Original Article

Congenitally Missing Mandibular Incisors and Mandibular Symphysis Morphology

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ABSTRACT
Objective: To explore the association between congenital absence of permanent mandibular incisors and craniofacial and mandibular symphysis morphology in Japanese orthodontic patients.
Materials and Methods: A total of 27 girls with one or two congenitally absent mandibular incisors (group M) were selected and divided into group 1M (16 girls with the absence of one incisor) and group 2M (11 girls with the absence of two incisors). In addition, 20 other Japanese girls without hypodontia and with little or no mandibular incisor crowding were enrolled as a control (group C). Using the lateral cephalogram of each subject, 17 angular, 8 linear, and 3 area measurements were made for evaluation of craniofacial and mandibular symphysis morphology. The cephalometric data thus obtained were statistically analyzed and compared between the groups.
Results: A significantly greater retroclination of the retained mandibular incisors was found in group 1M than in group C. Groups 1M and M showed a significantly greater retroclination of mandibular alveolar bone than group C. Groups 2M and M exhibited a significantly smaller mandibular symphysis area than group C.
Conclusion: The retroclination of the mandibular incisors and alveolar bone and the reduced mandibular alveolar bone area should be taken into consideration in planning orthodontic treatment on patients with congenitally missing permanent mandibular incisors.

KEY WORDS: Mandibular symphysis; Congenitally missing tooth; Mandibular incisor; Craniofacial morphology; Japanese patients

INTRODUCTION

Hypodontia is one of the most common dental anomalies in permanent dentition.[1] The reported hypodontia rates (third molars excluded) range from 3.5% in an American population[2] to 10.1% in a Norwegian population.[3] Most previous studies have found higher prevalence rates in females than in males.[3–8] Some investigators have reported that the prevalence of hypodontia is strongly influenced by ethnicity.[5,7,8] Most previous studies dealing with Caucasian populations have revealed that the most commonly congenitally missing teeth are either the mandibular second premolars[1,3,6,7] or the maxillary lateral incisors.[2,4,9,10] Niswander and Sujaku[11] and Davis[5] showed that the mandibular incisors were the most commonly missing teeth in Japanese as well as Chinese populations. Endo et al[8] has reported that the characteristic of hypodontia in a Japanese population compared with foreign populations was a higher prevalence of mandibular lateral incisor agenesis in children with minor hypodontia.

Several studies have shown the association of hypodontia with smaller cranial base length[12–14] and angle,[12,15] more retrognathic[15–18] and shorter maxilla,[12–14,17,19] more prognathic mandible,[12–14,20] smaller mandibular plane[13,15,20] and sagittal jaw relationship angles,[15,16] straighter facial convexity,[15,17,18] greater retroclination of maxillary[12,14–16,18] and mandibular incisors,[12,14–16] larger interincisal angle,[12,14,15,18] and shorter lower anterior facial height.[13,15] However, some other studies have revealed that hypodontia has little or no effects on craniofacial morphology.[21,22]

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Table 1. Description of Sample

	Group 1M	Group 2M	Group M	Group C
Number of subjects	16	11	27	20
Age	8 y 9 mo ± 1 y 2 mo	8 y 6 mo ± 9 mo	8 y 7 mo ± 1 y	8 y 10 mo ± 11 mo

Other studies concerning the association of the distribution of hypodontia in the dentition with craniofacial morphology have found that craniofacial morphology has nothing to do with the location of the congenitally missing teeth whether agenesis occurs in the maxilla, mandible,[17] or the anterior or posterior region.[14,21] There is only one study that argues for the effect of one type of congenitally missing teeth on craniofacial morphology.[13] In an investigation of craniofacial morphology in individuals with congenital absence of maxillary lateral incisors, which were the most commonly congenitally missing teeth in Caucasian populations,[2,4,9,10] Woodworth et al[13] found shorter maxillary and mandibular lengths, a tendency to forward mandibular rotation, and shorter upper and lower anterior facial heights.

The mandibular symphysis is orthodontically defined as the area covering the mandibular symphyseal region on the lateral cephalogram. It has been reported that morphological changes in the mandibular symphysis are associated with mandibular growth[23,24] as well as types of malocclusion[25] and orthodontic treatments.[24,26] Buschang et al[23] demonstrated that vertical and horizontal growth changes during childhood and puberty were most pronounced in the upper 20% and the upper half of the mandibular symphysis, respectively. Tooth eruption plays a critical role in continuous growth of the mandibular symphysis, resulting in an increase in the height of the mandibular body.[23] Therefore, it can be said that mandibular incisor agenesis has a large effect on mandibular symphysis morphology.

