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The Relationship between Ankyloglossia and Oral-Pharyngeal Dysphagia

By Michael Olive

A thesis

submitted in partial fulfillment of

the requirements for the degree of

Master of Science in Speech Language Pathology

Idaho State University

Summer 2016

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Michael M. Olive find it satisfactory and recommend that it be accepted.

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Research Approvals Page

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February 22, 2016

Mike Olive
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RE: regarding study number IRB-FY2016-262 : The Relationship Between Ankyloglossia and Oral-Pharyngeal Dysphagia

Dear Mr. Olive:

I have reviewed your request for expedited approval of the new study listed above. This is to confirm that I have approved your application.

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You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before Feb 21, 2017, unless closed before that date.

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Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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List of Abbreviations

Abbreviations used in Results:

iopitipavg = average force for IOPI tongue tip measure

iopidorsavg = average force for IOPI tongue dorsum measurement

iopilipsavg = average force for IOPI lips measurement

iopimraxavg = average force for IOPI right masseter measurement

iopimlaxavg = average force for IOPI left masseter measurement

mcbARMSav = right masseter contraction baseline average

mcbBRMSav = left masseter contraction baseline average

mcpud1ARMS = right masseter contraction for 1/2 tsp. pudding trials

mcpud1BRMS =left masseter contraction for 1/2 tsp. pudding trials

mcpud2ARMS = right masseter contraction for 11/2 tsp. pudding trials

mcpud2BRMS = left masseter contraction for 11/2 tsp. pudding trials

mc10ccARMS = right masseter contraction for 10cc H_20 trials

mc10ccBRMS = left masseter contraction for 10cc H_20 trials

mccrackARMS = right masseter contraction for Triscuit cracker trials

mccrackBRMS = left masseter contraction for Triscuit cracker trials

stcpud1avg = average swallowing timing with contraction for 1/2 tsp. pudding trials

stcpud2avg = average swallowing timing with contraction for 11/2 tsp. pudding trials

stc10ccavg = average swallowing timing with contraction for 10cc H_20 trials

stccrackavg = average swallowing timing with contraction for Triscuit cracker trials

The Relationship between Ankyloglossia and Oral-Pharyngeal Dysphagia

Thesis Abstract—Idaho State University (2016)

This study analyzed swallowing data from 8 subjects, ages 18 to 41 years. The swallowing patterns of 3 males and 5 females with tongue tie were investigated. Subjects diagnosed with tongue tie were evaluated using the Lingual Frenulum Protocol along with information from Holtzman (2014). In addition, subjects were tested for masseter activity using electromyography (EMG), oral muscle strength by means of the Iowa Oral Pressure Instrument (IOPI), and oropharyngeal swallow timing using a combination of the 4 finger palpation method and EMG. Subjects were compared with normative data found in Holzer et al (2011).

Results revealed a correlation of subjects diagnosed with tongue tie and oral-pharyngeal dysphagia (OPD). Notably, subjects with tongue tie demonstrated marked differences exhibited by reduced IOPI and EMG masseter measurements. Additionally, subjects presented with noticeably longer swallowing times when compared to the normative data indicating a potential risk factor associated with OPD.

Key words: tongue tie, oral-pharyngeal dysphagia.

Chapter 1: Literature Review

Introduction

The importance of the tongue in the production of speech has been documented from as early as the times of biblical Moses. Exodus 4:10 states, "And Moses saith to the Lord, O my Lord, I am not eloquent, neither heretofore, nor since thou hast spoken unto thy servant: but I am slow of speech, and of a slow tongue." As was recognized by Moses, the tongue has been described as the principal articulator for speech. Wallace (1963) is credited with the first medical use of the term ankyloglossia; however, Obladen (2009) notes that the term 'ankyloglosson' has been used since the time of Galen in the second century AD. The term ankyloglossia derives from the Greek words "agkilos" meaning curved and "glossa" meaning tongue (Suter & Bornstein, 2009). Today ankyloglossia is commonly known as tongue-tie.

The tongue contains two primary points of attachment within the mouth, "the tether holding the front of the mouth is called the frenum [and] in the back of the mouth the tongue is anchored into the hyoid bone [via the genioglossus muscle]" (WebMD, 2005-2015). As a result of these two points of attachment there are two primary types of tongue tie disorders: an anterior tongue tie and posterior tongue tie. Using manual palpation, an anterior tongue tie is indicated in the presence of a prominent lingual frenum, restricted tongue protrusion, tongue tip tethering, or a combination of any of the previous. A posterior tongue tie is indicated when there is a less prominent lingual frenum upon manual palpation, but through the use of grooved directors (to be discussed) the lingual frenum is found to be tight, short, or thick (Hong et al., 2010).

Gender differences reveal a male predominance in individuals with anterior tongue tie while the opposite has been observed for posterior tongue ties (Hong et al.,

2010). Overall, tongue tie occurs more commonly in males than females with a 3:1 ratio (Johnson, 2006; Segal, Stephenson, Dawes, & Feldman, 2007). Although there is no clear ethnic link associated with tongue tie, studies have found familial components associated with certain genes (Segal et. al., 2007, Morowati, Yasini, Rankbar, Peivandi, & Ghadami, 2010, Lalakea & Messner, 2003a).

In a study done by Klockars and Pitkaranta (2009) four age ranges (0-23 months, 2-5 years, 6-12 years, and 13-18 years old) were compared for prevalence of symptoms related to tongue tie (i.e. speech, movement, nutrition, and a combination of the previously mentioned). Findings from their study revealed that children aged0-23 months had an even mix of problems associated with tongue tie. However, as children got older, 2-5 years old and 6-12 years old, speech problems became the most prominent deficit, coming in at least three times greater than the number of other associated issues. Lalakea and Messner (2003b) reported similar findings relating that speech was the number one problem (50%) associated with individuals 14-68 years of age who had tongue tie (N=14).

Beginning Controversy

Controversy regarding ankyloglossia has existed from as early as the third century B.C., resulting from varying opinions concerning the need for treatment, how to properly treat tongue-tie, and who was qualified to treat tongue tie. Historically, midwives and surgeons were tasked with the diagnosis and treatment of issues with the tongue. The most common sign warranting treatment of tongue tie was disordered speech. Despite common symptomology, even within individual occupations, views on interventions regarding treatment were not cohesive, as creeds either “obliged or prohibited” the

separating of the frenum (Burckhard, 1912). Controversy regarding treatment not only involved who should perform the surgical procedure, but also the methods of treatment, which centered on the use of tools. Typically, midwives used their nails to separate the frenum, while surgeons used tools that they had invented. Both of these treatment methods lacked precision and further emblazoned the controversy surrounding the treatment of tongue tie (Obladen, 2009). An excerpt from a 1620s surgeon named Fabricus ab Aquapendente expressed the magnitude of the controversy,

> "I must emphasize the great presumptuousness the midwives exert everywhere; when they without exception, disrupt the band under each new born infant's tongue using their forefinger's nail, which they maintain sharp and pointed for this purpose; under the pretext that, if they wouldn't do it, the infant never would to speak understandably; as if the ability of speech, which is peculiar to humans, would not be nature's gift but would be endowed by a silly woman's mediation… I wonder why the authorities do not pass a specific law forbidding in full seriousness this multiple child-murder committed by the midwives. Thereupon I warn you never to allow the midwife to even touch the tongue of your or other people's infants with their nails….But when in one in hundred thousand infants the tongue would be attached too much the operations should be performed cautiously by an experienced surgeon…" (as cited in Obladen, 2009, p.84-85).

With controversy and severe ramifications arising from botched treatments and other more severe complications such as hemorrhages, the formation of cysts, and even death, people's perspective on the need for treating tongue tie began to shift from a liberal prescription to a much more conservative view. This conservative view followed

clear into the present era. Peter Dunn (1995), stated that, "tongue tie has become a medical non-event…We see a quite extraordinary difference in professional attitude…from earliest times up to the present century" (as cited in Obladen, 2009, p.87).

Bringing Tongue Tie Back into Focus

Early on, the justification for treatment of tongue tie was to improve the speech of an individual; but as the "renaissance of breastfeeding" occurred during the 1990s, the shift of treatment moved from improving speech to supporting feeding. Although breastfeeding brought about a renewed interest in tongue tie, it also added to the controversy of how to diagnose it. For example, instead of diagnosing and treating a tongue tie issue based on symptoms related to speech (i. e., articulation issues), tongue tie began being diagnosed and treated for issues such as relieving sore nipples and improving infant weight gain (Messner & Lalakea, 2000).

Controversy in Diagnosing Tongue Tie

The lack of clear severity ratings and a definition regarding what constitutes a tongue tie has been a major factor behind the current (and historic) controversy of whether or not its treatment is necessary (Hong et al., 2010). Traditional definitions of tongue tie have involved the length of the lingual frenulum, the amount of tongue movement, the appearance of the tongue tip being 'heart shaped,' the presence of a thick fibrous cord being palpated on physical examination, and, in lactation literature, the symptomatic complaints of mothers (Griffiths, 2004). Traditional methods of severity include measurements of tongue protrusion and thickness of the lingual frenum, to simply classifying a person as being with or without a "free tongue." Kotlow (1999) defined the term free tongue as, "the length of tongue from the insertion of the lingual frenum into

the base of the tongue to the tip of the tongue," and expressed that a free tongue was "clinically acceptable/normal" when the length was greater than 16mm (p. 259). Kotlow (1999) further categorized a severity rating for tongue tie by developing 4 classes according to lingual length: a class I tongue tie is equated to a mild tongue tie with lingual length measuring between 12 to 16mm, a class II tongue tie is equated to a moderate tongue tie with lingual lengths between 8 to 11 mm, class III is a severe tongue tie measuring between 3 to 7 mm, and, finally, a class IV tongue tie, or complete tongue tie is considered when measurements are less than 3 mm. Messner and Lalakea (2002) add to the controversy regarding severity ratings by declaring that previous studies, such as those provided by Kotlow, have emphasized that tongue length and tongue protrusion, or the ability to protrude the tongue past the lower dentition, have been the best indicator for the need of remediation by way of surgery. Their study confirmed findings from Williams and Waldron (1985), indicating that interincisal distance measurement is a more accurate tool in determining the need for surgical remediation. Interincisal distance includes measuring the distance between the upper and lower teeth once the tongue tip is placed and kept in contact with the upper teeth and the client's jaw is opened as wide as possible. Hong et al. (2010) summarize the controversy surrounding diagnosing tongue tie and add to it by stating, "Currently, there is no consensus regarding the precise definition of ankyloglossia and while several classification systems have been proposed to grade the degree of ankyloglossia, none of the systems have been correlated to symptomatic severity" (p. 1003).

General Impact of Tongue Tie

Whatever the diagnostic method, tongue tie has proven to be problematic in several general areas. Messner and Lalakea (2000), note that tongue tie has been shown to negatively impact the areas of breastfeeding and articulation. In addition to standard breast feeding issues and speech disorders, Messner and Lalakea (2002) note difficulty playing a wind instrument, cuts beneath the tongue, diastemas in the lower incisors, and trouble with French kissing as some of the aversive effects of ankyloglossia. Lalakea and Messner (2003a) stated that 57% of the patients in their study (N=15) had oral-motor dysfunction (i.e. difficulties with kissing, licking the lips, licking an ice cream cone, keeping the teeth clean, and doing tongue tricks) related to tongue tie. In addition, they noted social issues such as embarrassment (47%), being teased by childhood peers (27%), and regret for not undergoing surgical correction as a child (60%) to be among the areas impacted by tongue tie. These findings were confirmed in a study done by Klockars and Pitkaranta (2009) (N=317) in which the main indication for frenulum division was speech/articulation problems (64%), followed by restricted movement (18%), lactation/nutrition problems (8%), or different combinations of the preceding issues (5%).

Controversy of Tongue Tie and its Impact on Speech

Controversy involving tongue tie and speech revolves around the questionable effects of tongue tie on the speech abilities of children. Dollberg, Manor, Makai, and Botzer (2011) stated that there was, “no current medical data indicating any association between speech difficulties and tongue tie in children” (p. e127). Conversely, Shen and Sie (2014) stated that, “up to one half of young children with ankyloglossia referred for otolaryngology evaluation have articulation difficulties” (p. 594). Messner and Lalakea

(2002) indicate that results differ due to varying severities of tongue tie and that studies have demonstrated drastic variations of children being able to compensate without previously noted treatments, while others have specific errors resulting from their tongue tie issues.

Within the definition of the word 'tongue-tie' it is implied that the most obvious clinical symptom would be limited movement of the tongue. Suter and Bornstein (2009) state, "Speech problems can occur when there is limited mobility of the tongue due to ankyloglossia" (p.1213). Dollberg et al., (2011) performed a study on 23 age matched children who either had tongue tie and were treated, had tongue tie and were not treated, or did not have tongue tie. The results of their study indicated that as a whole, those with tongue-tie had more articulation errors than those without; however, those who had tongue-tie, but had not been treated were found to have twice the number of articulation errors when compared to those who had been treated. The most difficult articulation errors were consistent for both groups (/t/, /d/, /l/, and /r/). Predictably, tongue movement was limited to a greater degree in those who had tongue tie, but those who had not been treated did the poorest in these measures. Interestingly there were no differences of intelligibility between the three groups. Messner and Lalakea (2002) pointed out that clinicians must be aware that tongue tie affects articulation (particularly lingual sounds and sibilants such as /t, d, d, z, s, θ, ð, n, l/), but does not cause a lack of speech, for which the latter would require further evaluation to determine its cause. Findings from their study infer that children will have speech difficulties related to tongue tie (71% in their study, N= 30) and that releasing of the tongue through frenuloplasty can be effective in improving articulation and tongue mobility.

Controversy of Tongue Tie and its Impact on Swallowing

There has long been disagreement concerning the impact of tongue tie on feeding and swallowing issues. For example, Messner and Lalakea (2000) polled practicing Otolaryngologists, Pediatricians, and Lactation consultants in regards to the correlation of tongue tie with sucking and feeding issues in infants. The data from their study revealed that 90% of pediatricians and 70% of otolaryngologists believe that tongue tie "rarely or never causes feeding difficulties" (p. 124). Whereas a majority of lactation consultants (69%) believe that tongue tie frequently interferes with breastfeeding in infants.

This study brings to light the current controversy surrounding tongue tie and swallowing which includes not only the disagreement between professionals on the impact of tongue tie, but additionally, that most research available is focused on infant breastfeeding issues. The few studies that have included "swallowing" have done so under the guise of breastfeeding and, rather than providing formal swallowing measures, rely on maternal reports of symptom and severity (Jones, 2003 as cited in McBride, 2005, p. 242). Other studies mention swallowing as a sign associated with tongue tie but provide no evidence to back up the assertion. For example, Shen and Sie (2014) mention that a few symptoms of tongue tie include problems with deglutition but provide no substantiating evidence or references for the claim. In a systematic review of the literature, Chinnadurai et al. (2015) state that, "Although we looked for them, no studies included data related to …dysphagia in the nonbreastfeeding child" (p. 1469).

As was previously alluded to, when approaching tongue tie issues in regard to breastfeeding the controversy exists in the fact that results are based on the subjective statements or symptomatic complaints of mothers (Hong et al., 2010, p. 1005; Webb,

Hao, & Hong, 2013, p. 1212). Consequently, the information that is available focuses on maternal reports of their infants being unable to breastfeed, unable to latch, and/or having insufficient or continuous feedings, and the mother having severe nipple pain/trauma (Griffiths 2004; Messner & Lalakea, 2002; Webb, Hao, & Hong, 2013).

Francis, Krishnaswami, and McPheeters (2015) indicate an additional issue with a focus on breastfeeding alone is, "not all patients identified with ankyloglossia may have difficulties breastfeeding and/or need surgery. However, no data exists to differentiate how these patients may fare later in life" (p. 1463). Chinnadurai et al. (2015) confirm this by stating that the, "Absence of evidence makes it difficult to objectively inform parents about the long-term implications of ankyloglossia, which complicates the decision-making process, and guidance to date has focused exclusively on breastfeeding issues" (p. 1468).

Treatment: Frenotomy and Frenuloplasty

Continuing with a theme of controversy surrounding tongue tie, a brief discussion of the main methods for treating tongue tie, which are frenotomy and frenuloplasty is essential. Whether these methods are effective remains another critical part of the controversy surrounding tongue tie (Messner & Lalakea, 2000). Using frenotomy to treat tongue tie has been around for approximately 2000 years (Horton, Crawford, Adamson, & Ashbell, 1969). Frenotomy has been defined simply as clipping the frenum, or a division of the frenulum without sutures (Klockars & Pitkaranta, 2009; Lalakea & Messner, 2003a). A more specific definition of frenotomy includes, "incising a few millimeters into the lingual frenulum" (Shen & Sie, 2014, p. 594). Frenotomy, which can typically be performed as an outpatient procedure in a clinic, is beneficial for younger

children (newborns and infants), as it does not require anesthesia and results in minimal discomfort post treatment.

Frenuloplasty is the preferred procedure for children older than 1 to 2 years old as it generally allows a more complete release of the tongue (Lalakea & Messner, 2003a). Frenuloplasty is a slightly more invasive procedure that requires anesthesia and can result in a longer recovery period. Shen and Sie (2014) describe the process of frenuloplasty as involving the use of tools such as a groove retractor and a penetrating clamp to retract the tongue and expose the thickened frenulum. Division of the frenulum is accomplished in a horizontal manner to the level of the ventral tongue. The result of this division creates a "diamond shaped defect." The division is continued posteriorly until sufficient release of the tongue is accomplished. Wounds are typically cauterized and closed in a vertical fashion with the use of sutures (p. 594).

Klockars and Pitkaranta (2009) reported that 84% of parents of children with tongue tie reported a benefit from surgery, and that a first surgery was sufficient for 85% of the children in their study (N=317). Interestingly, surgery efficacy stemmed more from adequate division and the means of the delivery of anesthesia rather than the technique (i.e. frenuloplasty and frenotomy). When anesthesia was provided, generally only 1 out of 181 of the children needed revision-surgery, whereas, 30 out of 115 who received no or local anesthesia needed follow up surgery. Age was noted to be the main factor as to whom received what kind of anesthesia, but age itself was not the main indicator to affect the outcome as the revision rate was similar under both types of anesthesia. These results indicate that consideration of the mode of anesthesia plays a

much more significant role in whether further surgeries are needed; but, ultimately, frenotomy and frenuloplasty are effective methods in treating tongue tie.

In regard to speech, Messner and Lalakea (2002) stated that post-operative results utilizing frenotomy indicated an improvement in mobility (tongue elevation 5.2mm pre-operative to 22mm post-operatively, protrusion 14.2mm pre-operative to 25.8mm post-operative). Post-operative speech evaluations also found that 82% of clients also had improved articulation (N=30). Walls et al. (2014) also found a statistically significant difference in the speech development of children who had tongue tie and were treated by means of frenotomy compared to those who had tongue tie and had not been treated.

Conclusion

Despite the diverse attempts to define, quantify, and treat ankyloglossia, Lalakea and Messner (2003a) state, "At present there is no way to predict—based on examination findings—which children are likely to have, or to develop, speech or mechanical symptoms related to their ankyloglossia" (p.388). From the information that is available we know that even within the field of Speech Language Pathology there is no clear consensus of the effects of ankyloglossia and how to properly assess or treat it. As of the year 2000, Speech Language Pathologists report divided opinion within the profession regarding the effect of tongue tie on speech and how efficacious speech therapy was in treating speech disability related to ankyloglossia. For example, 70% of speech pathologists reported that symptomatic ankyloglossia was a rare occurrence. A similar lack of consensus is found when comparing the field of speech pathology to other professions as exemplified in a greater amount of Otolaryngologists correlating adverse speech problems with ankyloglossia (Messner & Lalakea, 2000). Although insightful, the

study once again brings to light the disparity of available research and information concerning the area of dysphagia or swallowing disorders, which is now under the purview of a licensed Speech Language Pathologist.

In regards to deglutition, we know that the tongue plays a vital role during three of the four stages of the swallow. In the oral preparatory phase, it is crucial that the tongue has the mobility needed to manipulate the bolus for appropriate placement during mastication. During the oral phase, tongue elevation to achieve an appropriate anterior to posterior movement of the bolus is vital in order to trigger the swallow. Lastly, in the pharyngeal stage of the swallow the tongue, "acts like a piston, thrusting backwards" (Wright, 1995, p. 277). This having been said and as has previously been indicated, claims have been made indicating an impact of tongue tie on the swallow, without any data to back up the claim. In addition, there is limited research on the effects of tongue tie on adults. It was not until 2003b that Lalakea and Messner stated that, to their knowledge, their study was, "the first to prospectively evaluate the effects of ankyloglossia in adolescents and adults" (p.750). Since that time nothing new or revealing related to swallowing has been included in the research. Knowing the role of the tongue in swallowing, the controversy surrounding ankyloglossia, and the lack of information available, the question that needs to be asked is why no formal swallowing measures exist in regard to the claimed impact of tongue tie on swallowing. This study sought to obtain such data and determine if a relationship exists between tongue tie and oropharyngeal dysphagia (OPD). Thus, the question posed is: Do individuals with signs of ankyloglossia show marked differences in oropharyngeal transit time, tip strength, and tongue dorsum strength when compared with a normative sample?

Chapter 2: Methodology

The purpose of the present study was to examine variables related to assessment of oral-pharyngeal dysphagia (OPD) and individuals with ankyloglossia, to gather preliminary normative data, as well as to examine possible relationships between the defining characteristics of both disorders as seen in the clinical evaluation. To my knowledge, this study is the first of its kind to be performed. Measures of ankyloglossia, tongue strength, lip strength, masseter strength and contraction, oral pharyngeal transit time, and laryngeal elevation were examined in 6 participants between the ages of 18 and 50. It should be noted that the following methodology has been standardized and thus the methodology will contain verbatim elements found in other studies.

Research Hypotheses

The following research hypotheses were posed:

H_{0a}: No relationship exists between variables associated with oropharyngeal dysphagia and those associated with ankyloglossia.

$H_{1a:}$ A relationship exists between variables of oropharyngeal dysphagia and ankyloglossia.

H_{0b}: No noticeable difference exists in masseter contraction based on side and/or bolus type.

$H_{1b:}$ A noticeable difference exists in masseter contraction based on side and/or bolus type.

H_{0c}: No obvious difference exists in laryngeal timing based on bolus type and/or measurement type.

$H_{1c:}$ An obvious differences exists in laryngeal timing based on bolus type and/or measurement type.

H_{0d}: No marked difference exists in force, as measured by IOPI, based on IOPI location.

