Journal of Dental Sciences 17 (2022) 928–934

Available online at www.sciencedirect.com

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Original Article

Relationship between craniofacial morphology and congenitally missing mandibular incisors

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Received 7 December 2021; Final revision received 9 December 2021
Available online 17 February 2022

KEYWORDS
Congenital missing;
Craniofacial morphology;
3-Incisor;
2-Incisor;
Mandibular incisor

Abstract *Background/purpose:* Treatment of incisors' agenesis is challenging that arouses orthodontists' interests. The purpose of this study was to compare the craniofacial pattern of individuals with or without congenitally missing mandibular incisors.
Materials and methods: This retrospective study included patients receiving orthodontic consultation between 1999 and 2019 at the Orthodontic Division of the Dental Department of Taipei Medical University Hospital. Cephalometric measurements were obtained through manual tracing and by using computer software. A total of 31 measurements were obtained to evaluate skeletal, dental and soft tissues, and chin morphology. A multivariate analysis of covariance, analysis of covariance, and Scheffé's post hoc tests were used to analyze the differences among a group of patients with one congenitally missing mandibular incisor (M1), a group of patients with two congenitally missing mandibular incisors (M2), and the control group. Student's t-test was used to analyze the differences between the M1 or M2 group and the control group. Significance was set at $P < 0.05$.
Results: Significant differences were observed between the M and control groups in terms of lower incisor angulation and facial balance. Regarding chin morphology, significant differences were noted between the M and control groups and also among the M1, M2, and control groups.
Conclusion: The lower incisors of the M group are more retroclined than those of the control group, resulting in retrusive lower lips. Facial balance varies between the M and control groups. Congenitally missing mandibular incisors affect chin morphology, making the chin button prominent.

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https://doi.org/10.1016/j.jds.2021.12.009
1991-7902/

Introduction

The most common congenitally missing tooth is the mandibular second premolar, followed by maxillary lateral incisor, maxillary second premolar, and mandibular incisors.[1] Mandibular incisor agenesis is uncommon, and the treatment of incisors' agenesis is challenging for orthodontists. Several orthodontists have reported cases of congenitally missing mandibular incisors. Howard J. Buchner treated 2 patients with 3 lower incisors through the extraction of the ipsilateral maxillary lateral incisor, which resulted in acceptable occlusion and outcomes.[2] Extraction of 2 maxillary first premolars is often considered a treatment option in cases of class II division 1 malocclusion,[3] bimaxillary protrusion,[4] and maxillary dentition crowding.[4,5] Newman substituted lateral incisors with canines and canines with first premolars in patients with 2 congenitally missing mandibular incisors,[6] whereas Nagaveni and Umashankara suggested a removable partial denture for their patients.[7] Prakash and Hallur used composite interim restoration,[8] and Kagitha and Namineni used lingual arch—supported acrylic prosthesis.[9] Although various treatment modalities have been proposed, careful calculation of the Bolton ratio and efficient model setup are required for excellent arch coordination.[10,11] Huang and Yang indicated that the extraction of the mandibular premolar from the nonmissing tooth side does not affect the Bolton index as much as the extraction of one central incisor.[10]

Orthodontists have noted that congenitally missing teeth influence craniofacial morphology.[12—17] Sarnäs and Rune reported an increased retrognathic maxilla and decreased sagittal jaw relationship angle in children with hypodontia.[15] Moreover, Costa and Trevizan suggested that tooth agenesis is associated with a small ANB angle.[14] Chung and Hobson[17] and Acharya and Jones[18] suggested that patients with hypodontia tend to have a class III relationship. By contrast, Kreczi and Proff concluded that tooth agenesis might negatively influence sagittal jaw development.[19] Yüksel and Uçem noted that tooth agenesis negligibly influenced the dentofacial structure.[20] Tavajohi-Kermani and Kapur[21] noted little correlation between tooth agenesis and changes in cephalometric measurements. Endo and Ozoe focused on mandibular symphysis morphology in a study consisting of 27 Japanese girls aged 8 years.[22] The results revealed retroclination of the mandibular incisors and alveolar bone and a reduced mandibular alveolar bone area. Hence, these correlations should be considered during orthodontic treatment planning.

