Original Article

Hypodontia Patterns and Variations in Craniofacial Morphology in Japanese Orthodontic Patients

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ABSTRACT

Objective: The purpose of this study was to explore the association of hypodontia patterns and variations in craniofacial morphology in Japanese orthodontic patients.

Materials and Methods: A total of 50 girls with hypodontia (the total group) were selected and categorized into anterior, posterior, and anterior-posterior groups according to the location of the congenitally missing teeth. By using the lateral cephalograms of each subject, 28 angular and 37 linear measurements were made. The cephalometric data were statistically analyzed and compared among the groups and with the Japanese cephalometric standards from 36 age-matched female subjects without hypodontia or malocclusion (the control group).

Results: Every hypodontia group showed shorter anterior and overall cranial base lengths, shorter maxillary length, greater retroclination and elongation of mandibular incisors, and a larger interincisal angle than the control group. The total and anterior-posterior groups especially exhibited a significantly more prognathic mandible, larger retroclination of maxillary incisors, and a more counterclockwise-rotated occlusal plane. Furthermore, these skeletal and dental deviations were more remarkable in the anterior-posterior group than in either the anterior or the posterior group. Anterior hypodontia exerted as much influence on craniofacial morphology as posterior hypodontia.

Conclusions: When orthodontic treatment is performed on patients with hypodontia, not only the number but also the distribution of missing teeth should be taken into consideration, though there was no significant difference in craniofacial morphology between anterior hypodontia and posterior hypodontia.

KEY WORDS: Hypodontia; Hypodontia pattern; Craniofacial morphology; Japanese patients

INTRODUCTION

Hypodontia is one of the most common dental anomalies in the permanent dentition.[1,2] Numerous studies have been published on the prevalence of hypodontia (third molars excluded) in various populations.[3] The reported hypodontia rates range from 3.7% in an American population[2] to 10.1% in a Norwegian population.[4] Almost all studies have reported higher occurrences in females than in males.[3–11] The majority of previous studies dealing with Caucasian populations have revealed that the most commonly congenitally missing tooth is the mandibular second premolar, followed by either the maxillary lateral incisor[1,2,12] or the maxillary second premolar.[4,6–8,10] Some studies have shown that ethnicity strongly influences the prevalence of hypodontia.[8,9] The hypodontia rate in Japanese populations reportedly ranges from 7.4%[11] to 8.5%,[3] and the mandibular lateral incisor is more commonly missing in Japanese than in any other ethnic groups.[3,11]

Several studies have associated hypodontia with smaller cranial base length[13,14] and angle,[13,15] more retrognathic[15–18] and shorter maxilla,[13,14,17,19] more prognathic mandible,[13,14,20] smaller mandibular plane[14,15,20] and sagittal jaw relationship angles,[15,16] straighter fa-

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TABLE 1. Sample Description of Patients per Group

	Total	Anterior	Posterior	Anterior–Posterior	Control
n	50	25	15	10	36
Age	13 y ± 1 y 8 mo	12 y 8 mo ± 1 y 9 mo	13 y 6 mo ± 1 y 6 mo	13 y 3 mo ± 1 y 7 mo	13 y 2 mo ± 1 y 2 mo

cial convexity,[15,17,18] greater retroclination of maxillary[13,15,16,18] and mandibular incisors,[13,15,16] larger interincisal angle,[13,15,18] and shorter lower anterior facial height.[14,15] Some other studies have concluded that hypodontia has little or no effect on craniofacial morphology.[21,22]

A few studies have been conducted on the effect of the pattern of hypodontia or the distribution of congenitally missing teeth in the dentition on craniofacial morphology.[14,17,18,22] Wisth et al[17] revealed more retrognathic and shorter maxilla and more proclined maxillary incisors in Norwegian children with up to six congenitally missing teeth and found that these deviations were independent of whether the congenitally missing teeth were located in the maxilla or in the mandible. Yuksel and Ucem[22] classified Turkish orthodontic patients with tooth agenesis into three groups according to the location of missing teeth and found no statistically significant differences in craniofacial morphology between the patients with anterior tooth agenesis and those with posterior tooth agenesis. In an investigation of the effects of the distribution of congenitally missing teeth on craniofacial morphology in Israeli orthodontic patients, Ben-Bassat and Brin[18] demonstrated that anterior tooth agenesis predominantly influenced craniofacial morphology compared with posterior tooth agenesis. Woodworth et al[14] investigated craniofacial morphology in individuals with bilateral maxillary lateral incisor agenesis and found shorter maxillary and mandibular lengths and a tendency for forward mandibular rotation and shorter upper and lower anterior facial heights.

No literature on the association of the distribution of congenitally missing teeth with craniofacial morphology in Japanese patients was found in a PubMed search on the Internet. The purpose of the present study was to explore the relationships between hypodontia patterns and variations in craniofacial morphology in Japanese orthodontic patients.