$H_{1d:}$ A marked difference exists in force, as measured by IOPI, based on IOPI location.

Participants

Participants were chosen by a convenience sample, and appropriately included 8 subjects (5 female; 3 male). Subjects were excluded if they had a history of craniofacial abnormalities, intellectual or motor limitations, or neurogenic or structural impairments to the head or neck, as indicated by observation, subject report, and survey results (Marchesan, 2012). All individuals with a history of neurogenic disorders or traumatic brain injury with coma were excluded from the sample, as well. Subjects who had received a concussion with a period of unconsciousness lasting no more than 5 minutes, and who had no reported reduction in motor or cognitive function were retained in the study, reflecting the high incidence of such events during sports-related activities of adolescents. Upon entering the study, a demographic survey was given to each participant (see Appendix A). It asked for the participants' birth date, gender, any history of serious medical conditions or disorders, and any drinking, smoking, and tobacco chewing habits. The participant was then given a case history from the *Lingual Frenulum Protocol* developed by Marchesan (2012) (see Appendix B). It asked for the participants name, gender, examination date, age, work history, personal information (e.g., address, phone number, email), how the participant was referred, main complaint, other complaints associated with ankyloglossia, family history of frenulum alteration, health and breathing problems, feeding (chewing and deglutition) difficulties, oral habits,

speech alterations, social or professional issues due to speech alteration, voice alteration, and history of frenulum surgery.

Variables

The independent variables are participant age, gender, and bolus characteristics. When evaluating the participants, the following bolus consistencies and sizes were used: ½ teaspoon of pudding, 1 ½ teaspoon of pudding, a Triscuit cracker, and 10 cc of water delivered from a cup. The following subjective variables were recorded for each participant: presence of open mouth or closed mouth at rest posture, presence of tongue protrusion during swallow, rated cohesion of the bolus, and residue on the tongue and in the sulci following the swallow. Objective measures were used to measure superior tongue tip and dorsum strength, lip strength, masseter strength as *reflected by peak EMG, and behaviorally measured oral pharyngeal transit time.*

Instruments and Materials

Three protocols were used to assess the participants: A Demographic Survey (see Appendix A), the *Lingual Frenulum Protocol* (See Appendix B), and a Clinical Evaluation Protocol (see Appendix C).

The Iowa Oral Performance Instrument (IOPI) (Breakthrough model 1.5) was used to measure superior tongue strength, lip strength, and masseter strength. A two channel Infiniti EMG (Thought Technology) was used while measuring masseter contraction, strength, and oral pharyngeal transit time, using surface electrodes. For the clinical evaluation, Hunt's Snack Pack Sugar Free chocolate pudding was used, as well as water, and Triscuit brand crackers. A syringe calibrated for volume measured in cubic

centimeters was used to measure pudding amounts and water. Other clinical materials that were used included: gloves and tongue depressors.

Procedures

Three protocols were developed, providing a counterbalanced order of presentation of measurement. Subjects were assigned to one of the three groups as they entered the study (see Table 1). Males and females were treated as separated groups, so that both groups have fully counterbalanced presentation. The varied presentation helps account for measurement presentation effect, if one was present, which could include fatigue or familiarity. It should be noted that the tongue tie evaluation was adjusted in all cases as it was a vital step in being able to appropriately diagnose an individual with tongue tie. Participants were allowed to take a drink of water after each bolus upon completion of the trial.

Group A	Group B	Group C
Lingual frenulum protocol	Lingual frenulum protocol	Lingual frenulum protocol
IOPI force	EMG masseter contraction	EMG laryngeal timing
EMG masseter contraction	EMG laryngeal timing	IOPI force
EMG laryngeal timing	IOPI force	EMG masseter contraction

Table 2.1. Presentation Order of the Measurement Tasks

Subjects were tested in the Idaho State University Speech and Hearing Clinic (Pocatello, Idaho), or in their homes. The test environment was quiet and free of distractions. Participants were seated comfortably in an upright position. They were first presented with a human subjects consent form, followed by the demographic survey (See Appendix A), then the tongue tie evaluation was performed, according to the protocol of Appendix B, and described below. Upon completion of the survey and tongue tie

evaluation, they were presented with the stimuli (3 presentations of each stimulus), according to the protocol of Appendix C, and described below. The participants were informed that an IOPI bulb would be placed between their lips and in their mouth, as well as electrodes on their throat and jaw. They were given an option of ending the procedures at any point during the process if they became uncomfortable.

Tongue tie diagnosis and classification.

The clinical evaluation was divided into two parts: the first investigated general aspects of the frenulum and tongue by using the quick tongue tie assessment tool (the QTTA), which took measurements in millimeters. The first measurement included placing the QTTA at the, "superior right or left incisive to inferior right or left incisive" and considered the same tooth for all measurements. The researcher then recorded the participant's ability to open the mouth wide (MOmax), open the mouth wide with the tongue tip touching the incisive papilla (MOtts), and then determined the difference between the two measurements, in percentage. Next, measurements of alterations during tongue elevation were achieved by having the participant open his/her mouth wide while raising the tongue without touching the palate. The researcher also noted the tip of the tongues shape (oblong, square, or like a heart). Measures of frenulum fixation were taken by researcher observation of the frenulum being viewed at the mouth floor and sublingually. A clinical frenulum classification was then assigned by the researcher as either normal, borderline, or altered. The best result of the general test resulted in a score of zero while the worst result equaled a score of 8. An altered lingual frenulum was considered when the score of the general tests were equal to or greater than 3. The second portion of the clinical evaluation included functional tests of tongue mobility by having

the participant protrude and retract the tongue, touch the superior lip with the apex, touch the right and left corners of the mouth, touch the upper and lower molars, and suck the tongue against the palate. These were judged as either successful, partially successful, or unsuccessful. Tongue positioning during rest was also assessed as either not visible, on the floor of the mouth, protruding between the teeth, or laterally protruding between the teeth. Three speech tasks were also performed by the participant through an informal speech measure of counting from 1 to 20, and then naming pictures. Errors of omission, substitution, and distortion along with corresponding phonemes were recorded. In addition, other aspects were observed during speech such as mouth opening, tongue position, mandible movements, speech precision, and voice. The researcher recorded all results on the protocol, see Appendix B. The best result of the functional portion was indicated with a score of 0 and the worst result was indicated by a score of 40. The frenulum was considered altered when the score of the functional evaluation was equal to or greater than 25 (Marchesan, 2012).

Holtzman (2014) indicated that the measurement of the tongues ability to suction against the palate (MOWS) was a more accurate measure in determining the presence of a tongue tie when compared to MOtts. This measurement included having the participant open their mouth maximally while suctioning the tongue flat against the palate while the researcher measured the distance between lower and upper central incisors with the QTTA. Holtzman (2014) noted that individuals with tongue tie often cannot complete suction flat to the palate and indicated that using MOtts minus 5 is an acceptable replacement for this measure, stating that it has been found that for most clients, Motts is "5mm greater" than MOWS.

Tongue, Lip, and Masseter Strength.

The IOPI measurements were taken first to measure tongue tip strength, tongue dorsum strength, and lip strength. The IOPI bulb was first placed on the tongue tip, and participants were instructed to occlude their teeth and lips and to compress the bulb against the alveolar ridge with their tongue as hard as they could for approximately two seconds. This was completed three times, with the researcher recording the force exerted after each of the three attempts. The subject was then asked to sustain phonation of the vowel /a/ to facilitate placement of the IOPI bulb on the tongue dorsum. The researcher placed the bulb on the tongue dorsum inferior to the juncture of the hard and soft palates, as indicated by the peak of the tongue during the phonation of /a/. Participants were then instructed to occlude their teeth and lips while pushing against the bulb against the hard palate with as much force as they could. This was completed for three 2 second trials with the bulb being repositioned after each attempt. The researcher recorded the readings of the IOPI after each attempt.

Finally, the bulb was placed between the lips of the participants, and they were instructed to press their lips together as hard as they could without biting down on the bulb with their teeth. This was also completed for three 2 second attempts, with the bulb being repositioned and the IOPI readings being recorded by the researcher after each attempt.

EMG Masseter Contraction.

Next, the EMG measurements were taken with the EMG electrodes being placed on the lateral facial surface, in order to record masseter contraction. Electrodes were first

placed to obtain a masseter baseline and measure masseter contraction. The participants were then instructed to clench their back teeth as the researcher palpated the masseter belly. The EMG electrodes were placed bilaterally on the masseter belly in a vertical plane. Channel A was assigned to the right masseter, and Channel B was assigned to the left masseter. The ground electrode was placed on the subject's clavicle. The researcher clipped the electrode cables to the subject's sleeves/collar to avoid tension reducing contact or entirely pulling the electrode off the applied area.

Masseter contraction was then measured. A masseter baseline was recorded and used in comparison with masseter contraction during swallow trials. Participants were instructed to bite down with their back teeth as hard as possible and then to relax, repeated for a total of 3 trials. The researcher recorded the EMG reading of contraction. Subsequently, groups were presented each bolus (½ teaspoon of pudding, 1 ½ teaspoon of pudding, 10 cc of water, and a Triscuit cracker). The participants were given the bolus and instructed to hold the bolus in their mouth until instructed to swallow. The researcher palpated the lateral neck and submental region, using the five-finger method of Logemann (1998), and depressed the spacebar of the laptop computer at initiation of the swallow, which placed a marker on the EMG recording. The exception to this was for the Triscuit cracker: In this case, participants were allowed to chew until they were prepared to swallow, and then swallowed with their own timing. It is felt that this was minimally disruptive to the swallow timing itself. EMG was recorded for all boluses, and later measured. Again, the researcher marked timing of the swallow using the spacebar. Upon each swallow, the researcher circled absence or presence of masseter contraction as

indicated on the EMG reading. Each stimulus was presented three times, and the researcher recorded the EMG reading after each presentation.

In a separate trial, bolus cohesion and residue was examined for the Triscuit cracker. Subjects were told to chew the cracker until they were ready to swallow, and then to open their mouths so that the researcher could examine the bolus. The researcher then rated the cohesion of the bolus on a 5-point scale. The participants then swallowed and opened their mouth. A 5-point scale was used to rate the residue in the sulci and on the tongue. The masseter strength and start time of the swallow were recorded. Each stimulus was presented three times.

EMG and Behavioral Laryngeal Timing

Oropharyngeal transit timing was measured both instrumentally and behaviorally. The goal of this measure was to identify the initiation and termination of swallow. Initiation of swallowing was defined as movement of the tongue and was instrumentally measured by recording the EMG of the submental region. Termination of the swallow was defined as the depression of the larynx following swallow, which gave no myogenic response because of the passive nature of depression. This was subsequently measured behaviorally using the 5 finger palpation method.

Channel A and Channel B electrodes were then removed from the masseter and prepared to measure laryngeal elevation. Channel A was placed on the submental region, approximating the mylohyoid muscle. The first electrode was placed approximately two centimeters posterior from the chin point, and the second electrode was placed two centimeters posterior to the first. Channel B placement included one electrode being

placed to the left of the thyroid notch with the other electrode being placed two centimeters posterior to the first. The participants were then given ½ teaspoon of pudding and instructed to clean the spoon and swallow when ready. This was completed three times. For behavioral measurement of laryngeal timing, the researcher palpated the lateral neck and submental region, using the five-finger method of Logemann (1998), and depressed the spacebar of the laptop computer at initiation of the swallow and at depression of the larynx, which placed a marker on the EMG recording.

Next, the researcher pulled down the participant's lower lip during a swallow to reveal lingual function. One and a half teaspoon of pudding was given to the participants. They were instructed to clean the entire spoon and swallow when ready. The researcher observed for tongue protrusion during the bolus preparation and the swallow and circled for presence of absence of protrusion on the protocol. The researcher also checked for completion of the task. The remaining boluses were sampled, as well. Each stimulus was presented three times before moving to the next stimulus. Measurements were taken with each presentation.

Reliability

Inter-judge Reliability. For ten percent of laryngeal timing recordings of subjects were re-measured by a second judge. The paired responses were compared using Pearson Product Moment Correlation Coefficients.

Intra-judge reliability. To examine intra-judge reliability, the EMG of 10% of participant's laryngeal timing measurements was re-measured by the researcher and cast into a Pearson Product Moment Correlation.

Chapter 3: Results

The purpose of this study was to determine if a relationship existed between tongue tie and oral-pharyngeal dysphagia. Eight participants diagnosed with tongue tie were assessed utilizing EMG and IOPI instrumentation to determine tongue strength, lip strength, masseter strength, and swallowing timing. Measurements were examined to determine if differences existed between the measures on tongue tie participants and normative data from previous research. Data from the study can be found in Appendix D.

Demographic Survey

Eight subjects (3 males and 5 females) between the ages of 18-41 years participated in the study. Mean age of the subjects was 28.75 years (27.3 years for males, 29.6 years for females). Of the 8 subjects, 7 were European American and one was of mixed ethnicity. In each of the following categories only one subject indicated having a prior history of; having their tonsils/adenoids removed, a deviated septum, TMJ, finger sucking (stopped around the age of 4), current spaces in dentition, and allergies. Two individuals reported having a history of cheek biting, mouth breathing, oral sores, other surgeries, and avoiding foods due to texture aversion. Three individuals were taking medication at the time (two were taking birth control and one was taking medication for allergies.) Four individuals reported a history of having open spaces during the mixed dentition stage. Five individuals reported having oral surgery, four of these included the removal of their wisdom teeth, and one included a Le Forte procedure involving the upper jaw. Results from the demographic survey are summarized in Table 3.1. All other areas listed in the demographic survey (Appendix A) were not indicated as present in any of the participants.

Table 3.1 Demographic Survey Results

	Males	Females	Total
European American	2	5	7
Other/Multiracial	1	0	1
Heart & Blood Problems (including chest pain due to heart problems, irregular heartbeat, high blood pressure, blood clots, anemia, hypertension, blood transfusion, high cholesterol, heart failure, or heart bypass surgery)	0	1	1
Cheek Biting		2	2
Deviated Septum		1	1
Tonsils/Adenoids Removed		1	1
Mouth Breather		2	2
Enlarged Tonsils/Adenoids		1	1
TMJ Syndrome		1	1
Finger Sucking		1	1
Open Spaced During Mixed Dentition	1	3	4
Current Spaces in Dentition		1	1
Allergies		1	1
Oral Sores		2	2
Medications (birth control, allergies)		3	3
Oral Surgery (reconstructive upper jaw-Le Forte procedure, wisdom teeth)	3	2	5
Other Surgery (PE tubes as a kid, Appendectomy,)	1	1	2
Avoid Foods (Caramel, Candy, Cottage cheese (2), Pickles (2), Tomatos (2), Relish, Cream Cheese, Coconut)	1	1	2

All participants received assessment using the *Lingual Frenulum Protocol*. Following are summaries of diagnostic information for each participant.

Subject 2

Subject 2 was a 27-year-old female identified with tongue tie using the *Lingual Frenulum Protocol* (LFP). Subject 2 participated as Group C order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session.

Table 3.2 reveals behavioral and clinical results for Subject 2 classified with tongue tie. She demonstrated difficulty with touching the superior lip with the apex of the tongue, touching the upper and lower molars with apex of the tongue, as well as sucking the tongue up against the palate. Examination of the tongue and frenulum revealed a tongue tip that appeared heart shaped and square, and the frenulum was observed to be attached sublingually between the middle and apex of the tongue as well at the alveolar crest. Utilizing measurements taken from the LFP, results of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot (MOtts) minus five per the recommendation of Holtzman (2014), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=55mm, Motts=16, MOWS=11. According to the LFP when the ratio of MOmax and MOtts are smaller than 50% this can indicate a tongue tie. S. R. Holtzman further indicates that when measurements are only slightly greater than 50% this can also be considered a red flag indicating tongue tie (personal communication, January 28, 2016). The ratio of MOW and MOtts was 29% indicating a significant tongue tie. Additionally, the difference between MOWS was less than ½ of MOmax further indicating a tongue tie. Overall the result of the general section resulted in a score of 6 indicating an altered lingual frenulum. Results of the functional test of the Lingual Frenulum Protocol were reported in Table 3.2. Oral facial examination revealed a high and narrow palate with sharply defined rugae on the alveolar ridge. During swallow trials the client stated that she would swallow at least twice to clear the bolus, this was present during deglutition and observed on EMG recordings as discussed in chapter 4 (See Figure 4.2). She also demonstrated difficulty with oral toilet as indicated by having to use her fingers to clear out additional residue. Tongue protrusion was indicated for bolus

and liquid trials. Results for bolus formation was an average of 3 indicating that bolus formation consistently demonstrated some evidence of cohesion and some scattering. Results for presence of residue after deglutition was an average of 3.67 indicating that there was some evidence of residue present after the swallow.

Table 3.2. Behavioral/Clinical Indicators, Subject 2.

Indicators	Results
Ratio of MOmax and MOtts	29%, indicating tongue tie
MOWS	11mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was square shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, indicating tension from lingual frenulum
Frenulum observed from the alveolar crest	Present, indicating anterior point of attachment
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum classified as altered	Yes, the frenulum was attached between the middle and apex of the tongue.
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	6/8 indicating the frenulum is altered.
Touch the upper lip with tip of tongue	Partially successful, required jaw support to be able to do so.
Touch upper and lower molars	Partially successful, required jaw manipulation to be able to do so. Struggled to get tongue on top of molars and into buccal cavity.
Sucking against the palate	Partially successful, 11mm
Tongue resting on the floor of the mouth	Yes

Table 3.3 reveals objective data measured during assessment with EMG and IOPI, as well as behavioral and observational data noted during swallowing trials, as compared with the Holzer (2011) norms. As can be seen from Table 3.3 all IOPI and masseter measurements, except for the left masseter measurement on the Triscuit cracker, were markedly below the normative data (Holzer, 2011). Figure 3.1 reveals that IOPI force

was noticeably below measurements of tongue tip, dorsum, and between lips compared to the normative data. Dorsum strength, as well as left masseter strength, resulted in slightly lower measurements compared to normative data (Holzer, 2011). Masseter contraction as measured by EMG was considerably less when compared to the normative population for all swallow trials of ½ and 1 ½ teaspoon of pudding, 10cc of water, and Triscuit cracker. Subject 2 also shows distinctly delayed oral-pharyngeal transit times (shown in Figure 3.2) for all boluses as measured through laryngeal elevation and depression indicated by EMG for swallow timing. She reported having to perform multiple swallows which was indicated in EMG readings and shown below in figure 4.2. Additionally, she reported and demonstrated multiple instances of a preparatory swallow during EMG bolus trials (see figure 4.5). Subject 2 also demonstrated forward tongue posture during deglutition for all boluses. Of these objective data, the masseter contraction, tongue protrusion, decreased bolus cohesion, and reduced labial and lingual strength are indicators of an OMD. Increased oral-pharyngeal transit time (swallow time) is an indicator of oral-pharyngeal dysphagia.

Table 3.3. Observed data for Subject 2.

Measurement	**#2**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	28	47.08	16.42
iopidorsavg	36	42.33	17.38
iopilipsavg	5	17.33	7.81
mcbARMSav	57.71	282.92	233.70
mcbBRMSav	42.84	470.66	306.95
mcpud1ARMS	12.19	42.74	33.43
mcpud1BRMS	15.37	85.43	104.40
mcpud2ARMS	17.45	68.44	88.16
mcpud2BRMS	21.04	136.74	171.51

mc10ccARMS	13.08	29.45	29.21
mc10ccBRMS	28.03	100.16	142.83
mccrackARMS	187.51	125.04	121.92
mccrackBRMS	110.29	159.86	149.08
stcpud1avg	2.33	1.15	0.54
stcpud2avg	2.36	1.07	0.48
stc10ccavg	1.52	0.91	0.37
Stccrackavg	1.79	1.04	0.45

Figure 3.1 IOPI Measurements of Subject 2.

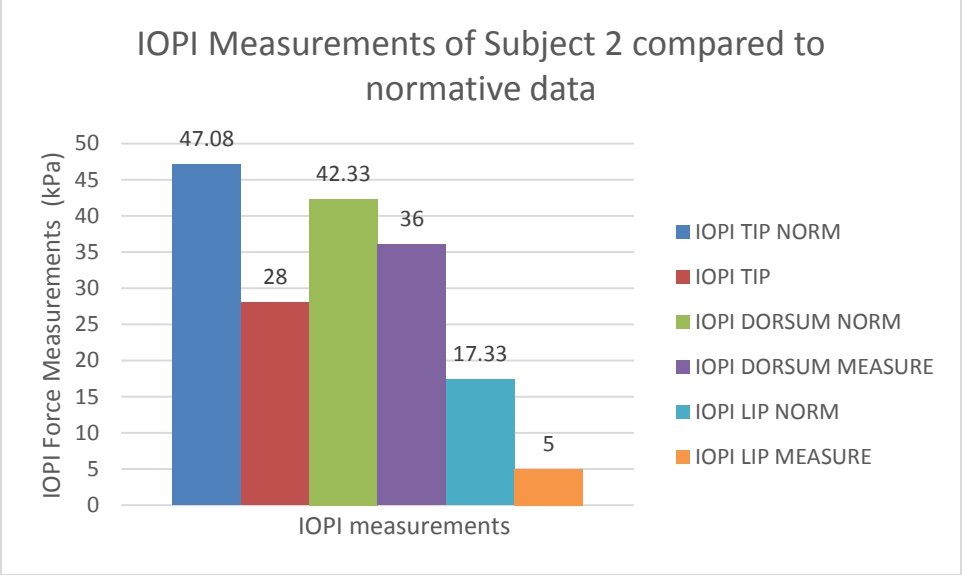
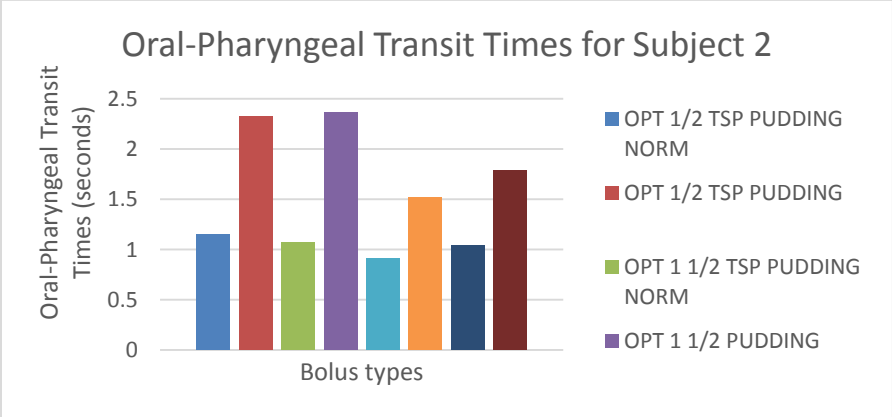


Fig 3.2 Oral-Pharyngeal Transit Times for Subject 2



Subject 3

Subject 3 was an 18-year-old female identified with tongue tie using the *Lingual Frenulum Protocol* (LFP). Subject 3 participated as Group A order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session. Demographic history revealed that she had a family history of lingual frenulum alteration including her mother and her mother's brother. She also had a history of open mouth breathing which can be indicative of a tongue tie. She had a Le Forte procedure done on August 10th 2015 and currently has a palatal bar in place to prevent jaw narrowing. She reported that the palatal bar was put in around September 21st, 2015.

