	3.4		145.4	3.4		145.7	3.3		149.9	2.8		148.1	2.4		144.1	5.5		146.5	3.6		147.4	3.5		146.3	3.5		147.2	4.5
	Frontal index of flatness	13.5	2.3		14.4	2.9		14.6	1.3		12.1	2.5		16.9	2.8		13.8	1.2		15.3	2.4		14.1	2.8		13.6	1.4		13.3	2.5
	Zygomatic index of flatness	21.9	2.8	≪	23.8	2.5		24.2	3.0		19.0	2.3		23.9	1.8		22.5	3.0		23.0	4.5		21.9	3.0		20.5	3.0		20.4	3.4
	Simotic index of flatness	24.6	12.7	≪	29.2	11.0	≪	27.5	14.0		20.3	15.1		33.5	10.3		23.8	5.6		27.4	7.4		22.8	11.5		23.0	11.4		20.1	6.3
43/8	Index	74.5	3.5	>	73.1	3.0	>	74.2	3.7		74.4	2.9		78.0	5.3		72.5	3.0		72.9	1.8		74.4	2.4		74.5	2.8		75.8	3.3
46/45	Index	74.6	2.5		74.5	3.1		75.0	3.4		74.6	2.5		75.0	2.7		74.7	3.1		73.9	2.8		74.7	2.4		74.8	3.2		75.3	2.9
48/45	Index	53.6	3.0	≪	55.4	2.8	<	55.5	1.2		50.2	1.8		51.3	2.2		57.1	2.7		51.2	1.5		53.6	2.9		52.5	3.6	≫	50.9	3.2
48/46	Index	71.9	4.6	<	74.5	5.0	≪	74.1	3.1		67.4	3.5		68.4	4.1		76.4	4.3		69.3	1.2		71.8	4.1		70.3	5.9	≫	67.7	4.3
9/45	Index	71.4	2.9		72.3	3.0		73.9	3.0		70.6	4.2		76.0	2.5		73.0	3.1		72.0	4.0		71.5	4.6		71.5	2.7		70.8	2.9
45/8	Index	93.8	3.5	>	91.7	3.5	≫	92.7	3.4		95.2	3.2		95.2	3.2		89.5	3.8		91.9	3.0		93.0	3.9		93.9	4.1	<	96.6	3.4
50/44	Index	17.5	1.7		17.6	1.8		18.4	1.9		19.8	1.3		17.9	1.0		18.5	2.7		17.1	1.2		17.8	2.2		17.6	1.7	<	18.8	1.9
52/51	Index	81.6	4.6		84.1	4.6	≪	85.6	3.8		79.6	2.6		81.8	5.8		84.8	6.0		84.1	4.8		82.9	6.5		80.6	4.6		80.5	6.3
54/55	Index	50.3	3.7		49.6	4.2		48.2	2.6		54.9	3.8		51.6	0.2		50.6	5.1		50.4	1.9		49.6	4.1		51.1	2.9		50.7	3.2
61/60	Index	121.9	8.7		126.3	8.9		127.2	7.9		130.3	7.8		124.6	5.9		131.4	6.3		118.7	9.5		122.0	10.5		125.8	10.4		122.4	7.6
63/62	Index	86.0	6.9		89.3	7.3		91.8	8.0	<	98.4	7.8		91.9	10.9		92.8	6.0		95.9	8.3		90.6	8.6	≪	93.3	9.3	≪	93.8	8.2
68/65	Index	58.3	4.7		59.3	4.1		58.2	3.5		55.1	4.4		58.9	5.3		55.6	3.3		58.5	7.9		57.9	4.1		57.8	3.5		58.1	4.6
69(3)/69(1)	Index	44.1	4.2		42.4	4.5		43.7	5.1		46.2	2.8		38.3	2.4		43.1	1.9		45.7	7.0		48.0	3.1		46.5	5.4		46.2	5.5
69b/69(2)	Index	68.5	6.9		67.5	8.9		70.1	8.2		64.3	4.4		65.3	2.6		68.1	3.1		72.7	9.1		72.3	7.0		68.7	7.8		68.3	7.0
71/70	Index	57.6	5.9	≫	54.2	4.9		54.1	3.1		55.5	2.4		55.8	5.0	>	52.3	4.9		52.6	5.1		56.3	5.6		57.4	4.6		58.6	4.8
72	Total profile angle	81.2	3.4		82.6	2.6		80.1	2.8		83.3	3.3		85.5	5.5		83.4	2.4		84.8	3.5		80.6	3.4	<	82.9	2.8		81.4	3.1
74	Alveolar profile angle	62.9	6.3		64.1	5.5		64.9	7.5		71.2	11.0		68.2	7.3	≪	72.9	8.4		64.5	7.4		64.4	8.4		63.9	4.7		64.1	5.8
75	Profile angle of nasal bone	64.9	5.0		64.5	5.0		65.6	4.7		68.4	4.9		70.6	3.6		65.1	4.7		68.9	6.6		68.5	7.2	≪	68.4	4.9		66.0	6.1
79	Mandibular angle	126.6	7.2		129.4	7.0		127.3	5.2		123.5	4.4		123.2	5.9		130.1	5.8		129.6	5.4		126.6	6.1	>	123.7	4.9	≫	119.9	6.1

