1-1-2023

Assessing The Accuracy Of Dental Age Estimation Methods In A Native American Pediatric Sample

Cal Matthew McGehee

ASSESSING THE ACCURACY OF DENTAL AGE ESTIMATION METHODS IN A NATIVE AMERICAN PEDIATRIC SAMPLE

A Thesis
presented in partial fulfillment of requirements
for the degree of Master of Arts
in the Department of Sociology and Anthropology
The University of Mississippi

by

Cal Matthew McGehee

May 2023

ABSTRACT

Dental age estimation is a common method used to determine the age of juvenile individuals in forensics, medicine, and bio-archaeology. This thesis examines how accurate three dental development methods are in estimating the ages of two Native American sample groups. Further, it will explore how different variables like sex, age, secular (temporal) change, and an individual's body mass index (BMI) affect dental development rates in the two groups of individuals. The first group consists of 60 Native Americans between the ages of 7 and 21 years of age who received dental work between 1970-1990 by Dr. James Economides of Albuquerque, New Mexico. The second group consists of 165 contemporary New Mexico Native Americans who died between the ages of 0.6 months to 20.9 years of age between 2011-2019. This thesis examines the radiographs and postmortem computed tomography (PMCT) scans to determine tooth maturity and estimate the individuals' ages using the London Dental Atlas (2011), Ubelaker's dental charts (1989), and the Moorrees et al. dental charts (1963). Average group real ages were calculated, along with the average group age estimates to determine a mean age difference, referred to as the Delta Age.

The results reveal that the London Dental Atlas (AlQahtani et al., 2010), was the most accurate method, with an average Delta Age of around +0.50 years for both sample groups. Ubelaker's dental charts had an average Delta Age of around -0.67 years, and the Moorrees et al. charts were the least accurate with Delta Ages of -2.92 and -3.01 for each group respectively. There was some evidence to suggest that between the ages of 7-16, females age estimates are

consistently overestimated, indicating they are more dentally mature than their male counterparts until age 17, at which point the third molar is the last tooth developing in the dentition and males are more dentally advanced. The were no obvious changes in tooth variation between the sample groups and the London Dental Atlas and there was little evidence to suggest that factors such as obesity, measured through an individual's BMI, and secular change, have a significant effect on dental development for the sample groups in this study. Overall, it seems that the main reason for the difference between an individual's real age versus their estimated age is dependent upon the dental development method utilized and the natural variation in an individual's dental development.

DEDICATION

This thesis is dedicated to my parents. Without their love and support, I might have not taken the steps needed to enter graduate school and develop a thesis. They pushed me to use my intelligence and my drive for learning to continue my education, where I have learned much and met many great people.

ACKNOWLEDGMENTS

My deepest gratitude towards my academic advisor Dr. Lexi O'Donnell. Dr. O'Donnell, you have always been there to offer me advice and support during the writing of this thesis. Your expertise with dental anthropology and the sample groups, as well as insight into my writing abilities, helped me to stay on track and was vital to my completing this thesis and making it as excellent as possible. I take great pride in being your student and I can only offer my deepest gratitude for all you've done for me in both my undergraduate and graduate studies.

I would also like to thank Dr. Carolyn Freiwald and Dr. Matthew Murray as individuals who have mentored me and agreed to be members of my thesis committee. Dr. Freiwald, in my undergraduate studies you always encouraged me and believed I have the potential to do great things. That only grew as I entered graduate school and began to write my thesis, where you always demonstrated the utmost confidence in my ability to write a great thesis. Dr. Murray, you taught me how to be a professional writer and take pride in my work. You have always encouraged me and complimented my writing, offering steadfast support for my abilities.

I want to give a heartfelt thank you to the friends I have made along my journey through graduate school. To my colleagues, Kolbe, Nikki, and Max, thank you all for being great friends and colleagues to work with and hangout together. From sitting in the office helping to edit our papers for Dr. Mendoza, to suffering together during our comprehensive exams, we've had some interesting times together. To my friends I made in the South Oxford Center: Katie K., Sam, Katie R., Marley, Case, Will, Acadia, Emily, Emmie, Will, Natalie, and Matthew, thank you all for the fun if strange and wacky times in the lab. Your friendship and support mean more to me than you all realize.

TABLE OF CONTENTS

LISTS OF FIGURES

FIGURE PAGE

LIST OF TABLES

Chapter 1: Introduction

Estimating age is important to archaeologists, forensic anthropologists, and medical practitioners. In archaeological contexts, the age of the deceased is often unknown, and accurate age estimates can potentially inform bioarchaeologists about a population's health and mortality patterns (Buckley, 2000; Raitapuro-Murray et al., 2014; Vodanović et al., 2005). In forensic cases, age estimates are used in conjunction with other biological markers to identify deceased individuals of unknown identity (Balla et al., 2019; Schmeling et al., 2001; Thevissen et al., 2010). For medical purposes, having an accurate age estimate can allow for the planning and deployment of proper medical treatment, as certain medications and surgical operations may not be suitable for individuals of older or younger ages (FDA.gov; Geifman et al., 2013).

Age estimation is usually dependent upon the remains made available to a coroner, pathologist, forensic anthropologist, or other professionals attempting to identify human remains. In an ideal circumstance, the estimated age would be based on a combination of skeletal and dental development in children/adolescents, and observing dental and skeletal wear in adults. Skeletal and dental age estimations may be used independently of one another, but these methods work best if used in combination, wherever possible. However, teeth most often provide the best evidence for age estimation, as they are highly resistant to external factors such as fire, weather, or erosion after death and during decomposition (Forshaw, 2014; Manoilescu et al., 2015). In archaeological contexts, teeth often outlast bones by hundreds or thousands of years of environmental exposure and animal predation, leaving teeth as the main source of biological information about past populations (Forshaw, 2014; Irish & Scott, 2016). In most legal and forensic cases, teeth are used by forensic odontologists to determine a person's identity in several contexts. Institutions including the American Academy of Forensic Sciences and the International Association of Identification teach forensic odontology in their classes for educational forensics in how teeth can be used as evidence in legal cases (Krishan et al, 2015).

Several methods exist which are used in estimating an individual's age from infancy to adulthood. For adults, studying the attrition of the enamel is common because teeth can better withstand a variety of factors than other bodily tissues, including food acids, soil pressure, water movement, and other factors (Lease, 2016). Furthermore, enamel does not regrow, making each tooth a "permanent record, unlike skeletal and all other tissues of the body" (Larsen, 2016). Additional methods for estimating adult ages using teeth include dental wear, dental caries prevalence, gingival emergence/eruption, root resorption, tooth root/dentin translucency, and measuring the pulp-to-tooth area ratio (Manjunatha & Soni, 2014; Puranik et al., 2015; Verma et al., 2019; Vodanovic et al., 2011). Each of these methods works in different manners, measuring various parts of teeth and their growth and wear to determine age, providing age estimates of varying reliability (Graham et al., 1974; Maber et al., 2006; Puranik et al., 2015; Roberts et al., 2008). However, many of these methods are applicable only after the tooth is fully developed, meaning they are exclusive to adults.

When studying children and adolescents, the most common age estimation practice is to measure tooth development and overall growth patterns along the teeth, alongside the timing of their eruption (AlQahtani et al., 2014; Balwant & Anand, 2006; Santana et al., 2017). Tooth development, or odontogenesis, refers to the cellular formation and growth of a tooth and its different structures such as its roots, enamel, and dentin (hopkinsmedicine.org, n.d; Rathee &

Jain, 2021). Tooth eruption is a process of tooth development in which the tooth physically "erupts" past the gingiva, or gum line, inside the mouth and becomes visible (Kjær, 2014).

The overall process of dental development is largely determined by genetics and hormonal signals controlled by the brain and sent throughout the body (Lewis & Garn, 1960, Thesleff, 2006). To be specific, odontogenesis is controlled by homeobox (HOX) genes (Cakan et al., 2013) and through several neural signals transmitted from the skin cells of the mouth and embryonic cells during fetal growth (Bei, 2009). Despite the mostly internal genetic causes of tooth development, there is a debate concerning the influence external factors such as malnutrition and diet can have on dental development. Research has provided evidence that suggests that malnutrition and a poor diet can affect skeletal growth, but other studies suggest they have less of an effect on tooth growth and dental eruption (Cameriere et al., 2007; Cardoso, 2007; Elamin & Liversidge, 2013; Garn et al., 1965). Alternative research suggests that such external sources have a noticeable effect on dental development, often delaying or stunting tooth growth and eruption (Alvarez & Namia, 1989; Heinrich-Weltzien et al., 2013; Holman & Yamaguchi, 2005). This debate and subsequent studies conducted on the topic have the potential to change the way age estimation is conducted on populations which might be more exposed to these external environmental and socio-economic factors involved in an individual's diet.

An individual's health status may also affect dental development. The available literature on the relationship between disease and dental development shows that certain chronic illnesses like celiac disease, chronic renal failure, and cancer might negatively affect dental development (Alamoudi et al., 2020; Campisi et al., 2007; Jaffe et al., 1990; Proctor et al., 2005). Other studies have found that obesity, a disease caused by a multitude of environmental and socio-economic factors, is associated with accelerated dental development in several sample groups of juveniles (Cardono, 2021; Garn et al., 1965; Hilgers et al., 2006; Kadavy, 2017; Must et al., 2012; Nicholas et al., 2018). There is far less literature regarding dental development and its association with being underweight (Hedavati & Khalafinejad, 2014; Kadavy, 2017; Kumar et al., 2013).

In legal and forensic cases, forensic anthropologists attempt to identify deceased individuals, often using only skeletal remains (Ubelaker, 2006). Data such as height, geographic ancestry, sex, and age are used to create a profile that the police and other government agencies might use to help identify a deceased person. In addition, accurate age estimates are needed for forensic legal cases involving identifying immigrants and asylum seekers who are unable to provide information regarding their identity (Schmeling et al., 2001). Therefore, obtaining accurate age estimates through observing and measuring the rate of dental development is essential for the identification of juveniles in a variety of situations.

In archaeological contexts, accurate age estimations are used to study a population's health. Bioarcheologists use age estimation to track mortality patterns and health issues facing juveniles, the most vulnerable population to disease and environmental factors. However, ascertaining the health status of the deceased in an archaeological sample is arguably more difficult as compared to living individuals due to what is known as the Osteological Paradox (Wood et al., 1992). The Osteological Paradox discusses how the dead can reveal patterns of selective bias, or where deceased individuals may have died before signs of disease or other negative health consequences developed on the bones (Wood et al., 1992). In addition, certain health conditions such as obesity, are not readily observable in archaeological assemblages. This makes it difficult to determine how certain illnesses and diseases might have affected the dental development of past populations, which could affect age estimation in such cases.

An additional issue that should be considered when estimating the age of individuals from an archaeological population is changes in dental development rates. Evidence suggests that modern humans are reaching puberty earlier than in the past (Parent et al., 2003; Worthman et al., 2010). However, past populations had different lifestyles, diets, and overall levels of health that undoubtedly influenced the overall development of these people. This, and any other temporal and evolutionary changes in the body occurring over generations has been referred to by the term “secular,” (Weisensee & Jantz, 2011). If the overall process of puberty can be subject to change over time, then it is possible that the process of dental development could be described as secular itself. There are several studies which suggest this is the case, and I seek to see if this is also true in my testing (Heuzé et al., 2008; Nadler, 1998; Sasso et al., 2013; Vucic et al., 2014).

The goal of this thesis is to answer several different but connected questions related to the accuracy of age estimation methods derived from measuring dental development. It explores factors which may influence age estimation such as sex, variation in tooth development, secular change, and obesity as observed through an individual’s body mass index (BMI). The study examines two different groups of children/adolescents from New Mexico who are classified as Native American through race and/or ethnicity (see next section). The first group consists of living individuals who received orthodontic care from Dr. James Economides between the 1970s to the 1990s. The second group is composed of deceased individuals who died in New Mexico between 2011 and 2019 and were examined at the New Mexico Office of the Medical Investigator (OMI). Age estimates will be determined using three different methods, 1. Moorrees et al. Dental Charts (1963a, 1963b), 2. Ubelaker’s Dental Charts (1979), 3. The London Dental Atlas (AlQahtani et al, 2010).

Race & Ethnicity

The individuals in this thesis are described as Native American (a more detailed discussion can be found in the methods section). However, modern anthropologists, biologists, and other scientists recognize that the race concept is not a biological truth, but is instead a social construct that combines phenotypic genetics expressed through physical traits, along with cultural traits, to create what is known as a "race" (Ford & Kelly, 2005; Gravlee, 2009; O'Donnell & Edgar, 2020).

Despite the recognition that race is a cultural/social construct, the construction of race has real and lasting biological impacts which affect both the physical and mental health of both an individual and a larger population (Gravlee, 2009; O'Donnell & Edgar, 2020; Santos et al., 2009). The use of race also affects forensic identification and age estimation, as racially categorized populations are believed to have different physical characteristics (Blumenfeld, 2000; Yahya et. al, 2013), as well as different rates of dental development (Adams et al., 2019; Steggerda & Thomas, 1944). Therefore, the social construct of race is still a topic that is explored in anthropological research. However, this thesis does not support or attempt to justify negative views or stereotypes of individuals who are socially classified as belonging to any race category.

Unlike race, ethnicity refers to a common identity shared by a group of people based on shared cultural practices, traditions, history, and/or religion (Ford & Kelly, 2005; Ford et al., 2010; Munasinghe, 2018). Like race, ethnicity is a Western social construct that in the recent era of post-colonialism, has been used to separate groups by common ancestry and shared beliefs. According to Hutchinson & Smith (1996: 6-7), six recognized features constitute an ethnic group:

> 1. a common *proper name*, to identify and express the "essence" of the community;
>
> 2. a myth of common ancestry that includes the idea of common origin in time and place and that gives an ethnie a sense of fictive kinship;
>
> 3. shared historical memories, or better, shared memories of a common past or pasts, including heroes, events, and their commemoration;
>
> 4. one or more elements of a common culture, which need not be specified but normally include religion, customs, and language;
>
> 5. a link with a homeland, not necessarily its physical occupation by the ethnie, only its symbolic attachment to the ancestral land, as with diaspora peoples; and
>
> 6. a sense of solidarity on the part of at least some sections of the ethnie's population

Frequently, ethnicity is used interchangeably or side by side in a sort of dichotic relationship with race (Baumann, 2004). However, race is attributed to a person from outside groups separate from the community into which a person is born. Ethnicity is defined by members of a group within a community (Baumann, 2004). In this sense, ethnicity is a form of social identity used by a person to identify themselves both within, and outside of, their community. This definition is important, as the individuals studied in this thesis were unable to provide their personal beliefs regarding their ethnicity. Instead, their ethnicity was viewed much like their race and attributed to them through things such as names, physical characteristics, and other cultural and biological factors.

In this thesis, all research questions or hypotheses focus on the social construction of race and its impacts on people's health. All people physically embody their social and cultural experiences, and this thesis attempts to avoid mixing the biology of skin color, genetics, or the geography of location as something innately found inside someone that causes them to be a certain "race" (Krieger, 1999; Krieger, 2010). However, most individuals today associate certain genetic ancestry with a socially constructed race. In a study of schoolchildren in Brazil, researchers listened to the childrens' self-reports of their races and then told them the percentage of their genetics which were "European," "American Indian", or "African". Many of the individuals contested their genetic ancestry results in favor of their views of their self-perceived race, demonstrating the connection between a person's ideas about race and ancestry (Santos et al., 2009). In this thesis, any "differences" identified by the present for the Native American samples during the research most likely stem from the specific culture within which I as the researcher live and operate, and the larger standards set by other anthropological researchers. Ultimately, how I view someone who is "Native American" in my research, is not the same as how someone born and raised in an ethnic community that classifies itself as "Native American" might identify themselves and their ethnicity.

Research Questions & Hypotheses

In this thesis, I address five interrelated research questions and provide the background information necessary to explain the hypotheses and expected results. The background section of this thesis explores the ideas more thoroughly. Below are five hypotheses I formulated for this thesis to attempt to answer.

