

Structural and functional impact of lingual frenulum alterations on oral and craniofacial development in children during the mixed dentition stage

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Abstract

Background The clinical relevance of ankyloglossia in children remains controversial, largely due to the absence of standardized diagnostic criteria and the predominant reliance on morphological assessment. Evidence linking the combined anatomical and functional characteristics of the lingual frenulum to objective functional outcomes during mixed dentition remains limited. Therefore, this study aimed to evaluate the association between lingual frenulum characteristics and oral and craniofacial functional outcomes in children during the mixed dentition period.

Methods In this cross-sectional study, 170 children aged 7–12 years were evaluated. Anatomical and functional characteristics of the lingual frenulum were assessed using the Marchesan Lingual Frenulum Protocol. Orofacial functions, including breathing pattern, mentalis muscle activity, and swallowing, were examined using selected components of the Orofacial Myofunctional Evaluation with Scores (OMES/OMES-E). Upper airway patency was evaluated using the Mallampati and Brodsky classifications, malocclusion was assessed clinically, and postural alignment was analyzed using the New York Posture Scale. Intergroup comparisons were performed ($p < 0.05$). Multivariate logistic regression analyses were conducted to identify independent predictors of swallowing dysfunction.

Results Maximum mouth opening did not differ significantly between groups ($p = 0.137$). However, reduced tongue range of motion ($\leq 50\%$) was significantly more frequent in children with an altered frenulum ($p < 0.001$). No significant differences were observed in respiratory pattern, mentalis muscle activity, Mallampati or Brodsky scores ($p > 0.05$). Swallowing-related dysfunction, involving lip ($p = 0.012$) and tongue ($p = 0.002$) behavioral alterations, as well as malocclusion ($p = 0.010$), were significantly more prevalent in the altered frenulum group. Regression analyses demonstrated that altered frenulum independently predicted tongue-related swallowing dysfunction ($OR = 2.513$, $p = 0.015$), whereas breathing disturbance showed the strongest independent predictor ($OR = 5.249$, $p < 0.001$).

Conclusion Lingual frenulum morphology was associated with reduced tongue mobility and domain-specific functional impairments, particularly in swallowing. These findings support the integration of functional evaluation alongside structural assessment in the clinical management of ankyloglossia.

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Introduction

Normal craniofacial growth and development is predicated on a synchronized interplay between structural, neuromuscular and functional components of the orofacial complex [1]. In this context, the stomatognathic system represents a highly integrated neuromuscular functional unit responsible for essential activities such as breathing, swallowing and speech, and plays a fundamental role in the regulation of orofacial development [2, 3]. From a developmental and neurofunctional perspective, the oral cavity, pharynx, and larynx constitute an integrated functional continuum, reflecting their shared embryological origin and interconnected neural control. Disruptions within this continuum may extend beyond localized dysfunction, potentially compromising upper airway patency and global postural alignment through myofascial compensations [1].

As a key regulator of tongue posture and mobility, the lingual frenulum is a three-dimensional, dynamic structure essential for stabilizing the tongue during oral functions [4, 5]. Ankyloglossia, representing the restrictive end of the morphological spectrum, is a congenital condition that limits this functional range [6, 7]. Restricted lingual mobility has been associated with several clinical outcomes, including malocclusion, atypical swallowing and altered respiratory patterns, with some effects persisting into adolescence [8, 9]. However, the extent to which morphological variations of the lingual frenulum are associated with clinically meaningful functional impairment, particularly during the mixed dentition period, remains unclear. Existing evidence is heterogeneous and findings across functional domains remain inconsistent [10, 11].

Despite its clinical relevance, the diagnosis of ankyloglossia remains challenging and heterogeneous, largely due to the focus on isolated anatomical classifications rather than a comprehensive morpho-functional analysis [6, 12–15]. Previous studies have reported inconsistent findings regarding the relationship between lingual frenulum morphology and functional impairment [10, 11] and although various grading systems exist, none have established a definitive, objective link between the degree of anatomical restriction and specific degrees of functional impairment [16]. This diagnostic ambiguity is particularly relevant in pediatric patients, as timely recognition of functional alterations has been emphasized as important for guiding appropriate management [6].

Although function-oriented assessment approaches have been increasingly adopted in the evaluation of lingual frenulum alterations, few studies have comprehensively investigated the relationship between lingual frenulum characteristics and multiple structural and functional domains within a single cohort [16, 18]. To address this gap, the present study aimed to evaluate the association between lingual frenulum restriction and key orofacial and postural characteristics by examining the stomatognathic system as a unified functional entity during the mixed dentition period. The null hypotheses were that structural alterations of the lingual frenulum would not be associated with reduced tongue range of motion during the mixed dentition period, and that structural alterations of the lingual frenulum would not be associated with swallowing dysfunction during the mixed dentition period. Tongue range of motion and swallowing function were considered the primary outcomes of this study, while other orofacial and postural parameters were evaluated as secondary outcomes.

Materials and methods

Study design

This cross-sectional study was conducted at the Department of Pediatric Dentistry, Istanbul Health and Technology University, between May 2024 and November 2024. Ethical approval was obtained by the Istanbul Health and Technology University Scientific Research and Publication Ethics Committee at its meeting dated 22.01.2024 (Approval No: 2024/02–01). Written informed consent was obtained from parents/legal guardians and verbal assent was obtained from all children.

Participants

Sample size was calculated using G*Power 3.1.9.7 (Franz Faul, Germany). Based on an effect size of $d=0.354$, a 95% confidence interval, and 85% statistical power, the minimum required sample size was determined to be 158. To account for potential data loss and maintain adequate statistical power, a total of 170 children were ultimately included in the study. The study population consisted of healthy, non-syndromic children aged 7–12 years who were cooperative and able to follow instructions. Children with systemic diseases, craniofacial anomalies, a history of orofacial myofunctional therapy or previous frenectomy, as well as those for whom reliable measurements could not be obtained, were excluded. All eligible participants were recruited consecutively. No preferential selection of predefined subgroups was applied, and recruitment was conducted to reflect the characteristics of the target population as broadly as possible.

Clinical and functional assessment

Clinical and functional evaluations were performed using standardized protocols by a single experienced examiner. The lingual frenulum was evaluated according to the protocol developed by Irene Q. Marchesan [18], which includes a structured anamnesis and clinical examination comprising a General Test (assessment of mouth opening and frenulum attachment characteristics) and a Functional Test (assessment of tongue mobility, functional positioning, and speech). In this scoring system, a General Test score ≥ 3 indicates possible structural alteration, whereas a Functional Test score ≥ 20 suggests functional impairment. These predefined cut-off values were adopted without modification for participant classification in the present study.