MATERIALS AND METHODS

Subjects

A total of 50 Japanese girls with hypodontia (the total group), excluding third molars, were selected as the subjects from the files of orthodontic patients who had been treated at our clinics in The Nippon Dental University Niigata Hospital (Niigata, Japan). Boys were not included in this study so as to avoid skewing cephalometric measurements with sexual differences in craniofacial morphology. The subjects were selected on the basis of the following criteria: a dentition showing the eruption of second molars or within approximately 6 months after full eruption of all four second molars, no premature loss of deciduous teeth, no previous orthodontic or prosthodontic treatment, and no craniofacial anomalies. The mean age of the subjects was 13 years (SD 1 year 8 months, Table 1).

Hypodontia was diagnosed by using orthodontic records, which included orthopantomograms, cephalograms, and anamnestic data. A tooth was identified as a congenitally missing tooth when there was no evidence that it had been extracted and when no mineralization of the tooth crown could be recognized on orthopantomograms.[3,7] The anamnestic data were used as reference material to avoid wrong diagnoses. Longitudinal orthopantomograms were examined to exclude the registration of late mineralized teeth as congenitally missing teeth. A final orthopantomogram examination was performed on the subjects of 13 years of age and older. The criteria for the finals were based on the finding by Aasheim and Ogaard,[7] who reported that apart from third molars no tooth had been found mineralized after the age of 12 years. Third molars were excluded from the present study. The same investigator reexamined each orthopantomogram, and a reproducibility of 100% was obtained in the identification of hypodontia.

Our hypodontia subjects (the total group) were categorized into three groups according to the distribution of congenitally missing teeth in the dental arches. The anterior group consisted of 25 patients with hypodontia in the anterior region only (incisors and canines). The posterior group consisted of 15 patients with hypodontia in the posterior region only (premolars and molars). The anterior-posterior group consisted of 10 patients with hypodontia in both anterior and posterior regions. The numbers and mean ages of patients, the distribution of patients by the number of missing teeth, and the distribution of different missing teeth in each group are shown in Tables 1–3.

Cephalometric Analysis

A single investigator prepared and assessed lateral cephalograms, which were taken with the same cephalostat and with the standardized settings. Seventeen reference points were marked, and 11 reference

TABLE 2. Numbers and Percentages of Patients by the Number of Missing Teeth in Each Hypodontia Group

No. of Missing Teeth	Total (%)	Anterior (%)	Posterior (%)	Anterior–Posterior (%)
1	19 (38.0)	14 (56.0)	5 (33.3)	0 (0.0)
2	15 (30.0)	11 (44.0)	4 (26.7)	0 (0.0)
3	3 (6.0)	0 (0.0)	2 (13.3)	1 (10.0)
4	2 (4.0)	0 (0.0)	1 (6.7)	1 (10.0)
5	1 (2.0)	0 (0.0)	1 (6.7)	0 (0.0)
6	1 (2.0)	0 (0.0)	1 (6.7)	0 (0.0)
7	3 (6.0)	0 (0.0)	1 (6.7)	2 (20.0)
8	1 (2.0)	0 (0.0)	0 (0.0)	1 (10.0)
9	3 (6.0)	0 (0.0)	0 (0.0)	3 (30.0)
10	1 (2.0)	0 (0.0)	0 (0.0)	1 (10.0)
17	1 (2.0)	0 (0.0)	0 (0.0)	1 (10.0)
Total	50 (100.0)	25 (100.0)	15 (100.0)	10 (100.0)

TABLE 3. Numbers and Percentages of Different Missing Teeth in Each Hypodontia Group

Fédération Dentaire Internationale Tooth No.	Total (%)	Anterior (%)	Posterior (%)	Anterior–Posterior (%)
Maxilla				
17	1 (0.6)	—	0 (0.0)	1 (1.2)
16	5 (3.1)	—	0 (0.0)	5 (6.0)
15	11 (6.9)	—	6 (14.6)	5 (6.0)
14	7 (4.4)	—	3 (7.3)	4 (4.8)
13	7 (4.4)	2 (5.6)	—	5 (6.0)
12	8 (5.0)	4 (11.1)	—	4 (4.8)
11	0 (0.0)	0 (0.0)	—	0 (0.0)
21	0 (0.0)	0 (0.0)	—	0 (0.0)
22	11 (6.9)	6 (16.7)	—	5 (6.0)
23	6 (3.8)	2 (5.6)	—	4 (4.8)
24	6 (3.8)	—	2 (4.9)	4 (4.8)
25	14 (8.8)	—	7 (17.1)	7 (8.4)
26	5 (3.1)	—	0 (0.0)	5 (6.0)
27	2 (1.3)	—	0 (0.0)	2 (2.4)
Total	83 (51.9)	14 (38.9)	18 (43.9)	51 (61.4)
Mandible				
47	3 (1.9)	—	1 (2.4)	2 (2.4)
46	0 (0.0)	—	0 (0.0)	0 (0.0)
45	14 (8.8)	—	9 (22.0)	5 (6.0)
44	1 (0.6)	—	0 (0.0)	1 (1.2)
43	1 (0.6)	0 (0.0)	—	1 (1.2)
42	13 (8.1)	11 (30.6)	—	2 (2.4)
41	5 (3.1)	1 (2.8)	—	4 (4.8)
31	7 (4.4)	3 (8.3)	—	4 (4.8)
32	9 (5.6)	6 (16.7)	—	3 (3.6)
33	2 (1.3)	1 (2.8)	—	1 (1.2)
34	1 (0.6)	—	0 (0.0)	1 (1.2)
35	18 (11.3)	—	12 (29.3)	6 (7.2)
36	0 (0.0)	—	0 (0.0)	0 (0.0)
37	3 (1.9)	—	1 (2.4)	2 (2.4)
Total	77 (48.1)	22 (61.1)	23 (56.1)	32 (38.6)

