MALOCCLUSION PREVALENCE IN A NORTH PHILADELPHIA ORTHODONTIC POPULATION

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ABSTRACT

Objectives: This study aims to examine malocclusion traits of a racially diverse population to determine the validity of the malocclusion prevalence reported in the NHANES III survey. Additionally, the cephalometric database from the American Association of Orthodontists Foundation Legacy Collection (AAOF-LC) was used for skeletal malocclusion prevalence. The sample used data collected at the Temple University orthodontic screening clinic (TUKSoD) from 2012-2020.

Methods: Malocclusion prevalence of the TUKSoD population (n=7713) was compared to the NHANES III (n=7000) and AAOF-LC (n=1198) for dental and skeletal traits respectively. The TUKSoD population is 51.5% Black, 38% Hispanic, 2.7% White, 1.1% Asian, 0.2% American-Indian, and 1.1% other; age range 6-78 (mean 21.05±10.47), 60.4% females/39.6% males. The AAOF-LC is comprised primarily of Caucasian patients; age range 1-47, 48% females/52% males. The NHANES III survey included Black, Caucasian, and Mexican-American participants, with results weighted to represent American population demographics. Traits were compared in the transverse (dental), vertical (dental/skeletal), and sagittal (dental/skeletal) planes. Prevalence was recorded as percentage of the total population.

Results: Significant differences were found for all dental comparisons: Sagittal (Class-I,II,III; p=8.59E-7), Vertical (Open-bite/Deep-bite; p=1.53E-13), and Transverse (crossbites). Significant differences were found for all skeletal comparisons: Sagittal (Class-I,II,III; p=5.38E-6), and Vertical (Open-bite/Deep-bite; p=8.89E-5).

Conclusion: TUKSoD serves a diverse patient population which has significantly different skeletal and dental malocclusion prevalence compared to the control populations. These differences are likely the result of the genetic influences underlying the demographics. As the NHANES III and AAOF-LC represent common standards, comparison to genetically heterogenous contemporary populations is challenging, underscoring the need for more personalized approaches to determining malocclusion demographic characteristics.

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CHAPTER 1

INTRODUCTION

Human awareness of malocclusion, defined as deviations from the ideal positioning of teeth in relation to one another, dates to at least 1000 B.C. (Proffit, 2018). Attempts to obtain straight teeth date to equally distant times, with a published systematic description of orthodontics appearing in Norman Kingsley's *Oral Deformities* shortly after 1850 A.D. (Kingsley, 1880). Orthodontic treatment planning requires an understanding of the goals one would like to achieve with treatment, and so it is necessary to specifically define the concept of malocclusion and create a definition of ideal norms. Edward Angle's theory of occlusion is based on a full complement of teeth with the mesiobuccal cusp of the upper first molar occluding in the groove of the lower first molar, with the remainder of the teeth situated on a smoothly curving line. This is perhaps the best-known definition of normal occlusion. Excepting cases of abnormal tooth sizes, this definition has proved to be repeatable and has been the most commonly used definition over the past century (Proffit, 2018).

In addition to the concepts of dental occlusion put forward by Angle, it is understood that the skeletal components of the craniofacial complex influence the occlusal pattern (Graber, 2017). In the same way that deviations from the norm exist in the dentition, they may exist in the craniofacial skeletal structure. In such cases, the teeth may compensate to approach a Class I normal dental occlusion, or may present with a corresponding malocclusion (Profitt, 2018).

A significant portion United States' population possesses some form of malocclusion (Proffit, 1998). The etiology of these malocclusions may be environmental- such as the early loss of a primary tooth resulting in the undesirable eruption pattern of the permanent tooth, or hereditary, as craniofacial growth patterns are largely determined by the genetic composition of an individual (Graber, 2017). Ideally, every individual could be genetically tested to determine which malocclusions are likely to develop, and appropriate action could then be taken. However, in the present, no such test exists. In the absence of these patient-specific tests, it is necessary that orthodontists use the tools available to them in the present to best understand- and therefore to best treat- their patients. To that end, numerous studies have examined the prevalence of malocclusions- both skeletal and dental- in a variety of patient populations throughout the world.

Historically, most malocclusion and growth studies have examined Caucasian populations. For example, the American Association of Orthodontics Foundation Growth Legacy Collection is comprised of nine of the most comprehensive and high-quality cephalometric growth studies ever conducted. This collection can be viewed as a single larger database or as nine separate data sets. For our purposes, we will be using all nine studies as a single dataset. These studies are landmark studies in the field of cephalometrics, and all nine of them derive their data from primarily Caucasian populations. Data from these studies have been used to define norms, and have been used in the diagnosis and treatment of patients of all races. However, it is known that significant differences in cephalometric relationships and occlusion exist between various racial groups (Drummond, 1968; Beane, 2003; Ngan, 2015).

This study will examine a diverse population and will, based on the comparative results to prior studies, indicate a need or lack thereof for further studies into diverse patient populations to increase the specificity of care for individuals. These studies could inform and influence the ways in which we determine orthodontic treatment need and allocate resources to accomplish that treatment.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Classifying Malocclusions

Orthodontists diagnose and treat deviations from the norm in the position of the teeth and jaws. These deviations are referred to as malocclusions, and may further be categorized into dental and skeletal malocclusions. Dental malocclusions are limited to the position of teeth, while skeletal malocclusions involve the underlying craniofacial bones. Patients may possess one or both categories of malocclusions. Precisely describing these malocclusions is typically accomplished by reviewing them in three planes of space: transverse, vertical, and sagittal (Profitt, 2017). The transverse plane may be referred to as the frontal plane; the vertical plane may be referred to as the coronal plane, and the sagittal plane may be referred to as the antero-posterior plane (Figure 1). Although not specifically correlated to any of the three planes of space, crowding, spacing, and generally misaligned teeth are also considered to be elements of malocclusion, and affect at least two-thirds of the U.S. adult population (Profitt, 2017).

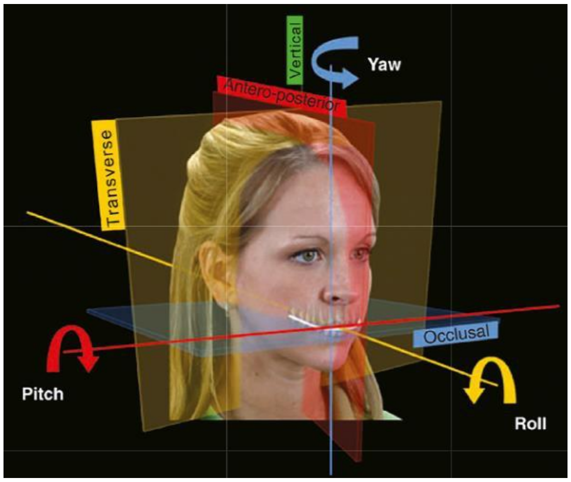

Figure 1. **Malocclusion and Planes of Space. (Proffit, 2017)**

2.2 Transverse Discrepancies

Dental malocclusions are discrepancies from the ideal occlusal norms. These discrepancies are frequently referred to by the plane of space in which they occur (Profitt, 2018). Dental transverse discrepancies are often referred to as posterior crossbites (Almeida, 2012). These crossbites present when the buccal cusps of the mandibular posterior teeth are more buccal than the buccal cusps of the maxillary posterior teeth, as seen in Figure 2. These discrepancies may present as a single tooth or as multiple posterior teeth, and are commonly observed in the mixed dentition stage, when both primary and permanent teeth are present in the mouth. A recent study reported a posterior crossbite prevalence of 5-8% in children in the United States aged 3-12 years (Bell and Kiechbach, 2012). A systematic review of malocclusion traits globally reported a prevalence of posterior crossbites in the permanent dentition as 9.39% averaged across all included populations (Alhammadi, 2018).

