5-2024

Tongue-tie: Impact on oropharyngeal function during swallow.

Kolbie A. Vincent
University of Louisville

TONGUE-TIE: IMPACT ON OROPHARYNGEAL FUNCTION DURING SWALLOW

By

Kolbie A. Vincent

B.S.- University of Louisville,
Louisville, Kentucky
May 2021

A Dissertation
Submitted to the Faculty of the
School of Medicine of the University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Master of Science
in Communicative Disorders

Department of Otolaryngology – Head/Neck Surgery and Communicative Disorders
University of Louisville
Louisville, Kentucky

May 2024

TONGUE-TIE: IMPACT ON OROPHARYNGEAL FUNCTION DURING SWALLOW

By

Kolbie A. Vincent

B.S.- University of Louisville
Louisville, Kentucky
May 2021

A Thesis Approved on

April 11th, 2024

by the following Thesis Committee:

_____
Rhonda Williams, Ed.D, Thesis Advisor

_____
Michael Frazure, Ph.D.

_____
Alan Smith, Ed.D.

DEDICATION

To my mother, Terena, who never saw this adventure. Rest assured; I will catch you up one day.

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my thesis advisor, Dr. Rhonda Mattingly-Williams for her guidance throughout this process. Without her expertise and mentorship, this work would not have been possible. My sincere appreciation also goes to my family, friends, and especially my husband Ben. Their unwavering support, understanding, and belief in me have been a constant source of strength throughout this thesis project and my academic endeavors. This accomplishment would not have been possible without their encouragement. Thank you.

ABSTRACT

TONGUE-TIE: IMPACT ON OROPHARYNGEAL FUNCTION DURING SWALLOW

Kolbie A. Vincent

April 11th, 2024

Swallowing is an intricate process involving over 50 muscle pairs and numerous nerves, with dysphagia resulting from deficits in various stages (Hennessy & Goldenberg, 2016). Lingual restriction may adversely impact swallowing function, affecting bolus preparation, size, and overall efficiency. Tongue-tie can pose challenges to speech, chewing, and swallowing (Becker & Mendez, 2022; Chaubal et al, 2011; García-Pola, M. J., et al., 2002). This pilot study seeks to determine how tongue-tie affects swallowing function in an adult male, and whether surgical revision of a submucosal lingual tether leads to measurable changes in oropharyngeal swallow function. Results showed inconsistent changes in diameter and area measurements and in MBSImP™© scoring for swallow function post-frenectomy. Further research is needed to explore therapy's influence on swallow outcomes after a frenulectomy procedure in a larger patient sample undergoing tongue-tie surgical revision.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER 1

INTRODUCTION

Swallowing

Mastication and deglutition are complex processes that involve precisely timed sequences and coordination of over 50 pairs of muscles and numerous nerves during the process of moving food through the phases of a normal swallow (Hennessy & Goldenberg, 2016). The process of swallowing involves 4 stages: Oral preparatory, Oral, pharyngeal, and esophoageal (Dodds & Stewart & Logemann, 1990; Logemann, 1998, Matsuo & Palmer, 2008; Frazure, 2023). The oral preparatory stage is characterized by liquid being held, food being manipulated, and solids being masticated to form a bolus (Logemann, 1984, 1998). During the oral stage, the bolus is transported to the back of the oral cavity to be swallowed (Logemann, 1984, 1998, 2007; Matsuo & Palmer, 2008). Tongue mobility plays a critical role during the oral preparatory and oral stages, as it supports mastication, bolus formation, and anterior-posterior bolus movement (Abd-el-Malek, 1955; Matsuo & Palmer, 2008).

The pharyngeal stage of swallow corresponds with the pharyngeal swallow reflex, which is normally evoked when a bolus contacts the anterior faucial aches and/or pharyngeal surface (Logemann, 2007; Pitts & Iceman, 2023; Frazure, 2023). Several movements are involved in pharyngeal bolus transit: The soft palate elevates to close the velopharyngeal port; the hyoid bone and larynx are superiorly and anteriorly elevated to

assist with closure of the airway; and synchronized tongue base retraction, pharyngeal constriction and upper esophageal sphincter relaxation propel the bolus through the pharynx and into the cervical esophagus (Abd-el-Malek, 1955; Logemann, 2007; Matsuo & Palmer, 2008; Pitts & Iceman, 2023).

During the esophageal stage, ingested material is moved downward by wavelike esophageal peristalsis and gravity (Logemann, 1984; Matsuo & Palmer, 2008; Pitts & Iceman, 2023). Once the bolus passes through the lower esophageal sphincter it enters the stomach (Logemann, 1984; Logemann, 1998; Matsuo & Palmer, 2008).

A deficit during any part of these swallow stages can result in dysphagia (Matsuo & Palmer, 2008). Factors such as such as medical conditions, muscular disorders, and structural abnormalities can cause the diagnosis (O'Rourke et al., 2014). Appreciating these barriers to swallow are critical when understanding how to diagnose and treat swallowing disorders effectively. A deficit in tongue mobility can greatly impact both mastication and deglutition (Abd-el-Malek, 1955; Moulton et al., 2018). This condition will be further investigated in this research study.

Tongue-Tie

The tongue is a muscular and sensory structure that plays a critical role beginning in utero and continues throughout the life span (Abd-el-Malek, 1955). During fetal development, the tongue's positioning and movements are instrumental in craniofacial development, preventing premature fusion of the palate and jaw by its downward and forward actions (Hong et al., 2015; Katsube et al., 2021). The proper positioning of the tongue also aids in the formation of the oral cavity into its optimal form (Siebert, 1986), which accommodates palate formation (Diewert & Lozanoff, 1993; Katsube et al., 2021).

