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I, H. Zeynep Cilingir, hereby submit this original work as part of the requirements for the degree of Doctor of Musical Arts in Trumpet.

It is entitled:
The Relationship of Oral Anatomy and Trumpet Performance: Prediction of Physical Talent

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The Relationship of Oral Anatomy and Trumpet Performance:
Prediction of Physical Talent

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by

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Abstract

In this study, the relationship of the oral anatomy and performance skills of trumpet players is examined. Seventy-one subjects were recruited from trumpet students at twelve universities in the Midwest. The study took place in three phases: 1) questionnaire and recording sessions; 2) oral examination; and 3) analysis and reporting. In Phase 1, after given a questionnaire on their musical and medical background, participants played a series of exercises demonstrating selected performance skills (tone production, flexibility, articulation, range, intonation, and endurance) on their instruments while being audio and video recorded. Recordings were analyzed using computer software (MatLAB and Audacity) to derive numerical scores. In phase 2, oral anatomy (dental structure, volume of airways, and facial morphology) of the participants was examined using a three-dimensional cone-beam computed tomogram (a three-dimensional x-ray), and three-dimensional photographs at the Indiana University School of Dentistry Orthodontics and Oral Facial Genetics Department. Images obtained from these devices allowed craniofacial measurements such as length, width, inclination, crowding of the teeth; volume of the oral and nasal cavity, sinuses, and pharynxes; thickness and width of the lips, distances across the face; and others. In phase 3, extensive statistical analyses were conducted to examine relationships among questionnaire, skills test, and oral anatomy measures. Techniques such as multiple regression, MANCOVA, canonical correlation, data visualization\(^1\), among others, were used to associate physical characteristics important to successful trumpet performance.

\(^1\) These are data analysis techniques found to be appropriate for the study.
Preface

Just like any other performer, every trumpet player has strengths and weaknesses when playing the instrument. For instance, playing in the high register itself is a struggle for many trumpet players, while it comes natural to others. Likewise, most players are naturally good at certain technical aspects, while they have to put in extra effort to achieve competence in other aspects. Why is this the case? Why do the students taking the same lessons, practicing similar amounts, and playing in the same ensembles end up with totally different sets of strengths and weaknesses? Of course, the simplest answer to this question is ‘talent.’ If we take the discussion to a further level, then the question becomes “what is ‘being talented towards trumpet’?” I believe that the answer to this question might lie in our physical makeup.

Through personal experiences, observing other players, and listening to their experiences along the years, I came to the conclusion that the oral anatomy affects our performance abilities more than we realize. I witnessed my own playing change instantly with minor dental adjustments. Likewise, I saw and heard of many other players improve certain aspects of their playing, which were problematic despite long hours of practice, with similar processes. Also, upon further research, I found numerous articles by trumpet players, and/or their dentists, that report comparable cases.
Despite all the evidence showing that our dental structure has an influence on our performance skills, I failed to locate an empirical source that explored the relationship of the oral anatomy and trumpet technique. This document, which is the partial result of a collaborative research study with orthodontists, is an attempt to fulfill the need for such a source. It is designed to investigate the correlations among oral anatomy measurements, performance skills, and performance background of the participant trumpet players with objective and scientific methods. It should, however, be noted that many of these methods are created for the purpose of this study, and are exploratory in nature.

Lastly, this study is only scratching the surface of a much larger topic. It should, however, be considered that there are infinite possibilities of different dental structures and ways to measure music performance skills. With this study, we examined only 70 participant university students and observed patterns and tendencies, hoping that they may lead us to some answers about the ideal physical makeup for trumpet performance. However, none of the results of this study should be considered conclusive. After all, music performance is a combination of numerous aspects of human mind and body, which are full of endless capabilities. I believe that anyone, regardless of their physical makeup, can succeed becoming an excellent performer with enough determination.
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Chapter 1

Introduction

1.1 Background

1.1.1 Musical Talent: Psychological vs. Physical Aspects

“Talent” is undoubtedly one of the most important components of success in music performance. Particularly in Western cultures, it is widely believed that exceptional musical ability and precocious musical accomplishment can only be explained by innate talents.\(^2\) Being such a significant part of musical ability, talent has been a prominent topic of research, especially in music psychology chambers. Today, the source of musical talent and the factors that make a person talented, however, are still in discussion.

Dianna Richardson suggests that musical talent is a combination of innate and learned skills, and it shows its signs early during childhood.\(^3\) Likewise, according to the *Association for Supervision and Curriculum Development,*

 [...] children who are musically gifted show early developmental signs of musical precocity, which may include noticing off-key music, remembering melodies, singing in tune, fondness for playing instruments in preschool, rhythmic ways of moving and speaking, humming to themselves, tapping rhythmically while working, and sensitivity to environmental sounds (waterfalls, rain on the roof, etc.).\(^4\)

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\(^{4}\) Ibid.
Common musical talent assessment tests also focus on similar mental skills. For instance, the well-known *Measures of Musical Talent* by Carl E. Seashore consisted of the six measures of musical talent: 1) the sense of pitch, 2) the sense of intensity, 3) the sense of time, 4) the sense of consonance and dissonance, 5) tonal memory, and 6) auditory imagery.⁵ Likewise, Edwin Gordon in his recognized test *Musical Aptitude Profile* measures the mental factors “tonal imagery, rhythm imagery, and musical sensitivity.”⁶

Any of the skills mentioned above might be signs of a child’s ability to be involved with music in one way or another. Since these skills have been primarily researched in the areas of psychology, or music psychology, I believe it is appropriate to refer to them as “psychological talent.”

In the case of playing a musical instrument, however, one more factor needs to be taken into account while searching for talent: physical makeup. Certain physical characteristics might very well influence the musical abilities of an instrumental performer, as well as the course of their progress. For instance, physical features such as the length of the fingers or the shape of the lips might determine the “physical talent” for a specific instrument. These and other physical features are often influential in the selection of the right instrument for the potential music student. Judy Judge supports this idea in her article titled “Musical Talent: Born Genius?” She suggests,

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Giftedness certainly requires some physical innate skill, such as “having a good ear,” and the ability to physically play a certain instrument, for example having a good-sized hand span, good physical coordination or even hypersensitivity to music from a young age.⁷

Most likely, a potential trumpet player would not benefit from having a ‘good-sized hand span’ as much as, for instance, a future pianist would. This brings us to the question that Richard Giangiulio asks in his article: “What does it really mean to be ‘talented’ as a brass player” (more particularly as a trumpet player)?⁸

1.1.2 Physical Talent for Trumpet

Understanding the physical aspects of trumpet performance plays an important role in determining elements of physical talent towards trumpet. For all brass players, especially trumpet players, embouchure is the most important part of the “physical complex,”⁹ and it plays a vital role in the player's technical abilities on the instrument, including flexibility, range, and endurance. Embouchure is defined and emphasized in Grove Music Online as “the coupling mechanism, during the playing of a wind instrument, between the air supply of the player and the instrument. Embouchure is a matter of such vital importance that its nature will influence the wind instrument player’s progress and ultimate capability as a musician.”¹⁰

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¹⁰ Ibid.
If the embouchure is such a vital part of trumpet technique, then the physical characteristics that affect its formation in a player can be considered the most important elements that make a brass player “physically talented.” The physical features that influence functioning of the embouchure are primarily the dental (the length, alignment, angulation of the teeth) and jaw (overjet\textsuperscript{11}) structure. The importance of these features on embouchure setting is pointed out in many sources. For instance, Giangiulio, as an answer to his earlier question about talent and brass playing, states “It is my belief that the most uniformly important common denominator in a good player’s physical ability to play a brass instrument is to have good dental support for the embouchure.”\textsuperscript{12} Likewise, Raymond A. Kopczyk suggests “The front teeth directly affect the lip, which is one of the vital components of the embouchure. [...] There are other factors that can also affect the lip tension and vibrating surface—length of teeth, the way the back teeth bite, holes from decay, receding gums, habits, tooth fractures and tooth alignment.”\textsuperscript{13}

Independent from embouchure formation, the topic of ‘desired physical attributes for specific instruments’ is also a very common source of discussion for band directors. Every year, numerous band directors guide beginning band students in the process of choosing their instruments. While some of them give more importance to this topic than others, in the course of selection process, many of them report taking physical features into consideration as a part of suitability for an instrument.

\textsuperscript{12} Giangiulio, 20.
Below are some theories from the guidelines for choosing an instrument by band directors of different schools in regards to physical talent for trumpet:

- Lips should be firm, and not too large; teeth should be even.\(^{14}\)
- Slight overbite is OK, but severe underbite hinders the progress\(^{15}\)
- Preferable physical attributes include evenness of the upper and lower jaw; normal alignment of the front teeth; thin - medium lips, with no scar tissue; upper lip even with or longer than the teeth.\(^{16}\)

The topic of ideal physical attributes for trumpet performance is also discussed in trumpet pedagogy books. David Hickman, in his book *Trumpet Pedagogy*, suggests that the straight teeth providing a smooth surface, and a perfect occlusion\(^{17}\) are two important physical attributes for trumpet performance. Frank Gabriel Campos also covers the same topic in the “Optimal Teeth Formations”\(^{18}\) section of his book *Trumpet Technique*. Mentioned in this section, especially the work of the Shiner brothers from 1960s and 70s brings an interesting theory to the table. Matthew and Edwin Shiner were professors of trombone and trumpet at the Duquesne University. They theorized that a high point on the surface of the teeth, where mouthpiece is placed, improves performance skills. Their theory is explained by Campos:


The Shiners maintained that the optimal upper (maxillary) teeth formation must have a convex contact point or “V” where the mouthpiece is placed. This configuration is the most effective for performance because the “V” bears the weight of mouthpiece pressure and supports the embouchure, yet it allows free vibration of the embouchure [or lips] on either side of the contact point.\footnote{Campos, 94.}

Following this theory, the Shiner brothers encouraged many of their students to have orthodontic treatment providing a “convex contact point” in order to improve their playing. During the same period, other trumpet players, such as Jerry Franks, also followed the Shiners’ idea and directed their students towards the same path. Franks and the orthodontists he worked with, Dr. Van Osdol and Dr. Morehad, developed an overlay that would fit on the front teeth to form the “convex contact point” that the Shiners advocated. Franks, Van Osdol, and Morehead wrote about their experiences with this overlay in their article “Dentistry for Music’s Sake: II. The overlay that corrects notes.”\footnote{Morehead, Twanette, “Dentistry for music's sake. II. The overlay that corrects notes,” (Dr. Thomas D. Van Osdol, Jerry Franks), Tic 38, no. 12 (December 1979): 4-5.}

Below is a summarized list of theories or hypotheses found in books, articles, or academic writings (which will be discussed in detail in Chapter 2) regarding the physical talent for trumpet:

- The teeth need to be aligned for a smooth surface (Hickman, 2006; Bilgen, 2012; Seiwald, 2011; Austin).