The purpose of this study was to explore the association between congenital absence of permanent mandibular incisors and craniofacial and mandibular symphysis morphology in Japanese orthodontic patients.

MATERIALS AND METHODS

Subjects

A total of 27 Japanese girls with one or two congenitally missing mandibular incisors (the hypodontia group, group M) 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 to avoid skewing cephalometric measurements because of gender differences in craniofacial and mandibular symphysis morphology. A total of 20 Japanese girls without hypodontia and with little or no mandibular incisor crowding were also selected from the same files as above. They constituted the control group in this study (group C). All subjects, including those in the control group, were selected on the basis of the following criteria: (1) the dentition during the eruption of canines and premolars after full eruption of incisors other than congenitally missing incisors, (2) no premature loss of deciduous teeth, (3) no previous orthodontic or prosthodontic treatment, and (4) no craniofacial anomalies. The subjects in the hypodontia groups had no other missing teeth than mandibular incisors. Third molars were excluded from this study. The mean ages of the subjects in groups M and C was 8 years 7 months (SD = 1 year) and 8 years 10 months (SD = 11 months), respectively (Table 1).

Incisor agenesis was diagnosed using orthodontic records, which included orthopantomograms, cephalograms, and anamnestic data. The incisor that was absent from the dentition 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. The anamnestic data were used as reference to avoid wrong diagnoses. Longitudinal orthopantomograms were examined to identify the formation of the other teeth. A final orthopantomographic examination was performed on the subjects 13 years of age and older. The criteria for the final examinations were based on the findings by Aasheim and Ogaard,[6] who reported that apart from third molars, no tooth had been found to be mineralized after the age of 12. Each orthopantomogram was reexamined by the same investigator, and a reproducibility of 100% was obtained in the identification of the incisor agenesis.

Group M was categorized into two groups by the number of congenitally missing mandibular incisors: one was a group of 16 girls (group 1M) with agenesis of one mandibular incisor (mean age = 8 years 9 months, SD = 1 year 2 months; Table 1); the other group consisted of 11 girls (group 2M) with agenesis of two mandibular incisors (mean age = 8 years 6 months, SD = 9 months; Table 1). Group 1M was composed of two subjects with congenital absence of the right central incisor, nine subjects with absence of the right lateral incisor, two subjects with the left central incisor missing, and three subjects with the missing left lateral incisor. Group 2M was composed of five

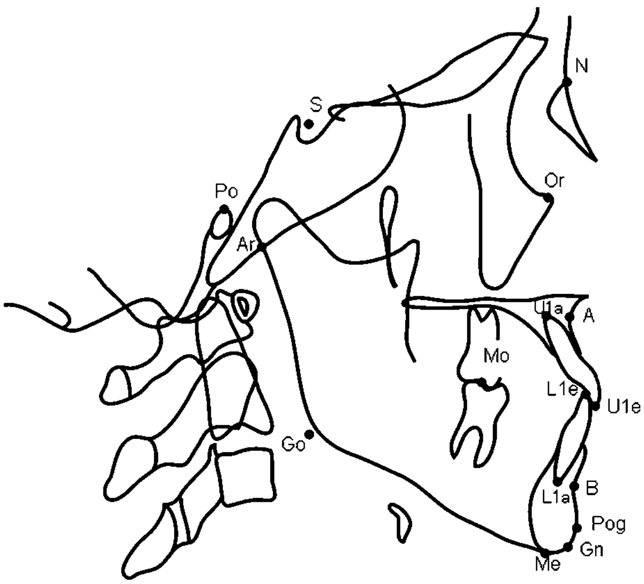

Figure 1. Reference points used for craniofacial morphology analysis.

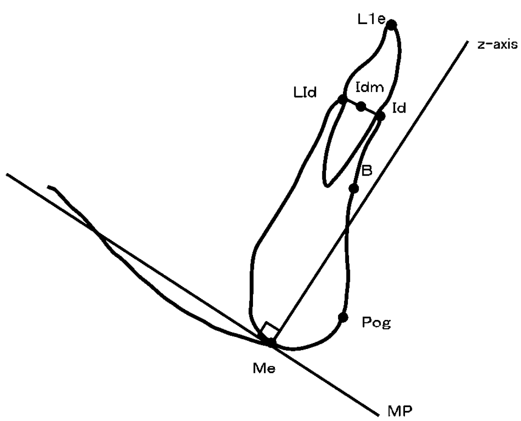

Figure 2. Reference points and lines used for mandibular symphysis morphology analysis.

subjects with two congenitally missing central incisors and six subjects with two congenitally missing lateral incisors.