1. **Which of the three methods of age estimation (Moorrees et al. 1963; Ubelaker 1978; AlQahtani et al. 2010) is the most accurate when applied to a Native American population?**

   Past studies of dental age estimation methods have shown that different geographic and genetic populations have different rates of dental development (Dhamo et al, 2018; Tompkins, 1996). Studies have also shown that some dental development age estimation methods are not as accurate when applied to certain populations and in people with specific health conditions and that those groups need specific methods created for them (Adams et al., 2018; Pereira et al., 2019; Putri et al., 2021). If all three methods have large margins of error for individuals who died of natural causes, a new or updated method of dental age estimation is likely necessary for Native American populations and for individuals who are ill. The expected result of this first hypothesis is that Ubelaker's dental charts (1978) will be the most accurate due to similarities in sample groups, with the London Dental Atlas (2010) being the next most accurate, and the Moorrees et al. dental charts (1963a, 1963b) being the least accurate of all three methods selected in this thesis.

2. **Do differences exist between the sexes in dental development?**

Research on dental development and sexual dimorphism reveals that males and females differ in their rates of dental development for both deciduous and permanent dentition (Garn et al., 1958; Meredith, 1946; Steggerda & Thomas, 1944). I will examine individuals of both sexes, along with individuals who have both deciduous and permanent teeth, [mixed dentition], to test if age estimates are consistent within a Native American population of differently aged individuals. The expected result is that females will display more advanced rates of dental development, based on previous studies (Garn et al., 1958; Meredith, 1946; Steggerda & Thomas, 1944). This means that males' age estimates will be closer to their real ages, while females' age estimates will be consistently older than their real ages. However, this also depends on the overall accuracy of the dental age estimation methods tested.

3. **Are certain teeth more prone to being under or over-developed compared to the rest of the teeth?**

   This question is relevant because some teeth, such as the third molars, are the only teeth still developing past the age of 14 (Liversidge & Marsden, 2010). Furthermore, certain teeth are highly variable in the timing of their formation, mineralization, and eruption (Mincer et al., 1993; Trakiniene et al., 2019). For my third hypothesis, I expect that third molars are more variable in their development rates than other teeth, with canines being another possible tooth with more variable dental development rates than other teeth.

4. **Is there evidence of secular change in dental development?**

   It is known that the dental development rates of individuals several hundreds of years ago differ from those of modern populations (Heuzé et al., 2008; Nadler, 1998; Sasso et al., 2013; Vucic et al., 2014). Although the two groups involved in this study are not separated by hundreds of years, in some cases there is a difference of several decades. Therefore, I attempted to view signs of changes in dental development rates among the older generation of individuals compared to individuals in the newer generation. The expected result is that there will be a small, but statistically significant amount of change between these two groups in terms of dental development. More specifically, individuals from Group 2, who are of a more recent generation, will have a noticeable difference in the rate of their dental development than similarly aged individuals from Group 1, who are from an older generation.

5. **What is the relationship between body mass index (BMI) and an individual's dental development?**

Contemporary research has shown that individuals with high BMI have more advanced rates of dental development and eruption compared to individuals with normal BMI, even after accounting for differences in sex and ancestry (Must et al., 2012; Nicholas et al., 2018). In addition, certain chronic illnesses have been known to stunt the physical growth of affected adolescents, including dental growth dentition (Jaffe et al., 1990; Proctor et al., 2005). Specifically, I wish to see how BMI, often associated with precocious (early) puberty, might affect the rate of a person's dental development. The fifth hypothesis of this thesis argues that individuals with BMIs classified as overweight or obese will have more advanced rates of dental development (e.g., their age estimates will be consistently older than their true ages), compared to those of average or underweight BMIs. Furthermore, this fifth hypothesis posits that individuals who are underweight will show evidence of decelerated dental development (e.g., their age estimates will be consistently behind their true ages).

Chapter 2: Review of the Literature

In the field of biological anthropology, there is a plethora of literature that examines, tests, and reviews different methods for estimating an individual's age, from analyzing long bone length to studying the growth and wear of teeth. One of the more common methods of estimating age comes from measuring dental development and eruption (Hillson, 1996). Humans are diphyodont, which means that their teeth develop in two sets: 1) primary dentition, commonly referred to as "deciduous dentition", and 2) permanent dentition (Harris, 2016). In the primary dentition, humans have 20 teeth which include a central and lateral incisor, a canine, and two molars per quadrant of the mouth. The permanent dentition consists of 32 teeth, a central and lateral incisor, a canine, two premolars, and three molars per quadrant of the mouth. However, the past few decades have seen an increasing number of individuals who are born without third molars in what is known as third molar agenesis (Carter, 2016; Scheiwiller et al., 2020). In addition, many individuals often have their third molars removed due to complications as the teeth erupt, with potentially harmful and painful effects. In a study of an Iraqi population, Hasan et al. (2016) found that of 880 individuals, over 1,100 third molars were impacted, with 663 being surgically removed. The lack of a third molar can create problems in dental age estimates because the third molar is the only tooth that can be used to estimate age until 21 (Liversidge & Marsden, 2010).

Despite the documented increase in third molar agenesis and the common practice of removing third molars, estimating age using dental development is still considered highly accurate. This accuracy is attributed to the fact that tooth growth in both the primary and permanent dentition occurs at defined age ranges set by the work of many researchers, allowing tooth development to be tracked alongside the growth of a person. Furthermore, as the teeth erupt past the gum line into the mouth, eruption may also be tracked due to innate biological timing that has been documented from tooth development to gingival emergence (AlQahtani et al., 2014).

In addition to the consistency associated with tooth development/eruption and age, the use of teeth in estimating age is preferred due to their resistance to external factors. Compared to the rest of the human skeleton, teeth are less likely to be affected by environmental decay during bodily decomposition because they are made of some of the body's hardest tissue. (Irish & Scott, 2016; Forshaw, 2014; Higgins & Austin, 2013; Manoilescu et al., 2015). Besides age estimates obtained from morphological changes like growth, wear, and size, genetic material such as DNA, RNA, and mitochondrial DNA can also be extracted from teeth. The extraction of such valuable genetic material makes the study of teeth vital in the analysis of ancient human remains as such information can be used to establish a post-mortem interval date (Heathfield et al., 2021; Higgins & Austin, 2013; Higgins et al., 2015).

This literature review seeks to explore the history of dental development in estimating age, and the creation, evolution, and changes found with the use of dental development age estimation methods. It also examines the process of dental development and the biological and environmental factors that may influence it. Finally, the relationship between dental development and health will be examined with a specific focus on dental development as influenced by an individual’s body mass index (BMI)

Historical use of dental development in estimating age

The use of dental development in estimating age has existed for thousands of years and has persisted into modern times due to its reliability. One of the earliest instances in which tooth development was used for age estimation occurred during the era of the Roman Empire. Part of the Roman Empires' method of maintaining its armed forces was through conscription, and the eruption of the second permanent molar indicated a young male was old enough for military conscription (Müller, 1990). A more recent use of measuring tooth development in estimating age occurred during the height of the industrial revolution in England, where factory owners would check the eruption of a child’s permanent teeth to determine eligibility for work in the factories (Saunders, 1847). Although these casual observations of dental development did fulfill the requirements of their times, the need eventually arose for a more comprehensive method.

Origins of modern-age estimation methods using dental development

The first chart created that tracked dental development and tooth formation was developed by Legros and Magitot in the 19th century (1880). Legros and Magitot (1880, 1881) created several tables which displayed the “appearance of dental tissues and structures for both the deciduous and permanent teeth, with emphasis on prenatal formation” (Arumugam & Doggalli, 2020). Legros & Magitot’s work displayed the formation of tooth development from the formation of the crown to full root completion and attempted to link this growth with certain ages in their subjects. Their work was the first known professional attempt to document and track dental formation and timing, setting a precedent for future research.

In 1933, dental practitioners William Logan and Rudolf Kronfield documented and measured the skeletal growth of the mandible and maxilla, in addition to the deciduous and permanent teeth housed in the jaw. Their work, titled, "Development of the Human Jaws and Surrounding Structures from Birth To the Age of Fifteen Years", provided information regarding initial calcification, tooth formation, and eruption of both primary and permanent teeth in the human dentition (Logan & Kronfield, 1933). However, their information contained inaccuracies and suffered from a lack of clarity regarding sample size. Still, their work paved the foundation for the eventual creation of more modern and accurate age estimation techniques focusing solely on dental development and eruption.

Years after Logan and Kronfield (1933) published their research on the developing jaw and teeth, Issac Schour and Maury Massler (1941) created a dedicated tooth atlas that tracked dental development and eruption through detailed illustrations of the human dentition at various ages. It begins with an examination of dental development while an individual is *in-utero,* and tracks development yearly until age 12, at which point it proceeds directly to age 15, followed by ages 21 and 35. This atlas applied to both males and females, while also detailing teeth in both the maxilla and the mandible, thus allowing for a wider range of usage.

Schour and Massler's (1941) atlas, however, included some issues in age estimation. Their atlas did not account for possible sexual dimorphism in dental development. In addition, the omission of ages 15 through 21 ignored significant variability in dental development due to third molar growth and the final development of other teeth such as the canine and second molar. In their original 1941 atlas, there were also several inconsistencies in data collection, a lack of detail on the sample group used as the basis for dental age estimation, and a failure to account for differences in population ancestry and health. Schour and Massler updated their work in 1944 to include new illustrations which were more accurate and provided updated information on the sample group they used in their work (Schour & Massler, 1944). However, even after these improvements, Schour and Massler's atlas has been viewed by many as outdated and inaccurate, but still highly acknowledged for its early accomplishments in the field of dental age estimation and used in testing against other methods (AlQahtani et al., 2014).

Of the three dental development methods reviewed in this thesis, the Moorrees et al. dental chart is the method with the longest history. C. F. A. Moorrees published several papers in the late 1950s documenting his findings of tooth development during puberty, including one in 1959 which would lead to his development of a later method for tracking dental development (Moorrees, 1959). In 1963 Moorrees, in conjunction with Elizabeth A. Fanning and Edward Hunt Jr., documented the growth and calcification of ten permanent teeth, using two different sample groups of White Americans (Moorrees et al., 1963a). In their paper, Moorrees et al. assigned new terms to 13 different stages of tooth growth and root development for the maxillary central and lateral incisors, as well as all the mandibular teeth. A second paper published in the same year applied the same stages of tooth growth and development to three deciduous teeth, the canine, the first molar, and the second molar (Moorrees et al., 1963b).

While an improvement from Schour and Massler's (1944) work, the method devised by Moorrees et al. (1963a) contained several issues, including an inability to track dental development in maxillary teeth besides the central and lateral incisors. While this does not inherently prevent age estimations from being formed, accurate aging is best obtained by using the entire human dentition. Thus, the method devised by Moorrees and colleagues was, and is, still not accepted as the single best method for dental age estimation, leading to several other methods being created over the following decades.

In the 1950s, Carmen M. Nolla developed a method of tracking dental development which would help assist other dentists in their work creating treatment plans (Nolla, 1952).

Similar to the method devised by Moorrees et al. (1963a), Nolla estimated age by observing the calcification of the permanent dentition and created 10 stages of tooth development as opposed to the 13 used by Moorrees et al. Nolla had separate tables for both males and females, while also including tables that included estimated ages both containing and omitting, third molars (Nandlal et al., 2014; Nolla, 1960). Other methods were developed or refined in the 50s and 60s, but Nolla and Moorrees et al. were the most popular methods devised.

Beginning in the 1970s, biological anthropologists were focusing on successfully identifying and aging archaeological remains discovered in the field. During this time, forensic anthropologist Douglas H. Ubelaker developed a new method of estimating age using dental development, inspired by Schour and Massler's (1944) atlas developed earlier in the century. Ubelaker's dental charts used the same form and manner of tracking dental development through illustrations of human dentition at varying ages from in-utero to age 35, also jumping from age 15 to 21. Ubelaker's dental charts differed, however, in that they used an archaeological Native American sample group and were created specifically to help provide accurate age estimations for Native American remains. Over the next decades, Ubelaker would update his charts for use on another population, Australian aboriginals, where he also created separate charts for males and females (AlQahtani et al., 2014). The creation of this separate chart has the benefit of showing that Ubelaker's dental charts could be adapted to other population groups as a preferred method for estimating age.

In 1973, Demirjian, Goldstein, and Tanner developed an entirely new method that deviated from previously existing methods. Their method measures dental development by using tooth calcification as a base, rather than using overall tooth growth as is most common. Their method was updated three years later (Demirjian et al., 1976), and has become one of the most popular methods for estimating age using dental development. The following decades saw several updates of existing methods, such as the 1980s work by W. A. Brown (1985) and Kahl & Schwarze (1988) which acted as improved versions of Schour and Massler's 1944 atlas, using newer sample sizes and population groups in an attempt to be more accurate and provide greater transparency than Schour and Massler's (1944) original work.

One of the most recent methods for estimating dental development is known as the London Dental Atlas of Tooth Development and Eruption (AlQahtani et al., 2010), which takes aspects from both Schour and Massler's work (1941), as well as the work of Moorrees et al. (1963a), by providing illustrations of dental development and tooth eruption beginning between 28 weeks in utero to 23 years of age. To complement the illustrations, the London Dental Atlas includes a series of tables that display the lowest, median, and most advanced development stage of each tooth in the dentition based on the age of the individual being observed, covering ages in utero to age 23.

The twentieth century has seen the creation of numerous methods for estimating age by measuring dental development, but there is not one single method accepted as the most accurate. Depending upon the population being analyzed and the goals of the research, the chosen method used may vary, with many methods being crafted for use on specific populations. Several of the more popular methods, including the Demirjian et al. (1973, 1976) and the London Dental Atlas (AlQahtani et al., 2010), are consistently reviewed and tested to measure their accuracy in estimating age for different populations (AlQahtani et al., 2014; Arumugam & Doggalli, 2020; Mohammed et al., 2015). Thus, just as there is a large body of research on estimating age using dental development, there is also an abundance of literature that examines which methods work best for certain populations.

Factors that affect dental development

The use of dental development in age estimations is in part due to the innate biological and genetic factors of different population groups which affect tooth development and eruption. Populations are often divided into geographical categories, such as African, Asian, or European, and different geographical populations are known to have differences in their dental development (Steggerda & Thomas, 1944; Tompkins, 1996). However, differences in sex, body weight, genetics, culture, race/ethnicity, and individual agency have been revealed to influence dental development (Almonaitiene et al., 2010; Pahel et al., 2017). For many years, the process of dental development and eruption has been known as resistant to environmental factors (Elamin & Liversidge, 2013; Garn et al., 1965; Lewis & Garn, 1960). In the following sections, the specific findings regarding dental development to factors such as sex, ancestry, weight, and generations are further analyzed and reviewed.

Dental development among different populations

Most of the research by individuals studying dental age estimation methods is focused on how specific population groups show varying rates of dental development. There is much evidence to state that dental development rates are population-specific throughout the world. In the twentieth century, research conducted on the subject has revealed that certain population groups have more advanced rates of dental development than others, like in the United States, where research into dental development rates between individuals of African ancestry vs those of European ancestry has been extensively researched. A 1996 study by R. L. Tompkins observed the dental development of Black Africans from the southern regions of Africa, White French Canadians, and Native Americans. He found that certain teeth, such as the second and third molars, develop and erupt earlier in Black African individuals as compared to White French

Canadians (Tompkins, 1996). In addition, Tompkins found different rates of development that supported earlier advancement of certain teeth in French Canadian females and Black southern African females, while males showed no difference between groups (Tompkins, 1996). His findings supported the hypothesis that dental development rates are variable and exclusive to different population groups, as well as reaffirming the concept that there are differences in dental development between sexes.