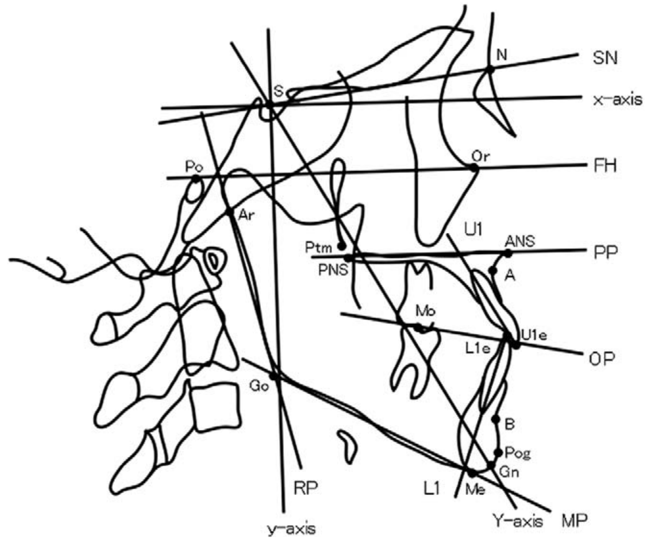

Figure 1. Reference points and lines used. N indicates nasion; S, sella turcica; Or, orbitale; Po, porion; Ptm, pterygomaxillary fissure; Ar, articulare; ANS, anterior nasal spine; PNS, posterior nasal spine; A, point A; U1e, maxillary incisor edge; L1e, mandibular incisor edge; B, point B; Pog, pogonion; Gn, gnathion; Me, menton; Go, gonion; Mo, molare; SN, sella turcica- nasion plane; FH, Frankfort horizontal plane; PP, palatal plane; OP, occlusal plane; MP, mandibular plane; RP, ramus plane; Y-axis, sella turcica–gnathion line; U1, long axis of maxillary central incisor; L1, long axis of mandibular central incisor; x-axis, line parallel to Frankfort horizontal plane through sella turcica; and y-axis, line perpendicular to Frankfort horizontal plane through sella turcica.

lines were manually drawn on each tracing paper (Figure 1). For each tracing, 26 linear and 17 angular measurements were made with a vernier type of micrometer and a protractor (Table 4). Eleven linear measurements (eg, U1e-x, U1e-y) were made by a coordinate system with the x-axis parallel to the Frankfort horizontal plane and the y-axis perpendicular to the Frankfort horizontal plane through the sella turcica (Figure 1, Table 4). The linear and angular measurements were estimated to the nearest 0.1 mm and 0.5°, respectively.

Statistical Analysis

Statistical analyses were performed by a StatMate III Statistical Package (ATMS Co Ltd, Tokyo, Japan). Differences in mean values between the values measured in each hypodontia group and the Japanese cephalometric standards[23] and among the hypodontia groups were assessed for each measurement by using Student's *t*-test or Welch's test after testing the homogeneity of the variances. The control samples (the control group) used as the Japanese cephalometric standards were sex matched and almost age matched to the patients in each hypodontia group for proper statistical comparisons. The Japanese cephalometric standards were developed from 36 Japanese girls