Tongue range of motion was assessed according to Marchesan's quantitative protocol. The tongue range of motion ratio (TRMR) was calculated as: $\text{TRMR (\%)} = (\text{MOTTIP} / \text{MIO}) \times 100$. For clearer clinical interpretation, results were reported as the percentage reduction obtained by subtracting TRMR from 100 ($100 - \text{TRMR}$), with the higher values indicating greater functional restriction of tongue movement. However, categorical classification was based on the original Marchesan cut-off values rather than the derived percentage reduction, a $\text{TRMR} \leq 50\%$ was used as a descriptive and exploratory threshold to identify an altered lingual frenulum in subgroup analysis [16, 19].

The speech assessment was performed by the principal investigator, a pediatric dentist with certified training in speech and language disorders, to identify speech characteristics relevant to lingual frenulum alterations within routine pediatric dental practice. As the original MLFP includes English-language articulation stimuli, the speech component was linguistically adapted for Turkish using the Ankara Articulation Test [20] as a phonetic and linguistic reference to select corresponding Turkish articulation phonemes. The Ankara Articulation Test was neither administered nor scored as an independent diagnostic instrument. All speech findings were evaluated according to the MLFP scoring criteria.

To enable a comprehensive evaluation of the stomatognathic system, orofacial function was assessed using the Orofacial Myofunctional Evaluation with Scores (OMES) and its expanded version (OMES-E) protocols [21, 22]. Swallowing patterns, breathing patterns and mentalis muscle activity were evaluated and classified according to the standardized clinical definitions within these protocols. The swallowing parameter of the OMES protocol was partially modified to standardize the assessment conditions for lip and tongue behaviors. Swallowing was evaluated using a saliva-swallowing command without food or liquids, thereby minimizing variability associated with bolus consistency and volume. This approach also facilitated a more feasible and consistent application within a pediatric dental clinical setting. The operational definitions were applied as described in the original protocols. Because the present study focused on the qualitative characterization of individual orofacial behavior, each selected parameter was analyzed independently, and no composite score was calculated.

The selected protocol parameters were translated from English into Turkish by a native Turkish speaker fluent in English, which was then back-translated into English by a native English speaker fluent in Turkish. The translated version was subsequently reviewed by two pediatric dentists to verify linguistic accuracy and clinical

relevance. Prior to data collection, the principal examiner underwent a calibration process on a randomly selected group of 20 participants at the Istanbul Health and Technology University Pediatric Dentistry Clinic to standardize the assessment procedures. The calibration process and scoring consistency were subsequently reviewed and verified in collaboration with three experienced clinicians. Formal intra-observer reliability was assessed in 40 participants, who were re-evaluated after a two-week interval under identical conditions.

Dental occlusion was evaluated clinically using Angle's classification with additional assessment of transverse, vertical and sagittal discrepancies. For the primary analysis, malocclusion was recorded as a binary variable (present/absence) with "present" defined as the presence of any abnormalities in at least one of these three dimensions.

Upper airway patency was assessed using the Mallampati classification [23] and tonsillar hypertrophy was graded according to the Brodsky scale [24]. For statistical analyses, Mallampati scores were categorized into class I–II versus class III–IV, and Brodsky tonsil grades were categorized into grades 0–2 versus grades 3–4, consistent with prior pediatric studies employing this classification. These groupings were selected because they represent clinically relevant thresholds of upper airway obstruction and reduce sparse observations across categories, thereby improving the robustness and interpretability of the statistical comparisons [23, 25].

Parental perception of posture was recorded during history-taking for descriptive purposes only and was not included in the statistical analysis. Postural alignment was objectively assessed using the New York Posture Rating Chart [26], focusing on head and neck posture as well as shoulder and trunk alignment based on standardized observational scoring criteria.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Normality and homogeneity of variance were assessed using the Shapiro–Wilk and Levene tests, respectively. Continuous variables were summarized as mean $\pm$ standard deviation or median (min–max), and categorical variables as frequencies and percentages. For normally distributed continuous variables, between-group comparisons were conducted using the Student's *t*-test or one-way ANOVA, while the Mann–Whitney *U* test was applied when parametric assumptions were not met. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. Tongue-mobility sub-items were evaluated and analyzed as binary outcomes (normal vs. altered); intermediate response levels were not modeled separately in order to avoid sparse cells and preserve the stability of the categorical comparisons.

Multivariate logistic regression analysis was performed to assess independent predictors of tongue dysfunction during swallowing. Independent variables for the multivariate regression models were selected a priori based on their clinical relevance, biological plausibility and functional assessment during routine pediatric dental examination rather than a statistical variable selection procedure, in order to construct a parsimonious model while minimizing the risk of overfitting [17, 27]. Odds ratios with 95% confidence intervals and Wald statistics were calculated. In a sensitivity analysis, the model was additionally adjusted for age and sex. Statistical significance was set at $p < 0.05$. Intra-observer reliability was assessed using intraclass correlation coefficients (ICC(A,1)) for continuous variables and Cohen's kappa (κ) or weighted kappa (κ^w) for categorical variables.

Results

Participant characteristics and reliability of measurement

A total of 170 children were included in the study with a mean age of 9.2 ± 1.8 years. The study population consisted of 52.4% girls ($n = 89$) and 47.6% boys ($n = 81$). Intra-observer reliability was excellent across all measurements.

ICC(A,1) values ranged from 0.974 to 0.988. Cohen's kappa values ranged from 0.890 to 0.894 and weighted kappa values from 0.827 to 0.902, indicating very good to excellent agreement.

General and functional MLFP findings and myofunctional assessment

MLFP general test scores ranged from 0 to 8, with a mean score of 3.1 ± 2.1 . Comparisons between children with normal and altered lingual frenulum based on general test scores are presented in Table 1, showing that maximum mouth opening was comparable between groups, whereas mouth opening measured during tongue–incisive papilla contact was significantly reduced in the altered frenulum group ($p < 0.001$). Consistently, intraoral tongue mobility was markedly restricted, with a significantly smaller functional tongue movement area and a higher proportion of children demonstrating tongue movement confined to $\leq 50\%$ of the oral cavity in the altered frenulum group ($p < 0.001$).