Other studies also note differences between Black individuals of African descent and White individuals of European origins (Adams et al., 2019; Steggerda & Thomas, 1944). Several papers have examined dental development in populations such as Hispanics (Hernandez, 2011), Iranians (Bagherpour et al., 2010), Indonesians (Putri et al., 2021), Czech (Šindelárová et al., 2017), and numerous other populations, including Native Americans. These papers show how populations of different geographical ancestry often differ in their dental development, leading to the question of how effective non-population-specific age estimation methods would work. This observable difference leads to questions about the accuracy of the numerous methods which are founded upon non-Native American samples, which are then applied to Native American individuals.

Numerous researchers tested the accuracy of modern dental age estimation methods used on Native American sample groups, with interesting results (Adams et al., 2019; Dahlberg & Menegaz-Bock, 1958; Owsley & Jantz, 1983; Steggerda & Thomas, 1944; Tompkins, 1996). One of the earliest papers on the subject, published by Steggerda & Thomas in 1944, compared White Americans, Black Americans, Native Americans (Navajo), and individuals from a Maya population together in one dental development comparison. The results of their study found that the Native American Navajo individuals had more advanced rates of tooth development and eruption as compared to the white American population. The White American sample group was overall the most dentally delayed when compared to the other three sample groups in overall dental development (Steggerda & Thomas, 1944). This finding, along with the support of numerous other studies, suggests that Native Americans may have more advanced rates of dental development when compared to other populations found in the United States (Adams et al., 2019; Dahlberg & Menegaz-Bock, 1958; Owsley & Jantz, 1983; Tompkins, 1996).

The reasons for such differences in dental development observed in Native American populations are currently unknown. In a 1958 paper, Dahlberg and Menegaz-Bock argued that there are three possible causes, genetic, environmental, or some combination of the two (Dahlberg & Menegaz-Bock, 1958). Additional factors, including socioeconomic status, may also relate to the prevalence of dental caries (Vazquez-Nava et al., 2008), as well as skeletal and dental development (Cardoso, 2007), but there is a lack of literature examining how socioeconomic and other sociocultural factors might affect dental development in Native American populations.

In an article by the National Community Reinvestment Coalition, Native Americans had the highest amount of unemployment in the U.S. in 2018, and a poverty rate three times higher than that of white Americans (Ramirez, 2019). Future research will potentially reveal how these socio-economic factors might influence the dental development rates of Native American populations in the U.S. Regardless, the current literature supports the notion that Native American populations have more advanced dental development rates than white North American/European populations used in other dental age estimation methods such as the Moorrees et al. (1963a), the AlQahtani (2010), and many other methods (Demerjian et al., 1973 & 1976; Havvikko, 1970; Nolla, 1952).

A study by Adams et al. in 2018 tested the accuracy of Updated (1989) and the new London Atlas (2010) on several different population groups, including Native Americans, African Americans, Asian Americans, Hispanic Americans, and white European Americans. The results showed that both dental age estimation methods overestimated the ages of Native Americans and African Americans, with observable patterns of over-or under-estimation of ages regarding specific population groups (Adams et al., 2019). Several other population-specific studies show that modern dental age estimation methods based on White populations tend to over-or underestimate different population groups (Heinrich-Weltzien et al., 2013; Maber et al., 2006). These findings suggest when aging Native American individuals, it would be of interest to create a population-specific method, something Ubelaker (1979) attempted to do.

Dental development and sexual dimorphism

For centuries, biologists have noted that many mammalian species on earth are sexually dimorphic, with males often being larger and anatomically different than females of the same species. Medical professionals and anatomists have observed that human males and females are no exception to this and that humans present evidence of sexual dimorphism, and this dimorphism is observable in many different areas of the body. The most immediate area in which sexual dimorphism is observable is in the pelvis, where there are distinct morphological differences due to adaptations necessary for childbirth (Correia et al., 2005; Ubelaker 1978). The skull is also a collection of bones that are sexually dimorphic. Males statistically have larger and more pronounced mastoid processes and supraorbital brow ridges on their crania when compared to females (Toldeo Avelar et al., 2017; Ubelaker, 1978). Further examination of the skull reveals that the mandible is sexually dimorphic, as males show an increase in mandible size and differences in the shape of their mandibles when compared to females (Coquerelle et al., 2011).

In further research on the sexual dimorphism of the human mandible, a link was noted between mandibular growth and dental development. Coquerelle et al. (2011) found that even as females' mandibles stop growing, their third molars continue to grow and develop. Meanwhile, males' mandibles grow and change shape alongside third molar development. In 1955, Edward E. Hunt and Izacc Gleiser developed a technique that was used to estimate an individual's sex through a comparison of tooth calcification to skeletal maturations of the post-cranial skeleton (Ubelaker, 1978). The research of Hunt and Gleser (1955) and Coquerelle et al. (2011), provides evidence that the development of the mandible and dental development itself is sexually dimorphic.

Females are known to typically have more advanced rates of permanent dentition development than males (Demirjian & Levesque, 1980; Garn et al., 1958; Šindelárová et al., 2017; Steggerda & Thomas, 1944). Research indicates that males have more advanced rates of deciduous dental development when compared to similarly aged females (Meredith, 1946; Taranger et al., 1976). However, opposing studies support more equal rates of dental development for both sexes during deciduous tooth growth (Demirjian & Levesque, 1980). Despite this disagreement rate over whether males or females are more advanced regarding deciduous tooth growth, there is evidence to suggest that the rates of permanent dental development are sexually dimorphic. Therefore, biological sex should be considered in any study of dental development age estimation methods.

Differences in rates of dental development across generations (secular change)

In the field of bioarcheological research, focus is placed on studying the remains of individuals from historic and ancient civilizations, where records of age are unlikely to be found for the deceased. Over the last ten thousand years, there have been numerous changes in humanity's diet and lifestyle, which have impacted our biological characteristics. Modern humans tend to grow taller and are capable of living longer and healthier lives due to modern medicine, nutrition, and science when compared to ancestral human populations (Alter, 2004; Bogin & Rios, 2003; Finch, 2010). As some research suggests that dental development is affected by factors such as diet and health, there is a strong possibility that there have been changes in the rate of dental development over the past several centuries, or even in the past few decades due to changes in our diets, lifestyle, and medicinal advances.

Many studies on the subject conducted in the past few decades support the idea that dental development rates have indeed changed across generations (Heuzé et al., 2008; Nadler, 1998; Sasso et al., 2013; Vucic et al., 2014). This has led to researchers describing dental development as a secular process, with the term "secular" referring to evolutionary and temporal change in part of the body that has occurred over generations (Weisensee & Jantz, 2011). This knowledge creates concerns as to how accurate dental developmental age estimation methods will work on modern vs. archaeological populations. This is because most dental age estimation methods use a modern sample population (AlQahtani et al., 2010; Demirjian et al., 1976; Moorrees et al., 1973a & 1973b) and are not designed using archaeological samples. Of course, this is because most archaeological samples often lack age-at-death information, and thus establishing a baseline for an age estimate is impossible. Douglas Ubelaker used a relatively contemporary Native American sample population for his sample in the creation of his atlas, therefore there exists a possible problem in accurately estimating the age of individuals in ancient archaeological samples (Ubelaker, 1978).

Health and the relationship with skeletal and dental development

Most existing literature that examines human growth in relation to health focuses on skeletal development and how it might be impacted in ill adolescents. Bone growth, influenced by the work of osteoblasts which create new bone, and osteoclasts which remove old bone, are highly sensitive to external sources. However, existing research indicates that dental development is more buffered than the skeleton in the event of illness, perhaps because of the degree of canalization of dental development.

Although dental development may be buffered from influence by most illnesses, research suggests that in children, certain chronic illnesses like chronic renal disease, celiac disease, and cancer, have been shown to negatively influence dental development, and in some cases, the treatment for chronic conditions might also affect dental development (Alamoudi et al., 2020; Campisi et al., 2007; Jaffe et al., 1990; Proctor et al., 2005). One example is the relationship between chemotherapy radiation and dental development in patients with cancer (Vasconcelos et al., 2008; Marec-Berard et al., 2005; Jodlowska et al., 2021). In one study comparing 46 childhood cancer patients with 46 healthy children, the child subjects with cancer had higher rates of dental caries, bacterial infections, and delayed root development compared to their healthy counterparts (Vasconcelos et al., 2008). It is therefore possible that delayed dental maturity is linked to the treatments for cancer (and other illnesses), rather than the illness itself (Jodlowska et al., 2021; Marec-Berard et al., 2005; Vasconcelos et al., 2008;).

Dental development and body mass index

The relationship between BMI and dental development has been studied extensively over the last few decades. Researchers have examined how individuals in different classes on the BMI scale (e.g., underweight, obese) have different rates of dental development. In recent years, following increased rates of obesity across the globe, much research examines the relationship between dental development and overweight/obesity. According to CDC.gov, individuals who fall between the 85th and 95th percentile are considered overweight. If an individual is in the 95th percentile or above, they are considered obese. Individuals who are between the 5th and 85th percentile are at a "healthy weight", while individuals below the 5th percentile are considered underweight.

Many factors might affect an individual's weight, including disease, genetics, socioeconomic status, sex, and diet (CDC.gov, 2022; Clevelandclinic.org, 2022; niddk.nih.gov, 2018). The consensus by most researchers is that individuals who are overweight or obese are known to have advanced rates of tooth development for their age (Cardono, 2021; Garn et al., 1965; Hilgers et al., 2006; Kadavy, 2017; Must et al., 2012; Nicholas et al., 2018). However, while obesity causes accelerated dental development, starvation, and malnutrition have been shown to potentially delay normal dental development rates (Hedavati & Khalafinejad, 2014; Kumar et al., 2013).

The terms "starvation" and "malnutrition" were occasionally used similarly in how they affect dental development. Malnourishment is often viewed in combination with starvation, leading to the view that being underweight equals being malnourished. However, the term "malnourished" refers to an individual whose diet is lacking in the essential vitamins and nutrients needed for healthy bodily functions (NHS.gov, 2020; johnhopkins.org, n.d.). While a lack of vitamins and minerals is more common in starvation, individuals who are overweight and obese might also be malnourished as they might be eating low-quality foods that are lacking appropriate micronutrients (johnhopkins.org, n.d.). Therefore, malnutrition and weight share an interesting relationship, one in which a person can be properly nourished but at an unhealthy weight, or they can be at a healthy weight but still malnourished (NHS.gov, 2020). This clarification is important because it can be a factor if malnutrition does delay dental development, then an obese individual might still show a delay, but because they are malnourished and not because they are obese.

Chapter 3: Subjects, Materials, and Methods

This thesis incorporates data from two groups, Group 1, an orthodontic treatment sample with associated (radiographs), and Group 2, a pediatric autopsy sample with data from postmortem computed tomography, PMCT. The total number of individuals included in this study totaled 225 individuals. Of the 225 individuals, 108 individuals are female and the remaining 117 are males.

Group 1 received orthodontic care from Dr. James Economides of Albuquerque, New Mexico between the years of 1960 to the late 1990s, at which point Dr. Economides retired. The first group (Group 1) includes 60 radiographs of individuals of known age and sex provided by the Economides orthodontics dental collection from the University of New Mexico (The University of New Mexico Health Sciences Center, https://searchorthodontics.health.unm.edu/). The 60 individuals examined were between seven and twenty-one years of age (n= 30 male, n= 30 female). Group 1 was included as a controlled variable designed to test the preliminary accuracy of the three dental age estimation methods used in the thesis, as chronological ages and biological sex are already known and available for direct accuracy comparison. However, weights were not available for individuals within this sample. Therefore, this sample provided zero additions to the study between BMI and dental development rates.

The second group (Group 2) contains individuals who died in the state of New Mexico between 2011 and 2019 and were examined at the New Mexico Office of the Medical Investigator (OMI). PMCT scans were taken for 165 individuals between the ages of 0.5 to 20.9

years in the course of normal autopsy procedures. Each individual in Group 2 is of known age and sex, manner of death, and most have a known cause of death. Additionally, each individual has weight and height data, which was used for BMI calculations (Cole et al., 2000). Cause of death refers to the actual event which led to an individual's death, such as disease, blunt force trauma, overdose, etc. Manner of death refers to how the individual died, either through accidental means, natural causes, homicide, suicide, or an undetermined manner. Furthermore, many child/adolescent deaths in New Mexico are investigated, and the juvenile sample from the OMI is a representative child mortality sample for the state, even though not all of the deceased individuals are included (O'Donnell et al., 2020). Initial data collection for Group 2 was conducted blind, so age, sex, cause, and manner of death were unknown when collecting data or estimating age.

Patient demographics: race and ethnicity

Race and ethnicity were assigned by two different sources for each sample group. For Group 1, the Economides collection, race/ethnicity was not assigned by either Dr. Economides or by using the patient's self-identification (Edgar et al., 2011). Instead, race/ethnicity was assigned to the patients by eight observers, with two observers assigned to examine each patient's records. The observers consisted of a mix of undergraduate and graduate students, and staff of the Anthropology Department at the University of New Mexico. The observers classified the race/ethnicity of all individuals in the collection through five predetermined indicators which met three larger criteria for ethnicity and race indication selected by the research focus group. The five indicators included: 1. patient name, 2. patient address, 3. skin color, 4. facial features, 5. hair form and color. These five indicators met three criteria chosen by the anthropological researchers who were conducting a study regarding ethnicity and race using the Economides' collection. These three criteria were used to help make observable indicators of a person's race for their study: 1. Must be available in over 95% of records from materials such as intake forms, treatment records, and patient photographs; 2) Must be informative about patients' biology or group affiliation; 3) Must be available to an observer without special equipment or training so that the parameters would be experienced in a manner similar to members of the general public (Edgar et al., 2011).

Race and ethnicity of the individuals in Group 2 originate from the OMI of New Mexico records. The individuals' race and ethnicity were determined by the on-site field investigator working at the OMI based on an individual subject's circumstances (e.g., whether the individual lived and died on tribal land or a reservation). In some cases, ethnicity was supplemented by reports which were obtained directly from the individuals' families. Unfortunately, as all members of Group 2 are deceased, race/ethnicity could not be obtained by asking individuals (many of which are young children) about their self-identification, which is the most accurate with regards to perceived ethnic and racial identity. Thus, race was attributed through the OMI death investigation alone. The methods through which race and ethnicity were attributed to individuals in Groups 1 and 2 are likely an unintended good measure of common social ascriptions of race/ethnicity in identity.

The individuals in both Group 1 and Group 2 were racially and ethnically classified by people other than the individuals themselves. I, therefore, had to rely on the word of other individuals in classifying all the individuals in my study as Native American, and I had to trust that this was still viable for my purposes. Ultimately, it must be stated that an individual's race and ethnicity are best identified but the individual themselves.

Data collection

Dental development was measured from the radiographs and PMCTs of both samples using standards set by three different dental age estimation methods, 1) Moorrees et al. (1963a & 1963b) Dental Charts, 2) Ubelaker's dental charts (1978), and 3) the London Dental Atlas (AlQahtani et al., 2010 & 2012). Radiographs obtained from Group 1, the Economides' collection, were reviewed on an Apple iPad and saved to images, where photo editing was available to adjust contrast and lighting for image alteration of subjects' radiographs to allow for better observation of dental development. The PMCTs of Group 2 were examined using Horos Viewer, a free and open-source code software (FOSS) program distributed under an LGPL license (Horos, 2021, Version 3.0, LGPL 3.0) and viewed with an Apple iMac computer. The Horos software allowed for multiple forms of two-dimensional (2D) and three-dimensional (3D) viewing and manipulation of the PMCTs to ascertain dental development as accurately as possible.

Dental development was scored for each available tooth from the left and right sides of the mouth, as well as both the maxilla and mandible. The radiographs selected in Group 1 were chosen because they provided a panoramic view of the dentition and had a majority of teeth visible. Radiographs that were unclear for viewing, meaning they were blurry (Figure 3.1), overexposed (Figure 3.2), or only provided a side profile (Figure 3.3), were excluded from the study. If a tooth was missing or could not be accurately observed even after editing, it was recorded as unobservable and not counted in age calculations. In a few specific cases, a singular tooth was underdeveloped compared to the rest of the dentition. In order to avoid such an extreme outlier from skewing age estimation results, such teeth were also excluded from the age estimation.

