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ORIGINAL RESEARCH

Should this tongue be untied—the pivotal role of tongue mobility in frenectomy decision-making

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Abstract

Background: Ankyloglossia (tongue tie) is a condition of limited tongue mobility caused by a restrictive lingual frenulum, often considered a factor that can affect oral motor function and development. The present study aimed to explore associations between certain skeletal and dental characteristics in adolescents and partial ankyloglossia. **Methods**: The following data were collected from 100 subjects (53% male, mean age 15.7 $\pm$ 2.9 years): general demographic information (*e.g.*, history of breastfeeding, use of a pacifier, past tonsillectomy, mouth breathing, snoring, sleep and/or awake bruxism and other), clinical evaluation (including maximal mouth opening, the shape of profile, free tongue measurement), and evaluation of dental and skeletal characteristics (measured on dental study models and cephalograms). The degree of ankyloglossia was evaluated through free tongue measurement. **Results**: Both maxillary inter-molar wide/length proportion and Frankfurt mandibular plane angle (FMA) can significantly predict tongue mobility (free tongue measurement). For a one-unit increase in the maxillary inter-molar wide/length proportion, there was a decrease of about 6.3 millimeters in the free tongue measurement. For each degree in FMA, free tongue measurement increased by about 0.2 millimeters. **Conclusions**: Results failed to present strong evidence to support a direct association between the severity of ankyloglossia and various skeletal and occlusal characteristics. Maxilla development is complex and multifactorial, including factors such as free tongue length, tongue mobility, and other oral functions, tongue tie being only one piece of the puzzle.

Keywords

Ankyloglossia; Tongue tie; Frenectomy; Free tongue measurement; Kotlow classification; Craniofacial characteristics

1. Introduction

The lingual frenulum (a mucous membrane that connects the ventral surface of the tongue to the floor of the mouth), provides stability to the tongue [1] and maintains a balance between the soft tissue structures and the growing maxillofacial skeleton [2, 3]. Occasionally, a congenital developmental anomaly characterized by a short lingual frenulum occurs. Ankyloglossia (tongue tie), is a condition of limited tongue mobility caused by a restrictive lingual frenulum [4]. It is often considered an imbalance of the fascial roles [5] affecting oral motor function and development [6, 7]. Its prevalence in the general population ranges between 4.2–10.7% [8], with a slight male predominance [9, 10].

Over the years several diagnostic classifications for ankyloglossia have been proposed based on anatomical and functional criteria, but none has been universally accepted [8, 11]. No single anatomical variable of the frenulum has been shown in isolation to correlate directly with impaired tongue function [5].

The tongue's ability to elevate (rather than to protrude) is important for breastfeeding, speech and the development of dental arches [12, 13]. The tongue exerts an outward pressure on the teeth, counteracting the constricting effect of the orbicularis oris and buccal muscles. Arch width maintenance is a result of equilibrium between these two groups of muscles [14]. Thus, an altered position of the tongue may affect the position of the mandible [15]. Elongated soft palate, high-arched palate, and reduced palate width have been associated with tongue tie [12, 13].

One of the main reasons parents seek frenotomy is due to breastfeeding difficulties. Ankyloglossia has been associated with sucking/breastfeeding difficulties in subjects younger than 2 years [16]. A clinical consensus published by the American Academy of Otolaryngology-Head and Neck Surgery, showed a strong consensus among members of the panel that anterior ankyloglossia is a potential contributor to infant breastfeeding problems and that the maternal and infant breastfeeding dyad should be recognized as a vulnerable patient population. The panel recommends that before lingual frenotomy, Ankyloglossia in an infant should be carefully evaluated, ideally by a lactation consultant [4]. Other adverse effects of ankyloglossia include speech problems in subjects aged 2 years and older [16]. Yoon *et al.* [12] found an association between restricted tongue mobility, maxillary dental width narrowing, and soft palate elongation, and suggested that variations in tongue mobility affect maxillofacial morphology and may lead to a high-arched palate with transverse deficiency.

A recent review [17] indicated an agreement regarding the negative effect of functional imbalances caused by ankyloglossia on the correct growth and development of the stomatognathic system. Controversies, however, exist as to the necessity of surgical interventions, especially in mild and moderate degrees of tongue tie (partial tongue tie).