As development progresses, the tongue allows humans to suckle, turn solid food into swallowable mash, and aids in other essential functions such as speech and taste (Maynard et al., 2020).

Ankyloglossia, or tongue-tie, exists when the frenulum that connects the underside of the tongue to the floor of the mouth, is abnormally tight, short, or thick (Francis et al., 2015; Daggumati et. al., 2019). The congenital anomaly restricts the tongue's overall range of motion (Francis et al., 2015), and occurs in up to approximately 1%-10% of newborns (Becker & Mendez, 2022) and 0.1% to 2.07% of individuals of all ages (Chaubal et al., 2011; García-Pola et al., 2002). Lack of mobility of the lingual muscles can impact speech, chewing, swallowing, oral hygiene, breathing functions, temporomandibular function, and sleep (Zaghi et al., 2019; Lalakea & Messner, 2003; Williams & Waldron, 1985). Adults with ankyloglossia who have not been diagnosed or treated have likely developed strategies to compensate for the effects of reduced tongue mobility (Zaghi et al., 2019; Frezza et al., 2023). Despite the ability to use compensation strategies, it is known that tongue-tie can continue to cause functional difficulties and impact aspects of oral health and overall well-being (Santiago, 2021; Zaghi et al., 2019).

Tongue-Tie Diagnosis

Diagnosis of tongue-tie should be performed through a comprehensive standardized evaluation of the tongue's anatomical and functional characteristics, mobility, and quality of movement (Segal & Stephenson & Feldman, 2007). Assessment of craniofacial development, resting tongue position, and reflexes must be performed, and in some cases, feeding trials might be necessary to determine severity (Walsh & Benoit, 2019).

Several classification systems have been developed to evaluate and describe the lingual frenulum in newborns. The Kutlow grading system uses measurements of the length of the "free tongue" from the point of frenulum attachment to the tongue's tip. For this, a measurement of greater than 16mm is considered normal. Anything below this is classified into stages ranging in 4 classes of ankyloglossia from mild (12-16mm) to complete (<3mm) (Kutlow, 1999). The Coryllos classification comprises four frenulum types determined by attachment points (Coryllos et al., 2004). This classification also encompasses 4 types of ankyloglossia, including criteria representative for the type of frenulum, such as the posterior ankyloglossia, which will be discussed later in this literature review.

There are also functional anatomic scales, like the Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF) and the Bristol Tongue Assessment Tool (BTAT), which provide objective determinations for tongue-tie by striving to incorporate functionality (Amir et al., 2006). The HATLFF is a 12-point scale including anatomical (5) and functional (8) criteria. A score of 24 indicates within functional limits (Amir et al., 2006). The BTAT was created in reference to the HATLFF, with a scale with 4 items grading tongue tip appearance, alveolar attachment location, tongue lift, and tongue protrusion (Ingram et al., 2015).

While these grading systems play a critical role in diagnosis, there still are many cases where patients meet structural definitions of ‘normal’, yet still have deficits (Zaghi & Valcu-Pinkerton, 2018). Because of this, an alternate classification system was created to prioritize tongue mobility rather than looking at the tongue-tie alone (Yoon et al., 2017). The tongue range of motion ratio (TRMR) is derived by measuring the oral

opening when the tongue tip is elevated to the incisive papilla, measuring of the maximum degree of oral opening, and comparing the difference between maximal tongue elevation and maximum oral opening (Zaghi et al., 2021; Yoon et al., 2017). TRMR can be used to measure elevation of the posterior portion of the tongue rising as well (Zaghi et al., 2021). Measurements are taken when the tongue approximates the incisive foramen tongue function during a suction hold (Zaghi et al., 2021; Yoon et al., 2017). The overall percentage is categorized into grade levels ranging 1-4, with grade 1 (>80%) being in the top 10^{th} percentile and grade 4 (<25%) in the bottom 10^{th} percentile (Yoon et al., 2017).

Tongue-Tie Management

Ankyloglossia may be surgically managed and can be categorized into three different procedures (Chaubal et al., 2011). Frenectomy is defined as a complete removal of the frenulum, frenuloplasty involves an incision of the lingual frenulum with a rearrangement of the tissue (eg, horizontal to vertical, z-plasty) (Chaubal et al., 2011; Messner et al., 2020), and the most common procedure is frenotomy or frenulectomy (Brzęcka et al., 2019). Typically performed in an outpatient setting, this divides the tight or thickened frenulum that is attached to the tongue (Baker & Carr, 2015; Brzęcka et al., 2019). This surgery has become increasingly common for health professionals to complete, with procedures nearly doubling since the year 2000 (Larrain, 2022; Baxter, 2018). However, in the last 50 years, tongue-tie and the manner in which the condition is managed has become a point of controversy (Ruffoli, 2005; Larrain, 2022).

Controversy Among Professionals

There is a lack of consensus among healthcare professionals regarding the definition, diagnosis, treatment, and extent to which a tongue-tie causes functional issues,

as well as the ethical considerations surrounding the care of infants in vulnerable situations (Larrain, 2022; Messner & Lalakea, 2000; Baxter, 2018; Olive, 2016). A study by Messner & Lalakea, (2000) surveyed practicing otolaryngologists, pediatricians, speech-language pathologists, and lactation consultants to investigate the potential link between tongue-tie and sucking or feeding issues in infants. The results indicated that 90% of pediatricians, 70% of otolaryngologists, and 70% of speech-language pathologists felt that ankyloglossia rarely causes feeding problems. In contrast, 69% of lactation consultants held the opinion that tongue-tie frequently disrupt breastfeeding in infants (Messner and Lalakea, 2000).