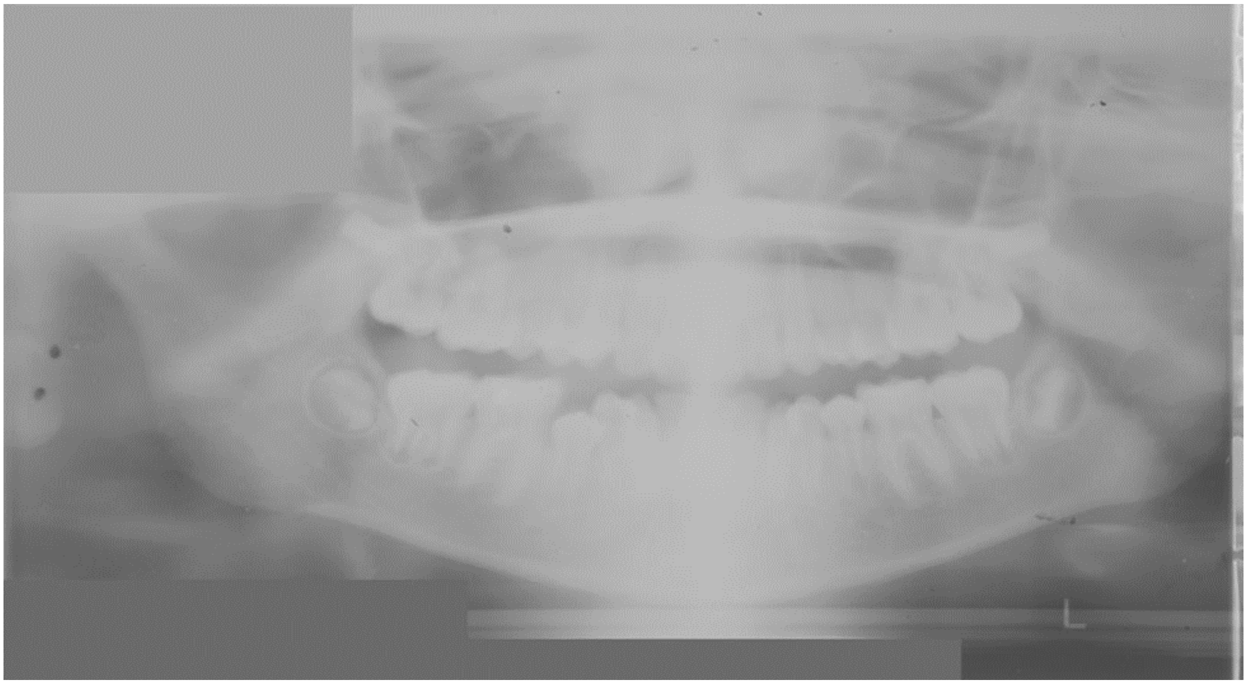

Figure 3.1 Blurred radiograph from the Economides collection

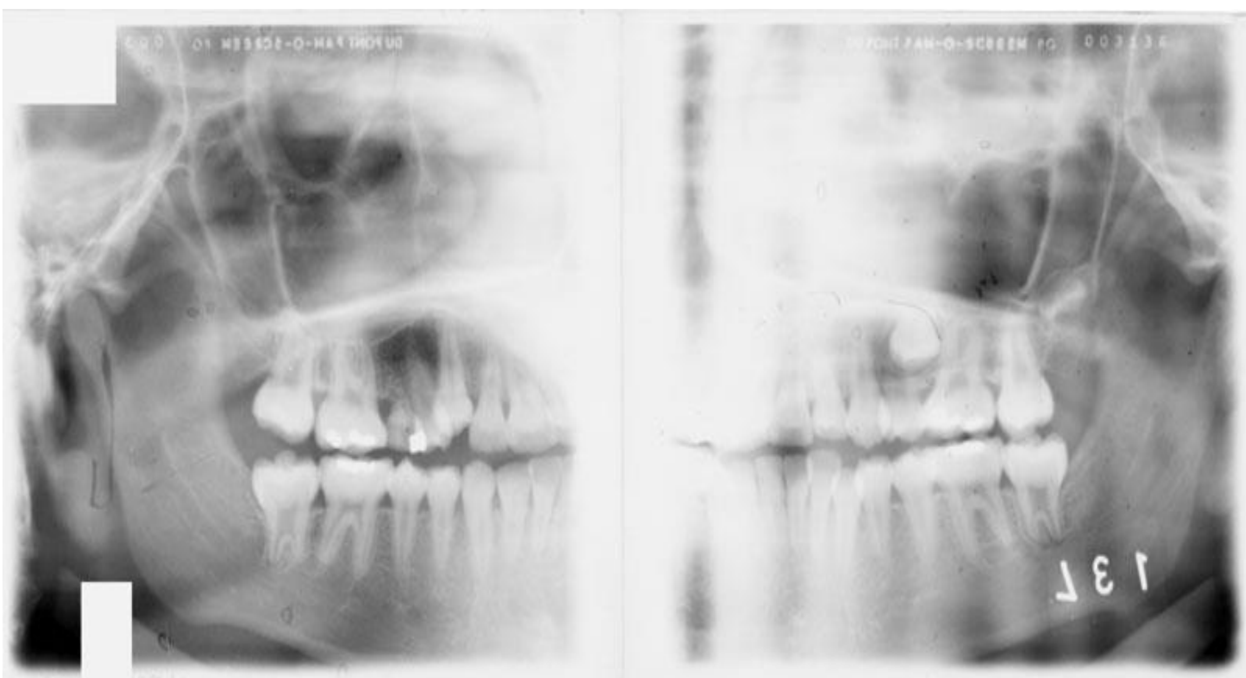

Figure 3.2 Overexposed radiograph from the Economides collection

Figure 3.3 Side profile radiograph from the Economides collection

<u>*Moorrees et al. (1963a, 1963b) dental chart methodology*</u>

Two research papers were used in the age estimation process for the Moorrees et al. method. One paper tracked dental development in the permanent dentition (Moorrees et al., 1963a), while the second paper tracked dental development in three deciduous teeth, the canines, and the molars (Moorrees et al., 1963b). The Moorrees et al. method (1963a & 1963b) classified tooth development into thirteen distinct stages of development, and four stages of resorption for the deciduous dentition.

For the Moorrees et al. method (1963a & 1963b), age estimates were made separately for males and females, as the method accounts for the possible sexual dimorphism in dental development. In Group 2, where initial data collection was done “blind”, individuals were estimated using both the male and female age data as put forth by Moorrees and colleagues. Age estimates were gathered by measuring a tooth’s associated development and its corresponding growth stage as defined by Moorrees et al., and then taking the provided estimated age at which a tooth was measured at that specific stage of development.

An important consideration is that historical limitations in the Moorrees et al. method prevented the obtaining of accurate age estimates of teeth in the maxilla besides the upper central and lateral incisors, which only measured up to the stages of root completion in males and apex half-closed in females. Therefore, the Moorrees et al. method data collected applied only to the maxillary incisors and mandibular teeth. Additionally, the Moorrees et al. method does not include tooth age estimates past full development age and two standard deviations of that age. In order to preserve the estimates of the method, the average age of each tooth for its development stage was used, even if it potentially underestimated the overall age of the subject. The Moorrees et al. method showed that ages on a line graph without clear numbers, where some tooth ages were between a half year and a whole year, leading to many ages being either rounded up or down depending upon how close the age appeared on the line graph. Figure 3.4 depicts a table from the original Moorrees et al. dental chart.

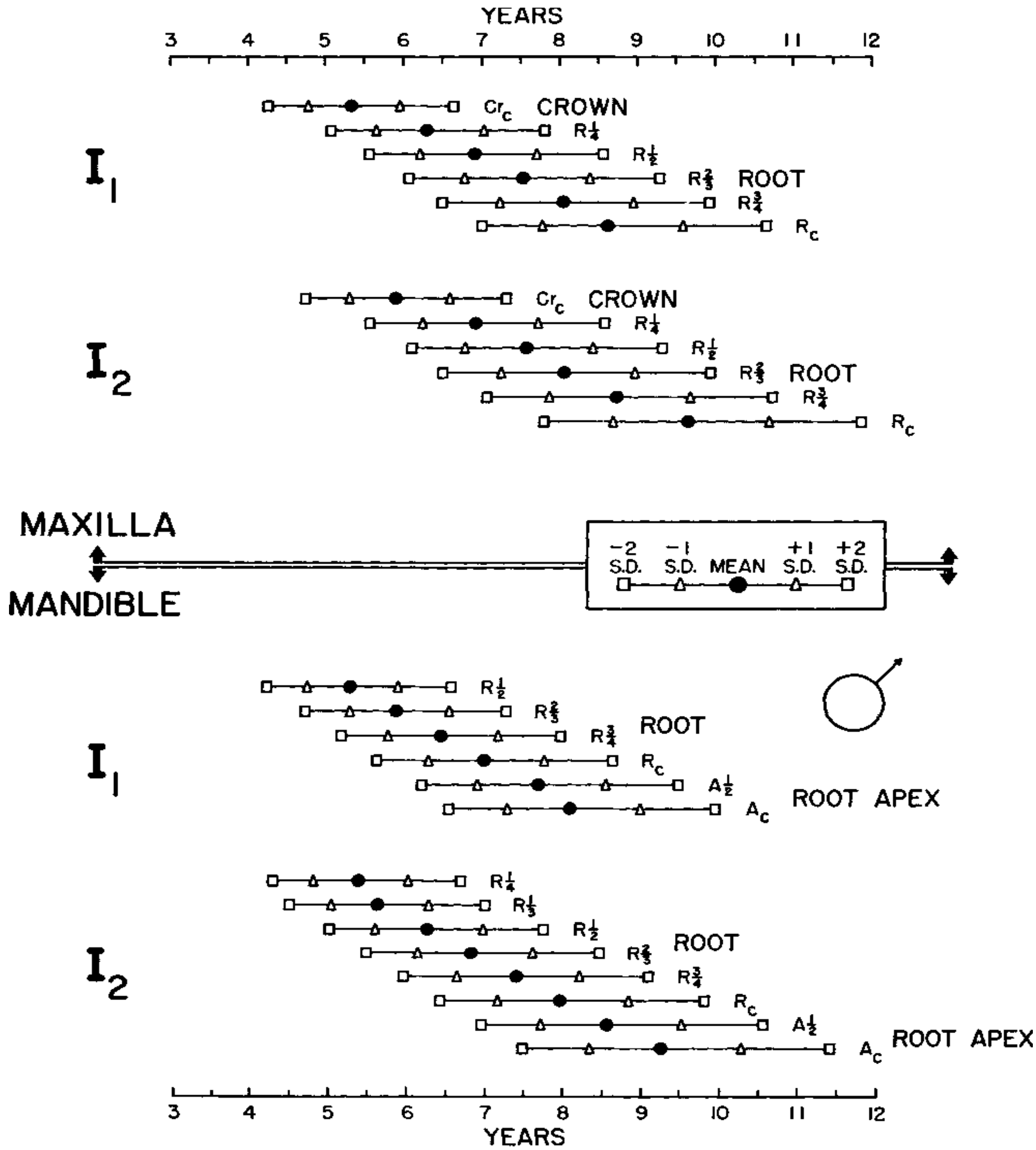

Figure 3.4. From Moorrees et al. 1963

Ubelaker's dental charts methodology

Ubelaker's dental charts consist of side profile illustrations of the human dentition with illustrations depicting the dentition from in-utero to birth and increasing yearly from age one until age 12, at which point the illustrations depict only ages 15, 21, and 35. There were no tooth development stages provided by Ubelaker's dental charts. Therefore, age estimates were obtained by measuring the development of each available tooth and making as close of a comparison with the images provided in his dental charts. The age at which the physical tooth most closely matched the drawing in the charts determined the estimated age associated with that tooth. Ubelaker's dental charts also provide age estimation ranges to allow for estimates which account for deviations in dental growth. The age ranges usually include a deviation of 24 months older or younger than the estimated age, although the range may shorten or lengthen depending upon the age (see Figure 3.9).

In addition, age estimates obtained using Ubelaker's dental charts are impacted by a lack of information on the root development of the third molar and its associated ages. Ubelaker's dental charts jumps from age 15 directly to age 21 with an accompanying tooth stage jump of R ¼ to Ac for the third molar. The lack of information on what age any stage between R ¼ and Ac should belong to could affect the estimated ages of individuals. For the purposes of the thesis, individuals with third molars at development stage Rc or higher were aged 21, while individuals with third molars between R 1/4 and R 3/4 were aged at 15. To compensate for this error, while accounting for the variable development of the third molar, I created a new table that excludes all individuals over the age of 17. This cutoff age was chosen because at around age 17, the only teeth still developing in the mouth are third molars.

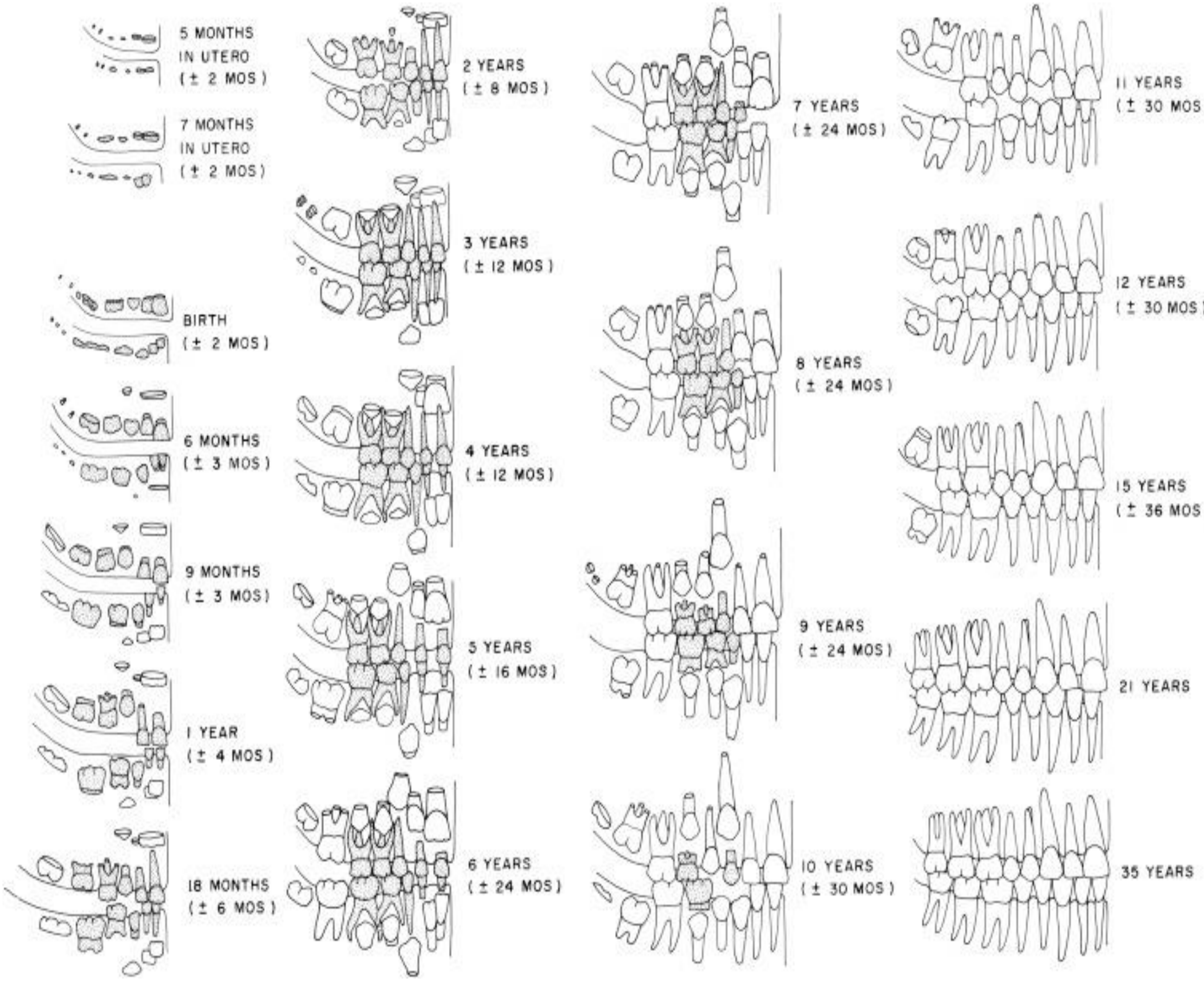

Figure 3.5. Ubelaker's dental charts from in-utero to Age 35

London Dental Atlas methodology

Age estimates created using the London Atlas (Alqahtani et al., 2010 & 2012) were obtained by recording all teeth available in the jaw, both from the maxilla and the mandible. There were no differences in estimating age by sex, but there were differences in development stages and age correlation based on whether a tooth was from the maxilla or the mandible. The London Atlas tracked dental development and resorption using the same stages as created by Moorrees et al. (1963a & 1963b). The stages of tooth development can be observed in Figure 3.5

for single-root teeth, and Figure 3.6 for multi-rooted teeth. Figure 3.7 represents deciduous tooth resorption stages.

