2015

Musculoskeletal Markers of Linguistic Variance on the Human Mandible

Hannah Catherine Hilbert

Follow this and additional works at: http://commons.emich.edu/honors

Recommended Citation
http://commons.emich.edu/honors/456

This Open Access Senior Honors Thesis is brought to you for free and open access by the Honors College at DigitalCommons@EMU. It has been accepted for inclusion in Senior Honors Theses by an authorized administrator of DigitalCommons@EMU. For more information, please contact lib-ir@emich.edu.
Musculoskeletal Markers of Linguistic Variance on the Human Mandible

Abstract
Skeletal morphology is greatly influenced by muscle action and articulation. Exertion of force by muscle use permanently alters bone shape. It can therefore be assumed that the muscles involved in speech production would play a role in shaping the stomatognathic structures (i.e. relating to the mouth and jaw). This study has been designed to explore the resulting cranio-facial manifestations of linguistic diversity amongst modern *Homo sapiens*. Utilizing data independently collected from American, French, and Philippine skeletal collections, it is concluded that a correlation exists (albeit not significant) between observed musculoskeletal markers on the human mandible and the repetitive tongue positions required of each population's presumed spoken language: American English, French, and Tagalog. Specifically, the production of vowel phonemes correlates to repetitive use of the genioglossus, which consequently affects mental spine formation.

Degree Type
Open Access Senior Honors Thesis

Department
Sociology, Anthropology, and Criminology

First Advisor
Megan K. Moore

Second Advisor
Liza Cerroni-Long

Keywords
phonetic, spoken language, orthographic, bioarchaeology, linguistic anthropology

This open access senior honors thesis is available at DigitalCommons@EMU: [http://commons.emich.edu/honors/456](http://commons.emich.edu/honors/456)
MUSCULOSKELETAL MARKERS OF LINGUISTIC VARIANCE ON THE HUMAN MANDIBLE

By

Hannah Catherine Hilbert

A Senior Thesis Submitted to the

Eastern Michigan University

Honors College

in Partial Fulfillment of the Requirements for Graduation

with Honors in Anthropology

Approved at Ypsilanti, Michigan, on this date December 1, 2015
TABLE OF CONTENTS

ABSTRACT.................................................................................................................. 2
INTRODUCTION............................................................................................................. 2

LANGUAGES .................................................................................................................. 3
  ENGLISH .................................................................................................................... 4
  FRENCH ..................................................................................................................... 8
  TAGALOG ................................................................................................................... 11
  COMPARISON OF LANGUAGES ............................................................................. 13

ANATOMY OF STOMATOGNATHIC STRUCTURES ...................................................... 15
  MUSCULATURE ....................................................................................................... 15
    Genioglossus ............................................................................................................ 16
    Hyoglossus ............................................................................................................. 17
    Styloglossus ........................................................................................................... 18
    Mylohyoid .............................................................................................................. 20

COMPARISON OF EXTRINSIC MUSCLES AS USED IN SPEECH.............................. 21

MANDIBLE .................................................................................................................. 22
  Mental Spines ........................................................................................................... 23
  Mylohyoid Line/Groove ............................................................................................ 23

HYOID .......................................................................................................................... 24

COMPARISON OF SKELETAL ELEMENTS AS USED IN SPEECH............................. 25

DATA COLLECTION ................................................................................................... 26
  MATERIALS ............................................................................................................ 26
  METHODS ............................................................................................................... 27

RESULTS ....................................................................................................................... 32
  COMPARISON OF SKELETAL FEATURE BY LANGUAGE GROUP......................... 34

DISCUSSION ................................................................................................................. 42

CONCLUSION .............................................................................................................. 44
  AGE RELATED CHANGES ....................................................................................... 44
  VARIED DISTRIBUTION TRENDS ......................................................................... 45
  AVERAGE PROMINENCE OF MENTAL SPINE ...................................................... 46

WORKS CITED ............................................................................................................. 48
Abstract

Skeletal morphology is greatly influenced by muscle action and articulation. Exertion of force by muscle use permanently alters bone shape. It can therefore be assumed that the muscles involved in speech production would play a role in shaping the stomatognathic structures (i.e. relating to the mouth and jaw). This study has been designed to explore the resulting cranio-facial manifestations of linguistic diversity amongst modern Homo sapiens. Utilizing data independently collected from American, French, and Philippine skeletal collections, it is concluded that a correlation exists (albeit not significant) between observed musculoskeletal markers on the human mandible and the repetitive tongue positions required of each population’s presumed spoken language: American English, French, and Tagalog. Specifically, the production of vowel phonemes correlates to repetitive use of the genioglossus, which consequently affects mental spine formation.

Introduction

The present research undertakes a substantial, first-in-field endeavor to explore the manifestations of language from the bioarchaeological record. The purpose of this research is to analyze the possible relationships between spoken languages and the resulting musculoskeletal markers, operating under the following hypothesis: if different spoken languages require varied repetitive muscle use, then stomatognathic structures will be altered in a measurable way because skeletal morphology is a direct result of repetitive motion.
First, a linguistic analysis compares the orthographic (i.e. referring to written, alphabetic language) and phonologic (i.e. referring to spoken, auditory units of language) characteristics of American English, French, and Tagalog. Next, the known attributes of musculature used during speech production are assessed, in correlation to the sounds that each muscle is capable of producing. Finally, independently gathered data on the unique markers of the stomatognathic structures of the mandible is presented and analyzed.

The present research is limited in terms of reference material and many of the concepts presented are novel; thus, much of the methodology was developed for the purpose of this research. Due to small sample size and budgetary constraints, the scope of this research is limited; however, the results are encouraging and in support of the hypothesis, warranting further exploration.

Access to three separate skeletal collections proved invaluable for unique, relevant measurements. Still, this research must assume that these collections are indeed representative of the corresponding populations of language speakers. It is also assumed that orthographic and phonological trends within the selected three languages have varied only minimally over time and space. Operating under these assumptions, however, it is possible to draw substantiated conclusions concerning the relationships between linguistic variance and resulting musculoskeletal markers on the mandible.

**Languages**

In order to better understand the musculoskeletal markers correlated to language, it is necessary to separately analyze each language according to available statistics of three specific arenas: orthographic vowel frequency, phonemic vowel frequency, and
corresponding tongue placement frequency. Only then can trends and patterns of speech production be established to distinguish languages. The three languages to be explored in the present research are American English, French, and Tagalog.

