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Original Research Article

Maxillary labial frenum and malocclusion: An overriding or an overlooked tissue?

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ABSTRACT

The influence of the maxillary labial frenum in relation to the midline diastema has been a proven fact to clinicians for many years. A pilot study was carried out to investigate the relationship between a low maxillary labial frenum attachment and skeletal malocclusions (class I, II, and III). Astonishingly, it was observed that the class III malocclusion had a statistically high number of cases with low frenum attachments. The objective of the study was to understand the underlying skeletal class III dysplasia in these cases. A comparative cross-sectional study was performed on 300 consecutive subjects between 13-30-years of age. Based on the cephalometric parameters the participants were categorized into 98 skeletal class I, 102 class II, and 100 class III subjects. Variations in the frenum attachment were clinically evaluated using Placek classification. The insertion level and width of the frenum were also measured by using a caliper and the data were statistically analyzed for determining the association between the frenum attachment and skeletal malocclusion. The prevalence of low frenum attachment in class III subjects was found to be 64%. Also, the mean attachment level of the frenum was significantly closer to the gingival margin in skeletal class III subjects compared with that of the other groups ($p<0.01$). The study identified that the subjects with a low frenum attachment had a tendency towards a retruded maxilla in terms of linear dimension. Therefore the present study supports the hypotheses that the skeletal Class III malocclusion may be associated with low frenum attachment.

1. Introduction

The maxillary labial frenum is formed by a fold of mucous membrane, connective tissue, and sometimes a few fibers of the nasolabial muscles that attach to the philtrum of the upper lip, alveolar mucosa, and underlying periosteum. It received attention in orthodontic literature by Angle and others who described the median diastema resulting from aberrant frenum.[1] The insertion level of the frenum plays an important role in differentiating its normal and abnormal variations.[2,3]

The average width of the attached gingiva in the maxillary anterior region is established to be 3.5-4.5 mm.[4] Furthermore, Miller stated that the frenum is considered aberrant when it is unusually wide or there is no apparent zone of attached gingiva along the midline or the interdental papilla shifts when the frenum is extended.[5] The aberrant frenum appears inordinately large and/or attached close to the gingival margin and the residual fibers persist between maxillary central incisors attaching to the periosteum and connective tissue of the interincisal suture.[6] The functional classification of frenum attachment as mucosal, gingival, papillary, and papillary penetrating, introduced by Placek, is the most commonly cited one in the literature. Clinically, papillary and papillary penetrating types of frenum are considered as a potentially pathological factor and hence an aberrant attachment.[3]

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The maxillary labial frenum lodges the septopremaxillary ligament (SPL),[7] a fibrous connective tissue extending from the anterior border of the nasal septum to the anterior nasal spine and median suture of the premaxilla forming the cellular septum of the upper lip.[8,9] Anteriorly, the septum is firmly connected to the premaxilla by the SPL anchoring the septum in the midline and thus plays an important role in the forward growth of the upper jaw.[10] Experimental studies in the chimpanzee model indicate that a disruption in the SPL results in reduced premaxillary growth.[11] The nasolabial muscles which are inserted onto the anteroinferior aspect of the septum and premaxilla also contribute to the facial growth regulation where the movement of projection is transmitted to the interincisal suture.[7]

The influence of the growth process on the labial frenum begins early during embryonic development when the developing alveolar process divides the tectolabial frenum into palatine papilla and the labial frenum. This continues through fetal and postnatal life, causing apical migration of the attachment of frenum away from the gingival crest as the alveolar process continues to grow downwards with age. In certain cases, these series of events do not occur and the tectolabial frenum persists.[1] The residual frenum fibers then may lead to median diastema and restriction of the upper lip movement.[12,13] Though several studies have been done on these aspects, a pilot study was carried out to investigate the relationship between a low maxillary labial frenum attachment and skeletal malocclusions (class I, II, and III). Astonishingly, it was observed that the class III malocclusion had a more number of cases with low frenum attachment.

The purpose of the present study was to determine the association between the low maxillary labial frenum attachment and skeletal patterns. Additionally, it was intended to understand if the class III skeletal pattern was caused due to deficient maxilla.

