Correlation of Tongue Soft Tissue and Dentofacial Deformities in Retrognathism and Prognathism: a Comparative Cephalometric Study

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Abstract

Tongue is one of the important organs of our body. It plays the main role in many functions. Tongue posture also has a great significance on dentofacial deformities and the development of craniofacial structures. This study aimed to evaluate the relationship between tongue soft tissue and dentofacial deformities in Skeletal Class II (Retrognathism) and Skeletal Class III (Prognathism) groups. Cephalometric radiographs of 140 patients were randomly retrospective collected and allocated equally into 2 groups based on the ANB angle. Skeletal Class II or retrognathism was defined by ANB angle > 4°, and Skeletal Class III or prognathism was defined by ANB angle < 0°. The tongue soft tissue parameters of Skeletal Class II and Skeletal Class III were compared by the Mann-Whitney U test. The relationship between tongue soft tissue and skeletal cephalometric variables were assessed by Pearson's correlation coefficient.

The majority of the tongue variables mean (tongue length; TL, tongue height; TH, tongue-hyoid; THy) were significantly greater in Skeletal Class II than in Skeletal Class III ($p < 0.01$). The tongue tip position (TN) in Skeletal Class II was also higher but there was no significant difference. Although the values of tongue analysis in Skeletal Class II were more than in Skeletal Class III, the ratio of tongue length and tongue height (TL: TH) in both groups was approximately the same (Skeletal Class II 2.47±0.32, Skeletal Class III 2.46±0.3; p=0.904). Moreover, all tongue variables were correlated among themselves in both skeletal groups. There is a significant relationship between tongue soft tissue and dentofacial deformities. The cephalogram of tongue soft tissue revealed an exceptional degree of constancy in tongue length and tongue height ratio (TL: TH) in both skeletal groups.

Keywords: *tongue, cephalometry, dentofacial deformity, retrognathism, prognathism*

1. Introduction

Tongue is one of the important organs of our body. It plays the main role in the digestive system by crushing food against the hard palate, manipulating food for mastication, and is used in the act of swallowing. It is the primary organ of taste in the gustatory system as well. It is sensitive, kept moist by saliva, and richly supplied with nerves and blood vessels. It serves as a natural means of cleaning the teeth. It is also an important oral structure that affects speech, the position of teeth, individual social activities, and breathing. Moreover, tongue posture has a great significance in dentofacial growth and the development of craniofacial structures (Jamilian, Fattahi, & Kootanayi, 2014).

Numerous studies have reviewed the correlation between the tongue and craniofacial morphology. The previous study that measured the acceleration of tongue growth in adolescents revealed that the tongue becomes relatively larger concerning the intermaxillary space in both sexes, but this tends to occur earlier in females (Cohen, & Vig, 1976). It has been suggested that the forward tongue posture maybe prevent anterior open-bite malocclusion by limiting vertical eruption of the anterior teeth (Lowe, & Johnston, 1979). The previous research investigated subjects with different types of sagittal malocclusions; Class II malocclusion may be attributed to the tongue being in a different location than in other skeletal configurations (Ansar et al., 2015). Conversely, some researchers stated the low postured tongue contributes to the mandibular growth in a prognathic manner, resulting in skeletal class III malocclusion (Horton, Crawford, & Adamson, 1969).

The postural tongue activity was found to play an essential role in the development of dentofacial deformity (Lowe, & Johnston, 1979). The previous study presumed that the larger the ANB angle may lead to a different location of the tongue and mandible in Skeletal Class II (Ceylan & Oktay, 1995). While other researchers mentioned that the reduced maxilla and mandibular protrusion in Skeletal Class III have correlated to inferior and anterior tongue posture (Iwasaki et al., 2019).

However, a multivariate evaluation of the correlation between tongue soft tissue and dentofacial deformities has not been cleared. This study aims to document the relationship between tongue parameters at rest position and craniofacial skeletal in adults with retrognathism and prognathism.

2. Objectives

To evaluate the tongue soft tissue that affects dentofacial deformities in the Retrognathism group and Prognathism group

3. Materials and Methods

A retrospective study was conducted on lateral cephalogram of 140 patients who enrolled in the Oral and Maxillofacial Department for Orthognathic surgery between January 1, 2017, and December 31, 2019. The inclusion criteria were those older than 18 years old diagnosed with mandibular prognathism or mandibular retrognathism and who underwent bilateral sagittal setback osteotomy or bilateral sagittal advancement osteotomy, respectively. All individuals have no history of previous orofacial myotherapy or tongue exercise, frenectomy or tongue surgery, and no associated syndromes. The study was approved by The Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (HREC-DCU 2020-085).