**English**

The English language is limited orthographically to five distinct vowels absent of diacritical marks\(^1\): “a”, “e”, “i”, “o”, and “u”. In 2015, the Mathematical Association of America (MAA) utilized an algorithm to calculate letter frequency within the written English language, from which orthographic vowel frequency can be calculated, as seen in Figure 1 (Lewand).

![English - Orthographic Vowel Frequency Relative to Other Vowels](image)

**Figure 1. Orthographic Vowel Frequency Relative to Other Vowels in English.**

The five vowels of the English language are responsible for the pronunciation of a variety of different phonemes above and beyond the juxtaposed phonetic pairs of “hard”

---

\(^1\) Symbols used in addition to alphanumeric characters (i.e. accent, diéresis, tilde)
and "soft" vowels taught to English-speaking youth. According to the 2012 *WordPress* summary of English phonemes, fifteen English phonemes are readily evident in an American English speaker’s recitation of a Standard English text: /a/, /i/, /I/, /e/, /æ/, /u/, /e/, /a/, /æ/, /o/, /o/, /aʊ/, /o/, and /ɒ/ (Cmloegermluin). Examples of English words containing each of these phonemes can be seen in Table 1, with the instance of each vowel phoneme underlined.

Table 1. English Word Examples by Phoneme.

<table>
<thead>
<tr>
<th>phoneme</th>
<th>word example</th>
<th>phoneme</th>
<th>word example</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>mother</td>
<td>/at/</td>
<td>bite</td>
</tr>
<tr>
<td>/i/</td>
<td>bite</td>
<td>/a/</td>
<td>barn</td>
</tr>
<tr>
<td>/I/</td>
<td>bean</td>
<td>/o/</td>
<td>god</td>
</tr>
<tr>
<td>/e/</td>
<td>bed</td>
<td>/ɒ/</td>
<td>house</td>
</tr>
<tr>
<td>/æ/</td>
<td>pat</td>
<td>/aʊ/</td>
<td>house</td>
</tr>
<tr>
<td>/u/</td>
<td>boon</td>
<td>/ɒ/</td>
<td>book</td>
</tr>
<tr>
<td>/e/</td>
<td>pet</td>
<td>/ɒ/</td>
<td>boy</td>
</tr>
<tr>
<td>/ə/</td>
<td>but</td>
<td>/ɒ/</td>
<td></td>
</tr>
</tbody>
</table>

The frequencies of the twelve single-letter phonemes and three diphthongs can be found in Figure 2 below.

---

2 "Hard" vowels are sometimes referred to as "long" vowels, and include the following underlined vowels: ace, bee, bite, bone, duke. "Soft" vowels are also referred to as "short" vowels, and include the following: bad, bed, bit, body, bud.

3 Diphthongs result from the combination of unique vowel phonemes.
To diagram tongue placement frequency, two factors must be considered: tongue height and tongue frontness (or backness). In order to better exhibit the concept of tongue placement, examples of English words within the standard placement categories can be found in Table 2 below.

**Table 2. English Word Examples by Tongue Placement.**

<table>
<thead>
<tr>
<th>Height</th>
<th>Frontness / Backness</th>
<th>Front</th>
<th>Central</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOSE</td>
<td></td>
<td>bean</td>
<td>X</td>
<td>boon</td>
</tr>
<tr>
<td>CLOSE-MID</td>
<td></td>
<td>pet</td>
<td>mother</td>
<td>god</td>
</tr>
<tr>
<td>OPEN-MID</td>
<td></td>
<td>bed</td>
<td>X</td>
<td>but</td>
</tr>
<tr>
<td>OPEN</td>
<td></td>
<td>pat</td>
<td>X</td>
<td>pot</td>
</tr>
</tbody>
</table>
An individually constructed chart of the twelve single-letter phonemes, based on frequency information from the textbook *How English Works*, which considers predominately American English speakers, can be seen below in Figure 3 (Curzan).

VOWELS

\[
\begin{array}{c}
\text{Front} \\
\text{Close} \quad \text{i} \\
\text{Close-mid} \quad \text{e} \\
\text{Open-mid} \quad \text{æ} \\
\text{Open} \\
\end{array}
\]

\[
\begin{array}{c}
\text{Central} \\
\text{u} \\
\text{o} \\
\end{array}
\]

\[
\begin{array}{c}
\text{Back} \\
\text{ʊ} \\
\text{ʌ} \\
\text{ɒ} \\
\end{array}
\]

**LEGEND**

- <5% of Frequency relative to vowels only
- ≥5% of Frequency relative to vowels only
- ≥10% of Frequency relative to vowels only
- ≥30% of Frequency relative to vowels only

**ENGLISH**

Figure 3. Vowel Phoneme Placement and Frequency in English.

It is significant to note that nearly half of the vowels are frontal vowel phonemes (47.40%) while very few are “back” vowels (17.70%). Additionally, there is a high frequency of “close” or “mid-close” vowel phonemes in English: combined 70.12% of all vowels. In brief, the most frequent vowel patterns in the English language are produced frontally and with high tongue height.
French

French is a romance language of the Indo-European family, and is native to the European country of France. Due to the lasting effects of colonization, native French speakers can be found today across Africa, the Americas, and Asia.

French is far more diverse in its orthographic vowel composition, though the basic five vowels are the same: “a”, “e”, “i”, “o”, and “u”. However, the inclusion of diacritical marks (i.e. diacritic acute, circumflex, grave, and umlaut) increases the number of possible vowels to twenty. Utilizing the Corpus of Thomas Temp, authors from Bépo were able to determine relative frequencies of all orthographic vowel characters in the French language, as evidenced in Figure 4 below (Fréquence).

![French - Orthographic Vowel Frequency Relative to Other Vowels](image)

**Figure 4.** Orthographic Vowel Frequency Relative to Other Vowels in French.

A basic understanding of the French language shows that only twelve phonemes are consistently recognized: /a/, /ɛ/, /e/, /ɛ/, /æ/, /o/, /ɔ/, /œ/, /œ/, /o/, /ɔ/, /u/, and /y/. Examples of French words containing these phonemes were sought out in the reputable French dictionary Collins and can be seen below in Table 3.
Table 3. French Word Examples by Phoneme.