Behavioral and clinical results are revealed in Table 3.4 indicating the presence of a tongue tie for this individual. She revealed a tongue tip that was square shaped and heart tipped upon elevation. The frenulum's point of attachment was short or attached below the middle and base of the tongue as well as attached at the alveolar crest. Abnormal movement, indicated by upward twisting/rolling of the sides of her tongue, was present during tasks requiring her to touch the right and left sides of her mouth. Jaw manipulation was also required during a task which required her to touch the upper and lower molars. The tongue was observed to be resting on the floor of the mouth and suction against the palate was only partially successful, requiring greater effort and jaw manipulation. Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot minus 5 (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=60mm, MOtts=31, MOWS=32. The ratio of MOmax to MOtts was 52%, along with behavioral observation this indicated the presence of a tongue tie. In addition, the difference between MOWS and

MOmax was only slightly greater than ½ of MOmax indicating a tongue tie. Overall the result of the general section resulted in a score of 5 indicating an altered lingual frenulum. Results of the functional test of the LFP are reported in Table 3.4. There were no significant results from the informal and formal speech measures performed during the functional test. Oral facial examination revealed a high palate with well-defined rugae on the alveolar ridge. Subject 3 also presented with tongue protrusion for bolus and liquid trials. Results for bolus formation were an average of 1.67 indicating that bolus formation was between being organized in a ball or tube in the middle of the tongue as it should be and demonstrating some evidence of cohesion and scattering. Results for presence of residue after the swallow were an average of 1 indicating that there was minimal to no residue remaining after deglutition.

Table 3.4. Behavioral/Clinical Indicators, Participant 3.

Indicators	Results
Ratio of MOmax and MOtts	52% (MOmax =60, MOtts =31)
MOWS	32mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was square shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, indicating tension from lingual frenulum
Frenulum observed from the alveolar crest	Present, indicating anterior point of attachment
Frenulum classified as altered	Yes, the frenulum was short.
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5/8 indicating the frenulum is altered.
Touch right comissura labiorum	Partially successful, there was abnormal movement present.
Touch left comissura labiorum	Partially successful, there was abnormal movement present.
Touch upper and lower molars	Partially successful, required jaw manipulation to be able to do so.

	Struggled to get tongue on top of molars and into buccal cavity.
Sucking against the palate	Partially successful, 32mm
Tongue resting on the floor of the mouth	Yes

Objective data gathered from IOPI and EMG measurements are revealed in Table 3.5. IOPI measurements were significantly lower for subject 3 when compared to normative data (see figure 3.5). With the exception of the left side EMG masseter reading for ½ teaspoon of pudding (mxpud1ARMS), which was only slightly above the mean, all other measurements indicate markedly weaker measurements when compared to the normative data. Additionally, there are strikingly longer oral-pharyngeal transit times for all boluses during swallow trials as shown in figure 3.6. Subject 3 also presented with tongue protrusion upon pulling down the lip on three separate swallow trials. Increased oral-pharyngeal transit time (swallow time) is an indicator of OPD and was noticeably delayed when compared to normative data.

Table 3.5. Observed data for Participant 3.

Measurement	**#3**	**Norms**	
	Observed	**Mean**	**SD**
Iopitipavg	21.67	44	11.56
Iopidorsavg	26	42.29	10.92
Iopilipsavg	13	39.29	16.99
mcbARMSav	97.72	115.31	98.87
mcbBRMSav	70.39	107.31	96.34
mcpud1ARMS	35.37	34.61	35.94
mcpud1BRMS	28.85	40.80	47.78
mcpud2ARMS	40.80	37.28	27.16
mcpud2BRMS	30.74	65.93	80.42
mc10ccARMS	33.15	112.75	307.34
mc10ccBRMS	25.11	200.28	340.03
mccrackARMS	53.65	108.129	117.34

mccrackBRMS	46.40	128.76	171.57
stcpud1avg	2.58	0.98	0.21
stcpud2avg	2.64	0.98	0.28
stc10ccavg	1.93	0.37	0.07
Stccrackavg	3.16	0.43	0.11

Fig 3.5 IOPI Measurements of Subject 3

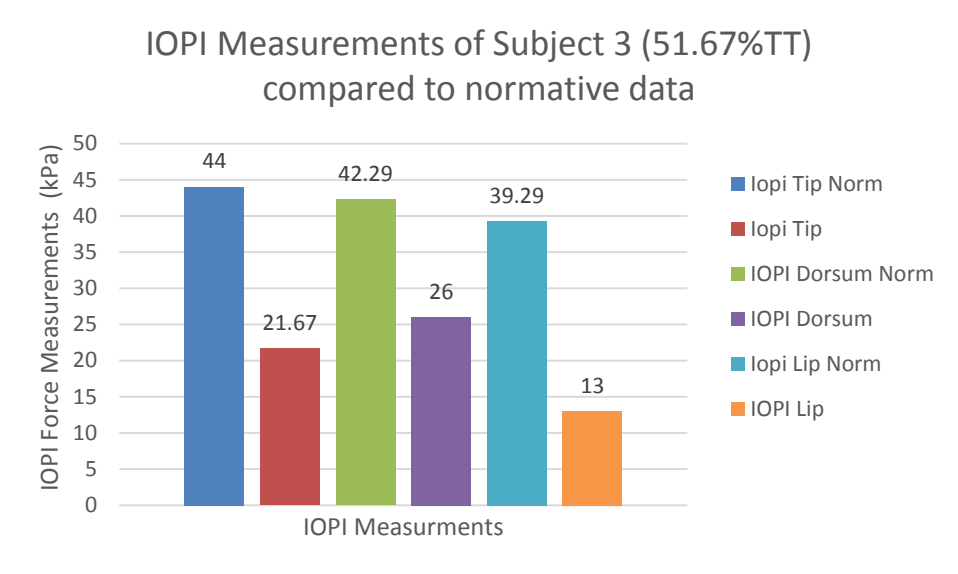
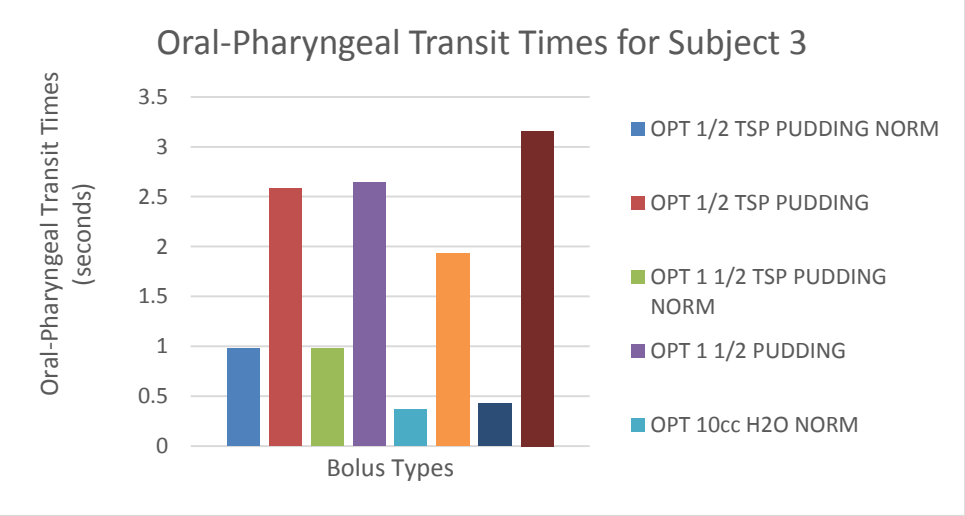


Fig 3.6 Oral-Pharyngeal Transit Times for Subject 3.



Subject 4

Subject 4 was a 41-year-old female identified with tongue tie using the *Lingual Frenulum Protocol* (LFP). Subject 4 participated as Group A order of presentation in which the, LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session. Case history included family history for lingual frenulum alteration including her brother and daughter. She also reported a previous lingual and lip frenulum release at the age of 2, which was noted as unsuccessful. She reported associated issues with posture, neck pain, shoulder pain, deglutition difficulties, headaches, a hyperactive gag, oral habits such as sucking on her cheeks, and chewing difficulties. Deglutition difficulties were self-reported as having to take small bites and choking easily. A hyperactive gag was noticed during IOPI dorsum measurements. Additionally, the client was unsuccessful in performing the between the lips measurement of the IOPI. Clinical examination revealed a tongue tip that was oblong and heart shaped. Sublingual frenulum attachment occurred between the middle and apex of the tongue as well as the alveolar crest. The tongue was observed to rest at the floor of the mouth and suction of the tongue to the palate was only partially successful. Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot minus five (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=52mm, MOtts=25, MOWS=30. The ratio of MOmax and MOtts was 48% indicating the presence of a tongue tie. The difference between MOmax and MOWS was also slightly greater than half and a red flag indicating the presence of tongue tie (Holtzman, personal communication, January 28, 2016). Overall the result of the general section resulted in a score of 6 indicating an altered lingual frenulum. Results of the

functional test of the LFP are reported in Table 3.6. There were no significant results from the informal and formal speech measures performed during the functional test. Oral facial examination revealed a high palate with well-defined rugae on the alveolar ridge and a class 1 malocclusion. Tongue protrusion was indicated for bolus and liquid trials. Results for bolus formation were an average of 1.67 indicating that bolus formation was between being organized in a ball or tube in the middle of the tongue as it should be and demonstrating some evidence of cohesion and scattering. Results for presence of residue after the swallow were an average of 1.67 indicating that there was somewhere between minimal to no residue present after deglutition to some evidence of residue remaining after deglutition.

Table 3.6. Behavioral/Clinical Indicators, Participant 4.

Indicators	Results
Ratio of MOmax and MOtts	22mm, altered (MWO =52, MOtts=25)
MOWS	30mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was oblong shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, indicating tension from lingual frenulum
Frenulum observed from the alveolar crest	Present, indicating anterior point of attachment
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum classified as altered	Yes, the frenulum seems normal but is attached beyond the middle and apex of the tongue
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5-6/8 indicating the frenulum is altered.
Sucking against the palate	Partially successful, 30mm
Tongue resting on the floor of the mouth	Yes

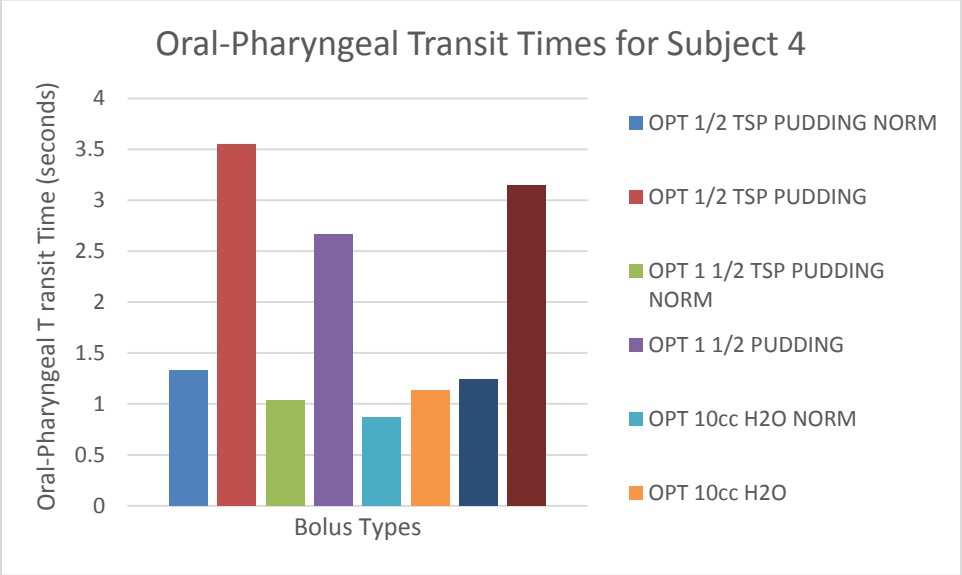
Table 3.7 reveals objective data gathered from IOPI and EMG measurements. IOPI tip and dorsum measurements of pressure in kPa were all below the mean. Subject 4

was unsuccessful in being able to get her lips around the IOPI bulb enough to obtain a measure which is why she received a score of 0 for this measure. Masseter baselines and bolus measurements were all considerably below the mean of the normative data. Oral-pharyngeal transit time measured in seconds was also substantially delayed compared to the normative data (see figure 3.7). Subject 4 also demonstrated with tongue protrusion on three separate bolus trials (1/2 tsp pudding, 10cc H2O, and Triscuit cracker). The client stated that she performs multiple swallows to clear a bolus and this was demonstrated in EMG readings (see Figures 4.3 and 4.4) and the reported oral-pharyngeal transit times.

Table 3.7. Observed data for Participant 4.

Measurement	**#4**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	37.33	41.38	10.81
iopidorsavg	46	53.63	11.51
iopilipsavg	0	28.88	10.75
mcbARMSav	79.42	94.60	105.63
mcbBRMSav	52.24	151.84	207.74
mcpud1ARMS	59.26	71.97	146.08
mcpud1BRMS	40.23	229.36	407.94
mcpud2ARMS	27.96	75.54	131.47
mcpud2BRMS	40.74	189.78	306.96
mc10ccARMS	16.29	92.62	175.38
mc10ccBRMS	17.98	160.90	248.88
mccrackARMS	123.79	143.88	242.78
mccrackBRMS	100.93	194.51	286.90
stcpud1avg	3.55	1.33	0.69
stcpud2avg	2.66	1.04	0.21
stc10ccavg	1.13	0.87	0.36
Stccrackavg	3.15	1.24	0.41

Fig 3.7 Oral-Pharyngeal Transit Times for Subject 4.



Subject 5

Subject 5 was a 30-year-old male identified with tongue tie using the *Lingual Frenulum Protocol* (LFP). Subject 5 participated as Group A order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session.

Table 3.8 reveals the behavioral and clinical indicators indicating the presence of a tongue tie. Previous history was minimal and included issues with his temporomandibular joint clicking. He reported that he was unsure of his family history due to being adopted. Clinical examination revealed a square and heart shaped tongue tip. Frenulum attachment occurred between the middle and apex of his tongue, and his frenulum was considered short. He was partially successful in touching his upper lip with the tip of his tongue and required jaw support in being able to do so. He also demonstrated difficulty touching his

upper and lower molars without manipulating his jaw. He was partially successful in sucking his tongue against his palate.

Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot minus five (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=55mm, MOtts=26, MOWS=25. The ration of MOmax and MOtts was 47% indicating the presence of tongue tie. In addition, the difference between MOmax and MOWS was less than half providing another measurement verifying the presence of tongue tie. Overall the result of the general section resulted in a score of 6 indicating an altered lingual frenulum. Results of the functional test of the LFP are reported in Table 3.8. There were no significant results from the informal and formal speech measures performed during the functional test. Results for bolus formation and presence of residue were an average of 1 respectively, indicating that the bolus was able to appropriately be formed and minimal to no residue remained after deglutition.

Table 3.8. Behavioral/Clinical Indicators, Participant 5.

Indicators	Results
Ratio of MOmax and MOtts	47% (MWO =55, TP =26)
MOWS	25mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was square shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, indicating tension from lingual frenulum
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum classified as altered	Yes, the frenulum is short
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	6/8 indicating the frenulum is altered.
Touch the upper lip with tip of tongue	Partially successful, required jaw support to be able to do so.

Touch upper and lower molars	Partially successful, required jaw manipulation to be able to do so. Struggled to get tongue on top of left molar and into buccal cavity.
Sucking against the palate	Partially successful, 25mm

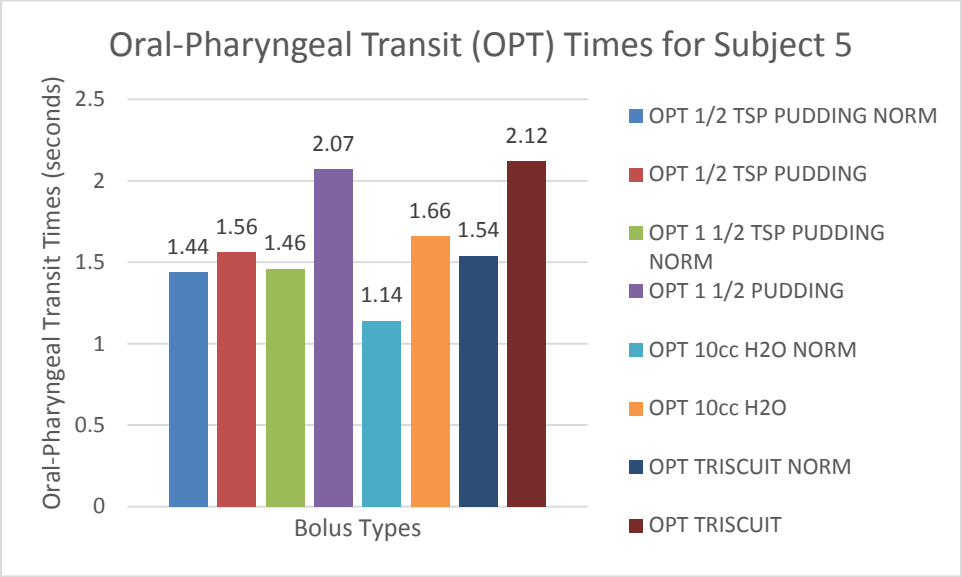
IOPI and EMG measurements for Subject 5 are presented in Table 3.9. All measures were distinctly below normative data. Specifically left and right masseter measurements for all boluses were markedly weaker than the normative data, coming in less than half the means of the norms. Oral-pharyngeal transit times for subject 5 also appeared delayed when compared to the normative data (see figure 3.10 below). During trials of the Triscuit cracker, Subject 5 reported, as well as demonstrated, that he drops the bolus to the area of the valleculae during deglutition.

Table 3.9. Observed data for Participant 5.

Measurement	**#5**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	31.33	52.42	12.65
iopidorsavg	32.67	55.75	12.58
iopilipsavg	24.33	34.58	20.83
mcbARMSav	61.87	234.18	218.73
mcbBRMSav	98.68	123.08	178.15
mcpud1ARMS	18.52	77.08	160.49
mcpud1BRMS	16.60	57.47	95.77
mcpud2ARMS	20.04	49.59	110.88
mcpud2BRMS	16.18	90.55	156.28
mc10ccARMS	17.85	53.45	131.81
mc10ccBRMS	17.16	113.34	236.52
mccrackARMS	80.86	107.75	189.75
mccrackBRMS	101.22	154.52	298.71
stcpud1avg	1.56	1.44	0.38
stcpud2avg	2.07	1.46	0.38
stc10ccavg	1.66	1.14	0.23

Stccrackavg	2.12	1.54	0.55

Fig 3.10 Oral-Pharyngeal Transit Times for Subject 5.



Subject 6

Subject 6 was a 26-year-old female identified with tongue tie using the *Lingual Frenulum Protocol*. Subject 6 participated as Group B order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session. Previous history includes issues with neck and shoulder pain, dry lips, voice problems-listed as occasional laryngitis, headaches, and deglutition indicated as swallowing too much air. Demographic survey revealed a history of braces, cheek biting (1-2 times a month), oral sores (once a month), and PE tubes as a child.

Table 3.10 revealed behavioral and clinical indicators of tongue tie including a tongue tip that was oblong shaped. Frenulum attachment occurred below the middle and apex of the tongue and was short. The client was also partially successful in being able to

touch the upper lip with the tip of her tongue but required jaw support by narrowing the opening of the mouth and resting the tongue on the jaw while doing so.

Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot minus five (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=51mm, MOtts=24, MOWS=28. The ration of MOmax and MOtts was 47% which is indicative of a tongue tie. Additionally, the difference of MOmax and MOWS was only slightly greater than half which is a red flag indicating the presence of tongue tie. Overall the result of the general section resulted in a score of 4 indicating an altered lingual frenulum. There were no significant results from the informal and formal speech measures performed during the functional test. Oral facial examination revealed a high palate with well-defined rugae on the alveolar ridge. Results for bolus formation was an average of 3.67 indicating that bolus formation was somewhere between demonstrating some evidence of cohesion and scattering and being disorganized or scattered on the tongue. Results for presence of residue after the swallow were an average of 1.67 indicating that there was somewhere between minimal to no residue present after deglutition to some evidence of residue remaining after deglutition.

Table 3.10. Behavioral/Clinical Indicators, Participant 6.

Indicators	Results
Ratio of MOmax and MOtts	47% (MOmax =51, MOtts =24)
MOWS	28mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was oblong shaped indicating tension in the lingual frenulum.
Frenulum attachment occurring below the middle and apex of the tongue	Present, indicating an abnormal point of attachment
Frenulum classified as altered	Yes, the frenulum is short.
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	3-4/8 indicating the frenulum is altered.

