

Relationship between the lingual frenulum and craniofacial morphology in adults

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Introduction: The purpose of this study was to determine the relationship between the length of the lingual frenulum and craniofacial morphology and test the hypothesis that skeletal Class III malocclusion is related to tongue-tie, in which the lingual frenulum is short and restricts the mobility of the tongue. **Methods:** The sample consisted of 50 skeletal Class I patients ($0^\circ < \text{ANB angle} < 4^\circ$), 50 skeletal Class II patients ($\text{ANB angle} > 4^\circ$), and 50 skeletal Class III patients ($\text{ANB angle} < 0^\circ$). Direct and indirect measuring methods were used to quantify the length of the lingual frenulum. The median lingual frenulum length was measured directly with a lingual frenulum ruler. It was evaluated indirectly by measuring the differences between the maximum mouth opening with and without the tip of the tongue touching the incisive papilla. A lateral cephalogram was taken for each subject and a computerized cephalometric analysis was used to assess the cranial morphology. Analysis of variance (ANOVA) was used to compare the differences among the 3 groups. The Pearson correlation analysis was used to detect any relationship between the lingual frenulum length and cephalometric variables. **Results:** The median lingual frenulum length was significantly longer in the skeletal Class III subjects compared with the skeletal Class I and Class II subjects. The maximum opening of the mouth was significantly reduced in the skeletal Class III subjects compared with Class I and Class II subjects. Significant correlations were also found among the median lingual frenulum length, maximum mouth opening reduction, and the cephalometric variables such as the SNB and ANB angles, Wits appraisal, mandibular length, and the interincisal angle. **Conclusions:** The present study supports the hypothesis that skeletal Class III malocclusion is related to long median lingual frenulum or a tongue-tie tendency. Patients diagnosed with tongue-tie might have a tendency toward skeletal Class III malocclusion. (Am J Orthod Dentofacial Orthop 2011;139:e361-e367)

The relationship between tongue posture and skeletal structures of the face is an essential element in understanding the growth and development of craniofacial structures, the etiology of malocclusions, and the prediction of stability after orthodontic treatment.

While it has been suggested that the mandible grows to a genetically predetermined size and shape, it also appears that a range of physiologic, pathologic, and mechanical factors can influence this growth.^{1,2} Proffit² suggested that the teeth and alveolus lie in a balanced position between the cheeks, lips, and tongue; however, research has shown that the tongue is more powerful. Proffit and Mason³ have suggested that the tongue posture could be more influential than its action.

Many studies have evaluated the interaction between the position of the tongue and malocclusion.³⁻⁸ Tuerk and Lubit⁴ suggested that restriction of the free upward and backward movement of the tongue may result in an exaggerated tongue thrusting against the anterior body of the mandible, producing malocclusions such as anterior open bite and mandibular prognathism. Whitman and Rankow⁵ suggested that nearly all Class III patients have genioglossus muscle fibers that are too short or are positioned abnormally low. Hopkin⁷ studied the tongue posture and found that the tongue position is highest in Class II, lowest in Class III, and intermediate in Class I malocclusions.

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Ankyloglossia is a developmental anomaly of the tongue characterized by a short vertical lingual frenulum length (Fig 1, A), which may result in a varying degree of decreased tongue tip mobility. The clinical consequences of ankyloglossia include infant breastfeeding difficulties, speech disorders, various mechanical and social issues related to the inability of the tongue movement, and orthodontic anomalies.⁸⁻¹⁰ Sometimes low tongue posture may cause a forward and downward pressure to the mandible with different consequences on face development.¹¹

Several clinical reports suggested that ankyloglossia may produce anterior open bite and mandibular protrusion malocclusions because of tongue posture.^{4,5,8} However, current literature regarding the lingual frenulum and tongue posture is scarce and has generally focused on the influence of the lingual frenulum in relation to dentoalveolar anomalies.⁴⁻⁶ The relationship between the lingual frenulum and craniofacial morphology has not been investigated. The purpose of this study was to determine if there is a relationship between the median lingual frenulum length and the craniofacial morphology. We hypothesize that the skeletal Class III malocclusion is related to the median lingual frenulum length and restricted mouth opening.