<table>
<thead>
<tr>
<th>phoneme</th>
<th>French word example</th>
<th>English translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>sa</td>
<td>his/her</td>
</tr>
<tr>
<td>/o/</td>
<td>pâte</td>
<td>dough</td>
</tr>
<tr>
<td>/e/</td>
<td>fée</td>
<td>fairy</td>
</tr>
<tr>
<td>/ε/</td>
<td>fait</td>
<td>goes</td>
</tr>
<tr>
<td>/a/</td>
<td>cê</td>
<td>this/that</td>
</tr>
<tr>
<td>/œ/</td>
<td>sœur</td>
<td>sister</td>
</tr>
<tr>
<td>/œ/</td>
<td>ceux</td>
<td>those</td>
</tr>
<tr>
<td>/i/</td>
<td>si</td>
<td>if</td>
</tr>
<tr>
<td>/o/</td>
<td>sot</td>
<td>silly</td>
</tr>
<tr>
<td>/ɔ/</td>
<td>sort</td>
<td>fate</td>
</tr>
<tr>
<td>/u/</td>
<td>sous</td>
<td>under</td>
</tr>
<tr>
<td>/y/</td>
<td>su</td>
<td>known</td>
</tr>
</tbody>
</table>

The frequencies of these twelve single-letter phonemes can be found charted by orthographic correlation in Figure 5.

Figure 5. Phonemic Frequency Relative to Other Vowels in French.
A similar diagram of tongue placement frequency can be created for the French language, as seen below in Figure 6.

![Vowel Phoneme Placement and Frequency in French](image)

**Figure 6. Vowel Phoneme Placement and Frequency in French.**

Most notable about the French phonemic frequencies is the disproportionately high frequency of front vowels: 70.87% of all vowel phonemes. Tongue placement frequency for French speakers is fairly well distributed in terms of height, though a combination of “mid-close” and “mid-open” vowels do account for 64%, while the extremities of simply “close” or “open” only 17.32% and 18.68% respectively. In short, the French language is certainly notable for its tendency to rely upon frontally produced vowels with no specific preference for tongue height.
Tagalog

Tagalog is spoken across the Philippines, particularly in its standardized form of “Filipino”. These languages belong to the Austronesian language family, which also includes languages such as Indonesian and Hawaiian.

Tagalog, like English, is absent of diacritical marks on any vowels, limiting it orthographically to the same five vowels: “a”, “e”, “i”, “o”, and “u”. Vowel frequency results from an algorithm calculated specifically for Tagalog can be found in Figure 7 (Trost).

![Tagalog - Orthographic Vowel Frequency Relative to Other Vowels](image)

*Figure 7. Orthographic Vowel Frequency Relative to Other Vowels in Tagalog.*

The Tagalog language relies upon a standard set of ten phonemes: /a/, /u/, /e/, /o/, /l/, /i/, /ɛ/, /o/, /i/, and /u/. Tagalog words that contain each of these phonemes can be seen in Table 4 below, as compiled from various online Tagalog dictionaries.
Table 4. Tagalog Word Examples by Phoneme.

<table>
<thead>
<tr>
<th>phoneme</th>
<th>Tagalog word example</th>
<th>English translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>asoge</td>
<td>mercury</td>
</tr>
<tr>
<td>/e/</td>
<td>tanso</td>
<td>nut</td>
</tr>
<tr>
<td>/e/</td>
<td>tsinelas</td>
<td>slippers</td>
</tr>
<tr>
<td>/i/</td>
<td>itak</td>
<td>sit</td>
</tr>
<tr>
<td>/i/</td>
<td>ibon</td>
<td>bird</td>
</tr>
<tr>
<td>/o/</td>
<td>oyayi</td>
<td>lullaby</td>
</tr>
<tr>
<td>/o/</td>
<td>isoli</td>
<td>returned</td>
</tr>
<tr>
<td>/u/</td>
<td>utang</td>
<td>debt</td>
</tr>
<tr>
<td>/o/</td>
<td>ulól</td>
<td>foot</td>
</tr>
<tr>
<td>/e/</td>
<td>mayroon</td>
<td>available</td>
</tr>
</tbody>
</table>

An approximate frequency of these phonemes has been independently calculated to show general patterns, and can be observed in Figure 8 below.

Figure 8. Phonemic Frequency Relative to Other Vowels in Tagalog.

Figure 9 displays the diagram of tongue placement frequency, as roughly estimated according to the ten phonemes previously mentioned.
In summary, Tagalog phonemic frequencies are most notable for majority frontal vowels (53.55%) as compared to central and back vowels (23.36% and 23.11% respectively). Additionally, most Tagalog vowels are “open” or “mid-open” at a cumulative total of 64.39%. This phonemic trend is undoubtedly due to the disproportionate frequency of the written “a”, and the fact that “a” transcribes exclusively to the four “open” or “open-mid” phonemes: /a/, /e/, /e/, and /a/.

**Comparison of Languages**

Beyond a comparison of language families, it is of course necessary to compare trends of musculature during speech production; most directly, by comparing data of
tongue frontness/backness and tongue height, it is possible to predict a correlation of
different musculoskeletal markers of spoken language.

First, in terms of frontness and backness, an overarching preference for frontal
vowels is noted across all three languages; French has the highest proportion (70.87%),
though Tagalog and English also boast around half of their vowels as frontal vowels
(53.55% and 47.4% respectively). On the other extreme, French has the lowest
percentage of back vowels (13.35%), American English follows with a slightly higher
percentage (17.70%), and Tagalog is not far behind (23.11%).

Therefore, in terms of frontness/backness, it may be possible to predict that
French speakers would more frequently utilize muscles that produce frontal vowels, but
the distinction would likely be insignificant. Moreover, a distinction of this type is
unlikely to exist at all between Tagalog and American English speakers. It would be
more beneficial to focus on more clear distinctions amongst the spoken languages.

Far more distinct are vowel trends concerning tongue height, or how “open” or
“closed” a vowel phoneme is. These distinctions consider that the majority percentage of
each language’s vowels in their summarized category either:

1) falls into a category which includes the extremity (i.e. “open” or “close”) as
   well as the corresponding “mid-” category, or
2) is intermediate between the extremes, considering exclusively the combined
   percentages of “mid-” categories (i.e. “mid-open” and “mid-close”).

Therefore in these general terms, American English is a predominately “closed”
language, Tagalog is mostly “open”, and French is intermediate. The continuum created
with these three languages is interesting to consider, as it allows the prediction of a
continuum of musculoskeletal marker presence and prominence as well. As patterns of speech vary according to language, so also may the resulting bony projections of the stomatognathic structures.

**Anatomy of Stomatognathic Structures**

In addition to the written and auditory properties of a language, the complexities of the speech production mechanism must be considered before the speech production process can be fully understood. Fortunately, the mechanisms of speech production are generally limited to the cranio-facial region, though select other muscles are employed for air supply and breath support. Therefore, the present research chooses to focus on the cranio-facial structures, and specifically those of the mouth and jaw in direct relationship to the tongue.

Two different classes of anatomical material factor into the speech production mechanism: muscular and skeletal. These will be analyzed individually and in terms of their cross-functional relationships.

