



Article

Morphology of the Labial Frenum by Age Cohort: A Cross-Sectional Study

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Abstract

Background/Objectives: The labial frenum is a variable oral structure with potential impacts on infant feeding, speech development, periodontal health, and aesthetics. Several classification systems have been established, but the age-related natural history and its relationship with midline diastema remain incompletely defined. This study aimed to systematically evaluate age-related changes in maxillary and mandibular labial frenum morphology and tension, and their association with midline diastema across pediatric age groups. **Methods:** A cross-sectional study was conducted on 1068 patients (ages 1 day–47 years) presenting for routine dental examinations at two pediatric dental clinics. Frenum morphology was classified as mucosal, gingival, papillary, or papillary-penetrating. Palpable tension was assessed by manual lip pulling and recorded as present or absent. Midline diastema was defined as ≥ 1 mm spacing between the maxillary central incisors, measured at the incisal midline with a periodontal probe. Data were analyzed using Pearson's chi-square tests with Bonferroni correction for multiple comparisons, and logistic regression was applied to evaluate independent predictors. Inter-examiner agreement was assessed using Cohen's κ . **Results:** Among 1068 participants, maxillary frenum morphology varied significantly by age. In children < 3 years, papillary and papillary-penetrating insertions predominated (65.7%), while gingival and mucosal insertions were more frequent in older children and adults (72.8%). Palpable tension declined sharply with age, from 92.5% in infants to $< 10\%$ in adults. Midline diastema was significantly associated with papillary-penetrating frena (RR = 3.47, 95% CI 2.45–4.91) and with the presence of tension (RR = 1.68, 95% CI 1.34–2.11). Logistic regression confirmed both phenotype (OR = 6.2, 95% CI 3.8–10.1) and tension (OR = 2.1, 95% CI 1.5–2.9) as independent predictors of diastema. In contrast, mandibular frena showed minimal variation by age and limited functional impact. **Conclusions:** The maxillary labial frenum demonstrates predictable developmental change, migrating apically and losing tension most prominently between 3 and 6 years of age, while the mandibular frenum remains largely stable. Papillary and papillary-penetrating phenotypes with palpable tension carry the greatest risk of midline diastema. These findings emphasize that management should prioritize functional symptoms and growth trajectory rather than appearance alone, with frenectomy reserved for cases of demonstrable impairment.



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Keywords: maxillary labial frenum; mandibular labial frenum; morphology; tension; diastema; pediatric dentistry

1. Introduction

The labial frenum is a fold of mucosa and connective tissue connecting the lip to the alveolar mucosa or gingiva, most commonly located in the midline above the maxillary central incisors [1] (Figure 1). Although a normal anatomical structure, it exhibits wide variability in size, thickness, and site of attachment. Widely referenced classification frameworks include an anatomic system describing mucosal, gingival, papillary, and papillary-penetrating insertions [2] (Figure 2), and a functional grading scale often used in pediatric dentistry where considerations of feeding and speech are most relevant [3]. A recent scoping review summarizes diagnostic criteria and management strategies and highlights the need for standardized functional measures [4], underscoring ongoing uncertainty in clinical decision-making.

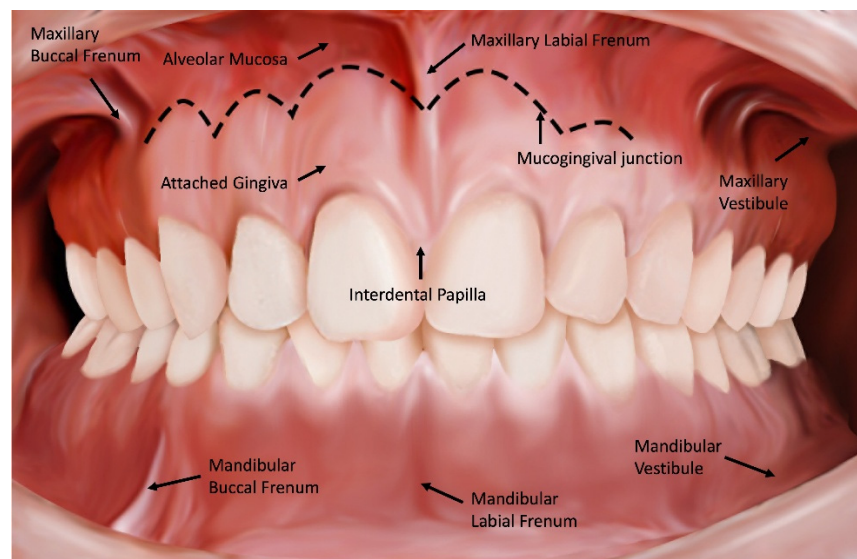


Figure 1. Clinical anatomy of the oral cavity.

Population-based studies demonstrate variability across regions. In European cohorts, papillary insertions are reported in up to 40% of children [5], whereas U.S. [6] and Asian data [7] suggest higher rates of mucosal or gingival types. These differences underscore the need for large, age-stratified datasets to clarify developmental patterns and their clinical significance.