Final age estimates were obtained by tracking the general development of each individual's dentition and comparing the radiographs and PMCTs visually to illustrations provided by the London Dental Atlas. These illustrations provided general ages and expected development of each tooth at a particular age, where ages were also listed at mid-year stages such as 11.5 and 12.5 years of age. Teeth were then assigned an age based on their development stage in relation to the median ages of development listed by the London Atlas for that specific tooth (Figure 3.8).

The London Dental Atlas does not account for differences in dental development between males and females. As several previous studies have noted (Demirjian & Levesque, 1980; Garn et al., 1958; Šindelárová et al., 2017; Steggerda & Thomas, 1944), females tend to have advanced rates of dental development compared to males; which suggests that sex differences should be considered. In this thesis, I make sure to consider this difference even when using this method in estimating age.

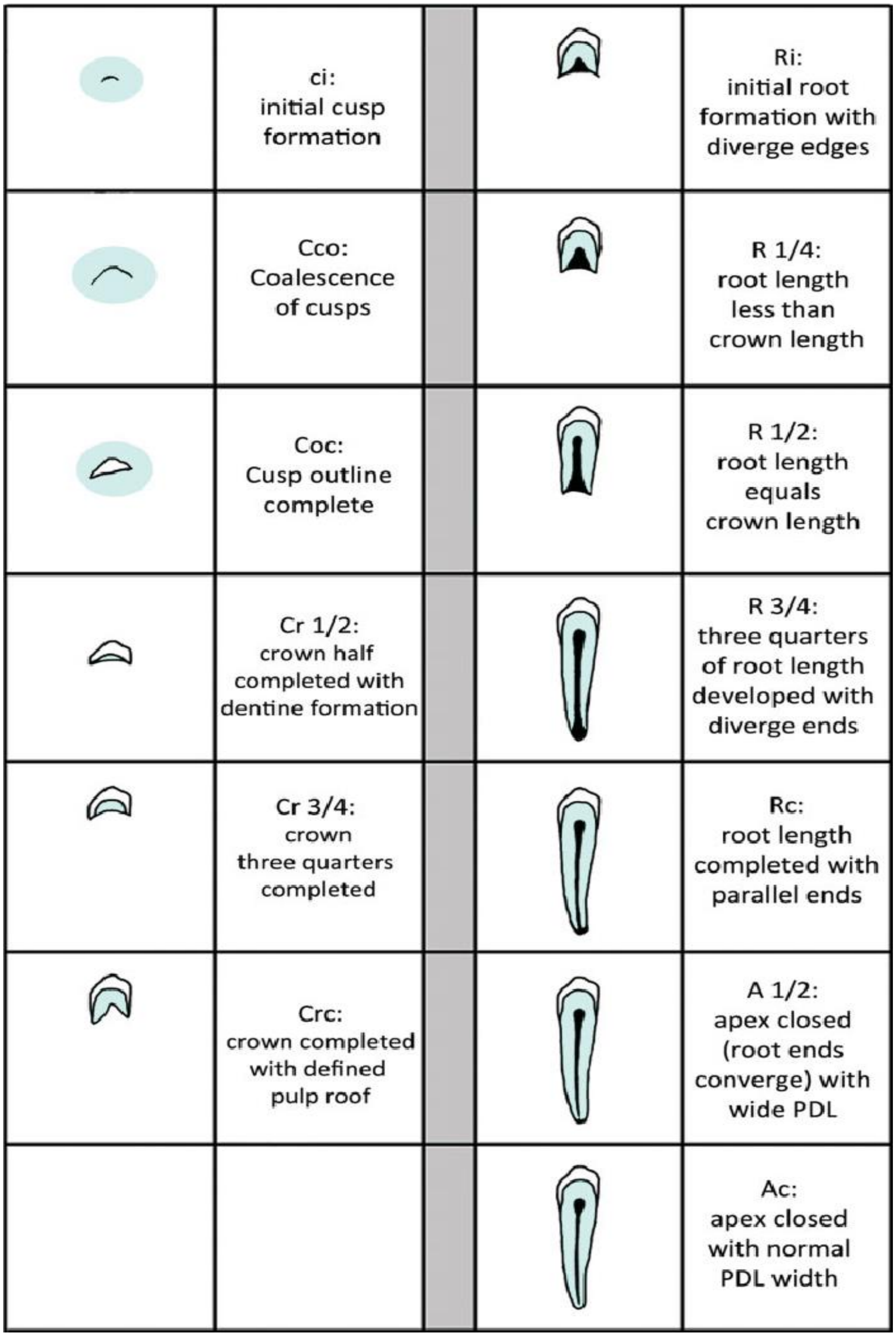

Figure 3.6. Dental development chart (AlQahtani et al., 2010:483)

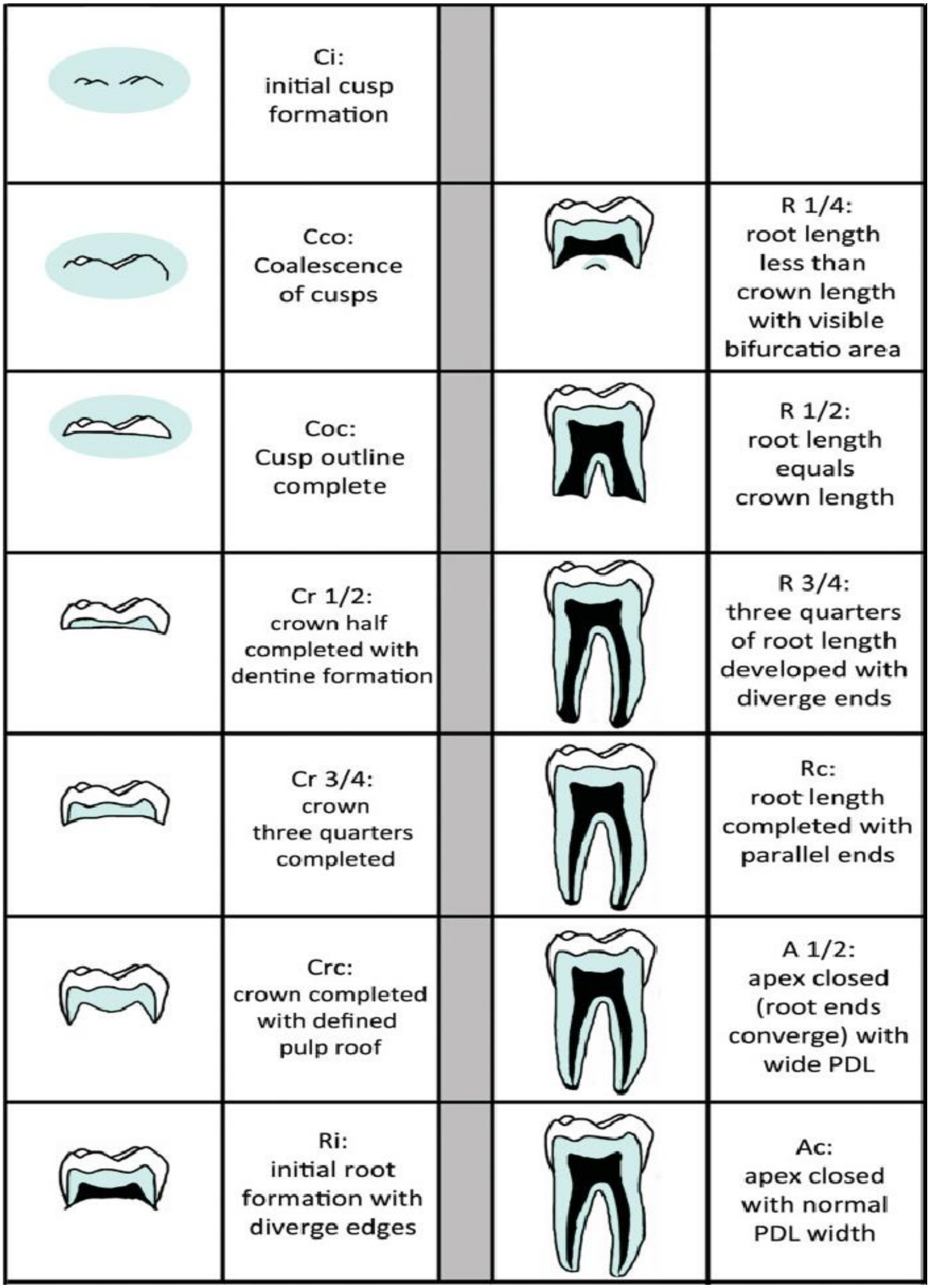

Figure 3.7. Dental development chart (AlQahtani et al., 2010:483)

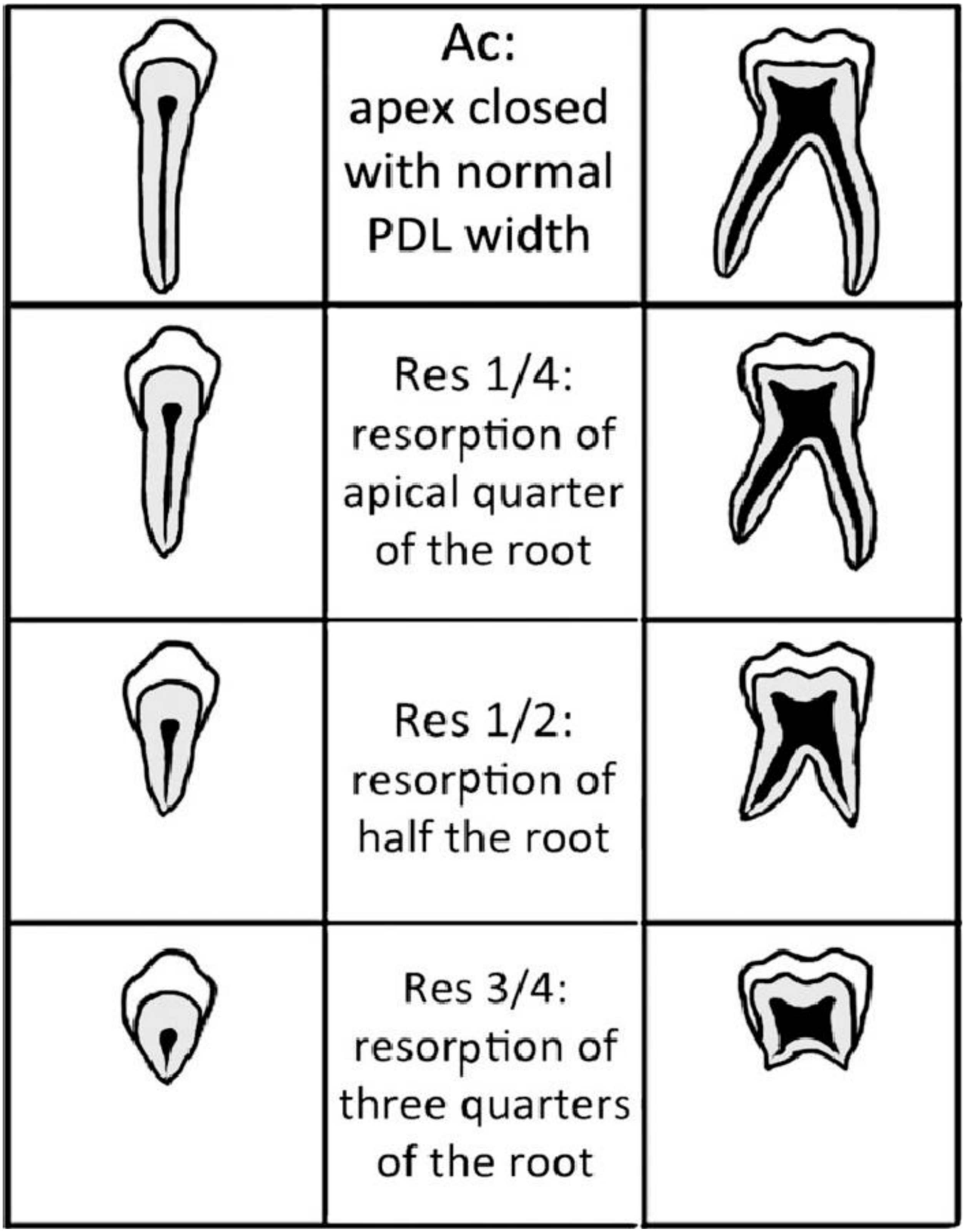

Figure 3.8. Dental development chart (AlQahtani et al., 2010:484)

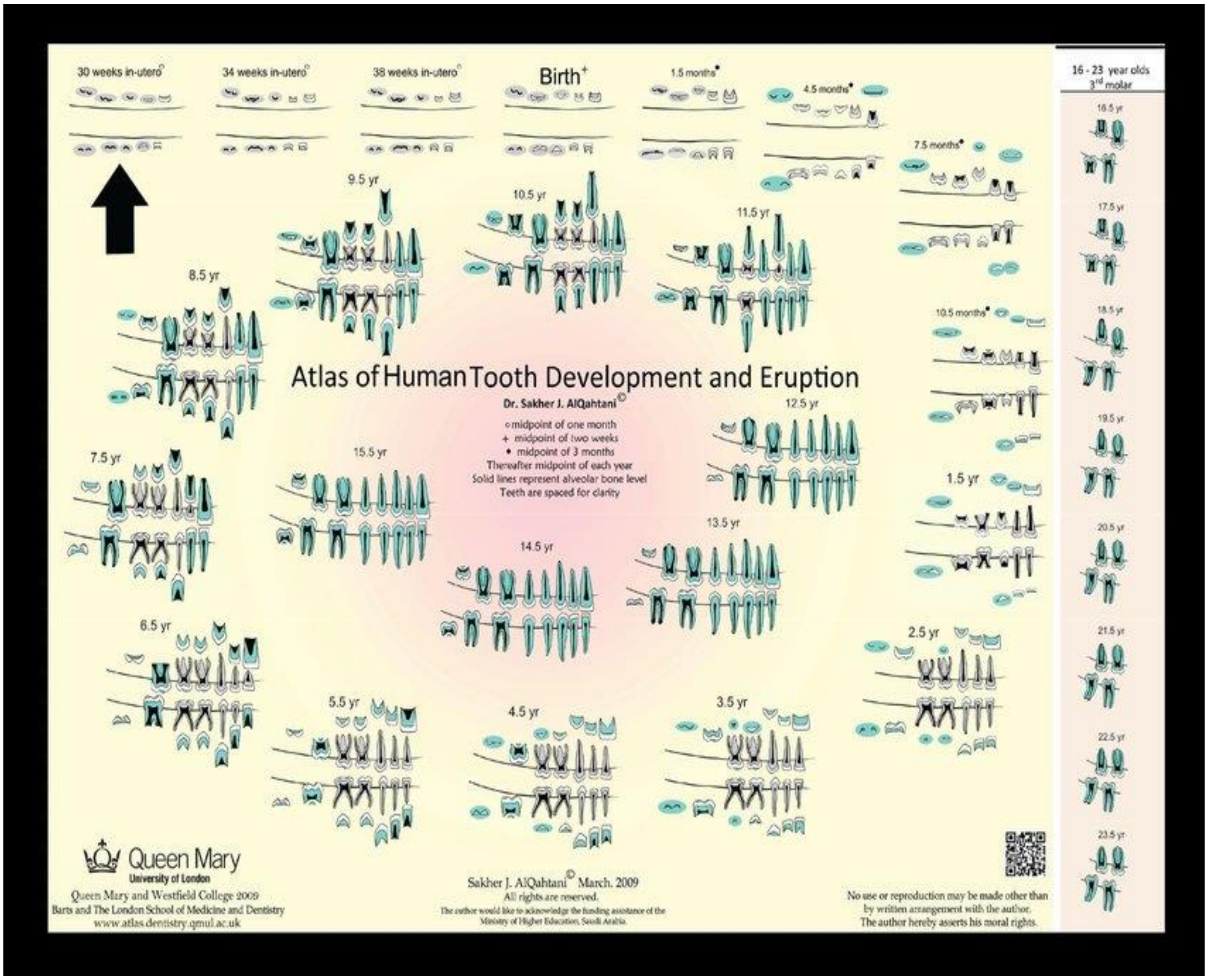

Figure 3.9. Illustration of human tooth development and eruption used in the London Dental Atlas by AlQahtani and colleagues (2010

Formulation of age estimates and error tests

For all three methods, overall estimates of an individual's age were obtained by creating an average from the estimated ages of all recorded teeth. There were separate ages for teeth in the permanent dentition and deciduous dentition. If an individual had mixed dentition, their dental age was the average of their permanent and deciduous dentition ages. The mean estimated and real ages of individuals from both groups were then recorded and used to create a Delta Age for each group and applied to each method. The Delta Age is made by subtracting the average chronological age (CA) of each group from the average estimated age (EA) of each group to create a "Delta Age" for all three age estimation methods. If the Delta Age for a group was a positive value over zero, this meant the group had its overall age overestimated. If the Delta Age value was below zero and a negative number, then this meant the group had its overall age underestimated. The use of Delta Values allows for easy comparison of accuracy between groups as whichever Delta Age for the method is closest to zero, is the most accurate method.