Cephalometric Analysis

Lateral cephalograms for the subjects were assessed by a single investigator. All these cephalograms were taken with the same cephalostat and with standardized settings. Nineteen reference points were marked, and two reference lines were manually drawn on tracing paper (Figures 1 and 2). All the points and lines except for Id, LId, Idm, U1a, L1a, and the z-axis were described previously.[12,14] The definitions of these measurements were as follows: Id indicates infradentale; LId, lingual infradentale; Idm, a midpoint of Id and LId; U1a, upper incisor root apex; L1a, lower incisor root apex; and z-axis, a line perpendicular to the mandibular plane through menton.

Table 2. Definitions of Measurements Used

Measurement	Definition
MeIdm-MP (°)	Inclination of mandibular symphysis relative to MP
MeB-MP (°)	Inclination of basal bone relative to MP
BId-MP (°)	Inclination of alveolar bone relative to MP
Id-B-Me (°)	Inclination of alveolar bone relative to basal bone
B-z (mm)	Distance from B to the z-axis
Id-z (mm)	Distance from Id to the x-axis
L1e-z (mm)	Distance from L1e to the z-axis
B-MP (mm)	Distance from B to MP
Id-MP (mm)	Distance from Id to MP
L1e-MP (mm)	Distance from L1e to MP
Pog-th (mm)	Symphyseal thickness at Pog
B-th (mm)	Symphyseal thickness at B
BB (mm^2)	Basal bone cross-sectional area (area outlined by mandibular symphysis surface and line parallel to MP through B)
AB (mm^2)	Alveolar bone cross-sectional area (area outlined by mandibular symphysis surface, line parallel to MP through B, and line between Id and LId)
MS (mm^2)	Mandibular symphysis cross-sectional area (area outlined by mandibular symphysis surface and line between Id and LId)

Craniofacial morphology for each subject was evaluated using a computer system including a WinCeph analysis software program (Rise Corp, Japan). Thirteen angular measurements, the definitions of which were described previously,[12,14] were selected for quantitative cephalometric evaluation of craniofacial morphology. For each cephalometric evaluation of mandibular symphysis morphology, four angular and eight linear measurements were made with digital calipers and a protractor, and three area measurements were made with a computer system including a Scion Image software program (Scion Corp, Frederick, Md; Table 2). The linear, angular, and area measurements were estimated to the nearest 0.1 mm, 0.5°, and 0.1 mm^2, respectively.

Statistical Analysis

Statistical analyses were performed with the software Stat Mate III (ATMS, Japan). Descriptive statistics were calculated for each measurement of each hypodontia group and the control group. The one-way analysis of variance was used to determine whether significant differences in each measurement existed among the groups. If significant differences were confirmed, the Tukey multiple comparison test was used to identify where there were significant differences between various groups. The level of significance for the Tukey test was set at $P < .05$. Of 13 measurements

Table 3. Craniofacial Morphology

Measurement	Group 1M	Group 2M	Group M	Group C	Significance
FH-Npog, °	83.7 ± 3.9	85.7 ± 4.2	84.5 ± 4.1	83.0 ± 2.9	
N-A-Pog, °	171.8 ± 6.6	171.5 ± 7.5	171.7 ± 6.8	169.0 ± 3.7	
MP-FH, °	32.3 ± 4.2	29.9 ± 5.8	31.3 ± 5.0	33.2 ± 5.0	
y-axis-FH, °	64.1 ± 3.4	62.6 ± 4.3	63.5 ± 3.8	64.6 ± 3.7	
S-N-A, °	81.8 ± 4.1	81.0 ± 4.1	81.4 ± 4.1	81.3 ± 2.6	
S-N-B, °	78.2 ± 4.3	77.3 ± 3.7	77.9 ± 4.1	76.2 ± 2.2	
A-N-B, °	3.5 ± 3.4	3.7 ± 3.5	3.6 ± 3.4	5.0 ± 1.4	
MP-RP, °	129.2 ± 5.9	127.4 ± 6.8	128.4 ± 6.2	128.7 ± 6.4	
RP-FH, °	83.1 ± 5.7	82.5 ± 7.1	82.9 ± 6.2	84.5 ± 6.0	
OP-FH, °	13.5 ± 3.5	13.2 ± 4.1	13.3 ± 3.7	15.2 ± 3.1	
L1-MP, °	85.7 ± 6.4	92.6 ± 8.3	88.5 ± 7.9	93.3 ± 6.9	1M<C
U1-SN, °	103.8 ± 5.6	103.5 ± 9.0	103.7 ± 7.5	103.6 ± 6.4	
U1-L1, °	132.5 ± 9.9	125.0 ± 14.9	129.5 ± 12.5	123.2 ± 10.5	