Larrain (2022) states that the controversy around tongue-tie "pits varieties of medicine that emphasize surgical intervention against those that emphasize care and support" (Larrain, 2022, p 447). Differences in opinion relate in part to varying methods used in research studies but in a greater degree are due to the lack of consensus over a definition of tongue-tie (Baxter, 2018; Messner & Lalakea, 2000). For example, the term *anterior* tongue-tie is used by medical professionals when referring to the prominent restrictive frenulum located on the front portion of the tongue (Messner & Lalakea, 2000; Mills et al., 2019; Larrain, 2022). The term *posterior* tongue-tie is characterized by a restrictive frenulum that is further back under the tongue, is best identified by palpation, or by using a grooved director to visualize the restriction under the mucosa (Chu & Bloom, 2009; Mills et al., 2019; Larrain, 2022). Diagnosis of the tongue-tie that is more posterior has sparked controversy due management of it requiring an incision to the sub-lingual space, and disagreement among health professionals about whether the tongue tie exists. (Larrain, 2022).

Tongue-Tie and Swallowing Function

Lingual restriction has the potential to negatively impact swallowing function (Moulton et al., 2018; Dydyk et al., 2023). Oliver, 2016 assessed data from 8 patients diagnosed with ankyloglossia relating to oropharyngeal transit time, masseter contraction, and laryngeal timing during swallowing and force measurements based on the Iowa Oral Performance Instrument (IOPI) of the tongue tip, dorsum, and lips comparing to norms documented in an earlier study by Holtzer et al (2011). The findings revealed that all participants experienced a significant delay in oropharyngeal transit time across bolus consistencies and had notable variations in masseter contraction, pronounced delays in laryngeal timing, and diminished strength in the tongue tip, dorsum, or lips (Oliver, 2016).

Restricted tongue mobility can result in deficits in the oral preparatory stage which may include challenges adequately mixing saliva with food, forming an appropriate bolus size and consistency, and in efficient preparation of food boluses and liquid for swallowing (Matsuo & Palmer, 2008; Moulton et al., 2018; Frezza et al., 2023). Bolus size can impact the efficiency and safety of swallowing (Rizzo et al., 2016; Moulton et al., 2018). If the bolus is too large or poorly formed, it may be more difficult to swallow, increasing the risk of choking or aspiration (Nascimento et al., 2015). If the bolus is too small, it may affect the overall nutrition and hydration of an individual over time (Nascimento et al., 2015; Rizzo et al, 2016).

The tongue plays a crucial role in propelling the food bolus from the oral cavity to the pharynx during swallowing (Matsuo & Palmer, 2008). Restricted tongue motion can lead to dependence on compensatory muscle movements and increased effort during

swallowing (Zaghi et al., 2019; Frezza et al., 2023). Strength, coordination, and overall function of the oral and pharyngeal muscles involved in the swallowing process can be impacted (Moulton et al., 2018).

A tongue-tie can also potentially affect the oropharyngeal space and swallowing function (Correa et al, 2022). The oropharyngeal space refers to the area at the back of the mouth and throat, including the oral cavity and the pharynx (Bruss & Sajjad, 2023). This space plays a crucial role in functions such as swallowing, speech production, and breathing (Correa et al, 2022). Lingual mobility allows for contact of the tongue to the hard palate and prevents the structure from infringing on the retroglossal space (Abd-el-Malek, 1955; Moulton et al., 2018). Immobility of the tongue in which elevation to the hard palate is restricted results in expanding the posterior volume, and results in the structure invading the oropharyngeal airway (Correa et al, 2022).

Historically, tongue-tie in relation to swallowing has been studied in infants and children, with the bulk focusing on breastfeeding (Oliver, 2016). In a systematic review of the literature, Chinnadurai et al (2015) found a notable absence of studies addressing the relationship between frenotomies and non-breastfeeding outcomes.

The lack of evidence beyond breastfeeding and in the populations of children, adolescents, and adults reduces the availability of objective information regarding the long-term consequences of ankyloglossia. Without comprehensive insight into other potential implications the decision-making process regarding management of tongue-tie is limited (Chinnadurai et al, 2015).

Measuring the Pharyngeal Space

The oropharyngeal space plays an essential role encompassing not only the act of swallowing, but functions such as respiration, coughing, phonation, and fulfilling nutritional requirements (Sapienza & Hoffman Ruddy, 2013). Given these vital functions, the overall integrity of this space is crucial. There is limited research on differences in oropharyngeal diameter related to ankyloglossia specifically, but research does support the importance of oropharyngeal airway diameter in conditions association with ankyloglossia, such as obstructive sleep apnea (Ruangsri et al, 2016; Schellenberg et al, 2000). Proper dimensions and movement of the pharynx directly impact the coordination and efficiency of swallowing (Matsuo & Palmer, 2008; Hennessy & Goldenberg, 2016).

Standardized Measures of Swallow Function

A videofluoroscopic swallowing study (VFSS), also referred to as a modified barium swallow study or a videofluoroscopy, is an instrumental diagnostic procedure used to objectively evaluate swallowing function in real-time (Logemann, 1997; Martin-Harris & Jones, 2008). During the study the patient swallows contrast-enhanced food and liquid and a continuous sequence of images is captured that allows for visualization of the oral, pharyngeal, and esophageal stages of swallowing (Martin-Harris & Jones, 2008). Coordination of muscles involved in swallowing, the clearance of food and liquids to the stomach, and how swallowing physiology is influenced by bolus volume, viscosity, and compensatory strategies is evaluated (Logemann, 1997, 1999).