"<" and "≪" mean the results of the Dunnett's test or the Steel's test for multiple comparison between "Hayaoke" group and each groups.

"<" means P<0.05 and "≪" means P<0.01 respectively.

carried out for variables of doubtful normal distributions as a multiple comparison procedure (Nagata and Yoshida, 1997); 3)Forty-seven variables that had been chosen in the previous study (Sakaue, 2012) were also used for multivariate analysis in this study. Principal component analysis was performed to elucidate group differences in cranial variations in all samples of the Edo and medieval periods; 4) the plot of factor scores were made in order to elucidate group differences in the cranial variation of all samples.

All statistical analyses were carried out with SYSTAT 13 and Excel 2010.

Results

Table 2 and 3 show the descriptive statistics of cranial variables and the results of statistical tests. Even if the sample size of the Hayaoke group and the Kamekan group increased in this study, the same tendencies of group differences can be recognized as more brachycephalic cranium, less height in face and orbit, more stout in mandible, and smaller indexes of facial flatness in the Hayaoke group than in the Kamekan group in both sexes as shown in Sakaue (2012). All regional groups except for the Kyusyu group show some significant differences (0-5 variables in males and 1-4 variables in females) with the Hayaoke group, while the Kyusyu group has even more differences (14 variables in both sexes) and more resemblance to the Kamekan group. The craniofacial morphology of the medieval period has more variables showing significant differences (15 in male and 20 in female) with the Hayaoke group than with all regional groups. In particular, the variables indicating breadth of face and mandible were significantly higher than those of the Hayaoke group in both sexes.

Table 4 shows the results of the principal component analysis of males. The first principal component can be interpreted as indicating total skull size because of relatively high loading values for almost all measurements. The second principal component, accounting for 7.6% of the total variance, can be interpreted as positive loading values in the calvarial breadth and negative high values in the sagittal diameters of the facial structure. The third principal component, accounting for 6.8% of the total variance, is interpreted as indicating that the three subtenses of facial flatness correlate with the height of the orbit, the nose, and the mandibular symphysis. Table 5 shows the results of the principal component analysis of females. The first principal component may be also interpreted as indicating the total size of skulls. For the second principal component, accounting for 8.5% of the total variance, the sagittal size of the calvaria and facial structure negatively correlate with the variables of the calvarial breadth and the height of facial components. The third principal component, accounting for 7.0% of the total variance, is interpreted as indicating that skull height negatively correlates with facial breadth. These results are almost the same as those presented in Sakaue (2012).

The scatter plots of the second and third principal component scores of the Hayaoke group, the Kamekan group, the higher class group (“Daimyo” in male, and “Ooku” in female. see the details in Sakaue’s 2012 study), the early Edo group (Sakaue, 2013), and the medieval group are presented in Figure 1 for males and in Figure 2 for females. The ellipses in these plots represent the 68.27% confidence interval for each group. A dashed thick line indicates the standard deviations of the factor scores of the medieval group, and a dashed thin line does those of the early Edo group, a thick line does those of the Hayaoke group, a thin line dose the Kamekan group, and a dashed thin line dose of the higher class. In these plots, the transitional cline of the medieval group, the Hayaoke group, the Kamekan group, and the higher class group is evident in both sexes.