MATERIAL AND METHODS

Patient sample

The sample was collected from the patients who were enrolled for orthodontic treatment at the Department of Orthodontics, Gangneung-Wonju National University Dental Hospital, Gangneung, South Korea. The selection criteria were as follows: no history of (1) previous lingual frenectomy, (2) previous orthodontic treatment, (3) previous orthognathic surgery, or (4) disorders of the temporomandibular joint and jaw-muscle. Based on the ANB angle, patients were classified as skeletal Class I ($0^\circ < \text{ANB} < 4^\circ$), skeletal Class II (ANB angle $> 4^\circ$), and skeletal Class III (ANB angle $< 0^\circ$) groups and each group has 50 patients. The distributions of age and ANB angle in different groups for all subjects are shown in Table 1.

Length of the median lingual frenulum

The measurements of the lingual frenulum were made by measuring the median lingual frenulum length using a lingual frenulum ruler (Dong-A Pharmaceutical Co., Ltd., Seoul, Korea) according to the procedures proposed by Lee et al⁶ (Fig 1). The patient was instructed to put the tip of his or her tongue on the incisive papilla, and open the mouth to the maximum gap. The median lingual frenulum length was measured as the isthmus of

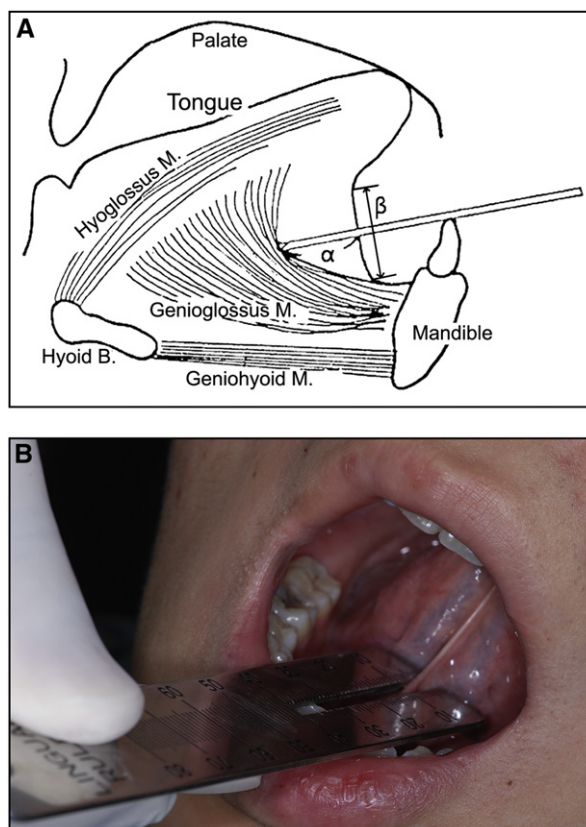


Fig 1. A, Measuring the median lingual frenulum length. α indicates the median lingual frenulum length and β indicates the vertical lingual frenulum length. **B,** Measuring method according to Lee et al.⁶

the ruler was fully inserted and the other side of the ruler was touched on the lower anterior teeth (Fig 1). This measurement represented the maximum lingual frenulum length in the middle of the tongue-tie. To reduce the measurement error by hand pressure to the lingual frenulum, the length was recorded as the ruler was touched on the soft tissue as lightly as possible; the average value of triplicate measurements was also recorded.

Maximum mouth opening reduction

The amount of maximum mouth opening reduction was measured by using a digital caliper (Digimatic, Mitutoyo, Tokyo, Japan) with a resolution of 0.01 mm, a nominal capacity of 150 mm, as previously described by Marchesan.¹² First, the patient was requested to open his or her mouth as widely as possible and the caliper was positioned so that its extremities were in contact with the incisal margins of the maxillary central incisor and the mandibular homolateral central incisor.