**Musculature**

Although myriad muscles are found connected to the mandible, only certain muscles influence speech production through tongue motion. Specifically, four extrinsic muscles are responsible for controlling tongue height and forwardness: genioglossus, hyoglossus, styloglossus, and mylohyoid. These extrinsic muscles are most relevant to

---

4 Of or relating to the skull and associated anatomy.
5 Generally understood simply as “bones”.
6 Extrinsic muscles of the tongue originate elsewhere, but directly impact the motion of the tongue.
analysis because they, by definition, articulate with the bones of the stomatognathic structure and would likely provide evidence of this articulation (Sanguineti).

It is therefore through analysis of these extrinsic muscles that muscle origin and insertion can correlate to, and possibly be explained by, the frequency of certain sounds spoken within a specific language. In detail, the general mass, provenience\(^7\), and extension of each extrinsic muscle permits a better understanding of its role in the speech production process.

Genioglossus

The majority of a tongue's bulk can be attributed to the mass of the genioglossus; in fact, the entire inferior surface of the tongue is covered by muscle fibers of the genioglossus, although other muscle fibers are also dispersed throughout (Epstein). In terms of sheer mass, the genioglossus is arguably the most notable of all tongue muscles, since its nonexistence would all but render the tongue limp.

---

\(^7\) Provenience refers to the relative location of an item.
The origin of the genioglossus is the superior portion of the genial tubercles, or mental spines, which are located medially and symmetrically. After running posteriorly and superiorly, the lowest fibers of the genioglossus insert into the anterior surface of the hyoid at a very fine point of insertion (Frazer). The remaining fibers fan out across the inferior surface of the tongue anteriorly, spanning from the root to the near tip of the tongue.

The genioglossus can be typically considered as a muscle that lowers the mandible, though it has been known to elevate the hyoid if the mandible is fixed. However, this muscle is truly unique for its ability to propel the tongue forward, or anteriorly. As relevant for current research, proper function of the genioglossus is necessary to create all frontally produced sounds. Only the genioglossus specifically allows accuracy and precision when articulating front vowel phonemes such as /i/, /e/, /æ/, and /a/ (Epstein). That is not to say that the genioglossus alone allows the utterance of such phonemes, but rather that it serves the role of maintaining consistency and accuracy.

**Hyoglossus**

Though not as large in terms of sheer volume, the hyoglossus is a muscle of wide breadth and surface area. It works intimately alongside the styloglossus, as the inserting fibers from these two muscles do interdigitate\(^8\) with additional muscles (i.e. superior longitudinal and inferior longitudinal) upon insertion into the mass of tongue muscle (Epstein).

---

\(^8\) To interdigitate is to lock together, as in interlocking fingers of two hands.
The hyoglossus originates at the hyoid, specifically running parallel and interior to the middle constrictor down each of the greater horns. Here, as it nears the body of the hyoid, the hyoglossus encroaches upon the articulatory area of the geniohyoid (Frazer). Upon extension away from the hyoid, the hyoglossus runs the lateral surfaces of the tongue, where the fibers intertwine to form the postero-inferior surface (Epstein).

In the instance of a fixed hyoid, the hyoglossus can lower the entirety of the tongue, particularly as it connects to the chondroglossus, which extends to the tip of the tongue (Epstein). Generally, however, as it is the depressor, the hyoglossus is attributed with the downward motion of the tongue; proper function of the hyoglossus specifically permits pronunciation of such low or “open” vowel phonemes as /a/, /o/, and /æ/ but also the “mid open” vowels /e/ and /a/.

Although the hyoglossus is one of the four extrinsic muscles, it does not articulate directly with the mandible and its mental spines. Therefore, without the presence of matching hyoids for each mandible, it would be difficult to determine variance among languages insomuch as the hyoglossus is concerned.

**Styloglossus**

The styloglossus works intimately with the hyoglossus, as the inserting fibers of these two muscles interdigitate upon approximation to the tongue. Still, the styloglossus does not exist exclusively as a means to support the hyoglossus, but rather is unique in its connecting force between the skull and the mandible, via the tongue.

As evidenced by its name, the styloglossus does originate on the portion of the skull referred to as the styloid process, specifically on the lateral and anterior surface of that process (Epstein). This styloid process is the inferior-most portion of the temporal
bone of the cranium, and projects in an anterior-inferior direction. As a slender, bony projection, it serves the traditional purpose of muscle attachment. Naturally, due to its location relative to the stomatognathic structures, the type of muscles found attaching to this styloid process are purposed for either mastication\(^9\) or speech production.

The fibers of the styloglossus are divided into two parts upon approach to the tongue: inferior to blend with the hyoglossus and slightly superior to course the lateral edge of the tongue toward the tip. Therefore, the styloglossus is easily capable of superior and posterior motion, with the support of the miniscule palatoglossus. Movement backward and upward is crucial in the utterance of high, back vowels, such as /u/, /u/, /o/, /A/, and /o/. Most specifically, the styloglossus allows bunching of the tongue with the sides down to produce these phonemes (Epstein).

Additionally, the inferior and superior longitudinal muscles have fibers that intertwine along the lateral edges of the tongue and assist in the motion of the styloglossus. The inferior longitudinal muscle serves as a necessary antagonist to the styloglossus, allowing constancy and precision of speech production. Most specifically, all these muscles together help maintain the raised lateral portion of the tongue during "grooved articulations" of [s] and [z] (Epstein). Though these consonants are not a focus at the present time, the unique importance of lateral muscles to induce "grooving" on the margins of the tongue cannot be overlooked.

The styloglossus, like the hyoglossus has no direct articulation with the mandible and its mental spines. Further analysis might be possible using the temporal bone of the cranium, should it be available as a matched pair in future research.

\(^9\) Mastication is synonymous with "chewing".
Mylohyoid

The mylohyoid muscles cover a great area of the floor of the mouth and are only supplemented by the accompanying fleshy and fatty tissue. This means that the mylohyoid can occasionally assist in lowering the mandible. In general, the mylohyoid muscles serve as a supportive sling on the underside of the tongue’s main body, formed as each mylohyoid runs medially from the horizontal ramus of the mandible and joins at the midline raphe directly medial on the underside of the tongue (Epstein).

In anatomical terms, the mylohyoid originates at the mylohyoid line, or the prominent ridge located inferiorly on the interior surface the horizontal mandibular ramus. It runs in an inferior and medial direction until inserting into the hyoid bone, at the anterior portion of the corpus (Epstein).