- The supporting points on front teeth, between the mouthpiece and lips, are important and they need to be symmetrical, otherwise no alignment is necessary (Giangiulio, 1979).
• The ideal position for the upper front teeth is in an obtuse angle with mildly pointed center (Morehead, 1979; Campos, 2005; Bilgen, 2012).

• Slight overbite\(^{21}\) is desired, extensive overbite is not (Hickman, 2006; Austin; Wise).

• The opening of the median space (space between the upper central incisors) affects playing in different ways. It might provide technical ease on the instrument, especially in the high register (Nemoto; Bilgen, 2012;).

There are also other theories that professional trumpet players and pedagogues have mentioned in personal conversations but are not published. Some of these are,

• Slightly protruded and wider teeth (especially central and lateral incisors) are desired. They allow easier vibration of the lips by enabling quicker contact with the mouthpiece. They also provide protection against deformation of the lips due to mouthpiece pressure; therefore, they bring technical ease on the instrument (Bilgen, 2012).\(^{22}\)

• Although the trumpet mouthpiece does not contact the teeth in the back of the mouth, these teeth are also important since the facial muscles on the sides of the mouth (corners) gain support from them. The first molars are usually the most important teeth because, due to their position, in most cases they are the supporting body behind the corners while playing (Slaughter, 2007).\(^{23}\)

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\(^{21}\) It is observed that due to a confusion in terminology, often times the term “overbite” is used in place of “overjet” by most trumpet players. For detailed definition of these terms see chapter 3, section 3.3.2.

\(^{22}\) Erden Bilgen, personal communication, September 2010.

1.2 Statement of the Problem

The effects of the dental and jaw structure on trumpet performance has been the subject of many written works both by musicians and dentists (or dentist-musicians) over the years. Although the critical importance of these features on trumpet performance is frequently discussed, surprisingly, empirical research studies to understand the details of this relationship have been rare, if any at all. The existing information on this subject results from personal experiences of the players and/or their dentists, and hypotheses by trumpet instructors concerning the physics of trumpet performance.

The lack of thorough understanding of this topic causes various problems. For instance, in grade schools many students who have less than ideal dental characteristics are selected as trumpet players by their band directors early in their musical training. As a result, often times these students face a steep learning curve that might affect their motivation, cause frustration, and eventually result in the student abandoning the instrument.
Similar problems can also occur with collegiate trumpet majors or even professionals. If there are dental characteristics—that are innate or developed over time—working against players’ embouchure setting, they might have technical problems that are prominent, and significantly difficult to overcome despite the long hours of practicing. In these circumstances, the player might try to change equipment or playing habits. If the problem stems from unsuitable dental structure, however, these changes in equipment or habits would be only partial solutions and would require excessive practicing to maintain. In such cases, minor adjustments to the dental structure could be far more effective solutions to the player’s problem.

Ned Gardner, a professional trumpet player, is one of the many trumpet players who experienced the instant influence of minor dental adjustments in his playing. In his article from 1986, he states that he viewed himself as a member of the “put the horn on your mouth and play” school and did not contemplate that his teeth affected his playing. After hearing a lecture titled “Dental Considerations for Brass Players,” however, his approach changed. He explains,

My bottom teeth are a bit crowded so that one middle tooth has been pushed forward. [...] I wondered what would be the effect on my playing if there was a more even surface across my lower teeth so that the stress on my lower lip was not so isolated. [...] To fill out the surfaces I used dental putty (“block out” type of dental wax could also be used). The effect of the broader, more even surface was immediately apparent. My range, endurance, and sound were significantly improved. It was simply easier to play.

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25 Ibid.
1.3 Statement of Purpose

The primary goal of this research study is to examine the relationship of the oral anatomy to selected aspects of trumpet performance technique. With this information, it will be possible to determine the advantageous versus disadvantageous physical characteristics—in other words, the definition of physical talent—for trumpet.

The characteristics of the oral anatomy studied are dental structure (i.e. length, width, angulation, inclination, crowding of the teeth; extent of the overbite and overjet, distances inside the mouth), volume of airways (oral and nasal cavity, sinuses, and pharynxes), and facial morphology (i.e. lip thickness; measurements along the face). The aspects of trumpet technique measured are tone quality, flexibility, articulation, range, intonation, and endurance.

In order to collect the needed data, a group of seventy-one college trumpet students were examined to determine their technical abilities on trumpet and their characteristics of the oral anatomy. The information gathered was compared in order to explore the relationships between the studied physical characteristics and different aspects of trumpet technique.
While determining the oral anatomy measurements to be documented, prominent existing hypotheses about the topic were taken into account. These hypotheses were mainly in two categories: 1) Ideas of band directors and trumpet pedagogues, 2) Individual experiences of trumpet players and dentists/orthodontists who treat them. While some of this information was found in written sources (articles, online sources, books, doctoral document/dissertations), others were reached through unwritten sources (private conversations, notes from master-classes/clinics).

1.4 Significance of the Study

It is my belief that comprehensive knowledge on this topic will be an essential contribution to trumpet pedagogy, which can be used in a number of ways:

- Identification of dental features associated with successful trumpet performance will help define the most important aspects of the physical talent for trumpet performance.
- Band directors and trumpet instructors can use this information in guiding prospective music students for instrument selection.
- Current and future professional trumpet players and instructors will be able to use a new approach in detecting the cause of technical problems in trumpet performance, which will save a considerable amount of time and energy, and enhance motivation in trumpet students and educators.
- An exploratory research study will provide a valuable background for further and more detailed research.
Chapter 2

Theoretical Framework & Literature Review

2.1 Theoretical Framework

Throughout the years, there have been different approaches to trumpet instruction. Perhaps the most prominent of these is the “put the horn to your mouth and play” school that Gardner mentioned in his article26. In this approach practicing is considered the solution to all problems in trumpet performance, unless there are extreme deficiencies in the physical features of the student or the equipment used.

The opposite of this is a more investigational approach, which seeks the root of the student’s technical problems in aspects other than practicing habits, such as the equipment used (the mouthpiece and/or the trumpet), dental structure, posture, hand position, and angle of the instrument. Instructors using this approach experiment with their students and try to solve the technical problems by making adjustments in these aspects. Many of the instructors make use of both approaches as necessary.

26 Gardner, 19.
In the last forty to fifty years, with the growing demands put on professional musicians, instrumental education has become increasingly specialized, and the interest in the investigational approach has grown as well. Instructors have begun to incorporate technical devices in their teaching techniques. For instance, devices such as decibel meter and recording equipment, as well as medical devices used for measuring and maximizing the lung capacity, have long been used in the trumpet studios. Moreover, there has been an increase in the manufacturing of practice aids such as tools for strengthening or rehabilitation of the facial muscles and instrument improvement accessories by individuals and manufacturers.

As a part of this move towards technologically advanced music instruction, research about the physical aspects of trumpet playing has also increased. For instance, medical equipment for imaging has been used in studies to assess the physical activities of the players while playing the trumpet. In these studies, physical activities such as tongue and the jaw movement and facial muscle activity, teeth aperture, and tongue arch during performance were monitored (Amstutz, 197027; Olson, 200628; White and Basmajian, 197329). Likewise, measurements such as the inter-oral air pressure and flow of air during trumpet playing have also been topics of different studies (Olson, 2006; Fréour, Caussé, and Cossette, 201030).

Dental considerations have also become important for further understanding of the physical aspects of trumpet playing. Experimenting musicians and their dentists have written articles about their or their patients’ experiences with dental adjustments, solutions to possible problems stemming from dental structure, and general information drawn from examinations of dental structures of the professional players (Kopczyk, 1982; Giangiulio, 1979; Morehead, 1979; Gardner, 1986; Nemoto, 1995-2003). These studies, however, have only shed partial light on the topic.

2.2 Literature Review

Although the review of the existing literature clearly reveals that there is a need for an empirical study that explores the relationship of dental characteristics on trumpet performance skills, there are a good number of sources written in the joint field of orthodontics/dentistry and trumpet. Several are books resulting from papers presented at conferences, but the majority are either journal articles—many of which are from the International Trumpet Guild (ITG) Journal archive—or academic works such as theses and dissertations. These works are authored by both dentists and trumpet players.
One of the books in this field is *Orthodontics and Wind Instrument Performance* by Glen R. Wiesner\(^3\), Dr. Daniel R. Balbach\(^3\), and Dr. Merrill A. Wilson\(^3\), which was presented at the *Music Educators National Conference* in 1973. Written for “teachers who work with wind players and wind players exhibiting malocclusions\(^3\) that require dental or orthodontic attention,”\(^3\) it focuses on the types of orthodontic treatments and their effects on different aspects of wind instrument playing, such as mouthpiece pressure, breath support, and facial muscles.

A similar source is the master’s thesis in music education by Christine R. Walen written in 1995 at the University of Toledo titled *Orthodontics and Playing the Trumpet*. It is in the format of “an instructional booklet for trumpet players to effectively manage playing the trumpet while wearing braces.”\(^3\) The author discusses the details of orthodontic treatment and offers suggestions on playing the trumpet with braces.

\(^{31}\) Glen R. Wiesner; Brasswind performer and Chair of Music Department at Western Illinois University.
\(^{32}\) Dr. Daniel R. Balbach: Dental instructor and orthodontist in Ann Arbor.
\(^{33}\) Dr. Merrill A. Wilson: A dentist and former brasswind performer and instrumental music instructor.
\(^{34}\) Malocclusion: Malocclusion is a problem in the way the upper and lower teeth fit together in biting or chewing. It can be seen as crooked, crowded, or protruding teeth, and might affect a person’s appearance, speech, and/or ability to eat.
Another group of writings focuses on the influence of wind instrument playing on dental development. These works are written strictly from the dentist’s perspective. The thesis by Dr. Clarence E. Shelton, *The Malocclusion as Related to Wind Instrument Playing,*\(^{37}\) is based on a study of professional brass and woodwind players and another group of non-musicians. The differences between the dental characteristics of the two groups are discussed. Articles in the same category include: “Look for Harmony: Musical Wind Instruments and Dental Development”\(^ {38} \) and “A Study of Dental Factors Concerned with Playing a Musical Wind Instrument,”\(^ {39} \) both by Dr. Howard. E. Kessler, and also “Can Orthodontic Treatment Be Influenced by Wind Instruments”\(^ {40} \) by Dr. S. Seidner.