Subject organization

The pre-surgery lateral cephalometric radiographs were selected randomly. The skeletal classification was determined by an experienced oral and maxillofacial surgeon using ANB angle measurement. The samples were allocated into 2 groups; 70 samples for each group:

1. Skeletal Class II (Retrognathic group): ANB angle > 4
2. Skeletal Class III (Prognathic group): ANB angle < 0°

Cephalometric assessment

The lateral cephalometric radiographs were obtained following the standard protocol and taken with the Frankfort horizontal plane of individuals parallel to the floor. All participants were instructed to keep teeth in centric occlusion or the rest position. The tongue and lips were relaxed by pronouncing "M," then stop after pronouncing. The exposure parameters were arranged to visualize all the landmarks.

The selected lateral cephalometric radiographs were saved from INFINITT Radiologists' PACS and converted to JPEG files to be seen in image file formats. All files were printed on 80 grams A4 papers via Microsoft Publisher. This program was used to set up the actual size of the images calibrated with the original printed film. Then the tracing process went on by using acetate papers. A single investigator performed all the tracing. This study used 15 landmarks and 13 measurements, as illustrated in Figure 1 and Table 1. The reliability of the cephalometric measurements was assessed by the same examiner by duplicating tracings on 15% cephalograms chosen randomly at intervals of 14 days.

The tongue tip position was measured by the vertical distance from the tongue tip (T) perpendicular to the SN-7^{O} plane (Figure 1) The SN-7^{O} plane was indicated by 7 degrees below the SN plane and was used to represent the horizontal reference plane (Hsu et al., 2012; Joss & Thüer, 2008).

Statistical analysis

Intra-rater reliability was measured by the intra-class correlation coefficients for linear and angular measurements. The Kolmogorov Smirnov test was used to access data normality and homoscedasticity of variances. Continuous data were summarized as mean ± standard deviation. Statistical differences in tongue variables among groups (Skeletal Class II and Skeletal Class III) were assessed by the Mann-Whitney U test. Pearson's correlation test was performed to analyze the correlation of tongue soft tissue with skeletal cephalometric variables. A value of $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS software (21.0 version).

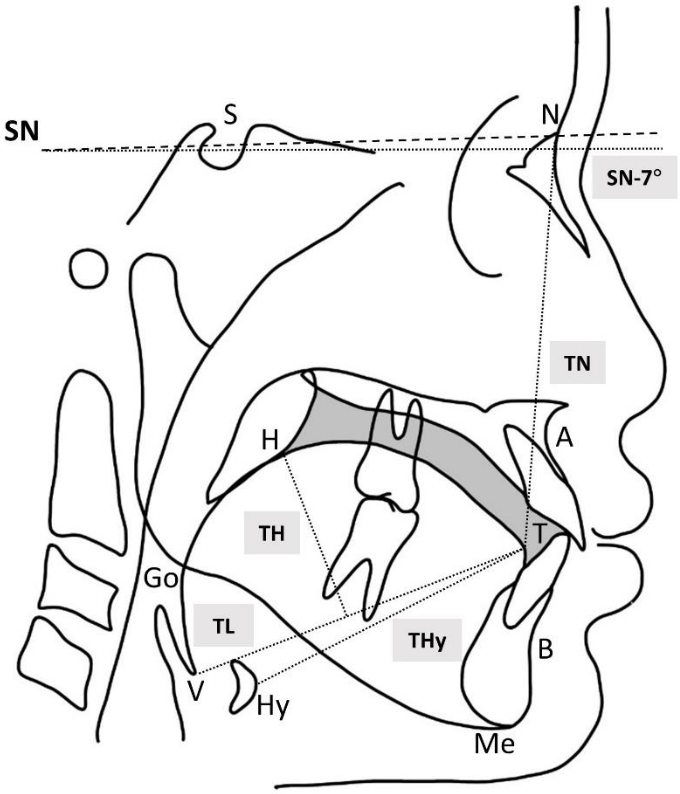

Figure 1 Cephalometric landmarks and parameters; **S** = The center of sella turcica, **N** = The most anterior point of the frontonasal suture, **A** = The innermost point on the contour of the maxilla between the anterior nasal spine and the incisor, **B** = The innermost point on the contour of the mandible between the incisor and the bony chin, **Go** = The point on the curvature of the angle of the mandible located by bisecting the angle formed by the lines tangent to the posterior ramus and the inferior border of the mandible, **Me** = The most inferior point on the mandibular symphysis in the midline, **H** = The most superior point of tongue perpendicular to the line from V to T, **T**= Tip of the tongue, **V** = Vallecula (intersection of epiglottis and base of tongue), **Hy** = The most anterosuperior point of the hyoid