Table 4. Mandibular Symphysis Morphology

Measurement	Group 1M	Group 2M	Group M	Group C	Significance
MeIdm-MP, °	82.3 ± 4.8	81.1 ± 6.1	82.1 ± 5.6	85.7 ± 5.0	
MeB-MP, °	90.9 ± 4.7	91.1 ± 7.6	91.0 ± 5.9	92.4 ± 6.5	
BId-MP, °	82.6 ± 6.7	84.1 ± 5.3	83.2 ± 6.1	90.3 ± 6.7	1M < C, M < C
Id-B-Me, °	171.7 ± 4.7	172.0 ± 6.6	172.4 ± 5.5	178.1 ± 9.3	1M < C, M < C
B-z, mm	0.0 ± 1.7	0.1 ± 2.6	0.0 ± 2.0	0.6 ± 2.4	
Id-z, mm	−1.1 ± 2.4	−0.6 ± 3.0	−0.9 ± 2.6	0.6 ± 2.6	
L1e-z, mm	−5.0 ± 3.5	−3.1 ± 4.6	−4.2 ± 4.0	−2.0 ± 3.5	
B-MP, mm	20.7 ± 2.0	20.2 ± 2.1	20.5 ± 2.0	21.0 ± 2.3	
Id-MP, mm	29.7 ± 3.5	28.6 ± 3.4	29.3 ± 3.4	30.5 ± 3.5	
L1e-MP, mm	40.8 ± 3.5	39.3 ± 3.1	40.2 ± 3.4	41.5 ± 3.3	
Pog-th, mm	13.2 ± 1.3	12.8 ± 1.3	13.0 ± 1.3	13.7 ± 1.1	
B-th, mm	8.6 ± 0.7	8.5 ± 1.2	8.6 ± 0.9	9.0 ± 1.2	
BB, mm^2	223.8 ± 33.9	215.5 ± 36.5	220.4 ± 34.5	238.3 ± 27.7	
AB, mm^2	94.4 ± 21.1	83.6 ± 17.7	90.0 ± 20.2	107.8 ± 20.2	2M < C, M < C
MS, mm^2	318.2 ± 41.9	298.5 ± 49.5	310.2 ± 45.3	346.2 ± 37.4	2M < C, M < C

for craniofacial morphology, the L1-MP angle alone showed a statistically significant difference between groups 1M and C. Therefore, Pearson's product–moment correlation analysis was used to assess the relationships between the L1-MP angle and the measurements of mandibular symphysis morphology.

Measurement Error

Measurements of 15 randomly selected lateral cephalograms were made by the same investigator 1 month after the first measurements, and the means of each measurement were used to evaluate measurements errors. Student's *t*-test with a 95% confidence interval did not reveal any systematic measurement errors. Measurement errors, which were assessed with the Dahlberg formula,[27] were found to be less than 0.4 mm for linear measurements, less than 0.5° for angular measurements, and less than 1.3 mm^2 for area measurements.

RESULTS

Craniofacial Morphology

The L1-MP angle was significantly smaller in group 1M than in group C (Table 3).

Mandibular Symphysis Morphology

The BId-MP and Id-B-Me angles were significantly smaller in groups 1M and M than in group C. The AB and MS areas were significantly smaller in groups 2M and M than in group C (Table 4).

Correlation Analysis

The L1-MP angle had significantly positive correlations with the MeIdm-MP, MeB-MP, and BId-MP angles and the B-z, Id-z, and L1e-z dimensions in every hypodontia group. Moreover, the L1-MP angle had significantly positive correlations with the Id-B-Me angle in group 1M; the Pog-th dimension; the BB, AB, and

Table 5. Correlation Analysis[a]

Measurement	L1-MP Group 1M	L1-MP Group 2M	L1-MP Group M
MeIdm-MP, °	0.797***	0.797**	0.698***
MeB-MP, °	0.673**	0.727*	0.638***
BId-MP, °	0.869***	0.864***	0.805***
Id-B-Me, °	0.525*	NS	NS
B-z, mm	0.730**	0.760**	0.686***
Id-z, mm	0.839***	0.854***	0.803***
L1e-z, mm	0.912***	0.846**	0.869***
B-MP, mm	NS	NS	NS
Id-MP, mm	NS	NS	NS
L1e-MP, mm	NS	NS	NS
Pog-th, mm	NS	0.836**	NS
B-th, mm	NS	0.941***	0.509**
BB, mm²	NS	0.647*	NS
AB, mm²	NS	0.671*	NS
MS, mm²	NS	0.717*	NS

[a] NS indicates not significant.
* $P < .05$; ** $P < .01$; *** $P < .001$.