The clinical significance of the labial frenum is well documented. In infants, restrictive maxillary frena may interfere with latch and breastfeeding efficiency, often accompanied by secondary symptoms such as reflux, aerophagia, and poor weight gain [8–10]. In older children, restrictive frena have been linked to impaired bilabial speech sounds (/b/, /p/, /m/, /w/), lip incompetence, mouth breathing, increased risk of dental caries, and orthodontic or aesthetic concerns such as midline diastema [11]. In adults, though less frequently studied, aberrant frena have been implicated in gingival recession and periodontal challenges [12]. From a periodontal perspective, frenectomy is indicated when the frenum contributes to midline diastema, gingival recession, or impedes oral hygiene. Techniques include scalpel excision, electrocautery, and CO₂ laser release, with the choice depending on age, tissue characteristics, and operator preference [13].

The relationship between frenum type and midline diastema has long been recognized, with papillary and papillary-penetrating attachments most strongly associated [14]. Systematic reviews confirm this association and further suggest that frenectomy is best delayed until eruption of the permanent lateral incisors, underscoring the importance of longitudinal follow-up [15,16]. Nevertheless, most existing studies remain limited to small cohorts or narrow age groups, and large-scale, age-stratified datasets integrating both morphological and functional measures are still lacking [17]. Although apical migration of the maxillary frenum with age has been described, the timing, variability, and clinical implications remain incompletely defined.

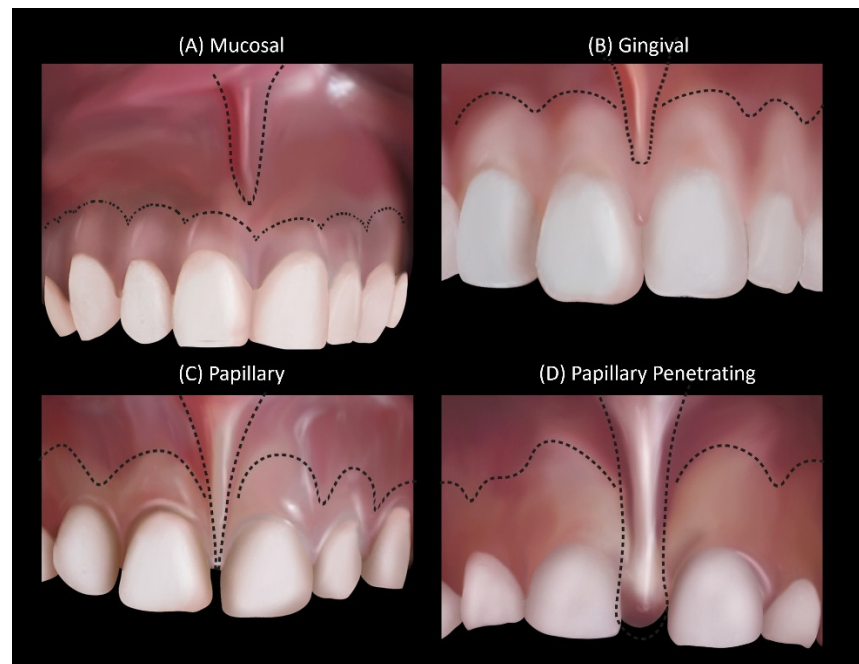


Figure 2. Classification of the maxillary labial frenum types: (A) Mucosal, (B) Gingival, (C) Papillary, (D) Papillary-Penetrating.

Aim: The purpose of this study was to systematically evaluate the morphology and tension characteristics of the maxillary and mandibular labial frena across age cohorts and dentition stages, and to examine their association with the presence of midline diastema. By analyzing a large, cross-sectional, age-stratified dataset, this study seeks to provide evidence to inform clinical decision-making regarding observation versus intervention.

2. Materials and Methods

2.1. Study Design

This investigation was designed as a prospective cross-sectional observational study conducted between January 2021 and June 2023 at two private pediatric dental clinics. Consecutive patients presenting for routine dental examinations during the study period were screened. Although recruitment occurred in pediatric dental clinics, adult patients were included when they presented as parents or caregivers receiving concurrent examinations, allowing adult data to serve as a reference for end-stage frenum morphology. Of 1086 assessed patients, 1068 met eligibility criteria and were included in analyses. The study protocol was approved by the University of California, Los Angeles IRB (IRB# 22-001626) on 25 January 2023 and adhered to the Declaration of Helsinki (1975, as revised in 2013). Data were collected prospectively during routine care and analyzed in de-identified form;

accordingly, the IRB waived informed consent for research use of anonymized clinical records. Reporting follows STROBE guidelines.

2.2. Participants and Eligibility Criteria

Participants included all patients aged 1 day to 47 years who presented for routine dental examinations during the study period and met eligibility criteria for standardized assessment of labial frenum morphology, tension, and midline diastema. All had sufficient clinical documentation to allow standardized assessment of labial frenum morphology, tension, and midline diastema, and had no prior maxillary or mandibular frenectomy. Adult participants were included for comparative purposes only, to contextualize developmental endpoints rather than to drive pediatric clinical recommendations.