Studies on the skeletal, dental, and facial patterns of patients with congenitally missing teeth have been conducted in Sweden,[15] Denmark,[16] Turkey,[20] the United States,[21] Israel,[12] Japan,[22] the United Kingdom,[18] Germany,[19] Greece,[13] and Brazil.[14] These studies used diverse measurement methodologies and sample sizes to produce different outcomes. Some studies have revealed that the prevalence of congenitally missing mandibular incisors is higher in Chinese and Japanese populations than in other ethnic groups.[23—25]

Hence, we conducted a study with a large sample size and considered patients with 1 or 2 congenitally missing mandibular incisors. An in-depth understanding of craniofacial morphology enables orthodontists to efficiently treat their patients. We established 2 hypotheses: the null hypothesis (H_0), that no difference in the craniofacial patterns exists between individuals with and without congenitally missing mandibular incisors, and the alternative hypothesis (H_1), that no significant difference in the craniofacial patterns exists between individuals with and without congenitally missing mandibular incisors.

Materials and methods

Samples and exclusion criteria

Ethical approval for this study was obtained from the Institutional Review Board of Taipei Medical University (TMU-JIRB No: N202004152). This retrospective study enrolled patients who received orthodontic consultation between 1999 and 2019 at the Orthodontic Division of the Dental Department at Taipei Medical University Hospital. Patients with one or two congenitally missing mandibular incisors were recruited to the experimental group and categorized into the M1 (one congenitally missing mandibular incisor) and M2 (two congenitally missing mandibular incisors) groups. The control group comprised orthodontic patients selected through systemic sampling method with an orthodontic serial number that was a multiple of 5. This study required the complete panoramic and lateral cephalometric radiographic records of all participants.

The inclusion criteria were as follows: (1) no other congenitally missing teeth, except mandibular incisor, in the experimental group; (2) no congenitally missing teeth in the control group, except for wisdom teeth; and (3) permanent dentition.

The exclusion criteria were as follows: (1) history of facial trauma and facial surgery; (2) cleft lip and palate; (3) previous orthodontic treatment; (4) systemic disease associated with congenitally missing teeth; (5) incomplete orthodontic records; and (6) nonpermanent dentition.

Cephalometric tracing and measurements

All cephalometric films were manually traced by two experienced orthodontists. A third orthodontist was consulted in case of disagreement regarding the placement of cephalometric landmarks. A consensus was reached before the hand-traced films were fed into Hiroshima University cephalometric software, which was used for all linear and angular measurements. Craniofacial morphology measurements were divided into the following 3 categories: skeletal pattern, dental and soft tissue measurements, and chin morphology.

The skeletal pattern category consisted of 9 measurements: SNA, SNB, ANB, SND, Frankfort mandibular angle (FMA), GoGn—SN, and distances from the A point, B point, and pogonion to the N perpendicular (A—Nv, B—Nv, and Pog—Nv, respectively). The dental and soft tissue category consisted of 13 measurements: U1—SN, U1—NA, incisor mandibular plane angle (IMPA), L1—NB, U1—L1, overbite, overjet, nasolabial angle, upper lip to E-line distance, lower lip to E-line distance, labio-mental angle, Z angle, and Frankfort mandibular incisor angle (FMIA).

Regarding chin morphology, we defined several specific landmarks for further measurements (Fig. 1). Five linear measurements were included, namely distances from the B point, $L1_b$, and $L1_i$ to the mandibular plane (MP) and distance from the B point and pogonion to $L1_{axis}$. Furthermore, 4 angular measurements were included, namely the angles between lines Me—$L1_m$ and MP, Me—B and MP, and $L1_b$—B and MP, and the $L1_b$—B—Me angle.

To ensure the reliability of cephalometric tracing and measurements, test—retest reliability was determined. A month after the measurements of the 160 patients were obtained, 10 samples were selected randomly for manual retracing and further measurement, and the above-mentioned procedures were repeated. Intraclass correlation coefficients (ICCs) were used to evaluate the intrarater agreement.

Statistical analysis

Analysis of variance and Pearson chi-square tests were used to determine the differences among the M1, M2, and control groups in terms of mean age and sex, respectively. Moreover, a *t* test and chi-square test were used to determine differences between the M (M1 and M2) and control groups. The interactions of age and sex with the groups (M1, M2, and control groups) were observed.