MS areas in group 2M; and the B-th dimension in groups 2M and M (Table 5).

DISCUSSION

It has been reported that mandibular symphysis morphology was changed with mandibular growth and orthodontic treatment.[23,24,26] A clear understanding of mandibular symphysis growth and morphology is very useful for orthodontic diagnosis and treatment planning. The most commonly congenitally missing teeth are the maxillary lateral incisors in Caucasian populations[2,4,9,10] and the mandibular incisors in Japanese populations.[8,11] In Japanese orthodontic patients, the congenital absence of mandibular incisors may be one of the chief factors affecting mandibular symphysis growth and morphology.

The most striking finding of craniofacial morphology in this study was the significantly greater retroclination of the mandibular incisors in group 1M as compared with group C. Similar findings have been reported by other researchers investigating individuals with severe hypodontia,[12,15,16] and with anterior and/or posterior hypodontia.[14] The mandibular incisor retroclination found in our study may have been due to a disturbance in a tongue-lip pressure balance and a lack of lingual support as a consequence of mandibular incisor agenesis. A greater retroclination of the mandibular incisors in group 1M than in group 2M may have been caused by a different amount of space created by mandibular incisor agenesis. It could be speculated that a larger amount of space at the mandibular incisor segment was created in group 2M than in group 1M so that a greater tongue pressure was brought on the remaining mandibular incisors in group 2M, allowing the mandibular incisors in group 2M to be less retroclined than those in group 1M.

The significantly great retroclination of the alveolar bone found in groups 1M and M support the finding by Buschang et al[23] that the growth of alveolar bone is associated with continuous eruption of the dentition. Presumably, the conspicuous alveolar bone retroclination may have been due to the retroclination of the mandibular incisors, which was confirmed by significantly positive correlations of the L1-MP angle with the BId-MP angle and the B-z and Id-z dimensions. Sarnas and Rune[16] also reported both the retroclination of the mandibular incisors and symphysis in individuals with severe hypodontia.

Almost all previous studies have used the traditional angular and linear measurements to determine the influence of hypodontia on craniofacial morphology.[12–22] In the present study, we made an extensive investigation of the possible influences of the congenital absence of mandibular incisors on the mandibular symphysis morphology using area measurements in addition to traditional measurements. The mandibular symphysis area was significantly smaller in groups 2M and M than in group C, although neither mandibular symphysis height nor thickness showed any significant differences between the groups. These results supported the previous finding that area measurements of partial skeletal structure were useful for identifying the effects of hypodontia.[19] The significantly small alveolar bone area was responsible for the small mandibular symphysis area in groups 2M and M, which was in agreement with the fact that continuous growth of alveolar bone could be related to tooth eruption.[23]

Homeobox genes MSX 1, MSX 2, PAX 9, and TGFA are known to play a critical role in regulating tooth and craniofacial morphogenesis. Vastardis et al[28] and Lidral and Reising[29] reported that selective agenesis of the second premolars and third molars was caused by Arg31Pro and Met61Lys mutations in the MSX 1, respectively. Based on these pieces of evidence of the different mutations, it may be said that there are some genetic factors related to mandibular incisor agenesis in the Japanese populations. It has been reported that MSX 1 is associated with some craniofacial abnormalities and tooth agenesis in mice and humans.[30,31] This finding may support our results that deviations of craniofacial and mandibular symphysis morphology, in addition to mandibular incisor agenesis, occurred in every hypodontia group. A mutation in PAX 9 is also associated with autosomal dominant oligodontia, which involves the normal primary dentition and the lack of most of the permanent molars.[32] It has been shown that TGFA and the MSX 1 and PAX 9 interaction play a role in human tooth agenesis.[33] The genetic heterogeneity for hypodontia might be responsible for the variability of craniofacial and mandibular symphysis morphology associated with mandibular incisor agenesis.

CONCLUSIONS

- A significantly greater retroclination of mandibular incisors was found in group 1M than in group C.
- Groups 1M and M showed a significantly greater retroclination of the mandibular alveolar bone than group C.
- Groups 2M and M exhibited a significantly smaller mandibular symphysis area than group C.

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