The scatter plot of the factor scores of regional groups for males is presented in Figure 4 with the same ellipses as above. Almost all individuals of the regional groups are within the distribution ellipse of the Hayaoke group. One of the Chugoku group, three of the Chubu, and four of Tohoku are distributed outside Hayaoke’s ellipse and near the distribution of the medieval group. Six of the Kyusyu group, three of the Chugoku,

Table 4. Result of principapal component analysis with all male samples.

		1	2	3	4	5	6
1	Maximum length	**0.674**	−0.161	0.176	**0.313**	0.154	**−0.343**
8	Maximum breadth	**0.344**	**0.572**	0.111	0.204	0.162	**0.400**
17	Basion-Bregma height	**0.550**	−0.015	−0.297	**0.331**	0.223	0.133
9	Least frontal breadth	**0.582**	**0.415**	0.135	0.090	−0.212	−0.227
10	Maximum frontal breadth	**0.418**	**0.617**	0.153	0.148	0.047	−0.017
5	Basion-Nasion length	**0.573**	**−0.328**	−0.083	0.009	0.077	−0.045
11	Biauricular breadth	**0.596**	0.260	0.194	−0.188	0.143	**0.407**
12	Biasterionic breadth	**0.454**	0.039	0.076	0.230	0.165	0.189
40	Basion-Prosthion length	**0.514**	**−0.594**	0.022	0.091	0.007	−0.085
14	Minimum cranial breadth	**0.461**	**0.433**	−0.138	**−0.363**	−0.047	−0.033
7	Foramen magnum length	0.280	0.109	0.026	−0.141	0.300	**−0.364**
16	Foramen magnum breadth	0.164	0.189	−0.021	−0.155	**0.357**	−0.215
23	Horizontal circumference	**0.735**	0.153	0.189	**0.307**	0.197	−0.173
24	Transverse arc	**0.482**	**0.450**	−0.150	**0.471**	0.157	0.198
29	Frontal sagittal chord	**0.488**	0.018	−0.104	**0.426**	0.193	0.069
30	Parietal sagittal chord	**0.398**	0.005	0.093	**0.350**	0.128	**−0.395**
31	Occipital sagittal chord	**0.417**	0.021	−0.107	**0.371**	0.077	0.063
43	Outer biorbital breadth	**0.774**	0.153	0.147	−0.161	−0.153	−0.248
	Nasion subtence (calculated)	0.140	0.002	**−0.309**	0.224	**−0.429**	−0.083
44	Biorbital breadth	**0.654**	0.107	0.096	**−0.324**	−0.021	−0.262
45	Bizygomatic breadth	**0.751**	0.093	0.239	**−0.364**	0.054	0.191
46	Bimaxillary breadth (zm)	**0.705**	−0.163	0.138	−0.269	−0.043	0.109
	Subspinale subtence (calculated)	0.085	−0.028	**−0.487**	0.004	−0.235	0.016
48	Upper facial height	**0.475**	0.047	**−0.669**	−0.075	−0.150	−0.070
48d	Malar height	**0.513**	−0.221	−0.179	0.010	−0.123	0.179
49a	Interorbital breadth	**0.500**	0.076	0.289	0.140	**−0.459**	−0.171
50	Anterior interorbital breadth	**0.472**	0.068	0.291	0.107	**−0.478**	−0.166
51	Orbital breadth	**0.518**	0.191	−0.243	**−0.302**	0.098	−0.244
52	Orbital height	0.266	**0.383**	**−0.451**	−0.070	0.129	−0.098
54	nasal breadth	**0.495**	−0.093	0.274	−0.132	−0.079	0.005
55	nasal height	**0.430**	0.083	**−0.539**	−0.156	−0.121	0.023
57	Least nasal breadth	0.232	0.080	0.196	0.093	−0.624	0.135
	Nasal subtense (calculated)	0.063	0.014	**−0.362**	0.043	**−0.449**	0.205
60	External palate length	**0.451**	**−0.516**	−0.136	0.094	−0.059	−0.075
61	External palate breadth	**0.585**	−0.046	−0.246	−0.118	−0.021	0.142
66	Bigonial breadth	**0.438**	−0.062	0.187	−0.171	0.131	0.220
68	Projective length of mandible	**0.473**	**−0.402**	−0.097	0.037	0.022	0.173
65	Bicondylar breadth	**0.487**	−0.026	0.061	−0.255	0.083	0.173
65(1)	Bicoronoid breadth	**0.547**	0.291	0.175	−0.229	−0.094	0.099
67	Bimental breadth	**0.528**	−0.142	0.021	0.056	0.002	0.236
69	Height of mandibular symphysis	**0.373**	−0.109	**−0.545**	0.101	−0.165	−0.073
69(1)	Mandibular body height	**0.443**	−0.122	**−0.508**	0.069	−0.116	−0.050
69(3)	Mandibular body breadth	**0.344**	**−0.433**	**0.319**	0.137	0.017	0.172
70	Height of mandibular ramus	**0.394**	−0.125	−0.214	−0.181	0.029	−0.064
71a	Minimum width of ramus	**0.465**	**−0.571**	0.212	−0.037	0.089	0.123
71(1)	Condylo-cornoid breadth	**0.307**	**−0.451**	0.082	−0.155	0.225	−0.199
	Mandibular condyle breadth	**0.470**	−0.204	0.014	−0.126	0.068	0.139
	Eigenvalues	11.02	3.58	3.20	2.16	2.07	1.70
	Percent of explained (%)	23.4	7.6	6.8	4.6	4.4	3.6