A multivariate analysis of covariance (MANCOVA) was performed on craniofacial morphology, skeletal pattern, dental and soft tissue measurements, and chin morphology. An analysis of covariance (ANCOVA) with Scheffé's post hoc test was used to compare 31 variables between the 3 groups (M1, M2, and control groups) with control for age and sex. The *t* test was performed to compare the M and control groups. All analyses were performed using SPSS (version 25, IBM SPSS Statistics, Chicago, IL, USA). Significance was set at $P < 0.05$.

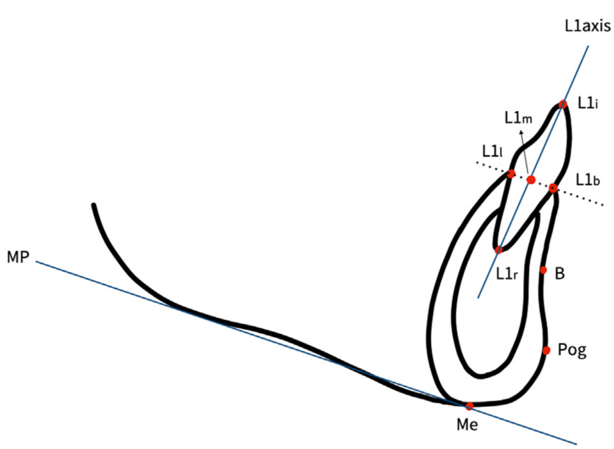

Fig. 1 Landmarks and reference lines used for chin morphology measurements. $L1_i$: incisal edge of measured mandibular incisor. $L1_r$: root tip of measured mandibular incisor. $L1_b$: buccal alveolar bone level of measured mandibular incisor. $L1_l$: lingual alveolar bone level of measured mandibular incisor. $L1_m$: intersection point of $L1_{axis}$ and the line between $L1_l$ and $L1_b$. $L1_{axis}$: line between $L1_i$ and $L1_r$. MP: line between the menton (Me) and gonion (Go).

Results

This study consisted of 160 patients, with 48 in the M1 group, 32 in the M2 group, and 80 in the control group. Table 1 presents detailed demographic information of the patients. A power analysis was performed to calculate the sample size. With alpha error = 0.05, number of groups = 3, and power >0.8, the sample size should be > 21 (e.g., SNA). The sample size (n = 160) of this study was adequate. The reliability of the cephalometric tracing and measurements was high, with all ICC values > 0.8. No statistically significant differences in mean age or sex were observed among the M1, M2, and control groups or between the M and control groups. Shapiro—Wilk normality tests were conducted, and the assumption was met. For example, for SNA, the *P* values of the M1, M2, and control groups were *0.574*, *0.500*, and *0.437*, respectively.

The overall craniofacial morphology of the M1, M2, and control groups was significantly different (MANCOVA; $P < 0.001$). No significant difference was observed in the skeletal pattern (MANCOVA; $P = 0.785$). However, significant differences in chin morphology were observed among the 3 groups (MANCOVA; $P < 0.001$). Tables 2 and 3 present the skeletal pattern and dental and soft tissue measurements. The skeletal pattern measurements indicate no significant differences among the M1, M2, and control groups or between the M and control groups. Therefore, 1 or 2 congenitally missing mandibular incisors had no apparent effect on the anteroposterior position of the maxillary and mandibular bones according to the SNA, SNB, SND, A—Nv, B—Nv, and Pog—Nv results. The intermaxillary relationship in the anteroposterior direction and vertical divergence of the mandible were not influenced by ANB, FMA, or GoGn—SN.

Regarding the dental and soft tissue measurements, the ANCOVA revealed a significant difference among the M1, M2, and control groups in the distance from the lower lip to the E-line and Z angle. Paired comparisons revealed a significant difference between the M2 and control groups, indicating that 2 congenitally missing mandibular incisors affect the lower lip in the anteroposterior direction and facial balance. Significant differences in IMPA, L1—NB, U1—L1, the distance from the lower lip to the E-line, Z angle, and FMIA were observed between the M and control groups.

Tables 4 and 5 present the chin morphology measurements. Significant differences were observed among the M1, M2, and control groups in terms of B—MP (mm), $L1_b$—MP (mm), $L1_i$—MP (mm), and $L1_b$B—MP. Paired comparisons revealed significant differences between the M1 and

Table 1 Demographic information of the included individuals.