Figure 2. **Dental Crossbites. (Graber, 2017)**

Skeletal transverse discrepancies occur when there is a significant difference between the width of the maxilla and the width of the mandible. Literature on the prevalence of these discrepancies is extremely limited. As noted by Vanarsdal, there are no tooth measurements that can reliably indicate a skeletal discrepancy, and clinical inspection is not adequate for diagnosis of skeletal transverse discrepancies (Vanarsdal, 1995). The standard for radiographic diagnosis of these discrepancies has been the posterior-anterior cephalogram (Betts, 1995). These radiographs are typically taken in addition to the standard records, with only 13.3% of orthodontists taking them as standard procedure, thus limiting the amount of available data on these discrepancies (Allen 2003). The increasing popularity of cone-beam computed tomography (CBCT) in orthodontics significantly increases the amount of data available for transverse analysis, and may improve our understanding of this dimension in the future (Miner, 2012).

2.3 Vertical Discrepancies

Dental vertical discrepancies exist when there is an increased amount of vertical overlap (overbite) between maxillary and mandibular teeth, or a decreased amount. These discrepancies are referred to as either deep bites, or open bites, respectively. The normal occlusal pattern seen in Figure 3 occurs when the mandibular incisors contact the maxillary incisors at, or incisal to the cingulum, resulting in 1-2mm of overbite (Profitt, 2018)

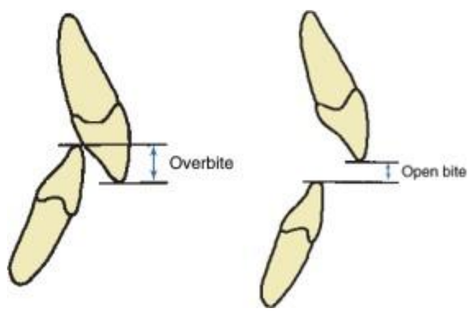

Figure 3. Comparison of Normal Overbite and Open Bite (Profitt 2018)

Existing studies suggest a wide range of vertical occlusal discrepancy prevalence in various populations. The largest malocclusion study to date found that approximately 50% of the adult population in the United States presents with increased dental overbite (3mm or more). Less than 10% of the total population possesses dental open bites, and less than 5% of children presented with dental open bites (Profitt, 2018). Historically, studies have noted racial associations with open bites. A 1965 National Health Study on

7,400 adolescents aged 12-17 noted a four-times increase in open-bite prevalence compared to white children (16.3% to 4.0%) (Kelly, 1977). More recently, the NHANES III survey found an open bite prevalence for blacks of all ages of 6.6%, compared to 2.9% for whites and 2.1% for Mexican-Americans. Further supporting the varied prevalence across different populations, a recent study of Omani adolescents found a dental deep bite prevalence of 16.3%, and a dental open bite prevalence of 0.2% (Al Jadidi, 2018). These studies did not describe possible etiologies of the open bites.

Skeletal vertical discrepancies are categorized into skeletal open bites and skeletal deep bites. They may or may not associate with dental open and deep bites (Sassouni, 1969). The terms hypodivergent and hyperdivergent are often used to describe skeletal deep and open bites, respectively. Viken Sassouni emphasized the divergence, or lack thereof, of the supraorbital, palatal, occlusal, and mandibular planes. The mandibular plane may be appreciated clinically, while radiographs are needed to observe the others (Figures 4 and 5). Although a wealth of cephalometric records exists and numerous studies have examined dental vertical discrepancies, very few studies have evaluated the prevalence of the skeletal open and deep bites in a population. Oshagh, et. al (2010) reported a skeletal open bite prevalence of 56.6%, and a deep bite prevalence of 19.4% in Iranian schoolchildren using FMA as the sole determinant.

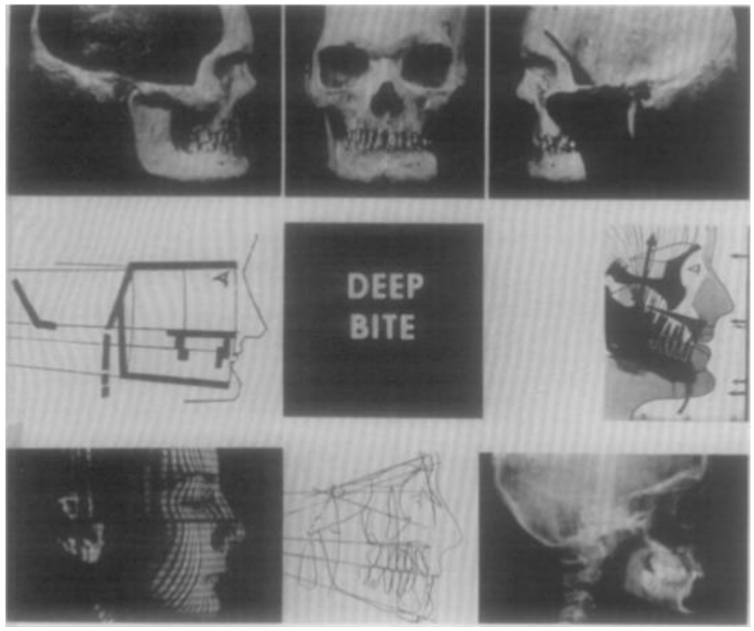

Figure 4. Deep Bite Skeletal Type. (Sassouni, 1969) (illustrates Sassouni Analysis)

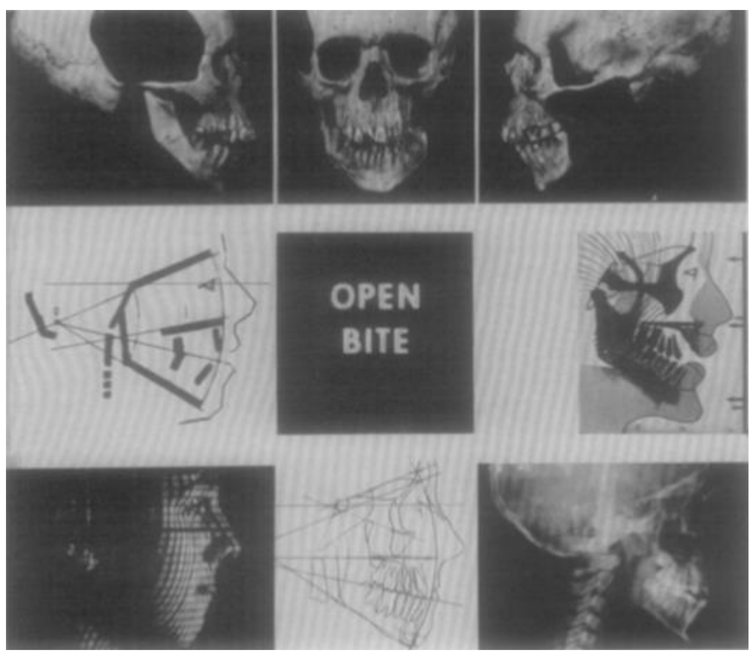

Figure 5. Open Bite Skeletal Type. (Sassouni 1969).

2.4 Sagittal Discrepancies

Dental sagittal discrepancies occur in the anterior-posterior plane of space, and are typically described using the Angle classification system (Proffit, 2018). As shown in Figure 6, Class I dental occlusions are the norm, although the presence of misaligned teeth, transverse, or vertical discrepancies may result in a Class I malocclusion. Class II dental malocclusions occur when the mesiobuccal cusp of the maxillary first molar is mesial to, or ahead of the buccal groove of the mandibular first molar. Class III dental malocclusions occur when the mesiobuccal cusp of the maxillary first molar is distal to, or behind the buccal groove of the mandibular first molar.