Three articles that focus on a similar topic were published in the *ITG Journal* during 1970s and 1980s. The first one, and possibly the most relevant to this document, was written by Richard C. Giangiulio in 1979, “The Role of Orthodontics in Correcting Selected Embouchure Problems.” The author, who is a professional trumpet player, discusses the effects of the front teeth and the alignment of the pressure points between the teeth and the mouthpiece on trumpet playing. He suggests that in order to have a good support for the embouchure, the four pressure points between the mouthpiece and teeth must be aligned. Furthermore, he explains auditory and visual symptoms of unaligned pressure points and concludes with possible solutions for treating this problem.


The second article was written by dentist Raymond A. Kopczyk in 1982, and is titled “Dental Considerations for the Brass Player.” Dr. Kopczyk discusses the effects of different types of tooth decay, gum problems, and mouth diseases on trumpet playing, as well as the treatments needed.

The last article from the ITG Journal was written in 1986 by Ned Gardner, professional trumpet player, in consultation with Dan Averett, dentist. In his article “Dental Bonding: An Aid for the Embouchure,” Gardner writes about his own experience of dental bonding. In this research study, he explains the process of dental bonding, his need for it, and the improvement it brought to his playing.

One of the most comprehensive of all sources in this interdisciplinary field is a series of articles written by the Japanese dentist Dr. Toshio Nemoto that appeared in Brass Bulletin between 1995 and 2003 under the title of “Dental Clinic for Wind Players.” In these brief articles Dr. Nemoto discusses a wide variety of dental problems that he encountered in numerous brass players he treated during his career. Some of the topics that Dr. Nemoto touches upon are the overjet and its effects, the use of facial muscles, lip vibration, neural dysfunction, effects of disorders of the side teeth, correction of irregularities of the front teeth, median space, tonguing mechanism, difficulties following improper dental treatment, and brass playing with orthodontics. Dr. Nemoto’s articles offer an extensive number of theories, some of which were put to the test with this research study.

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41 Dental bonding: The process in which tooth colored materials (composite resin) are adhered (bonded) to the tooth. This is a procedure that can be used to repair or improve the appearance of a tooth that has been badly stained, broken or chipped (Glossary of Terms, “Dental Bonding,” Light Street Dental, accessed on November 14, 2012, http://lightstreetdental.com/patient_education/glossary).

The relationship of dental structure and wind instruments has also been the focus of numerous medical works. Similar to Dr. Nemoto’s “Dental Clinic for Wind Players”43 is the series of articles written by Maurice M. Porter in the British Dental Journal between 1953 and 1968 titled “Dental Problems in Wind Instrument Playing.” Unlike Dr. Nemoto’s writings, Dr. Porter’s articles are written primarily for dentists who might need to treat wind players. Porter gives information on the nature of wind instrument playing and the individual cases of wind players with various dental problems and the treatments applied.

In his book Trumpet Technique, Frank Gabriel Campos dedicates a large section to the oral anatomy in relation to trumpet technique. He reviews various topics such as oral cavity, tongue, and jaw in relation to trumpet performance skills. The most relevant section to this document is the section titled “Optimal Teeth Formations”44. His book provides a brief but well-organized introduction to this topic, and guidance for further research in the field.

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44 Campos, 98-99.
The Shiner brothers in the 1960’s advocated that a “convex contact point” between the teeth and the mouthpiece improves performance skills in brass players. Although I was not able to find a source written by the Shiners or on their experience, I was able to locate an article about further work done based on their ideas. Following the Shiners’ idea, trumpet player Jerry Frank and two orthodontists, Dr. Van Osdol and Dr. Morehad, tried to help trumpet students by making an overlay that would fit on the front teeth in order to form a “convex contact point.” Their article “Dentistry for Music’s Sake: II. The overlay that corrects notes” explains the experiences of Franks, Van Osdol, and Morehead with this overlay experimentation.
Chapter 3
Methodology

In this chapter, the methods and the equipment used for the collection and assessment of the data, as well as limitations faced during the process are discussed in detail. Since this study is one of the first empirical attempts to evaluate the physical talent for trumpet performance, many of the methods used were developed for the purpose of the study and were experimental in nature.

3.1 Limitations

Methods used for the evaluation of the technical skills (skills test) and recording of the performance background information (questionnaire) were developed for the purpose of this study. While these methods were prepared under the guidance of multiple trumpet professors of major music schools, they were still experimental in nature, and they posed various limitations and challenges during the application as explained below:

1) Quantification of the participants’ technical skills:
   a) The identification of aesthetical values audible to the trained ears (such as beauty of tone, ease of connection of the notes) in scientific terms. Although there is an advanced technology of sound analysis available, it primarily serves the purposes of sound engineering areas. It is a true challenge to build a bridge between the scientific and musical worlds and to explain one world with the terms of the other.
b) Every participant responded differently to the testing environment; while some of them became nervous about being tested, others did not. The nervousness might have affected the performance of the participants.

c) The skills test could capture participants’ abilities only at the time of the test. A number of uncontrollable factors such as fatigue or lack of practice from the day(s) preceding, the nature of the prior warm up, and the travel made to the test location might have had some effect on the participants’ performance.\textsuperscript{45}

2) The questionnaire response: Some of the questions inquired about the participants’ practice habits, which students in general tend to exaggerate when asked. This might have affected the results of the data analysis.\textsuperscript{46}

3) Time restraint: A large amount of data was collected for the purpose of this study; however, due to time restraint only a portion of the information was evaluated and analyzed in preparation of this document. Following this document, more data will be analyzed, and findings will be reported in different sources as they become available.

\textsuperscript{45} The results of the initial data analysis showed that the correlations among different skills were consistent, and no significant evidence of the limitations 1b and 1c affecting the performance was found at the time this document was being written.

\textsuperscript{46} After the initial data analysis was completed, it became evident that the self-rating and other responses of the participants were consistent with their skills scores at the time of the testing. This shows that most likely the participants were being truthful about answering the questionnaire and the skills test was accurately capturing the skills levels of the participants.
3.2 Participants

Following Institutional Review Board approval by the University of Cincinnati and Indiana University, the investigator contacted the trumpet professors at 11 music schools (Table 3.1) within a two-hour driving distance from Indianapolis, the location of testing. Following their permission, the study was explained during the studio classes at the attending schools, where the students could signup for the study at their will. A total of 107 subjects (16 female, 55 male) were initially recruited. After dropouts and cancellations, complete data sets were collected from 70 participants.

<table>
<thead>
<tr>
<th>Music School</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indiana University Jacobs School of Music</td>
<td>11</td>
</tr>
<tr>
<td>Indiana State University</td>
<td>2</td>
</tr>
<tr>
<td>Ball State University</td>
<td>9</td>
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<tr>
<td>University of Louisville</td>
<td>6</td>
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<td>Northern Kentucky University</td>
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<td>University of Indianapolis</td>
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<td>University of Cincinnati</td>
<td>16</td>
</tr>
<tr>
<td>Wright State University</td>
<td>7</td>
</tr>
<tr>
<td>Butler University</td>
<td>9</td>
</tr>
<tr>
<td>Miami University</td>
<td>2</td>
</tr>
<tr>
<td>Bowling Green State University</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3.1 List of music schools and number of participants

3.3 Research Methods and Equipment

The study took place in three phases: 1) Questionnaire and Recording Session, 2) Imaging Session, and 3) Data Analysis.
Phase 1 took place at the Indiana University, Music Technology Department in Indianapolis, IN. The participants filled out the questionnaire alone, then performed the skills test at a designated soundproof practice room where the recording equipment was set up. They performed the skills test under the guidance of the investigator while being audio and video recorded. After completion of Phase 1, they immediately traveled three blocks to the Indiana University School of Dentistry Orthodontics and Oral-Facial Genetics Department for attending Phase 2, imaging session.

Phase 2 included two parts: 1) three-dimensional (3D) Cone-beam computed tomogram (CBCT) and 2) three-dimensional (3D) Photography. 3D CBCT, which is a 3D x-ray of the head, was for the imaging of the dental structure and the airways; it was taken while participants were holding a natural position. The 3D photography was for the 3D imaging of the facial morphology. A total of three photographs of the participants’ faces were taken: 1) In natural position; 2) while playing a low C (C4); 3) while playing a high G (G5). Due to time restraint only the dental measurements were obtained using the 3D CBCTs for the purpose of this document. The measurements of the airway volume and facial morphology will be used for further data analysis once this document is completed, and the findings will be shared in other sources. Samples of the 3D photographs and 3D CBCTs can be found in Appendix A.
The data analysis, phase 3, was exploratory in nature. The departure point for the selection of variables for primary analysis was the existing theories and/or hypotheses about the topic. I found some of these theories and hypotheses in the existing literature and the presentations I attended; others evolved during private conversations with other trumpet players or dentists who had experiences in this field. A list of these theories can be found at the end of Chapter 1 of this document. The data analysis methods and significant results will be discussed separately in the next chapter (Chapter 4: Data Analysis & Significant Findings).

3.3.1 Questionnaire and Recording Session

*Questionnaire:*

The questionnaire was designed to gather data about variables that might affect the outcome of the relationship between oral anatomy and performance. For instance, if a trumpet player has physical features that negatively affect their playing, they might be able to overcome the difficulties either by extreme practice, or by creating habits that would compensate for the physical difficulty such as thrusting the jaw to compensate for an exaggerated *overjet*. Therefore, it was important to collect information about these factors and to take them into account during data analysis.

The following topics were considered in the questionnaire:

1) Performance background (i.e. years of experience, practice habits, equipment);
2) Performance habits which might be influenced by the oral anatomy and airways (i.e. placement of the mouthpiece, movement of the muscles during performance, movement of the jaw, existence of any tension in the body);

3) Natural abilities (i.e. strength and weaknesses as a beginner player);

4) Medical background (i.e. inquiry of allergies, tonsillectomy, adenoidectomy surgeries, and the like).

A copy of the questionnaire can be found in Appendix B.

*Recording Session*

The subjects performed the exercises in the skills test while being audio and video recorded. The purpose of the audio recording was to analyze the performances of the participants in detail with sound analysis and verification of the scores given during the test at a later time. The purpose of the video recordings was to analyze the facial movement during different performance situations such as rapid leaps, repetitive tonguing, extremes of the register, and fatiguing situations. During the preparation of this document only a part of the audio recordings were used, video recordings and part of the audio recordings were kept for future research after the completion of the document.

*Recording Room and Equipment*

For the skills test, a soundproof practice room at the Indiana University Music Technology Department was used. The conditions and setup of the room (Figure 3.1) were the same throughout the study.
As seen in the figure, the camcorder was set up to record the view of the face while playing; the microphone was located close to the bell of the trumpet in order to get the clearest sound from the instrument. Other equipment used were a computer with two earphones (with a metronome application for tempo), a decibel meter and a tuner.

Below is a list of equipment and the settings used during the recording session. Detailed information about the manufacturers of the equipment can be found in Appendix C.