	M1	M2	Control	*P*-value[1]	M (M1+M2)	Control	*P*-value[2]
Age, mean ± SD	20.3 ± 8.8	18.1 ± 5.9	20.1 ± 4.7	*0.252*	19.4 ± 7.8	20.1 ± 4.7	*0.541*
Sex, N(%)							
Female	28 (58.3%)	24 (75%)	50 (62.5%)	*0.299*	52 (65%)	50 (62.5%)	*0.869*
Male	20 (41.7%)	8 (25%)	30 (37.5%)		28 (35%)	30 (37.5%)	
Total	48 (100%)	32 (100%)	80 (100%)		80 (100%)	80 (100%)	

M1 group: Patients with one congenitally missing mandibular incisor; M2 group: Patients with two congenitally missing mandibular incisors; Control group: Patients without congenitally missing teeth except the wisdom teeth.
Differences in mean age and sex among the three groups (M1, M2, and control) determined using ANOVA and Pearson chi-square tests, respectively, are presented in the column of *P* value.[1] Differences between the M (M1+M2) group and control group determined using *t* and chi-square tests are presented in the column of *P* value[2].

Table 2 Results of skeletal pattern, dental and soft tissue measurements (M1, M2 and Control groups).

	M1	M2	Control	*P*-value
Skeletal Pattern				*0.637*[#]
SNA	82.97 ± 4.26	83.69 ± 3.67	83.87 ± 3.73	*0.336*
SNB	79.47 ± 4.37	79.38 ± 4.33	79.66 ± 4.34	*0.918*
ANB	3.50 ± 3.18	4.31 ± 2.41	4.21 ± 2.76	*0.367*
SND	76.70 ± 4.23	76.81 ± 4.34	76.51 ± 5.39	*0.813*
FMA	27.34 ± 6.60	26.33 ± 4.36	26.65 ± 6.26	*0.611*
GoGn–SN	33.39 ± 6.79	33.08 ± 4.93	32.83 ± 6.36	*0.774*
A–Nv	0.15 ± 4.43	0.65 ± 3.89	1.35 ± 3.47	*0.205*
B–Nv	1.08 ± 7.53	−0.16 ± 7.10	−0.01 ± 8.25	*0.750*
Pog–Nv	0.81 ± 8.19	−0.43 ± 7.51	0.19 ± 9.00	*0.886*
Dental and soft tissue measurements				*0.003*[#]
U1–SN	107.54 ± 8.62	107.95 ± 10.25	109.54 ± 9.25	*0.404*
U1–N	24.57 ± 7.66	24.27 ± 9.48	25.67 ± 8.35	*0.678*
IMPA	91.39 ± 9.47	90.91 ± 6.69	94.02 ± 8.58	*0.125*
L1–NB	26.36 ± 6.86	25.20 ± 5.17	28.05 ± 6.33	*0.075*
U1–L1	125.57 ± 12.59	126.22 ± 11.04	122.21 ± 11.21	*0.163*
OB	1.92 ± 1.86	0.94 ± 2.77	1.89 ± 1.81	*0.085*
OJ	3.87 ± 4.09	5.33 ± 3.40	3.95 ± 2.72	*0.109*
NLA	88.35 ± 10.86	86.22 ± 11.44	88.06 ± 7.01	*0.571*
E-line(U)	0.35 ± 3.33	0.29 ± 2.56	1.11 ± 2.45	*0.167*
E-line(L)	2.09 ± 2.90[ab]	1.12 ± 2.69[a]	2.76 ± 2.43[b]	*0.009*
LMA	129.72 ± 15.59	125.70 ± 11.98	130.90 ± 11.94	*0.192*
Z angle	110.18 ± 9.12[ab]	108.00 ± 8.35[a]	112.26 ± 8.26[b]	*0.045*
FMIA	61.26 ± 7.82	62.76 ± 6.98	59.31 ± 8.16	*0.080*

M1 group: Patients with one congenitally missing mandibular incisor; M2 group: Patients with two congenitally missing mandibular incisors; Control group: Patients without congenitally missing teeth except the wisdom teeth.
Comparisons in measurements among the three groups (M1, M2 and control) were determined using the MANCOVA[#] and ANCOVA tests.
[a-b] Different letters in the same row indicated significant differences in paired comparisons using Scheffé post-hoc tests.
Significant difference was set at $P < 0.05$.

control groups in terms of B–MP (mm), $L1_b$–MP (mm), and $L1_i$–MP (mm) and between the M2 and control groups in terms of $L1_bB$–MP. Significant differences were observed between the M and control groups in terms of B–MP (mm), $L1_b$–MP (mm), $MeL1_m$–MP, $L1_bB$–MP, and $L1_b$–B–Me. Large values for B–MP (mm), $L1_b$–MP (mm), and $L1_i$–MP (mm) represented increased vertical length in the M1 group, with the MP line as a reference. Fig. 2 presents a schematic of the chin morphology measurements with significant differences. Fig. 3 displays the differences in chin morphology among the 3 groups.