Significant differences were also observed in categorical clinical findings related to tongue morphology and frenulum attachment characteristics. Notably, Children with an altered frenulum more frequently demonstrated

Table 1 Comparison of general test parameters between groups classified by MLFP general test scores

Variable	Normal frenulum	Altered frenulum	<i>p</i> -value
A. Demographic characteristics	Mean $\pm$ SD	Mean $\pm$ SD	
Age (year) *	9.3 $\pm$ 1.8 <i>n</i> = 83 (%)	9.0 $\pm$ 1.7 <i>n</i> = 87 (%)	0.419 ^A
Gender			0.867 ^B
Female	44 (53.0%)	45 (51.7%)	
Male	39 (47.0%)	42 (48.3%)	
B. Mouth opening measurements	Mean $\pm$ SD	Mean $\pm$ SD	
Maximum mouth opening*	43.5 $\pm$ 5.3 mm	44.8 $\pm$ 6.0 mm	0.137 ^A
Mouth opening with tongue touching the incisive papilla*	28.0 $\pm$ 6.9 mm	22.6 $\pm$ 6.6 mm	<0.001 ^A
Mean percentage reduction (%) *	35.5 $\pm$ 14.2	49.2 $\pm$ 13.4	<0.001 ^A
C. Categorical clinical findings	<i>n</i> = 83 (%)	<i>n</i> = 87 (%)	
Area used by the tongue during movement within the oral cavity			<0.001 ^B
Tongue movement range within the oral cavity >50%	69 (83.1%)	43 (49.4%)	
Tongue movement range within the oral cavity <50%	14 (16.9%)	44 (50.6%)	
Tongue tip shape			
Rectangular	34 (41.0%)	32 (36.8%)	0.576 ^B
V-shape	10 (12.0%)	33 (37.9%)	<0.001 ^C
Heart-shaped	0 (0.0%)	14 (16.1%)	<0.001 ^C
Frenulum fixation – mouth floor			<0.001 ^C
Visible only from the sublingual caruncles	42 (50.6%)	9 (10.3%)	
Visible from the inferior alveolar crest	41 (49.4%)	78 (89.7%)	
Frenulum fixation – sublingual			<0.001 ^D
In the middle of the tongue	77 (92.8%)	10 (11.5%)	
Down the middle of the tongue	6 (7.2%)	2 (2.3%)	
Between the middle and apex of the tongue	0 (0.0%)	70 (80.5%)	
At the apex	0 (0.0%)	5 (5.7%)	

*Descriptive statistics are presented as mean $\pm$ standard deviation.

^A Student's *t*-test

^B Pearson's χ^2 test

^C continuity-corrected χ^2 test and

^D Fisher–Freeman–Halton test were used. Continuous values are presented as percentage reduction (100 – TRMR). Categorical classification (>50%/≤50%) is based on the original TRMR cut-off according to Marchesan's criteria

V-shaped or heart-shaped tongue configuration and attachment to the inferior alveolar ridge rather than the sublingual caruncle (all $p < 0.001$). Additionally, the position of the frenulum attachment below the midline of the tongue was significantly more prevalent among children with an altered frenulum ($p < 0.001$).

Myofunctional evaluation findings according to the MLFP general test classification are summarized in Table 2. Most myofunctional characteristics were comparable between groups (all $p > 0.05$). In contrast, swallowing-related functional impairments involving both lip and tongue behavior were significantly more frequent in children with an altered lingual frenulum ($p < 0.05$). The prevalence of malocclusion was also significantly higher in this group ($p = 0.010$).

Functional Test scores ranged from 0 to 41, with a mean value of 8.6 ± 8.2 . scores ≥ 20 were classified as indicative of an altered lingual frenulum. Comparisons based on functional test scores are presented in Table 3. Children with an altered lingual frenulum demonstrated significantly higher rates of functional restriction in tongue mobility tasks, abnormal resting tongue posture and speech-related impairments, most commonly involving distortion of the /s/ and /r/ sound.

As summarized in Table 4, most myofunctional evaluation variables did not differ significantly according to the functional test classification between groups ($p > 0.05$). However, children with an altered lingual frenulum exhibited significantly higher frequencies of functional disturbances in lip behavior during swallowing ($p < 0.001$). In contrast to general test classification, no significant association was observed between the functional test classification and malocclusion ($p = 0.557$).

Table 2 Myofunctional assesment according to MLFP general test scores

	Normal frenulum <i>n</i> = 83 (%)	Altered frenulum <i>n</i> = 87 (%)	<i>p</i> -value
Breathing			0.712 ^A
Normal	54 (65.1%)	51 (58.6%)	
Mild dysfunction	28 (33.7%)	35 (40.2%)	
Severe dysfunction	1 (1.2%)	1 (1.1%)	
Mentalis muscle activity			0.070 ^B
Normal	38 (45.8%)	25 (28.7%)	
Mild dysfunction	22 (26.5%)	27 (31.0%)	
Moderate dysfunction	18 (21.7%)	22 (25.3%)	
Severe dysfunction	5 (6.0%)	13 (14.9%)	
Swallowing- Lip Behavior			0.012^A
Normal	54 (65.1%)	36 (41.4%)	
Mild dysfunction	22 (26.5%)	34 (39.1%)	
Moderate dysfunction	6 (7.2%)	13 (14.9%)	
Severe dysfunction	1 (1.2%)	4 (4.6%)	
Swallowing- Tongue Behavior			0.002^A
Normal	60 (72.3%)	44 (50.6%)	
Adaptation/dysfunction	23 (27.7%)	38 (43.7%)	
Excessive protrusion	0 (0.0%)	5 (5.7%)	
Malocclusion	40 (48.2%)	59 (67.8%)	0.010^B
Mallampati Score			0.662 ^B
Class 1 ve 2	57 (68.7%)	57 (65.5%)	
Class 3 ve 4	26 (31.3%)	30 (34.5%)	
Brodsky Score			0.056 ^B
Grade 1 + 2 + 3	54 (65.1%)	44 (50.6%)	
Grade 4 + 5	29 (34.9%)	43 (49.4%)	
Postural Problems	39 (47.0%)	44 (50.6%)	0.640 ^B

^A Fisher–Freeman–Halton test

^B Pearson's χ^2 test

Table 3 Functional assessment outcomes between groups classified by MLFP functional test scores