The average percentage of patients diagnosed with ankyloglossia who undergo surgical procedures is 33% [18]. In recent years an increase of over 4 times occurred in the referral to surgical procedures aiming to untie the tongue (*e.g.*, frenotomy, frenectomy, frenuloplasty, miofrenuloplasty) [18–22].

A clinical consensus statement on ankyloglossia in children, published in 2020 [4], indicated that in some communities' infants and children are being over-diagnosed with ankyloglossia and a significant number of children undergo unnecessary surgery on the lingual frenulum. Moreover, clinical consensus exists regarding a lack of effect of ankyloglossia on speech in older children and a lack of a preferred surgical procedure for correction of ankyloglossia in older children. Evidence relating ankyloglossia and abnormal tongue position to skeletal development of Class III malocclusion is limited [23, 24]. Therefore, a complete orthodontic evaluation, diagnosis and treatment plan are recommended before any surgical intervention [23].

In the absence of sufficient evidence or understanding of the long-term effects of partial ankyloglossia on impaired dentofacial development, more information on the subject is needed. The present study aimed to explore associations between certain skeletal and dental characteristics and partial ankyloglossia.

2. Materials and methods

The study included subjects who arrived for orthodontic treatment at the Department of Orthodontics, The Goldschleger School of Dental Medicine, Tel-Aviv University, between the years 2022–2023. Inclusion criteria were an age of 10–25 years and the presence of first permanent mandibular and maxillary molars. Exclusion criteria were previous orthodontic treatment and/or previous frenotomy.

The following information was collected (all information was gathered by the same investigator):

2.1 Anamnestic information

Age, gender, history of breastfeeding (no/yes, if yes—age of weaning), use of pacifier (no/yes, if yes—age of weaning), past frenotomy (yes/no), past tonsillectomy (yes/no), oto-rhino-laryngological (ENT) problems (yes/no), chronic earache (past and/or present, yes/no for each), pain originating from the temporomandibular joint (TMJ) (past or present, yes/no for each), mouth breathing (yes/no), snoring (first or second party report, yes/no), sleep and/or awake bruxism (self or second party report, yes/no).

2.2 Clinical evaluation

(1) Maximal mouth opening (tongue in a relaxed position) in millimeters (mm);

(2) Shape of profile (straight/ concave/convex);

(3) Free tongue measurement (mm)—measured with a caliper between the frenulum point of attachment to the tip of the tongue (Fig. 1). The measurement was used as a continuous variable (mm) and as a tool to define ankyloglossia categories according to Kotlow [25] (see below).

FIGURE 1. Measurement of Ankyloglossia.

2.3 Dental and skeletal characteristics (measured on plaster study models or cephalograms, Figs. 2,3)

(1) Angle class classification [26]—Class I, II, III.

(2) Vertical, horizontal, and transverse dimensions:

(a) Vertical—overbite (mm), open bite (yes/no);

(b) Horizontal—overjet (mm);

(c) Transverse—the presence of crossbite (anterior to canines and/or posterior to canines; one-sided/two-sided/both).

(3) Arch parameters (Fig. 2):

(a) Inter molar arch width—measured between central fossae of first molars in both jaws (mm);

(b) Inter-canine arch width—measured between canine cup tips of both jaws (mm);

(c) Arch length—measured between buccal contact point of central incisors to the line indicating intermolar width, in both jaws (mm).

(4) Shape and height of palate (mesial to molar teeth)—assessed by the principal investigator (normal versus high and narrow).

(5) Skeletal measurements (Fig. 3):

Cephalogram x-rays were used to record the following parameters, according to Steiner's analysis [26]:

SNA (Angle formed by the sella-nasion plane and the nasion-A point plane): <80°; 80–84°; >84°;

SNB (Angle formed by the sella-nasion plane and the nasion-B point plane.): >78°; 78–82°; >82°;

ANB (Angle formed by point A and point B): <0°; 0–4°; >4°;

Go-Gn-Sn (Angle formed by Sella nasion and Gonion-Gnathion lines plane) :<27°; 27–36°; >36°.