The Modified Barium Swallow Impairment Profile (MBSImP) is a standardized procedure for interpreting and conveying swallowing impairment characterized by specificity, consistency, accuracy, and objectivity (Northern Speech Services, 2024). This

protocol involves a detailed analysis of up to 17 specific components related to the oropharyngeal function (Martin-Harris et al., 2008; Northern Speech Services, 2024). The MBSImP has exhibited practicality in clinical settings, displaying favorable interrater reliability during standardized training. Additionally, its validity has been confirmed through content and external validation processes (Martin-Harris et al 2008).

Purpose

This study aims to widen the gap in the literature regarding the effects of tongue-tie on swallowing function in adults. The purpose of this study is to determine whether surgical revision of a posterior tongue-tie will result in measurable changes in oropharyngeal physiology during swallowing.

Hypothesis

For this study, we hypothesize that changes in oropharyngeal diameter and area, including instances of both increases and decreases, will positively influence scores, and therefore enhance swallow function, as indicated by the Modified Barium Swallow Impairment Profile (MBSImP).

CHAPTER 2

METHODOLOGY

Participants

The study included a single participant, a 26-year-old male who complained of a history of lengthy mastication of solids and persistent “pocketing”. He was evaluated and diagnosed with a posterior tongue-tie by a Board-Certified Otolaryngologist affiliated with the University of Louisville. The initial attempt at oral tether release at the Louisville Center for Voice Care was unsuccessful due to the patient's inability to tolerate the procedure. Consequently, a partially sedated frenulectomy was performed in the operating room at the University of Louisville Hospital.

Measurements

Videofluroscopy

VFSS were conducted before and after frenulectomy. The participant was in seated in an upright position to allow for a lateral viewpoint. The VFSS were conducted at the University of Louisville Hospital Outpatient Radiology by a certified speech-language pathologist. Thin liquid was administered via cup, while puree and mechanical soft viscosities were provided via spoon. Additionally, a regular viscosity food was given for each exam. The speech-language pathologist recorded swallowing events for all viscosities and during quiet breathing.

Measurements of the Oropharyngeal Space

Frame-by-frame measurements of oropharyngeal space were extracted from DICOM recordings using RadiAnt software (© 2007-2017, MicroDicom Viewer)**.** The following parameters were measured both before and after the tongue-tie release: diameter and area of the base of the tongue, position of the vallecula, and maximal distension of the upper esophageal sphincter. These measurements were taken during swallows of thin liquid, puree, mechanical soft, and regular solid foods. Still shots were captured using RadiAnt software (© 2007-2017, MicroDicom Viewer). Measures were taken independently by a graduate student in speech-language pathology and by two certified speech-language pathologists.

The oropharyngeal measurements were then examined by employing components of the Modified Barium Swallow Impairment Profile (MBSImP). The selected components for evaluation included Component 5: Oral residue, Component 6: Initiation of the pharyngeal swallow, Component 14: Pharyngoesophogeal segment opening, Component 15: Tongue base (TB) retraction, and Component 16: Pharyngeal residue

CHAPTER 3

RESULTS

Area Measurements

Measurements of area and diameter were taken at the base of tongue prior to the swallow, the vallecula prior to the swallow, and the upper esophageal sphincter during the swallow. These measurements can be seen in Table 1. The results revealed changes in both area and diameter measurements across different viscosity categories and pharyngeal locations. For example, at the base of the tongue prior to swallow, there was a consistent decrease in mean area and diameter across all viscosity categories except for the area of the semisolid consistencies, where a small increase was noted. In the vallecula, significant decreases in both area and diameter were observed in the thin and puree viscosity categories, however, increases were observed in the semisolid and solid viscosity categories. In the UES during the swallow, there was a consistent decrease in mean area and diameter in the thin category. For puree, semisolid, and solid viscosities, there were varied changes in mean area and diameter, though generally showing decreases or slight changes.

Overall, all measurements showed varied patterns of change. These findings suggest there were more diameter and area increases in higher viscosity categories overall, but no direct significant relationship can be concluded based on these results.

MBSimP™© Scoring

Table 2 represents ratings from The MBSimP, which aided in the analysis of several components of the swallow. Specifically, Component 5: Oral Residue, Component 6: Initiation of Pharyngeal Swallow, Component 14: Pharyngoesophageal Segment Opening, Component 15: Tongue Base Retraction, and Component 16: Pharyngeal Residue. Changes to MBSImP scores did not show consistent improvement in swallow function in the components evaluated. Conversely, most scores exhibited a decrease of at least one point from before to after the procedure. The most notable improvement in scores across all raters was Component 6: Initiation of Pharyngeal Swallow, where scores uniformly decreased by one point in the solid viscosities. All other components exhibited either minimal changes or decreases in swallow function scores post-frenectomy.

Additionally, Kappa Values were analyzed to measure interrater reliability across the three raters (see Table 3). For all three raters pre-frenulectomy, the average rating difference was .248. For post-frenectomy, the average rating difference across all three raters increased to .370. Using the Fleiss Kappa interpretation table (see Table 4), this interprets to a fair agreement across procedures, with a slight increase in rating differences post-frenectomy (Fleiss, 1971).

CHAPTER 4

DISCUSSION

Despite observing changes in the area and diameter of BOT, vallecula, and UES, our study did not find corresponding improvements in swallowing function as measured by scores on the MBSImP. Our findings are important because they suggest that though surgical revision of tongue-tie impacts anatomy it does not improve swallow function. This supports the merit of interdisciplinary approaches that integrate tongue-tie revision with therapies targeting muscle and/or swallow function, such as myofunctional therapy and/or speech therapy. Scarano et al. (2023) conducted a study on 130 patients with ankyloglossia who received a frenulectomy followed by oro-myofunctional therapy. Significiant improvements in speech, feeding, and sleep were noted using the 10-point Parents Speech Satisfaction (PSS) at one week and two months postoperatively (Scarano et al., 2023).