A bold number means its loading score is greater than 0.3

two of the Kansai, and one of the Kanto are distributed outside Hayaoke's ellipse and near the distribution of the Kamekan group. Although there are no clear differences between the regional group distributions of these factor scores, it can be said that craniofacial morphologies of the skulls excavated from the Tohoku and Chubu regions tend to resemble those of the medieval group, and that individuals of the Kyusyu and Kansai region tend to resemble the

Table 5. Result of principapal component analysis with all female samples.

		1	2	3	4	5	6
1	Maximum length	**0.702**	**0.334**	0.172	−0.187	−0.083	0.244
8	Maximum breadth	**0.370**	**−0.612**	−0.224	**−0.396**	−0.194	−0.066
17	Basion-Bregma height	**0.473**	−0.232	**0.449**	−0.253	−0.017	0.168
9	Least frontal breadth	**0.670**	−0.189	−0.146	0.174	−0.222	0.252
10	Maximum frontal breadth	**0.520**	**−0.484**	−0.172	−0.201	−0.259	0.159
5	Basion-Nasion length	**0.692**	0.217	0.280	0.183	0.096	0.247
11	Biauricular breadth	**0.645**	−0.206	**−0.377**	−0.222	0.112	−0.185
12	Biasterionic breadth	**0.556**	0.021	−0.152	−0.239	−0.044	0.180
40	Basion-Prosthion length	**0.554**	**0.447**	**0.466**	0.157	0.070	0.098
14	Minimum cranial breadth	**0.513**	**−0.379**	−0.151	−0.043	0.212	−0.119
7	Foramen magnum length	0.179	0.164	−0.176	−0.203	**0.448**	0.147
16	Foramen magnum breadth	0.216	0.158	−0.236	−0.038	**0.495**	0.084
23	Horizontal circumference	**0.693**	0.025	−0.040	−0.274	−0.149	0.181
24	Transverse arc	**0.406**	**−0.554**	0.164	**−0.444**	−0.216	0.135
29	Frontal sagittal chord	**0.460**	−0.162	**0.324**	**−0.347**	−0.033	0.086
30	Parietal sagittal chord	**0.449**	0.192	0.161	−0.174	−0.197	0.170
31	Occipital sagittal chord	0.300	−0.045	0.171	−0.204	−0.095	0.218
43	Outer biorbital breadth	**0.797**	−0.007	−0.298	0.233	−0.056	0.116
	Nasion subtence (calculated)	**0.315**	−0.217	0.234	**0.429**	−0.027	0.266
44	Biorbital breadth	**0.778**	0.050	−0.282	0.266	−0.027	0.105
45	Bizygomatic breadth	**0.780**	0.063	**−0.396**	−0.066	0.112	−0.172
46	Bimaxillary breadth (zm)	**0.659**	0.298	−0.148	0.243	0.030	−0.227
	Subspinale subtence (calculated)	0.024	−0.250	**0.518**	**0.345**	0.043	−0.083
48	Upper facial height	**0.398**	**−0.540**	**0.331**	0.145	0.267	−0.223