Subjects were excluded if there was previous surgical modification of the labial frenum, known craniofacial anomalies or syndromic diagnoses affecting oral anatomy, or incomplete records.

Recruitment strategy: Consecutive sampling of all patients as well as their parents or caregivers meeting criteria in the two clinics across the study window.

2.3. Examiner Training and Calibration

All clinical examinations were performed chairside under standardized lighting by two calibrated pediatric dentists (SS, CH) following standardized examination protocols.

2.3.1. Examiner Training, Calibration, and Agreement

Before data collection, examiners jointly assessed a pilot series ($n \approx 30$) to standardize scoring for morphology and tension; quarterly recalibration sessions maintained consistency. A blinded double-rating subset ($n = 50$) was independently scored by both examiners. Inter-examiner agreement was excellent for attachment classification (Cohen's $\kappa = 0.86$, 95% CI 0.79–0.92) and substantial for tension ($\kappa = 0.78$, 95% CI 0.70–0.86). Intra-examiner reproducibility was periodically confirmed using stored photographs and remained high throughout the study.

2.3.2. Measurements and Operational Definitions

- Palpable tension (functional exposure): assessed by manual lip pulling to the mucogingival junction with a gloved finger. Tension was defined as visible blanching and/or palpable resistance relative to adjacent mucosa; recorded as present/absent.
- Midline diastema (primary outcome): defined as ≥ 1 mm spacing between maxillary central incisors, measured at the incisal midline using a periodontal probe under standardized lighting. If two immediate readings differed, the larger value was recorded; when feasible, the exact width in millimeters was also documented. Although transient midline spacing of up to 2 mm may be considered physiologic during the mixed dentition period, a ≥ 1 mm threshold was selected to ensure consistent identification of visible diastema across all age cohorts and to allow standardized regression modeling.
- Dentition stage: categorized as primary, mixed, or permanent per clinical criteria.
- Demographics and covariates: age and sex (complete cohort). In infants < 2 years, additional features such as lip flange seal, sucking/lip clicking, and bony notching were noted when present. Functional/behavioral covariates (habitual open-mouth posture, awake mouth breathing, drooling) were documented when observed.
- Periodontal findings: presence or absence of gingival recession at mandibular incisors was recorded.
- Photographic documentation: representative intraoral photographs were obtained in a subset for validation, documentation, and quality checks.

2.3.3. Bias Control and Handling of Missing Data

To minimize observer bias, a single standardized reading was recorded per site, with blinded duplicate ratings in the calibration subset. Morphology used a fixed, literature-based taxonomy [2]. Listwise deletion was applied for outcomes with missing component data; denominators are reported explicitly for each analysis. Age bins were selected to align with clinically meaningful dentition and developmental stages rather than to achieve equal sample sizes, consistent with prior pediatric craniofacial and dental literature.

2.4. Sample Size Determination

An a priori power analysis was conducted to ensure adequate sample size. Assuming a 10% difference in frenum morphology prevalence between age cohorts, with a standard deviation of 20%, $\alpha = 0.001$, and 99.9% power, the minimum required sample was $n = 511$. The final sample of 1068 participants exceeded this threshold, ensuring robust statistical power.

2.5. Statistical Analysis

- Analyses were performed in JMP Pro v16.0 (SAS Institute, Cary, NC, USA).
- Descriptive statistics: continuous variables as mean $\pm$ SD; categorical variables as counts and percentages $\pm$ SE.
- Group comparisons: Associations between age cohort, dentition stage, sex, and clinical outcomes (frenum morphology, palpable tension, midline diastema) were evaluated using Pearson's Chi-square tests. Bonferroni correction was applied for multiple comparisons, with statistical significance set at two-tailed $p < 0.001$.
- Effect sizes: Relative risks (RR) with 95% confidence intervals (CI) were calculated for associations between diastema and (i) frenum morphology and (ii) palpable tension.
- Regression modeling: Logistic regression was performed with diastema (present vs. absent) as the dependent variable and frenum morphology, tension, age, sex, and dentition stage as independent covariates. Odds ratios (ORs) with 95% CIs were reported. Sex-stratified models were conducted as sensitivity analyses. In a subset of patients, additional clinical covariates (e.g., mouth breathing, drooling, open-mouth posture) were explored in supplementary analyses.
- Missing data: Cases with incomplete records were excluded listwise from the relevant analysis; denominators are explicitly stated for each comparison.
- Sample size and power: An a priori sample size calculation estimated that 511 participants would be required to detect a 10% difference in proportions between age cohorts (SD = 20%, $\alpha = 0.001$, power = 99.9%). The final cohort ($n = 1068$) exceeded this requirement, ensuring robust power for the detection of clinically meaningful differences.

2.6. STROBE Compliance

The study design, sample size determination, data collection methods, reliability metrics, and statistical approach were developed and reported in line with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. A completed STROBE checklist is provided as Supplementary Table S1.