Further research also indicates that optimal and improved outcomes are attained through additional modalities following a tongue-tie release (Baxter et al., 2020; González et al., 2022), highlighting the importance of interdisciplinary collaboration. This type of collaborative care allows professionals to address a range of issues particularly concerning tongue-tie both pre and post release, targeting the issues of swallowing function, airway, dentition, lactation, and/or more if applicable. Studies also indicate the importance of analyzing both form and function when evaluating the presence of tongue-tie, further emphasizing the significance of collaborative teamwork

(International Affiliation of Tongue Tie Professionals, 2015; Brzęcka, et al, 2019; Walsh, & Tunkel, 2017).

The World Health Organization (WHO) has associated interprofessional collaboration (IPC) with enhanced outcomes across various domains, including family health, infectious disease management, humanitarian endeavors, epidemic responses, and noncommunicable diseases (Gilbert, et al, 2010). Additional research has indicated enhancements in healthcare accessibility, service coordination, safety measures, and perceived team effectiveness (Verville, et al, 2017; Lemieux-Charles & McGuire, 2006; Gilbert, et al, 2010).

Due to the general lack of consensus over the definition of tongue-tie, the overall perception of this condition varies across disciplines (Larrain, 2022; Baxter, 2018; Messner & Lalakea, 2000). Therefore, collaboration between discplines is critical when ensuring favorable patient outcomes (Green & Johnson, 2015). Consequential treatment strategies should be tailored to prioritize lingual function, emphasizing specialist IPC collaboration to extend beyond evaluation when necessary.

Limitations

This study had various limitations that should be considered when interpreting the results. Firstly, this study was limited to a single participant. A larger sample size is needed to be able to further generalize findings to a broader population. Secondly, while exercises were provided to the patient for rehabilitation purposes after the procedure, the patient admittedly did not perform them. These exercises could have impacted the

outcomes observed during the VFSS. Future directions should target how therapy influences swallow outcomes for a larger sample of patients undergoing surgical revision of tongue-tie. Additionally, it is important to note that bolus amounts administered during the VFSS were not standardized across all trials, potentially introducing confounding factors during the assessment. Future research should explore additional outcome measures and consider longitudinal follow-up to evaluate the long-term effects of frenulectomy on swallow function and patient outcomes.

Table 1

Alterations in Diameter, Area, and Standard Deviations Pre and Post Frenulectomy procedure across oropharyngeal spaces.

	Viscosity	Base of Tongue				Vallecula				UES			
		Diameter (mm)	SD (mm)	Area (mm^2)	SD (mm^2)	Diameter (mm)	SD (mm)	Area (mm^2)	SD (mm^2)	Diameter (mm)	SD (mm)	Area (mm^2)	SD (mm^2)
PRE	Thin	5.49	1.37	0.46945	0.35855	9.06	3.08	0.98645	0.88955	12.965	0.495	3.054	0.414
8/13/18	Puree	6.175	4.305	1.55235	0.92565	4.925	1.175	0.61495	0.35905	9.855	0.615	2.3205	0.0395
	Semisolid	9.815	0.285	0.82755	0.56845	6.88	0.22	1.339	1.233	9.88	0.1	2.077	0.192
	Solid	8.765	6.455	2.6964	1.8456	6.215	3.005	0.8181	0.6569	9.13	0.41	1.8275	0.3135
POST	Thin	2.17	1.08	0.27725	0.09775	3.365	0.715	0.2001	0.0859	9.56	0.11	1.6805	0.1535
7/3/19	Puree	5.97	1.04	1.2021	0.9169	3.43	0.36	0.49385	0.48215	5.325	4.295	2.238	0.104
	Semisolid	5.185	4.5	1.08175	0.62625	9.44	0.54	3.5	0.379	7.645	0.635	1.219	0.013
	Solid	5.145	1.81	0.59606	0.51195	6.1	0.15	3.5745	0.0345	7.26	0.83	2.114	0.102

Table 2

MBSimP Scores Per Rater Pre and Post Frenulectomy Procedure.

	Viscosity	Oral Residue Component 5			Initiation of Pharyngeal Swallow Component 6			Pharyngo-esophageal Segment Component 14			Tongue Base Retraction Component 15			Pharyngeal Residue Component 16		
PRE (8/13/18)	Thin	0	1	1	0	0	1	0	0	1	0	1	1	1	1	0
	Semisolid	0	2	2	3	3	3	0	0	1	1	1	0	1	1	0
	Solid	1	2	1	3	3	2	0	0	0	1	1	1	1	1	0
CCC																
Graduate Student																
POST (7/3/19)	Thin	0	1	0	0	0	1	0	0	0	1	1	2	1	2	2
	Puree	2	2	1	0	0	1	0	0	0	2	2	1	2	2	1
	Semisolid	1	2	2	3	3	3	1	1	1	1	1	1	2	2	1
	Solid	2	2	1	2	2	1	0	0	0	1	1	1	2	2	1

Note: This table is seperated by (2) CCC Speech-Language Pathologists and (1) Graduate Student in Speech-Language Pathology.

Table 3

Kappa Analysis measuring Interrater Reliability across Three Raters.

Rating Pair	Pre, all viscosities, all components	Post, all viscosities, all components
Rater 1 - Rater 2	-0.092	0.104
Rater 1 - Rater 3	0.181	0.187
Rater 2 - Rater 3	0.629	0.781
All three raters	0.248	0.37

Table 4

Fleiss Kappa Interpretation Agreement between Two or More Raters (Fleiss, 1971).