4. Results and Discussion

4.1 Results

The intra-class correlation coefficients for intra-rater reliability ranged from 0.921 to 0.998 for linear measurements, ranged 0.954 to 0.988 for angular measurements, and 0.925 to 0.997 for tongue measurements. The replication reliability study showed an intra-class correlation coefficient greater than 0.9 for all variables, indicating excellent reliability of the measurements.

The total number of participants was 140; 59 males and 81 females. There was no gender difference between Skeletal Class II and Skeletal Class III. The age ranged from 18 to 58 years with a mean of 27.51 ± 7.25 years. The mean age of Skeletal Class II was significantly greater than Skeletal Class III ($p < 0.05$) (Table2).

Regarding the measurements of the ANB, which indicates the anteroposterior relation of the maxilla and mandible, the ANB angle was significantly greater in Skeletal Class III than in Skeletal Class II ($p < 0.05$).

Table 1 Cephalometric variables; Definition of linear measurement and cephalometric angles

Sagittal analysis	
SNA angle (°)	The anteroposterior position of the maxilla in relation to the cranial base is represented by the angle formed by the intersection between SN and NA lines
SNB angle (°)	The anteroposterior position of the mandible in relation to the cranial base is represented by the angle formed by the intersection between SN and NB lines
ANB angle (°)	The difference between SNA and SNB angles
Mandibular body length (Go-Me) (mm)	Distance between point Go and point Me
Tongue analysis	
Tongue length (TL; T-V) (mm)	The distance between tongue tip (T) and vallecula (V) point
Tongue height (TH; H-VT) (mm)	The distance of the perpendicular line to the mid of the T-V line (It measures the height of the tongue during the rest and centric occlusion)
Tongue-hyoid (THy; T-Hy) (mm)	The distance between tongue tip (T) and hyoid (Hy) point
Tongue tip position (TN; T-N; mm)	The vertical distance of the tongue tip (T) from the N point denoted the superoinferior position of the tongue (The more value means the lower tongue position)

Almost the mean of tongue variables (tongue length; TL, tongue height; TH, tongue-hyoid; THy) was significantly greater in Skeletal Class II than in Skeletal Class III ($p < 0.01$). The tongue tip position (TN) in Skeletal Class II was also higher but there was no significant difference. Although the values of tongue analysis in Skeletal Class II were more than in Skeletal Class III, the ratio of tongue length and tongue height (TL: TH) in both groups was approximately the same. The results also revealed an exceptional degree of constancy in tongue length and tongue height ratio (TL: TH) in both skeletal groups (Table 2).

The majority of tongue variables and ANB angle had a significant correlation which represented a relationship between tongue soft tissue and types of skeletal classifications. Moreover, all tongue variables were correlated among themselves in both Skeletal Class II and Skeletal Class III, especially tongue length (TL) and tongue-hyoid (THy) which had a relationship in strong level (Table 3).

4.2 Discussion

According to a previous report, the growth of soft tissues has a substantial impact on skeletal growth (Moss, & Salentijn, 1969). This study is the first that investigates the tongue variables with craniofacial dimension-matched Skeletal Class II and Skeletal Class III. The cephalometric analysis enables the inspection of the skeletal deformities as well as soft tissue structure. A lateral cephalogram is a 2-dimensional analysis that is simple, non-invasive, and inexpensive. It is widely used for investigation and provides reliable information on craniofacial skeletal with less radiation than computed tomography, a 3-dimensional analysis (Ryu et al., 2015).