Discussion

Studies on the relationship between tooth agenesis or hypodontia and craniofacial morphology have yielded inconsistent outcomes. To eliminate bias, we only enrolled patients with 1 or 2 congenitally missing mandibular incisors in the experimental group rather than patients with all types of dental agenesis. Although Endo and Ozoe reported the mandibular symphysis morphology of patients with congenitally missing mandibular incisors, their sample was small (n = 27) and comprised 8-year-old patients with

Table 3 Results of Skeletal Pattern, Dental, and Soft Tissue Measurements (M and Control group).

	M (M1+M2)	Control	*P*-value
Skeletal Pattern			
SNA	83.26 ± 4.02	83.87 ± 3.73	*0.318*
SNB	79.43 ± 4.33	79.66 ± 4.34	*0.742*
ANB	3.82 ± 2.90	4.21 ± 2.76	*0.387*
SND	76.74 ± 4.25	76.51 ± 5.39	*0.757*
FMA	26.94 ± 5.80	26.65 ± 6.26	*0.759*
GoGn—SN	33.27 ± 6.08	32.83 ± 6.36	*0.654*
A—Nv	0.35 ± 4.20	1.35 ± 3.47	*0.102*
B—Nv	0.59 ± 7.34	−0.01 ± 8.25	*0.632*
Pog—Nv	0.31 ± 7.90	0.19 ± 9.00	*0.928*
Dental and soft tissue measurements			
U1—SN	107.70 ± 9.25	109.54 ± 9.25	*0.211*
U1—NA	24.45 ± 8.38	25.67 ± 8.35	*0.357*
IMPA	91.20 ± 8.42	94.02 ± 8.58	*0.038*
L1—NB	25.90 ± 6.23	28.05 ± 6.33	*0.031*
U1—L1	125.83 ± 11.92	122.21 ± 11.21	*0.050*
OB	1.53 ± 2.30	1.89 ± 1.81	*0.279*
OJ	4.45 ± 3.87	3.95 ± 2.72	*0.337*
NLA	87.50 ± 11.07	88.06 ± 7.01	*0.704*
E-line(U)	0.33 ± 3.03	1.11 ± 2.45	*0.073*
E-line(L)	1.70 ± 2.84	2.76 ± 2.43	*0.012*
LMA	128.11 ± 14.31	130.90 ± 11.94	*0.183*
Z angle	109.31 ± 8.83	112.26 ± 8.26	*0.031*
FMIA	61.86 ± 7.49	59.31 ± 8.16	*0.041*

M1 group: Patients with one congenitally missing mandibular incisor; M2 group: Patients with two congenitally missing mandibular incisors; Control group: Patients without congenitally missing teeth except the wisdom teeth.
Comparisons in measurements between the M (M1+M2) and control groups were determined using *t*-tests. Significant difference was set at $P < 0.05$.

mixed dentition.[22] By contrast, our study enrolled 160 patients with permanent dentition.

Regarding the skeletal pattern, no statistically significant difference was noted between the groups. Costa and Trevizan,[14] Chung and Hobson,[17,20] and Acharya and Jones[18] suggested that tooth agenesis is associated with a small ANB angle and class III relationship. Our results revealed a small ANB angle, small A—Nv distance, and large B—Nv and Pog—Nv distances in the mean values of the measurements, albeit without significant differences, are associated with tooth agenesis. Therefore, congenitally missing mandibular incisors barely affect the anteroposterior position of the maxillary and mandibular bones and intermaxillary relationship; these findings are concordant with those of the study by Yüksel and Uçem.[20]

Regarding dental measurements, the lowest mean IMPA and L1—NB values were observed in the M2 group, followed by the M1 and control groups, although no statistically significant difference was observed. A significant difference was observed between the M and control groups. Endo and Ozoe reported a retroclined lower incisor in patients with congenitally missing mandibular incisors.[22] This compensatory phenomenon might be attributable to the presence of more space in the lower anterior area. Therefore, this aspect should be considered during diagnosis and treatment planning. With retroclined mandibular incisors and spacing, extraction of other teeth in the mandibular dentition is not recommended in the absence of crowding. Hence, creating space for further rehabilitation might be a superior alternative. However, careful diagnosis and treatment planning are required for each case.