Table I. Mean and standard deviation of ages and ANB angle for each group

Groups	Gender	n	Age (years)		ANB angle (degree)	
			Mean	SD	Mean	SD
Class I	Male	22	25.7	5.7	2.3	1.1
	Female	28	23.3	5.5	2.2	1.1
	Total	50	24.4	5.7	2.2	1.1
Class II	Male	21	25.1	6.5	5.1	1.3
	Female	29	23.9	7.9	6.2	1.6
	Total	50	24.4	7.3	6.0	1.5
Class III	Male	28	25.0	5.1	-2.4	2.8
	Female	22	27.1	8.9	-1.9	2.0
	Total	50	25.9	7.0	-2.2	2.4

The patient was then requested to put the tip of his or her tongue on the incisive papilla maintaining it on that point and to open the mouth again to the maximum gap. The support points for the digital caliper were the same. The reduced amount of maximum mouth opening was then calculated by the difference of the 2 measurements.

Cephalometric analysis

The lateral cephalograms were taken in habitual occlusion with the CX-90SP (Asahi Roentgen Ind. Co., Ltd., Japan) by using a standardized technique and fixed anode-midsagittal plane distance. No correction was made for the constant linear enlargement of 10%. The lateral cephalograms of each subject were traced on acetate paper by 1 examiner (S.J.J.) in order to minimize interexaminer error. Computer-assisted cephalometric analysis was carried out by means of a Numonics digitizer (Quick Ceph Systems, San Diego, Calif) and of Quick Ceph Image Pro software, version 4.4 (Quick Ceph Systems, San Diego, Calif). Table II shows the angular and linear measurements used in this study.

Method errors

The reliability of the measurements of the lingual frenulum was determined on 20 randomly selected adults not included in this study. These adults were examined at intervals of 14 days, by using the same method as in the present investigation. Testing for the method error of all measurements was done with Dahlberg's formula¹³ (method error = $\sqrt{\sum d^2/2n}$ where *d* is the difference between 2 measurements of a pair, and *n* is the number of subjects). The method error of the measurements of the median lingual frenulum length and maximum mouth opening reduction was found to be 0.57 mm and 1.66 mm, respectively.

The reliability of the cephalometric measurements was assessed by the same examiner duplicating tracings

Table II. Cephalometric variables

Variables
Sagittal measurements
SNA angle (°)
SNB angle (°)
ANB angle (°)
Wits appraisal (mm)
Maxillary length (Co-A) (mm)
Mandibular length (Co-Pog) (mm)
Mandibular body length (Go-Me) (mm)
Point A to nasion perpendicular to FH plane (A-N perp) (mm)
Pogonion to nasion perpendicular to FH plane (Pog-N perp) (mm)
APDI
Vertical measurements
Mandibular plane angle (FH/MP) (°)
Occlusal plane angle (SN/OcclPI) (°)
Palatal plane angle (FH/PP) (°)
Gonial angle (Ar-Go-Me) (°)
Posterior facial height (S-Go) (mm)
Anterior facial height (N-Me) (mm)
Facial height ratio (S-Go/N-Me)
ODI
Dental measurements
Upper incisor inclination (U1/FH) (°)
Lower incisor inclination (IMPA) (°)
Edge of lower incisor to NB line distance (L1-NB) (mm)
Interincisal angle (°)

FH plane, Frankfort horizontal plane; *APDI*, mathematical sum of the facial angle (N-Pog/Po-Or), the A-B plane angle (A-B/N-Pog), and the palatal plane angle (ANS-PNS/Po-Or); *ODI*, mathematical sum of the A-B plane to the mandibular plane angle (A-B/Go-Me) and the palatal plane angle (ANS-PNS/Po-Or).

on 20 randomly chosen cephalograms at intervals of 14 days. The method errors calculated with Dahlberg's formula¹³ ranged from 0.17 to 0.94 mm for linear measurements and from 0.53° to 1.27° for the angular measurements.