2. Materials and Methods

In the present comparative cross-sectional study, 2750 subjects visiting the Department of Orthodontics (from December 2018 to October 2021) were screened. The study participants consisted of 300 consecutive subjects, who met the inclusion criteria, both males and females between 13-30 years of age undergoing Orthodontic treatment in the Department of Orthodontics. The study was conducted following the ethical guidelines of the Helsinki Declaration (version 2013), and ethical clearance was obtained from the Institutional Ethics Committee. All the subjects included in the study gave their due informed consent to be a part of the study.

According to the power analysis performed based on the pilot study, the theoretical sample size was estimated to be 281 individuals to determine significant differences at the 95% confidence level, 5% absolute precision with 80% power. However, an effort was made to recruit the maximum number of participants to include a total of 98 subjects in class I, 102 class II subjects, and 100 class III subjects from the population of individuals that sought treatment/consultation at the Department of Orthodontics. The data is reported according to the STROBE guidelines.

The inclusion criteria were subjects with the complete eruption of maxillary anterior teeth with no previous history of orthodontic or orthopedic treatment, orthognathic or frenal surgeries. The participants who had any congenital or developmental defects, trauma/injuries in the premaxillary region, syndromic or dysmorphic facies, or/and under any medication known to affect the gingiva were excluded from the study.

Placek's classification system was applied to assess the variations in the attachment level of the maxillary labial frenum. The insertion site and anteroposterior dimension (width) of the frenum were also measured using a caliper under direct visual method and intraoral photographs were taken (Figure 1).

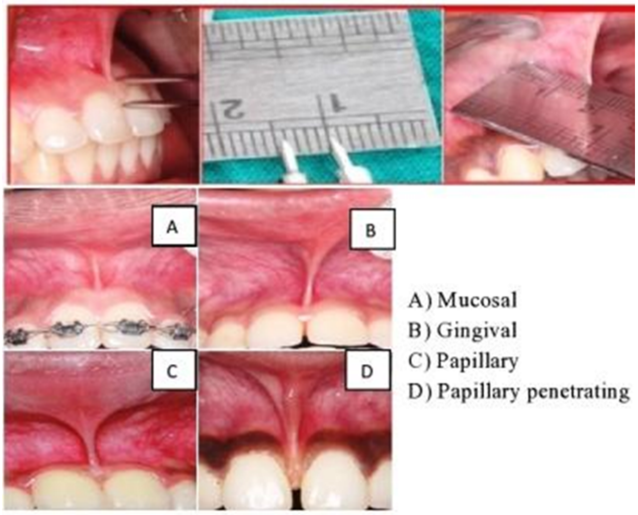


Fig. 1: Measurement of attachment level and width of the frenum

The pretreatment cephalograms were digitized using the Dolphin software system for cephalometric analysis. Based on the Beta angle, ANB angle, and Wits appraisal, the study sample was classified into skeletal class I, class II and class III malocclusion. Parameters of malocclusion type measured on cephalograms for class I were based on $27^o <$ Beta angle $< 35^o$, $0^o <$ ANB $< 4^o$, and $0 <$ Wits appraisal $<$ 2 mm, for class II on Beta angle $< 27^o$, ANB $> 4^o$, and Wits appraisal $>$ 2 mm, and for class III on Beta angle $> 35^o$, ANB $< 0^o$, and Wits appraisal $<$ 0 mm (Figure 2 A). The subjects were grouped into any of the three groups when at least two out of three of the above parameters were met. The distributions of age, gender, Beta angle, ANB angle, and Wits appraisal in different skeletal groups were shown in Table 2. Table 1 and Figure 2 B show the cephalometric variables used in the study which includes four angular and seven linear measurements. All these measurements were carried out by a single examiner and a representation of graphical abstract as shown in Figure 3.