The first observation of soft tissue is crucial in the analysis. The M1 and M2 groups exhibited significant differences in the distance from the lower lip to the E-line compared with that of the control group. This observation indicates that a congenitally missing mandibular incisor affects facial esthetics, particularly that of the lower part of the face. Accordingly, retroclined lower incisors result in a slightly retrusive lower lip. A comparison of the M and control groups revealed that facial balance is influenced by significant differences in the Z angle and FMIA. Therefore, orthodontists should not neglect soft tissue during treatment planning because such differences are visible to the untrained eye and can directly influence patient satisfaction.

Table 4 Results of Chin Morphology Measurements (M1, M2 and control group).

	M1	M2	Control	P-value
Chin morphology				$< 0.001^{\#}$
B—MP (mm)	21.45 ± 2.70[a]	20.70 ± 3.23[ab]	19.62 ± 1.65[b]	< 0.001
$L1_b$—MP (mm)	34.20 ± 4.09[a]	32.96 ± 5.08[ab]	31.98 ± 2.71[b]	*0.003*
$L1_i$—MP (mm)	43.04 ± 4.64[a]	41.27 ± 6.07[ab]	41.00 ± 3.13[b]	*0.038*
B—$L1_{axis}$ (mm)	3.36 ± 0.80	3.35 ± 0.77	3.23 ± 0.59	*0.487*
Pog—$L1_{axis}$ (mm)	9.68 ± 2.16	9.96 ± 1.93	9.38 ± 1.75	*0.185*
Me$L1_m$—MP	79.36 ± 8.34	78.28 ± 5.22	81.26 ± 6.59	*0.072*
MeB—MP	81.82 ± 6.50	79.80 ± 5.88	81.82 ± 6.92	*0.272*
$L1_b$B—MP	87.69 ± 8.45[ab]	86.64 ± 6.16[a]	90.83 ± 7.37[b]	*0.012*
$L1_b$—B—Me	173.01 ± 4.67	172.51 ± 4.81	170.94 ± 5.48	*0.068*

M1 group: Patients with one congenitally missing mandibular incisor; M2 group: Patients with two congenitally missing mandibular incisors; Control group: Patients without congenitally missing teeth except the wisdom teeth.
Comparisons in measurements among the three groups (M1, M2 and control) were determined using the MANCOVA# and ANCOVA tests.
[a-b] Different letters in the same row indicated significant differences in paired comparisons using Scheffé post-hoc tests.
Significant difference was set at $P < 0.05$.

Table 5 Results of Chin Morphology Measurements (M and control group).

	M (M1+M2)	Control	*P*-value
B–MP (mm)	21.15 ± 2.93	19.62 ± 1.65	*< 0.001*
$L1_b$–MP (mm)	33.71 ± 4.52	31.98 ± 2.71	*0.004*
$L1_i$–MP (mm)	42.33 ± 5.29	41.00 ± 3.13	*0.054*
B–$L1_{axis}$ (mm)	3.35 ± 0.78	3.23 ± 0.59	*0.272*
Pog–$L1_{axis}$ (mm)	9.79 ± 2.06	9.38 ± 1.75	*0.178*
$MeL1_m$–MP	78.93 ± 7.24	81.26 ± 6.59	*0.035*
MeB–MP	81.01 ± 6.30	81.82 ± 6.92	*0.440*
$L1_bB$–MP	87.27 ± 7.59	90.83 ± 7.37	*0.003*
$L1_b$–B–Me	172.81 ± 4.70	170.94 ± 5.48	*0.022*

M1 group: Patients with one congenitally missing mandibular incisor; M2 group: Patients with two congenitally missing mandibular incisors; Control group: Patients without congenitally missing teeth except the wisdom teeth.
Comparisons in measurements between the M (M1+M2) and control groups were determined using *t* tests. Significant difference was set at $P < 0.05$.