Various sounds are produced with the help of the mylohyoid, since it works generally with the elevation of the floor of the mouth as well as positioning of the hyoid and the mandible. In the production of high vowels, the mylohyoid is utilized for raising the body of the tongue (Epstein). The extremely high vowels (sometimes referred to as “closed” vowels) include the following phonemic utterances: /i/, /y/, /u/, and /o/. Although not as extreme in their height, these phonemes can also be considered as fairly high vowels (or “mid-closed”): /e/, /æ/, and /o/. The mylohyoid indisputably assists in the production of these seven major phonemes, though could assist with several additional phonemes as well.

---

10 A raphe is a raised line at the union of separate symmetrical parts. As such, the “midline raphe” mentioned in the text refers to the raised line of palatal union located centrally underneath the tongue.
Comparison of Extrinsic Muscles as Used in Speech

In order to better understand how frequent muscle use might leave skeletal markers, it is most necessary to categorize muscles that do and do not articulate with various bones of the stomatognathic structures. More precisely, the current research focuses predominately on the muscles that articulate on the mandibular features (i.e. mental spines and mylohyoid line/groove) with a peripheral understanding of musculature that articulates with the hyoid. The mandible has a better survival rate in archaeological contexts than does the hyoid and is therefore the main skeletal element of interest in this study.

Two of the aforementioned muscles articulate directly on the mandible: the genioglossus and the mylohyoid. These two muscles both originate on the mandible before coursing away, with the genioglossus’ origin at the mental spines and the mylohyoid’s at the aptly named mylohyoid line. Fortunate for current research is the difference between these two origins, as the genioglossus’ unique production of frontal vowel phonemes can be contrasted with the mylohyoid’s production of generally high or “open” vowel phonemes. Only for a select few vowel phonemes is there an overlap of both frontal and “open” vowels: /i/, /y/, and /u/.

As for the hyoid itself, three of the muscles articulate directly with the hyoid. Of the three, only the hyoglossus originates at the hyoid, while the genioglossus and styloglossus only insert into the hyoid at their points of termination. The hyoglossus generally articulates with the hyoid over the greatest surface area, including the length of the greater horns of the hyoid, while the genioglossus and styloglossus only insert at fine points on the anterior sections of the hyoid.
Mandible

For the purpose of this research, the skeletal elements are limited to that which has been most consistently available for analysis. As such, the human mandible has become the primary focus. The mandible is an indispensable component in the speech production process, as its function begins even before articulation is audible and continues proportionately after (Bell-Berti).

The structure of the mandible is unique; although congruent to a synovial joint, the resulting mandible does not contain hyaline cartilage as would be expected. Instead, the heterogeneous fibrocartilage of which the mandible is composed is known for durability under the pressure of tensile forces\textsuperscript{11}, and develops greater strength with time. This distinguishes the mandible from any of the long bones, likely because of embryological differences in the bone cells themselves (Gingerich).

In order to consider the relative importance of the mandibular body itself, it is necessary to understand the features that articulate directly with the aforementioned extrinsic muscles. As previously mentioned, these most notable features are the mental spines and the mylohyoid lines/grooves. From the current research, it appears that these features become defined as a human ages, arguably as a result of mastication and/or speech production.

\textsuperscript{11} Tensile forces are known to pull and stretch.
Mental Spines

The mental spines are located on the interior and posterior surfaces of the mandible, medial and inferior relative to the teeth. Standards dictate that these mental spines consist of two separate pairs of spinous processes, which form a quadrilateral of varied dimensions relatively parallel to the transverse plane. Across populations, all four spinous processes are not always distinguishable, but rather might exist simply as a pair, a singular fused mass, or not at all (Frazer).

Though sometimes referenced as “genial tubercles”, the mental spines are nevertheless understood for their role in anchoring the genioglossus (Frazer). Indeed, as previously mentioned, the Genioglossus originates at the mental spine. However, the hyoglossus and styloglossus do not articulate directly with the mental spine.

Mylohyoid Line/Groove

The mylohyoid line/groove is appropriately named after the muscle by the same name: the mylohyoid. As mentioned previously, the mylohyoid line is the origin for the
mylohyoid muscle. The line is a notable, palpable ridge on the interior surface of the mandible, found superior to the lesser mylohyoid groove (Frazer).

The mylohyoid groove crosses the medial surface of the ramus in an anterior and inferior direction from the mandibular foramen and supporting the mylohyoid blood vessels and nerve (White et al.). The increase in the size of the nerves and blood vessels likely indicating an increased investment to this muscle and is less subjective to score than is the mylohyoid line. Due to the difficulty in replicating the scoring for the prominence of the mylohyoid line, the mylohyoid groove was preferred for the current study, as the depth of the groove may indicate the nervous and vascular support for the mylohyoid muscle.

Due to assumed symmetry of the craniofacial structures, a pair of nearly identical mylohyoid lines and grooves can be found on a typical mandible. In an effort to standardize measurements, the osteological convention is to select the left side to consistently measure and disregard the right, unless noted. Just as any other protruding feature, the mylohyoid line and groove can be measured ordinally\textsuperscript{12} in terms of sharpness and depth.

**Hyoid**

The hyoid bone is located at the tongue's base, approximately at the same level as the mandibular base when in a static state. This bone develops as an individual reaches maturity, ultimately developing symmetrical pairs of cornua\textsuperscript{13} from the more medial

\textsuperscript{12} Ordinal classifications are defined in sequence of severity, with lower numbers generally indicating less severity and higher numbers indicating greater severity.

\textsuperscript{13} Cornua are sometimes referred to as "horns", and are the protrusions from the body of the hyoid that create the "U" shape of this bone. The so-called "lesser cornua" form a shallow shape, while the "greater cornua" ultimately form a deep "U".
body. This development is a direct result of the ossification that occurs around the pharyngeal arches, and can result in unique formations even at different stages in a human's life (Frazer).

As previously mentioned, the present research has made use of those bones available for analysis. Unfortunately, the miniscule hyoid is often lost from skeletal collections, or never recovered, and as such is not typically available for analysis from bioarchaeological collections.

**Comparison of Skeletal Elements as Used in Speech**

It can be concluded that the prominence of the two aforementioned mandibular features (mental spines and mylohyoid line/groove) would indicate repetitive use of the muscles that directly attach to them: the genioglossus and the mylohyoid. The absence of either of these features could indicate that a language speaker relies predominately upon other extrinsic muscles of the tongue for speech production, which could only be tested with matching craniofacial structures (i.e. the hyoid and the cranium).