2.4 Indices

(1) Ankyloglossia categories according to Kotlow [25], as follows: normal >16 mm; mild 12–16 mm; moderate 7–12 mm; severe 3–7 mm; complete <3 mm;

(2) As a measure for jaw shape, inter-molar wide/length proportions were calculated for each of the jaws;

(3) Tooth size-arch discrepancy (TSLAD, a measure of tooth crowding) as follows: ≤3mm, 4–7 mm, >7 mm [27];

(4) Frankfurt mandibular plane angle (FMA) calculated according to Tweed [28]: hypo divergent (<20°); normal (20–30°); hyper divergent (>30°).

2.5 Statistics

Data were analyzed using IBM SPSS software version 28.0 (Chicago, IL, USA). Chi-square analyses were used to study categorical variables. Pearson correlation coefficients (2-sided) were used to evaluate associations between free tongue measurement (in mm) and continuous variables. A stepwise regression was used to evaluate which of the study variables can serve as possible predictors of free tongue measurement.

3. Results

A total of 118 patients were approached. 6 refused to participate, 8 were excluded due to incomplete medical files, 2 were excluded due to previous orthodontic treatment, and 2 were excluded due to medical condition (Cleidocranial dysplasia) or previous frenotomy (85% response rate).

The final study group included 100 subjects, 53% male, mean age of 15.7 ± 2.9 years.

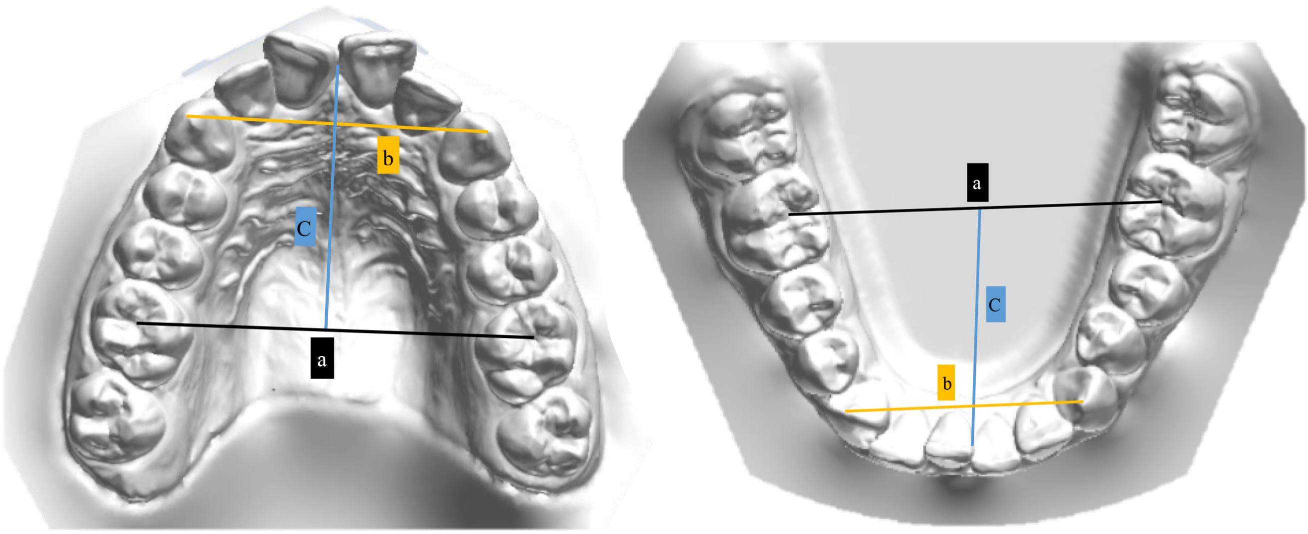

FIGURE 2. Arch measurements on dental casts. a: Inter-molar arch width (mm)—measured between central fossae of first molars, b: Inter-canine arch width (mm)—measured between canine cusp tips, c: Arch length (mm)—measured between the buccal contact point of central incisors to the line indicating inter-molar width.