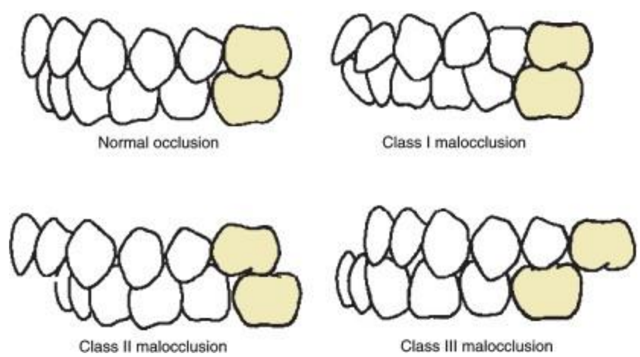

Figure 6. Comparison of Dental Sagittal Occlusions. (Profitt, 2018)

A variation of sagittal classification was used by Proffit, et al (2018) to analyze the results of the NHANES III study on occlusion. In this study, overjet measurements were substituted for molar relationships, with five millimeters or more corresponding to Class II malocclusions, and zero mm or less corresponding to Class III malocclusions. Overjet measurements of one to two millimeters were considered to be ideal Class I relationships. Using these parameters, Proffit et al. found that approximately 67% of the U.S. population had overjet between zero and four millimeters, indicating Class I occlusions. Class II malocclusions were found in 23% of children, 15% of youths, and 13% of adults. Class III malocclusions were found the be the rarest, affecting 3% of children and 5% of adults. Thilander, et al. (2001) found a prevalence of 20.8% Class II, 3.7% Class III, and 75.5% Class I molar occlusions in Columbian children and adolescents. Gelgor et a. (2007) examined adolescents in Central Anatolia (Turkey) and found the predominant occlusal pattern to be Class II, with a prevalence of 44.7%. That same population presented with 34.9% Class I occlusions and 4.7% Class III occlusions. A study by Isiekwe (1983) revealed an increased Class III malocclusion prevalence in Nigerian schoolchildren: 8.4%. This same population demonstrated a decreased Class II prevalence when compared to similar studies in other populations (14.7%), and a Class I prevalence of 76.8%.

Skeletal sagittal discrepancies are described in a similar way as dental malocclusions, though they are not based on dental relationships. Skeletal sagittal occlusal schemes are based on the position of the maxilla and mandible relative to each other (Proffit, 2018). Some analyses, such as that published by Steiner (Figure 7), use cranial landmarks as reference marks to describe the position of the jaws (Jacobson, 2006). Others, such as the Wits Analysis (Figure 8), compare the position of the jaws with regards to each other, without external landmarks (Jacobson, 2006).

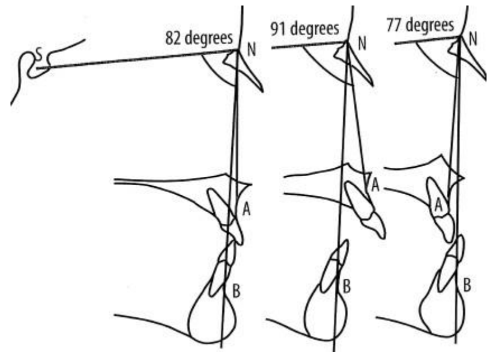

Figure 7. Steiner's Comparison of Skeletal Occlusal Schemes. (Jacobson, 2006)

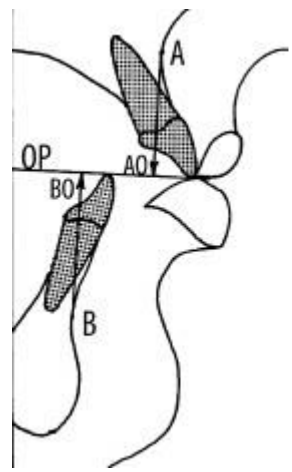

Figure 8. Evaluation of Jaw Relationships Using the Wits Analysis (Jacobson, 2006)

Regardless of the method used, Class I skeletal relationships are considered the norm. Class II skeletal relationships refer to a maxilla that is more anterior to the mandible than normal, and Class III the opposite.

Studies on the prevalence of sagittal skeletal relationships are limited, but Tokunaga et al. (2014) reported Class I, II, and III prevalence of 53.3%, 37.1%, and 9.6% in Mexican patients respectively across an age range of 8-40 years using Steiner measurements using the following intervals: Class I: 0-4 degrees, Class II: 3 degrees or more, Class III: -1 degree or less. Oshagh et. al (2010) utilized both the Steiner and Wits analyses to determine skeletal patterns, and reported a Class I, II, and III prevalence of 18.0%, 70.0%, and 12.0% respectively across a total of 700 patients.

2.5 Limitations of Past Studies

Numerous studies investigating the prevalence of dental malocclusion have been done in various populations. The limitations of all of these studies is the same: they can be applied only to specific patient populations. Existing studies have demonstrated large discrepancies in the prevalence of various malocclusion traits between different populations. As noted by Kelly, et. al (2017), patient demographics and genetic background are likely to play a significant role in the prevalence of malocclusions. This has been concluded numerous times in the literature. "Malocclusion often develops as a complex trait condition that is influenced by combinations of transcription and growth factors acting on bone, teeth, and skeletal muscles" (Zebrick, et al, 2014). While this does explain the existing discrepancies in the literature, it also highlights the need for additional studies on new patient populations.

In addition to the limitations regarding dental malocclusion, there is a stark lack of literature on skeletal malocclusion prevalence across all three planes of space. This study will examine a patient population that has not yet been examined from both the dental and skeletal perspectives. It will also provide additional information on the relationship and associations of dental malocclusions with skeletal malocclusions.

CHAPTER 3

AIMS OF THE INVESTIGATION

The aim of this study is to determine the prevalence of malocclusion in the orthodontic patient population screened at the Temple University Kornberg School of Dentistry (TUKSoD) Department of Orthodontics, and to compare this data with existing studies. Specific aims are

- To collect data on dental and skeletal malocclusions in the transverse, vertical, and sagittal planes of space from the patient population in the TUKSoD Orthodontic screening clinic in order to determine prevalence of dental and skeletal malocclusions in the TUKSoD Orthodontic screening population
- To compare determined dental malocclusion prevalence with the data from the NHANES III malocclusion study
- To compare determined skeletal malocclusion prevalence with the data from the American Association of Orthodontists Foundation (AAOF) Legacy Collection

The null hypothesis is: No significant difference in malocclusion prevalence exists between the TUKSoD population and the historic control groups.

3.1 Rationale for Study

If significant differences are found between the TUKSoD patient population and the comparison groups, it will highlight the need for continued analysis of specific patient populations in the absence of readily available genetic testing to ensure optimized treatment and maximized benefits for individual patients.

CHAPTER 4

MATERIALS AND METHODS

All patients seeking orthodontic care at the Temple University Kornberg School of Dentistry are subject to a standardized screening appointment to assess skeletal and dental malocclusions. Data is recorded and logged into Axium patient management software (Appendix A).

During the screening appointment, a clinical exam is conducted on each patient. This exam includes determining the patient's dental and skeletal characteristics in the transverse, vertical, and sagittal planes of space. This collected data is digitally stored in the Axium software utilized by the orthodontic department for charting and record keeping (Appendix A). The raw data for 7,713 patients was extracted to a spreadsheet to permit quantitative analysis (Appendix B**).** This was done with the assistance of Dr. Carlos Echeverri in the Information Technology Department at TUKSoD. A search was run of the entire Axium system for all patients with a completed Orthodontic Screening Form by Dr. Echeverri. This search was expanded to include gender and age. The results appear on Axium in table form. This table was then copied and pasted in entirety to a Microsoft Excel spreadsheet in order to allow for quantitative analysis, which cannot be conducted in Axium. This spreadsheet format can be viewed as Appendix B**.** The data was analyzed in the following way. First, the total number of completed screening forms was used as a representative population of the North Philadelphia area. Secondly, recorded factors including dental occlusal relationships and skeletal relationships were analyzed on a quantitative basis and compared to the total number of screened patients to ascertain the prevalence of the various screened metrics. For example, the total number of screened patients that have class II dental occlusions was divided the total number of patients screened, giving a percent of total population who possess that particular trait. These percentages are reported as the prevalence of various traits in this population. These prevalence rates were compared to prevalence rates obtained from the NHANES III Oral examination (for dental characteristics, approximately 7,000 patients) and the AAOF Legacy Collection (for skeletal characteristics, 1198 records). In order to determine these prevalences for future studies, the two right-most columns of the TUKSoD raw data sheet (see Appendix B) must be merged. Then, a search of the raw data sheet must be done using the trait in question followed by the word “Yes.” For example, if one wanted to determine the total number of Class I dental patients, the steps would be as follows:

1. Merge the rightmost two columns labeled “F. Item Text” and “F. Answer” by highlighting both entire columns and selecting “merge cells.” This step only needs to be completed once before all traits can be searched.
2. Use the control-find function to search for “Class I Yes”. The total number of matches will be the number of patients in the population possessing the characteristic in question. This is the way in which column 2 of Appendix D was generated.