Analysis of the aforementioned mandibular features is most beneficial in the examination of the current hypothesis: if different spoken languages require varied repetitive muscle use, then stomatognathic structures will be altered in a measurable way because skeletal morphology is a direct result of repetitive motion. Here, it is determined that the muscles in question are the genioglossus and mylohyoid, and the stomatognathic structures are the mental spines and mylohyoid groove.
Data Collection

The bioarchaeological data collection was the result of time spent analyzing three separate collections of human skeletal remains with basic measuring instruments (such as calipers and photography with millimeter scale) and data recording software. All methods were consistent across the three skeletal collections examined.

Materials

The first collection is located at the Milford Lab of 231 West Hall at the University of Michigan, Ann Arbor, Michigan. This collection of North American remains is referred to as the “Ford Collection” because it is the result of the work of Dr. Corydon La Ford, M.D. near the end of the 19th century. Dr. La Ford collected skeletons with origins in the 16th and 17th centuries (Ford). A sample of five intact crania and corresponding mandibles were identified for analysis. The five individuals whose crania were analyzed were all of adult age at time of death, though sex estimation cannot be used to sex these individuals.

The second collection was also housed at the same lab at the University of Michigan. As explained by University of Michigan curators, this collection consists of various human remains from the 19th century in the Philippines, including five complete, intact crania and corresponding mandibles. Again, these complete skulls were from adults of unidentified sex. Both University of Michigan collections were preserved in good condition and sorted and labeled accordingly.

The third and final collection analyzed was of an early medieval French population sample. This collection was discovered by the French Department of Transportation during the construction of a highway through the early medieval village
and cemetery of Saleux. The village and cemetery was excavated by French state archaeologists in 1993 and 1994 (Catteddu et al.). As of the summer of 2014, the collection was housed by a private curator in the commune of Saint-Valery-sur-Somme, along the northern coast of France. The bones present are fairly well preserved, although the majority of individuals are found to be missing some skeletal elements and there is some fragmentation.

Methods

The primary instrument used for skeletal measurements was a 12-inch/300 millimeter Vernier electronic digital caliper. This caliper was equipped with two sets of jaws, allowing for measurements that were internal (i.e. foramen width) or external (i.e. mandibular breadth). The electronic gauge could be manually reset, or "zeroed", and measurements could be recorded in either the English or Metric System.

All data was recorded on a 17" MacBook Pro using Excel 2010. All numbers were entered in cells with "number" formatting turned on. Where calculations were necessary, all steps are visible in the "function" bar. The data was saved daily in a non-corruptible "Read-only" Excel Workbook (*.xlsx) and also in PDF form. Statistical analysis was conducted using the software program SPSS Version 21.0. These files were saved to the computer hard drive as well as a 16GB SanDisk flash drive.

All photos were taken using an iPhone 4, with a metric photographic reference scale visible in every image. When possible, and always with the first photograph of a new object, labels were included in the images. Many images were taken alongside a straight reference plane (either black or white) to emphasize severity of a certain spine,
protuberance, or other feature. All images were saved to the same MacBook Pro in separate folders sorted by collection and titled by the reference number.

Unfortunately, none of the measurements required of this research was available in the literature. Therefore, the author developed a novel methodology for scoring the size and shape of the skeletal features. Still, it was necessary to emulate the creation of prior standards in constructing relevant measurement techniques for manifestation of language. The measurements detailed in this section are based on an understanding of general language biomechanics, and then concentrated depending on specific characteristics of the target language.

Measurement classifications were taken of the mental spines and various foramen around the interior, posterior and lingual surface of the mandible. Unless otherwise specified, these visual measurement classifications were taken from the superior surface. Also, the anatomical left was observed and reported for measurement unless otherwise stated. Foramina were generally measured for location and individual diameter. Additionally, mandibular breadth was measured.

Ordinal classifications were observed consistently for the mental spine(s) and left mylohyoid groove, though various other measurements were recorded for reference. For each of these two main markers, two distinct variables were measured, and these were measured relative to the series of diagrams seen in Table 5 and Table 6 and given a score of 0 – 3.
Table 5. Mental Spine Reference Chart.

<table>
<thead>
<tr>
<th>MENTAL SPINE</th>
<th>Bifurcation</th>
<th>example</th>
<th>Rugosity</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image0" alt="Bifurcation Example 0" /></td>
<td><img src="image1" alt="Example 0" /></td>
<td><img src="image2" alt="Rugosity Example 0" /></td>
<td><img src="image3" alt="Example 0" /></td>
</tr>
<tr>
<td>1</td>
<td><img src="image4" alt="Bifurcation Example 1" /></td>
<td><img src="image5" alt="Example 1" /></td>
<td><img src="image6" alt="Rugosity Example 1" /></td>
<td><img src="image7" alt="Example 1" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image8" alt="Bifurcation Example 2" /></td>
<td><img src="image9" alt="Example 2" /></td>
<td><img src="image10" alt="Rugosity Example 2" /></td>
<td><img src="image11" alt="Example 2" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image12" alt="Bifurcation Example 3" /></td>
<td><img src="image13" alt="Example 3" /></td>
<td><img src="image14" alt="Rugosity Example 3" /></td>
<td><img src="image15" alt="Example 3" /></td>
</tr>
</tbody>
</table>
Table 6. Mylohyoid Groove Reference Chart.

<table>
<thead>
<tr>
<th>MYLOHYOID GROOVE</th>
<th>Sharpness example</th>
<th>Depth example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image1" alt="Sharpness Example" /></td>
<td><img src="image2" alt="Depth Example" /></td>
</tr>
<tr>
<td>1</td>
<td><img src="image3" alt="Sharpness Example" /></td>
<td><img src="image4" alt="Depth Example" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image5" alt="Sharpness Example" /></td>
<td><img src="image6" alt="Depth Example" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image7" alt="Sharpness Example" /></td>
<td><img src="image8" alt="Depth Example" /></td>
</tr>
</tbody>
</table>
Each ordinal classification was reevaluated a second time during the same day. Then, if possible on a later date, each ordinal measurement was recorded a third time blindly (meaning that the observer had not reviewed initial scores before reevaluation). An average was then calculated of these two or three measurements and rounded to the nearest half (0.5). If the range of measurements was greater than one (1), then the score was to be disregarded as overly subjective. Fortunately, none of the measurements taken had to be disregarded, as the scores tended to concentrate tightly around the average.
Results

The resulting data for these three populations offers two distinct branches of analysis: mandibular features evidenced in correlation to age and feature differences according to population.