Condition	*k*	Interpretation
	< 0	Poor agreement
Subjective	0.01 – 0.20	Slight agreement
example:	0.21 – 0.40	Fair agreement
only for two	0.41 – 0.60	Moderate agreement
annotators,	0.61 – 0.80	Substantial agreement
on two classes.	0.81 – 1.00	Almost perfect agreement

REFERENCES

Abd-el-Malek S (1955). The part played by the tongue in mastication and deglutition. *J Anat* 89:250–255.

Amir, L. H., James, J. P., & Donath, S. M. (2006). Reliability of the hazelbaker assessment tool for lingual frenulum function. *International breastfeeding journal*, *1*(1), 3. https://doi.org/10.1186/1746-4358-1-3

Baker, A. R., & Carr, M. M. (2015). Surgical treatment of ankyloglossia. Operative Techniques in Otolaryngology - Head and Neck Surgery, 26(1), 28-32. https://doi.org/10.1016/j.otot.2015.01.006

Baxter, R. (2018). Tongue-Tied: How a Tiny String Under the Tongue Impacts Nursing, Speech, Feeding, and More, Alabama Tongue-Tie Centre.

Baxter, R. (2021). "Do Tongue-Ties Affect Adults? What Symptoms Do They Have?". from https://tonguetieal.com/do-tongue-ties-affect-adults-what-symptoms-do-they-have/#:~:text=How%20common%20is%20a%20tongue,of%2025%25%20if%20properly%20checked.

Baxter, R., Merkel-Walsh, R., Baxter, B. S., Lashley, A., & Rendell, N. R. (2020). Functional Improvements of Speech, Feeding, and Sleep After Lingual Frenectomy Tongue-Tie Release: A Prospective Cohort Study. *Clinical pediatrics*, *59*(9-10), 885–892. https://doi.org/10.1177/0009922820928055

Becker, S., & Mendez, M. D. (2022). Ankyloglossia. In *StatPearls*. StatPearls Publishing.

Bruss DM, Sajjad H. (2023) Anatomy, Head and Neck: Laryngopharynx. In StatPearls. StatPearls Publishing; https://www.ncbi.nlm.nih.gov/books/NBK549913/

Brzęcka, D., Garbacz, M., Micał, M., Zych, B., & Lewandowski, B. (2019). Diagnosis, classification and management of ankyloglossia including its influence on breastfeeding. Developmental period medicine, 23(1), 79–87. https://doi.org/10.34763/devperiodmed.20192301.7985

Chaubal, T. V. and M. B. Dixit (2011). "Ankyloglossia and its management." J Indian Soc Periodontol 15(3): 270-272.

Chinnadurai, S., Francis, D. O., Epstein, R. A., Morad, A., Kohanim, S., & McPheeters, M. (2015). Treatment of ankyloglossia for reasons other than breastfeeding: a systematic review. *Pediatrics*, *135*(6), e1467–e1474. https://doi.org/10.1542/peds.2015-0660

Chu, M. W., & Bloom, D. C. (2009). Posterior ankyloglossia: a case report. *International journal of pediatric otorhinolaryngology*, *73*(6), 881–883. https://doi.org/10.1016/j.ijporl.2009.02.011

Correa, E. J., et al. (2022). "Does Frenotomy Modify Upper Airway Collapse in OSA Adult Patients? Case Report and Systematic Review." J Clin Med 12(1).

Coryllos, E., Genna, C. W., & Salloum, A. C. (2004). Congenital tongue-tie and its impact on breastfeeding. *Breastfeeding: Best for mother and baby Newsletter*, 1-6.

Daggumati, S., et al. (2019). "Speech and Language Outcomes in Patients with Ankyloglossia Undergoing Frenulectomy: A Retrospective Pilot Study." OTO Open 3(1): 2473974x19826943.

Diewert, V. M., & Lozanoff, S. (1993). Growth and morphogenesis of the human embryonic midface during primary palate formation analyzed in frontal sections. *Journal of Craniofacial Genetics and Developmental Biology*, *13*(3), 162–183.

Dodds, W. J., Stewart, E. T., & Logemann, J. A. (1990). Physiology and radiology of the normal oral and pharyngeal phases of swallowing. *AJR. American Journal of Roentgenology*, *154*(5), 953–963.

Dollberg, S., Manor, Y., Makai, E., & Botzer, E. (2011). Evaluation of speech intelligibility in children with tongue-tie. Acta Paediatrica (Oslo, Norway : 1992), 100(9), 125–7. https://doi.org/10.1111/j.1651-2227.2011.02265.x.

Dydyk, A., Milona, M., Janiszewska-Olszowska, J., Wyganowska, M., & Grocholewicz, K. (2023). Influence of Shortened Tongue Frenulum on Tongue Mobility, Speech and Occlusion. *Journal of clinical medicine*, *12*(23), 7415. https://doi.org/10.3390/jcm12237415

Francis, D. O., et al. (2015). AHRQ Comparative Effectiveness Reviews. Treatments for Ankyloglossia and Ankyloglossia With Concomitant Lip-Tie. Rockville (MD), Agency for Healthcare Research and Quality (US).