Touch the upper lip with tip of tongue	Partially successful, required jaw support to be able to do so.
Sucking against the palate	Successful, 28mm

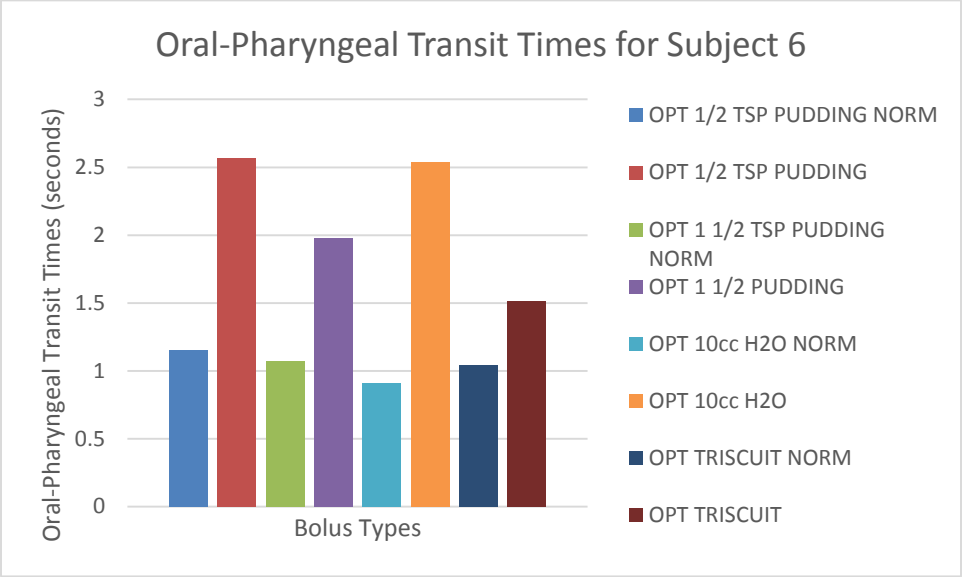
Objective data for IOPI and EMG measurements are revealed in Table 3.11. All measures for Subject 6 were well below the means of the normative data. IOPI tip, dorsum, and between the lip pressure readings were weaker than normative averages. Specifically, left and right masseter baseline measurements were substantially lower than normative averages, as well as left and right masseter readings as measured by EMG for all measurements, except for the right sided EMG reading on the Triscuit (mccrackBRMs). Delayed oral-pharyngeal transit times are present in all 4 of the bolus measurements for subject 6, as shown in Figure 3.11, this is indicative of oral-pharyngeal dysfunction.

Table 3.11. Observed data for Subject 6.

Measurement	**#6**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	33	44.90	13.51
iopidorsavg	23	46.90	9.41
iopilipsavg	11.33	21.40	11.69
mcbARMSav	56.91	282.92	233.70
mcbBRMSav	113.61	470.66	306.95
mcpud1ARMS	17.73	42.74	33.43
mcpud1BRMS	31.57	85.43	104.40
mcpud2ARMS	12.14	68.44	88.16
mcpud2BRMS	21.01	136.74	171.51
mc10ccARMS	9.80	29.45	29.21
mc10ccBRMS	24.93	100.16	142.83
mccrackARMS	106.59	125.04	121.92
mccrackBRMS	193.13	159.86	149.08
stcpud1avg	2.57	1.15	0.54
stcpud2avg	1.98	1.07	0.48
stc10ccavg	2.54	0.91	0.37

Stccrackavg	1.51	1.04	0.45

Fig 3.11 Oral-Pharyngeal Transit Times for Subject 6.



Subject 7

Subject 7 was a 25-year-old male identified with tongue tie using the *Lingual Frenulum Protocol*. Subject 7 participated as Group C order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session. Case history indicated issues relating to TMJ clicking and pain, neck pain, chewing, voice, and headaches. Additionally, he reported that his daughter has been diagnosed with a tongue tie and demonstrates difficulty with breastfeeding as a result.

Behavioral and clinical indicators are reported in Table 3.12 and indicate the presence of tongue tie. His tip of tongue was square shaped and demonstrated a classic heart shape appearance. The frenulum was attached between the middle and apex of the tongue and considered altered due to this attachment. Distortion indicated by rolling of the side of his tongue upward, was demonstrated when touching the sides of his mouth with

his tongue. He also demonstrated difficulty in sucking his tongue against his palate as indicated by having to narrow his mouth opening while doing so.

Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot (minus five) (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=52mm, MOtts=24, MOWS=30. When the difference of MOmax and MOtts are smaller than half the MOmax this can indicate a tongue tie. The ratio of MOmax to MOtts was 46% and indicative of a tongue tie. Overall the results of the general section were a score of 6 indicating an altered lingual frenulum. There were no significant results from the informal and formal speech measures performed during the functional test. Oral facial examination of Subject 7 revealed a high palate with moderately defined rugae on the alveolar ridge. Results for bolus formation was an average of 1 indicating that bolus formation was organized in a ball in the middle of the tongue. Results for presence of residue after the swallow was an average of 3.67 indicating greater presence of residue after deglutition.

Table 3.12. Behavioral/Clinical Indicators, Participant 7.

Indicators	Results
Ratio of MOmax and MOtts	46% (MOmax =52, MOtts =24)
MOWS	30mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was square shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, participant had classic heart shaped tip indicating tension from lingual frenulum
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum classified as altered	Yes, the frenulum was attached between the middle and apex of the tongue.

General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5/8 indicating the frenulum is altered.
Touch right comissura labiorum	Partially successful, some distortion in movement when performing this task.
Sucking against the palate	Partially successful, 30mm

Table 3.13 reveals objective data for EMG and IOPI measurements during assessment of Subject 7. As can be seen from Figure 3.12, the IOPI tip measurement was the only measure lower than normative averages. EMG masseter right and left baseline, ½ teaspoon, 1 ½ teaspoon, 10cc H2O, and Triscuit cracker measurements were well below the means of normative data, indicating weakness of the masseter muscle. This correlates with self-reported chewing difficulties. Data for subject 7 also revealed delayed oral-pharyngeal transit times which is indicative of OPD (see Figure 3.13 below).

Table 3.13. Observed data for Participant 7.

Measurement	**#7**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	37	48.25	13.38
iopidorsavg	60.67	38.25	17.63
iopilipsavg	19.67	13	4.546
mcbARMSav	87.38	317.62	120.10
mcbBRMSav	120.22	523.11	415.93
mcpud1ARMS	18.34	37.92	24.48
mcpud1BRMS	36.68	68.79	71.43
mcpud2ARMS	11.59	40.09	26.67
mcpud2BRMS	21.25	90.82	123.48
mc10ccARMS	9.83	20.87	14.72
mc10ccBRMS	15.68	51.27	57.96
mccrackARMS	104.29	99.38	60.78
mccrackBRMS	121.59	141.00	76.40
stcpud1avg	1.6	1.13	0.46
stcpud2avg	1.64	1.16	0.47
stc10ccavg	1.25	0.86	0.30

Stccrackavg	1.76	1.04	0.27

Fig 3.12 IOPI Measurements for Subject 7.

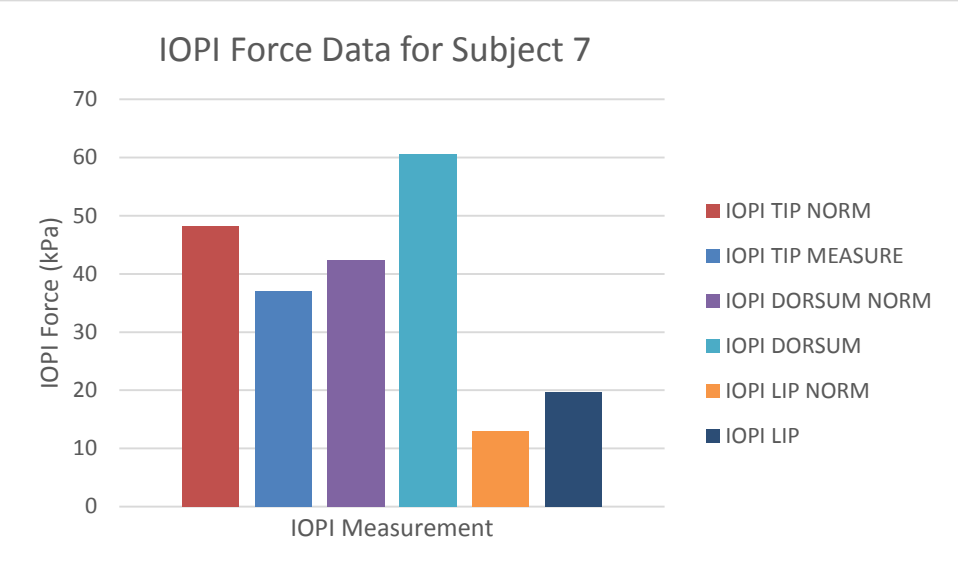
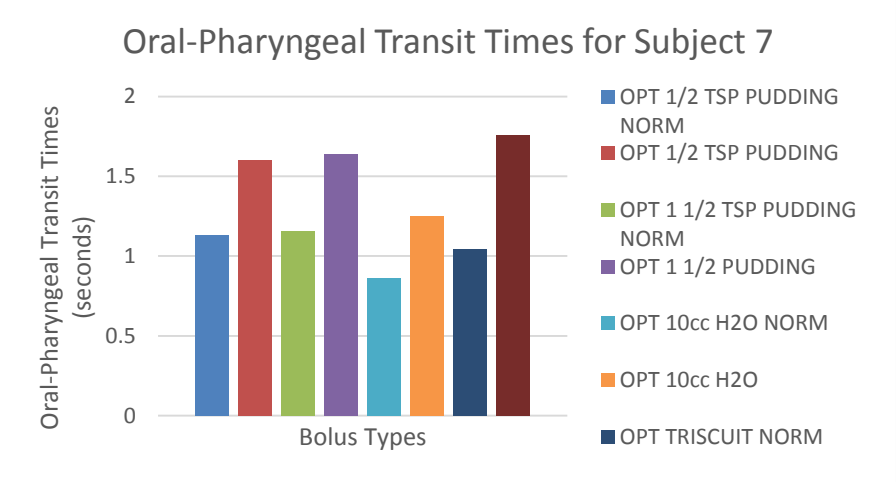


Fig. 3.13 Oral-Pharyngeal Transit Times for Subject 7.



Subject 8

Subject 8 was a 27-year-old male identified with tongue tie using the *Lingual Frenulum Protocol*. Subject 3 participated as Group B order of presentation. The IOPI,

EMG masseter, and EMG swallowing measurements were completed in one session. Case history indicates that the client has a hyperactive gag which was observed in behavioral and clinical measures including the pudding bolus trials and IOPI measurements. In conjunction with a hyperactive gag, subject 8 demonstrated severe texture aversions and was unable to perform the bolus trials using pudding. Applesauce was substituted for pudding in this instance. He also reported other texture aversions with foods including, mayonnaise, sour cream, mustard, ketchup, cream cheese, relish, and cottage cheese. Oral facial examination revealed a high palate and well defined rugae along with a class 1 malocclusion.

Behavioral and clinical indicators indicating the presence of tongue tie are revealed in Table 3.14. The tip of his tongue was oblong and demonstrated a notch indicating tongue tension. The frenulum was attached between the middle and apex of the tongue as well as at the alveolar crest. He demonstrated difficulty without the use of his jaw to support his tongue in protruding and retracting, touching the upper lip with the tip of his tongue, as well as touching the upper and lower molars with his tongue tie. Distortion, indicated by the rolling upwards of the side of his tongue was present when he touched the right and left corner of his mouth with his tongue. He also struggled to suck his tongue up against his palate for even a short period of time and exhibited severe neck and mentalis tension during this measure. His tongue was observed to be resting behind his lower teeth and he demonstrated tongue protrusion on 3 trials of ½ teaspoon of applesauce and one trial of 10cc water.

Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla/to spot (minus five) (MOtts), and

during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=55mm, MOtts=27, MOWS=22. The ratio between MOmax and MOtts was 49% which qualifies as being indicative of having a tongue tie. In addition, the difference of MOWS was less than half of MOmax which further indicates a tongue tie. Finally, the results of the general section of the LFP indicated a final score of 6, indicating an altered lingual frenulum. There were no significant results from the informal and formal speech measures performed during the functional test. Oral facial examination of subject 8 revealed a high palate with well-defined rugae on the alveolar ridge. Results for bolus formation were an average of 1.67 indicating that bolus formation was between being organized in a ball or tube in the middle of the tongue as it should be and demonstrating some evidence of cohesion and scattering. Results for presence of residue after the swallow were an average of 2.33 indicating that there was some evidence of residue remaining after deglutition.

Table 3.14. Behavioral/Clinical Indicators, Participant 8.

Indicators	Results
Ratio of MOmax and MOtts	49%, indicating a tongue tie (MOmax =55, MOtts=27)
MOWS	22mm
Tip of tongue appearing oblong or square shaped	Tip of tongue was square shaped indicating tension in the lingual frenulum.
Tip of tongue appearing like a heart	Present, indicating tension from lingual frenulum
Frenulum observed from the alveolar crest	Present, indicating anterior point of attachment
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum attachment occurring below the middle and apex of the tongue	Present, indicating an abnormal point of attachment
Frenulum classified as altered	Yes, the frenulumis short.

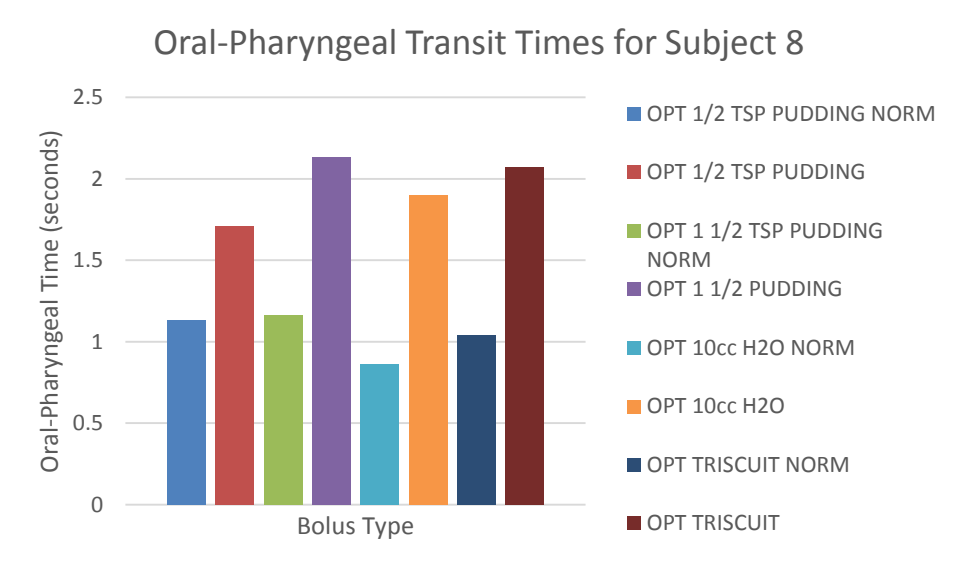
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	6/8 indicating the frenulum is altered.
Protrude and retract tongue	Partially successful, limited tongue/jaw differentiation
Touch the upper lip with tip of tongue	Partially successful, required jaw support to be able to do so.
Touch right comissura labiorum	Unsuccessful, major tongue distortion/rolling upon movement.
Touch left comissura labiorum	Unsuccessful, major tongue distortion/rolling upon movement.
Touch upper and lower molars	Partially successful, required jaw manipulation to be able to do so. Struggled to get tongue on top of molars and into buccal cavity.
Sucking against the palate	Partially successful, 22mm
Tongue resting behind bottom teeth	Yes

Objective data of measurements of IOPI and EMG measurements for Subject 8 are revealed in Table 3.15. IOPI measurements were within normal limits for both dorsum and between the lips pressure readings. The recorded IOPI tip measurement was slightly below the mean for normative data. In contrast, right and left masseter baseline measurements were less than half of normative data. Subject 8 had measurements within normal limits for left EMG 10cc H2O (mc10ccARMS), as well as right and left Triscuit measurements (mccrackARMS, mccrackBRMS). As was previously mentioned, neck and mentalis tension were observed during Triscuit bolus trials. All other right and left EMG masseter measurements as indicated in Table 3.15 were below the normative averages. Forward tongue protrusion was demonstrated during all ½ tsp applesauce and one H2O trials. Recorded data for Subject 8 also indicates a noticeable delay in oral-pharyngeal transit times for all bolus consistencies (see Figure 3.14), this is indicative of oral-pharyngeal dysfunction.

Table 3.15. Observed data for Participant 8.

Measurement	#8	Norms	
	Observed	Mean	SD
iopitipavg	46.67	47.08	16.42
iopidorsavg	48.67	42.33	17.38
iopilipsavg	19	17.33	7.808
mcbARMSav	84.94	317.62	120.10
mcbBRMSav	174.09	523.11	415.93
mcpud1ARMS	21.62	37.92	24.48
mcpud1BRMS	61.05	68.79	71.43
mcpud2ARMS	27.07	40.09	26.67
mcpud2BRMS	24.29	90.82	123.48
mc10ccARMS	58.62	20.87	14.72
mc10ccBRMS	50.91	51.27	57.96
mccrackARMS	112.15	99.38	60.78
mccrackBRMS	237.05	141.00	76.40
stcpud1avg	1.71	1.13	0.46
stcpud2avg	2.13	1.16	0.47
stc10ccavg	1.90	0.86	0.30
Stccrackavg	2.07	1.04	0.27

Fig 3.14 Oral-Pharyngeal Transit Times for Subject 8.



Subject 9

Subject 9 was a 36-year-old female identified with tongue tie using the *Lingual Frenulum Protocol*. Subject 3 participated as Group A order of presentation. The LFP, IOPI, EMG masseter, and EMG swallowing measurements were completed in one session. Case history revealed that she has issues with TMJ clicking, mandible range of motion, and chewing issues. She also reported a family history of tongue tie. Oral examination revealed a high palate and moderately defined rugae, as well as a class 1 malocclusion.

Behavioral and clinical indicators reveal the presence of tongue tie demonstrated by an oblong tongue tip, frenulum attachment occurring between the middle and apex of the tongue as well as at the alveolar crest. She demonstrated the use of jaw support in being able to touch her upper lip with the tip of her tongue, as well as her upper and lower molars. Tasks involving toughing the right and left corners of her mouth also demonstrated distortion of the tongue indicated by the sides of her tongue rolling slightly upwards. She demonstrated difficulty sucking her tongue against her palate by closing her mouth making it impossible to get an accurate measurement.

Results for measurements of having the mouth opened maximally (MOmax), maximally opened with tongue at the incisive papilla (minus five) (MOtts), and during suction of the tongue against the hard palate (MOWS) are reported as follows; MOmax=34mm, MOtts=20, MOWS=unable to get a reliable measure. The ratio of MOmax and MOtts was 59% which can be considered within normal limits, however, considering the overall results of the general section of the LFP (5) and observed behaviors previously mentioned, subject 9 was considered as tongue tied. Results of the functional test of the Lingual Frenulum Protocol are reported in Table 3.16. There were no significant

results from the informal and formal speech measures performed during the functional test. Results for bolus formation were an average of 1.67 indicating that bolus formation was between being organized in a ball or tube in the middle of the tongue as it should be and demonstrating some evidence of cohesion and scattering. Results for presence of residue after the swallow were an average of 1indicating that there was no evidence of residue remaining after deglutition.

Table 3.16. Behavioral/Clinical Indicators, Participant 9.

Indicators	Results
Ratio of MOmax and MOtts	59%, (MWO =34, TP =20)
MOWS	0, Unable to obtain measure
Tip of tongue appearing oblong or square shaped	Tip of tongue was oblong shaped indicating tension in the lingual frenulum.
Frenulum observed from the alveolar crest	Present, indicating anterior point of attachment
Frenulum attachment occurring between the middle and apex of the tongue	Present, indicating an anterior point of attachment
Frenulum classified as altered	Yes, the frenulum was attached between the middle and apex of the tongue.
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5-6/8 indicating the frenulum is altered.
Touch the upper lip with tip of tongue	Partially successful, required jaw support to be able to do so.
Touch right comissura labiorum	Partially successful, some distortion in movement when performing this task.
Touch left comissura labiorum	Partially successful, some distortion in movement when performing this task.
Touch upper and lower molars	Partially successful, required jaw manipulation to be able to do so. Struggled to get tongue on top of molars and into buccal cavity.
Sucking against the palate	Unsuccessful

Table 3.17 reveals objective data collected for EMG and IOPI recorded for subject 9. Pressure measurements for the IOPI tip were within normal limits but IOPI

dorsum and between the lips measurements were below the normative data (see Figure 3.15 below). Right and left EMG masseter baseline data was markedly lower than normative averages. Left EMG masseter (mcpud1ARMS and mcpud2ARMS) measurements during ½ and 1 ½ pudding trials were above the means when compared to normative data. However, all other EMG masseter measurements were below the normative data. Oral-pharyngeal transit times are shown below in Figure 3.16 for Subject 9 and were markedly lower than the means of normative data.

Table 3.17. Observed data for Participant 9.

Measurement	**#9**	**Norms**	
	Observed	**Mean**	**SD**
iopitipavg	45.33	41.40	12.93
iopidorsavg	45	58.80	6.14
iopilipsavg	10	31.2	12.91
mcbARMSav	142.04	252.56	192.20
mcbBRMSav	109.36	264.02	218.52
mcpud1ARMS	114.84	83.60	101.77
mcpud1BRMS	59.24	85.72	110.70
mcpud2ARMS	104.48	102.99	109.32
mcpud2BRMS	30.86	117.47	142.98
mc10ccARMS	32.66	39.09	26.38
mc10ccBRMS	24.82	38.62	39.69
mccrackARMS	145.41	160.64	162.49
mccrackBRMS	70.58	182.39	194.70
stcpud1avg	3.28	1.49	0.36
stcpud2avg	3.52	1.49	0.56
stc10ccavg	3.56	1.14	0.32
Stccrackavg	2.82	1.34	0.35

Fig 3.15 IOPI Measurements for Subject 9.