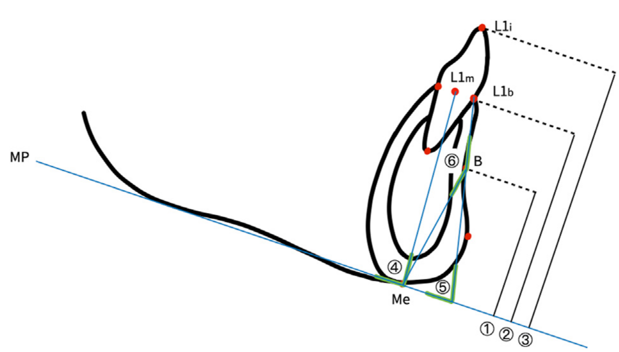

Fig. 2 Schematic of Chin Morphology Measurements with Significant Differences in Paired Comparisons. ① B–MP (mm): significant differences were noted between the M1 and control groups and between the M and control groups. ② L1b–MP (mm): significant differences were noted between the M1 and control groups and between the M and control groups. ③ L1i–MP (mm): significant difference was noted between the M1 and control groups. ④ MeL1m–MP: significant difference was observed between the M and control groups. ⑤ L1bB–MP: significant differences were noted between the M2 and control groups and between the M and control groups. ⑥ L1b–B–Me: a significant difference was noted between the M and control groups.

Regarding chin morphology, the distances from the B point, $L1_b$, and $L1_i$ to the MP were larger in the M1 group than in the control group, indicating elongated mandibular incisors and mandibular symphysis. The M2 group had a smaller $L1_bB$–MP length than did the control group, resulting in increased retroclined mandibular symphysis and anterior position of the chin. Although no significant difference was revealed by the pairwise comparison of the M1 and M2 groups, these findings imply that 1 and 2 congenitally missing mandibular incisors might have different effects on chin morphology. We suspect that the etiologies of 1 and 2 congenitally missing mandibular incisors differ, resulting in different chin morphology.

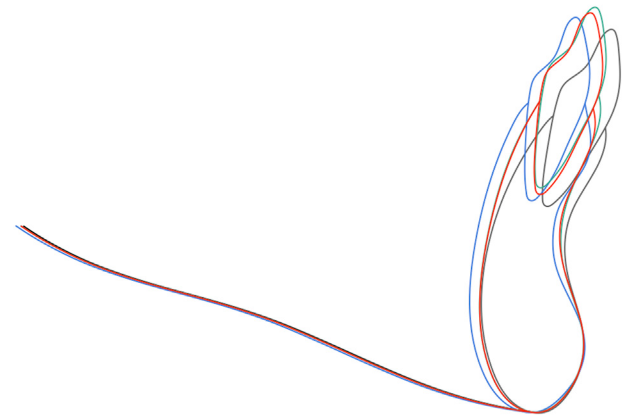

Fig. 3 Schematic of chin morphology on the basis of the mean value of measurements. The blue line represents the M2 group; the red line represents the M group; the green line represents the M1 group, and the black line represents the control group. Superimposed on the MP and Me.

The smaller the $MeL1_m$–MP and $L1_bB$–MP angles, the more anterior the lower chin position. A large $L1_b$–B–Me angle might be associated with the increased anterior position of $L1_b$ or Me because the position of the B point was proven to be unaffected in terms of the skeletal measurements (SNB and B–Nv). Significant differences in the $MeL1_m$–MP, $L1_bB$–MP, and $L1_b$–B–Me angles were observed between the M and control groups. This finding indicates that such patients exhibit a prominent chin button.

In this 20-year retrospective study, we used 2-dimensional images to evaluate skeletal patterns, dental and soft tissue measurements, and chin morphology. Dental compensation, lower incisor angulation, and facial balance were affected by the congenital agenesis of mandibular incisors. Differences in chin morphology were observed between the control and M groups and among the M1, M2, and control groups. Chin morphology might differ because neural crest cells lead to odontogenesis and skeletogenesis in the facial region. Another hypothesis is that the absence of tooth buds would be correlated with the underdevelopment of the apical base according to Moss's functional matrix concept.[12]

Because we used 2-dimensional images, we could not obtain information related to corpus thickness, transverse width, or its radian. Therefore, research with 3-dimensional images, which are already common in dental clinics, could offer more information regarding this aspect. Hence, our subsequent study will involve 3-dimensional images with complete data and dental records.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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