- **Microphone & Accessories:**
  - Sennheiser MD421 II Unidirectional microphone,
  - XLR cable
  - Microphone clip
  - Tripod boom
Two sticks were taped on to the sides of the microphone in order to mark the 6" distance, and the subjects were instructed to keep the bell of their trumpet at this distance.

- **Audio Recorder:**
  - Zoom H4n Handy Recorder
  - Storage: 8GB memory card
  - Setting:
    - Recording level: 50% (to ensure no distortion occurs during loud playing)
    - Recording type: stereo
    - File type: wave file

- **Video Recorder:**
  - Sony DCR-DVD650 Camcorder
  - Storage: 8GB memory card
  - Setting:
    - Long-play mode
    - Placed to monitor the embouchure and sides of the mouth as closely as possible

- **Other:**
  - Laptop (metronome application)
    - Used with 2 earphones (one for the subject, one for the investigator) and a splitter.
\begin{itemize}
  \item Decibel meter: Radioshack Sound Level Meter
    \begin{itemize}
      \item Placed 19” away from the bell
      \item Set to minimum 110db
    \end{itemize}
  \item Tuner: Korg
\end{itemize}

**Skills Test:**

The skills test was designed to illustrate the participants’ abilities in different aspects of the trumpet technique. These aspects were 1) Tone quality, 2) Flexibility, 3) Articulation, 4) Range, 5) Intonation, and 6) Endurance. Simple exercises that are widely known to trumpet students were selected for the illustration of these skills. Attention was given to keep the exercises as simple as possible in order to avoid difficulties from sight-reading and to make sure that the weakness in one skill does not affect another (i.e. difficulty in the high register affecting the performance of a flexibility exercise that goes too high).

Due to time restraint, only a portion of the skills will be included in the data analysis for the purpose of this document. Below, the exercises in the skills test used in data analyses will be illustrated and discussed in terms of goal, instructions given to the subjects, procedure, measurement criteria, and limitations of measurement, if any. The complete skills test can be found in the Appendix D.
Flexibility:

a)  

b)  

c)  

- Goal: Measuring the ability to move quickly between the different registers.

- Instructions:
  
  o  Start with a comfortable tempo
  
  o  Repeat each exercise and increase the tempo until you reach the fastest you can play while all notes are being heard.

- Procedure: Each participant started playing the exercise at the tempo of 70 bpm, and depending on the performance and feedback of the participant, the tempo was increased or decreased by 5 bpm at a time.

- Measurement criteria:
  
  o  The fastest tempo in bpm participant could play the exercises without skipping any of the notes.
Articulation:

a) Single Tongue
b) Double Tongue
c) Triple Tongue
d) Flutter Tongue

- Goal: Measuring the ability of fast single, double, triple tonguing (a, b, c), as well as flutter tonguing (d) throughout the register of the trumpet.

- Instructions:
  
  o Start with a comfortable tempo (a, b, c)
  o Repeat each exercise and increase the tempo until you reach the fastest you can play while all notes are being heard (a, b, c)
  o Flutter tongue each note (d)
  o Stop or breath as you need to (d)
  o Continue as high/low as you can (d)
  o Stop where the flutter tonguing is not possible anymore (d)

- Procedure:
  
  o Exercises a, b, c: Each participant started playing the exercise at the tempo of 90 bpm, and depending on the performance and feedback of the participant, the tempo was increased or decreased by 5 bpm at a time until fastest tempo participant could play was reached.
o Exercise d: Each participant started the flutter tonguing exercise at a comfortable note (G4 in most cases) and continued as low and as high as they could until the flutter tonguing was impossible.

• Measurement criteria:
  o Exercises a, b, c: The fastest tempo the participants could play the exercises without difficulty.
  o Exercise d: The highest or lowest note the participants could flutter tongue.
    - The notes were assigned numerical scores starting from the middle G (G4) being 1 and increasing by 1 for every semi-tone below and above.
      The scoring chart can be found in the appendices section.

• Limitations:
  o The low range flutter tongue assessment included the pedal tones, however, the experience of playing in the pedal register differed among most participants.
    Therefore, the low range scoring was left out during the initial data analysis.
  o In extremely fast tempi (i.e. around 200bpm), it became difficult to hear if the attacks are still accurately in time.
Range:

Goal: Measuring the range of notes playable on the trumpet.

Instructions:
- Play at a comfortable tempo
- Breath as you need to
- Stop where the notes are out of your range

Procedure:
- Participants began playing at a comfortable note in the exercise, and continued until they reached the lowest (including pedal tones) and highest notes they could play.
- There were no tempo or dynamic indications.
- Participants could slur or tongue the notes.

Measurement criteria:
- The highest or lowest notes each participant could produce on their instruments.
- The notes were assigned numerical scores starting from the middle G (G4) being 1 and increasing by 1 for every semi tone below and above. The scoring chart can be found in the appendices section.
The score of the highest and the lowest notes participants could reach were taken as the high and low range scores.

**Limitations:**
- The low range assessment included the pedal tones, however, the experience of playing in the pedal register differed among most participants. Therefore, the low range scoring was left out during the initial data analysis.

### Endurance:

- **Goal:** Measuring the endurance in continuous and loud playing situations.

- **Instructions:**
  - Repeat the pattern as many times as you can
  - Stop when you can not continue anymore
  - Stay above 110 db at all times
  - Follow the tempo strictly
  - Breathe as you need to

- **Procedure:**
  - The decibel meter was placed on the stand, 19 inches away from the bell of the trumpet.
  - The participants performed the pattern at the tempo of 100 bpm as many times as possible until they were not able to produce one or more of the notes.
During their performance the investigator monitored the decibel meter in order to make sure that the sound stays above 110 db at all times.

Measurement criteria:

- The duration participants were able to continuously play the pattern (the number of seconds).

### 3.3.2 Imaging Session

The imaging procedures took place at the Indiana University School of Dentistry, and were conducted by the orthodontics faculty. Two kinds of images were taken: 1) three-dimensional Cone-beam computed tomograms (3D CBCT-iCAT); and 2) three-dimensional (3D) photographs (3dMD). 3D CBCTs were used in order to gather measurements of dental structure and volume of the airways while the 3D photographs were used for measurements of the facial morphology in natural and playing positions. The images were stored in the Indiana University system for long-term quantification.

At the time this document was being written, only the dental measurements were quantified; the other measurements were in progress. Due to time restraint, only a portion of the dental measurements will be included in this document.

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**3D Cone-beam computed tomogram**

The 3D CBCT is a 3D x-ray of the head. It is taken with an i-CAT radiographic machine (Figure 3.2), which is a commonly used device in dental offices to gather the 3D imaging of the bone structure and the outlines soft tissues. Below is the illustration of the i-CAT machine used in this study.
The i-CAT machine was set to 8.9 seconds scanning time with a resolution of 0.3 voxels\(^47\). The dimensions of the scans were 23cm to 17cm, which approximately covers the area of the head from the cranial base to the cervical vertebra number four.

After 3D CBCTs were taken, they were measured using the 3D Dolphin imaging software by one of the investigators. These images were used to measure selected characteristics of the dental structure such as length, width, angulation, and inclination of the teeth, distances across the oral cavity, overbite, and overjet.

The dental measurements gathered from the 3D CBCTs will be explained and illustrated below.

*Dental Measurements and Explanations:*

The 3D CBCT machines have adequate resolution (0.3 voxels) to capture numerous details about the oral anatomy; it is possible to measure numerous aspects of the dental features with these scans. For practical purposes, it was crucial to limit the number of measurements to be investigated and included in the data analyses. The investigators chose to examine the measurements of the dental features 1) indicated in the existing literature and anecdotal evidence, and 2) that they perceived to be possibly influential on trumpet performance.

Most of these measurements are commonly used for dental studies, and the measuring techniques are part of common practice in dentistry. Only the *length and width of the teeth* is a less frequently used measurement.

The unit for distance measurements (length, width, overjet, overbite, mid-diastema, and Little's index) is millimeter and the unit for angulation (rotation) and inclination measurements is degree.

Each dental measurement obtained will be discussed below in terms of definition, obtaining methods, related hypotheses, and limitations if any. In this section a number of dental terms will be used; a glossary of dental terms can be found in the Appendix E of this document.
1) **Length and Width of the Maxillary Six Anterior Teeth and the First Molar:**

The length of each tooth was measured from the midpoint on the incisal line to the midpoint on the cervical line, while the width of each tooth was measured from the mesial height of the contour to the distal height of the contour—the widest part of the tooth—as illustrated below in Figure 3.3 (left to right: canine, lateral incisor, central incisor).

![Figure 3.3 Length and width of maxillary anterior teeth](image)

These measurements were obtained to evaluate the hypothesis speculating that the wider teeth, (especially the lateral incisors) help to achieve a better-focused tone by providing greater support for the muscles surrounding the embouchure; and that they can protect the lips against the mouthpiece pressure, and provide ease in technique by preventing the deformation of the lips (Bilgen, 2012).
2) **Overjet:**

*Overjet* is the **horizontal** distance between the upper central incisors and lower central incisors. This measurement is particularly important since it gives an idea about how well the upper and lower jaws can be aligned while playing the trumpet. This specific physical feature is repeatedly stated to be important for trumpet performance by many pedagogues and band directors.

In order to measure the overjet, the horizontal distances (Figure 3.4) from a reference line (facial plane) to the tips of the lower and upper central incisors were measured; the difference between the two values was calculated as the overjet measurement.
While overjet measurement gives a good idea about the alignment of upper and lowers jaws, it is important to remember that many players thrust their jaws during performance, especially if there is an exaggerated overjet. Although it is possible to measure the overjet in natural position with the imaging equipment used in this study, it was not possible to measure the amount of overjet during playing taking the jaw thrusting into account.

3) **Overbite:**

*Overbite* is the **vertical** distance between the incisal tips of the upper central incisors and lower central incisors. In order to measure this distance a similar process to the overjet measurement was used. A vertical reference line was established (also facial plane); the tips of the lower and upper central incisors were marked on the facial plane; and the distance between the two points were documented as the overbite measurement.

The overbite measurement was not mentioned in any of the existing hypotheses, however, the research team found it important to explore any possible relationship there may be between the overbite and performance because of the potential lack of embouchure support in the case of a negative overbite.
It is also important to repeat the common misuse of the terms overjet and overbite in the literature. During the literature review it was found that the term overbite was mistakenly used for the term overjet in an overwhelming number of sources. After consulting with the orthodontists, these terms are properly used in this document. The figure below would help clarify the difference between the two measurements:

![Diagram of Overbite and Overjet](image)

Figure 3.5 Overbite and overjet

4) **Interincisal Inclination (1/1 (°))**: 

*Interincisal inclination* is the measurement of how much the central incisors are proclined horizontally relative to each other. According to some trumpet pedagogues, the extended protrusion can make the high notes easier and improve overall playing (Bilgen, 2012).