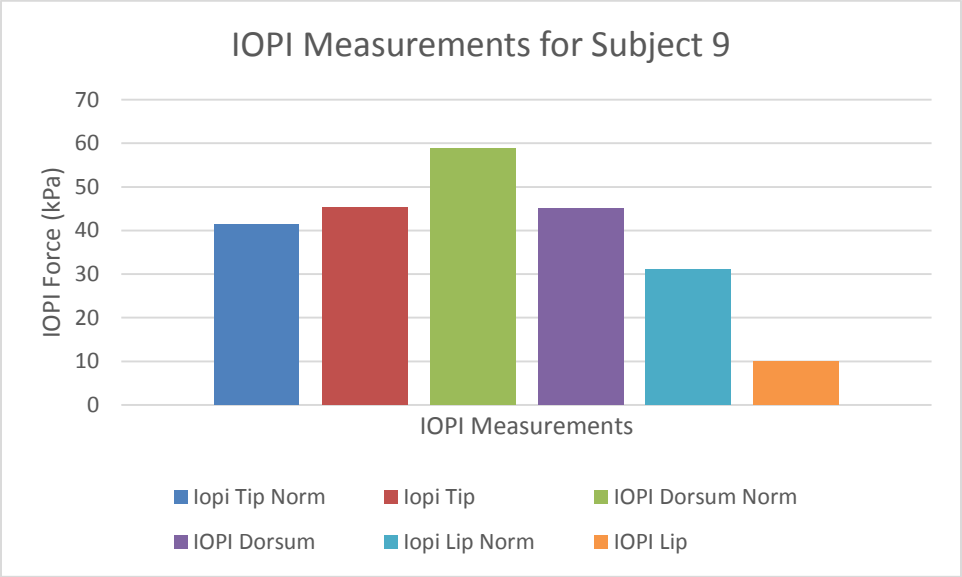
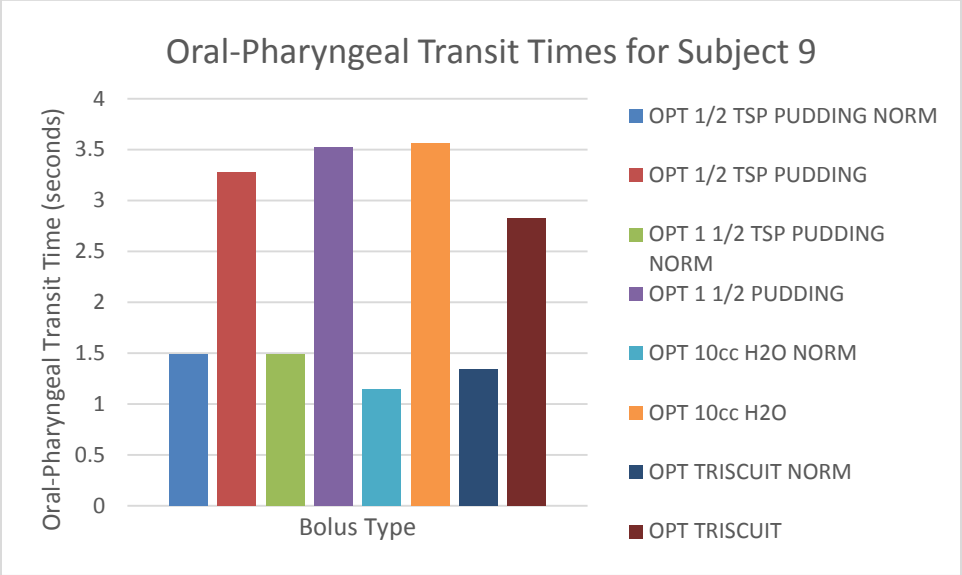


Fig 3.16 Oral-Pharyngeal Transit Times for Subject 9.



Group Trends

Group comparisons of all subjects to normative data for IOPI tip, dorsum, and between the lips measurements are shown in figures 3.17, 3.18, and 3.19 respectively. With a few exceptions, overall, individuals with tongue tie showed a decreased ability to generate force when compared to individuals of the same age, without tongue tie.

Figure 3.17 IOPI Tip Comparison by Severity of Tongue Tie. Note that low tongue tie coefficient indicates greater involvement.

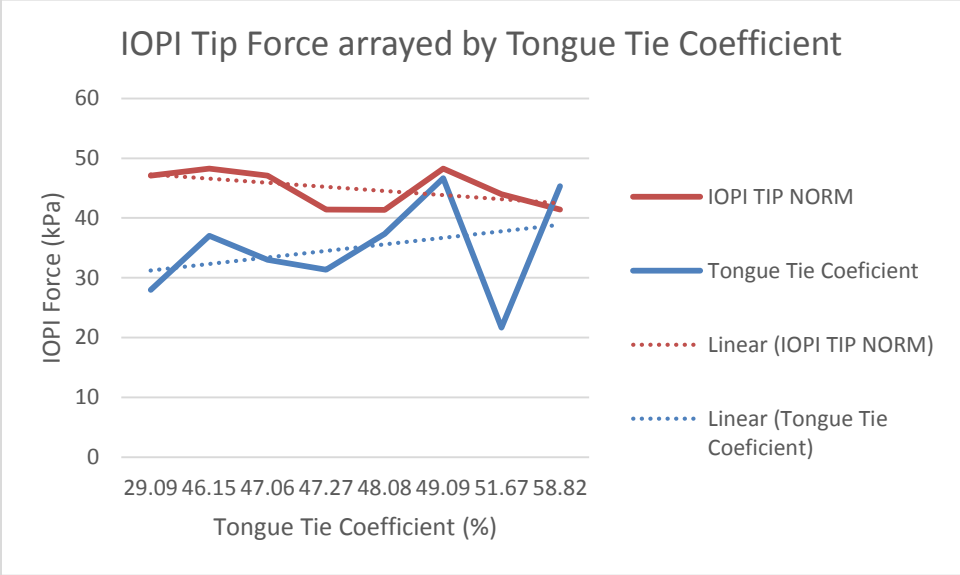


Figure 3.18 IOPI Dorsum Comparison by Severity of Tongue Tie. Note that low tongue tie coefficient indicates greater involvement.

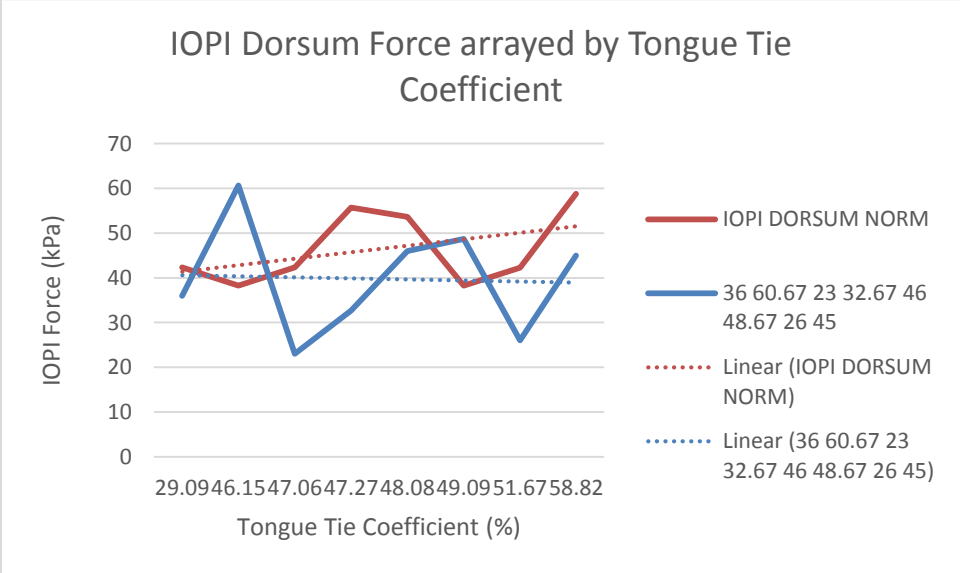
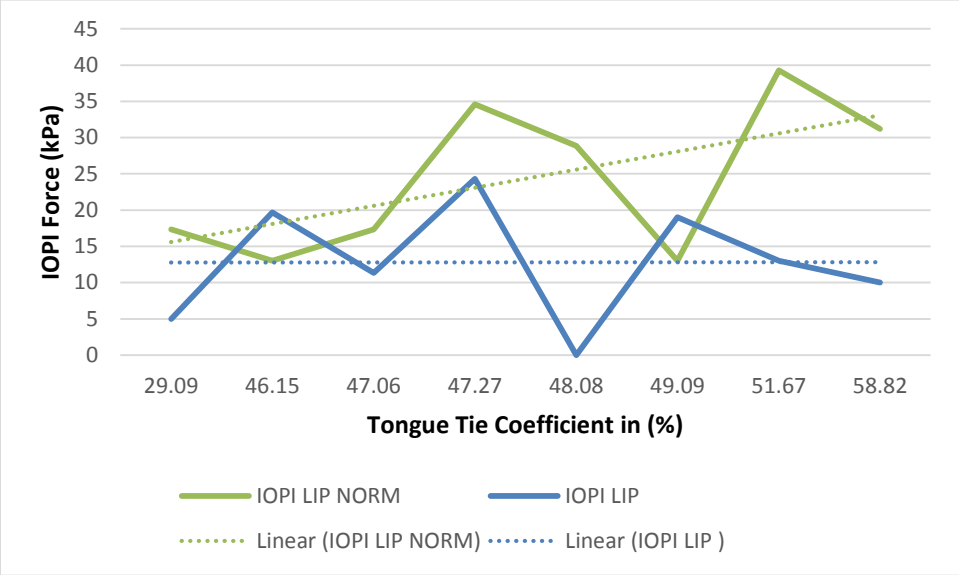


Figure 3.19 IOPI between the Lips Comparison by Severity of Tongue Tie. Note that low tongue tie coefficient indicates greater involvement.



Figures 3.20, 3.21, 3.23, and 3.24 reveal oral pharyngeal transit times for all bolus consistencies. This data indicates prolonged oral-pharyngeal transit times for all consistencies for individuals with a tongue tie.

Figure 3.20 Group Oral-Pharyngeal Transit Time for ½ TSP Pudding.

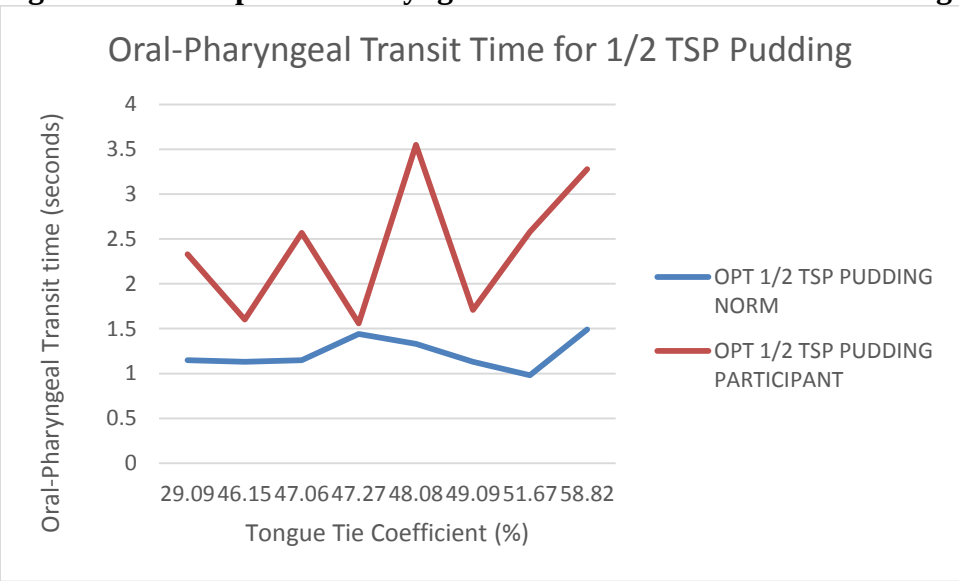


Figure 3.21 Group Oral-Pharyngeal Transit Time for 1 ½ TSP Pudding.

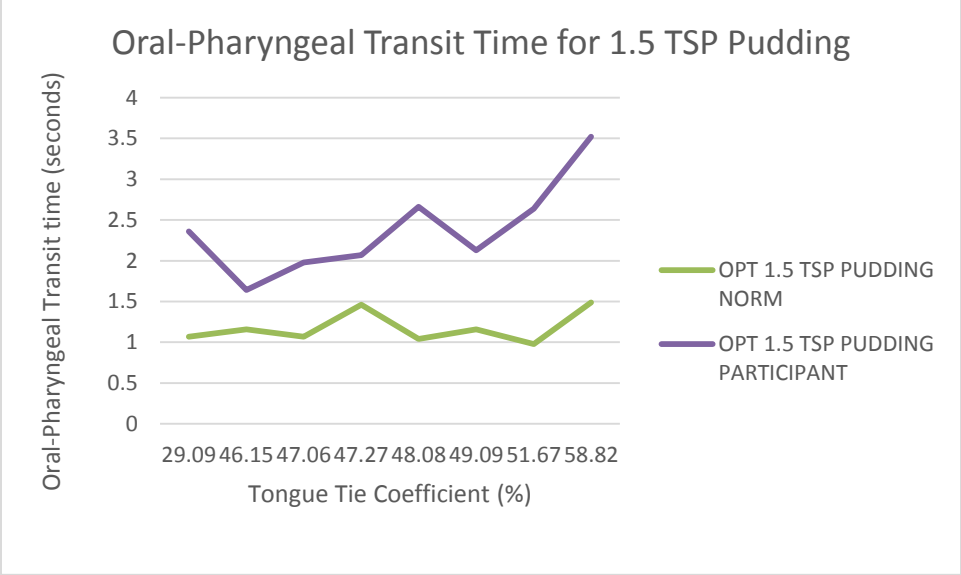


Figure 3.22 Group Oral-Pharyngeal Transit Time for H2O Trials.

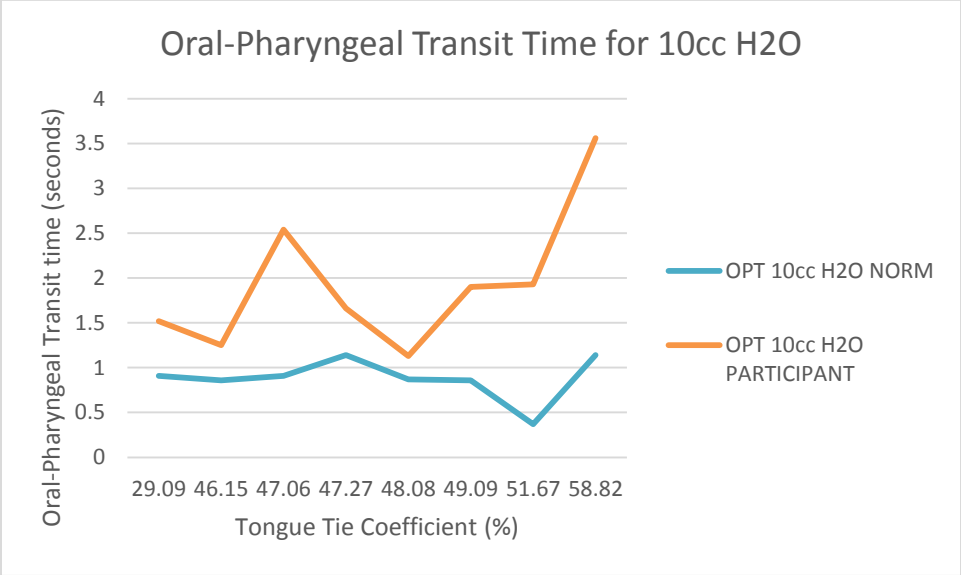
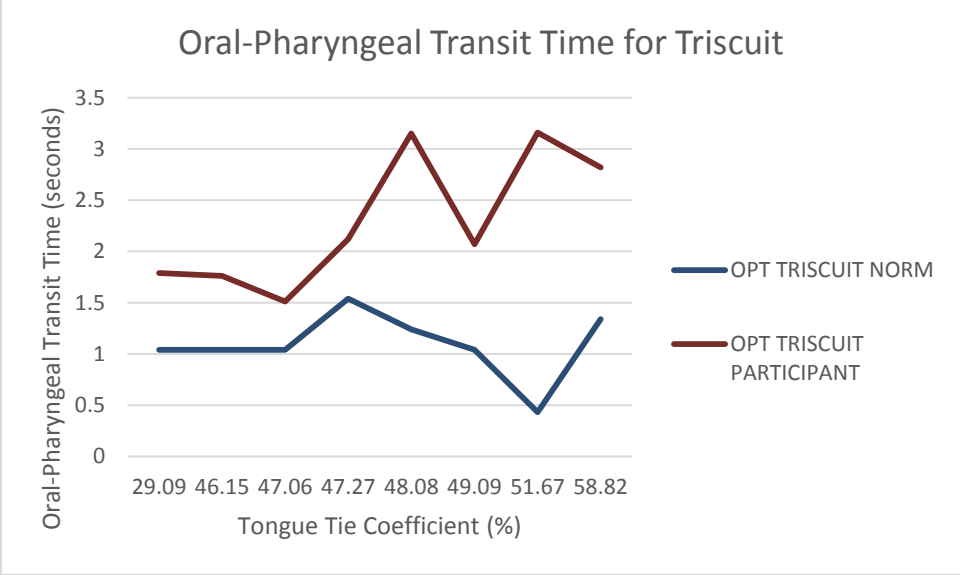


Figure 3.23 Group Oral-Pharyngeal Transit Time for Triscuit Trials.



Group trends gathered from behavioral observations of the tongue indicated that 4/8 subjects exhibited tongue protrusion during bolus trials. Additionally, 7/8 subjects revealed a high vaulted palate with defined rugae, 6/8 revealed an attachment of the frenulum between the middle and apex of the tongue, 5/8 revealed an anterior connection of the frenulum at the alveolar crest, 5/8 exhibited a square shaped tongue, while 3/8 exhibited an oblong tongue share, lastly 6/8 demonstrated tension in the tongue tip indicated by a notch or heart shape near/at the tip. Seven of eight subjects were only partially successful with sucking the tongue against the palate and struggled to keep the tongue up there for more than a second or two, exhibited the need to manipulate their jaw, and keep the tip to the base up against the palate.

Chapter 4: Discussion

The purpose of this study was to gather preliminary normative data and examine possible relationships between oral-pharyngeal dysphagia (OPD) and individuals with ankyloglossia. To my knowledge this study was the first of its kind to be performed. Data was gathered on 8 participants, 3 males and 5 females with actual ages from 18-41 years old using the IOPI and EMG measurements. Measurements of tongue tip, tongue dorsum, and lip force, masseter contraction, and laryngeal timing were examined for tongue tied individuals. The measures of force and masseter contraction were gathered for preliminary normative data, as well as to examine possible relationships between the defining characteristics of both disorders. The measure of swallowing timing provided a measure of OPD. These data were then compared with normative data of Holzer (2011) to determine significant differences.

Research Hypothesis:

The hypotheses examined for this study were as follows:

Question 1

H_{0a}: No relationship exists between variables associated with oropharyngeal dysphagia and those associated with ankyloglossia.

$H_{1a:}$ A relationship exists between variables of oropharyngeal dysphagia and ankyloglossia.

Question 2

H_{0b}: No noticeable difference exists in masseter contraction based on side and/or bolus type.

$H_{1b:}$ A noticeable difference exists in masseter contraction based on side and/or bolus type.

Question 3

H_{0c}: No obvious difference exists in laryngeal timing based on bolus type.

$H_{1c:}$ A obvious differences exists in laryngeal timing based on bolus type.

Question 4

H_{0d}: No marked difference exists in force, as measured by IOPI, based on IOPI location.

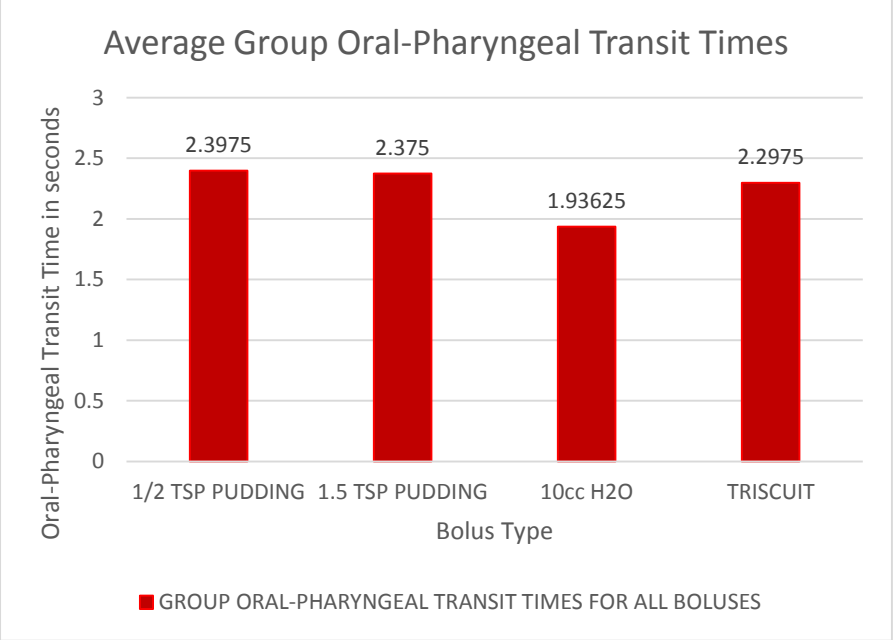
$H_{1d:}$ A marked difference exists in force, as measured by IOPI, based on IOPI location.

Research Findings

Question 1: Is there a relationship between variables associated with oral-pharyngeal dysphagia and those associated with ankyloglossia?

The main indicator for oral-pharyngeal dysphagia is delayed oral-pharyngeal transit times (Evers, 2013). In this study, the main indicator for ankyloglossia was tongue tie severity as indicated by the tongue tie coefficient. Based on the results, the null hypothesis must be accepted in that no relationship exists between variables associated with oral-pharyngeal dysphagia and those associated with ankyloglossia. However, as was indicated by Figures 3.20 to 3.23 there is a noticeable delay in oral-pharyngeal transit times demonstrated for all bolus consistencies for individuals diagnosed with tongue tie. An overall average of the 8 individuals in this study was performed for each of the four bolus consistencies as shown in Figure 4.1. These averages reveal a global delay of oral-pharyngeal transit time of over 1.5 second for all bolus consistencies.

Figure 4.1 Average Group Oral-Pharyngeal Transit Times.



Question 2: Is there a noticeable difference between masseter contractions based on side and/or bolus type?

Overall the results for masseter contractions as measured by EMG readings indicate that there are no noticeable differences based on both side and bolus type for individuals with tongue tie when compared to normative data of those without tongue tie. However, there was a trend revealing that a majority of individuals with tongue tie presented with measurements below the normative data. Measurements below the normative data indicate reduced master activity which could be the result of the tongues tip being unable to make contact with the roof of the mouth and generate counter pressure. During a normal swallow the tongue tip makes contact with the roof of the mouth generating counter pressure at the base, which then in turn activates the masseter for stabilization of the tongue (T. Seikel, personal communication, May 7th, 2016). Limited mobility of the tongue to reach the roof of the mouth is something we might

anticipate with an anterior point of attachment at the alveolar crest, which was exhibited for 63% of the individuals, and/or a point of attachment of the frenulum between the middle and apex of the tongue, which was exhibited for 75% of the individuals with tongue tie. Additionally, the inability of the tongue to approximate with the roof of the mouth was also evidenced as 7/8 individuals exhibited a high vaulted palate. In typical development the tongue is the driving force that helps to spread the palate out, and consequently a high vaulted palate is indicatory of the tongues inability to perform this function.