TABLE 4. Definitions of Measurements Used

Measurement	Definition
S-N (mm)	Anterior cranial base length
N-Ar (mm)	Overall cranial base length
S-Ar (mm)	Posterior cranial base length
N-S-Ar (°)	Cranial base angle
SN-FH (°)	Facial inclination
ANS-PNS (mm)	Maxillary length
A-y (mm)	Distance from point A to the y-axis
ANS-y (mm)	Distance from anterior nasal spine to the y-axis
Ptm-y (mm)	Distance from pterygomaxillary fissure to the y-axis
S-N-A (°)	Prognathism of maxillary alveolar bone
PP-FH (°)	Frankfort palatal plane angle
Me-Go (mm)	Mandibular body length
Go-Ar (mm)	Ramus height
Ar-Me (mm)	Maximum mandibular length
B-y (mm)	Distance from point B to the y-axis
Pog-y (mm)	Distance from pogonion to the y-axis
S-N-B (°)	Prognathism of mandibular alveolar bone
S-N-Pog (°)	Prognathism of the mandible
FH-Npog (°)	Facial angle
MP-FH (°)	Mandibular plane angle
Y-axis-FH (°)	Y-axis inclination relative to Frankfort horizontal plane
RP-FH (°)	Ramus inclination
MP-RP (°)	Gonial angle
A-N-B (°)	Sagittal jaw relationship angle
N-A-Pog (°)	Facial convexity
U1e-x (mm)	Distance from maxillary incisor edge to the x-axis
U1e-y (mm)	Distance from maxillary incisor edge to the y-axis
U1-FH (°)	Maxillary incisor inclination
L1e-x (mm)	Distance from mandibular incisor edge to the x-axis
L1e-y (mm)	Distance from mandibular incisor edge to the y-axis
L1-MP (°)	Mandibular incisor inclination
U1-L1 (°)	Interincisal angle
Mo-x (mm)	Distance from molare to the x-axis
Mo-y (mm)	Distance from molare to the y-axis
OP-FH (°)	Occlusal plane inclination
N-Me (mm)	Total anterior facial height
N-ANS (mm)	Upper anterior facial height
ANS-Me (mm)	Lower anterior facial height
U1e-ANS (mm)	Distance from maxillary incisor edge to anterior nasal spine
L1e-Me (mm)	Distance from mandibular incisor edge to menton
S-Go (mm)	Total posterior facial height
S-Ar (mm)	Upper posterior facial height
Ar-Go (mm)	Lower posterior facial height

without hypodontia or malocclusion and with a mean age of 13 years 2 months (SD 1 year 2 months, Table 1). The means and standard deviations of the S-N, N-Ar, and S-Ar dimensions and the N-S-Ar angle were calculated from the data of the control group.[23] In particular, the concept of propagation error was used to make the calculation of standard deviations.

Measurement Error

Twenty lateral cephalograms were used for measurement once again after 3 weeks, and the means of each measurement were used in the statistical calculations. Student's *t*-test with a 95% confidence interval did not reveal any systematic measurement errors. Measurement errors, which were assessed with the Dahlberg[24] formula, were found to be $<$0.4 mm for linear measurements and $<0.5°$ for angular measurements.

RESULTS

The means and standard deviations for all the measurements and the level of significant difference are shown in Table 5.

Cranial Base

The S-N and N-Ar dimensions were significantly smaller in the total, anterior, and posterior groups than in the control group.

Maxilla and Mandible

The ANS-PNS dimension was significantly shorter in every hypodontia group than in the control group. The Ptm-y dimension was significantly larger in the total and posterior groups than in the control group. A significantly larger Pog-y dimension and a significantly smaller RP-FH angle were found in the total group than in the control group. A significantly larger FH-Npog angle and a significantly smaller Y-axis-FH angle were found in the total and anterior-posterior groups than in the control group. This significantly larger FH-Npog angle might have been caused by the retrusion of nasion as well as the protrusion of pogonion, which was shown by the significantly smaller S-N dimension. The N-A-Pog angle was significantly larger in the anterior-posterior group than in the control group. This was because point A was not in a retrusive position and pogonion was in a protrusive position. A significantly larger Ptm-y dimension and a significantly smaller RP-FH angle observed in the total group and a significantly larger FH-Npog angle and a significantly smaller Y-axis-FH angle in the total and anterior-posterior groups reflected a tendency for the mandible to be in a forward position.

The MP-FH and the Y-axis-FH angles were significantly smaller in the anterior-posterior group than in the posterior group. The A-N-B angle was significantly larger in the total, anterior, and posterior groups than in the anterior-posterior group. The N-A-Pog angle was significantly larger in the anterior-posterior group than in the total, anterior, and posterior groups and