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In order to measure the interincisal inclination (Figure 3.6) the investigator extended a line from the root apexes (farthest point on the root) to the tips of both maxillary and mandibular central incisors. The angle of the two lines is documented as the interincisal inclination measurement. The most protrusive central incisors in the maxilla and in the mandible were used for the measurement.
5) **Rotation Angle of the Maxillary Central Incisors (1-1 rotation):**

*1-1 rotation angle* calculates the horizontal angulation (rotation) of the two upper central incisors. Frank Gabriel Campos explains in his book⁴⁹ that the rotation of the upper central incisors was considered to be crucial by the Shiner brothers at Duquesne University around 1960s. They experimented with this idea and tried to form a “high point” in the center by making changes in the rotation of the upper central incisors of their students. Details of this theory can be found in the Background and Literature Review sections of Chapter 2 of this document.

While measuring the 1-1 rotation angle, the occlusal view (Figure 3.7) of the upper jaw was used. Two lines from the distal height to the mesial height of the contours of the both left and right upper central incisors were extended. The angle between the two lines was documented as the 1-1 rotation angle measurement.

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⁴⁹ Campos, 94.
6) **Inter-canine and Inter-molar Width (Mx 3-3 & Md 3-3, Mx 6-6 & Md 6-6)**

*Inter-canine width* (Figures 3.8 and 3.9) is the distance inside the mouth from the cusp tip of one canine to the cusp tip of the contralateral canine within the same arch; and the *inter-molar width* is the distance from the mesiobuccal cusps of the one first molar to the contralateral molar within the same arch. Both distances are measured separately for upper (maxillary) and lower (mandibular) jaws. These measurements help to evaluate the horizontal space inside the oral cavity, which might be important in aspects of the trumpet technique involving tongue movement, as well as tone production.

7) **Maxillary 1st Molar Proclination (Right and Left):**

Some trumpet players suggest that the proclination of the first molars has a positive influence on performance (Figure 3.10). Since these teeth do not have direct contact with the vibrating part of the lips, their influence can be associated with the use of the muscles around the embouchure. They can act as the pillars of the embouchure muscles.
During private conversations with several professional trumpet players, it was mentioned that the first molar is especially important since it provides the main support for the corners—the muscles on the sides of the lips. These players experimented by building additional substance on and around the labial surfaces of their first molars with the use of ‘inserts’ made with dental materials (specifically acrylic). They found that these inserts helped them keep their corners stable, which is one the most important aspect of trumpet technique (Slaughter, 2007; Bilgen, 2012).

Due to the hypothesis mentioned above, it became important to include the measurement of the proclination of the first molars.

For measuring the proclination of the first molars, two lines were extended from the mesio-buccal cusp tips to the palatal root apices of each first molar. Then the intersection angle of these lines to a horizontal reference line tangent to the nasal floor was measured.
8) Little’s Index of Irregularity (Maxillary and Mandibular):

*Little’s Index of Irregularity* (LI) is a widely used measurement by the orthodontists to assess the alignment of the teeth. It is the measurement of the horizontal distance between the normal contact areas of the teeth (Figure 3.11).

For the purpose of this study, this measurement is taken of the six upper and lower front teeth (1-central incisors; 2-lateral incisors; 3-canines) in millimeters. These teeth are numbered from right side of the jaw to the left as follows: 3-2-1-1-2-3. Then, the distance between the adjacent teeth are measured individually and documented. As a result, the following LI measurements were taken: 3-2, 2-1, 1-1, 1-2, 2-3 (separately for maxillary and mandibular). The smaller the total LI measurements are, the smoother a subject’s front teeth are. The illustration below shows the numbering of the teeth for LI measurements in blue. Also, in red, the distances measured and the labeling of the LI measurements can be seen.

*Figure 3.11 Numbering of teeth and labeling of Little’s Index*
LI is one of the important measurements for this study. Many of the existing hypotheses suggest that the general alignment of the teeth play an important role in trumpet performance. In this study, the totals of individual LI measurements for maxilla and mandible are used in order to evaluate the general alignment of the teeth for each jaw and compare them to performance skills.

A current limitation of the LI measurements is that the individual measurements quantified so far provide only the distances from one tooth to the next without any indication about the positioning of these teeth. In other words, the degree of unalignment is measured; however, the direction of the unaligned teeth is not documented. Due to this limitation, the findings including the individual LI measurements are not taken into account. Once this document is completed, the investigators will provide further details about the LI measurements and this information will be used for further analyses.
Chapter 4

Data Analysis & Significant Results

This chapter will present the sample, data, data analyses methods, statistical limitations, and significant results. All the figures mentioned in this chapter will be included in Appendix F.

It should be noted that, 1) the findings mentioned in this chapter are the results of exploratory analyses; further analyses will be conducted in order to investigate the relationships in detail, 2) the measurements of tone production and intonation skills are still in progress and they are not included in the initial analyses.

4.1 Sample

A target sample size of 93 subjects was estimated using power analysis for a linear regression model with 3 predictors, an effect size of 0.15, and power of 0.8, with an additional 20% increase in sample size to account for dropout, and potential data anomalies. Sample size for a reasonable regression model was estimated to allow for sufficient power with post-document analyses.

A total of 107 subjects were initially recruited. Data were collected from 71 participants; however, one participant provided incomplete data. As a result, we collected complete data sets from a total of 70 participants.
4.1.1 Descriptive Characteristics of the Participants

The participants for this study were self-selected college students who were at least eighteen years of age and taking trumpet lessons at the time of the study. Although the majority of students were performance and music education majors (49.29% performance majors, 29.57% music education majors), any field of study was acceptable as long as they received trumpet lessons at the college level. The age of participants ranged from eighteen to thirty-seven. The majority was, however, between the ages of nineteen and twenty-two (64.8%) (Figure 4.1). An overwhelming majority (77.5%) of the participants were male (Figure 4.2). Years of experience in trumpet playing varied widely among the participants from seven to twenty-eight years. The majority (35.2%), however, had between ten to eleven years of experience (Figure 4.3).

4.2 Variables

As a part of this study, a large amount of data was collected; however, due to time constraints only a selected portion of the data was ready to be analyzed at the time this document was written. The investigators selected the following variables among the available data for exploratory analyses:

1) Dental Measurements
   - Length and width of 6 anterior teeth & 1st molar (incisors and canines)
   - Overbite
   - Overjet
   - Interincisal rotation
o Interincisal angulation

o Angulation of canine and 1st molar

o Little’s Index of Irregularity

2) Skills Test Scores

o Flexibility (Exercises A, B, C)

o Articulation (Single, Double, Triple, Flutter Tongue High Range)

o Range (High Range)

o Endurance

3) Questionnaire Items

o How long have you been playing the trumpet?

o Do you play piccolo trumpet? (Y/N)

o Do you experience excess tension on your body while playing the trumpet (Y/N)

o On a scale from 1 to 10 how easy were the skills listed as a beginner player? (Skills: focusing sound, flexibility, fast single tonguing, fast double or triple tonguing, flutter tonguing, high notes, low notes, endurance, soft playing loud playing)

o Do you have a history of wisdom teeth removal?

o Do you have a history of orthodontic treatment? (Y/N)
4.3 Methods and Tests

Initial analyses included two different bi-variate tests. Each test was selected based on data characteristics. The tests are,

1) **Spearman’s Rank Correlation Coefficient**: “[A] statistical test for correlation between two rank-ordered scales. It yields a statement of the degree of interdependence of the [ranked] scores of the two scales.”

2) **Mann-Whitney U Test**: “A non-parametric test (distribution-free) used to compare two independent groups of sampled data. [...] This, like many non-parametric tests, uses the ranks of the data rather than their raw values to calculate the statistic.”

The table below explains the reasons for using each test and the variables analyzed.

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<thead>
<tr>
<th>Test</th>
<th>Reasons for use</th>
<th>Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman</td>
<td>The variables being analyzed were highly skewed.</td>
<td>• <strong>Skills &amp; Questionnaire</strong> <em>(Amount of Practice / Years of Experience / Beginner Self-Ratings)</em></td>
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<td></td>
<td>• <strong>Dental Measurements &amp; Questionnaire</strong> <em>(Self-ratings of beginner skills)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <strong>Dental Measurements &amp; Skills</strong></td>
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<tr>
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<td></td>
<td>• <strong>Skills &amp; Skills</strong></td>
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<tr>
<td>Mann-Whitney</td>
<td>Skewedness and heterogeneity of variance.</td>
<td>• <strong>Skills &amp; Questionnaire</strong> <em>(Piccolo Trumpet Playing / Excess tension / Muscle Stability / Jaw Protrusion / History of Wisdom Teeth Removal / History of Orthodontic Treatment)</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• <strong>Dental Measurements &amp; Questionnaire</strong> <em>(Piccolo Trumpet Playing / Excess tension / Muscle Stability / Jaw Protrusion)</em></td>
</tr>
</tbody>
</table>

Table 4.1 Tests and variables

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4.4 Statistical Limitations

There were a number of limitations with the data analyses due to the nature of the data. For instance, distributional challenges arose from heavily skewed or zero-inflated measures. Various solutions were considered such as transformation, non-parametric techniques, or removal of problematic outliers. Ultimately, for interpretability and data completeness, the non-parametric approach was chosen.

In data analysis, normally distributed data values create a bell-shaped curve with a peak in the middle when reflected on to a chart (Figure 4.4 Example of a bell-shaped curve). However, if the data is “skewed” it creates an asymmetrical curve with a peak away from the middle (Figure 4.5 Example of an asymmetrical curve). Similarly, zero-inflated data includes a large number of zero values (for instance, a number of participants were not able to flutter tongue and they received scores of zeros), which also creates an asymmetrical curve. The asymmetry causes problems with the analyses and affects the findings; therefore, a statistical solution needs to be considered. For the analyses included in this document a non-parametric approach was chosen, which means instead of using the actual data values, the data was ranked and the rankings were used for the analyses.

Due to the exploratory nature of the data analyses, a large number of tests were conducted. This might have increased the susceptibility to experimentwise error; which means that the probability of finding significant results by chance is unduly inflated. This is, unfortunately, an undesirable artifact of extensive exploratory analyses.
4.5 Significant Results

In statistical testing, there are two factors used for interpreting the outcome: “p-value” and “r-value.”

The p-value is used to decide if the correlation between two variables is significant or not. This number, in simplest terms, gives the probability of a correlation to be coincidental. Therefore, in general, the smaller p-value is, the more significant findings are considered. There are different approaches used in interpretation of p-values. For the purpose of this document, p-values below .05 (p<.05) were considered to be significant, and p-values below .01 (p<.01) were considered to be highly significant. This is one of the commonly used practices in statistical interpretation.