Variable	Normal frenulum	Altered frenulum	<i>p</i> -value
A. Demographic Characteristics	Mean ± SD	Mean ± SD	
Age (year)*	9.3 ± 1.8 <i>n</i> = 144 (%)	8.5 ± 1.5 <i>n</i> = 26 (%)	0.029^A
Gender			0.962 ^B
Female	76 (52.8%)	13 (50.0%)	
Male	68 (47.2%)	13 (50.0%)	
B. Tongue Functions			
Tongue mobility			
Sucking against palate	29 (20.1%)	14 (53.8%)	<0.001^B
Apex vibration	26 (18.1%)	8 (30.8%)	0.220 ^B
Protruding	35 (24.3%)	13 (50.0%)	0.015^B
Touch the upper lip with the apex	27 (18.8%)	12 (46.2%)	0.005^B
Touch right/left commissura labiorum	20 (13.9%)	7 (26.9%)	0.140 ^C
Tongue position during rest			0.021^D
Not visible: assessment is not possible	101 (70.1%) ^a	11 (42.3%) ^a	
Between the teeth/lateral	33 (22.9%) ^b	12 (46.2%) ^b	
On the floor of the mouth	10 (6.9%)	3 (11.5%)	
Speech problem	32 (22.2%)	26 (100.0%)	<0.001^B

*Data are presented as mean ± standart deviation (SD)

^A Student's *t* test

^B Continuity-corrected χ^2 test

^C Fisher's exact test

^D Pearson's χ^2 test

Functional findings according to tongue range of motion

Comparisons based on tongue movement area are presented in Table 5. Children with a tongue range of motion ratio of $\leq 50\%$ showed a significantly higher frequency of altered lingual frenulum according to the general test score ($p < 0.001$). While the distribution of breathing dysfunction severity did not differ significantly between groups ($p = 0.153$), swallowing-related functional impairments involving both lip and tongue behavior were significantly more severe in children with a tongue range of motion ratio of $\leq 50\%$ ($p < 0.001$ and $p = 0.011$, respectively). These findings were observed in parallel with differences identified by the structural assessment.

Multivariate logistic regression analysis

Multivariate logistic regression analysis is presented in Table 6. In model 1, dysfunction in mentalis muscle activity and the presence of an altered lingual frenulum based on morphology were identified as significant predictors of tongue dysfunction during swallowing. After additional adjustment for breathing pattern, age, and sex (Model 2), breathing dysfunction emerged as the strongest independent predictor, increasing the likelihood of tongue dysfunction during swallowing by 5.2-fold (95% CI: 2.379–11.620; $p < 0.001$), while morphologically altered lingual frenulum increased the risk by 2.5-fold after adjustment for other variables (95% CI: 1.199–5.266; $p = 0.015$).

Table 4 Myofunctional evaluation outcomes according to the MLFP functional test score

Variable	Normal frenulum (<i>n</i> = 144)	Altered frenulum (<i>n</i> = 26)	<i>p</i> -value
Breathing			0.061 ^A
Normal	94 (65.3%)	11 (42.3%)	
Mild dysfunction	48 (33.3%)	15 (57.7%)	
Severe dysfunction	2 (1.4%)	0 (0.0%)	
Mentalis muscle activity			0.204 ^B
Normal	57 (39.6%)	6 (23.1%)	
Mild dysfunction	42 (29.2%)	7 (26.9%)	
Moderate dysfunction	30 (20.8%)	10 (38.5%)	
Severe dysfunction	15 (10.4%)	3 (11.5%)	
Swallowing- lip behavior			<0.001 ^A
Normal	81 (56.3%)	9 (34.6%)	
Mild dysfunction	49 (34.0%)	7 (26.9%)	
Moderate dysfunction	13 (9.0%)	6 (23.1%)	
Severe dysfunction	1 (0.7%)	4 (15.4%)	
Swallowing- tongue behavior			0.079 ^A
Normal	92 (63.9%)	12 (46.2%)	
Adaptation/dysfunction	49 (34.0%)	12 (46.2%)	
Excessive protrusion	3 (2.1%)	2 (7.7%)	
Malocclusion	82 (56.9%)	17 (65.4%)	0.557 ^C
Mallampati score			>0.999 ^C
Class 1–2	97 (67.4%)	17 (65.4%)	
Class 3–4	47 (32.6%)	9 (34.6%)	
Brotsky score			0.833 ^C
Grade 0-1-2	84 (58.3%)	14 (53.8%)	
Grade 3–4	60 (41.7%)	12 (46.2%)	
Postural problems	70 (48.6%)	13 (50.0%)	>0.999 ^C

*Descriptive statistics are presented as median (minimum–maximum)

^A Fisher–Freeman–Halton test

^B Pearson's χ^2 test

^C continuity-corrected χ^2 test

Discussion

The present study demonstrated that an altered lingual frenulum was significantly associated with reduced tongue range of motion and swallowing dysfunction. In contrast, no significant associations were observed between lingual frenulum alterations and upper airway findings or postural alignment. The general and functional assessment components of MLFP yielded complementary findings, suggesting that structural and functional evaluation capture different dimensions of lingual frenulum alterations. These relationships were evaluated during the mixed dentition period, a development stage marked by neuromuscular maturation and ongoing functional adaptation [28, 29], making it particularly suitable for investigating morpho-functional interactions of the stomatognathic system.

These findings should be interpreted within the complexity of lingual frenulum assessment in children. Anatomical variability and functional adaptation may influence clinical presentation [30], meaning that anatomical restriction does not necessarily result in overt functional impairment, whereas subtle anatomical variations may still have clinical relevance [6, 31–33]. Taken together, the present findings highlight the value of a multidimensional morpho-functional assessment strategy that integrates structural and functional evaluation with complementary myofunctional assessments of breathing, swallowing, perioral muscle activity and posture.

Maximum mouth opening (MMO) has been reported as a clinical parameter in the assessment of mandibular function and did not differ between children with normal and altered lingual frenulum in the present study,

Table 5 Altered frenulum and myofunctional findings based on TRMR across general and functional scores

Variable	Greater than %50 (<i>n</i> = 112)	%50 or less (<i>n</i> = 58)	<i>p</i> -value
Generally test score			<0.001^A
Normal	69 (61.6%)	14 (24.1%)	
Altered frenulum	43 (38.4%)	44 (75.9%)	
Functional test score			0.464 ^B
Normal	97 (86.6%)	47 (81.0%)	
Altered frenulum	15 (13.4%)	11 (19.0%)	
Breathing			0.153 ^C
Normal	74 (66.1%)	31 (53.4%)	
Mild dysfunction	36 (32.1%)	27 (46.6%)	
Severe dysfunction	2 (1.8%)	0 (0.0%)	
Swallowing-lip behavior			<0.001^C
Normal	70 (62.5%)	20 (34.5%)	
Mild dysfunction	29 (25.9%)	27 (46.6%)	
Moderate dysfunction	12 (10.7%)	7 (12.1%)	
Severe dysfunction	1 (0.9%)	4 (6.9%)	
Swallowing-tongue behavior			0.011^C
Normal	76 (67.9%)	28 (48.3%)	
Adaptation/dysfunction	35 (31.3%)	26 (44.8%)	
Excessive protruding	1 (0.9%)	4 (6.9%)	