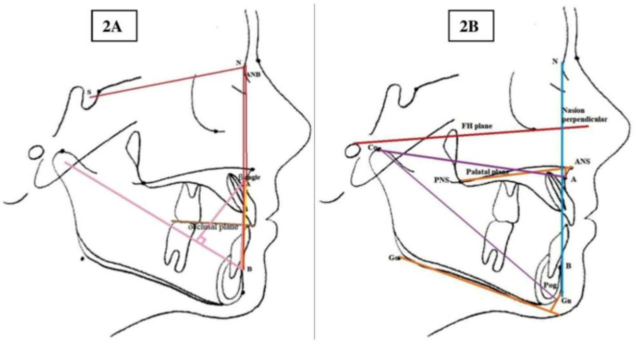


Fig. 2: Cephalometric variable used in the study **A:** Beta angle, ANB angle and Wits appraisal; **B:** Nasion perpendicular to point A and Pogonion, CoA, CoGn, measured Maxillary and Corpus length of Schwarz

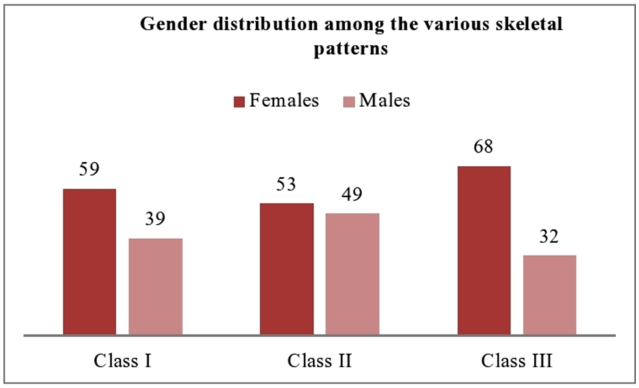
The reliability of the labial frenum measurements was determined by repeating the measurement on 20 randomly selected subjects who were examined at intervals of 14 days. Testing for the method error of all measurements was done with Dahlberg's formula (method error = $\sqrt{\sum d^2/2n}$ where d is the difference between 2 measurements of a pair, and n is the number of subjects). The method error of the measurements of the attachment level and width of the frenum was found to be 0.15 mm and 0.17 mm respectively. The reliability of the cephalometric measurements was evaluated by duplicating tracings on 20 randomly chosen cephalograms at 14-day intervals by the same examiner. The method errors calculated with Dahlberg's formula ranged from 0.11 mm to 1.46 mm for linear measurements and from 0.14° to 0.47° for the angular measurements.

2.1. *Statistical analysis*

The statistical analyses were performed using statistical software (IBM SPSS Statistics for Windows, Version 26.0 South-Asia Pvt. Ltd. Bangalore: IBM Corp). The gender and age differences in each of the 3 skeletal groups were tested by applying the Chi-square test and ANOVA respectively. The prevalence of the type of frenum attachments among the various skeletal patterns were compared by using the Chi-square test. ANOVA was applied to determine the difference in mean attachment level, and width of the frenum among various skeletal patterns. Post hoc multiple comparisons and analyses were performed using the Bonferroni correction at a 95% confidence interval. Pearson correlation analysis was also used to detect the relationship between the attachment level of the frenum and cephalometric variables. A p-value of ≤ 0.05 was considered statistically significant.

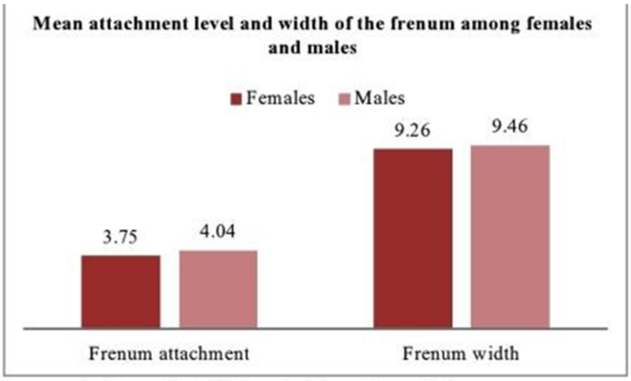
3. Results

The present study included the assessment of 98 class I, 102 class II, and 100 class III subjects with a mean age of 18.93 years, 17.64 years, and 18.57 years respectively (Table 2). There were 180 females (18.36±4.44 years) and 120 males (18.39±4.93 years). The relationship between age and skeletal malocclusion was found to be statistically insignificant by applying ANOVA (F statistic=2.10; p=0.12). The Chi-square analysis revealed insignificant difference (p=0.07) between gender and skeletal malocclusion (Graph 1). In addition, insignificant differences were found between females and males (p>0.05) after examining the relationship between gender, attachment level, and width of the frenum in the study sample using an independent sample t-test (Figure 4). Hence, the data for both genders in each group were combined.