For Ubelaker's dental charts, the average age was presented as an age range based on the tooth to match the appropriately corresponding age ranges for that year on his charts. The estimated age was considered accurate if it fell between the age range of the chronological age. The use of age ranges in his charts can make age estimates accurate, but not precise. I use the term 'accurate', to indicate age estimates that fall comfortably in the age ranges provided by Ubelaker's dental charts. However, I use the term 'precise', to refer to the possible ambiguity that the use of age ranges has in specifying an age estimate.

Error testing (intraobserver error)

Intra-rater reliability was measured using Cohen's Kappa (1960) to determine observer accuracy and statistical significance of tooth stage identification. This was achieved through the recollection of the radiograph and PMCT data from 20 individuals in both sample groups. The 20 individuals were randomly selected using a random number generator in order to avoid bias in sample selection. To test reliability, tooth stages were reobtained for each of the twenty individuals from both groups and then compared to their original scores. Cohens' Kappa was scored based on if the tooth stages were similar or different with each individual, and then the average score was taken for each group and then rated.

Secular change

One of the questions asked at the beginning of this thesis was if dental development undergoes secular change, or a temporal change in development that occurs across generations. The answer to this question may necessitate new research into how effective modern age estimation methods are when used on historical/archaeological populations. The most accurate method to measure secular change would be direct comparisons between similarly aged individuals with known birth dates from different generations. For Group 2, the decade of birth of each individual in the sample is known, but the exact year of birth is unknown. For the Economides collection, Group 1, only the decade of initial treatment is provided, leaving the year or even decade of birth nearly impossible to discern. Therefore, a wide range of possible year differences could occur between individuals in either sample. One potential age gap could be as large as 60 years, or as narrow as 10 years, with an average distance of around 25-30 years. Due to this inconsistency in accuracy regarding the difference in years between members of either sample group, secular change was tracked through an alternative method.

I examined differences in tooth stages between three teeth; the maxillary second incisors, the maxillary canines, and the maxillary third molars beginning at seven years of age, as Group 1 does not include individuals younger than seven years of age. These teeth were chosen because they cover the general span of an individual's life during dental development and changes in the development rate of these teeth could be reliable indicators of secular change. Individuals from both groups were divided into chronological age categories separated by year and the developmental stage of each tooth. I then plotted out the number of teeth from the individuals in both groups and compared the tooth stages to the median developmental stage for the selected tooth at each specific age as demonstrated in the London Dental Atlas (AlQahtani et al., 2012), as it was later determined as the most accurate method (see Chapter 4: Results). I used chi-squared and Fisher's tests for each age group to determine if there was a statistically significant difference in dental development between groups. I made figures that show the presence or absence of teeth relative to the median stage documented by the London Dental Atlas. These graphs provide a visual representation of the expected number of teeth that should be present at that stage versus the actual number of teeth present in each Group.

BMI calculations

For this thesis, body mass index (BMI) values were obtained for Group 2 by the OMI using a combination of sex, age, height, and weight. BMI was unable to be obtained by individuals in Group 1. Compared to the number of individuals who were utilized in determining age estimation accuracy for Group 2, three individuals could not have a proper BMI obtained and thus only 162 of the individuals in Group 2 were included in the analyses of BMI. BMI is typically classified into four main categories: underweight, normal, overweight, and obese. In this thesis, I focus on examining how individuals classified as overweight and obese, have their dental development affected by their BMI. In adults, the common cut-off points for obesity is a BMI of 25 kg/m^2 for overweight and a BMI of 30 kg/m^2 for obese (Cole et al., 2000). However, determining the cutoff BMI for overweight/obesity in children/adolescents is not as easy.

As the individuals in Group 2 all lived in the United States, I used BMI growth charts provided by the Centers for Disease Control (CDC) to determine if an individual was overweight/obese. The CDC's charts are separated by sex and through the use of nationwide data collected between 1963 to 1980, provide the weight that a child/adolescent between the ages of 2-20 must be to hit a certain BMI percentile (Figure 3.10) (cdc.gov, 2022). Table 3.1 demonstrates that if a BMI was between the 85^{th} and 95^{th} percentiles, it is classified as overweight, while BMIs above at the 95th percentile or higher are classified as obese. However, the CDC charts do not account for individuals younger than the age of 2, so charts from the World Health Organization (WHO) were used for individuals younger than 2. These charts were based on a study between 1997 and 2003 to create charts for determining the growth standards for children/adolescents including length/height-for-age, weight-for-age, body mass index-for-age, etc., (World Health Organization, 2009). Table 3.2 shows that for the WHO BMI percentile charts, BMIs between the 85th and the 97th percentiles are overweight while BMIs at the 97th percentile or higher are obese.

The BMI Analysis used a combination of a paired t-test and linear regression analysis. For the paired t-test, a confidence interval of 95% was set with a p-value of .05 as the standard, and this same standard is applied to any other t-tests utilized in this thesis. Linear regression was used to measure the influence BMI and obesity have on the average Delta Age for Group 2. The BMI of all the individuals in the sample was reorganized by sorting them to their closest BMI percentile continuous data based on the CDC and WHO BMI percentile charts. This was done because BMI values are dependent upon age and sex. For the BMI analysis, individuals at the 85th BMI percentile or higher were classified as obese.

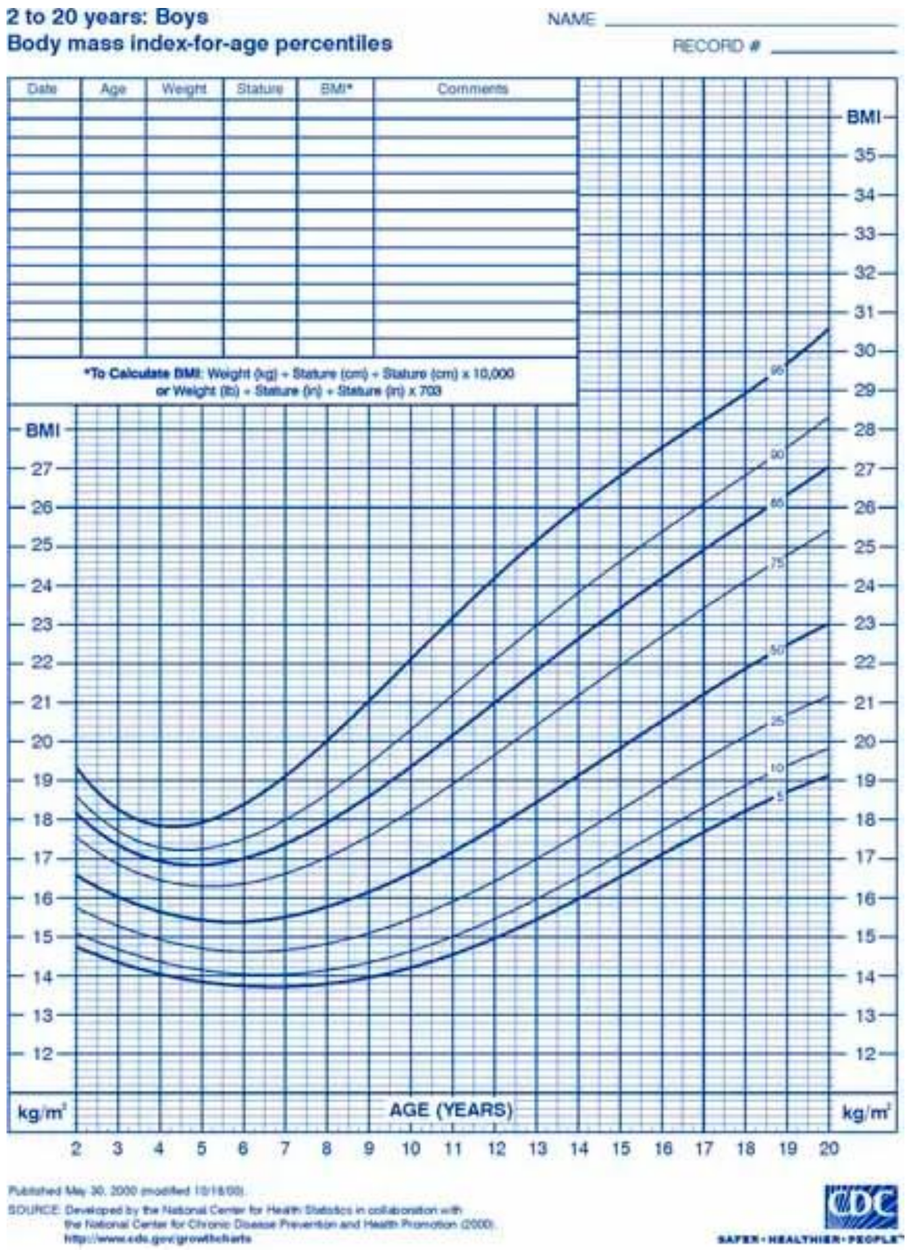

Figure 3.10. Boys CDC BMI growth chart

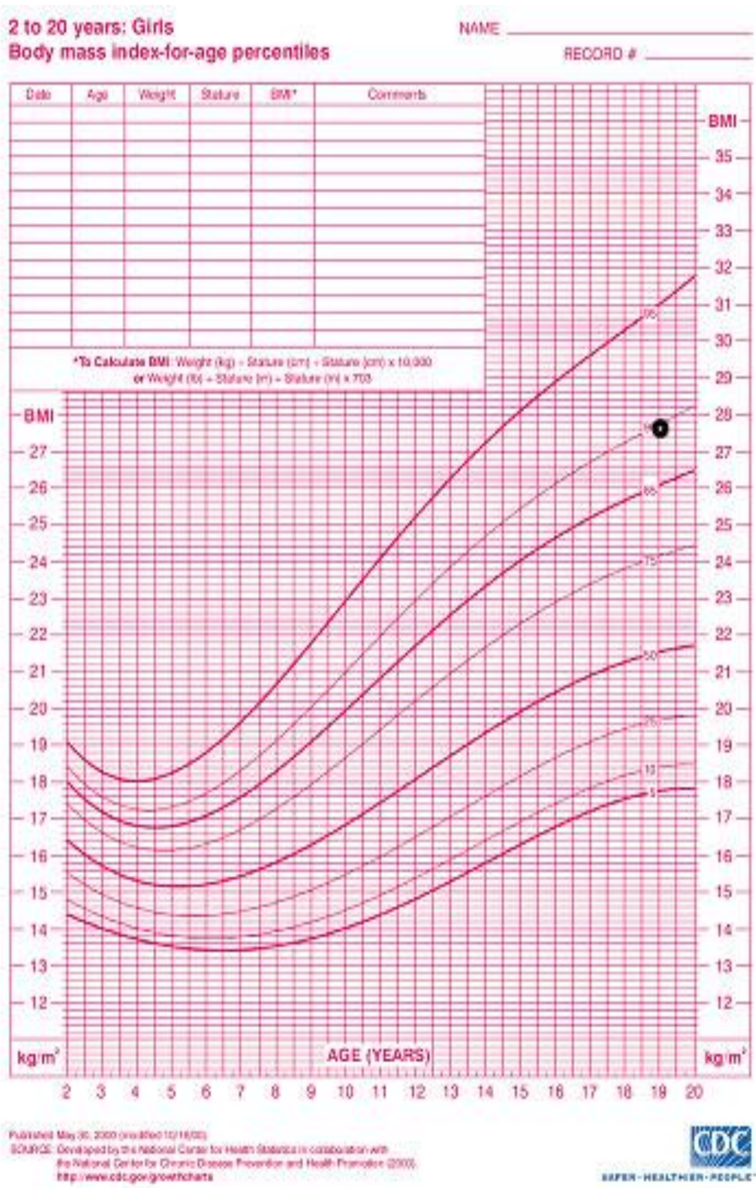

Figure 3.11. Girls CDC BMI growth chart

Table 3.1. CDC BMI percentile weight classification

CDC BMI Percentile	Classification
<5th	Underweight
5th-85th	Normal
85th-95th	Overweight
95th <	Obese

Table 3.2. WHO BMI percentile weight classification

WHO BMI Percentile	Classification
<3rd	Underweight
3rd-85th	Normal
85th-97th	Overweight
97th <	Obese

Data storage

Data collection began in October 2021 and lasted until October 2022. The data was collected and stored on a Microsoft Excel Spreadsheet, where a master list of all the individuals examined is located. The information on the spreadsheet contains, if available, the individuals' sex, and age for both groups, along with BMI and the causes and manner of death for individuals in Group 2. Data from the recollection period (used for intraobservor error testing) was obtained and placed on separate spreadsheets to avoid possible user errors in data input. An additional spreadsheet was created that lists tooth development stages reached at different ages for males and females. This spreadsheet was created to provide information on the tooth stages associated with different ages, as well as to note if there were major differences in tooth stages and age based on sex. All of the documents are stored on a computer hard drive, an external USB drive, and an online storage space (Box Storage).

Chapter 4: Results

Initial results reveal that the London Dental Atlas is the most accurate dental age estimation method tested by more than 0.15 years over the Ubelaker's dental charts and 2 years over the Moorrees et al. dental charts. When examining sex differences in aging, females tended to be overestimated until age 16, at which point third molar growth influenced age estimates more than sex. Secular (temporal) change in teeth was not documented in the sample groups of this thesis. There was no major variation in dental development observed in the sample groups studied that deviated drastically from the London Dental Atlas (the most accurate method). Results of linear regression analysis revealed that BMI does not seem to have any effect on age estimates in Group 2. Retesting of the samples using random number selection and running through a Cohen's Kappa analysis indicated significant reliability in the retested sample results.