3. To find prevalence, divide the numerical result of step 2 by the total population of the raw data sheet (7713) and multiply that result by 100. This is the way in which column 3 of Appendix D was generated.

The NHANES III oral examination involved an occlusal characteristics exam. This examination includes measurements of overjet, overbite, open bite, and posterior crossbite. The screening examination done in the TUKSoD Orthodontic Clinic is a nominal response form, with the answer to each parameter being “yes” if the characteristic is present, and “no” if it is not. This study used “yes/no” response format when using the NHANES data, and did not report on the degree to which each characteristic existed in each subject, only that the characteristic was present or absent. Open bite, overbite, overjet, and posterior crossbite were all included as characteristics of interest, with posterior crossbite and open bite being recorded as a “yes/no,” and the rest as numerical values. The raw data from the NHANES III study is maintained by the National Center for Health Statistics but is not currently publicly available. The 1998 analysis and summary by Profitt, Fields, and Moray provides excellent source to use for comparison as it describes the prevalence for all of the traits examined in this study. The AAOF Legacy collection is a publicly available database, complete with an interactive search function that allows specific traits and parameters to be set and found within the collection. This function also reports the total number of patients that fall within the set parameters from the entire collection, allowing prevalence to be easily obtained as percent of total.

The AAOF Legacy Collection includes 1,198 cephalometric radiographs from nine separate growth and development studies. Appendix C demonstrates an example search of the data contained in the AAOF Legacy Collection. In order to access this search function, one must selected the “search- ceph measurements” option on the AAOF Legacy Collection home webpage. The table at the top of Appendix C will load. From this point, one can select the cephalometric measurement of interest and the value limits using the dropdown menus. Clicking “search Legacy Collections” will then create a table of all the matching participants, also seen in Appendix C**.** All the subjects in the combined collection have identified FMA and ANB measurements, as were used in this study. However, some other possible cephalometric measurements were not quantified on every subject. If these measurements are used, the number of records would be less than 1,198.

In order to compare our skeletal analysis to this collection, we will define angular measure parameters for ANB, an angular measurement that relatively relates the position of the maxilla to that of the mandible. An ANB measurement of 2.0 degrees, with a standard deviation of 2.4 degrees is considered to be within normal limits and representative of a class I skeletal relationship (Jacobson, 2014). We will therefore isolate subjects from the collection whose ANB measurements are less than -.06 (Class III), between -0.59 and 4.40 (Class I), and 4.41 or greater (Class II).

The angle formed between Frankfort Horizontal and the Mandibular plane (FMA) is a commonly used measurement for describing the vertical skeletal pattern. An FMA measurement of 25.0 (+/- 5 degrees) is considered within normal limits. Measurements below 20.0 and above 30.0 degrees degrees are considered to be hypodivergent (skeletal deep-bite) and hyperdivergent (skeletal open-bite), respectively (Jacobson, 2014). This range will be used to determine the prevalence of these skeletal traits in the AAOF Legacy Collection.

Specific comparisons to be made between TUKSoD orthodontic screening population and NHANES III Survey Results are as follows:

1. Prevalence of Class I Dental Relationships as percent of total population
2. Prevalence of Class II Dental Relationships as percent of total population
3. Prevalence of Class III Dental Relationships as percent of total population
4. Prevalence of Crossbites as percent of total population
    a. The NHANES III survey determined patients with anterior edge-to-edge occlusion or crossbites to be Class III. The percentage of patients with Class III malocclusion will be added to the percentage with posterior crossbites in order to obtain the total percentage of patients with crossbites.
5. Prevalence of Dental Vertical Discrepancies (open and deep bite) as percent of total population

Specific comparisons to be made between TUKSoD orthodontic screening population and AAOF Legacy Collection are as follows:

1. Prevalence of Class I Skeletal Relationships as percent of total population
2. Prevalence of Class II Skeletal Relationships as percent of total population
3. Prevalence of Class III Skeletal Relationships as percent of total population

Statistical analysis will consist of a series of chi-squared tests comparing each variable in the TUKSoD population to the corresponding variable in the control populations to determine if statistically significant differences exist.

CHAPTER 5

RESULTS

In total, 7713 screening forms for individual patients were completed. The skeletal and dental traits were isolated and compared to the total population to obtain prevalence as a percentage of the whole. Dental characteristics were compared to the results of the NHANES III study, which had a sample size of approximately 7,000. Skeletal characteristics were compared to the total record pool of the American Association of Orthodontists Foundation Legacy Collection, which had a sample size of 1198 unique records. The level of statistical significance for all tests was set at $\alpha = 0.05$.

Figure 9 provides a detailed picture of the total screening population at the TUKSoD Orthodontics Department. Table 1 provides an overview of the comparison between the TUKSoD population and control populations, including statistical analysis of the distributions of the traits. Figure 9 is derived from columns one and two of the TUKSoD portion of Appendix D.

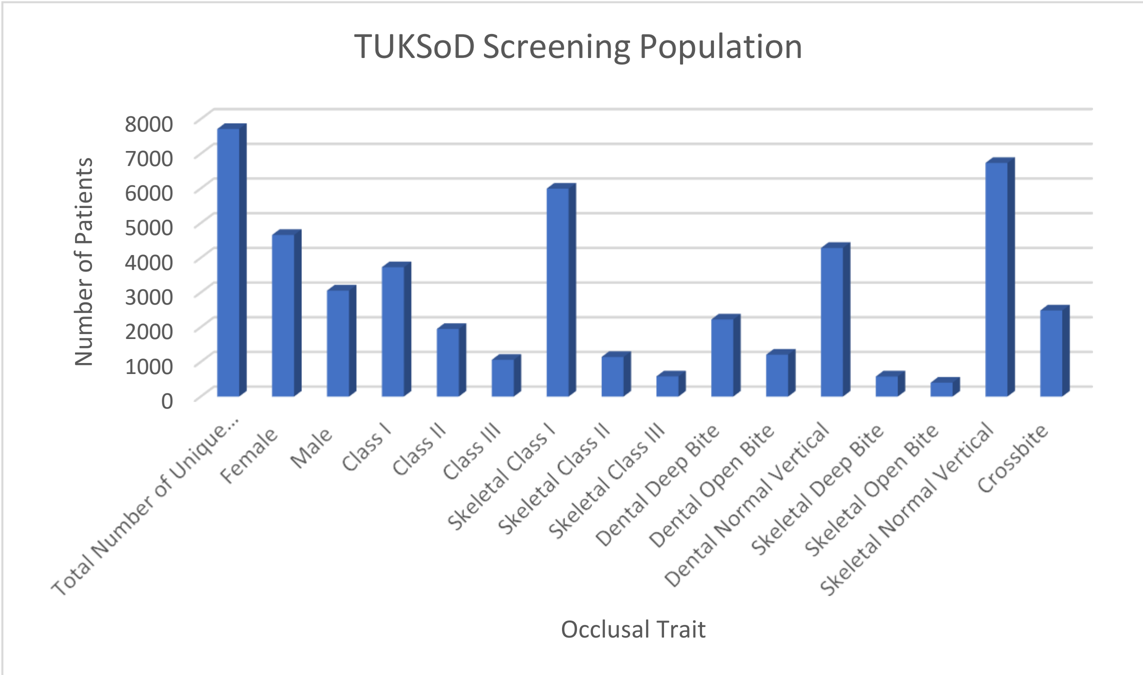

Figure 9, TUKSoD Screening Population

Dental trait comparisons were performed between the TUKSoD screening data and the NHANES III results. Sagittal comparisons are shown in Figure 10. In the TUKSoD population, the observed Class I dental prevalence was 48.5%, while the NHANES III study reported a Class I dental prevalence of 41.1%. Class II dental relationships were observed in the TUKSoD population 25.3% of the time, while the NHANES III results reported Class II dental relationships 53.5% of time. Class III dental relationships were reported in the TUKSoD population in 13.7% of subjects, while the prevalence rate seen in the NHANES III survey was 5.6%.