During these measures of masseter contraction, it was noted that one subject did have right and left masseter contractions above the means of normative data during the Triscuit swallows, and a left sided average above the mean during H2O trials (Subject 8: 67 compared to 20.87 [sd=14.72]). Interestingly, this subject presented with the most clinical indicators (tip of tongue being square shaped, heart shaped tip, anterior point of attachment at the alveolar crest as well as between the middle and apex of the tongue, difficulty touching the upper lip, right and left sides of the mouth, upper and lower molars, and sucking against the palate). They also presented with increased mentalis and neck tension throughout oral facial examination and swallow trials. This could be a contributing factor to the increased masseter readings observed during EMG measures, and could potentially be a result of having to compensate for limited tongue mobility.

Question 3: Is there an obvious difference in laryngeal timing based on bolus type?

Statistical significance, as revealed in tables 4.1- 4.4, was found for a majority of the subjects indicating that there is an obvious difference in laryngeal timing for individuals with tongue tie based on bolus type. All individuals demonstrated a marked

delay when compared to normative data regardless of bolus type. As a group, the participants in this study demonstrated an average delay of 2.39 seconds for ½ a teaspoon of pudding, 2.38 seconds for 1 ½ teaspoons of pudding, 1.94 seconds for 10cc of H20, and 2.30 seconds for the Triscuit cracker, see Figure 4.1. Compared to normative data a delay in oral-pharyngeal time is indicative of oral-pharyngeal dysphagia (Evers, 2013). It was also observed during swallow trials and EMG recordings that several subjects required multiple swallows to clear the bolus as indicated in Figures 4.2, 4.3, and 4.4). Figure 4.5 illustrates a case in which one subject was shown to demonstrate smaller swallows, in what she termed, "preparatory swallows." Figure 4.5 illustrates a preparatory swallow and can be implicated in prolonged oral-pharyngeal measures. The need for preparatory and multiple swallows could be indicative of the need to compensate for the limited ability of the tongue to form a cohesive bolus and functionally move the bolus in an anterior to posterior motion, due to a tongue tie. Revisiting the oral stage of the swallow, a tongue tie could impede proper formation of a bolus which can thus complicate a cohesive movement of the bolus in an anterior to posterior movement which is needed to trigger the swallow. Again these compensatory measures would consequently prolong the initiation and termination of the swallow.

Table 4.1 P-value for Oral-Pharyngeal Transit Times of ½ Teaspoon of Pudding Bolus

Subject	t-scores	p-value
2	69	p<.01
3	105	p<.01
4	155	p<.01
5	53	ns
6	73	p<.01
7	59	p<.05
8	61	p<.01
9	87	p<.01

Table 4.2 P-value for Oral-Pharyngeal Transit Times of 1 ½ Teaspoons of Pudding Bolus

Subject	t-scores	p-value
2	58	p<.05
3	92	p<.01
4	115	p<.01
5	61	p<.01
6	60	p<.01
7	59	p<.05
8	68	p<.01
9	82	p<.01

Table 4.3 P-value for Oral-Pharyngeal Transit Times of 10cc H2O Bolus

Subject	t-scores	p-value
2	64	p<.01
3	79	p<.01
4	73	p<.01
5	68	p<.01
6	88	p<.01
7	62	p<.01
8	82	p<.01
9	120	p<.01

Table 4.4 P-value for Oral-Pharyngeal Transit Times of Triscuit Cracker Bolus

Subject	t-scores	p-value
2	64	p<.01
3	116	p<.01
4	109	p<.01
5	59	p<.05
6	59	p<.05
7	70	p<.01
8	79	p<.01
9	78	p<.01

Fig 4.2 Multiple Swallows, ½ Teaspoon Pudding Trial (Subject 2 – Trial 1)

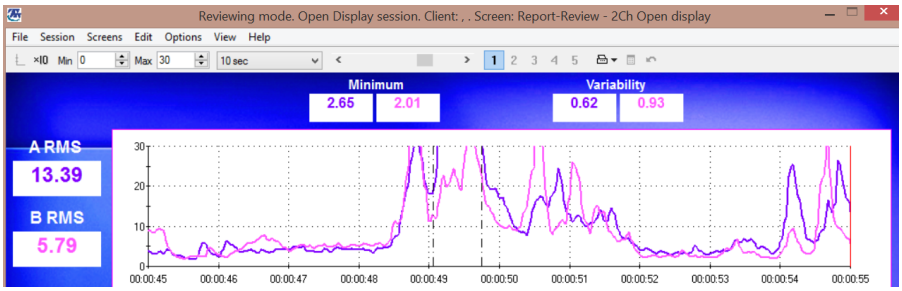


Fig 4.3 Multiple Swallows, 1 ½ Teaspoon Pudding Trial (Subject 4 – Trial 3).

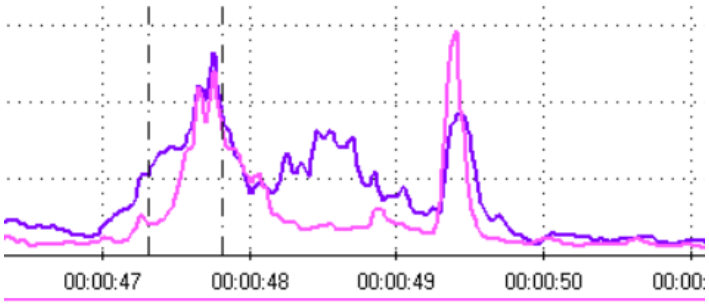


Fig 4.4 Multiple Swallows, 10cc H2O Trial (Subject 4 – Trial 3).

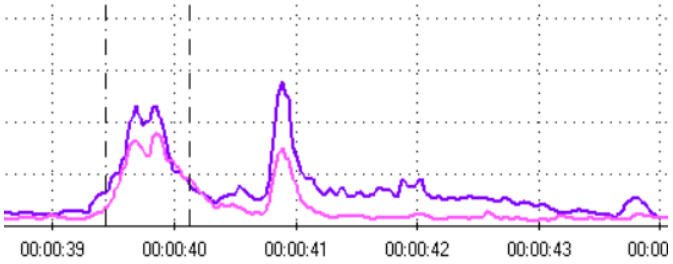
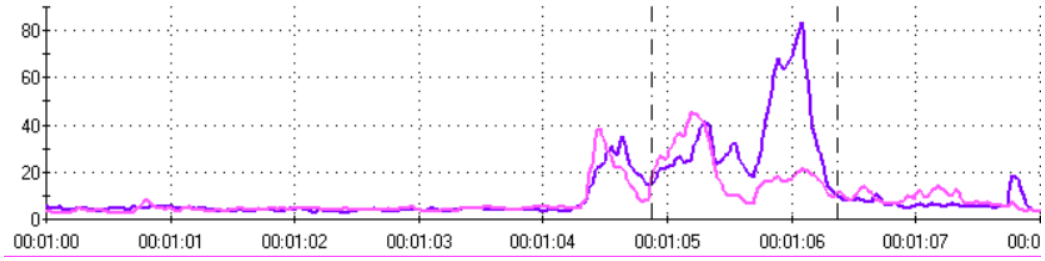


Figure 4.5 Preparatory Swallows ½ Teaspoon Pudding Trial (Subject 2- Trial 2).



Question 4: Is there a marked difference that exists in force based on IOPI location?

Measures of IOPI force were performed using the tongue tip, tongue dorsum, and the lips. Statistical analysis, as shown in Tables 4.5 – 4.7, indicate that no significance difference exists in force based on IOPI location, except for an IOPI dorsum measure of subject 7 *t score* (58), $p < .05$. Consequently, no definitive conclusions can be drawn regarding tongue tie and the ability of the tongue and lips to generate adequate pressure.

However, when comparing the raw data of IOPI tongue tip force measures with raw data of those of normative data, the culminated data revealed that there were marked differences for 7/8 individuals. The results of IOPI tip measurements indicate a reduced ability of the tongue tip to generate force, or reduced strength in the apex and involved musculature. These findings may be due to findings from the LFP revealing that 6/8 had an attachment of the frenulum between the middle and apex of the tongue and 5/8 revealed an anterior connection of the frenulum at the alveolar crest. These points of attachment can limit the mobility of the tongue tip, which translates to reduced use and development, resulting in a reduced measure of force. The one individual that was above the mean when compared to the normative data, scores exhibited an observed measure of 45.33 for tongue tip force compared to the mean of 41.40 (sd=12.93) from the normative data.

In regards to tongue dorsum and between the lips measurements of IOPI force, 6/8 subjects demonstrated markedly reduced force when compared to the mean from normative data for both types of measurements. The two subjects who were above the mean were the same individuals for both measures demonstrating means for dorsum force at 60.67 compared to a mean of 38.25 (sd= 17.63) and 48.67 compared to a mean of 42.33 (sd=17.38). Between the lips force indicated an observed reading of 19 compared to a norm of 17.33 (sd=7.81) and 19.67 compared to a mean 13 (sd= 4.55).

Although not statistically significant, there is an overall trend indicating that tongue tie does cause a reduced ability to generate force using the tongue tip, dorsum, and the lips. As H. L. Robinson stated, her tongue tie, led to improper development of the musculature of the tongue as would otherwise be indicated in the absence of a tongue

tie. This inability to utilize and develop the tongue musculature left her with a weakened tongue post tongue tie release (personal communication, February 24, 2016). Additionally, as was noted in the group trends 7/8 subjects demonstrated a vaulted palate indicating the tongue was unable to superiorly generate pressure to spread the hard palate, as is typical in normal development.

Table 4.5 P-value for IOPI Tongue Tip Measures (Note "ns" stands for not significant)

Subject	t-scores	p-value
2	42	ns
3	31	ns
4	52	ns
5	36	ns
6	46	ns
7	36	ns
8	44	ns
9	54	ns

Table 4.6 P-value for IOPI Tongue Dorsum Measures (Note "ns" stands for not significant)

Subject	t-scores	p-value
2	49	ns
3	38	ns
4	48	ns
5	41	ns
6	40	ns
7	58	$p<.05$
8	48	ns
9	44	ns

Table 4.7 P-value for IOPI Between the Lips Measures (Note "ns" stands for not significant)

Subject	t-scores	p-value
2	38	ns
3	36	ns
4	24	ns
5	53	ns
6	43	ns
7	47	ns

8	47	ns
9	16	ns

Clinical Implications

Currently there is no standardized way to assess for tongue tie in adults. Clinical assessment of tongue tie has revolved around informal, non-standardized means based on clinical experiences of Speech-Language Pathologists. Assessment of family history, personal history, signs and symptoms, oral motor assessment, and articulation assessment comprise various components of tongue tie assessment.

This study utilized the *Lingual Frenulum Protocol* (LFP) for evaluation of tongue tie in subjects. It was composed of two portions. The general test portion was the most helpful and included physical measurements of the ability of the mouth to open as wide as possible, open wide with tongue to spot, as well as physical observation of frenulum attachment and tongue tip shape. The second portion included measurements of tongue mobility including the tongues ability to: protrude and retract, touch the upper lip, right and left corners of the mouth, upper and lower molars, and the ability of the tongue to such against the palate. The investigator was unable to properly define aspects of this second portion, such as “apex vibration” and consequently was unable to utilize the scores for this section as intended. The functional test portion also included informal speech measures which included a conversational sample, asking the client to count from 1 to 20, state the days of the week and months of the year, as well as perform a picture naming task. None of the subjects in this study presented with any articulation errors as indicated by omissions, substitutions, or distortions. Additionally, other aspects of the speech section required a substantial amount of time to score. For these reasons the

results of the second portion of the LFP were utilized only as behavioral measures and no formal score indicating tongue tie was included from this section.

In conjunction with measurements gathered from the LFP, which included taking the measurements of the mouth wide open (MOmax) and mouth wide open with tongue to spot (MOtts), this study demonstrated that indicators of tongue tie also include behavioral measures of frenulum attachment, tip shape and appearance, as well as results from oral-facial examination for presence of a high-narrow vaulted palate. Holtzman (2014) stated that using the measurement of the mouth open wide with suction of the tongue to the palate (MOWS) was a more accurate measure than MOtts, and that if an individual was unsuccessful in being able to do so, MOtts could be used but that a value of -5 should be performed as MOtts is generally 5mm greater than MOWS.

Limitations of Current Study

Limitations of this study include a small sample size, the need for statistical analysis to determine significance of findings, and issues with utilizing the *Lingual Frenulum Protocol*. The investigator sought clarification for how to perform items such as "apex vibration", which is found on the second portion of the protocol, but was unable to get an explanation in a time frame appropriate for this study. Without knowing how to perform the second portion of the protocol in its entirety the second portion of the LFP was not scored. Lastly, there was an inherent time constraint in completing this thesis as part of the investigators master's degree.

Implications for Future Research

In future studies regarding the impact of tongue tie and oral-pharyngeal dysphagia, a larger sample size should be included, with more time to perform data

measure and analyze results. As half of the subjects in this study presented with forward tongue protrusion during bolus trials, an area of future research could include exploring the relationship between tongue tied individuals and tongue thrust. Additionally, it would be interesting to see how age affects tongue tie and an individual's ability to swallow.

Conclusions

The following study analyzed the data of 8 individuals with tongue tie aged 18-41 years of age in comparison to age and gender matched norms from Holzer (2011). Statistical significance has yet to be determined for masseter strength measurements, and there was no significance revealed for IOPI measures of tongue tip, tongue dorsum, and lip strength. However, statistically significant results were revealed demonstrating delayed oral-pharyngeal transit times for individuals with tongue tie. Based on the results of this study, indicators of dysphagic behaviors are present in individuals diagnosed with tongue tie.

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APPENDIX A: Demographic Survey

Subject ID#_____

Demographic Survey

1. Birth Date: _____

2. Circle One: MALE FEMALE

3. Ethnicity (check one):

- ☐ (1) European American (not Hispanic)
- ☐ (2) White Hispanic
- ☐ (3) Latino
- ☐ (4) Asian
- ☐ (5) African American
- ☐ (6) Native American
- ☐ (7) Other / Multi-racial

Health Status

4. Do you have or have you experienced any of the following? (check yes or no)

Heart & Blood

a. Heart & Blood Problems (including chest pain due to heart problems, irregular heartbeat, high blood pressure, blood clots, anemia, hypertension, blood transfusion, high cholesterol, heart failure, or heart bypass surgery)

   ☐ Yes ☐ No

b. COPD (Chronic Obstructive Pulmonary Disorder)

☐ Yes ☐ No

c. Bleeding GI (stomach, throat, intestines)

☐ Yes ☐ No

Psychiatric

d. Psychiatric Treatment for depression or anxiety

☐ Yes ☐ No

Illness

e. Cancer (what kind _____?)

☐ Yes ☐ No

f. Rheumatologic Disease (Sjogren's, Lupus, Arthritis)

☐ Yes ☐ No

Neuromedical Risks/Condition

g. Head injury (describe and include point of impact)

_____

_____

☐ Yes ☐ No

h. Loss of consciousness (how long?) _____

☐ Yes ☐ No

i. Seizures

☐Yes ☐ No

j. Stroke/TIA

☐Yes ☐ No

k. Sleep Apnea

☐Yes ☐ No

l. Toxin/Chemical Exposure (what kind?) _____

☐Yes ☐ No

m. Parkinson's Disease (when diagnosed?)_____

☐ Yes ☐ No

n. Huntington's Disease (when diagnosed?) _____

☐ Yes ☐ No

o. Brain Masses (location) _____

☐ Yes ☐ No

p. Multiple Sclerosis (when diagnosed?) _____

☐ Yes ☐ No

q. Cerebral Palsy

☐ Yes ☐ No

r. Dementia /Alzheimer's (when diagnosed?)

_____

☐ Yes ☐ No

s. Oral Apraxia (when diagnosed?) _____

☐ Yes ☐ No

t. Spinal Injury (describe) _____

☐ Yes ☐ No

u. Brain Surgery (describe) _____

☐ Yes ☐ No

v. Poliomyelitis (when diagnosed?) _____

☐ Yes ☐ No

w. Guillain-Barre (when diagnosed?) _____

☐ Yes ☐ No

aa. Riley-Day Syndrome or Dysautonomia (when diagnosed?) _____

☐ Yes ☐ No

bb. ALS (when diagnosed?) _____

☐ Yes ☐ No

cc. Werdig- Hoffmann Disease (when diagnosed?) _____

☐ Yes ☐ No

dd. Myasthenia Gravis (when diagnosed?) _____

☐ Yes ☐ No

ee. Muscular Dystrophy (when diagnosed?) _____

☐ Yes ☐ No

ff. Dystonia (when diagnosed?) _____

☐ Yes ☐ No

Oromyofunctional Risks/Conditions

gg. Recurrent Pneumonia

☐ Yes ☐ No

hh. Frequent Temperature Spikes

☐ Yes ☐ No

ii. History of Artificial Airway

☐ Yes ☐ No

☐

jj. Mouth Breather

☐ Yes ☐ No

kk. History of Finger Sucking

☐ Yes ☐ No

ll. History of Cheek Biting

☐ Yes ☐ No

mm. Deviated Septum

☐ Yes ☐ No

nn. Enlarged Tonsils/Adenoids

☐ Yes ☐ No

oo. Tonsils/Adenoids Removed

☐ Yes ☐ No

pp. Open Spaced During Mixed Dentition

☐ Yes ☐ No

qq. Current Open Spaces in Dentition

☐ Yes ☐ No

rr. Allergies (explain) _____

☐ Yes ☐ No

ss. TMJ Syndrome

☐ Yes ☐ No

tt. Eating Disorders

☐ Yes ☐ No

uu. Oral Surgery (explain) _____

☐ Yes ☐ No

vv. Neck Surgery (explain) _____

☐ Yes ☐ No

ww. Oral Sores

☐ Yes ☐ No

Other

xx. Other Surgery (explain) _____

☐ Yes ☐ No

5. List and describe any serious accidents that required hospitalization.

_____
_____
_____

Medications

6. Have you taken any medication today? ☐ Yes ☐ No

If yes, list medication, dose, time taken, and reason for taking it. (Use back of page for more room)

Name of medication	Time Taken	Dose	Reason for Taking
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____

_____ _____ _____mg _____

_____ _____ _____mg _____

_____ _____ _____mg _____

_____ _____ _____mg _____

Alcohol and Tobacco

7. Do you consume alcohol? ☐ Yes ☐ No

8. If you answered yes to question 7, how much alcohol do you typically consume in 1 month?

_____ glasses/month

9. Do you chew tobacco? ☐ Yes ☐ No

10. If you answered yes to question 9, how much do typically use in a month?

_____

cans/month

11. Do you smoke? ☐ Yes ☐ No

12. If you answered yet to question 11, how much do you smoke in a month?

_____ packs/month

Food Information

13. What are your three favorite foods? _____

14. What are your three least favorite foods? _____

15. Are there any foods that you avoid?

_____

16. How often do you chew gum? _____

17. Have you ever participated in tongue thrust therapy? ☐ Yes ☐ No

APPENDIX B: Lingual Frenulum Protocol

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Appendix A
LINGUAL FRENULUM PROTOCOL

HISTORY

Name: _____ **Gender**
F ( ) M ( )
Examination date: __ / __ / __ **Age:** ___ **years and** ___ **months** **Birth:** __ / __ / __
Responsible: _____ **Relative:** _____

Studying: ☐ yes ☐ no Grade:
Working: ☐ yes ☐ no Profession:
Worked before ☐ no ☐ yes Professional Area:
Practicing sports: ☐ no ☐ yes Type:

Address: _____
City: _____ **State:** _____ **ZIP:** _____
Phone: Home: (____) _____ Office: (____) _____ Cell: (____) _____
e-mail: _____
Father's name: _____ **Mother's name:** _____
Siblings:
☐ no ☐ yes How many: _____

Who referred patient for evaluation *(Name, specialist, phone)*:
_____
Why?

Main complaint:
_____

Other complaints affecting:
(0) no (1) sometimes (2) yes

( ) lips	( ) tongue	( ) sucking	( ) chewing	( ) deglutition
( ) breathing	( ) speech	( ) lingual frenulum	( ) voice	( ) hearing
( ) learning	( ) facial aesthetic	( ) posture	( ) occlusion	( ) headache
( ) TJM clicking	( ) TMJ pain	( ) neck pain	( ) shoulders pain	
( ) mouth opening difficulty	( ) mandible range of motion			( ) Other

Family history – any other relative has frenulum alteration
☐ no ☐ yes Who? Surgery was necessary: ☐ yes ☐ no

Health problems
☐ no ☐ yes What kind:

Breathing problems
☐ no ☐ yes What kind:

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Suckling

Breast- feeding:	☐ yes	Age: _____	☐ no	The baby had difficult suckling? ☐ no ☐ yes
Bottle:	☐ yes	Age: _____	☐ no	What difficulty: _____

Feeding – chewing difficulties

☐ no ☐ yes What:

Feeding – deglutition difficulties

☐ no ☐ yes What:

Oral habits:

☐ no ☐ yes What:

Speech alterations:

☐ no ☐ yes What:

Any social or professional issues due to speech alteration?

☐ no ☐ yes Social ☐ no ☐ yes Response: _____
Professional ☐ no ☐ yes Response:

Voice alteration:

☐ no ☐ yes What:

Lingual frenulum surgery:

☐ no ☐ yes When: _____ How many: _____
What professional performed surgery: _____
Results: ☐ good ☐ satisfactory ☐ unsatisfactory

Add other important information

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

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LINGUAL FRENULUM PROTOCOL (Continued)

CLINICAL EXAMINATION

I – GENERAL TESTS

Measurements using a caliper. Larger or equal 50,1% (0) – Less or equal 50% (1) FINAL RESULT =

Take measurements from superior right or left incisive to the inferior right or left incisive. Consider the same tooth for all the measurements.	**Value in millimeters**
Open mouth wide	
Open mouth wide with the tongue tip touching the incise papilla	
Difference between the two measurements, in percentage	%

Alterations during tongue elevation (best result = 0 worst result = 2) FINAL RESULT =

Open mouth wide; raise the tongue without touching the palate	NO	YES
1. Tip of the tongue's shape: oblong or square	(0)	(1)
2. Tip of the tongue's shape: like a heart	(0)	(1)

Frenulum fixation. Add A and B (best result = 0 e worst result = 3) Final result =

A – Mouth floor:	
Visible only from the sublingual caruncles	(0)
Visible from inferior alveolar crest	(1)

Fixation in another point:

_____

B – Sublingual:	
In the middle of the tongue	(0)
Between the middle and the apex of the tongue	(1)
At the apex	(2)

Clinical frenulum classification (best result = 0 e worst result = 2) Final result =

Normal (0)	Borderline (1)	Altered (2)

If the frenulum was considered altered it would be because:

The frenulum seems normal but it is attached between the middle and the apex of the tongue	The frenulum is short	The frenulum is short and it is fixed between the middle and the apex of the tongue	
Ankyloglossia (frenulum attached to apex of the tongue)		Another reason	Unsure

General tests evaluation total score: best result = 0 worst result = 8

When the score of the general tests evaluation is equal or greater than 3, the frenulum may be considered altered.