3. Results

3.1. Demographic Characteristics

Of 1086 screened patients, 1068 met eligibility criteria and were included in analyses. The mean age was 9.3 ± 5.3 years (range: 1 day–47 years). The cohort comprised 558 females (52.7%) and 501 males (47.3%), with sex unreported in 9 participants. Dentition stage at examination was primary in 279 (28%), mixed in 507 (51%), and permanent in

209 (21%); dentition stage was not recorded in 73 cases. Missing data reflected incomplete documentation of ancillary chart fields during routine care rather than post-enrollment exclusion or loss to follow-up. For clinical context, ages are displayed in bins reflecting dentition and developmental stage: 0–6 months (edentulous), 6–12 months (eruption of first primary teeth), 1–3 years (established primary dentition), 3–6 years (full primary dentition), 7–9 years (early mixed dentition), 10–12 years (late mixed/early permanent dentition), 13–18 years (permanent dentition established in youth), 18–25 years (young adults), and ≥ 25 years (adults) (Table 1).

Table 1. Demographics.

Characteristic	Value
Total N	1068
Mean Age (years)	9.3 $\pm$ 5.3
Age Range	1 day–47 years
Female	558 (52.7%)
Male	501 (47.3%)
Sex Unreported	9
Dentition: Primary	279 (28%)
Dentition: Mixed	507 (51%)
Dentition: Permanent	209 (21%)
Dentition Not Recorded	73

3.2. Maxillary Labial Frenum: Morphology by Age Cohort and Dentition Stage

Maxillary frenum attachment varied significantly with age (Pearson χ^2 , $p < 0.001$), with the steepest developmental shift occurring between 3 and 6 years (Table 2). Maxillary frenum morphology showed significant age-related differences in attachment site, with the most clinically relevant changes occurring during early childhood. Adult data are presented only for context, to demonstrate the endpoint of growth-related migration. In children younger than 3 years ($n = 70$), coronal insertions (papillary and papillary-penetrating) predominated (46/70; 65.7 $\pm$ 5.7%), whereas apical insertions (gingival + mucosal) were less frequent (24/70; 34.3 $\pm$ 5.7%). In contrast, among participants aged ≥ 3 years ($n = 998$), coronal insertions declined sharply to 26.6% (266/998), while apical insertions rose to 72.8%.

Table 2. Maxillary labial frenum (upper lip).

			Insertion Site/Attachment Point								Palpable Tension			
			Mucosal		Gingival		Papillary		Papillary-Penetrating		No		Yes	
Age Cohorts (Years)	N	% of Total	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort
0–1	40	3.7%	1	3.1%	0	0.00%	22	68.8%	9	28.1%	2	6.3%	30	93.8%
1–2	14	1.3%	0	0.0%	1	16.7%	4	66.7%	1	16.7%	1	16.7%	5	83.3%
2–3	16	1.5%	1	7.7%	3	23.0%	7	53.9%	2	15.4%	3	23.1%	10	76.9%
3–4	39	3.7%	1	2.6%	22	57.9%	14	36.8%	1	2.6%	22	56.4%	17	43.6%
4–5	58	5.4%	3	5.2%	37	63.8%	14	24.1%	4	6.9%	36	62.1%	22	37.9%
5–6	98	9.2%	6	6.2%	64	66.0%	25	25.8%	2	2.1%	62	64.6%	34	35.4%
6–9	327	30.6%	30	9.2%	198	60.7%	81	24.9%	17	5.2%	225	70.5%	94	29.5%
9–12	214	20.0%	18	8.4%	127	59.4%	55	25.7%	14	6.5%	159	75.7%	51	24.2%

Table 2. Cont.

Age Cohorts (Years)	Insertion Site/Attachment Point										Palpable Tension			
	Mucosal		Gingival		Papillary		Papillary-Penetrating		No	Yes	No		Yes	
	N	% of Total	N	% of Cohort	N	% of Cohort	N	% of Cohort			N	% of Cohort	N	% of Cohort
12–15	145	13.6%	14	9.8%	103	72.0%	22	15.4%	4	2.8%	107	74.8%	36	25.2%
15–18	70	6.6%	9	12.9%	51	72.9%	9	12.9%	1	1.4%	55	78.6%	15	21.4%
18–24	34	3.2%	3	9.1%	27	81.8%	3	9.1%	0	0.0%	26	76.5%	8	23.5%
≥24	13	1.2%	1	7.7%	11	84.6%	0	0.0%	1	7.7%	12	92.3%	1	7.7%
All	1068	100%	87	8.3%	644	61.7%	256	24.5%	56	5.37%	710	68.7%	323	31.3%

Analysis by dentition stage confirmed this pattern ($p < 0.001$): papillary insertions occurred in 28.5% of primary dentition cases, 25.0% of mixed dentition, and only 11.4% of permanent dentition (Figure 3). Together, these findings identify the 3–6-year period as a critical developmental window during which coronal attachments give way to apical phenotypes.