*A Pearson's χ^2 test

B continuity-corrected χ^2 test

C Fisher–Freeman–Halton test

Table 6 Multivariate logistic regression analysis of factors associated with tongue dysfunction during swallowing

	Odds Ratio	%95 Confidence Interval		Wald	<i>p</i> -value
		Lower bound	Upper bound		
Model 1	OR	L CI	U CI	Wald	<i>p</i> -value
Altered frenulum based on general score	2.085	1.054	4.122	4.463	0.035
Altered frenulum based on functional score	1.480	0.597	3.669	0.716	0.398
Dysfunction in mentalis muscle activity	4.449	2.068	9.572	14.582	<0.001
Model 2					
Altered frenulum based on general score	2.512	1.199	5.266	5.963	0.015
Altered frenulum based on functional score	1.141	0.421	3.096	0.067	0.795
Dysfunction in mentalis muscle activity	2.170	0.898	5.243	2.960	0.085
Breathing dysfunction	5.258	2.379	11.620	16.828	<0.001
Age	1.001	0.809	1.239	0.001	0.990
Sex	0.985	0.476	2.039	0.002	0.967

consistent with previously reported pediatric data [34, 35]. This finding suggests that MMO alone is insufficient to detect tongue-specific functional limitation, whereas proportional assessments of tongue movement were more likely to identify functional restriction. Within the Marchesan Lingual Frenulum Protocol, the ratio between maximum mouth opening and mouth opening with the tongue tip positioned at the incisive papilla has been defined as a meaningful indicator of functional ankyloglossia and has been identified as the only independent parameter directly associated with tongue mobility restriction [16, 36]. This measure was subsequently termed the tongue range of motion ratio (TRMR) by Yoon et al., who reported that values below 50% indicate severe limitation of tongue movement [16].

In the present research, a TRMR below 50% was more frequently observed in children with altered lingual frenulum based on MLFP general scores, leading to rejection of first hypothesis that structural alterations of the lingual frenulum are associated with reduced tongue range of motion [36, 37]. However, nearly half of these

children did not have this restriction, highlighting that morphological alteration does not necessarily correspond to functional impairment. These findings emphasize the importance of interpreting tongue range of motion using proportional indices and integrating quantitative measures with qualitative clinical assessment rather than relying on fixed thresholds alone. Accordingly, a TRMR cut-off of 50% should be regarded as an exploratory, supportive clinical reference rather than an independent diagnostic threshold [16, 17, 36, 38].

Based on general test results, significant differences were observed between groups in parameters related to mouth opening, tongue tip morphology and frenulum attachment sites, whereas no differences were detected in functional scores. This pattern also suggests that morphological alterations of the lingual frenulum may not always translate into functional limitation. Furthermore, the differences observed between the structural and functional MLFP classifications indicate that these scoring systems evaluate complementary rather than interchangeable aspects of lingual frenulum alterations. Collectively, these findings underscore the need for an integrated structural–functional approach to evaluate lingual frenulum characteristics, particularly in pediatric populations during the mixed dentition period, for which systematic data remain limited.

Functional assessments revealed higher rates of impairment in children with altered lingual frenulum, particularly in tasks requiring effective tongue–palate interaction, including tongue suction, tongue elevation and speech, consistent with previous reports [39–41]. Functional test scores appeared more sensitive than morphology-based assessments in detecting speech-related effects, in line with evidence that ankyloglossia does not prevent speech acquisition but may contribute to articulation difficulties, most commonly involving /s/ and /r/ sounds [42–44]. Although detailed speech-related observations were recorded as part of the original assessment protocol, they were not analyzed separately, as they form components of a composite speech assessment score rather than standalone outcome measures. Notably, while age did not differ between groups based on general test scores, children with altered frenulum identified by functional test scores were significantly younger, a finding that may reflect developmental differences in early, task-specific compensatory responses. Overall, these findings reinforce that lingual frenulum morphology alone is insufficient to predict speech disorders, whereas functional restriction appears clinically relevant, underscoring the importance of incorporating functional evaluation into diagnostic protocols.

Beyond speech and function, upper airway parameters were also examined as part of the multidimensional assessment. Previous studies have reported that children with a short lingual frenulum may exhibit narrowing of upper airway–supporting structures, increased mouth breathing, and a higher risk of obstructive sleep apnea [4, 38, 45, 46]. In the present study, breathing-related findings were mild and did not significantly differ between groups, nor were Mallampati or tonsillar parameters associated with frenulum classification. Given the relatively young age of the study population and cross sectional design, these findings should be interpreted with caution and may not be generalizable to other developmental stage or study.

Although mentalis muscle activity did not differ significantly between groups, the observed pattern may be consistent with previous reports suggesting compensatory activation of the mentalis muscle in individuals with lingual frenulum restriction [16]. However, this interpretation is based on clinical examination rather than direct measurement of muscle activity, which may require confirmation using objective techniques such as electromyography in future studies.

Previous studies have shown that reduced tongue range of motion can adversely affect swallowing and sucking functions and a short lingual frenulum accompanied by reduced tongue mobility is associated with an infantile swallowing pattern [47–49]. In agreement with these observations, the present findings demonstrated that children with an altered frenulum based on the general test scores demonstrated significantly higher rates of dysfunction in both lip and tongue behaviors during swallowing based on general test scores, with tongue-related impairment reaching statistical significance in functional assessments while lip behavior did not. Accordingly, our second hypothesis was rejected, as children with structural lingual frenulum alteration exhibited significantly greater swallowing dysfunction than those with a normal frenulum. This pattern suggests that tongue function may indicate the primary limiting factor, with perioral musculature, including the lips and mentalis muscle, recruited as part of early compensatory strategies to partially maintain swallowing performance [16]. As the

present study was designed to reflect routine pediatric dental practice, swallowing was assessed as a screening procedure using saliva swallowing rather than physiological food or liquid boluses. Therefore, these findings should be interpreted within this clinical context.