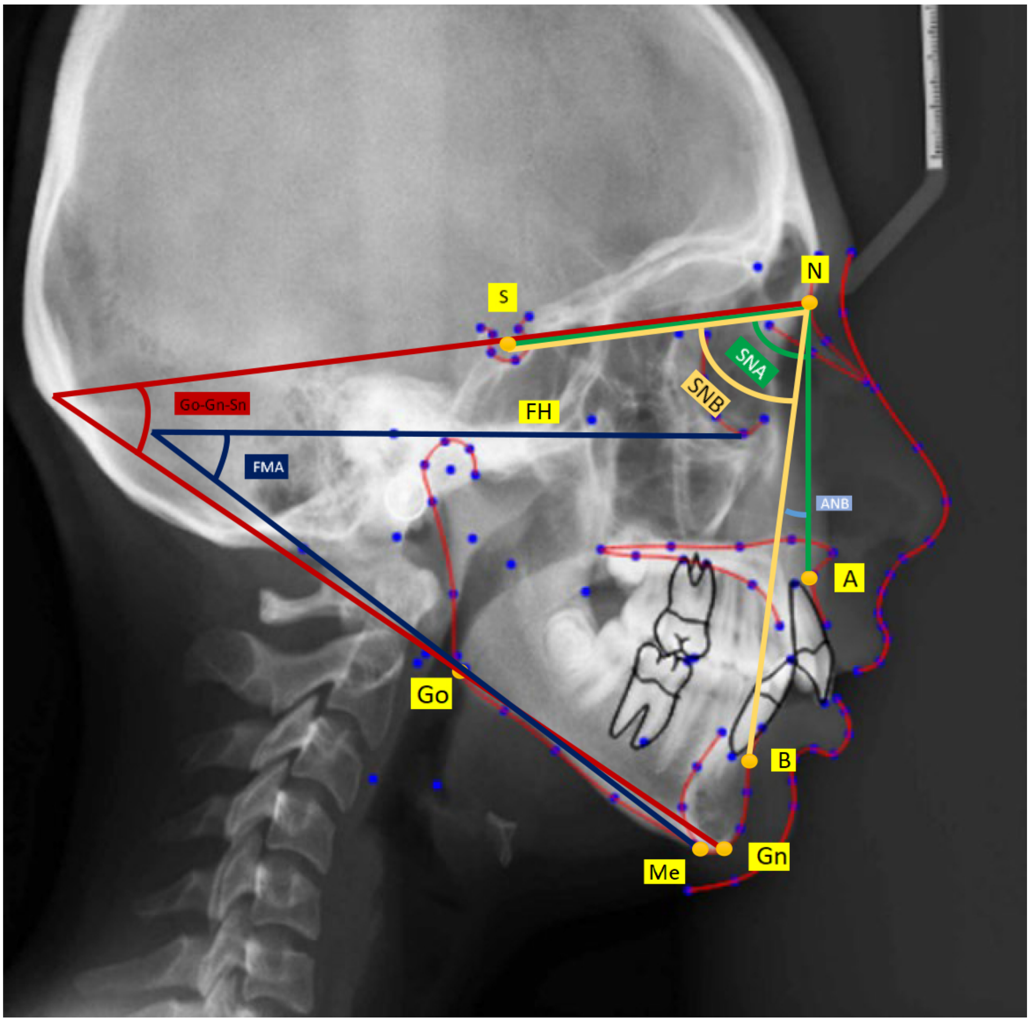

FIGURE 3. Lateral cephalometric measurement. SNA: Angle formed by the sella-nasion plane and the nasion-A point plane; SNB: Angle formed by the sella-nasion plane and the nasion-B point plane; Go-Gn-Sn angle: Angle formed by lines S-N and Go-Gn plane; FMA: A angle formed by the mandibular plane (Go-Me) and the Frankfurt plane (FH).

3.1 Descriptive data

The study population's demographic information and clinical characteristics are presented in Table 1. Over 75% of the subjects were breastfed with an average age of weaning of 7.6 ± 9.2 months and/or pacifier use with an average age of weaning of 2.1 ± 1.8 years.

TABLE 1. Demographic information (N = 100).