The mean values of tongue length, tongue height, and tongue-hyoid showed significantly higher in Skeletal Class II than in Skeletal Class III ($p < 0.01$). These presented results seem to support the previous theory that variations in the tongue may affect maxillofacial development (Yoon et al., 2017). A significant correlation between short tongue length and a low ANB angle was observed, which was also supported by earlier research (Lowe et al., 1985). Our results entirely agree with the previous report that performed measurements of tongue cross-sectional area and craniofacial dimensions using cephalograms (Tsuiki et al., 2008). This report demonstrated significantly increased tongue size in the long maxilla and short mandible-presumably the enlarged tongue length and height resulting in pushing maxilla forward and protrusion. The reduced mandible may also decrease airway space, inducing forward tongue posture to maintain the airway.

Table 2 Cephalometric characteristics of Skeletal Class II and Skeletal Class III

		Skeletal Classification		
		Class II (n=70) (Mean±SD)	**Class III** (n=70) (Mean±SD)	***p*-value**
Demographic data				
Gender (n)	Male	30	29	.864
	Female	40	41	
Age (years)		29±7.65	25.64±5.66	< .001**
Sagittal analysis				
ANB (°)		6.79±1.35	-7.56±2.44	< .001**
Tongue analysis				
Tongue length (TL) (T-V; mm)		70.24±7.31	63.9±6.29	< .001**
Tongue height (TH) (H-VT; mm)		28.66±3.23	26.23±3.4	< .001**
Tongue-hyoid (THy) (T-Hy; mm)		60.54±8.08	54.53±5.82	< .001**
Tongue tip position (TN) (T-N; mm)		64.3±4.62	62.44±6.69	0.1
Ratio				
Tongue length-height ratio (TL:TH)		2.47±0.32	2.46±0.3	.904

**Significant at p-value < .05*
***Significant at p-value < .01 by Mann-Whitney U, except gender by Chi-square)*
SD=Standard deviation, mm=millimetre

Table 3 Pearson correlation between ANB to tongue length (TL), tongue height (TH), tongue-hyoid (THy), and tongue tip position (TN), and the correlation among tongue variables in Skeletal Class II and Skeletal Class III

		Tongue analysis (mm)							
		Skeletal Class II				**Skeletal Class III**			
Sagittal analysis		**TL (T-V)**	**TH (H-VT)**	**Thy (T-Hy)**	**TN (T-N)**	**TL (T-V)**	**TH (H-VT)**	**THy (T-Hy)**	**TN (T-N)**
ANB (°)	Correlation	.280*	.119	.300*	.001	.271*	.262*	.255*	.031
	p-value	.019	.326	.012	.992	.023	.028	.033	.798
Tongue analysis									
Tongue length (TL) (T-V; mm)	Correlation	1	.318**	.918**	.176	1	.470**	.869**	.257*
	p-value		.007	<.001	.146		<.001	<.001	.032
Tongue height (TH) (H-VT; mm)	Correlation	.318**	1	.262*	.498**	.470**	1	.362**	.285*
	p-value	.007		.028	<.001	<.001		.002	.017
Tongue-hyoid (THy) (T-Hy; mm)	Correlation	.918**	.262*	1	.192	.869**	.362**	1	.300*
	p-value	<.001	.028		.111	<.001	.002		.012
Tongue tip position (TN) (T-N; mm)	Correlation	.176	.498**	.192	1	.257*	.285*	.300*	1
	p-value	.146	<.001	.111		.032	.017	.012	

**Significant at p-value < .05, **significant p-value < .01*

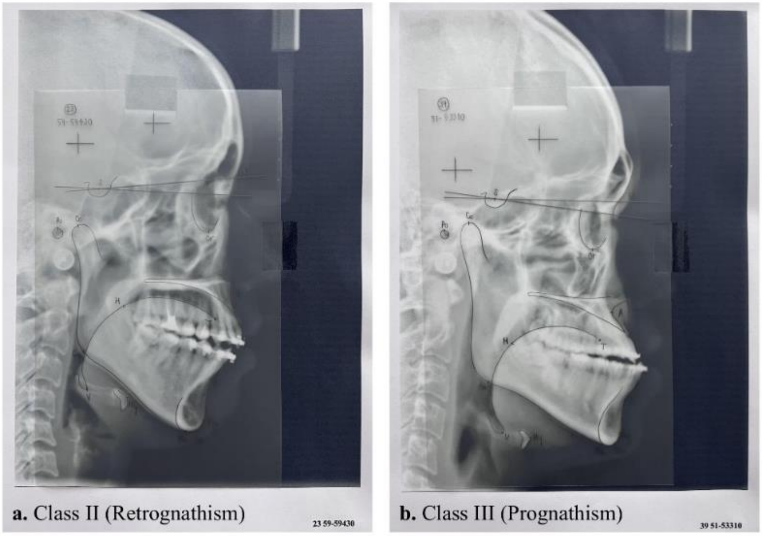

Figure 2. The examples of cephalometric radiographs tracing in 2 skeletal patterns;
a. Skeletal Class II (Retrognathism group), **b.** Skeletal Class III (Prognathism group)