Orofacial myofunctional disorders have been associated with malocclusion and craniofacial structural alterations, acting both as a contributing factor and a consequence of chronic oral dysfunction [50]. In the present study, malocclusion was assessed as an additional clinical parameter alongside the Marchesan lingual frenulum protocol. Although detailed occlusal characteristics, including sagittal, transverse, and vertical relationships, were recorded, only the overall presence or absence of malocclusion was included in the primary analyses. A higher prevalence of malocclusion was observed in children with an altered lingual frenulum when classification was based on the MLFP general score, whereas this association was not statistically significant when groups were defined according to functional test scores. From the perspective of the functional matrix theory [51], this pattern may indicate that occlusal alterations are more likely to reflect broader structural and postural adaptations accumulated over time rather than functional performance assessed at a single point in time. Therefore, the relationship between lingual frenulum status and malocclusion may vary depending on the assessment approach and should be interpreted cautiously within the multifactorial etiology of occlusal development.

The potential relationship between lingual frenulum morphology and postural function has been increasingly discussed in the literature [37, 52, 53]. In the present study, no significant differences in postural parameters were observed between normal and altered frenulum groups based on either general or functional test scores. As postural function matures throughout late childhood and is strongly influenced by environmental factors during childhood [54–57], the relatively young mean age of the study population and the use of static postural assessment methods may have limited the detection of frenulum–posture interactions. These findings suggest that postural adaptations, if present, may emerge later in development or require more sensitive dynamic assessment tools [57].

Multivariate regression analysis allowed evaluation of the independent associations between structural and functional factors and swallowing outcomes. Our findings indicate that swallowing-related tongue dysfunction showed a more direct association with lingual frenulum morphology, while respiratory dysfunction exerted the strongest overall influence, increasing the risk of tongue-related impairment by approximately fivefold. The attenuation of mentalis muscle contribution after adjustment, which reached only a borderline level of significance, suggests that tongue-mediated swallowing is primarily constrained by structural and respiratory factors, whereas neuromuscular compensation plays a secondary role. These findings further support a function-oriented evaluation model.”

Collectively, these findings support the value of an integrated morpho-functional assessment, which provides a more clinically meaningful evaluation than structural classification alone. Anatomical restriction appears to acquire clinical significance primarily when it translates into measurable functional limitation. Therefore, rigid morphology-based thresholds should be interpreted cautiously and contextualized within objective functional performance.

Despite its methodological strengths, the present study has several limitations that should be considered when interpreting the findings. Although all assessments were performed by a single examiner who underwent a calibration process with experienced clinicians prior to data collection and excellent intraobserver reliability was achieved, interobserver reliability was not formally assessed, which may limit the reproducibility of the findings across different examiners. Furthermore, the unequal group sizes arising from the functional test classification ($n=144$ vs. $n=26$) likely reflect the clinical prevalence of severe composite functional restriction within this sample and the reduced sample size in the functionally altered subgroup may have limited statistical power in subgroup-specific analyses; therefore, findings from these comparisons should be interpreted with caution. Finally, the cross-sectional design limits causal inferences and the single-center sample may reduce generalizability. Future longitudinal studies incorporating larger cohorts and objective digital or three-dimensional assessment tools are warranted to further refine morpho-functional diagnostic criteria.

Conclusion

In children during the mixed dentition period, structural and functional alterations of the lingual frenulum were associated with reduced tongue range of motion and tongue-related swallowing dysfunction. No significant associations were observed with breathing pattern, upper airway characteristics or postural alignment. The combined assessment of morphology and function may provide complementary information in the evaluation of lingual frenulum alterations.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The study was approved by the Istanbul Health and Technology University Scientific Research and Publication Ethics Committee (Meeting date: 22 January 2024, Meeting No: 2024/02, Decision No: 2024/02–01). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the parents/legal guardians of all participants, and assent was obtained from the children where applicable.

Consent for publication Not applicable.

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References

1. Dezio MPAGLDGPDGL. Tongue-tie, from embryology to treatment: A literature review. 2015;4(1):e040110.
2. de Lima ACD, Albuquerque RC, da Cunha DA, de Lima CAD, Lima SJH, da Silva HJ. Relação do processamento sensorial e sistema estomatognático de crianças respiradoras orais. Cotas. 2021;34(2):e20200251. <https://doi.org/10.1590/2317-1782/20212020251>.
3. Pereira TC, Furlan RMMM, Motta AR. Relationship between mouth breathing etiology and maximum tongue pressure. Cotas. 2019;31(2). <https://doi.org/10.1590/2317-1782/20182018099>.