Chi-square statistics = 5.42; p-value = 0.07

Graph 1: Gender distribution among the various skeletal patterns



Frenum attachment: t-statistics = -1.59; p-value = 0.11
Frenum width: t-statistics = -0.71; p-value = 0.48

Fig. 4: Mean attachment level and width of the frenum among females and males

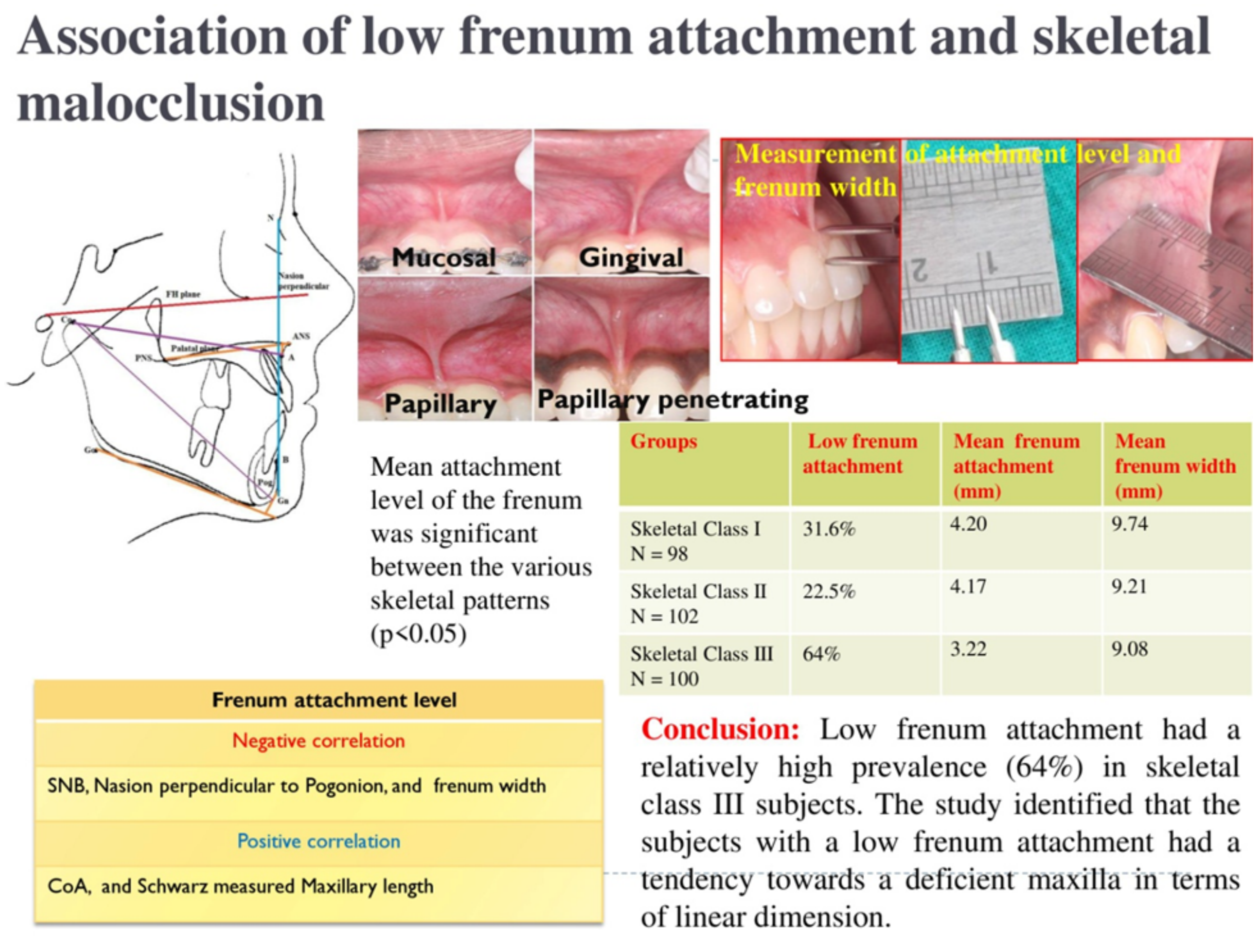


Fig. 3: Representation of graphical abstract

Table 1:

Angular measurements	
SNA	Anteroposterior relationship of the maxillary basal arch on the anterior cranial base
SNB	Anteroposterior relationship of the mandibular basal arch on the anterior cranial base
ANB	Anteroposterior relationship of maxilla to mandibular apical bases
Beta angle	Indicator of skeletal anteroposterior dysplasia
Linear measurements	
Nasion perpendicular to point A	Anteroposterior orientation of the maxilla relative to the cranial base
Nasion perpendicular to Pogonion	Anteroposterior orientation of the mandible relative to the cranial base
Co-A	Effective maxillary length
Co-Gn	Effective mandibular length
Effective Maxillary length of Schwarz	Linear measurement along the palatal plane from the projected point A to posterior nasal spine
Corpus length of Schwarz	Linear measurement along the inferior border of the mandible from the projected point Pogonion to Gonion
Wits appraisal	Maxillo-mandibular relation based on the occlusal plane

Table 2: Descriptive statistics of age, gender, Betaangle, ANB angle, and Wits appraisal in the three skeletal groups

			Age(years)	Beta angle (^{0})	ANB (^{0})	Wits appraisal (mm)
Groups	Gender		Mean± SD	Mean±SD	Mean±SD	Mean±SD
Class I	Female	59	17.97±3.66	30.07±2.74	3.68±2.02	1.44±1.77
	Male	39	20.38±5.11	30.54±2.63	3.43±1.60	1.90±2.91
	Total	98	18.93±4.43	30.26±2.70	3.58±1.86	1.63±2.29
Class II	Female	53	18.21±4.30	24.83±3.83	6.27±1.89	4.70±3.02
	Male	49	17.02±3.98	23.29±3.06	6.34±2.06	5.61±3.01
	Total	102	17.64±4.17	24.09±3.55	6.30±1.97	5.14±3.04
Class III	Female	68	18.81±5.13	38.51±5.36	-1.14±3.10	-5.00±4.19
	Male	32	18.06±5.35	40.16±5.26	-1.93±3.22	-5.84±3.71
	Total	100	18.57±5.18	39.04±5.36	-1.39±3.14	-5.27±4.04

Evaluation of mean frenum attachment among the 3 skeletal groups by applying ANOVA established a high statistical significance (p<0.01). Descriptive statistics and statistical comparisons of the attachment and width of the frenum in 3 skeletal groups were shown in Table 3. The mean attachment level of the frenum in skeletal class I, class II and class III were 4.20 mm, 4.17 mm, and 3.22 mm respectively. The mean width of the frenum in skeletal class I, class II and class III were 9.74 mm, 9.21 mm, and 9.08 mm respectively. The mean attachment level of the frenum in class III subjects was significantly reduced compared with that of the other groups (p<0.01) and statistically insignificant difference was found in the width of the frenum among the groups. Intra-group differences were analyzed using Post hoc multiple analyses with Bonferroni correction. It was thereby determined that the mean attachment level of the frenum was statistically significant between class I and III and also between class II and III.

The prevalence of normal and low frenum attachment in the study sample was 60.6% and 39.3% respectively (Table 4). While 64% of the class III subjects had low frenum attachment, only 31.6% of class I and 22.5% of class II subjects had low frenum attachment and was found to be highly significant (p<0.01) by applying the Chi-square test. Mucosal type of frenum was more prevalent in class I and class II subjects followed by gingival attachment.