The r-value, on the other hand, is used to determine the strength of association between two variables. It indicates how well one variable can predict the other one. It ranges from -1.0 to 1.0; while negative values indicate an inverse association (if one variable increases, the other one decreases), positive values indicate a direct association (if one variable increases, the other increases too). There are different practices used for the interpretation of the strength of r-values. For the purpose of this document following strength levels are used:\(^5^2\)

4.5.1 Skills Test & Questionnaire Correlations

*Skills – Years of Experience Correlations (Spearman)*

The Years of Experience responses were significantly correlated to Flexibility A ($r_s=.489, p<.01$), B ($r_s=.399, p<.01$), and C ($r_s=.443, p<.01$); and Triple Tongue ($r_s=.310, p<.01$) scores. It was also significantly correlated to the Double Tongue ($r_s=.293, p<.05$) and Flutter Tongue ($r_s=.276, p<.05$) scores. However, no significant correlation was found between Years of Experience responses and Single Tongue, High Range, and Endurance scores.

*Skills – Amount of Daily Practice Correlations (Spearman)*

The Amount of Daily Practice responses were significantly correlated to the Flexibility A ($r_s=.363, p<.01$), B ($r_s=.287, p<.05$), and C ($r_s=.309, p<.01$); Endurance ($r_s=.314, p<.01$); and Triple Tongue ($r_s=.331, p<.01$) scores. However, they had no significant correlation to Single, Double, Flutter Tongue; and High Range scores.

<table>
<thead>
<tr>
<th>r-value</th>
<th>Strength of relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.0 to -0.5</td>
<td>Strong</td>
</tr>
<tr>
<td>-0.5 to -0.3</td>
<td>Moderate</td>
</tr>
<tr>
<td>-0.3 to -0.1</td>
<td>Weak</td>
</tr>
<tr>
<td>-0.1 to 0.1</td>
<td>None or very weak</td>
</tr>
</tbody>
</table>

Table 4.2 R-value interpretation table
**Skills – Performance Habits (Piccolo Trumpet Playing / Excess tension / Muscle Stability / Jaw Protrusion) Correlations (Mann-Whitney)**

In the questionnaire, the participants were asked four yes/no questions about their performance habits. Since these habits could influence performance skills, analyses were planned in order to investigate the associations between performance skills scores and the responses to these questions.

Mann-Whitney U test was found to be appropriate for the analyses. For this statistical test to work however, it is necessary to have similar numbers of yes and no responses for each question.

The question regarding piccolo trumpet playing (question 7) received a similar number of yes and no responses (Y: 38, N: 31); likewise, the number of participants who reported to experience tension while playing (question 8) was close to the number of students who did not (Y: 40, N: 31). Since responses to these questions were virtually balanced, they were suitable for statistical testing. However, the responses of the questions regarding having difficulty keeping corners/chin stable while playing (questions 9: Y: 14, N: 56) and moving the jaw forward while placing the mouthpiece on the lips (question 11: Y: 13, N: 58) received a disproportionate number of yes/no responses; therefore, the findings utilizing these items will not be shared in this document.
The results of the tests have shown that participants who played piccolo trumpet were consistently better in most skills. We found significant differences between the participants who played piccolo trumpet and the ones who did not on their Flexibility A ($U=113.500, p<.01$), B ($U=177.000, p<.01$), and C ($U=144.000, p<.01$); Double ($U=198.000, p<.01$), Triple ($U=160.000, p<.01$), and Flutter Tongue ($U=306.000, p<.01$); High Range ($U=360.500, p<.01$); and Endurance ($U=382.500, p<.01$) scores.

The analyses showed no significant difference between any participant performance skills regardless of their response to reporting excess tension in the body while playing.

Skills – Dental History (History of Orthodontic Treatment and Wisdom Teeth Removal) Correlations (Mann-Whitney)

In the questionnaire, the participants were also asked if they had histories of orthodontic treatment and wisdom teeth removal. The responses to both questions were sufficiently balanced to support the statistical testing.

The analyses did not show any significant relationship between the History of Orthodontic Treatment responses and skills scores. However, the History of Wisdom Teeth Removal responses were significantly related to both Double ($U=433.000, p<.05$) and Triple ($U=392.500, p<.01$) scores. The participants whose wisdom teeth were extracted had better scores in these skills.
Skills – Self-Ratings as Beginner Players Correlations (Spearman)

In page two of the questionnaire, participants were asked to rate the difficulty of achieving the tested skills as beginner players on a scale from one to ten (1 being easy, 10 being difficult). The ratings for each skill were compared to the scores participants received for the same skill during the study.

A number of highly significant correlations were found: Fast Single Tongue ratings and Single Tongue scores ($r_s=-.516, p<.01$); Fast Double/Triple Tongue ratings and Double ($r_s=-.452, p<.01$) and Triple ($r_s=-.572, p<.01$) scores; Flutter Tongue ratings and Flutter Tongue scores ($r_s=-.682, p<.01$); and High Range ratings and High Range scores ($r_s=-.455, p<.01$) were all highly significantly correlated to each other. Although not as strongly, the Endurance ratings and Endurance scores ($r_s=-.286, p<.05$) were also significantly correlated. All of the correlations listed above were inverse correlations, which suggests that as the participants rated their skills to be achieved easier as beginner players (smaller rating), their scores of the same skill were higher.

4.5.2 Correlations Among Performance Skills

Skills – Skills Correlations (Spearman)

The skills measured so far (Flexibility, Articulation, High Range, and Endurance) were found to be significantly correlated with each other, and the strength of association mostly varied between moderate to strong. In other words, the participants who were good at one skill were mostly good at other skills too (Table 4.3).
Flexibility A scores were significantly correlated to Flexibility B ($r_s=.741$, $p<.01$) and C ($r_s=.782$, $p<.01$); Single ($r_s=.349$, $p<.01$), Double ($r_s=.563$, $p<.01$), Triple ($r_s=.667$, $p<.01$), and Flutter Tongue ($r_s=.352$, $p<.01$); High Range ($r_s=.349$, $p<.01$); and Endurance ($r_s=.295$, $p<.05$) scores.

Flexibility B scores were significantly correlated to Flexibility A and C ($r_s=.720$, $p<.01$); Single ($r_s=.328$, $p<.01$), Double ($r_s=.549$, $p<.01$), Triple ($r_s=.675$, $p<.01$), and Flutter Tongue ($r_s=.330$, $p<.01$); High Range ($r_s=.253$, $p<.05$); and Endurance ($r_s=.279$, $p<.05$) scores.

Flexibility C scores were significantly correlated to Flexibility A and B; Single ($r_s=.418$, $p<.01$), Double ($r_s=.556$, $p<.01$), Triple ($r_s=.724$, $p<.01$), and Flutter ($r_s=.341$, $p<.01$) tongue; and High Range ($r_s=.309$, $p<.01$) scores.

Single Tongue scores were significantly correlated to Flexibility A, B, and C; Double ($r_s=.550$, $p<.01$) and Triple ($r_s=.501$, $p<.01$) tongue; and High Range ($r_s=.256$, $p<.05$) scores.

Double Tongue scores were significantly correlated to Flexibility A, B, and C; Single, Triple ($r_s=.639$, $p<.01$) and Flutter ($r_s=.356$, $p<.01$) tongue; High Range ($r_s=.410$, $p<.01$); and Endurance ($r_s=.267$, $p<.05$) scores.

Triple Tongue scores were significantly correlated to Flexibility A, B, and C; Single, Double, and Flutter ($r_s=.390$, $p<.01$) Tongue; and High Range ($r_s=.361$, $p<.01$) scores.

Flutter Tongue scores were significantly correlated to Flexibility A, B, and C; Double and Triple Tongue; High Range ($r_s=.390$, $p<.01$); and Endurance ($r_s=.337$, $p<.01$) scores.
High Range scores were significantly correlated to Flexibility A, B, and C; Single, Double, Triple, Flutter Tongue; and Endurance ($r_s=.431, p<.01$) scores.

The table below shows the significant correlations and associations among the different performance skills scores measured. The numbers at the top are the p-values, and the numbers at the bottom are the r-values.

<table>
<thead>
<tr>
<th></th>
<th>Flexibility A</th>
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<th>Flexibility C</th>
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<th>Double Tongue</th>
<th>Triple Tongue</th>
<th>Flutter Tongue</th>
<th>High Range</th>
<th>Endurance</th>
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<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.675</td>
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<tr>
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<td>.006</td>
<td>.349</td>
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<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.002</td>
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<tr>
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<td>.563</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.639</td>
<td>.390</td>
</tr>
<tr>
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<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
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<tr>
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<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.639</td>
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<tr>
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<td>.352</td>
<td>.004</td>
<td>.004</td>
<td>.002</td>
<td>.002</td>
<td>.001</td>
<td>.356</td>
<td>.390</td>
</tr>
<tr>
<td>High Range</td>
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<td>.013</td>
<td>.001</td>
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<td>.022</td>
<td>.028</td>
<td>.028</td>
<td>.004</td>
<td>.337</td>
<td>.431</td>
</tr>
</tbody>
</table>

Table 4.3 Significant correlations and associations among performance skills

### 4.5.3 Dental Measurements & Skills Test Correlations

The correlations between dental measurements and skills test scores were analyzed with the Spearman test. A number of significant findings were observed.
**Dental Measurements – Skills Test Scores Correlations (Spearman)**

The Inter-incisal Rotation measurements were inversely correlated to both Flexibility A \( r_s = -0.251, p < 0.05 \) and B \( r_s = -0.329, p < 0.01 \) scores. In other words, as the rotation angle decreased, which created a higher contact point between the central incisors (see Chapter 3 section 3.4.2 for details), the flexibility scores were increased.

The Inter-molar Width measurements (maxillary and mandibular) had highly significant correlations to the Flutter Tongue scores. The correlation of the Mandibular Inter-molar Width \( r_s = 0.413, p < 0.01 \) was slightly stronger than the correlation of the Maxillary Inter-molar Width \( r_s = 0.343, p < 0.01 \).

The Inter-incisal Inclination measurements were significantly correlated to the Flutter Tongue \( r_s = -0.285, p < 0.05 \) scores. It was observed that with a smaller inclination angle, which conveys more outwardly inclined teeth, the participants received higher scores in flutter tonguing.