TABLE 5. Craniofacial Morphology in Each Hypodontia Group and Control Group

Measurement	Total (T)	Anterior (A)	Posterior (P)	Anterior–Posterior (AP)	Control	Significance
Cranial base						
S-N (mm)	67.9 ± 2.5**	67.4 ± 2.4**	68.0 ± 2.4*	68.4 ± 2.7	69.6 ± 2.6	
N-Ar (mm)	93.4 ± 4.1*	92.5 ± 4.4**	93.0 ± 4.5*	94.7 ± 3.5	95.5 ± 3.8	
S-Ar (mm)	36.3 ± 3.2	36.1 ± 3.4	36.4 ± 3.4	36.5 ± 2.9	35.3 ± 2.6	
N-S-Ar (°)	124.2 ± 6.2	123.4 ± 6.4	123.6 ± 5.5	125.7 ± 6.7	128.3 ± 14.1	
SN-FH (°)	9.1 ± 3.2	9.1 ± 2.9	8.7 ± 3.2	9.6 ± 3.5	8.3 ± 2.7	
Maxilla and mandible						
AN-PNS (mm)	49.9 ± 3.3***	49.4 ± 4.1***	50.1 ± 2.9**	50.2 ± 2.8**	53.5 ± 4.2	
A-y (mm)	67.7 ± 4.4	67.3 ± 3.9	68.6 ± 5.1	67.2 ± 4.2	67.2 ± 3.3	
ANS-y (mm)	71.5 ± 3.9	71.4 ± 3.6	72.2 ± 4.8	71.0 ± 3.3	72.6 ± 3.4	
Ptm-y (mm)	20.5 ± 2.9*	20.5 ± 2.7	20.9 ± 2.6*	20.1 ± 3.2	19.2 ± 2.5	
S-N-A (°)	81.5 ± 4.3	81.3 ± 3.8	82.5 ± 4.5	80.2 ± 4.4	80.1 ± 2.5	
PP-FH (°)	2.4 ± 2.3	2.2 ± 1.9	2.5 ± 2.3	2.4 ± 2.8	1.8 ± 2.4	
Me-Go (mm)	71.5 ± 4.7	70.8 ± 5.0	70.7 ± 5.1	72.9 ± 3.9	72.2 ± 6.1	
Go-Ar (mm)	44.8 ± 3.7	45.7 ± 3.5	43.7 ± 4.0	45.1 ± 3.7	45.8 ± 4.6	
Ar-Me (mm)	105.5 ± 5.3	105.2 ± 5.3	104.8 ± 6.2	106.6 ± 4.4	106.7 ± 5.9	
B-y (mm)	63.9 ± 7.2	62.7 ± 5.9	62.6 ± 7.6	66.3 ± 8.1	61.7 ± 3.1	
Pog-y (mm)	63.1 ± 8.7*	62.0 ± 7.4	60.8 ± 9.1	66.5 ± 9.8	60.0 ± 4.0	
S-N-B (°)	79.0 ± 4.6	78.5 ± 4.2	78.7 ± 4.5	79.7 ± 5.1	77.6 ± 2.2	
S-N-Pog (°)	78.9 ± 5.0	78.6 ± 4.3	78.1 ± 4.7	80.0 ± 5.8	77.4 ± 2.7	
FH-Npog (°)	88.1 ± 4.8**	87.4 ± 3.9	87.1 ± 5.1	90.0 ± 5.6*	85.7 ± 1.9	
MP-FH (°)	26.9 ± 6.3	27.1 ± 6.0	30.0 ± 6.0	23.5 ± 7.0	27.7 ± 4.5	AP < P****
Y-axis-FH (°)	61.1 ± 4.4*	61.6 ± 3.4	63.1 ± 4.4	58.7 ± 5.4*	62.7 ± 2.2	AP < P****
RP-FH (°)	81.5 ± 5.8*	83.0 ± 5.1	81.9 ± 6.2	79.8 ± 6.2	84.3 ± 4.1	
MP-RP (°)	125.0 ± 6.8	123.9 ± 7.5	127.9 ± 8.5	123.4 ± 4.3	123.4 ± 5.9	
A-N-B (°)	2.6 ± 2.9	2.9 ± 2.9	3.8 ± 2.9	0.5 ± 3.1	2.6 ± 1.7	AP < T·A,**** AP < P*****
N-A-Pog (°)	175.0 ± 6.9	173.8 ± 7.3	170.5 ± 6.3	180.7 ± 7.3***	173.6 ± 4.0	T·A·P < AP,**** P < T****
Incisors and molars						
U1e-x (mm)	73.8 ± 5.6	73.9 ± 4.5	74.9 ± 5.3	72.6 ± 6.9	75.3 ± 4.4	
U1e-y (mm)	70.9 ± 6.9	71.8 ± 5.5	72.8 ± 8.0	68.3 ± 7.2	72.1 ± 3.8	
U1-FH (°)	108.3 ± 11.4**	111.8 ± 8.3	111.3 ± 10.0	101.8 ± 16.0*	114.4 ± 4.8	
L1e-x (mm)	68.9 ± 5.5**	69.4 ± 5.1*	71.8 ± 5.5	65.6 ± 5.8***	72.2 ± 4.5	AP < P****
L1e-y (mm)	69.1 ± 5.8	69.2 ± 5.0	70.2 ± 6.7	67.9 ± 5.6	69.0 ± 3.6	
L1-MP (°)	87.0 ± 7.7***	89.3 ± 6.8***	89.5 ± 8.0***	82.1 ± 8.2***	96.4 ± 5.1	AP < T·A·P,**** T < P****
U1-L1 (°)	136.1 ± 12.4***	132.0 ± 10.8***	128.6 ± 12.1*	147.6 ± 14.4***	121.5 ± 6.9	A < AP,***** P < AP****
Mo-x (mm)	67.1 ± 4.4	67.1 ± 3.9	67.6 ± 5.0	66.2 ± 5.4	67.2 ± 3.8	
Mo-y (mm)	39.5 ± 5.2	39.0 ± 4.5	40.0 ± 6.4	40.1 ± 5.5	37.8 ± 3.3	
OP-FH (°)	9.2 ± 4.5**	9.7 ± 4.2	11.0 ± 5.1	7.0 ± 4.0***	11.5 ± 2.9	AP < P****
Vertical dimensions						
N-Me (mm)	120.9 ± 5.6	121.3 ± 4.3	122.8 ± 6.7	118.5 ± 5.9	121.6 ± 6.9	
N-ANS (mm)	55.3 ± 2.8	55.4 ± 2.5	55.5 ± 3.5	55.1 ± 2.5	56.8 ± 4.9	
ANS-Me (mm)	65.7 ± 4.6	66.1 ± 3.7	67.5 ± 4.9	63.6 ± 5.1	64.8 ± 7.0	
U1e-ANS (mm)	29.6 ± 2.4	29.2 ± 2.2	30.0 ± 2.4	29.5 ± 2.6	28.6 ± 5.6	
L1e-Me (mm)	41.2 ± 2.3	40.8 ± 2.5	40.7 ± 2.5	42.0 ± 1.8	39.3 ± 7.5	
S-Go (mm)	76.3 ± 4.5	77.0 ± 5.0	75.5 ± 4.8	76.3 ± 3.7	76.0 ± 3.8	
S-Ar (mm)	31.5 ± 3.0	32.0 ± 3.3	31.0 ± 3.4	32.4 ± 2.3	30.7 ± 2.5	
Ar-Go (mm)	44.8 ± 3.4	45.1 ± 3.3	44.5 ± 3.8	44.1 ± 3.2	45.3 ± 4.6	