Figure 3. Labial Frenum Morphology by Dentition Stage: Maxillary labial frenum.

3.3. Maxillary Labial Frenum: Incidence of Palpable Tension by Age Cohort

There was a significant inverse relationship between age and the presence of palpable tension in the maxillary frenum (Pearson χ^2 , $p < 0.001$). Tension was most prevalent in infants under 1 year (37/40; $92.5 \pm 4.2\%$) and remained high in toddlers aged 1–3 years (24/30; $80.0 \pm 7.3\%$). Prevalence declined sharply to $35.0 \pm 3.2\%$ in children aged 3–9 years (114/327), $22.5 \pm 2.9\%$ in adolescents and young adults aged 9–24 years (64/284), and only

$7.7 \pm 7.4\%$ in adults ≥ 25 years (1/13) (Table 2, Figure 4). These findings highlight a steep reduction in functional tension between early childhood and school age.

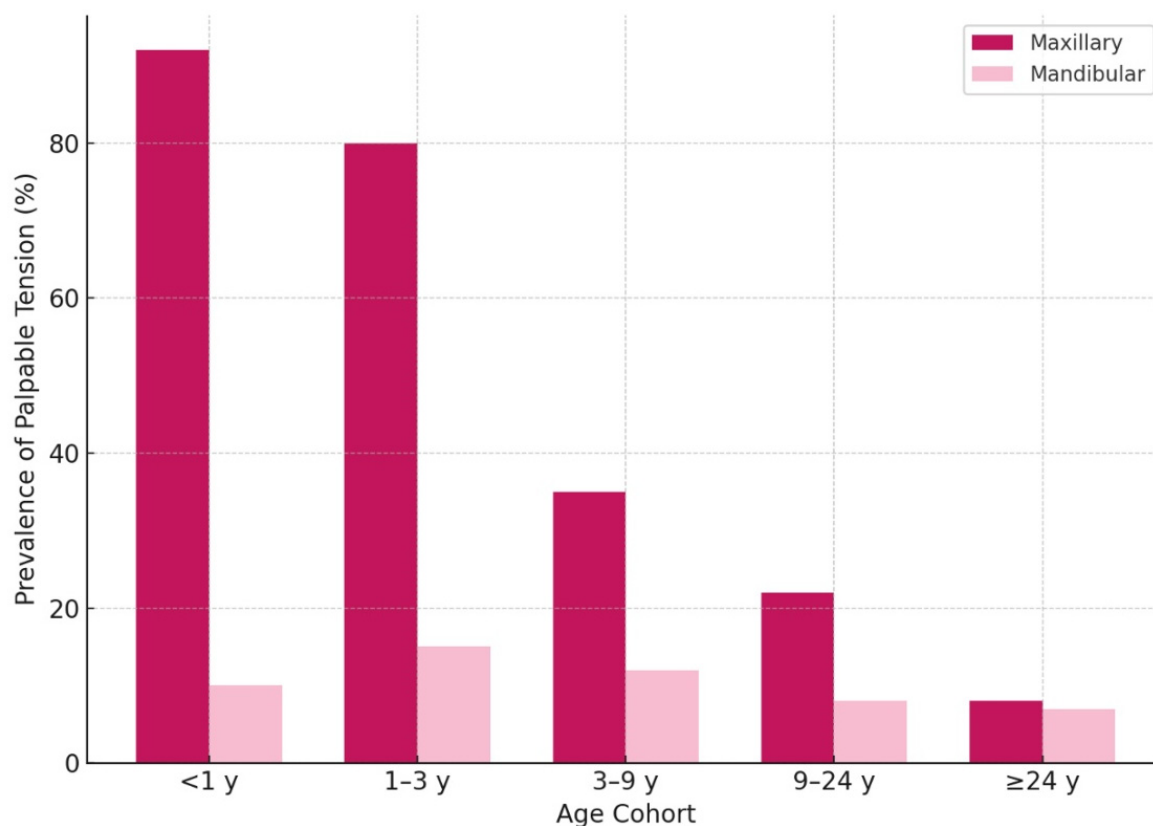


Figure 4. Prevalence of palpable tension by age cohort.

3.4. Mandibular Labial Frenum: Morphology by Age Cohort and Dentition Type

Unlike the maxilla, the mandibular frenum demonstrated minimal variation across age groups ($p = 0.08$). Across 1041 participants with complete data, mucosal and gingival insertions predominated, while papillary and papillary-penetrating types were rare, collectively accounting for $3.7 \pm 1.8\%$ of cases (range 0–12.9%) (Table 3). Among mandibular papillary or papillary-penetrating attachments only, gingival recession was observed in 2.8% ($n = 8/285$) of cases; however, prevalence was low and did not vary significantly by age.

Table 3. Mandibular labial frenum (lower lip).