Variable	Positive (%)
Breastfeeding	78
Use of pacifier	76
Tonsillectomy or ENT* surgery	9
Chronic earache (past or present)	3
TMJ** pain	6
Mouth breathing	30
Snoring	20
Possible Bruxism***	27

**ENT: Ear, Nose and Throat; **TMJ: temporomandibular joint; ***Based on self-report.*

27% of the subjects were classified as Angle Class I, 56% as Angle Class II, and 17% as Angle Class III.

9% of the subjects presented open bite. 26% were evaluated as having a high and narrow palate.

Subjects' profiles were evaluated as 32% straight, 5% concave, and 63% convex.

Additional jaw characteristics are presented in Table 2.

The rate of tooth crowding (TSLAD) is presented in Table 3.

Mean cephalometric measurements are presented in Table 4.

3.2 Evaluation of ankyloglossia

As Kotlow classification categories have been shown to be inadequately representative of tongue mobility, both Kotow categories and free tongue measurement (in mm) were evaluated.

According to Kotlow classification categories, 44% of the cases could be classified as normal, 41% as mild ankyloglossia, and 15% as moderate ankyloglossia. There were no cases of severe or complete ankyloglossia in the study group.

The average free tongue measurement was 16.75 ± 4.59 mm.

TABLE 2. Clinical characteristics—Jaw measurements (N = 100).

Variable	Mean ± SD (mm)
Maximum mouth opening*	40.94 ± 6.64
Overbite*	3.09 ± 2.72
Overjet*	3.34 ± 3.34
Maxilla**: length	30.09 ± 3.08
Inter-molar width	43.57 ± 4.28
Inter canine width	31.65 ± 3.26
Mandible**: length	25.25 ± 2.65
Inter-molar width	39.28 ± 2.78
Inter canine width	25.46 ± 2.06

**Evaluated clinically; **measured on study models. SD: standard deviation.*

TABLE 3. Clinical characteristics—tooth crowding (% of cases, N = 100).

Crowding* / Jaw	≤3 mm	4–7 mm	>7 mm
Maxilla	49%	34%	17%
Mandible	68%	26%	6%

**Evaluated on study models.*

TABLE 4. Cephalometric measurements.

Variable*	Mean ± SD (°)**
SNA	81.89 ± 3.97
SNB	78.83 ± 3.84
ANB	3.07 ± 2.56
Go-Gn-Sn	36.30 ± 6.00
FMA	25.67 ± 5.25

**Calculated on Cephalogram x-rays; **degree 9% of the subjects showed a 0° ANB angle, in 58% of the subjects ANB angle ranged between 0–4°, and in 33% the angle was higher than 4°.*
69% of the subjects showed normal FMA (Frankfurt Mandibular Angle) values, 13% were hypo-divergent and 18% were hyper-divergent.
FMA: Frankfurt mandibular plane angle; SNA: sella-nasion plane and the nasion-A point plane angle; SNB: sella-nasion plane and the nasion-B point plane angle; ANB: Angle formed by point A and point B.

3.3 Associations and multivariate analysis

(1) Significant correlations were found between free tongue measurement (mm) and the following parameters (Pearson correlation, 2-sided):

- Maximal mouth opening ($r = 0.206$, $p < 0.05$);
- Maxillary arch length ($r = 0.203$, $p < 0.05$);
- Maxillary wide/length proportion ($r = 0.268$, $p < 0.01$).

(2) A significant association was found between ankyloglossia and FMA categories (FMA: hypo-divergent/normal/hyper-divergent; Ankyloglossia: normal/mild/moderate) [25] (Table 5).

No associations were found between free tongue measurement (or ankyloglossia categories) and any of the other variables (longitudinal or categorical). FMA: Frankfurt mandibular plane angle.

(3) Stepwise regression was computed to calculate which variables can serve as possible predictors of free tongue measurement (Table 6). Variables included in the equation were the ones that were found to significantly correlate with the dependent variable.

Results show a significant effect of both maxillary inter-molar wide/length proportion and FMA. For a one-unit increase in the maxillary inter-molar wide/length proportion, there was a decrease of 6.328 units (mm) in the free tongue measurement. For each unit (degree) increase in FMA, the free tongue measurement increases by 0.168 units (mm).

4. Discussion

Frenotomy/frenectomy for functional limitations and symptomatic relief is often considered on an individual basis although evidence to promote the timing, indication, and type of intervention is limited [6, 8, 29, 30].