*, **, and *** indicate statistically significant differences ($P < .05$, $P < .01$, and $P < .001$, respectively between each hypodontia group and the control group). **** and ***** indicate that each measurement value is significantly larger ($P < .05$ and $P < .01$, respectively) on the right-side group than on the left-side group.

was significantly larger in the total group than in the posterior group.

Incisors and Molars

The U1-FH and OP-FH angles were significantly smaller in the total and anterior-posterior groups than in the control group. The L1e-x dimension was significantly smaller in the total, anterior, and anterior-posterior groups than in the control group. A significantly smaller L1-MP angle and a significantly larger U1-L1 angle were found in every hypodontia group than in the control group.

The L1e-x dimension and the OP-FH angle were significantly smaller in the anterior-posterior group than in the posterior group. The L1-MP angle was significantly smaller in the anterior-posterior group than in the total, anterior, and posterior groups and was significantly smaller in the total group than in the posterior group. The U1-L1 angle was significantly larger in the anterior-posterior group than in the anterior and posterior groups.

Vertical Dimensions

None of vertical dimension measurements showed any significant differences between each hypodontia group and the control group or among the hypodontia groups.

DISCUSSION

Some studies showed that the types of the most commonly missing teeth differed from one ethnic group to another.[4,8,9] In our study, the most commonly missing tooth was the mandibular second premolar, followed by the maxillary second premolar in the total and posterior groups. These findings were consistent with the results published by the majority of other researchers who used Caucasian populations.[5–8,10] The prevalence of mandibular lateral incisor agenesis was higher than that of maxillary lateral incisor agenesis in the total and anterior groups. This finding of ours was in disagreement with those of several other studies that found the prevalence of maxillary lateral incisor agenesis to be higher than that of mandibular lateral incisor agenesis in Caucasian populations[1,4–7,10,12] and was consistent with the previous studies that investigated the prevalence of hypodontia in Japanese[3,11] and Chinese[9] populations.

The findings of significantly shorter anterior and overall cranial base lengths in the total, anterior, and posterior groups were in agreement with the previous studies.[13,14] The significantly shorter maxillary length shown in every hypodontia group might have resulted from the interaction of anterior and posterior growth deficiency, when the ANS-y and Ptm-y dimensions were measured. In particular, the shorter maxillary length in the total and posterior groups was mainly attributed to the posterior growth deficiency caused by the significantly larger Ptm-y dimension and might have resulted from inadequate apposition to the tuberosity area in posterior tooth agenesis.[13] Some other investigators demonstrated that the shorter maxillary length was mainly caused by an anterior growth deficiency in individuals with hypodontia.[15–17,21]

None of the mandibular measurements showed any significant differences between the anterior and posterior groups and the control group, whereas the significant prognathism of the mandible was observed in the total and anterior-posterior groups compared with the control, anterior, and posterior groups. This prognathic mandible in the total and anterior-posterior groups might imply a predominant influence of the widespread distribution of congenitally missing teeth on the mandible. Yuksel and Ucem[22] also observed a more prognathic mandible in the bilateral anterior tooth agenesis group than in the control group without tooth agenesis or malocclusion. Similar findings to ours were published by other researchers investigating individuals with severe hypodontia[13,20] and with bilateral lateral incisor agenesis.[14] Therefore, not only the number but also the distribution of missing teeth should be taken into consideration when performing orthodontic treatment of patients with hypodontia.