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II – FUNCTIONAL TESTS

Tongue mobility (best result = 0 worst result = 14). Final result =

	Successful	Partially successful	Unsuccessful
Protrude and retract	(0)	(1)	(2)
Touch the superior lip with the apex	(0)	(1)	(2)
Touch the right commissura labiorum	(0)	(1)	(2)
Touch the left commissura labiorum	(0)	(1)	(2)
Touch U&L molars	(0)	(1)	(2)
Apex vibration	(0)	(1)	(2)
Sucking against the palate	(0)	(1)	(2)

Tongue position during rest (best result = 0 e worst result = 4). Final result =

Not visible	(0)
On the floor of the mouth	(1)
Protrudes between the teeth	(2)
Laterally protrudes between teeth	(2)

Speech (best result = 0 e worst result =12) Final result =

Test 1 – Informal speech
e.g.: What is your name? How old are you? Do you study/work? Tell me about your school/work. Tell me about something interesting.
Test 2 – Ask to count from 1 to 20. Ask to say the days of the week. Ask to say the months of the year.
Test 3 – Ask to name the pictures from the picture table

Speech tests	Omission		Substitution		Distortion	
	No	Yes	No	Yes	No	Yes
1	(0)	(1)	(0)	(1)	(0)	(2)
2	(0)	(1)	(0)	(1)	(0)	(2)
3	(0)	(1)	(0)	(1)	(0)	(2)

Check for which sound there is omission or substitution or distortion

p		t		k		b		d		g				m	
n		□		f		s		x		v				z	
j		l		□		r		rr		{S}	{R}			tl	
pr	br	tr	dr	cr	gr	fr	vr	pl	bl	cl		gl		fl	vl

If the alteration occurs in only one or two tests, identify in which test there was alteration

Other aspects to be observed during speech (best result = 0 e worst result =10) Final result =

Mouth opening: (0) adequate (1) reduced (1) open wide
Tongue position: (0) adequate (1) on the floor (2) protruded (2) visible sides
Mandible movements: (0) no alteration (1) right displacement (1) left displacement (1) forth displacement
Speed: (0) adequate (1) increased (1) reduced
Speech precision: (0) adequate (1) altered
Voice: (0) no alteration (1) altered

Functional evaluation total score: best result = 0 and worst result = 40

When the score of the functional evaluation is equal or greater than 25, the frenulum can be considered altered.

Documentation:
Photography and video of tongue mobility and speech evaluation

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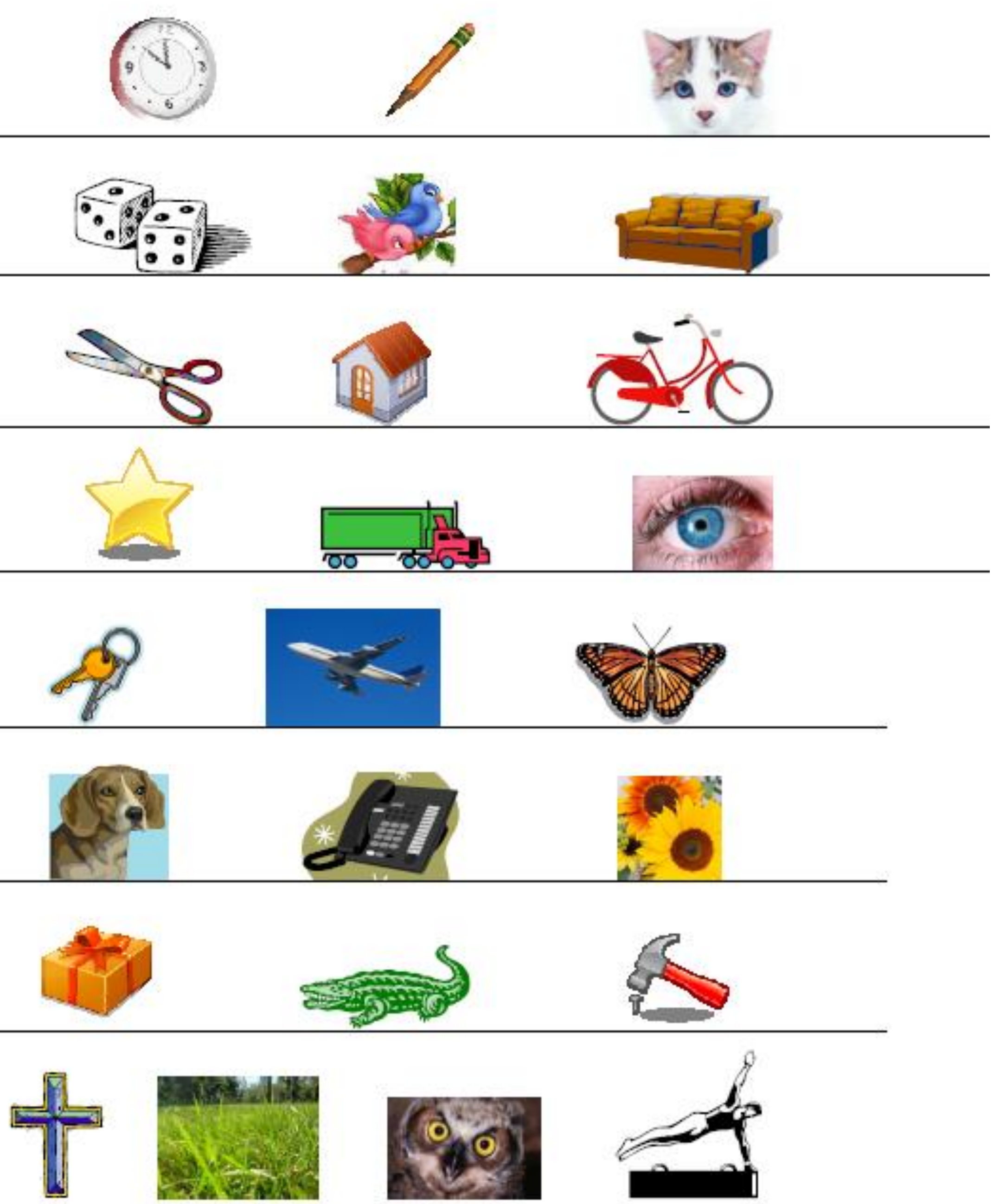
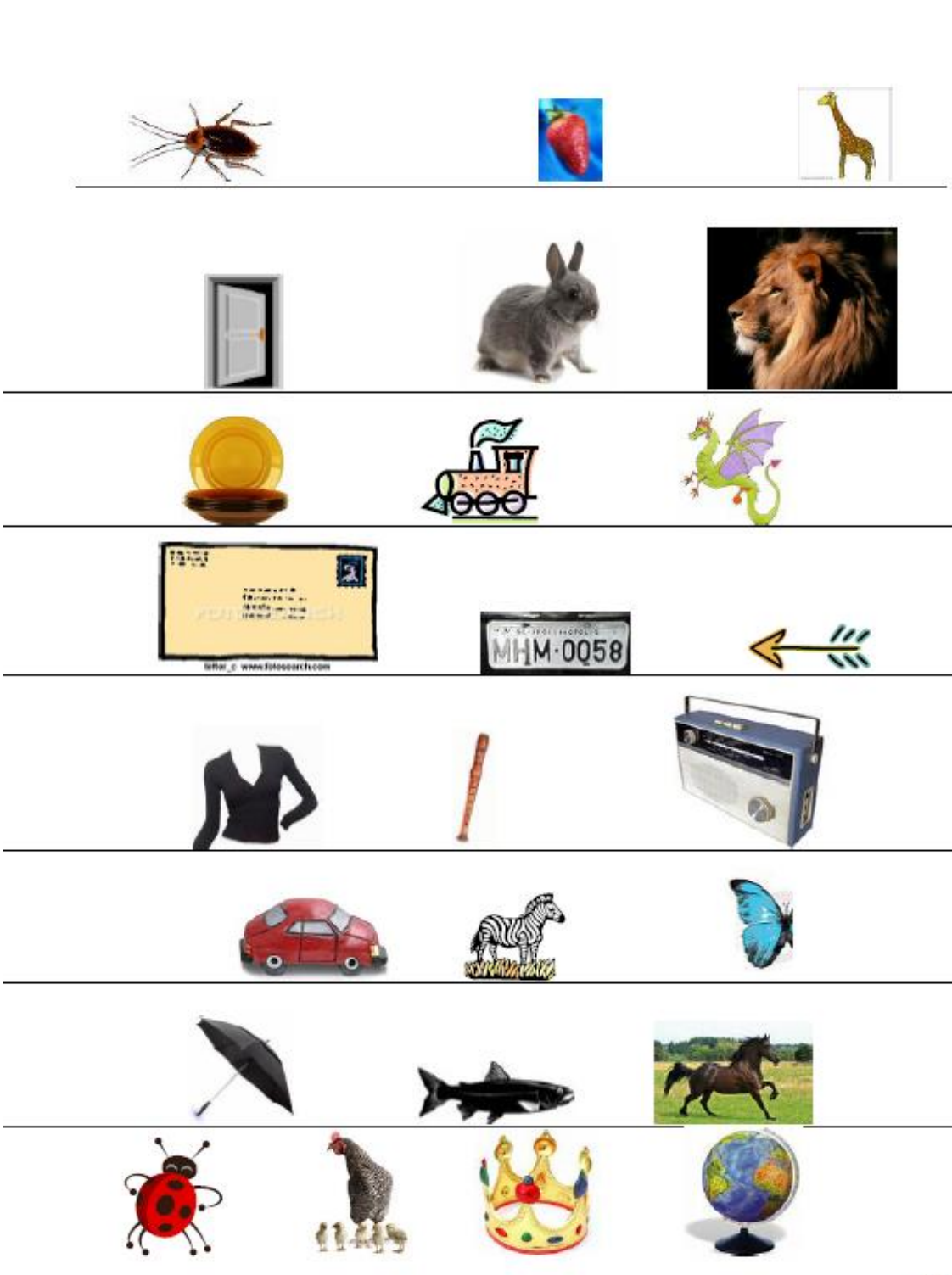
APPENDIX: C
LINGUAL FRENULUM PROTOCOL

TABLE WITH THE WORDS FOR SPEECH EVALUATION

Picture	Patient production	Picture	Patient production
Clock		Cockroach	
Pencil		Strawberry	
Cat		Giraffe	
Dice		Door	
Bird		Rabbit	
Sofa		Lion	
Scissors		Plate	
House		Train	
Bike		Dragon	
Star		Letter	
Truck		License plate	
Eye		Arrow	
Key		Blouse	
Airplane		Flute	
Butterfly		Radio	
Dog		Car	
Phone		Zebra	
Flower		Blue wing	
Gift		Umbrella	
Alligator		Fish	
Hammer		Horse	
Cross		Ladybug	
Grass		Chicken	
Owl		Crown	
Athlete		Globe	

PICTURE TABLE FOR THE SPEECH EVALUATION

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17

APPENDIX C: Clinical Evaluation Protocol

Subject number _____ Group _____ Date_____

1. Obtain informed consent.
2. Set up video camera. Press record.
3. Open Biograph Infiniti Program
4. Select Options and Notch Filters
5. Set them to EMG and 60 Hz and choose okay
6. Select Start Open Display Session
7. Select Add New Client and enter client number under Clinic ID & Name and select OK (see Table of Subjects and Researchers to determine client number)
8. Choose desired client from subjects and Define New session
9. Select Skeletal Muscle Rehab and M1revw- 2 ch Open Display.scr (be sure you have selected MyoTrac Infiniti as encoder type).
10. Make sure the encoder is connected to the computer. Then turn on the encoder. On the encoder, under "New Session" select "Open." A graph should display in Biograph Infiniti Program.
11. Once electrodes are in place, press record and instruct client to do desired task. The spacebar places event markers on the screen (used in swallow timing section/ LE and to mark swallow for masseter activity). Be sure that when you pause the session you press pause and not stop.
12. When you are done with the session, press stop and save it in an uncompressed version with the name being the task you just completed (ex. Masseter activity- 1 tsp pudding).
13. Choose not to review the session.
14. Continue recording with the same client set-up until you have completed the protocol for that client, following step 8-10.
15. Once you've recorded all the necessary sessions for the client and save as instructed in 9, close out the client. See the Biograph Infiniti program information for measuring data.

Group A	**Group B**	**Group C**
IOPI	EMG masseter (pg 10)	EMG swallow timing (pg 19)
EMG masseter	EMG swallow timing (pg 19)	IOPI (pg 2)
EMG swallow timing	IOPI (pg 2)	EMG masseter (pg 10)

GROUP A			
Task	Clinician's Instructions to Subject	What Clinician Does	Record Data

1. Human Consent Form			
Human Consent	"Today I will be using different measures and foods to assess your swallow function. I will be placing the IOPI (show them the instrument) on your lips and in your mouth, EMG electrodes (show them instrument) on your throat and jaw, and placing my hands on your face and throat. If at any time you feel uncomfortable please let me know. The IOPI measures how much force your tongue and lips can exert, and the EMG measures electrical activity of your muscles. Neither device should cause you any discomfort."		
2. Medical History Form			
Medical History Form (Appendix C)	"Please answer the following questions to the best of your knowledge. Please make sure to answer all of the questions. If you have any	Give subject the medical history form and consent form.	

	questions, please do not hesitate to ask me. This information will remain confidential. Here is a consent form for you to read as well. You do not need to sign it. It is strictly for your knowledge."		
3. Lingual Frenulum Protocol			
LFP	"I am now going to evaluate you using the Lingual Frenulum Protocol. This will allow me to determine the presence or absence of tongue tie."	Perform oral evaluation following LFP protocol (see attached).	Mark appropriate answers on record form. No names will be written on record form. Participant will be identified with their assigned number.
4. Oral Peripheral Exam (OPE)	Open your mouth	Look for vaulted palate	Circle for presence or absence of vaulted palate
OPE	Bite down on your teeth and smile	Look for molar classification (See picture on last page for malocclusion type)	Check for presence of each of the following: Crossbite _____ Labioversion _____ Normal malocclusion _____ Malocclusion I _____ Malocclusion II _____ Malocclusion III _____
5. Iowa Oral Performance Instrument (IOPI) Tongue Tip			

IOPI Tongue Tip		Procedures for Clinician 1.Press“Peak” and then press “Reset.” 2.Check screen for low battery symbol. Change battery if needed. 3. Attach connecting tube to tongue bulb. IOPI is now ready to use. 4. Turn IOPI screen away from subject	
IOPI Tongue Tip		If at any time the bulb moves out of place or directions are not followed, re-administer the directions.	
IOPI Tongue Tip	“I’m going to place this bulb on the tip of your tongue.”		
IOPI Tongue Tip	“Open your mouth”		
IOPI Tongue Tip		Clinician places bulb in mouth, making sure bulb is completely behind the front teeth.	
IOPI Tongue Tip		Make sure they are not biting on tubing.	

IOPI Tongue Tip	"Close your lips"		
IOPI Tongue Tip	"When I say go press with the tip of your tongue against the roof of your mouth as hard as you can, hold until you are told to stop."		
IOPI Tongue Tip – Trial 1	"Go"		
IOPI Tongue Tip – Trial 1		Have subject press until IOPI number stabilizes	
IOPI Tongue Tip – Trial 1	"Stop"		
IOPI Tongue Tip – Trial 1			_____Record final number on screen
		Check positioning of bulb and reposition if needed.	
	"We are going to do it again."	Push "reset"	
IOPI Tongue Tip – Trial 2	"Go"		
IOPI Tongue Tip – Trial 2	"Stop"		
IOPI Tongue Tip – Trial 2			_____Record second reading
		Check positioning of bulb and reposition if needed.	
	"We are going to do it again."	Push "reset"	

IOPI Tongue Tip – Trial 3	"Go"		
IOPI Tongue Tip – Trial 3	"Stop"		
IOPI Tongue Tip – Trial 3			_____Record third reading
6. IOPI Dorsum			
IOPI Dorsum	"Now I'm going to place the bulb on a different part of your tongue. Open your mouth and say /a/"	Push "reset"	
IOPI Dorsum		Look for the peak of the tongue dorsum when subject says /a/.	
IOPI Dorsum		Place the tip of the bulb at the peak.	
IOPI Dorsum – Trial 1	"Close your mouth and push as hard as you can against the bulb."	Have subject press until IOPI number stabilizes	
IOPI Dorsum – Trial 1	"Stop"		
IOPI Dorsum – Trial 1			_____Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 2	"Go"		
IOPI Dorsum – Trial 2	"Stop"		

IOPI Dorsum – Trial 2			_____Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 3	"Go"		
IOPI Dorsum – Trial 3	"Stop"		
IOPI Dorsum – Trial 3		Wipe bulb	_____Record reading
7. IOPI Lip strength		Push "reset"	
IOPI Lip Strength	"Bite down and clench your teeth together. Now I'm going to place this between your lips but be sure not bite the bulb directly"		
IOPI Lip Strength		Place bulb between lips (parallel with lips), but not between teeth.	
IOPI Lip Strength	"When I say go press your lips together"	Have subject press until IOPI number stabilizes	
IOPI Lip Strength – Trial 1	"Go"		
IOPI Lip Strength – Trial 1	"Stop"		
IOPI Lip Strength – Trial 1			_____Record reading

		Reposition bulb between lips parallel with lips & Repeat Push “reset”	
IOPI Lip Strength – Trial 2	“Go”		
IOPI Lip Strength – Trial 2	“Stop”		_____Record reading
		Reposition bulb between lips parallel with lips & Repeat Push “reset”	
IOPI Lip Strength – Trial 3	“Go”		
IOPI Lip Strength – Trial 3	“Stop”		_____Record reading
8. Masseter baseline			
Masseter Baseline		Select “start open display session” on computer. Add new client by number. Define new session and select “skeletal muscle rehab.” Choose screen M1revw-2ch open display screen. Then turn on the encoder.	
Masseter Baseline	“Clench your back teeth”	Palpate the Masseter, Feel for belly of masseter during contraction.	

Masseter Baseline	"Do you have skin allergies?" **(If subject has skin allergies don't use Nuprep, use alcohol swabs).**	Use Nuprep to exfoliate skin (masseter and clavicle). Rub for 30 seconds on location of electrode placement. Remove excess Nuprep with alcohol. **(If subject has skin allergies don't use Nuprep, use alcohol swabs).**	
Masseter Baseline	"Clench your back teeth"	Palpate masseter again and mark placement for electrodes with marker.	
Masseter Baseline	"Bite down for me while I place these electrodes on your muscle."	**Put conductive gel on electrodes**. Place EMG electrodes bilaterally on masseter belly in a vertical plane, **Channel A is on the subject's right masseter (yellow on superior/blue inferior) & Channel B is on the subject's left masseter (yellow superior/blue inferior). Place the ground electrode (black) on the subject's collar**	

		bone. (Reference Figure 1 for specific placement). Clip electrode cables to subject's sleeve if needed.	
Masseter Baseline		Select record	
Masseter Baseline – Trial 1 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 1 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 2 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial2 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 3 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 3 (max contraction)	"Stop"		_____Check for EMG reading of contraction
		Stop recording and save without	

		reviewing in non-compressed format and start new session with same client.	
9. Masseter Activity			
Masseter Activity		Electrodes will remain in the same placement. Select record	
Masseter Activity – Trial 1 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 1 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time

Masseter Activity – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 2 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 2 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 3 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, &	Watch for swallow initiation and press space bar	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-)

	swallow when I say swallow"	to mark swallow time.	_____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 1 (1 ½ tsp pudding)		Stop recording and save without reviewing in non-compressed format and start new session with same client.	
Masseter Activity – Trial 1 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon. Press record.	
		Have subject place the pudding in their mouth	
Masseter Activity – Trial 1 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-)

			_____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon. Press record.	
		Have subject place the pudding in their mouth	
Masseter Activity – Trial 2 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (1 ½ tsp pudding)			_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with	

		syringe and place on spoon. Press record.	
		Have subject place the pudding in their mouth	
Masseter Activity – Trial 3 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (1 ½ tsp pudding)			_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 1 (10 cc water)		Stop recording and save without reviewing in non-compressed format and start new session with same client.	
Masseter Activity – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
Masseter Activity – Trial 1 (10 cc water)	"I'm going to give you a small	Press record	

	amount of water in a cup."		
Masseter Activity – Trial 1 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
		Press record	
Masseter Activity – Trial 2 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time

Masseter Activity – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
		Press record	
Masseter Activity – Trial 3 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (10 cc water)			_____Check EMG for completion of task _____ Swallow initiation time
		Stop recording and save without reviewing in non-compressed format and start new session with same client.	
Masseter Activity – Trial 1 (Triscuit)			
Masseter Activity – Trial 1 (Triscuit)		Give subject whole Triscuit	
Masseter Activity – Trial 1	"Take a normal bite, chew it and	Press record	

(Triscuit)	open your mouth when you are ready to swallow. Signal to me when you are ready to swallow."		
Masseter Activity – Trial 1 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 1 (Triscuit)			1 3 5 Organized in ball or tube in middle of tongue / Some evidence of cohesion, some scattering / Disorganized or scattered on tongue
Masseter Activity – Trial 1 (Triscuit)		Participant signals ready to swallow. Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 1 (Triscuit)		Look for residue on sulci & tongue & rate residue	
Masseter Activity – Trial 1 (Triscuit)			1 3 5

			Minimal/No residue (few to no parts of residue)	Some evidence of residue	Significant amount of residue
Masseter Activity – Trial 2 (Triscuit)	"We are going to repeat the process 2 more times"				
Masseter Activity – Trial 2 (Triscuit)	"Take another bite & open your mouth when you are ready to swallow. Signal to me when you are ready to swallow."	Press record.			
Masseter Activity – Trial 2 (Triscuit)		Look in mouth & rate bolus			
Masseter Activity – Trial 2 (Triscuit)			1 Organized in ball or tube in middle of tongue	3 Some evidence of cohesion, some scattering	5 Disorganized or scattered on tongue
Masseter Activity – Trial 2 (Triscuit)		Participant signals when ready to swallow. Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:		