4. Defabianis P. Ankyloglossia and its influence on maxillary and mandibular development. (A seven year follow-up case report). *Funct Orthod*. 2000;17(4):25–33.
5. Meenakshi S, Jagannathan N. Assessment of lingual frenulum lengths in skeletal malocclusion. *J Clin Diagn Res*. 2014;8(3):202–4. <https://doi.org/10.7860/JCDR/2014/7079.4162>.
6. Messner AH, Walsh J, Rosenfeld RM, Schwartz SR, Ishman SL, Baldassari C, et al. Clinical Consensus Statement: Ankyloglossia in Children. *Otolaryngol - Head Neck Surg (United States)*. 2020;162(5):597–611. <https://doi.org/10.1177/0194599820915457>.
7. Ruffoli R, Giambelluca MA, Scavuzzo MC, Bonfigli D, Cristofani R, Gabriele M, et al. Ankyloglossia: a morphofunctional investigation in children. *Oral Dis*. 2005;11:170–4. <https://doi.org/10.1111/j.1601-0825.2005.01108.x>.
8. Lalakea ML, Messner AH. Ankyloglossia. Does it matter? *Pediatric Clinics of North America*. Volume 50. W.B. Saunders. 2003;50:381–97. [https://doi.org/10.1016/S0031-3955\(03\)00029-4](https://doi.org/10.1016/S0031-3955(03)00029-4).
9. Webb AN, Hao W, Hong P. The effect of tongue-tie division on breastfeeding and speech articulation: A systematic review. *Int J Pediatr Otorhinolaryngol*. 2013;77(5):635–46. <https://doi.org/10.1016/j.ijporl.2013.03.008>.
10. Calvo-Henríquez C, Neves SM, Branco AM, Lechien JR, Reinoso FB, Rojas XM, et al. Relationship between short lingual frenulum and malocclusion. A multicentre study. *Acta Otorrinolaringol Esp*. 2022;73(3):177–83. <https://doi.org/10.1016/j.otorri.2021.01.002>.
11. Caixeta JA, de Pazinato S, Padoin DB, Lubianca Neto RCPK, Avelino JF, Chen MAG. Brazilian Academy of Paediatric Otorhinolaryngology Task Force – lingual frenulum disorders in childhood – evidence-based recommendations. *Braz J Otorhinolaryngol Elsevier Editora Ltda*. 2026. <https://doi.org/10.1016/j.bjorl.2026.101762>.
12. Bin-Nun A, Kasirer YM, Mimouni FB. A Dramatic Increase in Tongue Tie-Related Articles: A 67 Years Systematic Review. *Breastfeed Med*. 2017;12(7):410–4. <https://doi.org/10.1089/bfm.2017.0044>.
13. Brinkmann S, Reilly S, Meara JG. Management of tongue-tie in children: A survey of paediatric surgeons in Australia. *J Paediatr Child Health*. 2004;40(11):600–5. <https://doi.org/10.1111/j.1440-1754.2004.00483.x>.
14. Lisonek M, Liu S, Dzakupas S, Moore AM, Joseph KS. Changes in the incidence and surgical treatment of ankyloglossia in Canada. *Paediatr Child Health (Canada)*. 2017;22(7):382–6. <https://doi.org/10.1093/pch/pxx112>.
15. Walsh J, Links A, Boss E, Tunkel D. Ankyloglossia and lingual frenotomy: national trends in inpatient diagnosis and management in the United States, 1997–2012. *Otolaryngol Head Neck Surg*. 2017;156(4):735–40.
16. Yoon A, Zaghi S, Weitzman R, Ha S, Law CS, Guilleminault C, et al. Toward a functional definition of ankyloglossia: validating current grading scales for lingual frenulum length and tongue mobility in 1052 subjects. *Sleep Breath*. 2017;21(3):767–75. <https://doi.org/10.1007/s11325-016-1452-7>.
17. Zaghi S, Shamtoob S, Peterson C, Christianson L, Valcu-Pinkerton S, Peeran Z, et al. Assessment of posterior tongue mobility using lingual-palatal suction: Progress towards a functional definition of ankyloglossia. *J Oral Rehabil*. 2021;48(6):692–700. <https://doi.org/10.1111/joor.13144>.
18. Marchesan I, Internat J, Orofacial Myology. *Myofunctional Ther*. 2012;38(1):89–103. <https://doi.org/10.52010/ijom.2012.38.1.7>.
19. Anatomical versus functional classification. of ankyloglossia and their association with temporomandibular joint disorders in adults: a cross sectional study. *J Oral Facial Pain Headache*. 2025. <https://doi.org/10.22514/jofph.2025.049>.
20. Ege P, AF, TF, Ege P, Acarlar F, Turan F. Psikoloji araştırma ve uygulamalarında ölçek/teknik/ vaka/yayın/kavram tamtimi IV: Ankara Artikülasyon Testi (AAT). *Türk Psikoloji Dergisi*. 2006;21:125–6.
21. de Felício CM, Ferreira CLP. Protocol of orofacial myofunctional evaluation with scores. *Int J Pediatr Otorhinolaryngol*. 2008;72(3):367–75. <https://doi.org/10.1016/j.ijporl.2007.11.012>.
22. de Felício CM, Folha GA, Ferreira CLP, Medeiros APM. Expanded protocol of orofacial myofunctional evaluation with scores: Validity and reliability. *Int J Pediatr Otorhinolaryngol*. 2010;74(11):1230–9. <https://doi.org/10.1016/j.ijporl.2010.07.021>.
23. Lesavoy B, Lumsden C, Grunstein E, Yoon R. Mallampati and Brodsky Classification and Children’s Risk for Sleep Related Breathing Disorder. *J Clin Pediatr Dent*. 2022;46(4):280–6. <https://doi.org/10.22514/1053-4625-46.4.4>.
24. Brodsky L. Modern assessment of tonsils and adenoids. *Pediatr Clin North Am*. 1989;36(6):1551–69. [https://doi.org/10.1016/S0031-3955\(16\)36806-7](https://doi.org/10.1016/S0031-3955(16)36806-7).
25. Mitchell RB, Archer SM, Ishman SL, Rosenfeld RM, Coles S, Finestone SA, et al. Clinical Practice Guideline: Tonsillectomy in Children (Update). *Otolaryngol Head Neck Surg*. 2019;160(1suppl):S1–42. <https://doi.org/10.1177/0194599818801757>.
26. McRoberts LB, Cloud RM, Black CM. Evaluation of the New York Posture Rating Chart for Assessing Changes in Postural Alignment in a Garment Study. *Cloth Text Res J*. 2013;31(2):81–96. <https://doi.org/10.1177/0887302X13480558>.
27. Gómez-González C, González-Mosquera A, Alkhraisat MH, Anitua E. Mouth Breathing and Its Impact on Atypical Swallowing: A Systematic Review and Meta-Analysis. *Dent J (Basel)*. 2024;12(2):21. <https://doi.org/10.3390/dj12020021>.
28. Sandhu A, Sakaria BA, Patel SD, Ahuja G, Jadeja N, Mehta A, et al. The Impact of Early Orthodontic Intervention on Dental and Skeletal Development in Children with Mixed Dentition. *J Pharm Bioallied Sci*. 2024;16:S821–3. https://doi.org/10.4103/jpbs.jpbs_1035_23.