Statistical analysis

The statistical analyses were carried out with the statistical software (SPSS for Windows, version 14.0, SPSS Inc, Chicago, Ill). The gender differences in each of 3 skeletal groups were tested by using the independent samples *t* test. The median lingual frenulum length and maximum mouth opening reduction of skeletal Class I, II, and III were compared through analysis of variance (ANOVA) and Scheffe test. Pearson correlation analysis was used to detect any relationship among the median lingual frenulum length, maximum mouth opening reduction, and cephalometric variables.

RESULTS

According to the independent samples *t* test, no difference related to gender was found for the median

Table III. Mean and standard deviation for sex differences in each of the 3 skeletal groups

Variables	Skeletal Class I					Skeletal Class II					Skeletal Class III				
	Males (n = 22)		Females (n = 28)		t test	Males (n = 21)		Females (n = 29)		t test	Males (n = 28)		Females (n = 22)		t test
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
MLFL	4.0	2.8	2.7	2.1	NS	3.0	2.6	3.1	2.7	NS	5.5	3.0	4.1	2.8	NS
MMOR	16.8	8.2	14.4	6.0	NS	18.3	9.4	15.2	8.1	NS	22.9	8.6	20.5	7.6	NS

MLFL, median lingual frenulum length; MMOR, maximum mouth opening reduction; NS, not significant.

Table IV. Comparison of the mean values of the median lingual frenulum length in 3 skeletal groups by analysis of variance and Scheffé test

Variables	Skeletal Class I (n = 50)		Skeletal Class II (n = 50)		Skeletal Class III (n = 50)		Scheffe test		
	Mean	SD	Mean	SD	Mean	SD	I-II	II-III	I-III
MLFL	3.3	2.5	3.1	2.6	4.9	3.0		†	*
MMOR	15.3	7.3	16.5	8.7	22.2	9.2		†	†

MLFL, median lingual frenulum length; MMOR, maximum mouth opening reduction.

* $P < 0.05$; † $P < 0.01$.

lingual frenulum length and maximum mouth opening reduction among the 3 skeletal groups (Table III). Therefore, data for both genders in each group were combined.

Descriptive statistics and statistical comparisons of the median lingual frenulum length and the measurements of maximum mouth opening reduction in 3 groups are shown in Table IV. The mean median lingual frenulum lengths were 3.3 ± 2.5 mm in skeletal Class I group, 3.1 ± 2.6 mm in skeletal Class II group, and 4.9 ± 3.0 mm in skeletal Class III group. The median lingual frenulum length was significantly longer in the skeletal Class III subjects compared with skeletal Class I ($P < 0.05$) and II ($P < 0.01$) subjects (Table IV). In addition, the amount of maximum mouth opening was significantly reduced in the skeletal Class III subjects compared with the skeletal Class I and Class II subjects ($P < 0.01$) (Table IV). The amount of maximum mouth opening reduction was increased significantly with an increasing median lingual frenulum length ($r = 0.436$, $P < 0.001$) (Table V).

The results from the Pearson correlation analysis among the median lingual frenulum length, maximum mouth opening reduction, and cephalometric variables are shown in Table V. The median lingual frenulum length and maximum mouth opening reduction had a significant positive correlation with the SNB angle, mandibular length, and interincisal angle, and a significant negative correlation with the ANB angle and Wits appraisal. With APDI (the mathematical sum of the facial angle [N-Pog/Po-Or], the A-B plane angle [A-B/N-Pog],

and the palatal plane angle [ANS-PNS/Po-Or]) and edge of lower incisor-to-NB line distance (L1-NB), the median lingual frenulum length showed a significant correlation.