48d	Malar height	0.157	−0.079	0.164	0.242	−0.041	**−0.326**
49a	Interorbital breadth	**0.532**	0.261	−0.150	0.286	**−0.429**	−0.101
50	Anterior interorbital breadth	**0.512**	0.162	−0.094	0.330	**−0.434**	−0.092
51	Orbital breadth	**0.524**	−0.096	−0.181	0.185	0.269	0.214
52	Orbital height	0.026	**−0.545**	−0.083	0.263	**0.361**	0.206
54	nasal breadth	**0.426**	−0.022	−0.172	**0.317**	−0.025	0.039
55	nasal height	**0.337**	**−0.529**	0.162	0.271	0.249	−0.087
57	Least nasal breadth	**0.384**	−0.202	−0.102	**0.477**	−0.171	0.160
	Nasal subtense (calculated)	0.060	**−0.370**	0.115	0.245	0.155	0.288
60	External palate length	**0.420**	0.190	**0.501**	0.022	0.124	0.008
61	External palate breadth	**0.443**	−0.125	0.260	0.104	0.077	**−0.344**
66	Bigonial breadth	**0.343**	0.071	**−0.317**	0.007	0.057	**−0.358**
68	Projective length of mandible	**0.476**	**0.358**	0.164	0.047	0.189	0.054
65	Bicondylar breadth	**0.552**	0.080	**−0.331**	−0.272	0.281	−0.101
65(1)	Bicoronoid breadth	**0.625**	−0.148	−0.281	−0.032	−0.075	−0.269
67	Bimental breadth	0.272	0.096	0.148	0.123	−0.242	−0.284
69	Height of mandibular symphysis	0.292	**−0.323**	**0.543**	−0.115	0.065	**−0.302**
69(1)	Mandibular body height	**0.492**	−0.202	**0.363**	−0.238	0.038	−0.270
69(3)	Mandibular body breadth	**0.421**	0.238	0.238	−0.169	−0.221	−0.154
70	Height of mandibular ramus	**0.384**	0.131	0.172	0.036	0.043	−0.221
71a	Minimum width of ramus	**0.451**	**0.592**	0.154	−0.180	0.089	−0.057
71(1)	Condylo-cornoid breadth	**0.408**	**0.506**	0.137	−0.115	0.256	0.177
	Mandibular condyle breadth	**0.426**	0.207	−0.111	−0.028	0.240	−0.172
	Eigenvalues	11.10	4.00	3.27	2.58	1.97	1.77
	Percent of explained (%)	23.6	8.5	7.0	5.5	4.2	3.8

A bold number means its loading score is greater than 0.3

Kamekan group. In Figure 5, the scatter plot for females is presented. As seen with males, almost all individuals of regional groups are within the distribution ellipse of the Hayaoke group. One of the Kyusyu group, two of the Chugoku, one of the Chubu, and two of the Tohoku are distributed outside Hayaoke's ellipse and near the ellipse of the medieval group. Although no individual of the regional groups of females are within the Kamekan group alone, three of the Kyusyu, two