29. Munirji L, Kumar A, Suzuki A, Omairi H, Grigoriadis J, Grigoriadis A. Influence of Dental Stages on Orofacial Muscle Strength and Oral Motor Behavior in Children. *Int Dent J*. 2025;75(6). <https://doi.org/10.1016/j.identj.2025.103870>. PubMed PMID: 40886505.
30. Mintz SM, Siegel MA, Seider PJ. An overview of oral frena and their association with multiple syndromic and nonsyndromic conditions. *Oral Surg, Oral Med, Oral Pathol. Oral Radiol Endod*. 2005;99(3):321–4. <https://doi.org/10.1016/j.tripleo.2004.08.008>.
31. Wei EX, Tunkel D, Boss E, Walsh J, Ankyloglossia. Update on Trends in Diagnosis and Management in the United States, 2012–2016. *Otolaryngol Head Neck Surg*. 2020;163(5):1029–31. <https://doi.org/10.1177/0194599820925415>.
32. Kapoor V, Douglas PS, Hill PS, Walsh LJ, Tennant M. Frenotomy for tongue-tie in Australian children, 2006–2016: an increasing problem. *Med J Aust*. 2018;208(2):88–9. <https://doi.org/10.5694/mja17.00438>.
33. Baxter R, Lashley A, Rendell N. Tongue Restriction Questionnaire: A New Screening Tool to Identify Tongue-Tied Patients. *Compend Contin Educ Dent*. 2021;42:e1–4.
34. Demir MG. The normal range of maximum mouth opening and its correlation with age, gender, height, and weight in Turkish children. *Cranio J Craniomandib Sleep Pract*. 2025;43(4):599–602. <https://doi.org/10.1080/08869634.2023.2226836>.
35. Kolçakoğlu K, Doğan S, Zararsız G, Kütük N, Gönen ZB. Relationship Between Temporomandibular Ankylosis And Maximum Mouth Opening In Children. *J Oral Rehabil*. 2023;50(10):940–7. <https://doi.org/10.1111/joor.13498>.
36. Marchesan I. Lingual frenulum: Quantitative evaluation proposal. *Int J Orofac Myology*. 2005;31(1):39–48. <https://doi.org/10.52010/ijom.2005.31.1.4>.
37. Saccomanno S. Does a short lingual frenulum affect body posture? Assessment of posture in the sagittal plane before and after laser frenulotomy: a pilot study. *J Biol Regul Homeost Agents*. 2021;35(3Suppl1). <https://doi.org/10.23812/21-3suppl1-21>.
38. Zaghi S, Valcu-Pinkerton S, Jabara M, Norouz-Knutsen L, Govardhan C, Moeller J, et al. Lingual frenuloplasty with myofunctional therapy: Exploring safety and efficacy in 348 cases. *Laryngoscope Investig Otolaryngol*. 2019;4(5):489–96. <https://doi.org/10.1002/lio2.297>.
39. Baxter R, Hughes L. Speech and Feeding Improvements in Children After Posterior Tongue-Tie Release: A Case Series. *Int J Clin Pediatr*. 2018;7(3):29–35. <https://doi.org/10.14740/ijcp295w>.
40. Ruffoli R, Giambelluca MA, Scavuzzo MC, Bonfigli D, Cristofani R, Gabriele M, et al. Ankyloglossia: a morphofunctional investigation in children. *Oral Dis*. 2005;11(3):170–4.
41. Lalakea ML, Messner AH. Ankyloglossia: the adolescent and adult perspective. *Otolaryngol Head Neck Surg*. 2003;128(5):746–52.
42. Chinnadurai S, Francis DO, Epstein RA, Morad A, Kohanim S, McPheeters M. Treatment of ankyloglossia for reasons other than breastfeeding: A systematic review. *Pediatrics*. 2015;e1467–1474. <https://doi.org/10.1542/peds.2015-0660>.
43. Kupietzky A, Botzer E. Ankyloglossia in the infant and young child: clinical suggestions for diagnosis and management. *Pediatr Dent*. 2005;27(1):40–6.
44. Ito Y, Shimizu T, Nakamura T, Takatama C. Effectiveness of tongue-tie division for speech disorder in children. *Pediatr Int*. 2015;57(2):222–6. <https://doi.org/10.1111/ped.12474>.
45. Guillemineault C, Huseni S, Lo L. A frequent phenotype for paediatric sleep apnoea: short lingual frenulum. *ERJ Open Res*. 2016;2(3):00043–2016. <https://doi.org/10.1183/23120541.00043-2016>.
46. Villa MP, Evangelisti M, Barreto M, Cecili M, Kaditis A. Short lingual frenulum as a risk factor for sleep-disordered breathing in school-age children. *Sleep Med*. 2020;66:119–22. <https://doi.org/10.1016/j.sleep.2019.09.019>.
47. Dydyk A, Milona M, Janiszewska-Olszowska J, Wyganowska M, Grocholewicz K. Influence of Shortened Tongue Frenulum on Tongue Mobility, Speech and Occlusion. *J Clin Med*. 2023;12(23). <https://doi.org/10.3390/jcm12237415>.
48. Kotlow LA. Ankyloglossia (tongue-tie): A diagnostic and treatment quandary. *Quintessence Int*. 1999;30:259–62.
49. Moulton K, Seikel J, Loftin J, Devine N. Examining the effects of ankyloglossia on swallowing function. *Int J Orofac Myology*. 2018;44(1):5–21. <https://doi.org/10.52010/ijom.2018.44.1.1>.
50. D’Onofrio L. Oral dysfunction as a cause of malocclusion. *Orthod Craniofac Res*. 2019;22(Supplq):43–8. <https://doi.org/10.1111/ocr.12277>. PubMed PMID: 31074141.
51. Moss ML, Salentijn L. The primary role of functional matrices in facial growth. *Am J Orthod*. 1969;55(6):566–77. [https://doi.org/10.1016/0002-9416\(69\)90034-7](https://doi.org/10.1016/0002-9416(69)90034-7).
52. Olivi GSAOMGMD. Lingual frenectomy: Functional evaluation and new therapeutical approach. *Eur J Paediatr Dent*. 2012;13(2):101–6.
53. Brożek-Mądry E, Burska Z, Steć Z, Burghard M, Krzeski A. Short lingual frenulum and head-forward posture in children with the risk of obstructive sleep apnea. *Int J Pediatr Otorhinolaryngol*. 2021;144:110699. <https://doi.org/10.1016/j.ijporl.2021.110699>.
54. Carini F, Mazzola M, Fici C, Palmeri S, Messina M, Damiani P, et al. Posture and posturology, anatomical and physiological profiles: Overview and current state of art. *Acta Biomed*. 2017;88(1):11–6. <https://doi.org/10.23750/abm.v88i1.5309>.

55. de Resende BB, Almeida PS, Silva MA, Santos PS, de Ávila MV, Guimarães AC, et al. Prevalence Of Postural Changes In School Children and Adolescents. *Acta Ortop Bras.* 2023;31(spe2). <https://doi.org/10.1590/1413-785220233102e262255>.
56. de Sá C, dos SC, Boffino CC, Ramos RT, Tanaka C. Development of postural control and maturation of sensory systems in children of different ages a cross-sectional study. *Braz J Phys Ther.* 2018;22(1):70–6. <https://doi.org/10.1016/j.bjpt.2017.10.006>. PubMed PMID: 29239806.
57. Błaszczyk JW, Fredyk A. Maturation of the postural control in adolescent girls: A 3-year follow-up study. *Gait Posture.* 2021;83:300–5. <https://doi.org/10.1016/j.gaitpost.2020.10.036>.
58. Masutomi Y, Goto T, Ichikawa T. Mouth breathing reduces oral function in adolescence. *Sci Rep.* 2024;14(1):3810. <https://doi.org/10.1038/s41598-024-54328-x>.

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