			Insertion Site/Attachment Point								Palpable Tension			
			Mucosal		Gingival		Papillary		Papillary-Penetrating		No		Yes	
Age Cohorts (Years)	N	% of Total	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort	N	% of Cohort
0–1	40	3.7%	23	71.9%	8	25.0%	1	3.1%	0	0.0%	31	100.0%	0	0.0%
1–2	14	1.3%	2	40.0%	3	60.0%	0	0.0%	0	0.0%	4	80.0%	1	20.0%
2–3	16	1.5%	3	23.1%	9	69.2%	1	7.7%	0	0.0%	11	84.6%	2	15.4%
3–4	39	3.7%	14	36.8%	24	63.2%	0	0.0%	0	0.0%	36	92.3%	3	7.7%
4–5	58	5.4%	13	22.4%	42	72.4%	3	5.2%	0	0.0%	51	92.7%	4	7.3%
5–6	98	9.2%	30	30.6%	64	65.3%	4	4.1%	0	0.0%	88	90.7%	9	9.3%

Table 3. Cont.

Age Cohorts (Years)	Insertion Site/Attachment Point										Palpable Tension			
	Mucosal		Gingival		Papillary		Papillary-Penetrating				No		Yes	
											N	% of Cohort	N	% of Cohort
6–9	327	30.6%	119	36.8%	190	58.8%	14	4.3%	0	0.0%	293	93.0%	22	7.0%
9–12	214	20.0%	71	33.3%	133	62.4%	8	3.8%	1	0.5%	198	95.2%	10	4.8%
12–15	145	13.6%	38	26.4%	104	72.2%	2	1.4%	0	0.0%	138	96.5%	5	3.5%
15–18	70	6.6%	25	35.7%	44	62.9%	1	1.4%	0	0.0%	67	97.1%	2	2.9%
18–24	34	3.2%	11	32.4%	23	67.6%	0	0.0%	0	0.0%	32	94.1%	2	5.9%
≥24	13	1.2%	6	46.2%	7	53.8%	0	0.0%	0	0.0%	12	92.3%	1	7.7%
All	1068	100%	355	34.1%	651	62.5%	34	3.3%	1	0.1%	961	94.0%	61	6.0%

Dentition stage was not significantly associated with mandibular frenum type ($p = 0.35$). Papillary insertions were observed in $3.5 \pm 1.4\%$ of primary dentition cases, $3.9 \pm 1.5\%$ of mixed dentition, and $2.8 \pm 1.7\%$ of permanent dentition (Figure 5). These findings indicate the relative stability of mandibular frenum morphology across development.



Figure 5. Labial Frenum Morphology by Dentition Stage: Mandibular labial frenum.

3.5. Prevalence of Palpable Tension by Age Cohort

A statistically significant inverse relationship was observed between age and the presence of palpable tension in the maxillary labial frenum (Pearson χ^2 , $p < 0.001$).

- Infants < 1 year ($n = 40$): $92.5 \pm 4.2\%$
- Children 1–3 years ($n = 30$): $80.0 \pm 7.3\%$
- Children 3–9 years ($n = 327$): $35.0 \pm 3.2\%$
- Adolescents/young adults 9–24 years ($n = 284$): $22.5 \pm 2.9\%$
- Adults ≥ 25 years ($n = 13$): $7.7 \pm 7.4\%$

These results demonstrate a consistent, age-related decline in maxillary frenum tension, with the steepest reduction occurring between early childhood and school age.

Mandibular Labial Frenum: Palpable Tension by Age Cohort: In contrast to the maxilla, mandibular frenum tension was consistently low (<20%) across all age groups, with no significant variation by age ($p = 0.35$) (Table 3 and Figure 4). This stability suggests limited functional consequences of mandibular frena across the lifespan.

3.6. Association Between Maxillary Frenum Morphology, Tension, and Midline Diastema

Of 972 participants with complete data, 264 (27.2%) exhibited a visible midline diastema (≥ 1 mm). Diastema prevalence differed significantly by frenum phenotype ($p < 0.001$): papillary-penetrating frena carried the highest prevalence (34/47; $72.3 \pm 6.5\%$), followed by papillary insertions (70/225; $31.1 \pm 3.1\%$). Lower rates were observed in gingival (128/612; $20.9 \pm 1.6\%$) and mucosal insertions (23/85; $27.1 \pm 4.8\%$) (Table 4).

Table 4. Maxillary labial frenum (upper lip) and Diastema.

Total			Mucosal				Gingival				Papillary				Papillary-Penetrating			
			No		Yes		No		Yes		No		Yes		No		Yes	
Diastema	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Present	264	27.2%	20	26.7%	1	20.0%	95	19.0%	33	30.6%	32	36.0%	47	35.1%	7	58.3%	27	77.1%
Absent	708	72.8%	55	73.3%	4	80.0%	406	81.0%	75	69.4%	57	64.0%	87	64.9%	5	41.7%	8	22.9%

Palpable tension was also significantly associated with diastema: 108/283 participants with tension ($38.2 \pm 2.9\%$) presented with diastema, compared with 154/678 without tension ($22.7 \pm 1.6\%$) ($p < 0.001$). Effect-size estimates confirmed these associations: papillary-penetrating attachments conferred a 3.5-fold higher risk of diastema relative to gingival/mucosal types (RR = 3.47, 95% CI 2.45–4.91), and palpable tension conferred a 1.7-fold increased risk (RR = 1.68, 95% CI 1.34–2.11).