Frazure, Michael. (2023). "Swallow, breathing and survival: sex-specific effects of opioids." Electronic Theses and Dissertations. Paper 4145. https://doi.org/10.18297/etd/4145

Frezza, A., Ezeddine, F., Zuccon, A., Gracco, A., Bruno, G., & De Stefani, A. (2023). Treatment of Ankyloglossia: A Review. *Children (Basel, Switzerland)*, *10*(11), 1808. https://doi.org/10.3390/children10111808

Fleiss, J. L. (1971). Measuring nominal scale agreement among many raters. *Psychological Bulletin*, *76*(5), 378–382. https://doi.org/10.1037/h0031619

García Pola, M. J., et al. (2002). "A study of pathology associated with short lingual frenum." ASDC J Dent Child 69(1): 59-62, 12.

González Garrido, M. D. P., Garcia-Munoz, C., Rodríguez-Huguet, M., Martin-Vega, F. J., Gonzalez-Medina, G., & Vinolo-Gil, M. J. (2022). Effectiveness of Myofunctional Therapy in Ankyloglossia: A Systematic Review. International journal of environmental research and public health, 19(19), 12347. https://doi.org/10.3390/ijerph191912347

Green, B. N., & Johnson, C. D. (2015). Interprofessional collaboration in research, education, and clinical practice: working together for a better future. The Journal of chiropractic education, 29(1), 1–10. https://doi.org/10.7899/JCE-14-36

Gilbert, J. H., Yan, J., & Hoffman, S. J. (2010). A WHO report: framework for action on interprofessional education and collaborative practice. *Journal of allied health*, *39 Suppl 1*, 196–197.

Hennessy, M. and D. Goldenberg (2016). "Surgical anatomy and physiology of swallowing." Operative Techniques in Otolaryngology-Head and Neck Surgery **27**(2): 60-66.

Holzer, K. L. (2011). *Swallowing function and oromyofunctional disorder across the lifespan*. Masters thesis, Idaho State University, Pocatello, Idaho.

Hong, S. J., Cha, B. G., Kim, Y. S., Lee, S. K., & Chi, J. G. (2015). Tongue Growth during Prenatal Development in Korean Fetuses and Embryos. *Journal of pathology and translational medicine*, *49*(6), 497–510. https://doi.org/10.4132/jptm.2015.09.17

Ingram, J., et al. (2015). "The development of a tongue assessment tool to assist with tongue-tie identification." Arch Dis Child Fetal Neonatal Ed **100**(4): F344-348.

International Affiliation of Tongue-tie Professionals (IATP). (2015). http://tonguetieprofessionals.org/

Katsube, M., et al. (2021). "A 3D analysis of growth trajectory and integration during early human prenatal facial growth." Scientific Reports 11(1): 6867.

Kotlow L. A. (1999). Ankyloglossia (tongue-tie): a diagnostic and treatment quandary. *Quintessence international (Berlin, Germany : 1985)*, *30*(4), 259–262.

Lalakea, M. L. and A. H. Messner (2003). "Ankyloglossia: does it matter?" Pediatr Clin North Am 50(2): 381-397.

Larrain, M. and E. G. J. Stevenson (2022). "Controversy Over Tongue-Tie: Divisions in the Community of Healthcare Professionals." Medical Anthropology 41(4): 446-459.

Lemieux-Charles, L., & McGuire, W. L. (2006). What do we know about health care team effectiveness? A review of the literature. *Medical care research and review : MCRR*, *63*(3), 263–300. https://doi.org/10.1177/1077558706287003

Logemann J. A. (2007). Swallowing disorders. *Best practice & research. Clinical gastroenterology*, *21*(4), 563–573. https://doi.org/10.1016/j.bpg.2007.03.006

Logemann, J. A. (1999). Behavioral management for oropharyngeal dysphagia. *Folia phoniatrica et logopaedica*, *51*(4-5), 199-212.

Logemann, J. A. (1998). *Evaluation and treatment of swallowing disorders* (2nd ed.). Austin, Tex.: PRO-ED.

Logemann, J. (1984). "Evaluation and Treatment of Swallowing Disorders." NSSLHA Journal **12**: 38-50.

Martin-Harris, B. and B. Jones (2008). "The videofluorographic swallowing study." Phys Med Rehabil Clin N Am **19**(4): 769-785, viii.

Martin-Harris, B., et al. (2008). "MBS Measurement Tool for Swallow Impairment—MBSImp: Establishing a Standard." Dysphagia 23(4): 392-405.

Matsuo, K. and J. B. Palmer (2008). "Anatomy and physiology of feeding and swallowing: normal and abnormal." Phys Med Rehabil Clin N Am **19**(4): 691-707, vii.

Maynard, T. M., Zohn, I. E., Moody, S. A., & LaMantia, A. S. (2020). Suckling, Feeding, and Swallowing: Behaviors, Circuits, and Targets for Neurodevelopmental Pathology. Annual review of neuroscience, 43, 315–336. https://doi.org/10.1146/annurev-neuro-100419-100636

Messner, A. H., & Lalakea, M. L. (2000). Ankyloglossia: controversies in management. *International journal of pediatric otorhinolaryngology*, *54*(2-3), 123–131. https://doi.org/10.1016/s0165-5876(00)00359-1

Messner, A. H., et al. (2020). "Clinical Consensus Statement: Ankyloglossia in Children." Otolaryngology–Head and Neck Surgery 162(5): 597-611.