Through collaboration with Eastern Michigan University colleagues, age estimations were performed upon the St. Valery population sample. These colleagues collaborated using both the Risser sign on the pelvis and the Demirjian method of tooth analysis to confirm adult age. Estimations using the Demirjian method are believed to be most accurate according to identifiers in dentition, which experiences the most rapid changes during youth and adolescence. For that reason, subjects identified as youth were given estimates for specific ages, while the rest were referred to simply as 1) young adult, 2) mature adult and 3) elderly adult. The adult age estimations were calculated by French osteologists shortly after the original bioarchaeological investigation in 1994 (Catteddu et al.). Though prepubescent subjects were only observed from one\textsuperscript{14} of the population samples, distinctions between age categories are significant. For the purposes of a clear division, pre-pubescence has been defined here as less than ten years of age, whereas the other group includes ages ten and above. The comparison between these groups is evidenced in Figures 12 and 13 below.

\textsuperscript{14} St. Valery – French speakers
Though genetic variation might influence bone structure to a point, it is apparent that osteological projections develop with age. Essentially, prepubescent mandibles can be observed as absent of unique, identifying projections. Particularly in terms of mental spine bifurcation, evidences are absent, as evidenced below in Table 7.
Table 7. Mental Spine Measurements for Pre-Pubescent French Individuals.

<table>
<thead>
<tr>
<th>Age Estimation (years)</th>
<th>Mental Spine</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bifurcation</td>
<td>Rugosity</td>
</tr>
<tr>
<td>0.75</td>
<td>0.00</td>
<td>1.25</td>
</tr>
<tr>
<td>2.00</td>
<td>0.00</td>
<td>2.25</td>
</tr>
<tr>
<td>2.00</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>3.00</td>
<td>0.00</td>
<td>0.25</td>
</tr>
<tr>
<td>4.00</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>5.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>9.00</td>
<td>2.25</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.43</strong></td>
<td><strong>1.00</strong></td>
</tr>
</tbody>
</table>

Though not as drastic in its development, there is variation between mylohyoid grooves according to the ages of individuals in the St. Valery collection, as seen below in Table 8.

Table 8. Mylohyoid Groove Measurements for Pre-Pubescent French Individuals.

<table>
<thead>
<tr>
<th>Age Estimation (years)</th>
<th>Mylohyoid groove</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sharpness left side</td>
<td>Depth of groove left side</td>
</tr>
<tr>
<td>0.75</td>
<td>2.00</td>
<td>2.50</td>
</tr>
<tr>
<td>2.00</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>2.00</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td>3.00</td>
<td>1.25</td>
<td>1.75</td>
</tr>
<tr>
<td>4.00</td>
<td>1.25</td>
<td>1.00</td>
</tr>
<tr>
<td>5.00</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>9.00</td>
<td>2.00</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>1.25</strong></td>
<td><strong>1.36</strong></td>
</tr>
</tbody>
</table>

Comparison of Skeletal Feature by Language Group

The results are presented according to population sample and different spoken languages. Shown first are the distributions of samples for each language population,
with linear representation of correlated trends. Figures 14 – 16 present ordinal classifications taken of the mental spines for each language population.

Figure 14. Ford Mental Spine Trends.

Figure 15. Philippine Mental Spine Trends.
When the means of each measurement are compared, the results for the mental spines are distinct, as seen below in Figure 17. For the purpose of this comparison, only individuals of ten years of age or older were considered.

The use of boxplots exhibits the mean and range for each mental spine measurement, as shown below in Figures 18 and 19. The data for these figures is limited exclusively to adults, considered as eighteen years of age or older.
Figure 18. Mental Spine Bifurcation by Language Group.

Figure 19. Mental Spine Rugosity by Language Group.
The case report summary including number of individuals, means, medians, and standard error of the means of mental spine measurements and the mylohyoid groove for each sample can be seen in Table 9 below.

Table 9. Summary Table for Mental Spine and Mylohyoid Groove Scores of Adults by Language Group

<table>
<thead>
<tr>
<th>Language</th>
<th>Mental Spine Rugosity</th>
<th>Mental Spine Bifurcation</th>
<th>Mylohyoid Groove Sharpness</th>
<th>Mylohyoid Groove Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td>N</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.08</td>
<td>1.84</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2.25</td>
<td>2.13</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>Std. Error of Mean</td>
<td>0.107</td>
<td>0.179</td>
<td>0.085</td>
</tr>
<tr>
<td>English</td>
<td>N</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Std. Error of Mean</td>
<td>0.354</td>
<td>0.224</td>
<td>0.423</td>
</tr>
<tr>
<td>Tagalog</td>
<td>N</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1.4</td>
<td>0.95</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>1.5</td>
<td>1</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>Std. Error of Mean</td>
<td>0.534</td>
<td>0.255</td>
<td>0.215</td>
</tr>
<tr>
<td>Total</td>
<td>N</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1.99</td>
<td>1.76</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2.25</td>
<td>2.18</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td>Std. Error of Mean</td>
<td>0.112</td>
<td>0.148</td>
<td>0.085</td>
</tr>
</tbody>
</table>

Similar analyses can be made concerning the mylohyoid groove. First, Figures 20 – 22 show trends within each population.
Figure 20. Ford Mylohyoid Groove Trends.

Figure 21. Philippine Mylohyoid Groove Trends.

Figure 22. St. Valery Mylohyoid Groove Trends.
A comparison can also be made according to means of the ordinal measure of sharpness and depth, as evidenced below in Figure 23. Then, Figures 24 and 25 include the boxplots concerning the individual measurements of adult mylohyoid grooves.

Figure 23. Mylohyoid Groove by Population.
Figure 24. Mylohyoid Groove Sharpness by Language Group.

Figure 25. Mylohyoid Groove Depth by Language Group.
Discussion

To begin with the discussion of the mental spine data, individual score ranges are examined. Though likely influenced by small sample size, it has been found that American English and Tagalog speakers have the smallest variation in range, particularly considering bifurcation, with American English speakers ranging from ordinal measurements of 1.5 to 2.5 and Tagalog speakers from 0.25 to 1.5. In the larger sample of adult\textsuperscript{15} French speakers, this range includes evenly distributed measurements of 0 to 3, with nearly the same number of individuals scoring greater than 1.5 as scoring less. Perhaps it is significant to consider that American English and Tagalog speakers apparently occupy different ends of the spectrum when bifurcation of the mental spines is concerned, and French speakers can be found in various states of bifurcation.

Less distinct trends can be identified when considering mental spine rugosity, since observed variance for all three languages spans nearly the same range of 0 to 3. Moreover, all three languages were found to have an individual with the highest measurable rugosity score of 3. Only slight differences can be observed in terms of the lowest rugosity scores, since Tagalog speakers exhibited a minimum score of 0, English speakers a minimum of 0.25 and American English speakers a minimum of 1. This analysis of rugosity lends no conclusion concerning differences in rugosity among languages.