With regards to anatomy, the lingual nerve has been shown to pass immediately beneath the fascia on the ventral surface of the tongue with smaller branches continuing into the lingual frenum [31]. As such, sensory input necessary for tongue shape may be compromised if the lingual nerve is damaged [32]. Additional complications may occur during or following frenulum surgical procedures and include excessive bleeding, formation of a mucus retention cyst, inappropriate scar formation which can lead to secondary ankyloglossia, hematoma formation, numbness or paresthesia, infection, scar tissue formation, and restriction in tongue movement [32].

The American Academy of Pediatric Dentistry (AAPD) [33] recognized that causes other than ankyloglossia are more common for breastfeeding difficulties and that not all infants with ankyloglossia require surgical intervention [3, 4]. Due to the broad differential diagnosis, a team-based approach including consultation with other specialists can aid in treatment planning. Further randomized controlled trials and other prospective studies of high methodological quality are necessary to determine the indications and long-term effects of the procedure.

Present results show limited associations between degrees of ankyloglossia categories (and/or free tongue measurement) and skeletal and dental characteristics in adolescence. As this is the age where most of the skeletal development has been finalized it may be assumed that the results concerning skeletal measurements are probably valid also in later age.

The major findings (as far as skeletal parameters are concerned) involve maxillary parameters, as well as the Frankfurt mandibular plane angle (FMA). It was suggested that a short lingual frenulum can limit the upward movement of the tongue during swallowing, causing the tongue to thrust anteriorly

TABLE 5. Associations among of FMA and ankyloglossia categories.

Ankyloglossia categories* / FMA categories	Normal	Mild	Moderate
Hypodivergent (<20°)	11.40%	9.80%	26.70%
Normal (20–30°)	59.10%	78.00%	73.30%
Hyperdivergent (>30°)	29.50%	12.20%	0.00%
Pearson Chi square (two sided Asymptotic significance)	0.131	0.039	0.123

According to Kotlow.

TABLE 6. Stepwise regression*.

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.	95.0% Confidence Interval for β	
	β**	Std. Error	β			Lower Bound	Upper Bound
1							
Intercept	26.890	3.543		7.589	<0.001	19.858	33.921
Maxillary intermolar wide/length	−6.943	2.407	−0.280	−2.884	0.005	−11.721	−2.165
2							
Intercept	21.668	4.359		4.971	<0.001	13.017	30.320
Maxillary intermolar wide/length	−6.328	2.391	−0.255	−2.646	0.009	−11.074	−1.582
FMA	0.168	0.084	0.193	1.999	0.048	0.001	0.335

**Excluded variables were maximum mouth opening (mm), and maxillary arch length (mm).*
***Statistical terms: unstandardized coefficient (β): the change in the dependent variable for a one-unit change in the predictor, holding other variables constant; standardized coefficient (β): the change in the dependent variable in terms of standard deviations for a one standard deviation change in the independent variable.*
Std. Error: standard error—accuracy of the coefficient estimate; Sig.: statistical significance. FMA: Frankfurt mandibular plane angle.

instead of elevating against the hard palate. This has been clinically associated with reduced palatal width [12]. Although no differences were found in the prevalence of high and narrow palates across the different severity groups of ankyloglossia, the difference in maxillary parameters across the ankyloglossia groups suggests that tongue mobility has the potential to affect the size and shape of the maxilla. Yoon *et al*. [12] suggested that the ratio of tongue range of motion is more indicative of palatal development than the Kotlow severity index, suggesting that the tongue may remain functional despite the degree of ankyloglossia. These results indicate that the degree of ankyloglossia, as classified by Kotlow, may not be the sole determinant of palatal morphology, and other factors related to tongue function may play a more significant role in the development of the palate.

The relationship between free tongue movement and the Frankfort Mandibular Plane Angle (a diminished tongue movement is associated with a reduced FMA) can be explained by the fact that in mild and moderate degrees of ankyloglossia, the tongue is functionally limited to the extent that it affects skeletal development to a lesser degree, and therefore does not lead to the development of a hyper divergent facial pattern associated with a high FMA angle. This may not be the case with more severe ankyloglossia and skeletal Class III malocclusion or mouth breathing (adenoid face).