On the other hand, the mean values of tongue variables in Skeletal Class III were supposed to be higher than in Skeletal Class II as the pathogenesis of Skeletal Class III seemed to have a more oversized tongue (Iwasaki et al., 2019). Previous studies reported that tongue length and tongue volume in Skeletal Class III was greater than in Skeletal Class II (Iwasaki et al., 2019; Kalogotra, & Mushtaq, 2016). Subjects with Skeletal Class III tended to have tongue-tie and it could limit the tongue in the lower position (Jang et al., 2011; Primozic et al., 2013). According to this study, the measurement of tongue soft tissue was done in 2-dimensional evaluation, so tongue-tie could cause the restriction of the tongue and make tongue length short in cephalograms. The comparison of volume or other parameters of the tongue should have been investigated in a 3-dimensional evaluation.

Moreover, these findings were in contrast to some studies. The previous research investigated the association between resting tongue posture and sagittal skeletal classification by measuring the distance at 0°, 30°, 60°, 90°, 120°, and 150° between the tongue and palate contours (Fatima, & Fida, 2019). The results presented no association between resting tongue posture and skeletal classification. Another earlier study has established that subjects with a flat mandibular plane and a large ANB showed a low tongue tip position, inferior to the occlusal plane (Lowe et al., 1985). Vice versa, subjects with a steep mandibular plane revealed a tongue tip ahead over the lower incisor. However, the authors believe that these results' variations may be related to the different methodologies, including different sample sizes, ethnicities, cephalometric parameters, and examination modalities (2D or 3D evaluation).

The complete growth of the tongue was established at 18 years old (Cohen, & Vig, 1976). Simultaneously, the mandible has a pre-pubertal growth spurt. An early diagnosis of improper tongue position and early correction should be made before the tongue will be positioned at a lower level, resulting in mandibular prognathism. Before starting the orthognathic surgery, considering the tongue soft tissue factor may enhance treatment efficacy and long-term stability.

The limitation of this study is the absence of a control group due to the lack of healthy individuals who undertake lateral cephalograms. Additionally, only one experienced master's program performed all tracing analyses without a reliability test with the radiologist. Although the cephalometric radiograph was appropriately accurate, a 2-dimensional radiograph alone may not give a complete representation of 3-dimension of the tongue. Besides, the muscle forces, one of the critical factors that may affect the skeletal pattern, were not analyzed.

For further study, the norm of all tongue variables in orthognathic patients should be added to be compared with the abnormality of the deformity groups. Also, the volumetric-3-dimensional analyses are necessary to provide conclusive pieces of evidence for an imbalance of tongue-occupied space in the oral cavity that leads to dentofacial deformities. Moreover, extending the follow-up period for cephalometric analysis may prevent the tongue's effect relapse to orthognathic surgery.

5. Conclusion

This study presented a relationship between tongue soft tissue and skeletal structures. All tongue variables have a significantly greater retrognathism. Tongue soft tissue in the cephalogram presented an exceptional degree of constancy in tongue length and tongue height ratio (TL: TH) among skeletal groups. These findings would provide valuable information for proper treatment planning during skeletal development and preventing dentofacial deformity.

6. Acknowledgement

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7. References

Ansar, J., Maheshwari, S., Verma, S. K., Singh, R. K., Agarwal, D. K., & Bhattacharya, P. (2015). Soft tissue airway dimensions and craniocervical posture in subjects with different growth patterns. *The Angle orthodontist, 85*(4), 604–610.

Ceylan, I., & Oktay, H. (1995). A study on the pharyngeal size in different skeletal patterns. *American journal of orthodontics and dentofacial orthopedics, 108*(1), 69–75.

Cohen, A. M., & Vig, P. S. (1976). A serial growth study of the tongue and intermaxillary space. *The Angle orthodontist, 46*(4), 332–337.