DISCUSSION

For more than a century, many theories have attempted to explain the etiology of malocclusion. Most have stated that it is genetically inherited,^{14,15} but more recently, greater emphasis has been placed on the influence of the environment, especially the activity and the posture of the oral soft tissues.^{1,11,20} The functional matrix hypothesis put forward by Moss and Rankow¹⁶ suggested that the soft tissue units guide the hard tissue to an extent that renders skeletal genes superfluous. Intrinsic genetic factors play only an initial role in determining size, shape, and growth of a bone; extrinsic functional or environmental factors become the predominant determiner of bone formation. Since the environment is constantly changing, bones never attain a final morphology and their shape is changing continuously.¹¹ Mew¹⁷ suggested that "In the short term, posture adapts to form while, in the longer term, there is a reciprocal response by bone to changes in posture."

Ankyloglossia or tongue-tie is manifested by an abnormal attachment of the lingual frenulum connecting the mobile tongue and the floor of the mouth. The pharyngeal musculature can maximize some etiologic trends toward the forward push of the tongue in this low posture of ankylosed tongue, thus leading to growth of the mandible in a more prognathic manner.¹⁸ Horton et al⁸

Table V. Pearson correlation analysis among the median lingual frenulum length, maximum mouth opening reduction, and other variables

Variables	Median lingual frenulum length		Maximum mouth opening reduction	
	Correlation (r)	P value	Correlation (r)	P value
Maximum mouth opening reduction	0.436	0.000 [†]		
SNB angle	0.196	0.016*	0.214	0.008 [†]
ANB angle	-0.218	0.007 [†]	-0.255	0.002 [†]
Wits appraisal	-0.176	0.031*	-0.217	0.008 [†]
Mandibular length (Co-Pog)	0.196	0.016*	0.348	0.000 [†]
APDI	0.174	0.034*	0.151	0.064
Edge of lower incisor to NB line distance (L1-NB)	-0.218	0.007 [†]	-0.100	0.221
Interincisal angle	0.260	0.001 [†]	0.175	0.032*

APDI, mathematical sum of the facial angle (N-Pog/Po-Or), the A-B plane angle (A-B/N-Pog), and the palatal plane angle (ANS-PNS/Po-Or).
* $P < 0.05$; [†] $P < 0.01$.

stated that any limitations of the free upward motion of the tongue that cause a forward tongue-thrusting may result in excessive growth of the anterior portion of the mandible. An example of this is noted in cases of congenital micrognathia treated by the Douglas operation,¹⁹ where surgical ankyloglossia is produced to protect these micrognathic infants from asphyxia by tongue swallowing. This in turn produces a marked increase in growth of the anterior portion of the mandible.

Despite these clinical opinions, few objective data support the theory of a causal relationship between the shortened vertical lingual frenulum and skeletal dysplasia. This might be because the tongue is completely a soft tissue structure with no fixed landmarks. Thus, impressionistic judgments rather than quantitative data continue to dominate descriptions of lingual morphology.⁹ To overcome such a problem, Lee et al⁶ measured the median lingual frenulum length with a lingual frenulum ruler to determine the abnormal tongue posture of ankyloglossia. Fletcher and Meldrum⁹ described a procedure for the measurement of the lingual frenulum in relation to the dimensions of the anterior and inferior segments of the tongue. For indirect measurement of the length of the lingual frenulum, Ruffoli et al²⁰ measured the length of the lingual frenulum and the interincisal distance in maximum opening of the mouth and with the tip of the tongue touching the palatal papilla.

In this study we used 2 different methods to quantify the length of the lingual frenulum. The first measured the length of the lingual frenulum directly by recording the median lingual frenulum length with a lingual frenulum ruler. This method has been shown to be accurate and reproducible in clinical dentistry. In the second method, an indirect evaluation of the length of the lingual frenulum was performed by measuring the maximum mouth opening with and without the tip of the tongue touching

the incisive papilla. The measurements of the reduced amount of maximum mouth opening were used to eliminate bias that could originate from the difference in absolute value of maximum mouth opening from individual variation of mandibular function.^{21,22} The reduction in the amount of maximum mouth opening was found to increase significantly with the increase in median lingual frenulum length (Table V). Marchesan¹² suggested that comparing the values measured with the full mouth opening and the values found when the mouth is open with the tongue leaning on the incisive papilla could be a viable indicator that a lingual frenulum is altered.