These findings are consistent with Srinivasan *et al*. [3], who showed that most cephalometric indices were not statistically significant in ankyloglossia (except for the Go-Gn-Sn-angle). Although the findings concerning FMA were not significant the angle was greater in the mild cases of ankyloglossia. The authors suggested that the altered position of the tongue in ankyloglossia can affect mandibular rotation.

Contrary to Srinivasan *et al*. [3] and to the present results, Jang *et al*. [24] showed a significant increase in the lingual frenulum length in subjects with Skeletal Class III subjects (ANB <0°). It is, however, noteworthy that their measurement referred to the length of the frenulum and not to the free tongue measurement, as performed here and by Srinivasan.

No associations were found, in the present study, between the shape of the profile and ankyloglossia. The existing literature has not directly examined the relationship between these factors. Srinivasan and Chittaranjan [3] assessed the skeletal and dental characteristics of patients with ankyloglossia, finding that the majority belonged to skeletal Class I, followed by Class II, with only 3.5% belonging to Class III [3]. Similarly, Yoon did not find a correlation between the skeletal base and ankyloglossia [12]. These findings suggest that the effect of ankyloglossia on the facial profile, which is largely influenced by the underlying skeletal tissues, may be minimal.

Regarding additional occlusal characteristics, no associations were found between either overbite, overjet, open bite, maxillary/mandibular tooth size-arch length discrepancy (TSALD), cross-bite and ankyloglossia. This is consistent with the findings presented in the systematic review and meta-analysis by Póvoa-Santos *et al*. [34] who claim that the evidence for an association between ankyloglossia and malocclusion is low to very low.

It is noteworthy that no cases of severe ankyloglossia were found in the present study. In Israel, health authorities emphasize the beneficiary impact of breastfeeding, with most of the mothers breastfeeding their newborn babies [35]. The newborns are being examined (in the hospital and dedicated mother-newborn clinics) by specialized pediatricians and pediatric nurses. The result is that a majority of severe ankyloglossia cases receive early diagnosis and are referred to tongue release. It is thus unlikely to encounter cases of severe ankyloglossia at an older age when subjects arrive for orthodontic treatment.

Study limitations: The cross-sectional investigation presented here was conducted at a single institution and the study population consisted of patients seeking orthodontic treatment. Thus, the findings may not be representative of the general population. The lack of cases with severe ankyloglossia in the examined group limited the diversity of the sample and might have affected the results. Moreover, using Kotlow free tongue measurement is not a definitive assessment of limited tongue mobility, and other measures might have resulted in more accurate results. Undoubtedly, the study could have been enhanced by involving a myofunctional speech therapist to assist in the diagnosis of the ankyloglossia cases.

5. Conclusions

No strong evidence was found to support a direct association between the severity of ankyloglossia and various skeletal and occlusal characteristics. These findings align with the existing literature, which suggests that the evidence linking ankyloglossia to occlusal and skeletal disorders is limited. When deciding whether to perform a frenectomy, clinicians should carefully evaluate whether the issue can be addressed through other means (such as myo-functional therapy, speech therapy, *etc*.). As most indications for frenectomy involve problems with breastfeeding this issue should receive extra attention. Ankyloglossia in an infant should be evaluated by a careful history (including lactation history) and physical examination, including inspection and palpation. When assessing older children, dentists, and pediatric dentists should be attentive to certain red flags that may indicate the need for a frenectomy. These include a palatal 1st molar width-to-length ratio of 0.8 or less and restricted mouth opening. Measurement of free tongue length or frenulum length alone is not a sufficient basis to determine the need for a frenectomy. Preferably, a professional in the field (*e.g.*, a myofunctional speech therapist) should assess the functionality of the tongue, particularly its ability to reach the palate. Future studies should employ standardized measurement techniques to establish consistent assessment criteria.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

AEP, ERS and NS—designed the research study. ERS—performed the research, data collection. AEP, ERS and IE—analyzed the data. AEP and IE—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Tel-Aviv University Institutional Ethical Committee (ID: 4529-1). Prior to participation, each subject's legal guardian signed an informed consent to participate in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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