Pearson correlation analysis was applied for determining the relationship between the frenum attachment level and cephalometric variables (Table 5). The attachment level of the frenum had a significant positive correlation with CoA and Schwarz Maxillary length. A significant negative correlation was noted between the frenum attachment level, frenum width, SNB, and Nasion perpendicular to Pogonion (p<0.01). However, the frenum attachment did not reveal any significant correlations with SNA and Nasion perpendicular to point A. The width of the frenum was not subjected to correlation analysis because the mean difference between the skeletal groups was determined to be insignificant.

4. Discussion

The findings of the present study shed light on the attachment level and width of the frenum in routine clinical practice. Kakodkar et al. asserted that the maxillary labial frenum is a significant anatomical landmark that serves as a clinical diagnostic marker.[14] Moreover, Mintz et al. also mentioned that an abnormal frenum is associated with syndromic and non-syndromic conditions.[15] The position of the frenum follows the normal development of the contiguous dental and premaxillary structures.[16] However, a detailed review of literature subsumes barely any mention of the prevalence of the frenum in various skeletal patterns.

The mean attachment level of the frenum was found to be highly significant between the groups. In the present study, papillary and papillary penetrating type of maxillary labial frenum was more prevalent among class III subjects indicating the extension of fibers of the frenum close to the gingival margin. A low frenum attachment presents as a wide fan-shaped attachment of the upper lip and bevels downward between the central incisors and inserted into the palatine papilla.[16] Papillary and papillary penetrating type of frenum is believed to be pathological if it subsists beyond the eruption of permanent canines.[17]

Various studies highlight that the prime role of the frenum is to maintain the balance between the lip musculature and tongue with the growing bones. A low frenum attachment may affect the movement of these structures, which in turn may affect on the position of jaws and arrangement of dentition.[18,19] Dewel asserted that the normal maxillary labial frenum culminates at a point 4 mm to 5 mm above the interproximal gingiva between the central incisors.[16] The methodology used in the present study is concurrent with a similar study conducted by Diaz-Pizan et al. and Ruli et al. for quantifying the insertion level of the frenum fibers in determining the association between the abnormal frenum and midline diastema.[2,20]

Apical migration of the frenum takes place with the vertical growth of the maxillary alveolar process and intra-alveolar eruption of the permanent maxillary anterior teeth.[2] Any impediment of this normal growth process in the

Table 3: Comparison of mean attachment level and width of the frenum in the 3 skeletal groups by ANOVA and Bonferroni correction

	ANOVA				Bonferroni correction		
Frenum	Skeletal		Mean±SD (mm)	p-value	I-II	II-III	I-III
Attachment level	Class I	98	4.20±1.59	<0.001**	1.00	<0.001**	<0.001**
	Class II	102	4.17±1.54				
	Class III	100	3.22±1.35				
	Total	300	3.86±1.56				
Width	Class I	98	9.74±2.35	0.13	0.36	1.00	0.16
	Class II	102	9.21±2.22				
	Class III	100	9.08±2.58				
	Total	300	9.34±2.40				

**highly significant

Table 4: Comparison of various types of frenum in the study sample

	Normal frenum		Low frenum attachment				
Skeletal groups	Mucosal	Gingival	Papillary	Papillary penetrating	Total	Chi-square	p-value
Skeletal class I (n)	41	26	26	5	98	48.21	<0.001**
% within skeletal groups	41.8%	26.5%	26.5%	5.1%	100%		
% within frenum groups	45.1%	28.6%	26.8%	23.8%	32.7%		
% of total	13.7%	8.7%	8.7%	1.7%	32.7%		
Skeletal class II (n)	40	39	18	5	102		
% within skeletal groups	39.2%	38.2%	17.6%	4.9%	100%		
% within frenum groups	44.0%	42.9%	18.6%	23.8%	34%		
% of total	13.3%	13.0%	6.0%	1.7%	34%		
Skeletal class III (n)	10	26	53	11	100		
% within skeletal groups	10.0%	26.0%	53.0%	11.0%	100%		
% within frenum groups	11.0%	28.6%	54.6%	52.4%	33.3%		
% of total	3.3%	8.7%	17.7%	3.7%	33.3%		
Total (n)	91	91	97	21	300		
% within skeletal groups	30.3%	30.3%	32.3%	7.0%	100%		
% within frenum groups	100.0%	100.0%	100.0%	100.0%	100%		
% of total	30.3%	30.3%	32.3%	7.0%	100%		