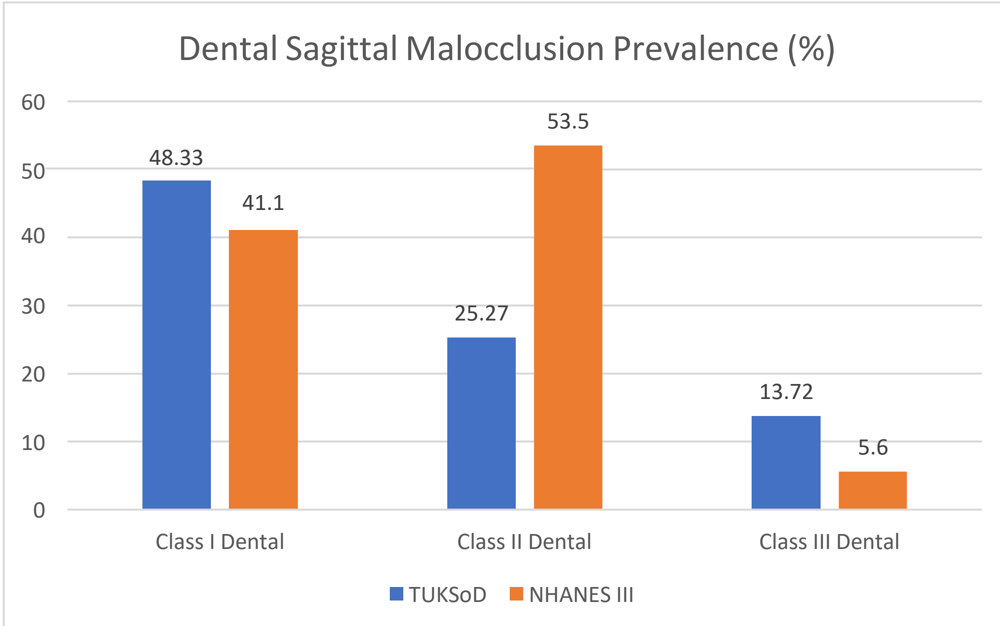

Figure 10, Dental Sagittal Malocclusion Prevalence

Vertical dental characteristics are divided in normal/ideal overbite, dental open-bite, and dental deep-bite. The comparison between the NHANES III survey and the TUKSoD screening data are represented in Figure 11**.**

The NHANES III study reported a dental open bite prevalence of 3.3%, and a 15.6% prevalence was observed in the TUKSoD screening population.

Normal to ideal overbites were observed in 47.5% of the NHANES III participants, while the TUKSoD screening population demonstrated an increased prevalence of 55.6%. Dental deep bites were observed in the NHANES III population in 49% of the subjects, while only 28.8% of subjects observed in the TUKSoD screening clinic presented with the malocclusion trait.

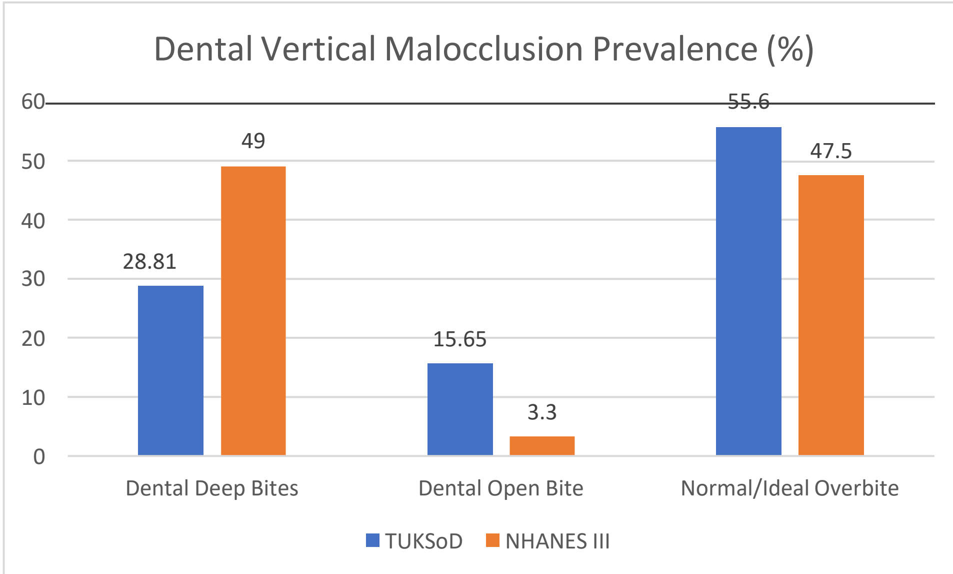

Figure 11, Dental Vertical Malocclusion Prevalence

Transverse dental characteristics were defined as the presence or absence of dental crossbites. The comparison between the NHANES III study and the TUKSoD Screening Data are represented in Figure 12**.**

The NHANES III study reported crossbites in 14.7% of subjects, while crossbite were identified in 32.16% of the TUKSoD Population.

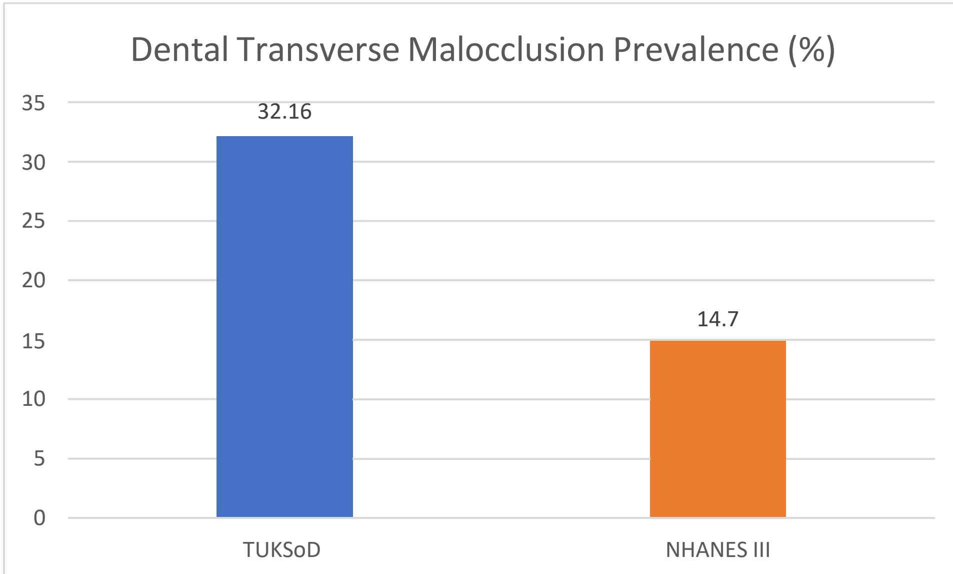

Figure 12, Dental Transverse Malocclusion Prevalence

Skeletal trait comparisons were performed between the TUKSoD Data and the American Association of Orthodontists Legacy Collection of cephalometric records. Sagittal occlusion was determined using cephalometric A and B point from the AAOF Legacy Collection, and soft tissue A and B point in the TUKSoD group. These comparisons are represented in Figure 13.