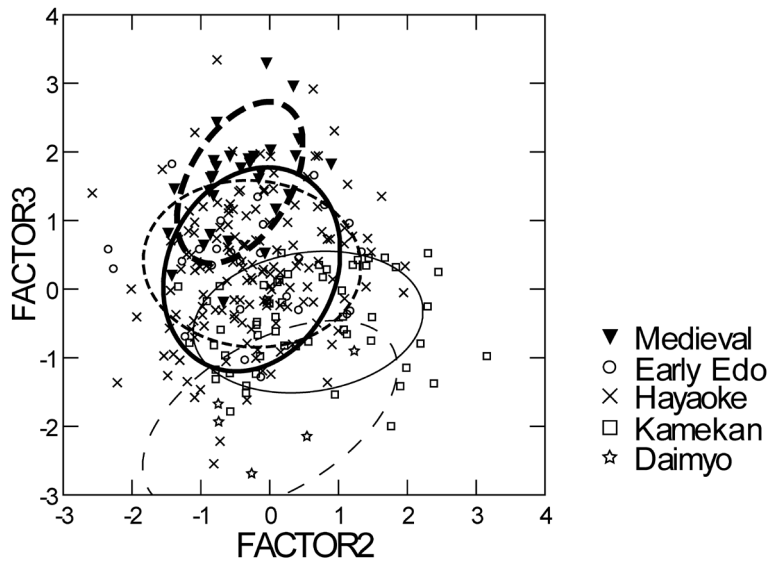

Figure 2. Plot of the second and third principal component scores of males.
The ellipses represent the 68.27% confidence interval for the medieval group (dashed thick line), the Early Edo group (dashed thin line), the Hayaoke group (thick line), the Kamekan group (thin line), and the Daimyo group (dashed thin line). The measurements of the Daimyo group were taken using elaborative casts (Sakaue, 2012).

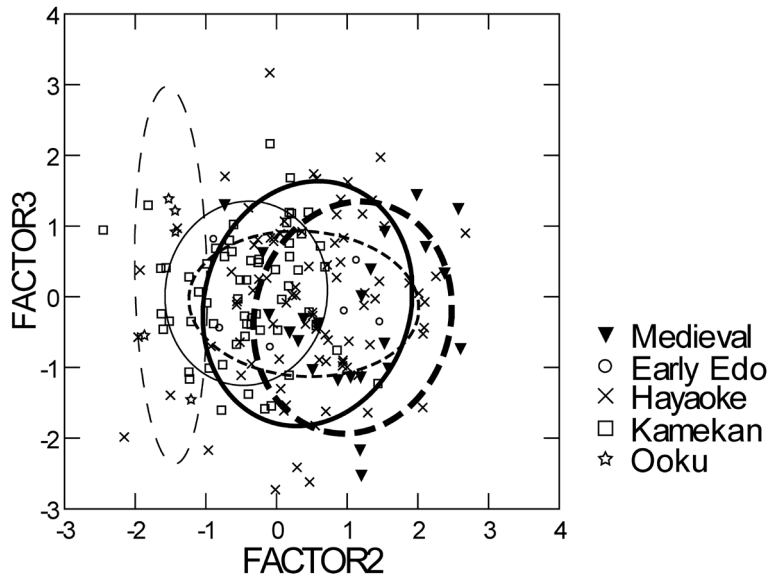

Figure 3. Plot of the second and third principal component scores of females.
The ellipses represent the 68.27% confidence interval for the medieval group (dashed thick line), the Early Edo group (dashed thin line), the Hayaoke group (thick line), the Kamekan group (thin line), and Ooku group (dashed thin line). The measurements of the Ooku group were taken using elaborative casts (Sakaue, 2012).

of the Kansai, and two of the Chubu are within the ellipses of the Hayaoke and Kamekan groups. This means that there are no clear regional decline in female but craniofacial morphologies of the skulls excavated from the Tohoku region tend to resemble the medieval group, and those of the Kyusyu and Kansai region resemble the Kamekan group.