**highly significant

Table 5: Pearson correlation analysis between attachment level of the frenum and cephalometric variables in the study sample

	Frenum attachment	
	Correlation coefficient (r)	p-value
SNA	-0.07	0.23
SNB	-0.27	<0.001**
Nasion perpendicular to point A	-0.06	0.28
Nasion perpendicular to Pogonion	-0.24	<0.001**
Co-A	0.12	0.05*
Co-Gn	0.05	0.36
Schwarz Measured Maxillary length	0.13	0.03*
Corpus length Schwarz	-0.03	0.63
Width of the frenum	-0.28	<0.001**

*significant; **highly significant

premaxillary area tends to retain the frenum close to the gingival margin even after the eruption of the permanent dentition.[16] The apparent migration of the attachment may, in fact, simply represent apposition on the alveolar process. If there is less such apposition, the frenum will have a more gingival attachment. Also, if the maxilla is retruded or small for some other reason (poor growth of synchondroses or septum, basicranial flexion, early suture fusion, etc.),[21] and there would be less space on the maxilla anteriorly and this too could cause a more gingival attachment level. According to the findings of the present study, only the linear cephalometric measurements reflecting maxillary length exhibited a significant correlation with the attachment level of the frenum. Thus it is not surprising that a low frenum attachment is more commonly found in Class III malocclusions caused due to the small maxilla. An underdeveloped maxilla would leave the otherwise fairly normal size frenum to appear overdeveloped.

Frankel et al. also shared a similar view that the translative maxillary growth and the alveolar basal bone development eventuate from the pull on the septopremaxillary ligament.[22] An example of this is noted in the case of the FR-3 (Frankel III) appliance used for the sagittal correction of the maxilla. In all probability, the functional activity of the fibers of the SPL enclosed within the low frenum are compromised as they are trapped in the periosteum of the interincisal suture.[23] Thus the absence of the muscle pull along with the tension of these tissues could act similar to scar tissue retarding growth.[24] Furthermore, the low frenum may restrict the movement of the upper lip which in turn strongly influences the angulation of the maxillary anterior teeth.[18,25]

The advancement of the midface could be the result of soft tissue matrices in which the skeletal elements are embedded. This forms the fundamental premise of Functional matrix theory. Furthermore, Servosystem model of the Petrovic describes that the displacement of the midface is mediated through the direct thrust of the nasal septum in conjunction with the nasolabial muscles and the maxillary labial frenum and SPL.[26–29] Similarly, Delaire has also entrenched that the anatomic-neurophysiologic interaction between the labial frenum, SPL and interincisal suture serves as a determining factor of vertical and anteroposterior maxillo-mandibular relation.[30] Thus, preserving the integrity of SPL and musculature of labioseptopremaxillary region facilitates normal anteroposterior midfacial growth.[7,11,31,32]

Despite the various clinical opinions concerning the abnormal maxillary labial frenum and midline diastema over the years,[1,6,33,34] this is one of the initial reports on the association between the low frenum attachment and skeletal patterns. Clarification of such a relationship between the labial frenum and maxillary growth could permit a better rationale for the treatment of Class III malocclusion.[9,11,30,31,35] The results of this study revealed the association between the Class III malocclusion and the low attachment level of the frenum. While the phenotype of an individual is inevitably the result of both genetic and environmental factors, further study is needed to clarify the cause and effect.

5. Conclusion

The present study revealed that low frenum attachment was more common in subjects with skeletal class III malocclusion. The mean attachment level of the frenum in skeletal class III subjects was found to be significantly closer to the gingival margin than that of class I and class II subjects. Statistically significant correlations were also found between the frenum attachment level and cephalometric variables such as CoA, and Schwarz measured maxillary length. Subjects with low frenum attachment had a tendency towards a deficient maxilla in terms of linear dimension.

6. Source of Funding

None.

7. Conflict of Interest

None to declare.

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