Multivariable logistic regression further demonstrated that both papillary-penetrating morphology (OR = 6.2, 95% CI 3.8–10.1) and palpable tension (OR = 2.1, 95% CI 1.5–2.9) were independent predictors of diastema after adjusting for age, sex, and dentition stage (Table 4). No significant sex differences were observed in frenum morphology, tension, or diastema prevalence (all $p > 0.05$).

Representative clinical examples of the maxillary labial frenum insertion types are shown in Figure 6.

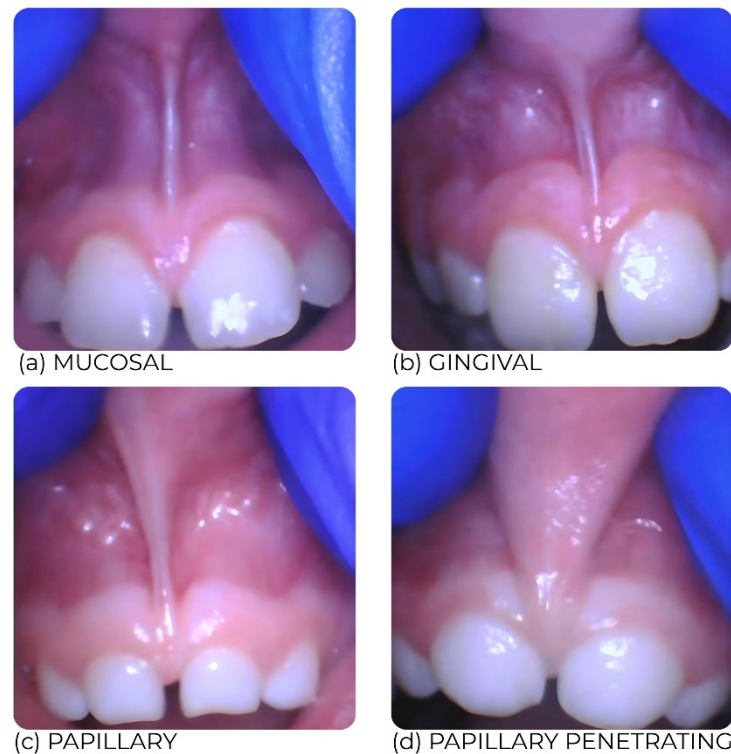


Figure 6. Representative Clinical Images of Maxillary Labial Frenum Insertion Types: (a) Mucosal, (b) Gingival, (c) Papillary, (d) Papillary-Penetrating.

4. Discussion

The maxillary labial frenum is a normal but highly variable anatomical structure that undergoes distinct developmental changes during early childhood, typically migrating to a more apical position by 3–6 years of age [18,19]. Our findings are therefore most relevant to pediatric populations, where clinical decisions about frenectomy are most often considered. Adult cohorts served primarily as a reference, confirming the trajectory of apical migration and declining tension observed in children. These results are consistent with recent reviews, which highlight both the variability and functional significance of labial frenum morphology across populations [20].

In this large, prospective cross-sectional study, we observed that papillary and papillary-penetrating insertions were most common in infants and toddlers, while gingival and mucosal insertions predominated in older children and adults. Palpable tension followed a similar age-related decline, being most frequent in infancy and steadily decreasing through adolescence. Importantly, midline diastema was strongly associated with papillary-penetrating frena, particularly when tension was present, underscoring the clinical relevance of this phenotype. Our findings are further supported by previously mentioned age-stratified datasets, which documented comparable migration patterns and identified 3–6 years as the critical window for morphological transition [17]. Recent pediatric cross-sectional and review-based studies also support these findings, demonstrating age-related variation in maxillary labial frenum attachment and reinforcing the clinical relevance of morphology-based assessment in children. Kaplan and Taraç [21] reported a higher prevalence of papillary and papillary-penetrating attachments in younger children, with progressive apical migration observed with increasing age, consistent with observations from contemporary pediatric cohorts [22] and recent syntheses highlighting developmental dynamics and diagnostic variability of the maxillary labial frenum [4].

In contrast, the mandibular labial frenum showed minimal variation across age groups. Mucosal and gingival forms predominated, papillary insertions were rare, and palpable

tension was consistently infrequent. This aligns with reports that mandibular frena usually have limited functional consequence, though restrictive insertions may occasionally contribute to gingival recession requiring surgical management [23].

Our results align with earlier descriptive studies documenting apical migration of the maxillary frenum during growth and eruption [4]. Histologic data support this developmental shift, linking it to eruption-related tissue remodeling and maxillary displacement [24]. Trauma in early childhood may also contribute by inducing partial frenum tears and fibrous repair [25]. The strong association we observed between papillary-penetrating frena, tension, and diastema reinforces earlier reports [14,26] and provides supporting age-stratified evidence for these relationships.