Masseter Activity – Trial 2 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (Triscuit)		Look for residue on sulci with tongue depressor if needed & tongue & rate residue	
Masseter Activity – Trial 2 (Triscuit)			1 3 5 Minimal/No residue (few to no parts of residue) Some evidence of residue Significant amount of residue
Masseter Activity – Trial 3 (Triscuit)	"Take another bite & open your mouth when you are ready to swallow. Signal to me when you are ready to swallow."	Press record	
Masseter Activity – Trial 3 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 3 (Triscuit)			1 3 5 Organized in ball or tube in middle of tongue Some evidence of cohesion, some scattering Disorganized or scattered on tongue
Masseter Activity – Trial 3 (Triscuit)		Participant signals ready to swallow. Watch for swallow	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-)

		initiation and press space bar to mark swallow time.	_____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (Triscuit)		Look for residue on sulci & tongue & rate residue	
Masseter Activity – Trial 3 (Triscuit)			1 3 5 Minimal/No residue (few to no parts of residue) Some evidence of residue Significant amount of residue
10. Laryngeal elevation (LE)			
LE		Remove channel A & B electrodes	
LE		Prepare skin for electrode placement. **Get new electrodes and place conductive gel on electrodes.** Put Channel **A electrode to geniohyoid**. Measure **2 cm posterior from chin point and**	

		place first (yellow) electrode and place second electrode (blue) 2cm posterior from the first. Place **channel B electrode just off lamina on left side.** Have subject perform dry swallow & feel for thyroid notch. Place electrodes 2cm apart in vertical alignment on left side of thyroid notch **with yellow electrode superior and blue electrode inferior.** (See Figure 2 for placement)	
LE – **<u>Trial 1</u>** (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
		Press record	
LE – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 1 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-)

		laryngeal elevation and depression	_____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
		Press record	
LE – Trial 2 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 2 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:

LE – Trial 2 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE – Trial 3 (1/2 tsp pudding)		Press record	
LE – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 3 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)

LE – Trial 3 (1/2 tsp pudding)		Stop recording and save without reviewing in non-compressed format and start new session with same client.	
LE – protrusion	"I'm going to pull down your lip when you swallow."		
LE/protrusion – Trial 1 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 2 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and	_____ Tongue protrusion (+/-)

		watch for protrusion of tongue.	
LE/protrusion – Trial 3 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE – Trial 1 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 1 (1 ½ tsp pudding)		Press record	
LE – Trial 1 (1 ½ tsp pushing)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 1 (1 ½ tsp pushing)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-)

			_____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 2 (1 ½ tsp pudding)		Press record	
LE – Trial 2 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 2 (1 ½ tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time

LE – Trial 2 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 3 (1 ½ tsp pudding)		Press record	
LE – Trial 3 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 3 (1 ½ tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non-compressed	

		format and start new session with same client.	
LE – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE – Trial 1 (10 cc water)		Press record	
LE – Trial 1 (10 cc water)	"I'm going to give you a small amount of water in a cup. Place it all in your mouth but don't swallow until I say swallow"		
LE – Trial 1 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	

LE – Trial 2 (10 cc water)		Press record	
LE – Trial 2 (10 cc water)	"I'm going to give you a small amount of water in a cup. Place it all in your mouth but don't swallow until I say swallow"		
LE – Trial 2 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE – Trial 3 (10 cc water)		Press record	
LE – Trial 3 (10 cc water)	"I'm going to give you a small amount of water in a cup. Place it all in your mouth but don't		

	swallow until I say swallow"		
LE – Trial 3 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non-compressed format and start new session with same client.	
LE/protrusion	"I'm going to pull down your lip when you swallow."		
LE/protrusion – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 1	"Open your mouth (place	Pull down lip while	_____ Tongue protrusion (+/-)

(10 cc water)	syringe in) close mouth & swallow when ready"	swallowing and watch for protrusion of tongue.	
LE/protrusion – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 2 (10 cc water)	"Open your mouth (place syringe in) close mouth & swallow when ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 3 (10 cc water)	"Open your mouth (place syringe in) close mouth & swallow when ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE – Trial 1 (Triscuit)		Give subject Triscuit	
LE – Trial 1 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 1 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-)

			Additional notes:
LE – Trial 1 (Triscuit)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 2 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (Triscuit)			_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	

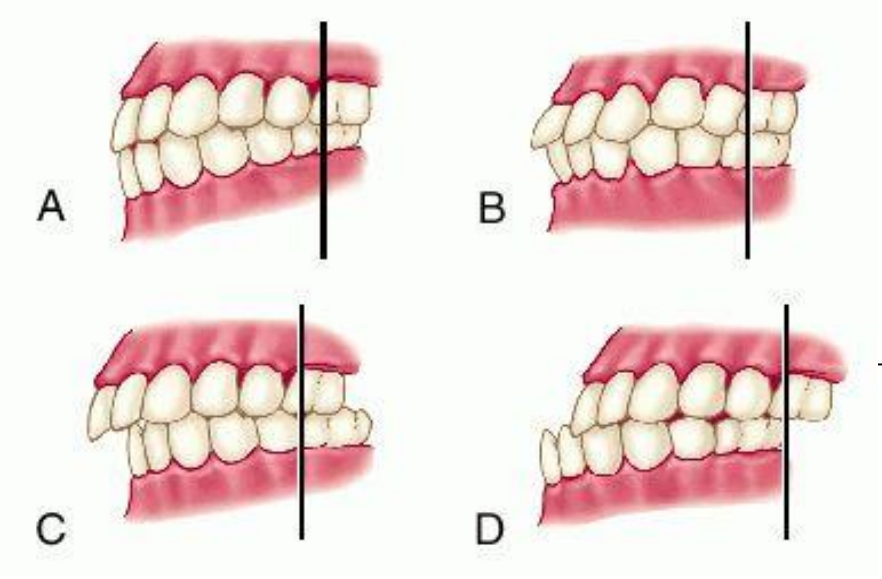
LE – Trial 3 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (Triscuit)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non-compressed format.	
LE/protrusion	"I'm going to have you chew the cracker. Let me know when you have finished chewing by raising your hand. Then I will pull your lip down. Then I want you to signal when you are ready to swallow."	Give subject Triscuit	
LE/protrusion – Trial 1 (Triscuit)		Pull lip down and watch for tongue protrusion.	_____ Tongue protrusion (+/-)

		Participant signals ready to swallow.	
LE/protrusion – Trial 2 (Triscuit)	"Take another bite. Let me know when you have finished chewing by raising your hand. Then I will pull your lip down. Then I want you to signal when you are ready to swallow."		
LE/protrusion – Trial 2 (Triscuit)		Pull lip down and watch for tongue protrusion. Participant signals ready to swallow.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 3 (Triscuit)	"Take another bite. Let me know when you have finished chewing by raising your hand. Then I will pull your lip down. Then I want you to signal when you are ready to swallow.		
LE/protrusion – Trial 3 (Triscuit)		Pull lip down and watch for tongue protrusion. Participant signals ready to swallow.	_____ Tongue protrusion (+/-)

		Stop recording and save without reviewing in non-compressed format and start new session with same client. Stop videorecorder.	

(A), Normal occlusion; *(B),* Class I malocclusion; *(C),* Class II malocclusion; *(D),* Class III malocclusion. Note the position of the mesial cusp of the maxillary molar relative to the mandibular molar in each type of occlusion.

http://medical-dictionary.thefreedictionary.com/_/viewer.aspx?path=dorland&name=malocclusion.jpg



General Layout of Protocol – GROUP A

- IOPI - tongue tip = 3 trials
- IOPI - dorsum = 3 trials
- IOPI - lip strength = 3 trials

- Masseter Baseline = 3 trials
- Masseter Activity - ½ tsp pudding = 3 trials
- Masseter Activity - 1 ½ tsp pudding = 3 trials
- Masseter Activity - 10 cc water = 3 trials
- Masseter Activity - bite of Triscuit = 3 trials

- LE - ½ tsp pudding = 3 trials
- LE protrusion - ½ tsp pudding = 3 trials
- LE - 1 ½ tsp pudding = 3 trials
- LE - 10 cc water = 3 trials
- LE protrusion - 10 cc water = 3 trials
- LE - bite of Triscuit = 3 trails
- LE protrusion - bite of Triscuit = 3 trials

APPENDIX D: Data for Subjects

PARTICIPANT #2 GROUP:	TRIAL 1	TRIAL 2	TRIAL 3	EXTRA
MASSETER BASELINE: A RMS MAX	99.64	100.74	95.17	
B RMS MAX	68.82	79.84	74.09	
A RMS AVG	57.43	63.26	52.44	
B RMS AVG	43.79	46.99	37.75	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	11.06	15.01	10.5	10.4
B RMS MAX	14.72	16.59	14.8	17.7
	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.54	1.87	3.58	2.5
P-DUR & END MARKER	1.35	1.6	1.31	2.

	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	8.71	15.05	28.58	10.3
B RMS MAX	18.89	22.62	21.62	27.0
	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.16	2.88	2.05	
P-DUR & END MARKER	1.83	2.25	2.6	

	WATER	WATER	WATER	EXTRA
MASSETER: A RMS MAX	14.09	12.58	12.57	
B RMS MAX	27.9	30.65	25.55	
	WATER	WATER	WATER	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.33	1.89	1.35	1.4
P-DUR & END MARKER	1.26	1.71	1.17	1.1

	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
MASSETER: A RMS MAX	20.97	227.59	236.93	98.0
B RMS MAX	33.7	149.96	130.46	50.4
	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.59	1.91	1.88	1.
P-DUR & END MARKER	1.33	2.04	2.06	1.3

PARTICIPANT #3 GROUP:	TRIAL 1	TRIAL 2	TRIAL 3	EXTRA
MASSETER BASELINE: A RMS MAX	163.43	155.5	132.73	
B RMS MAX	119.66	113.8	110.01	
A RMS AVG	106.93	108.21	78.02	
B RMS AVG	69.76	76.71	64.71	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	41.36	27.72	37.03	33.4
B RMS MAX	30.64	26.22	29.7	26.8
	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.11	1.99	3.64	
P-DUR & END MARKER	1.61	2.15	2.19	

	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	31.99	34.31	56.11	
B RMS MAX	14.85	37.45	39.91	
	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.51	2.54	2.86	
P-DUR & END MARKER	2.84	2.23	2.27	

	WATER	WATER	WATER	EXTRA
MASSETER: A RMS MAX	30.98	33.86	34.6	
B RMS MAX	20.81	25.69	28.84	
	WATER	WATER	WATER	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.87	1.56	1.36	
P-DUR & END MARKER	2.67	1.95	1.47	

	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
MASSETER: A RMS MAX	58.41	65.13	37.41	
B RMS MAX	57.54	27.87	53.79	
	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.47	5.22	1.8	
P-DUR & END MARKER	1.83	2.3	1.75	

PARTICIPANT #4 GROUP:	TRIAL 1	TRIAL 2	TRIAL 3	EXTRA
MASSETER BASELINE: A RMS MAX	112.96	116.71	103.61	
B RMS MAX	70.12	81.4	80.41	

A RMS AVG	78.7	80.75	78.81	
B RMS AVG	49.53	55.61	51.59	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	112.21	33.41	32.15	
B RMS MAX	65.19	26.15	29.34	
	1/2 TSP PUDDING	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	3.28	3.26	4.11	
P-DUR & END MARKER	1.1	1.07	1.08	

	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	31.16	34.34	18.39	24.5
B RMS MAX	58.43	42.88	20.9	18.9
	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.75	3.2	3.03	
P-DUR & END MARKER	1.5	0.89	0.88	

	WATER	**WATER**	**WATER**	**EXTRA**
MASSETER: A RMS MAX	13.91	19.67	15.29	
B RMS MAX	15.55	21.95	16.45	
	WATER	**WATER**	**WATER**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.2	1.1	1.09	
P-DUR & END MARKER	0.75	0.82	0.84	

	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
MASSETER: A RMS MAX	111.32	131.95	128.11	97.2
B RMS MAX	97.67	143.67	61.44	73.6
	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.45	3.81	3.2	1.7
P-DUR & END MARKER	1.7	1.66	1.32	1.

PARTICIPANT #5 GROUP:	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**EXTRA**
MASSETER BASELINE: A RMS MAX	103.85	99.27	59.92	
B RMS MAX	186.14	186.34	115.82	
A RMS AVG	76.08	68	41.52	
B RMS AVG	123.44	129.98	42.61	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	15.92	20.95	18.68	
B RMS MAX	15.75	15.42	18.62	
	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.59	1.58	1.51	
P-DUR & END MARKER	1.08	1.19	1.2	

	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	19.89	22.98	17.24	
B RMS MAX	14.76	16.37	17.42	
	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	2.07	1.93	2.2	
P-DUR & END MARKER	1.27	1.3	1.44	

	WATER	WATER	WATER	EXTRA
MASSETER: A RMS MAX	17.51	16.16	19.87	
B RMS MAX	16.21	16.88	18.4	
	WATER	WATER	WATER	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.48	1.95	1.56	
P-DUR & END MARKER	0.93	1.22	1.32	

	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
MASSETER: A RMS MAX	24.5	114.21	58.93	69.4
B RMS MAX	65.05	123.84	65.74	114.0
	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
LARYNGEAL ELEVATION: PHYS DUR	1.17	2.25	2.94	1.9
P-DUR & END MARKER	1.06	1.14	1.57	1.4

PARTICIPANT #6 GROUP:	TRIAL 1	TRIAL 2	TRIAL 3	EXTRA
MASSETER BASELINE: A RMS MAX	84.78	88.02	86.36	
B RMS MAX	178.3	178.19	165.36	
A RMS AVG	58.12	55.46	57.14	
B RMS AVG	111.79	116.86	112.19	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	1/2 TSP PUDDING	1/2 TSP PUDDING	1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	9.92	21.36	11.95	19.8

B RMS MAX	13.88	41.28	18.12	35.
	1/2 TSP PUDDING	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.31	2.92	2.5	2.1
P-DUR & END MARKER	1.9	2.69	0.59	1.9

	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	15.97	11.43	9.01	
B RMS MAX	32.67	19.62	10.75	
	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.29	1.67	1.97	
P-DUR & END MARKER	1.81	1.53	1.81	

	WATER	**WATER**	**WATER**	**EXTRA**
MASSETER: A RMS MAX	12.29	8.16	8.96	
B RMS MAX	14.75	27.94	32.12	
	WATER	**WATER**	**WATER**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.84	2.18	2.6	2.5
P-DUR & END MARKER	1.55	1.64	2.06	2.1

	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
MASSETER: A RMS MAX	99.78	102.08	117.9	
B RMS MAX	180.72	182.56	216.11	
	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.84	1.34	1.36	1.4
P-DUR & END MARKER	0.69	1.22	1.2	1.3

PARTICIPANT #7 GROUP:	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**EXTRA**
MASSETER BASELINE: A RMS MAX	160.95	187.19	111.57	
B RMS MAX	185.88	242.63	165.17	
A RMS AVG	90.12	95.82	76.21	
B RMS AVG	120.75	131.18	108.75	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	8.12	9.52	37.37	41.8
B RMS MAX	17.27	14.52	78.24	89.0
	1/2 TSP PUDDING	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.03	1.76	2.01	

P-DUR & END MARKER	1.58	1.45	1.79	

	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	10.35	13.22	11.2	
B RMS MAX	16.77	27.38	19.61	
	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.81	1.7	1.41	
P-DUR & END MARKER	1.29	1.25	1.01	

	WATER	**WATER**	**WATER**	**EXTRA**
MASSETER: A RMS MAX	10.39	8.85	10.24	8.1
B RMS MAX	16.98	13.06	17.01	10.7
	WATER	**WATER**	**WATER**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.32	1.27	1.15	
P-DUR & END MARKER	1.07	1.04	0.93	

	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
MASSETER: A RMS MAX	127.35	74.36	25.85	111.1
B RMS MAX	123.97	108.86	31.71	131.9
	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.61	1.77	1.89	1.7
P-DUR & END MARKER	1.41	0.82	1.03	1.1

PARTICIPANT #8 GROUP:	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**EXTRA**
MASSETER BASELINE: A RMS MAX	168.49	138.12	135.31	
B RMS MAX	250.84	279.92	235.74	
A RMS AVG	84.7	88.19	81.94	
B RMS AVG	186.74	172.62	162.92	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	25.29	16.67	22.91	
B RMS MAX	81.27	55.54	46.33	
	1/2 TSP PUDDING	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	1.53	1.72	1.88	
P-DUR & END MARKER	0.54	0.99	1.2	

	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	19.79	16.66	44.77	
B RMS MAX	19.22	17.02	36.64	
	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.1	2.34	1.96	
P-DUR & END MARKER	1.33	1.54	1.17	

	WATER	WATER	WATER	EXTRA
MASSETER: A RMS MAX	75.64	58.09	69.74	48.0
B RMS MAX	49.36	52.73	68.74	50.6
	WATER	**WATER**	**WATER**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.1	2.02	1.57	
P-DUR & END MARKER	1.43	1.09	0.91	

	TRISCUIT	TRISCUIT	TRISCUIT	EXTRA
MASSETER: A RMS MAX	87.15	158.58	90.71	
B RMS MAX	187.62	277.93	245.59	
	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.8	1.94	1.47	3.2
P-DUR & END MARKER	1.89	1.68	1.46	2.6

PARTICIPANT #9 GROUP:	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**	**EXTRA**
MASSETER BASELINE: A RMS MAX	206.50	270.09	241.84	
B RMS MAX	152.75	194.56	174.51	
A RMS AVG	115.71	161.12	149.29	
B RMS AVG	102.52	122.29	103.22	

Average Mass Baseline: 2.95-3.05

Avg for MASS: .95-1.05 sec	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
MASSETER: A RMS MAX	23.46	258.15	62.92	
B RMS MAX	47.03	103.62	27.08	
	1/2 TSP PUDDING	**1/2 TSP PUDDING**	**1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	3.84	2.95	3.06	2.32
P-DUR & END MARKER	2.68	2.65	2.50	2.85

	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	1 1/2 TSP PUDDING	EXTRA
MASSETER: A RMS MAX	120.28	92.80	100.36	138.5

B RMS MAX	32.55	25.16	34.88	39.70
	1 1/2 TSP PUDDING	**1 1/2 TSP PUDDING**	**1 1/2 TSP PUDDING**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	3.42	3.87	3.29	2.16
P-DUR & END MARKER	1.89	2.44	1.71	1.47

	WATER	**WATER**	**WATER**	**EXTRA**
MASSETER: A RMS MAX	15.53	28.98	53.47	
B RMS MAX	21.30	28.47	24.70	
	WATER	**WATER**	**WATER**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	4.75	2.95	2.99	
P-DUR & END MARKER	3.54	1.43	1.61	

	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
MASSETER: A RMS MAX	89.62	306.06	40.54	
B RMS MAX	30.76	140.04	40.97	
	TRISCUIT	**TRISCUIT**	**TRISCUIT**	**EXTRA**
LARYNGEAL ELEVATION: PHYS DUR	2.45	3.61	2.41	
P-DUR & END MARKER	2.88	3.49	2.07	

Figure 3.20 IOPI Tip Arrayed by Age.

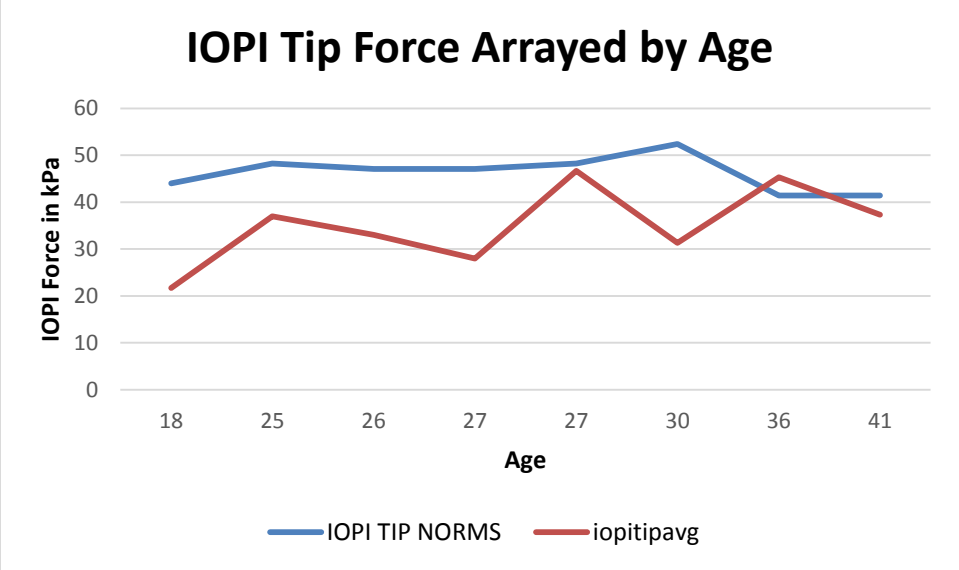


Figure 3.21 IOPI Dorsum Arrayed by Age.

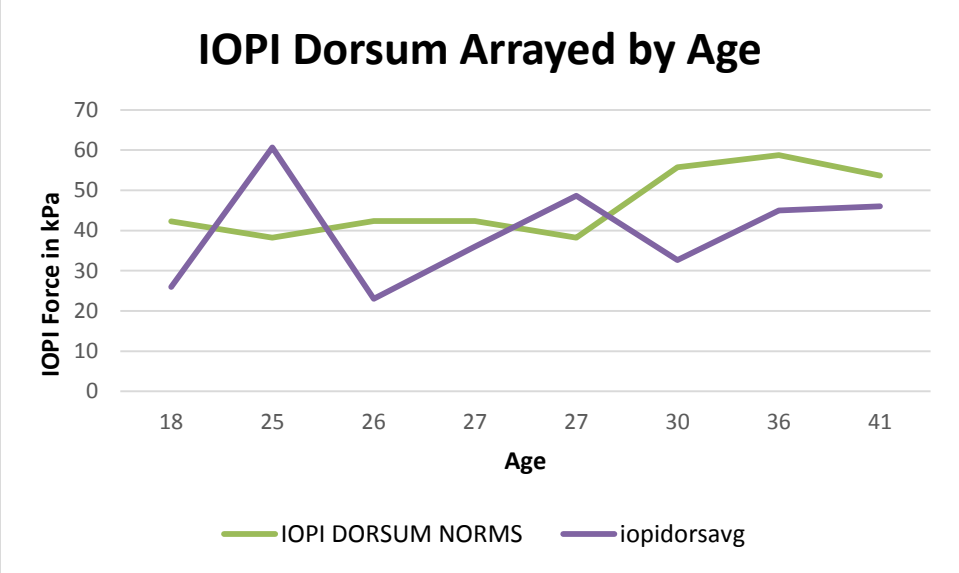


Figure 3.22 IOPI Between the Lips Arrayed by Age.