Several individual Little’s Index Measurements were correlated to a variety of skills scores, which made it difficult to decide if they were arbitrary or not. However, the Mandibular Little’s Index 2-3 (LI-23) measurements stand out among the others with their correlation to almost all of the skills. It was inversely correlated to Flexibility A \( r_s = -0.355, p < 0.01 \) and C \( r_s = -0.316, p < 0.01 \); Single Tongue \( r_s = -0.314, p < 0.01 \); Double Tongue \( r_s = -0.357, p < 0.01 \); Triple Tongue \( r_s = -0.253, p < 0.05 \); and High Range \( r_s = -0.246, p < 0.05 \) scores.
The totals of Maxillary LI measurements and Mandibular LI measurements were also included in the analyses. No significant correlation was found between Maxillary LI measurements and skills scores. However, Mandibular LI measurements were significantly correlated to Flexibility A ($r_s=-243$, $p<.05$) and C ($r_s=-253$, $p<.05$); and Double Tongue ($r_s=-279$, $p<.05$) scores.
Chapter 5

Conclusions, Discussions & Future Research

This chapter includes conclusions drawn from significant findings of the initial data analyses, discussion of these findings, as well as information about future research.

5.1 Conclusions & Discussions

Primary findings of this research focused on the Inter-incisal Rotation, Inter-molar Width, Little’s Index of Irregularity, and performance skills. However, the research also revealed information about the relationship among different performance skills; as well as the influence of experience, daily practice, and various performance habits on the skills.
5.1.1 Performance Skills and Oral Anatomy Relationships

*Multiple Tonguing & Distances Across the Oral Cavity*

During the literature review, the only hypothesis found about the relationship of anatomy and multiple tonguing was regarding the ability of rolling the “R”s (or trilling the tongue). Both David Hickman and Gardner Read suggest flutter tonguing is connected to this ability, which is hereditary.\(^\text{53}\) Hickman also suggested that a short frenulum could be the reason behind the incapacity of rolling the “R”s. However, Amy Cherry, in her doctoral document, opposes the idea and suggests that, “For those who are currently capable of rolling their Rs, challenges to the expert performance of flutter tonguing still exist, especially when it is combined with additional musical requirements.”\(^\text{54}\)

The Inter-molar Width, as discussed in Chapter 3, is the distance between the first molars on the left and right sides of the jaw. Since these teeth are located in the rear part of the oral cavity, the Inter-molar Width indicates the size of the space in this specific area for the tongue. Similarly, since the wisdom teeth are the last teeth on the dental arch in the farthest back portion of the oral cavity, it is possible to predict that removing them would create extra space here. As a result, both of these dental measurements give information regarding the size of the space in this area.

The data analysis has revealed that Inter-molar Width measurements were associated with Flutter Tongue scores and Flutter Tongue Self-Ratings; also History of Wisdom Teeth Removal responses were associated with Double and Triple Tongue scores.


\(^{54}\) Cherry, 62.
These associations suggest a possible relationship between multiple tonguing abilities and the space in the rear portion of the oral cavity. It appears that as this space becomes larger, multiple tonguing becomes easier for the trumpet players in general. Since multiple tonguing techniques require the use of the back part of the tongue as well as the front, a larger room in this area might allow the tongue to move more freely, in return creating a better ability to achieve the mentioned articulation.

The findings about the correlation between multiple tonguing (especially flutter tonguing) and the space in the back of the oral cavity appear to be an addition to the literature. These correlations will be further investigated with more complex data analyses in the next stages of this study.

Skills & Little's Index of Irregularity (Crowding)

The literature review revealed two kinds of hypotheses regarding the alignment of the teeth. While many trumpet pedagogues and band directors suggested that, in general, well-aligned teeth provide advantage for better performance skills, Richard Giangiulio advocated that as long as the four supporting points of the front teeth between the mouthpiece and lips are symmetrical, general alignment is irrelevant. In order to investigate these theories, Little's Index of Irregularity (LI) measurements and performance skills scores were compared for possible associations.
Individual LI measurements (each distance from one tooth to the next) as well as total LI measurements (as a means to provide information about the general alignment of the teeth) for maxilla and mandible were analyzed. It was observed that Total Mandibular LI measurements were significantly correlated to Flexibility (exercises A and C) and Double Tongue scores; however, no significant correlation was found between Total Maxillary LI measurements and skills.

A number of the individual LI measurements were also significantly correlated to various performance skills scores. However, with the current information we have about the LI measurements (only the distances between the teeth without any information about their position), it is difficult to know if these correlations were arbitrary or not. Nevertheless, the LI Mandibular 2-3 stands out among the others with its correlation to the almost all of the skills test scores, which makes it more unlikely to be arbitrary.

The initial findings of this study suggest that well-aligned lower teeth might influence flexibility and double tonguing abilities positively. However, according to the findings, the general alignment of the upper teeth seems to have no significant correlation to performance skills.

The minimal correlation between total LI measurements and performance skills partially accepts the hypothesis about the well-aligned teeth providing advantage for better performance skills. However, in order to test Giangiuilo's hypothesis, further information about the individual LI measurements (position of the teeth) is necessary. Further analyses including this information will be conducted in the next stages of the study.
Flexibility & Inter-incisal Rotation

One of the prominent theories about the dental aspects of trumpet performance was suggested by the Shiner brothers in 1960's. They theorized that a “V” shaped contact point on the dental arch, where the mouthpiece is placed, improved trumpet performance. Later, trumpet player Jerry Franks and orthodontists Dr. Van Osdol and Dr. Morehead put the Shiner brothers’ ideas into practice and made an overlay that would fit on the anterior teeth of the trumpet players in order to create the “V” shaped contact point. According to Franks, the overlay effectively improved high range and endurance.

In this research, the relationship between the rotation angle of the central incisors (Inter-incisal Rotation) and performance skills was analyzed in order to further investigate the Shiner brothers’ theory. The results showed an association between Inter-incisal Rotation Angle and Flexibility; participants with a more pronounced “V” shape between the central incisors received higher scores from Flexibility A and B exercises. However, no significant association was found between the Inter-incisal Rotation Angle and High Range or Endurance scores as hypothesized by the Shiners and Franks.

Our initial findings partially accepted the Shiner brothers’ theory. The “V” shaped contact point does seem to positively influence trumpet performance. Although our current findings showed an association with only flexibility skills, it is possible that we might be able to see further associations with a more detailed evaluation of the data, and additional data analyses.

55 Campos, 94.
56 Morehead, 10.
It should be noted that the Shiner brothers and Franks also mentioned that the V-shaped contact point does not have to be in the center of the dental arch between the central incisors. They suggested that the contact point can be between the teeth other than the central incisors (for instance right central incisor and right lateral incisor) and the same effect would be created if the mouthpiece is placed off of the center, on this point. Since most of the participants placed their mouthpieces in the center, it was more crucial to examine the angle between the central incisors at first place. However, part of the future research will be dedicated to further investigate this notion. The individual Little’s Index measurements including the direction of the teeth will be useful in this investigation too.

**Skills & Other Dental Measurements**

The initial findings of this study rejected a number of existing hypotheses mentioned in the literature review. However, it should be remembered that the initial findings are the results of exploratory analyses, and that findings of more in depth investigation in the next stages of the study might accept some or all of these hypotheses.

Overjet is repeatedly stated to be one of the important dental characteristics for trumpet performance. Many trumpet pedagogues and band directors suggest that a small overjet is ideal for trumpet performance and a severe overjet can make the learning process difficult.
Several professional trumpet players also hypothesized that the posterior teeth (especially the first molars) support the facial muscles on the sides of the mouth (corners) and when these teeth are protruded to be closer to these muscles, performance can improve.\(^{57}\) In order to test this hypothesis, the inclination of the first molars were measured for each participant and compared to their performance skills.

Also another hypothesis is that slightly protruded and wider teeth (especially central and lateral incisors) can make playing easier by enabling quicker contact with the mouthpiece and allowing easier vibration of the lips; and also that they can provide protection against deformation of the lips due to mouthpiece pressure.\(^{58}\) In order to test this idea, the length and width of the six anterior maxillary teeth were measured for each participant and compared to their performance skills scores.

The initial findings of the study rejected all three hypotheses mentioned above. No correlation was found between performance skills scored so far and overjet measurements, inclination angle of the first molars, or length and width of the six anterior teeth.

5.1.2 Other Relationships

Although the main purpose of this study was to investigate the relationship between the trumpet performance skills and oral anatomy, additional relationships among other variables were also discovered.

\(^{57}\) Slaughter; Bilgen.
\(^{58}\) Bilgen.
Skills

The results have shown that almost all of the skills were significantly correlated to each other at different levels. However, there were several exceptions: There was no significant correlation between Single Tongue and Flutter Tongue scores; also the Endurance scores showed no significant correlation to Flexibility Exercise C, Single Tongue, and Triple Tongue scores.

The levels of association among most of the skills were moderate to strong. I believe it is possible to conclude that when the students are usually good at one skill they tend to be also good at other skills too. This consistency also shows that the skills test successfully captured the levels of participants’ performance abilities. However, despite these associations, the performance skills were still diverse enough to have different degrees of associations with other variables.

Skills & Years of Experience - Amount of Daily Practice

The results have shown that Years of Experience in trumpet performance is significantly correlated to Flexibility, Double Tongue, Triple Tongue, and Flutter Tongue scores; also that Amount of Daily Practice is significantly related to Flexibility, Flutter Tongue, and Endurance scores. It appears that Single Tongue and High Range scores have no significant correlation to either Years of Experience or Amount of Daily Practice.
According to these results, flexibility and multiple tonguing skills seem to improve with practice and experience over the years, and endurance seems to improve with daily practice. However, since high range and single tonguing abilities are not influenced by daily practice or experience, unlike the other skills, they might have a stronger association to natural talent.

*Piccolo Trumpet Playing & Skills*

In general, the students who played piccolo trumpet at the time of the study ranked significantly higher at all the skills except single tonguing. There are two ways to look at these correlations: 1) The students who play piccolo trumpet are more advanced players than the ones who do not, therefore their skills test scores are higher; 2) playing the piccolo trumpet positively influences performance skills.

I believe both options 1 and 2 to be valid. Trumpet students, in general, do begin playing the piccolo trumpet once they are at an advanced level; thus, it is expected for them to have better performance skills scores. At the same time, piccolo trumpet encourages the students to play with less power but more efficiency. Since this instrument is much smaller than the daily used Bb trumpet, they face much bigger resistance while playing. Eventually, the students try harder to play more efficiently and use less force, which can also positively transform their technique in general. Therefore, I believe that the relationship between piccolo trumpet playing and performance skills is a two-way relationship.
5.2 Future Research

As mentioned in the previous chapters, due to time restraints only a part of this research study was completed while this document was being written. After the completion of this document, the study will continue with the following steps:

1) Capturing more data from audio and video recordings and oral images: Tone production and intonation skills scores, facial movements during playing, further details of the dental measurements, volume of the airways, and measurements of the facial morphology will be captured and included in the exploratory data analyses.