Additional support comes from retrospective and cross-sectional studies showing that many young children present with higher Kotlow classifications early in life, with scores decreasing as age and dentition advance [11,17]. Higher classifications have been associated with persistent diastema and a greater likelihood of surgical intervention, consistent with both classic diastema literature and contemporary pediatric outcomes [27].

Evidence from school-aged children demonstrates that frenum attachment types vary across regions and dentition stages [28]. These population-based data underscore the importance of accounting for regional variability when interpreting prevalence and severity trends. Integrative reviews likewise highlight the global heterogeneity of labial frenum morphology, reinforcing that appearance alone is an insufficient predictor of functional outcomes [16]. Together, these findings support a function- and symptom-guided approach that considers developmental trajectory and population context.

4.1. Clinical Implications

These results support a function- and symptom-guided approach to the management of restrictive frena in infants and children. Although papillary or papillary-penetrating insertions with tension are common in neonates, most migrate apically and lose tension with growth. Frenectomy should therefore not be recommended on appearance alone. Instead, intervention is appropriate only when restriction is accompanied by symptoms such as persistent breastfeeding difficulties, aerophagia-related reflux, or inadequate weight gain despite lactation support [9,10].

The AAPD 2024 Policy on Management of the Frenulum in Pediatric Patients emphasizes that treatment decisions should be guided by functional impact and symptom severity rather than anatomy alone [29]. In asymptomatic infants, careful observation is preferable, given the high likelihood of spontaneous regression. Systematic studies, including a 2020 analysis of morphology variation across pediatric populations, show that frenum types and attachment sites vary widely, and that many children with initially severe classifications improve without intervention over time [30]. Integrating our age-stratified dataset with these insights provides a stronger foundation for evidence-based guidelines that balance developmental trajectory, functional outcomes, and clinical judgment.

4.2. Strengths and Limitations

This study has several strengths, including its large sample size, prospective design, standardized assessments by calibrated pediatric dentists, explicit reporting of inter-examiner reliability, and detailed age stratification. Together, these features provide one of the most comprehensive datasets on labial frenum morphology to date. However, several limitations must be acknowledged. The cross-sectional design precludes longitudinal tracking of individual developmental changes, including determination of which infants with restrictive frena later required frenectomy. Data were drawn from two pediatric dental

clinics, which may limit generalizability, and some denominators were reduced due to incomplete documentation of ancillary variables.

The use of a uniform ≥ 1 mm diastema threshold across dentition stages may overestimate clinically transient spacing during mixed dentition; however, inclusion of dentition stage as a covariate mitigated this effect analytically. Potential confounders, including prior orthodontic treatment, oral habits (e.g., thumb sucking, tongue thrust), dental trauma, and periodontal disease, were not systematically excluded, reflecting real-world clinical populations. These factors may influence frenum morphology and diastema outcomes, particularly in adolescents and adults.

Quantitative assessment of gingival recession severity in mandibular papillary attachments was limited by inconsistent documentation. Adult cohorts were included solely as a reference for developmental stability and provided contextual comparison rather than guidance for pediatric clinical decision-making. Future studies incorporating standardized oral habit inventories, periodontal indices, and longitudinal follow-up are warranted to further clarify these associations.

4.3. Future Directions

Future prospective longitudinal cohort studies are needed to establish the developmental trajectory of restrictive frena, identify predictors of persistence versus spontaneous resolution, and evaluate long-term functional outcomes, including speech, feeding, orthodontic, and periodontal sequelae. Such work would help clarify optimal timing and indications for frenectomy, ultimately guiding more precise, evidence-based clinical protocols.

5. Conclusions

This study systematically evaluated developmental changes in labial frenum morphology and their association with midline diastema. Our findings confirm that the maxillary frenum undergoes predictable migration, shifting apically and losing tension most prominently between 3 and 6 years of age. Papillary and papillary-penetrating insertions with tension carried the greatest risk of midline diastema, whereas mandibular frena remained largely stable across age groups.

Clinically, these findings emphasize that frenectomy should not be recommended based on appearance alone. Instead, management should be guided by functional symptoms such as breastfeeding impairment, persistent diastema beyond expected developmental stages, or speech concerns. In asymptomatic infants and children, careful observation is appropriate given the high likelihood of spontaneous regression during normal growth.

Overall, this age-stratified dataset provides one of the most comprehensive evaluations of labial frenum development to date and offers practical guidance for clinicians navigating the balance between early intervention and watchful waiting. Prospective longitudinal studies are needed to further define predictors of persistence, clarify long-term functional outcomes, and refine evidence-based timing and indications for intervention.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/ijom52010003/s1>, Table S1: Completed STROBE Checklist.

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Abbreviations

The following abbreviations are used in this manuscript:

IRB	Institutional Review Board
SD	Standard Deviation
SE	Standard Error
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
RR	Relative Risk
CI	Confidence Interval

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