Nevertheless, it can be observed that both American English and French exhibit a positive correlation between bifurcation and rugosity, while Tagalog trends toward a

\textsuperscript{15} The term “adult” will continue to refer to individuals ten years or age or older. Furthermore, from henceforth, it can be assumed that only “adult” French speakers are being considered unless otherwise stated.
negative correlation. Though there is great variation with all three languages (r-squared values of 22.5% for American English, 17.3% for French, and 77.7% for Tagalog), the resulting linear trend line informs on the basic trend that distinguishes between Tagalog and the other two languages; while an increase in bifurcation correlates to a concurrent increase in rugosity for American English and French speakers, Tagalog speakers exhibit a decreased rugosity with an increase in bifurcation. In simple terms, mental spines on the mandibles of American English and French speakers tend to become more defined and sharp as the mental spines separate into bifurcated mental spines, whereas those of Tagalog speakers are most clearly defined when they are not bifurcated.

Finally, in a comparison of mean scores on the mental spines, further evidence exists to pair American English and French speakers at the exclusion of Tagalog speakers; mean values for both bifurcation and rugosity are higher among American English and French speakers than for Tagalog speakers. In fact, not a single Tagalog speaker exceeds the American English or French means for bifurcation, and only one individual exceeds the means for rugosity. This makes it evident that the Tagalog speakers produce significantly less prominent occurrences of mental spines than American English and French speakers. Despite the small sample sizes, the ordinal classification scores collected through this research are distinct between the samples and warrant further scientific consideration.
Conclusion

As evidenced by the present research, it is concluded that a correlation exists between certain spoken language and developed musculoskeletal markers on the human mandible (i.e. the mental spines). This conclusion is substantiated by three key items in relation to the mental spine: age related changes, varied distribution trends, and average prominence of occurrence. The mylohyoid groove did not prove to be as useful of an indicator for speech. Future research could focus on the mylohyoid line, although reliability of scoring this feature must be investigated.

Age Related Changes

As previously mentioned, mandibles of younger individuals were found to have less prominent mandibular projections. In fact, when the mean scores for both bifurcation and rugosity were calculated for the “pre-pubescent” individuals, they were found to be far under the lowest quartile of all ordinal classifications. Therefore, there is certain evidence that musculoskeletal markers are formed with time and maturation. This relationship with time correlates to habitual muscle movement of the individual, both for purposes of mastication and speech production. Of course, the conclusion that links speech production to the mental spine operates under the assumption that the individuals in question were active participants in a consistent community of language speakers; were the individual perchance altogether incapable of speech production, any developed skeletal feature would be irrelevant for linguistic analysis.

Future research on this matter would obviously benefit from larger sample sizes taken from other language populations; the current claim is limited to observations from only one sufficiently large sample with estimable age. Moreover, samples from mute
individuals would provide a good control group; individuals incapable of speech production would still develop musculoskeletal markers associated with mastication, which could be utilized as a base of comparison for understanding the markers unique to speech production. Most unique would be a possible longitudinal study\textsuperscript{16} to observe changes of the mental spine as an individual alters habitual muscle movement (such as after an accident requiring speech therapy or when completely changing to a new language population).

**Varied distribution trends**

It has been observed that only data collected from the Tagalog speakers exhibited a negative correlation between bifurcation and rugosity, while data from American English and French speakers exhibited a positive correlation. This correlation groups American English and French into one group, in which mental spines become more sharply defined as bifurcation becomes more pronounced. Tagalog is in a group of exactly the opposite; wherein pronounced bifurcation is related to less sharply defined mental spines.

To conclude the significance of these groupings, refer back to the presumed continuum of tongue height discussed previously, wherein it was found that American English was a predominately “closed”, or high-vowel language, French was intermediate, and Tagalog was mostly “open”, or low-vowel. With Tagalog at one extreme of this continuum, the concept of grouping American English and French at the exclusion of Tagalog is not negated. In fact, the grouping is actually further supported by the presumed utilization of the genioglossus in the production of frontal vowel phonemes;

\textsuperscript{16} A longitudinal study is designed to assess the same individual at various points throughout his/her life.
whereas American English employs six frontal vowel phonemes and French boasts seven, Tagalog uses only five. Though this difference is not great, it is interesting to note and may leave evidence on the mandible.

Further research would benefit from the inclusion of observations of the hyoid bone; this could substantiate the significance of the hyoglossus as it traditionally impacts the "open" or low vowel phonemes. A distinction concerning the musculoskeletal markers on the hyoid would support the higher habitual usage of the hyoglossus by Tagalog speakers, who are known to produce more low vowel phonemes than any other type of phonemes. In particular, observed differences of the musculoskeletal features at the origin of the hyoglossus, or along the greater cornua of the hyoid, could further distinguish among languages.

Furthermore, it is a bold assumption that the linguistic characteristics of modern spoken French are the same for the early medieval French, if that was in fact the language spoken by the inhabitants of Saleux in Northern France from the 7th to 11th centuries. Utilizing modern skeletal collections of known individuals to test this hypothesis is recommended.

**Average Prominence of Mental Spine**

Finally, a clear conclusion can be made concerning the average prominence mental spines. Again, this conclusion does pair American English speakers with French speakers at the exclusion of Tagalog speakers, as the mean values for both categories of mental spine scores are higher in the former group than the latter. As previously mentioned, not a single score from the Tagalog populations exceeds the American English or French means for bifurcation, and only one exceeds that for rugosity.
Still, mental spines were present across all population samples, and correlated to expected musculoskeletal markers; the genioglossus both attaches directly to the mental spines and is necessary for the production of frontal vowel phonemes. As all three languages were observed to contain high proportions of frontal vowel phonemes during speech production, the genioglossus would be employed in consistent use.

What cannot be determined in the present research is exactly how habitual muscle use would create a marker on the bone. Future research would benefit from deeper analysis of mental spine variance, considering the standard presence of a quadrilateral pairing of spines as opposed to simple pairs, singular masses, or complete absence (Frazer). Perhaps a technological instrument could simulate muscle use, and the resulting protuberances or protrusions could serve as a standard against which to compare human samples. This research, though preliminary supports the hypothesis the production of vowel phonemes correlates to repetitive use of the genioglossus, which consequently affects mental spine formation. This research could have an impact on future research in bioarchaeology, paleoanthropological questions about the origins of language in hominid evolution, as well as biomedical research in speech pathology and biomechanics.
Works Cited