Fatima, F., & Fida, M. (2019). The assessment of resting tongue posture in different sagittal skeletal patterns. *Dental press journal of orthodontics, 24*(3), 55–63.

Horton, C. E., Crawford, H. H., Adamson, J. E., & Ashbell, T. S. (1969). Tongue-tie. *The Cleft palate journal, 6,* 8-23.

Hsu, S. S., Huang, C. S., Chen, P. K., Ko, E. W., & Chen, Y. R. (2012). The stability of mandibular prognathism corrected by bilateral sagittal split osteotomies: a comparison of bi-cortical osteosynthesis and mono-cortical osteosynthesis. *International journal of oral and maxillofacial surgery, 41*(2), 142–149.

Iwasaki, T., Sato, H., Suga, H., Takemoto, Y., Inada, E., Saitoh, I., Kakuno, E., Kanomi, R., & Yamasaki, Y. (2017). Relationships among nasal resistance, adenoids, tonsils, and tongue posture and maxillofacial form in Class II and Class III children. *American journal of orthodontics and dentofacial orthopedics, 151*(5), 929–940.

Iwasaki, T., Suga, H., Yanagisawa-Minami, A., Sato, H., Sato-Hashiguchi, M., Shirazawa, Y., Tsujii, T., Yamamoto, Y., Kanomi, R., & Yamasaki, Y. (2019). Relationships among tongue volume, hyoid position, airway volume and maxillofacial form in paediatric patients with Class-I, Class-II and Class-III malocclusions. *Orthodontics & craniofacial research, 22*(1), 9–15.

Jamilian, A., Fattahi, F. H., & Kootanayi, N. G. (2014). Ankyloglossia and tongue mobility. *European archives of paediatric dentistry, 15*(1), 33–35.

Jang, S. J., Cha, B. K., Ngan, P., Choi, D. S., Lee, S. K., & Jang, I. (2011). Relationship between the lingual frenulum and craniofacial morphology in adults. *American journal of orthodontics and dentofacial orthopedics, 139*(4), e361–e367.

Joss, C. U., & Thüer, U. W. (2008). Stability of hard tissue profile after mandibular setback in sagittal split osteotomies: a longitudinal and long-term follow-up study. *European journal of orthodontics, 30*(4), 352-358.

Kalogotra, D. S., & Mushtaq, D.M. (2016). Position of Tongue in skeletal Class II & Class III-ACephalometric study, *IOSR Journal of Dental and Medical Sciences, 15(*4), 33-38.
Lowe, A. A., & Johnston, W. D. (1979). Tongue and jaw muscle activity in response to mandibular rotations in a sample of normal and anterior open-bite subjects. *American journal of orthodontics, 76(*5), 565–576.
Lowe, A. A., Takada, K., Yamagata, Y., & Sakuda, M. (1985). Dentoskeletal and tongue soft-tissue correlates: a cephalometric analysis of rest position. *American journal of orthodontics, 88*(4), 333–341.
Moss, M. L., & Salentijn, L. (1969). The primary role of functional matrices in facial growth. *American journal of orthodontics, 55*(6), 566–577.
Primozic, J., Farcnik, F., Perinetti, G., Richmond, S., & Ovsenik, M. (2013). The association of tongue posture with the dentoalveolar maxillary and mandibular morphology in Class III malocclusion: a controlled study. *European journal of orthodontics, 35*(3), 388–393.
Ryu, H. H., Kim, C. H., Cheon, S. M., Bae, W. Y., Kim, S. H., Koo, S. K., Kim, M. S., & Kim, B. J. (2015). The usefulness of cephalometric measurement as a diagnostic tool for obstructive sleep apnea syndrome: a retrospective study. *Oral surgery, oral medicine, oral pathology and oral radiology, 119(*1), 20–31.
Tsuiki, S., Isono, S., Ishikawa, T., Yamashiro, Y., Tatsumi, K., & Nishino, T. (2008). Anatomical balance of the upper airway and obstructive sleep apnea. Anesthesiology, 108(6), 1009–1015.
Yoon, A. J., Zaghi, S., Ha, S., Law, C. S., Guilleminault, C., & Liu, S. Y. (2017). Ankyloglossia as a risk factor for maxillary hypoplasia and soft palate elongation: A functional – morphological study. *Orthodontics , & craniofacial research, 20*(4), 237–244.