The present study investigates the relationship between the median lingual frenulum length and craniofacial morphology to test the hypothesis that skeletal Class III malocclusion may be related to the long median lingual frenulum length. Our results suggest that the greater the tongue-tie tendency, the more tendency toward a skeletal Class III malocclusion. This is the first study to report on the relationship between the length of the lingual frenulum and craniofacial morphology, and these results are in accordance with other clinical reports that suggested a relationship between ankyloglossia and mandibular prognathism.⁴⁻⁷

Several studies showed that mandibular displacement is the primary process and that condylar growth is secondary and adaptive.²³⁻²⁶ Petrovic²⁷ described the cybernetic model of mandibular growth and explained that anteroinferior growth of the maxilla functionally shifts the mandible, making the temporomandibular joint (TMJ) adjust to the new mandibular position, which leads to mandibular remodeling or growth. In the presence of a narrow or flattened palate as a consequence of restricted maxillary development, the upper portion of the lingual volume is diminished. Fränkel and Fränkel²⁸ suggested that this spatial

inadequacy tends to force the tongue to alter its postural position inferiorly, which in turn may influence mandibular alveolar growth unfavorably.

Finally, there is a wide range of opinion about the diagnosis and treatment of ankyloglossia. Orthodontic appliances—such as tongue pearl²⁹ and tongue elevator,³⁰ myofunctional therapy,³ and frenectomy—¹⁰ have been used to correct tongue position. The vertical lingual frenulum length is frequently short in the newborn, and as the infant grows, the tongue becomes longer and thinner at the tip, often decreasing the severity of tongue-tie.^{21,31} The tongue, following the neural growth curve, reaches its full size approximately at the age of 8 years.³ The mandible, in contrast, undergoes a growth spurt concurrently with the prepubertal growth spurt.^{3,32} Until the mandible reaches its full size, therefore, it may contain a low positioned tongue, resulting in mandibular prognathism. Therefore, the presence of early mandibular prognathism and the desire to prevent its development constitute a valid indication for the surgical correction of any significantly prominent degree of tongue-tie.³³

The relative influence of genetics and environmental factors in the etiology of malocclusion has been a matter for discussion, debate, and controversy in the orthodontic literature. The results of this study revealed only the association between the Class III malocclusion and median lingual frenulum length. While the phenotype is inevitably the result of both genetic and environmental factors, further study is needed to clarify the cause and effect.

To further clarify the role of the lingual frenulum, especially its relationship with mandibular prognathism in skeletal Class III anomalies, future research is recommended to focus on long-term changes of craniofacial morphology with or without frenectomy in growing patients. Clarification of the relationship between the lingual frenulum and craniofacial morphology could permit a better rationale for the treatment of Class III malocclusions relevant to ankyloglossia.

CONCLUSIONS

This study investigated the relationship between the length of the lingual frenulum and craniofacial morphology,

1. No gender difference was found between the median lingual frenulum length and the reduced amount of maximum mouth opening.
2. Reduction in the amount of maximum mouth opening was correlated with the longer median lingual frenulum length.
3. Subjects with Class III skeletal malocclusion were found to have significantly longer median lingual

frenulum lengths and more maximum mouth opening reduction compared with Class I and Class II subjects. Those with tongue-tie tended to have skeletal Class III malocclusion.

4. Correlations were also found between the median lingual frenulum length, maximum mouth opening reduction, and sagittal components of craniofacial morphology such as SNB and ANB angles, Wits appraisal, and mandibular length.

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