Comparison of delta age values

Examination of general mean age values of both sample groups provides a foundation for viewing any immediate differences between the age estimation methods used, their accuracy, and how each group might differ with regards to overall Delta Age. The Delta Age for each group is the total difference between the Group's average estimated age and the Group's average real age. The closer the difference, of Delta Age, is to zero, the more accurate the average estimated age is. By comparing the Delta Age values, they will indicate which of the three dental age estimation methods provides the most accurate age estimates.

For the Delta Age results, positive values mean the estimated age was higher than the average real age, while negative values indicate the estimated average age was lower than the average real age. Table 4.1. lists the respective average ages for each group, including average real age, average estimated age, average Delta Age, and average Delta Age using absolute values. Despite the differences in size and age values in either sample group, similar results were obtained for the average Delta Ages of each method. The London Dental Atlas was found to be the most accurate of all three methods, with an average Delta age of 0.49 for Group 1, and an average Delta Age of 0.44 for Group 2.

Table 4.1 provides the average real age, average estimated age, average Delta Age, and average Delta Age using absolute values of both groups for all individuals aged 17 and under. Table 4.2 shows that when third molars are excluded, Ubelaker's dental charts are the most accurate with a consistent underestimation of fewer than five months. The London Dental Atlas overestimates age for both sample groups with a Delta Age of 0.91 years in Group 1 and 0.58 in Group 2. The Moorrees et al. chart becomes more accurate than when including third molars, but still underestimates ages by nearly around two years in Group 1.

Table 4.1. Average real age, estimated age, and delta age for both groups by method used

Group & Method	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)
Group 1 London Dental Atlas	13.33	13.82	0.49	1.08
Group 1 Ubelaker	13.33	12.68	-0.65	1.0035
Group 1 Moorrees	13.33	10.42	-2.92	2.97
Group 2 London Dental Atlas	10.17	10.61	0.44	1.21
Group 2 Ubelaker	10.17	9.49	-0.68	1.37
Group 2 Moorrees	10.17	7.07	-3.10	3.14

Table 4.2. Groups and age estimation methods with average age groups (excluding 17+ individuals)

Group & Method	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)
Group 1 London Dental Atlas	12.12	12.77	0.91	0.96
Group 1 Ubelaker	12.12	11.80	-0.31	0.63
Group 1 Moorrees	12.12	10.13	-1.99	2.06
Group 2 London Dental Atlas	6.47	6.91	0.58	0.80
Group 2 Ubelaker	6.47	6.00	-0.47	0.81
Group 2 Moorrees	6.47	5.02	-1.35	1.40

Sex differences

The London Dental Atlas and the Moorrees et al. methods were more accurate for males than females in Group 1 when average ages were examined. Ubelaker's dental charts were the most accurate for females in Group 1. For Group 2, Ubelaker's dental charts and the Moorrees chart were the most accurate for males, while the London Dental Atlas was most accurate for females. To account for possible variations in third molar variation on age estimation, average estimated ages were obtained for males and females in both sample groups for all three methods while excluding individuals older than 17. A reexamination of Group 1 found that the London Dental Atlas and Moorrees charts were more accurate in estimating average ages for males, while Ubelaker's dental charts were more accurate for females. For Group 2, all three methods produced a more accurate average estimated age for males than females, with the London Dental Atlas being the most accurate overall in both sample groups based on Delta Ages. Table 4.3 provides the average estimated ages and Delta Age for Group 1 split by sex and divided into age categories. Table 4.4 provides the same information but applied to Group 2.

Overall, the examination of Tables 4.3 and 4.4 reveals that females and males have relatively equal rates of dental development in the years of infancy and childhood. At age seven, females start to show evidence of more consistent age overestimation compared to males, with this pattern being most prevalent between the ages of 12 and 16.99 (Table 4.3 & Table 4.4). At age 17 and older, there is a shift whereby males had their ages overestimated in higher amounts compared to females, with this being especially apparent in Group 2 (Table 4.4).

Table 4.3. Estimated age, delta age, etc. by age group and sex for group 1

	Females					**Males**				
Age Group	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)	Number of individuals	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)	Number of individuals
London Dental Atlas										
7-7.99 years	-	-	-	-	0	7	8.57	1.57	1.5	1
8-8.99 years	-	-	-	-	0	8	8.65	0.65	0.65	1
9-9.99 years	9	10.20	1.20	1.20	4	9	10.61	1.61	1.61	3
10-10.99 years	10	10.60	0.60	0.60	2	10	10.69	0.69	0.69	4
11-11.99 years	11	12.02	1.02	1.02	4	11	11.64	0.64	0.77	3
12-12.99 years	12	13.36	1.36	1.36	6	12	11.97	-0.03	0.74	3
13-13.99 years	13	12.57	-0.43	0.43	1	-	-	-	-	0
14-14.99 years	14	15.33	1.33	1.33	1	14	14.37	0.37	0.37	2
15-15.99 years	15	16.16	1.16	1.16	3	15	16.24	1.24	1.24	5
16-16.99 years	16	16.40	0.40	0.40	3	16	16.46	0.46	0.46	3

17-17.99 years	17	16.40	-0.60	0.60	2	17	16.41	-0.59	0.59	1
18-18.99 years	18	16.5	-1.5	1.5	1	18	18.46	0.46	0.46	1
19-19.99 years	19	16.43	-2.57	2.57	1	19	16.97	-2.03	2.03	2
20-20.99 years	20	16.5	-3.5	3.5	1	-	-	-	-	-
21-21.99 years	21	21.5	0.5	0.5	1	21	18.5	-2.5	2.5	1
Ubelaker										
7-7.99 years	-	-	-	-	0	7	6.56	-0.44	0.44	1
8-8.99 years	-	-	-	-	0	8	7.98	-0.02	0.02	1
9-9.99 years	9	9.10	0.10	0.50	4	9	9.45	0.45	0.45	3
10-10.99 years	10	9.94	-0.06	0.11	2	10	9.60	-0.40	0.95	4
11-11.99 years	11	10.40	-0.60	0.60	4	11	10.39	-0.61	0.61	3
12-12.99 years	12	12.31	0.31	0.69	6	12	10.97	-1.03	1.03	3
13-13.99 years	13	11.04	-1.96	1.96	1	-	-	-	-	0
14-14.99 years	14	14.54	0.54	0.54	1	14	13.30	-0.70	1.305	2
15-15.99 years	15	15	0	0	3	15	14.92	-0.08	0.08	5
16-16.99 years	16	14.92	-1.08	1.08	3	16	14.88	-1.12	1.12	3
17-17.99 years	17	15	-2	2	2	17	15	-2	2	1
18-18.99 years	18	15	-3	3	1	18	20.79	2.79	2.79	1
19-19.99 years	19	15	-4	4	1	19	15	-4	4	2
20-20.99 years	20	15	-5	5	1	-	-	-	-	-
21-21.99	21	21	0	0	1	21	21	0	0	1

Table 4.4. Estimated age, delta age, etc. by age group and sex for group 2

	Females					**Males**				
Age Group	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)	Number of individuals	Group Average Real Age	Group Average Estimated Age	Average Delta Age	Average Delta Age (ABS Value)	Number of individuals
London Dental Atlas										
0-0.9 years	0.69	1.03	0.34	0.34	8	0.63	0.8	0.17	0.17	5
1-1.99 years	1.52	1.88	0.36	0.36	8	1.72	2.23	0.56	0.60	6
2-2.99 years	2.61	2.92	0.31	0.31	3	2.60	2.87	0.26	0.35	5
3-3.99 years	3.51	3.77	0.26	0.46	5	3.47	3.61	0.13	0.69	7
4-4.99 years	4.44	4.87	0.43	0.43	6	4.46	5.16	0.71	0.71	3
5-5.99 years	5.43	6.36	0.93	0.97	3	5.35	5.99	0.64	0.94	4
6-6.99 years	-	-	-	-	0	6.28	7.64	1.36	1.36	2
7-7.99 years	7.98	9.62	1.64	1.64	1	7.58	8.18	0.6	0.6	2
8-8.99 years	-	-	-	-	0	8.51	9.47	0.97	0.97	3
9-9.99 years	9.55	10.09	0.54	0.88	2	9.63	10.30	0.67	0.92	4
10-10.99 years	10.57	11.75	1.18	1.18	1	-	-	-	-	0
11-11.99 years	11.41	12.4	0.99	2.4	3	11.17	12.34	1.17	1.17	2
12-12.99 years	12.7	13.81	1.11	1.11	1	12.26	12.96	0.7	0.77	2
13-13.99 years	13.35	15.08	1.74	1.74	4	13.65	13.82	0.17	0.17	2
14-14.99 years	-	-	-	-	-	14.38	14.22	0.16	0.16	1

15-15.99 years	15.85	16.43	0.58	0.58	4	15.49	14.73	-0.76	1.44	3
16-16.99 years	16.52	16.52	0	1.62	3	16.34	18.5	2.16	2.21	6
17-17.99 years	17.41	17.22	-0.19	1.03	4	17.54	18.17	0.63	1.36	3
18-18.99 years	18.47	19.12	0.65	2.09	5	18.53	18.845	0.98	2.22	7
19-19.99 years	19.60	17.98	-1.62	2.52	10	19.65	21.11	1.46	2.88	9
20-20.99 years	20.38	19.63	-0.75	1.59	7	20.37	21.17	0.8	3.56	3
Ubelaker										
0-0.9 years	0.69	0.43	-0.26	0.29	8	0.63	0.43	-0.20	0.33	5
1-1.99 years	1.52	1.06	-0.46	0.46	8	1.72	1.45	-0.27	0.37	14
2-2.99 years	2.61	2.24	-0.38	0.39	3	2.60	2.07	-0.48	0.48	5
3-3.99 years	3.51	3.08	-0.43	0.59	5	3.47	2.98	-0.49	0.88	7
4-4.99 years	4.44	4.03	-0.41	0.41	6	4.46	4.23	-0.22	0.78	3
5-5.99 years	5.43	4.66	-0.76	0.76	3	5.35	4.61	-0.74	0.74	4
6-6.99 years	-	-	-	-	0	6.28	6.11	-0.17	1.26	2
7-7.99 years	7.98	8.37	0.39	0.39	1	7.58	6.93	-0.65	0.65	2
8-8.99 years	-	-	-	-	0	8.51	8.52	-0.05	0.61	3
9-9.99 years	9.55	8.82	-0.76	0.8	2	9.63	8.90	-0.64	0.64	4
10-10.99 years	10.57	11.16	0.59	0.59	1	-	-	-	-	0
11-11.99 years	11.41	10.77	-0.63	1.49	3	11.17	11.03	-0.15	0.84	2

12-12.99 years	12.7	12	-0.7	0.7	1	12.26	11.10	-0.86	0.86	2
13-13.99 years	13.35	12.82	-0.53	1.52	4	13.65	12.76	-0.90	0.90	2
14-14.99 years	-	-	-	-	0	14.38	12.84	-1.54	1.54	1
15-15.99 years	15.85	14.91	-0.95	0.95	4	15.49	13.13	-2.36	2.36	3
16-16.99 years	16.52	14.88	-1.64	1.64	3	16.34	17	0.66	2.51	6
17-17.99 years	17.41	16.5	-0.91	2.50	4	17.54	17	-0.54	2.76	3
18-18.99 years	18.47	17.4	-1.07	3.01	5	18.53	18.43	-0.10	2.73	7
19-19.99 years	19.60	16.78	-2.82	3.73	10	19.65	18.34	-1.30	2.75	9
20-20.99 years	20.38	20.14	-0.23	1.43	7	20.37	19	-1.37	2.39	3

Secular change

To observe any development trends that have occurred between the generations of birth for individuals in Group 1 and Group 2, three sets of figures were created for the maxillary second incisors, canines, and third molars. Three tables were also created which include the results of chi-squared and Fisher's exact tests performed on each tooth chosen. Figure 4.1 provides results for the maxillary second incisor. Figure 4.2 provides results for the maxillary canines. Figure 4.3 provides results for the maxillary third molars. Tables A.9-A.11 found in the Appendix display the resulting values of the chi-squared and Fisher’s exact tests for secular change for all the maxillary lateral incisors, canines, and third molars respectively.

For the upper lateral incisors, only the age group of 9.5-year-olds suggest evidence of some secular change, with a χ^2 p-value of 0.04. For the upper canines, no chi-squared results suggest evidence of secular change. For the upper third molar, only ages 11.5 and 14.5 showed evidence of slight secular change, with the 11.5 age category having a χ^2 value of 0.04 and the 14.5 age category having a χ^2 value of 0.046.