Mills, N., Pransky, S. M., Geddes, D. T., & Mirjalili, S. A. (2019). What is a tongue tie? Defining the anatomy of the in-situ lingual frenulum. *Clinical anatomy (New York, N.Y.)*, *32*(6), 749–761. https://doi.org/10.1002/ca.23343

Moulton, K., et al. (2018). Examining the effects of ankyloglossia on swallowing function. International Journal of Orofacial Myology, 44(1), 5-21. DOI: https://doi.org/10.52010/ijom.2018.44.1.1

Nascimento, W. V., Cassiani, R. A., Santos, C. M., & Dantas, R. O. (2015). Effect of bolus volume and consistency on swallowing events duration in healthy

subjects. *Journal of neurogastroenterology and motility*, *21*(1), 78–82. https://doi.org/10.5056/jnm14055

Northern Speech Services. (2024). *What is the MBSIMPTM approach?*. MBSImP | Modified Barium Swallow Impairment Profile. https://www.northernspeech.com/MBSImP/?q=MBSImP%2F

Obladen, M. (2010). Much ado about nothing: two millenia of controversy on tongue-tie. Neonatology, 97(2), 83–89. https://doi.org/10.1159/000235682

Olive. M. (2016). *The relationship between ankyloglossia and oropharyngeal dysphagia.* Master's thesis, Idaho State University, Pocatello, Idaho.

O'Rourke, F., et al. (2014). "Swallowing and oropharyngeal dysphagia." Clinical Medicine 14(2): 196-199.

Pitts, T., & Iceman, K. E. (2023). Deglutition and the Regulation of the Swallow Motor Pattern. *Physiology (Bethesda, Md.)*, *38*(1), 0. https://doi.org/10.1152/physiol.00005.2021

Rizzo, K., Mong, L., Helser, M., Howard, N., Katz, I., & Scarborough, D. (2016). Effects of bolus size on swallow safety: A systematic review of external evidence. *EBP Briefs*, *11*(3), 1–12. Bloomington, MN: NCS Pearson, Inc.

Ruangsri, S., Jorns, T. P., Puasiri, S., Luecha, T., Chaithap, C., & Sawanyawisuth, K. (2016). Which oropharyngeal factors are significant risk factors for obstructive sleep apnea? An age-matched study and dentist perspectives. *Nature and science of sleep*, *8*, 215–219. https://doi.org/10.2147/NSS.S96450

Ruffoli, R., et al. (2005). "Ankyloglossia: a morphofunctional investigation in children." Oral Dis 11(3): 170-174.

Santiago, K. (2021, October 20). *Chronic pain or illness linked to tongue-ties in adults*. AirSync. https://www.airsyncwellness.com/blog/addressing-a-tongue-tie-in-adults

Sapienza, C. M., & Hoffman Ruddy, B. (2013). *Voice disorders* (2nd ed.). San Diego: Plural Pub.

Scarano, A., Di Giulio, R., Gehrke, S. A., Di Carmine, M., Bugea, C., Lorusso, F., & Rexhep Tari, S. (2023). Orofacial-Myofunctional therapy after lingual frenectomy in patient with tongue-tie: a systemic postural approach with mezieres method and postural bench. *European Journal of Paediatric Dentistry*, *24*(3), 201–206. https://doi.org/10.23804/ejpd.2023.1885

Schellenberg, J. B., et al. (2000). "Physical Findings and the Risk for Obstructive Sleep Apnea." American Journal of Respiratory and Critical Care Medicine 162(2): 740-748.

Segal, L. M., Stephenson, R., Dawes, M., & Feldman, P. (2007). Prevalence, diagnosis, and treatment of ankyloglossia: methodologic review. *Canadian family physician Medecin de famille canadien*, *53*(6), 1027–1033.

Siebert, J. R. (1986). Prenatal growth of the median face. *American Journal of Medical Genetics*, *25*(2), 369–379.

Verville, J., Palanisamy, R., & Taskin, N. (2017). Impact of trust and technology on interprofessional collaboration in healthcare settings: an empirical analysis. *International Journal of E-Collaboration (Ijec)*, *13*(2), 10–44. https://doi.org/10.4018/IJeC.2017040102

Walsh, J., & McKenna Benoit, M. (2019). Ankyloglossia and Other Oral Ties. *Otolaryngologic clinics of North America*, *52*(5), 795–811. https://doi.org/10.1016/j.otc.2019.06.008

Walsh, J., & Tunkel, D. (2017). Diagnosis and treatment of ankyloglossia in newborns and infants: a review. *Jama Otolaryngology-- Head & Neck Surgery*, *143*(10), 1032–1039. https://doi.org/10.1001/jamaoto.2017.0948

Williams, W. N. and C. M. Waldron (1985). "Assessment of lingual function when ankyloglossia (tongue-tie) is suspected." J Am Dent Assoc 110(3): 353-356.

Yoon, A., et al. (2017). "Toward a functional definition of ankyloglossia: validating current grading scales for lingual frenulum length and tongue mobility in 1052 subjects." Sleep Breath 21(3): 767-775.

Zaghi, S. and Valcu-Pinkerton, S. (2018, November 9). Evaluation, Diagnosis, and Treatment of Frenum Restrictions: Tongue, Lip, & Buccal Tie [Conference presentation]. AAPMD Conference, Las Vegas, NV, United States

Zaghi, S., et al. (2019). "Lingual frenuloplasty with myofunctional therapy: Exploring safety and efficacy in 348 cases." Laryngoscope Investigative Otolaryngology 4(5): 489-496.

CURRICULUM VITAE

NAME:	Kolbie Ann Vincent
ADDRESS:	Department of Otolaryngology – Head/Neck Surgery & Communicative Disorders 627 South Preston Street, Suite 220 University of Louisville Louisville, KY 40202
DOB	Bowling Green, Kentucky – March 6th, 1999
EDUCATION & TRAINING	B.A., Psychology, B.A., Communication University of Louisville 2017-2021 (Anticipated) M.S, Communicative Disorders University of Louisville May 2024
PROFESSIONAL SOCIETIES	American Speech Language and Hearing Association Kentucky Speech Language and Hearing Association National Student Speech Language and Hearing Association