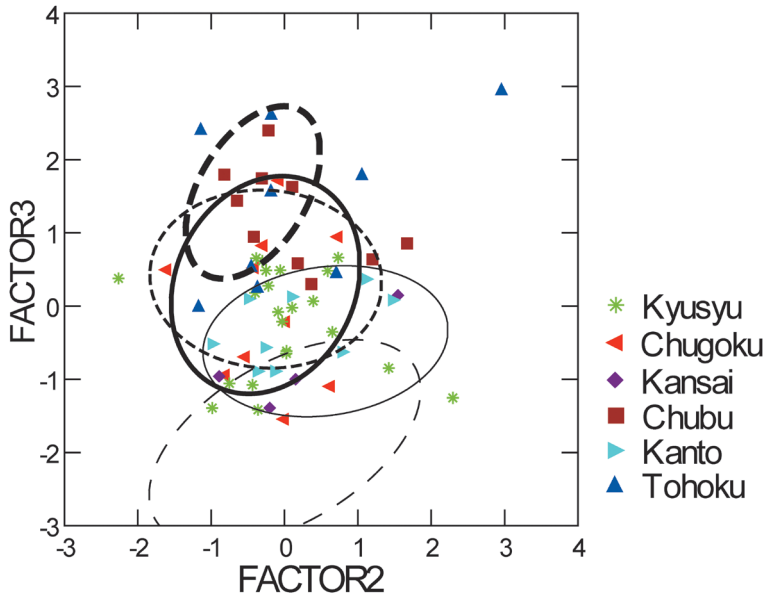

Figure 4. Plot of the second and third principal component scores of males in each regional group. The ellipses represent the 68.27% confidence interval as seen in Figure 2.

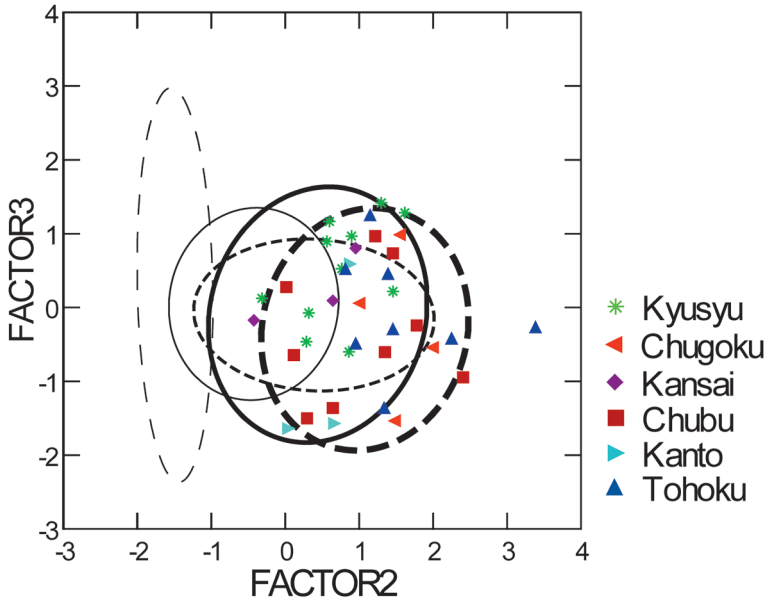

Figure 5. Plot of the second and third principal component scores of females in each regional group. The ellipses represent the 68.27% confidence interval as seen in Figure 3.

Discussion

This study reveals that the medieval group had statistical differences in many variables which indicated the breadth and flatness of faces in the Hayaoke group, and that many factor scores were distributed outside the Hayaoke group and the early Edo group. It can be said, therefore, that secular changes in cranial morphology occurred from the medieval period to the late Edo period.

It is also demonstrated that the craniofacial morphologies of the regional groups of the Edo period are essentially similar to those of the Hayaoke group. It is plausible that the people of the regional areas flowed into urban areas such as the city of Edo during the Edo period (Hayami, 2001). But there are same tendencies in both sexes, as individuals of the Tohoku group tend to be scattered near the medieval group, and the Kyusyu and Kansai groups tend to be near the Kamekan group. These results can be regarded as the relatively weak regional differences in craniofacial morphology that tend to exist in the Edo period.

As seen in Sakaue (2012), the Kamekan burial style was utilized almost entirely by the lower-middle class samurai, and the craniofacial morphology of the Kamekan group can be regarded as the features of the samurai class living in the city of Edo. It would be interesting to see whether these features of the samurai can be seen in the samurai class living in other regional areas as well. In this study, three out of six males who are plotted outside the ellipse of the Hayaoke group were excavated from the Inaridani burial site where the samurai of the vassals of the Takeda clan were buried in their family cemetery. It could be said that the features of the samurai were not restricted to the samurai within the city of Edo but were shared with the samurai class in the regional areas as well.

Unfortunately, the sample sizes of regional area are restricted because the preservation of skulls in each regional area tends to be poor. In the future, further studies and researches are needed to clarify the regional and social class differences between regional areas, after with new excavations of Edo burial sites in regional areas, more samples, and a new method for determining social class.

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