The AAOF Legacy Collection sagittal occlusion prevalence are: Class I 56.8%, Class II 38.9%, and Class III 4.75%. The TUKSoD sagittal occlusion prevalences are: Class I 77.69%, Class II 14.78%, and Class III 7.53%.

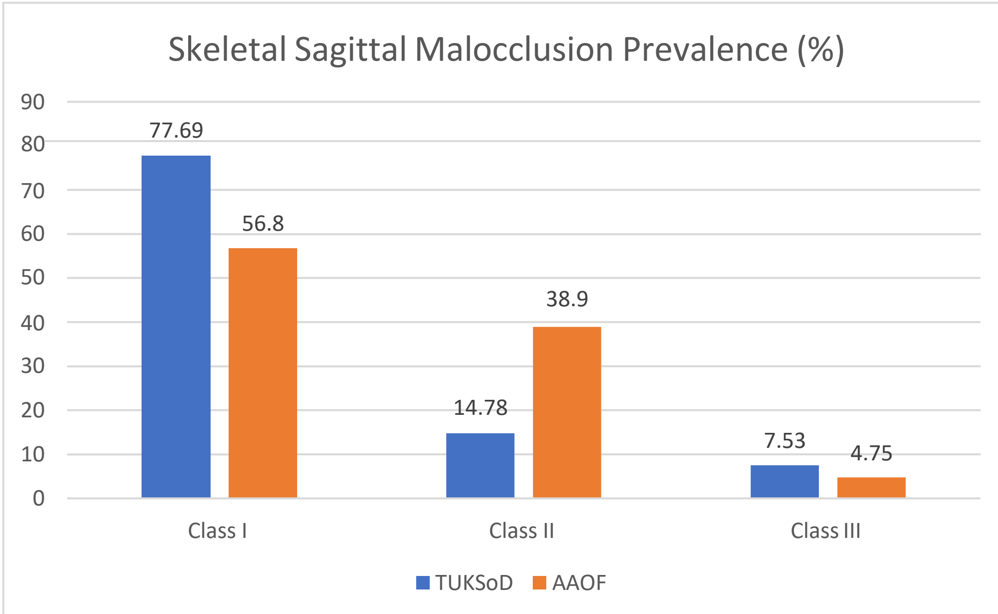

Figure 13, Skeletal Sagittal Malocclusion Prevalence

The vertical skeletal occlusal pattern was determined using the Frankfort Horizontal-Mandibular Plane Angle in the AAOF Legacy Collection, and the Margolis line relating the mandibular plane to the occiput in the TUKSoD population. These comparisons are represented in Figure 14**.**

7.51% of the TUKSoD population was considered to have a skeletal deep bite, while 11.0% of the AAOF Legacy Collection had a skeletal deep bite. Skeletal open bites were seen in 5.2% of the TUKSoD Population, and 23.5% of the AAOF Legacy collection group.

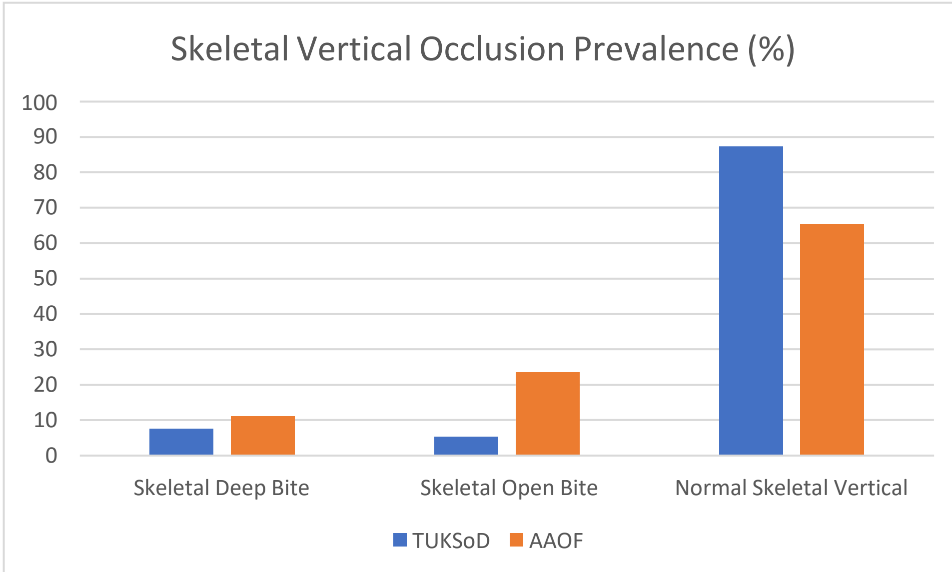

Figure 14, Skeletal Vertical Occlusion Prevalence

The total findings are summarized in Table 1. Chi-2 tests were used to determine the statistical significance of any difference in the distribution of categories in each trait. For example, in the dental-sagittal, a p-value of less than 0.05 would indicate that the distribution of Class I, II, and III is significantly different in the TUKSoD population than it is in the NHANES III population.

Significant differences were found for all dental comparisons: Sagittal (Class-I,II,III; p=8.59E-7), Vertical (Open-bite/Deep-bite; p=1.53E-13), and Transverse (crossbites). Significant differences were found for all skeletal comparisons: Sagittal (Class-I,II,III; p=5.38E-6), and Vertical (Open-bite/Deep-bite; p=8.89E-5). No p-value is available for dental crossbites, as this trait was recorded simply as “present” or “absent,” and could not be analyzed on the basis of distribution across a population.

Table 1, *Statistical Significance of Findings*

Dental	TUKSoD (%)	NHANES (%)	p-values
Class I	48.33	41.1	8.59E-07
Class II	25.27	53.5	
Class III	13.72	5.6	
Deep-Bite	28.81	49	1.53E-13
Open-Bite	15.65	3.3	
Crossbite	32.16	14.7	
Skeletal	TUKSoD	AAOF-LC	
Class I	77.69	56.8	5.38E-06
Class II	14.78	38.9	
Class III	7.53	4.75	
Deep-Bite	7.51	11	8.89E-05

CHAPTER 6

DISCUSSION

Orthodontists use normative values and standards of occlusion to determine treatment goals and, increasingly, indications for treatment need. The objective of this study was to evaluate a genetically diverse contemporary patient population and to compare the malocclusion prevalence in this population to historic normative populations. The results of this comparison could indicate the validity of these historic populations in describing malocclusion prevalence in the United States today. In total, 7,713 patients from the Temple University Kornberg School of Dentistry Orthodontic screening clinic were compared to approximately 7,000 patients from the NHANES III dental study for dental occlusal characteristics, and the American Association of Orthodontists Foundation Legacy Collection for skeletal characteristics. Significant differences were found across all measured comparisons.

The majority of existing studies on occlusion and malocclusion prevalence have examined racially homogenous populations in relatively small sample sizes. There are few, if any contemporary studies on malocclusion examining a large sample size, and none examining skeletal malocclusions in such a group. Our study examines a very large racially and genetically diverse population and acknowledges it as such. The malocclusion prevalence seen in this population differs significantly from both the NHANES III and AAOF Legacy Collection studies. The NHANES III stratified the examined population into Caucasian, Hispanic, and African-American groups, all of which were significantly different from the TUKSoD population. The primarily Caucasian population represented by the AAOF Legacy Collection also varied significantly in prevalence from the TUKSoD population.

Several interesting correlations may be noted in the TUKSoD population. First, in the sagittal dimension: When compared to the NHANES III, the TUKSoD population presents with a significantly higher prevalence of both Class I and Class III malocclusions, and a significantly lower prevalence of Class II malocclusions (**Table 2**). This pattern is replicated in the comparison between the TUKSoD population and the AAOF Legacy Collection with regards to sagittal skeletal pattern.

Table 2, *Sagittal Correlations*

Dental	**TUKSoD (%)**	**NHANES (%)**
Class I	48.33	41.1
Class II	25.27	53.5
Class III	13.72	5.6
Skeletal	**TUKSoD**	**AAOF**
Class I	77.69	56.8
Class II	14.78	38.9
Class III	7.53	4.75

While there is a direct correlation noted between the sagittal dental and sagittal skeletal patterns in the TUKSoD population compared to the control groups, there is an inverse correlation between the dental and skeletal open bite prevalence when compared to the controls.