2) Completion of the exploratory stage: The newly captured data will be used to complete the exploratory data analysis stage. With the completion of the exploratory stage, it will be possible to select certain variables for in-depth investigation.

3) In-depth investigation: In-depth investigation aims to assess the findings of the exploratory stage and further test the existing hypotheses in the light of multi-variate data analyses. In this stage, only the relationships found to be significant in the exploratory stage will be used and investigated in great detail.
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BOOKS


THESIS, DISSERTATION, AND DOCUMENTS


LECTURES AND PRESENTATIONS


APPENDIX A

SAMPLE IMAGES OF 3D PHOTOGRAPHS AND 3D CBCT SCANS
1) 3D Photograph and its superimposition onto another photograph in playing position: The colors on the second image show the areas and degrees of change.

![Natural position](image1.jpg) ![Superimposed](image2.jpg)

2) 3dMD Camera system:
3) 3D CBCTs showing the dental structure:

![3D CBCT images showing the dental structure](image1)

Right lateral oblique view  Frontral view  Left lateral oblique view

4) 3D CBCTs showing the volume of the airways

![3D CBCT images showing airway volumes](image2)

Total airway volume  Right and left maxillary sinus volume
“Oral Anatomy of a Trumpet Player”
Questionnaire

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<td>Email address:</td>
</tr>
<tr>
<td>School:</td>
<td>Degree/Year:</td>
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</table>

1. How long have you been playing the trumpet? _______ year(s)

2. How many hours do you practice a day (in average)? _______ hour(s)

3. How many hours do you play in the ensembles/perform a day (in average)? _______ hour(s)

4. How much time do you spend on technical studies and repertoire?
   Technical: _______ hour(s)/minute(s)  Repertoire: _______ hour(s)/minute(s)

5. What brand and size mouthpiece do you use? Brand: _______ Size: _______

6. What brand and model trumpet do you use (Bb)? Brand: _______ Model: _______

7. Do you play piccolo trumpet?   Yes ☐  No ☐
   How long have you been playing the piccolo trumpet? _______ month(s)/year(s)
   How much time a week (in average) do you spend playing the piccolo trumpet? _______ hour(s)/minute(s)

8. Do you experience excess tension in your body while playing? Yes ☐  No ☐
   If yes, which part(s) of your body? Lips ☐  Throat ☐  Chest ☐  Shoulders ☐  Other(s) _______
   Explain: ____________________________

9. Do you have difficulty keeping your corners/chin stable while playing? Yes ☐  No ☐
   Explain: ____________________________

10. Where do you place the mouthpiece on your lips?
    Center ☐  To the right ☐  To the left ☐  Above the center ☐  Below the center ☐

11. Do you move your jaw forward while placing the mouthpiece on your lips? Yes ☐  No ☐
    Explain: ____________________________
As a beginner trumpet player, how easy/difficult was it for you to achieve the technical skills below? Please rate on a scale from 1 to 10 (1 being the easiest, 10 being the most difficult).

<table>
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<th>Easy</th>
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<th>Easy</th>
<th>Easy</th>
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<tr>
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<td>9</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

In your opinion, what are your strongest and weakest attributes in your trumpet technique?

Strongest: __________________________________________

Weakest: __________________________________________
Height: __________ (inch)
Weight: __________ (pound)

Ethnic group: __________
(Asian – A; Black – B; Hispanic – H; White – W; Unknown – U; Other – O)

Do you have history of:
- Previous orthodontic treatment
- Orthognathic surgery
- Facial trauma or surgery
- Wound, burn, or scar tissue in the neck region
- Other systematic diseases or chronic illness
- Tonsillectomy
- Adenoidectomy
- Nasal allergies
- Sinus infections
- Wisdom teeth removal
- Others: ____________________________

Have you had any major dental work done in the past? Yes ______ No ______

Please explain: ____________________________________________________________

Do you breathe comfortably through the nose? Yes ______ No ______

Please explain: ____________________________________________________________

Do you think your front teeth moved because of playing the trumpet? Yes ______ No ______

Please explain: ____________________________________________________________

Have any of your front teeth died, needed a root canal, or changed color since you started playing the trumpet? Yes ______ No ______

Please explain: ____________________________________________________________

Would you like to hear about the findings of this study? Yes ______ No ______
APPENDIX C

MANUFACTURERS OF THE MAJOR EQUIPMENT
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Manufacturer &amp; Model</th>
<th>Model</th>
<th>Address</th>
</tr>
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<tbody>
<tr>
<td>Unidirectional microphone</td>
<td>Sennheiser GmbH &amp; Co. KG</td>
<td>MD421 II</td>
<td>Wedemark, Germany</td>
</tr>
<tr>
<td>Tripod boom</td>
<td>König &amp; Meyer GmbH &amp; Co KG</td>
<td>21021 Overhead Microphone stand</td>
<td>Wertheim/Main, Germany</td>
</tr>
<tr>
<td>Handy recorder</td>
<td>Samson Technologies Incorporation</td>
<td>Zoom H4n</td>
<td>Hauppauge, NY, USA</td>
</tr>
<tr>
<td>Camcorder</td>
<td>Sony Corporation</td>
<td>DCR-DVD650</td>
<td>Tokyo, Japan</td>
</tr>
<tr>
<td>Decibel meter</td>
<td>RadioShack Corporation</td>
<td>Digital Sound Level Meter</td>
<td>Fort Worth, TX, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catalog no: 33-2055</td>
<td></td>
</tr>
<tr>
<td>i-CAT radiographic machine</td>
<td>Imaging Sciences International, LLC</td>
<td></td>
<td>Hatfield, PA</td>
</tr>
<tr>
<td>3D Dolphin imaging software</td>
<td>Dolphin Imaging and Management Solutions and Patterson Technology</td>
<td></td>
<td>Chatsworth, CA</td>
</tr>
</tbody>
</table>
Performance Skills Test

1. Tone Production
Directions:
- Play with your best sound
- Keep the notes straight (no vibrato)
- Breath as you need to

\[ \text{mf} \]

1st time: \text{mf}
2nd time: as soft as possible
3rd time: as loud as possible

--- 1 min. break ---

2. Flexibility
Directions:
- Start with a comfortable tempo
- Repeat each exercise and increase the tempo until you reach the fastest you can play while all notes are being heard

\[ \text{mf} \]

--- 1 min. break ---

3. Articulation
Directions:
- Start with a comfortable tempo
- Repeat each exercise and increase the tempo until you reach the fastest you can play while all notes are being heard
a) SINGLE TONGUE
b) DOUBLE TONGUE
c) TRIPLE TONGUE
d) FLUTTER TONGUE
Directions:
- Flutter tongue each note
- Stop or breath as you need to
- Continue as high/low as you can
- Stop where flutter tonguing is not possible anymore

--- 1 min. break ---
4. Range
Directions:
- Play at a comfortable tempo
- Breath as you need to
- Stop where the notes are out of your range

--- 1 min. break ---

5. Intonation
Directions:
- TUNE BEFORE YOU BEGIN
- Make sure to separate the notes
- Play it as you would in an ensemble (correcting the notes as needed)

--- 1 min. break ---

6. Endurance
Directions:
- Repeat the patterns as many times as you can
- Stop when you can not continue anymore
- Stay above ... decibels at all times
- Follow the tempo strictly
- Make sure to take sufficient breath at the end of each time

Repeat as many times as possible
Three different sources were used for the definition of the terms below: 1) personal communication with the investigator in charge of dental measurements in this project;59 2) a commonly used dental anatomy book;60 and 3) online medical dictionary.61

Every tooth in the mouth is identified with its specific name and location in the mouth. Figure below shows the permanent teeth and their names in dental terms.62 As shown in the figure, the upper teeth are referred to as “maxillary” while the lower teeth are referred to as “mandibular.”

![Permanent Teeth Diagram](image)

**Figure E.1 Permanent tooth identification**

Below are the other terms used to describe the position of the teeth in the mouth or the direction of the measurements taken:

---

**Angulation (Rotation):** the mesial or distal turning of a tooth around its longitudinal axis (Medical Dictionary).

**Occlusal view:** View of the *occlusal surface* (the surface of the teeth that comes in contact with those of the opposite jaw) (Medical Dictionary).

**Lateral (view):** pertaining to the side. Lateral view is the side view (Medical Dictionary).

**Mesial:** Situated toward the middle of the front of the jaw along the curve of the dental arch (Medical Dictionary).

**Distal:** Situated farthest from the middle and front of the jaw, as a tooth or tooth surface (Medical Dictionary).

**Incisal line:** The cutting edges of the incisor and cuspid teeth (Medical Dictionary).

**Cervical line:** The dividing line between the crown and root portions of a tooth (Medical Dictionary).

**Buccal:** Related to or near the cheek; the buccal nerve innervates the cheek; the buccinator muscle is within the cheek; the buccal surface of a tooth is the side toward the cheek (also called *facial* side because it is toward the face we see) (Scheid, 2007).

**Labial:** Related to the lips; toward the lips (Medical Dictionary).

**Lingual/Palatal:** Next to or toward the tongue/palate (Medical Dictionary).

**Facial Plane:** A commonly used reference line for projecting linear dental measurements on. The line is drawn from the *nasion point* (horizontal middle intersection point of the frontal bone-forehead-and nasal bone) to the *pogonion point* (the most protruded mid point on the chin). See illustration on page 49 of the document (Ghoneima, 2012).

**Root Apex:** The apex of the root is the tip or peak at the end of the root (Scheid, 2007).

**Cusp (with a Cusp tip):** is a pointed part, or peak, located on the occlusal surfaces of molar and premolar teeth and on the incisal edges of canines (Scheid, 2007).

**Mesio-Buccal Cusp Tip:** The cusp tip of the molars that is on the side of the cheek and towards the midpoint on the arch (towards the incisors) (Ghoneima, 2012).

**Interincisal:** between incisors (Ghoneima, 2012).

**Anterior:** Of or relating to the front surface of the body, especially of the position of one structure relative to another; ventral (Medical Dictionary).

**Posterior:** In the back part of a structure, such as the dorsal surface of the human body (Medical Dictionary).

**Nasal Floor:** A horizontal line drawn at the base of the nose (Ghoneima, 2012).
APPENDIX F

CHAPTER 4 FIGURES
Figure 4.1 Age groups of participants

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<tr>
<th>Age</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
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</table>

Figure 4.2 Genders of participants

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Figure 4.3 Years of experience of participants

![Years of experience bar chart]

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Figure 4.4 Example of a bell-shaped curve

![Bell-shaped curve]

Figure 4.5 Example of an asymmetrical curve\textsuperscript{64}

\textsuperscript{64} Id.