The retroclination of the maxillary incisors in the total and anterior-posterior groups and the retroclination and elongation of the mandibular incisor in every hypodontia group were especially remarkable compared with the control group. The interincisal angle increased significantly in every hypodontia group, resulting from the retroclination of the maxillary and mandibular incisors. These dental deviations were consistent with the observations of some previous investigators[13,15,16,18] and contradictory to others.[21,22] The retroclination of incisors found in our study might have resulted from a disturbance in a tongue-lip pressure balance and a reduced lingual support caused by anterior tooth agenesis. Differences in significance level between maxillary and mandibular incisor retroclination in each hypodontia group indicated that disturbing influences of hypodontia on dental deviations were probably greater in the mandible than in the maxilla. This could be due to a higher prevalence of lateral incisor agenesis in the mandible than in the maxilla and the compensation of mandibular incisors for the significantly prognathic mandible. The upward-positioned mandibular incisors in our present study might have been caused by the interplay of the retroclination of the mandibular incisors and the dental compensation for the prognathic mandible, resulting in a counterclockwise-rotated occlusal plane, which was a significant difference between the total and anterior-posterior groups and the control group.

The skeletal and dental deviations were more remarkable in the total and anterior-posterior groups than in the anterior and posterior groups. Moreover, the anterior and posterior groups were much the same in the degree of skeletal and dental deviations. These findings were consistent with the results obtained by Yuksel and Ucem[22] and inconsistent with those reported by Ben-Bassat and Brin.[18] The sample in this study, as in the study by Yuksel and Ucem,[22] is based mainly on patients with only a few missing teeth, whereas the sample reported by Ben-Bassat and Brin[18] was based on multiple congenitally missing teeth. The findings of Ben-Bassat and Brin,[18] similar to those of Nodal et al,[20] indicated that the influence of hypodontia on the skeletodental pattern became greater as the number of missing tooth increased. The inconsistency of our results with those of Ben-Bassat and Brin[18] might have been because of a basic difference in the composition of the samples.

Homeobox genes have a critical role in regulating tooth and craniofacial morphogenesis. In mice, it is said that the expression of MSX 1 and MSX 2 is required for direct epithelial-mesenchymal interactions that initiate tooth formation.[25] The MSX 1 homeodomain missense mutation (arg31pro) has been reported to cause selective agenesis of the second premolars and third molars in an American family.[26,27] Another mutation (ser105stop) in MSX 1 has been regarded as responsible for orofacial clefting and tooth agenesis in a Dutch family.[28] From these different pieces of evidence of the mutation, it can be said that there is some genetic difference of the different populations in tooth agenesis. It has been reported that MSX 1–deficient mice exhibited a cleft secondary palate (a deficiency of alveolar mandible and maxilla) and abnormalities of the nasal, frontal, and parietal bones and of the malleus in the middle ear in addition to tooth agenesis,[29] which might suggest that tooth agenesis was genetically related to the development of cranium and maxillary complex. These observations were in accord with our findings that craniofacial morphological deviations occurred in every hypodontia group. PAX 9 is also associated with tooth agenesis. A frameshift mutation in PAX, resulting in an alternation in the paired domain of PAX 9, is associated with autosomal dominant oligodontia, which involves the normal primary dentition and the lack of most of the permanent molars.[30] A published study has shown that TGFA played a role in tooth agenesis in a Brazilian population, and statistically significant evidence was afforded to indicate that the MSX 1 and PAX 9 interact in tooth agenesis, though the interaction between MSX 1 and TGFA was not fully corroborated.[31] The genetic heterogeneity for hypodontia might be responsible for the variability of the association between hypodontia patterns and craniofacial morphology.

CONCLUSIONS

- Every hypodontia group showed shorter anterior and overall cranial base lengths, shorter maxillary length, greater retroclination and elongation of mandibular incisors, and smaller interincisal angle than the control group.
- The total and anterior-posterior groups, especially, showed more prognathic mandible, greater retroclination of maxillary incisors, and a more counterclockwise-rotated occlusal plane.
- These skeletal and dental deviations were more remarkable in the anterior-posterior group than in either the anterior or posterior group.
- Anterior hypodontia exerted as much influence on craniofacial morphology as posterior hypodontia.