Dentally, the TUKSoD population presents a 474% increase in open bite prevalence as compared to the NHANES III population (15.65% of cases compared to 3.3%, respectively). We might expect this increase to also be seen regarding skeletal open bites, as prior studies have noted the association between skeletal hyperdivergent patterns and dental open bites (Santo, 2020). However, the TUKSoD population displays skeletal open bite/hyperdivergent patterns 78% less often than was observed in the AAOF Legacy Collection group (5.2% of cases compared to 23.5%, respectively). This may indicate the presence of a confounding environmental factor, such as a high frequency of persistent digit-sucking habit (Tanaka, 2016), or possibly a genetic component influencing morphology.

Statistical analysis regarding dental crossbites in this study is not available, as crossbites were recorded simply as present or absent in both the TUKSoD and NHANES III population. However, the clinical significance of this difference cannot be ignored. Dental crossbite prevalence in the TUKSoD population was 32.16%, approximately 3.5 times the prevalence observed in the NHANES III group (9.1%). Dental crossbites are a specific form of malocclusion that often require particular mechanics and attention to successfully eliminate, and this distinct difference in prevalence would therefore be a clinically significant issue. Proffit, et. al (2018) noted several etiologies of crossbites that may be relevant to the TUKSoD population. First noted are prolonged digit sucking habits, which may result in narrowing of the maxillary arch and lingual crown torque of the maxillary posterior teeth. Since digit habits may also contribute to dental open bites (Tanaka, 2016), these characteristics may be related to a common environmental factor. Second, a significant sagittal skeletal discrepancy may be a factor in creating a posterior crossbite. Mandibular prognathism and maxillary retrognathism may create a dental crossbite even in the absence of a skeletal transverse discrepancy. Given the increased prevalence of Class III dental and skeletal relationships observed in the TUKSoD population, this seems likely to be a contributing factor and merits further study on a refined sample size.

Study Limitations and Suggestions for Future Research

The primary study limitation is the lack of a single, standardized method to defining malocclusion. Although dozens of studies on malocclusion prevalence have been performed on various groups, many of these studies use different tools to determine the presence of absence of malocclusion. For example, in the dental sagittal characteristic, Angle's molar classification, canine relationship, and overjet have all been used to define class I, II, and III. Similarly, there are numerous was to define skeletal hyper and hypodivergence, and utilizing different methods may well yield different results.

Unfortunately, the NHANES III study is challenging to examine based on sheer size and the lack of digitally available raw data. The work of Proffit, Fields, and Moray (1998) provides an excellent window into this data, but the actual records are not publicly available at this time. This prevents re-examination of these records to determine validity across a variety of measurement protocols.

The American Association of Orthodontists Legacy Collection is an excellent resource and perhaps an ideal template on which similar projects should be based. The raw cephalograms are publicly available, and there is a high degree of interaction that anyone using the AAOF-LC website can utilize. The limiting factor of this collection and therefore our study is that it is comprised almost entirely of Caucasian subjects from the early-to-mid 1900s, and therefore may not be a representative control group. This study currently not reproducible due to ethical concerns related to safe radiation exposure practices.

Human error in measurement is a major limitation of this study, as the approximately 15,000 subjects whose records comprise this data were all examined by humans. Calibration protocols exist for the record taking in all three populations, but some degree of error is still anticipated. In the TUKSoD screening clinic, for example, clinical findings are first recorded on paper during the examination, and are transferred to the patient's electronic chart after the appointment, which creates an opportunity for error. Additionally, if a patient elects to not proceed with treatment, comprehensive radiographic and photographic records may not be obtained, which prevents confirmation of the recorded occlusion.

One potential future area of study in the TUKSoD population would be a closer examination of dental crossbites. Specifically, determining the etiologies underlying this increase in prevalence and what percentage of that increase each etiology is responsible for.

The increase in both dental and skeletal Class III malocclusions is a notable correlation, but further cephalometric review of the dental Class III patients to determine if they are primarily skeletal Class III, at least to the extent that they are over-represented compared to the control populations.

This study did not examine patients in the transverse skeletal dimension. Unfortunately, due to the fact that traditional analysis of the transverse skeletal dimension was accomplished using posteroanterior cephalograms, such studies are in short supply. These cephalograms are not typically part of the standard records taken prior to orthodontic treatment. The majority of studies involving these records focus on patients with significant asymmetries or surgical treatment plans, which biases the study from the outset. As orthodontic record taking shifts towards three-dimensional CBCT analysis, it is likely that the supply of data on this dimension will increase and may create opportunities for future studies.

CHAPTER 7

CONCLUSIONS

The null hypothesis was rejected. The orthodontic screening population at the Temple University Kornberg School of Dentistry demonstrates significant variance in the prevalence of dental malocclusion characteristics from the NHANES III study, and skeletal characteristics from the AAOF Legacy Collection. It is important to remember that these high-quality historic collections examine specific groups at specific periods in history. We conclude that generalized malocclusion statistics in the United States should not be viewed as reliable descriptors of regional populations. More specifically, terms such as “African-American,” “Asian,” “Caucasian,” and “Hispanic” represent groups too large and diverse genetically and phenotypically to be grouped under single categories for cephalometric norms. To summarize:

- The TUKSoD population demonstrated significantly different prevalence in malocclusion across all factors when compared to normative populations.
- The dental and skeletal sagittal malocclusion distributions correlated with each other, both presenting an increase in Class I and Class III prevalence and a decrease in Class II prevalence.
- A follow-up study is needed to examine possible environmental factors related to the increased crossbite and open-bite prevalence in the TUKSoD population.

- As the population of the United States becomes increasingly genetically heterogenous (Kermany, 2015), the usefulness of population studies on malocclusion may decrease, highlighting the need to focus research efforts on personalized genetic testing to determine malocclusion characteristics.

A recent systematic review (Alhammadi, et. al, 2019) reviewed the global distribution of malocclusion traits and referenced the NHANES III analysis (Profitt, 1998) as the most recent analysis on the United States population and the most recent conducted in North America. Considering the significant differences existing between the population examined in the NHANES III and TUKSoD studies, the classical interpretation of malocclusion prevalence in North America may be inaccurate. Given the size and scope of the TUKSoD study, it may serve as a more modern view into a contemporary diverse population than prior studies.

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APPENDICES

APPENDIX A

AXIUM SCREENING FORM

Screening

Form Question	Answer
Diagnosis	
Dental stage	
Occlusion:	
Anterior-Posterior	
Vertical	
Transverse	
Arch Length	
Skeletal Type:	
Anterior-Posterior	
Vertical	
Transverse	
Functional	
Recommendations	
Assign to Graduate Ortho?	
Defer assignment to Graduate Orthodontics?	
Deny Assignment since no tx necessary	
Deny assignment due to malocclusiontype or special circumstance	
Possible Tx Plan Type: select all that apply	

APPENDIX B

RAW DATA CHART OF TUKSOD SCREENING CLINIC

Pt. Pat	Pt. Cha	Pt. Last	Pt. Firs	Pt. Sex	Pt. Birt	Pt. Age	Pt. Zip	Form C	Form T	F.Item	F.Item Text	F.Ans.
776	****	****	****	Male	****	38	****	ORTSCF	Shared	1	Dental stage	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Class I	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	ClassII	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	ClassIII	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Open Bite	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Deep Bite	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Cross Bite Left	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Cross Bite Right	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	crowding Maxilla	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Crowding Mandibl	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Spacing Maxilla	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Spacing Mandible	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Skeletal Class II	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Skeletal Class III	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Normal	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Skeletal Open Bite	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Skeletal Deep Bite	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Average	Yes
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Broad	No
776	****	****	****	Male	****	38	19126	ORTSCF	Shared	1	Narrow	No
.--Subjects 2 through 7,712--.												
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Dental stage	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Class I	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	ClassII	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	ClassIII	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Open Bite	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Deep Bite	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Cross Bite Left	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Cross Bite Right	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	crowding Maxilla	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Crowding Mandibl	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Spacing Maxilla	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Spacing Mandible	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Skeletal Class II	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Skeletal Class III	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Normal	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Skeletal Open Bite	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Skeletal Deep Bite	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Average	Yes
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Broad	No
1E+06	****	****	****	Female	****	18	****	ORTSCF	Shared	1	Narrow	No

APPENDIX C

AAOF LEGACY COLLECTION SEARCH

AAOF Craniofacial Growth Legacy Collection

Home | Collections | Search | About | Help

Search by Cephalometric Measurement and Age

Find Timepoints for Subjects from [Any] Collection
where the value of [Frankfort-Mandibular Plane Angle] at Age [Any Age]
is greater than [0] and is less than [20]

[Search Legacy Collections] • Mouse over values for descriptions • Click Subject Name for Images • Click column heading to sort table • Shift click for multiple column sort

Copy | CSV | Print

Collection	Subject	Image	Sex	Class	Age	SNA	SNB	ANB	NP2PA	NP2PO	SNDST	SNFHA	CONVX	WITSA	AB2FH	OB_FH	OJ_OC
Bolton-Brush Growth	B0387	3	M	Class III	16	85.8	88.3	-2.5	-2.1	-11.6	69.6	6.4	181.1	5.6	-5.7	2.8	2.7
Bolton-Brush Growth	B4377	2	F	Class III	6	79.5	82.7	-3.1	1.4	-4.3	62.2	8.7	178.1	n/a	-3.2	n/a	n/a
Bolton-Brush Growth	B4377	4	F	Class III	7	79.0	81.5	-2.5	0.5	-5.8	63.5	10.5	179.5	n/a	-3.2	n/a	n/a
Burlington Growth	76	4	M	Class I	18	86.3	85.4	0.9	-2.1	-3.8	67.6	6.1	168.8	-1.7	-0.1	1.8	1.8
Burlington Growth	76	3	M	Class I	16	86.1	86.1	-0.0	-1.3	-3.4	66.5	5.5	167.6	-1.3	-1.0	2.2	2.2
Burlington Growth	114	4	F	Class I	16	80.1	77.7	2.5	-3.9	-6.0	64.4	14.2	173.0	1.1	1.0	2.5	2.6
Burlington Growth	847	4	F	Class II	16	87.1	82.3	4.8	-1.8	4.4	59.5	5.0	162.8	1.2	5.7	2.1	2.6
Denver Growth	529	4	M	Class II	12	78.2	78.0	0.1	0.8	-3.2	66.7	11.0	173.1	-1.8	0.6	2.7	2.9
Denver Growth	529	9	M	Class II	17	80.4	80.4	-0.0	3.4	0.4	69.8	5.8	176.0	-0.7	2.2	2.2	2.3
Denver Growth	529	1	M	Class II	9	77.1	75.8	1.3	1.0	-0.5	64.9	11.7	173.3	0.4	2.4	3.1	3.2
Denver Growth	529	8	M	Class II	16	80.5	81.0	-0.5	4.4	1.9	69.9	4.4	174.4	-1.6	2.3	2.2	2.4
Denver Growth	529	6	M	Class II	14	80.5	79.8	0.7	4.3	3.3	68.5	4.7	172.8	0.9	3.5	2.2	2.4
Denver Growth	529	10	M	Class II	19	81.3	80.5	0.9	3.8	3.3	69.1	4.4	175.1	-0.9	3.7	2.5	2.8
Denver Growth	529	3	M	Class II	11	77.0	77.7	-0.7	6.0	5.6	66.1	5.8	174.1	-0.7	2.8	1.9	2.4
Denver Growth	529	2	M	Class II	10	77.3	76.8	0.5	4.8	4.9	65.3	7.1	170.8	0.7	3.4	2.2	2.6
Denver Growth	529	5	M	Class II	13	79.6	78.7	0.9	4.1	4.1	67.3	5.7	174.1	1.6	3.6	2.0	2.2
Denver Growth	529	7	M	Class II	15	80.2	80.2	0.0	7.0	7.1	69.1	2.0	174.8	-1.0	4.2	2.0	2.3
Denver Growth	588	8	M	Class I	17	83.4	81.5	1.9	1.2	4.0	68.8	5.5	165.4	1.8	3.8	2.9	3.5
Denver Growth	588	9	M	Class I	19	83.0	81.1	1.8	2.0	5.9	70.1	5.0	167.1	0.7	4.4	3.0	3.7
Forsyth Twin	03-11	11	M	Class I	16	75.3	77.2	-1.9	-1.1	-10.3	77.5	15.7	184.3	0.9	-3.8	4.8	4.3
Forsyth Twin	03-11	1	M	Class I	5	74.8	74.0	0.8	-5.2	-8.7	66.6	21.8	174.3	n/a	-2.4	n/a	n/a
Forsyth Twin	03-11	8	M	Class I	13	72.6	74.3	-1.7	-0.5	-6.8	74.3	17.9	180.2	0.8	-3.0	5.2	4.8
Forsyth Twin	03-11	12	M	Class I	17	74.4	77.3	-2.9	4.9	-2.2	78.6	11.0	185.4	1.7	-2.1	4.6	4.4
Forsyth Twin	03-11	2	M	Class I	6	78.1	75.2	2.9	-2.2	-0.1	65.4	14.7	171.4	1.1	2.4	3.2	3.3
Forsyth Twin	03-11	4	M	Class I	9	70.5	72.5	-2.0	3.4	0.1	72.6	15.8	179.3	0.7	-0.8	1.6	1.7
Forsyth Twin	03-11	5	M	Class I	10	72.2	72.1	0.1	1.6	-0.2	72.7	16.1	175.9	0.4	1.1	4.0	4.1
Forsyth Twin	03-11	3	M	Class I	8	72.0	73.0	-1.0	1.5	0.0	71.4	16.2	177.4	n/a	-0.4	n/a	n/a
Forsyth Twin	03-11	9	M	Class I	14	73.8	75.7	-1.9	2.4	-1.6	75.1	13.9	182.3	0.6	-1.7	4.3	4.2
Forsyth Twin	03-12	8	M	Class I	13	75.2	75.8	-0.5	0.1	-2.8	74.9	14.7	174.9	1.6	-0.8	3.6	3.3
Forsyth Twin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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APPENDIX D

TOTAL NUMERICAL DATASET FOR TUKSOD, NHANES, AAOF GROUPS

Malocclusion Prevalence from the Orthodontic Screening Clinic, Temple University			NHANES III Traits / AAOF Traits	
Trait	Total	Prevalence as Percent of Total (observed)	Prevalence as Percent of Total (expected)	
Total Number of Unique Patients Screened	7713	100	7000________1198	
Female Patients	4658	60.39154674		
Male patients	3055	39.60845326		
Class I Male & Female	3728	48.33398159	41.1	
Class II Male & Female	1949	25.26902632	53.5	
Class III Male & Female	1058	13.717101	5.6	Dental Sagittal
Skeletal Class I Male & Female	5992	77.68702191	56.8	
Skeletal Class II Male & Female	1140	14.78024115	38.9	
Skeletal Class III Male & Female	581	7.532736938	4.75	Skeletal Sagittal
Patients with Dental Deep Bite	2222	28.80850512	49	
Patient with Dental Open Bite	1207	15.64890445	3.3	Dental Vertical
Patients with Skeletal Deep Bite	579	7.50680669	11	
Patients with Skeletal Open Bite	401	5.2	23.5	Skeletal Vertical
Patients with Crossbite R Only	887	11.50006483		
Patients with Crossbite L Only	833	10.79994814		
Patients with R/L Crossbite	761	9.866459225		
Total Patients in Crossbite	2481	32.16	14.7	Dental Transverse