REFERENCES

1. Ingervall B, Seeman L, Thilander B. Frequency of malocclusion and need of orthodontic treatment in 10-year old children in Gothenburg. *Swed Dent J.* 1972;65:7–21.
2. Buenviaje TM, Rapp R. Dental anomalies in children: a clinical and radiographic survey. *ASDC J Dent Child.* 1984;51:42–46.
3. Endo T, Ozoe R, Kubota M, Akiyama M, Shimooka S. A survey of hypodontia in Japanese orthodontic patients. *Am J Orthod Dentofacial Orthop.* In press.
4. Hunstadbraten K. Hypodontia in the permanent dentition. *ASDC J Dent Child.* 1973;40:115–117.
5. Eidelman E, Chosack A, Rosenzweig KA. Hypodontia: prevalence amongst Jewish populations of different origin. *Am J Phys Anthropol.* 1973;39:129–133.
6. Nordgarden H, Jensen JL, Storhaug K. Reported prevalence of congenitally missing teeth in two Norwegian countries. *Community Dent Health.* 2002;19:258–261.
7. Aasheim B, Ogaard B. Hypodontia in 9-year-old Norwegians related to need of orthodontic treatment. *Scand J Dent Res.* 1993;101:256–260.
8. Backman B, Wahlin YB. Variations in number and morphology of permanent teeth in 7-year-old Swedish children. *Int J Paediatr Dent.* 2001;11:11–17.
9. Davis PJ. Hypodontia and hyperodontia of permanent teeth in Hong Kong schoolchildren. *Community Dent Oral Epidemiol.* 1987;15:218–220.
10. Castaldi CR, Bodnarchuk A, Zacherl WA. Incidence of congenital anomalies in permanent teeth of a group of Canadian children aged 6–9. *J Can Dent Assoc.* 1966;32:154–159.
11. Niswander JD, Sujaku C. Congenital anomalies of teeth in Japanese children. *J Phys Anthropol.* 1963;21:569–574.
12. Grahnen H. Hypodontia in the permanent dentition. *Odont Revy.* 1956;7(suppl 3):1–100.
13. Endo T, Yoshino S, Ozoe R, Kojima K, Shimooka S. Association of advanced hypodontia and craniofacial morphology in Japanese orthodontic patients. *Odontology.* 2004;92:48–53.

14. Woodworth DA, Sinclair PM, Alexander RG. Bilateral congenital absence of maxillary lateral incisors: a craniofacial and dental cast analysis. *Am J Orthod.* 1985;87:280–293.
15. Ogaard B, Krogstad O. Craniofacial structure and soft tissue profile in patients with severe hypodontia. *Am J Orthod Dentofacial Orthop.* 1995;108:472–477.
16. Sarnas K-V, Rune B. The facial profile in advanced hypodontia: a mixed longitudinal study of 141 children. *Eur J Orthod.* 1983;5:133–143.
17. Wisth PJ, Thunold K, Boe OE. The craniofacial morphology of individuals with hypodontia. *Acta Odontol Scand.* 1974; 32:281–290.
18. Ben-Bassat Y, Brin I. Skeletodental patterns in patients with multiple congenitally missing teeth. *Am J Orthod Dentofacial Orthop.* 2003;124:521–525.
19. Tavajohi-Kermani H, Kapur R, Sciote JJ. Tooth agenesis and craniofacial morphology in an orthodontic population. *Am J Orthod Dentofacial Orthop.* 2002;122:39–47.
20. Nodal M, Kjar I, Solow B. Craniofacial morphology in patients with multiple congenitally missing permanent teeth. *Eur J Orthod.* 1994;16:104–109.
21. Roald KL, Wisth PJ, Thunold K, Boe OE. Changes in craniofacial morphology of individuals with hypodontia between the ages of 9 and 16. *Acta Odontol Scand.* 1982;40:65–74.
22. Yuksel S, Ucem T. The effect of tooth agenesis on dentofacial structures. *Eur J Orthod.* 1997;19:71–78.
23. Japanese Society of Pediatric Dentistry. A study on the cephalometric standards of Japanese children. *Jpn J Pediatr Dent.* 1995;33:659–696.
24. Dahlberg G. Errors of estimation. In: Dahlberg G, ed. *Statistical Methods for Medical and Biological Students.* 1st ed. London, UK: George Allen Unwin Ltd; 1940:122–132.
25. Jowett AK, Vainio S, Ferguson MW, Sharpe PT, Thesleff I. Epithelial-mesenchymal interactions are required for msx 1 and msx 2 gene expression in the developing murine molar tooth. *Development.* 1993;117:461–470.
26. Vastardis H, Karimbux N, Guthua SW, Seidman JG, Seidman CE. A human MSX 1 homeodomain missense mutation causes selective tooth agenesis. *Nat Genet.* 1996;13: 417–421.
27. Vieira AR. Oral clefts and syndromic forms of tooth agenesis as models for genetics of isolated tooth agenesis. *J Dent Res.* 2003;82:162–165.
28. van den Boogaard MJ, Dorland M, Beemer FA, van Amstel HK. MSX 1 mutation is associated with orofacial clefting and tooth agenesis in humans. *Nat Genet.* 2000;24:342–343.
29. Satokata I, Maas R. Msx 1 deficient mice exhibit cleft palate and abnormalities of craniofacial and tooth development. *Nat Genet.* 1994;6:348–356.
30. Stockton DW, Das P, Goldenberg M, D'Souza RN, Patel PI. Mutation of PAX 9 is associated with oligodontia. *Nat Genet.* 2000;24:18–19.
31. Vieira AR, Meira R, Modesto A, Murray JC. MSX 1, PAX 9, and TGFA contribute to tooth agenesis in humans. *J Dent Res.* 2004;83:723–727.