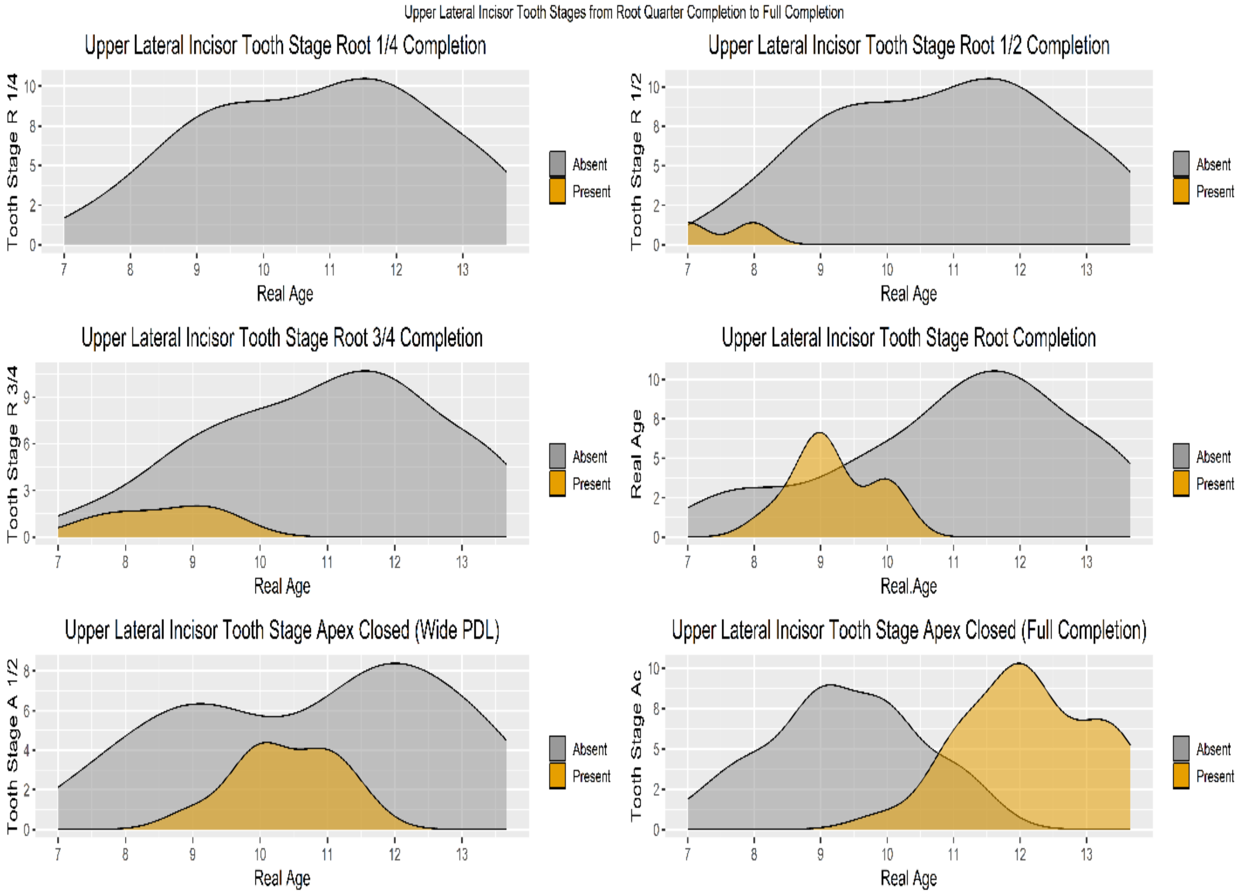

Figure 4.1. Upper lateral incisor tooth stage chart from R ¼ to full development

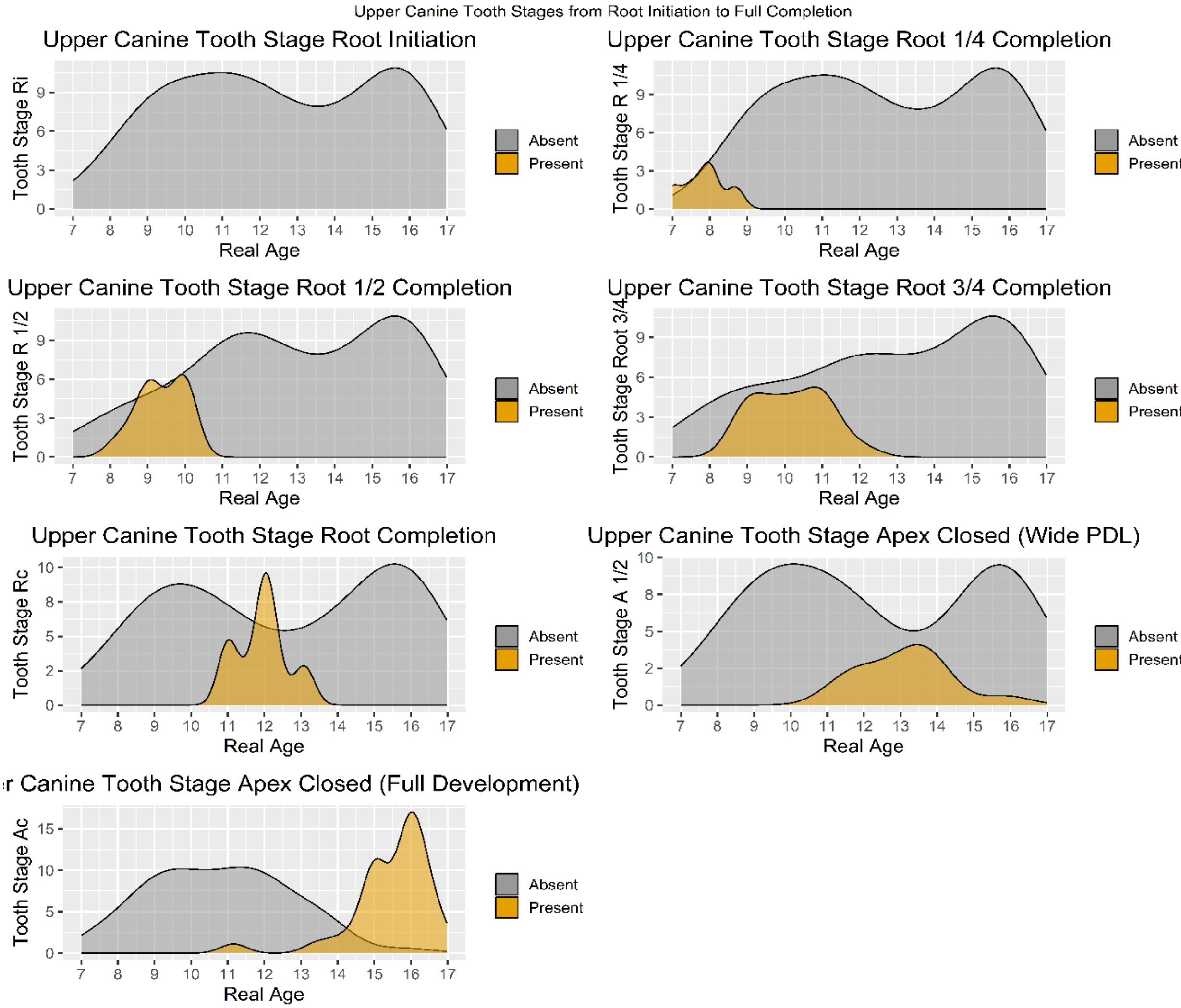

Figure 4.2. Upper canine tooth stages from root initiation to full development

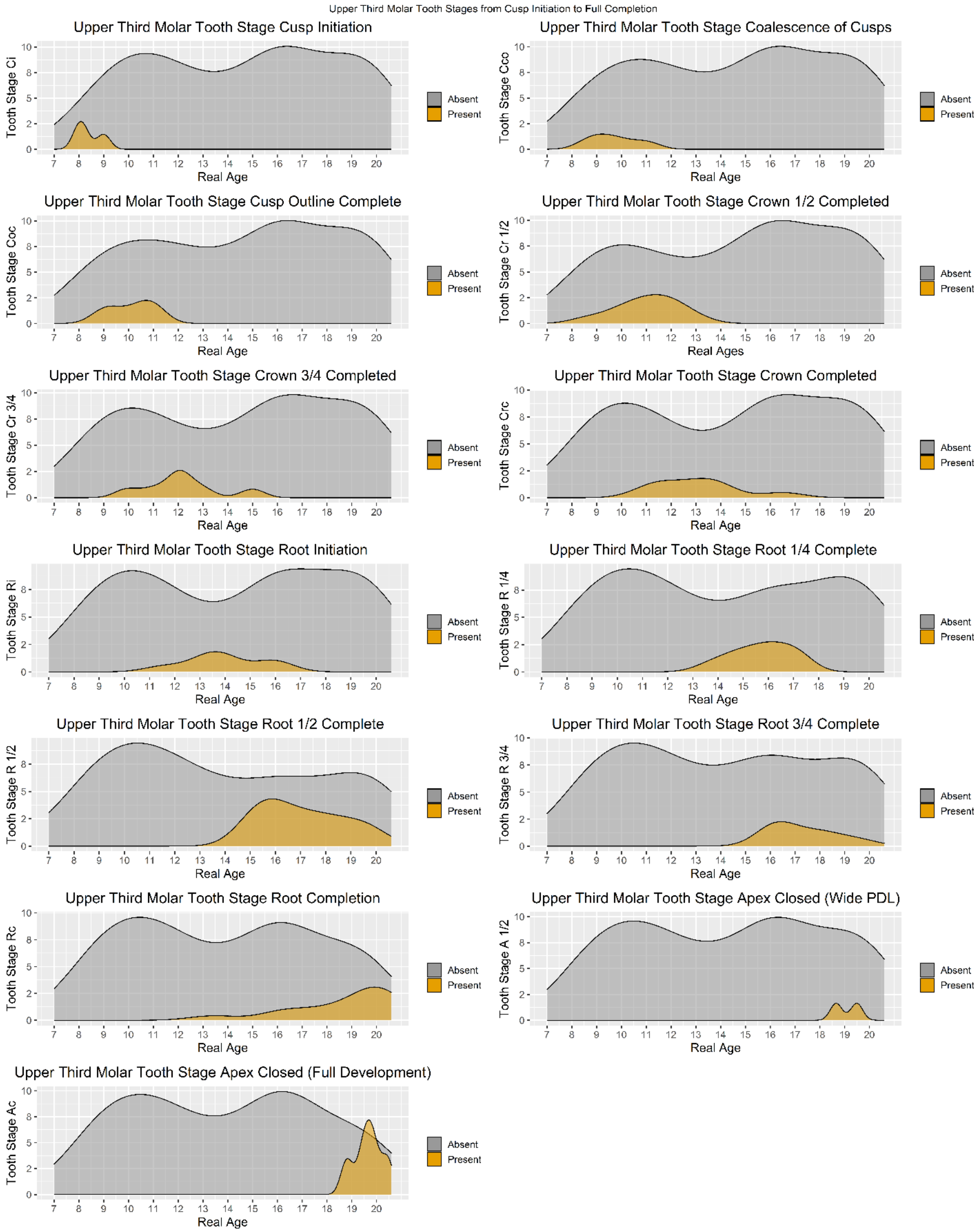

Figure 4.3. Upper third molar tooth stages from cusp initiation to full development

Variations in typical dental development

To measure the degree of variation in dental development for individuals in this thesis, figures were created based on those provided in the London Dental Atlas (2010) which track the minimum, median, and maximum developmental stages of each tooth at different ages. The tooth stage chart for Group 1 excludes individuals younger than 7.5 years of age because Group 1 contains no one younger than 7 years of age. Figure 4.4 provides the minimum, median, and maximum tooth stages recorded for Group 1 including both sexes, while Figure 4.5 provides the same information but using data recorded from Group 2. Additional charts separated by sex can be found in the Appendix as Figures A12-A15.

Table 4.5. Tooth stage chart of Group 1 individuals (All Sexes)

Maxilla						Mandible			
		Tooth Formation Stage				Tooth Formation Stage			
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
7.5 years	1	i^1	-	-	-	i_1	-	-	-
		i^2	-	-	-	i_2	-	-	-
		c'	-	-	-	c,	Ac	Ac	Ac
		m^1	Res 1/2	Res ½	Res 1/2	m_1	Res 1/2	Res 1/2	Res ½
		m^2	Res 1/4	Res 1/4	Res 1/4	m_2	Res 1/4	Res 1/4	Res ¼
		I^1	R 1/2	R 1/2	R 1/2	I_1	Rc	Rc	Rc
		I^2	R 1/2	R 1/2	R 1/2	I_2	R 3/4	R 3/4	R ¾
		C'	R 1/4	R 1/4	R 1/4	C,	Ri	Ri-R 1/4	R ¼
		P^1	Ri	Ri	Ri	P_1	Ri	Ri-R 1/4	R ¼
		P^2	Ri	Ri	Ri	P_2	Ri	Ri	Ri
		M^1	Rc	Rc	Rc	M_1	Rc	Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
		M^3	-	-	-	M_3	-	-	-
8.5 years	1	i^2	-	-	-	i_2	-	-	-
		c'	Res 1/4	Res ¼	Res 1/4	c,	(NA)	(NA)	(NA)
		m^1	(NA)	(NA)	(NA)	m_1	Res 1/4	Res 1/4	Res ¼
		m^2	Res 1/2	Res ½	Res 1/2	m_2	Ac	Ac	Ac
		I^1	Rc	Rc	Rc	I_1	Rc	Rc	Rc
		I^2	R 3/4	R ¾	R 3/4	I_2	R 3/4	R 3/4	R ¾
		C'	R 1/4	R ¼	R 1/4	C,	R 1/4	R 1/4	R ¼
		P^1	Ri	Ri	Ri	P_1	R 1/4	R 1/4	R ¼
		P^2	Ri	Ri	Ri	P_2	R 1/4	R 1/4	R ¼
		M^1	Rc	Rc	Rc	M_1	R 3/4	R 3/4-Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
		M^3	-	-	-	M_3	-	-	-
9.5 years	7	c'	Res 1/4	Res ½	-	c,	Res 1/4	Res 3/4	-

		m^1	Res 1/2	Res ¾	-	m_1	Res 1/2	Res 3/4	-
		m^2	Res 1/4	Res ½	-	m_2	Res 1/4	Res 1/2	-
		I^1	Rc	Rc	Ac	I_1	A 1/2	Ac	Ac
		I^2	R 3/4	Rc	A 1/2	I_2	Rc	A 1/2	Ac
		C'	R 1/2	R ¾	Rc	C,	R 1/2	R 1/2	R ¾
		P^1	R 1/4	R ½	Rc	P_1	R 1/4	R 1/2	R ¾
		P^2	Ri	R ½	R 1/2	P_2	Ri	R 1/4-R 1/2	R ¾
		M^1	A 1/2	Ac	Ac	M_1	Rc	A 1/2	Ac
		M^2	Ri	R 1/4	R 1/2	M_2	Ri	R 1/2	R ½
		M^3	-	-	Coc	M_3	-	Ci	Cco
10.5 years	6	c'	Res 1/2	Res 3/4	-	c,	Res 1/4	-	-
		m^1	Res 1/2	-	-	m_1	Res 1/2	-	-
		m^2	Res 1/4	Res 1/2	-	m_2	Res 1/4	Res 1/2	-
		I^1	Rc	A 1/2	Ac	I_1	A 1/2	Ac	Ac
		I^2	Rc	Rc	A 1/2	I_2	A 1/2	Ac	Ac
		C'	R 1/2	R 1/2	R 3/4	C,	R 1/2	R 1/2	Rc
		P^1	R 1/4	R 1/2	R 3/4	P_1	R 1/2	R 1/2	Rc
		P^2	R 1/4	R 1/2	R 3/4	P_2	R 1/4	R 1/2	R ¾
		M^1	A 1/2	Ac	Ac	M_1	A 1/2	A 1/2	Ac
		M^2	R 1/4	R 1/4	R 1/2	M_2	R 1/4	R 1/4-R 1/2	R ¾
		M^3	-	-	Cr 1/2	M_3	-	Cco	Cr ¾
11.5 years	7	c'	Res 1/2	Res 3/4	-	c,	-	-	-
		m^1	-	-	-	m_1	Res 3/4	-	-
		m^2	Res 1/2	-	-	m_2	Res 1/4	-	-
		I^1	A 1/2	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Rc	A 1/2	Ac	I_2	Ac	Ac	Ac

		C'	R 1/2	R 3/4	Rc	C,	R 3/4	R 3/4-Rc	A ½
		P^1	R 1/2	R 3/4	A ½	P_1	R 3/4	R 3/4	A ½
		P^2	R 1/2	R 3/4	A ½	P_2	R 1/2	R 3/4	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	R 1/2	Rc	M_2	R 1/2	R 1/2	Rc
		M^3	Cco	Cr 1/2	Cr ¾	M_3	Cco	Coc-Cr 1/2	Cr ½
12.5 years	7	c'	Res 1/2	-	-	c,	Res 3/4	-	-
		m^1	-	-	-	m_1	Res 3/4	-	-
		m^2	Res 1/2	-	-	m_2	Res 1/4	-	-
		I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	R 3/4	Rc	A 1/2	C,	R 1/2	A 1/2	A ½
		P^1	R 3/4	Rc	A 1/2	P_1	R 1/2	A 1/2	Ac
		P^2	R 1/2	Rc	Rc	P_2	R 1/4	Rc	A ½
		M^1	Ac	Ac	Ac	M_1	A 1/2	Ac	Ac
		M^2	R 1/2	Rc	Rc	M_2	R 1/2	Rc	Rc
		M^3	Cr 1/2	Cr 3/4	Crc	M_3	Cco	Cr 1/2	Crc
13.5 years	2	I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	Rc	A 1/2	C,	Rc	Rc-A 1/2	A ½
		P^1	Rc	A 1/2	Ac	P_1	R 3/4	R 3/4	A ½
		P^2	Rc	Rc-A 1/2	Ac	P_2	Rc	Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 3/4	R 3/4	Rc	M_2	R 1/2	R 3/4-Rc	Rc
		M^3	Cr 1/2	Cr 1/2-Cr 3/4	Cr 3/4	M_3	Cr 1/2	Cr 1/2	Cr ½
14.5 years	3	C'	Rc	A 1/2	A 1/2	C,	A 1/2	A 1/2	Ac
		P^1	A 1/2	Ac	Ac	P_1	A 1/2	A 1/2-Ac	Ac

		P^2	Rc	Ac	Ac	P_2	Rc	Rc-A 1/2	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	A 1/2	A 1/2	A 1/2	M_2	Rc	Rc	A ½
		M^3	Crc	Ri	Ri	M_3	Crc	Ri	Ri
15.5 years	8	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		P^1	Ac	Ac	Ac	P_1	Ac	Ac	Ac
		P^2	Ac	Ac	Ac	P_2	Ac	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	A 1/2	Ac	Ac	M_2	A 1/2	Ac	Ac
		M^3	Cr 3/4	R 1/2	R 1/2	M_3	R 1/2	R 1/2	R ½
16.5 years	6	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/4	R 1/2	M_3	R 1/4	R 1/4	R ½
17.5 years	3	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/4	R 1/2	M_3	Ri	R 1/4	R ½
18.5 years	2	M^3	R 1/2	R 1/2-R 3/4	R 3/4	M_3	R 1/2	R 1/2	R ½
19.5 years	3	M^3	R 1/4	R 1/4-R 1/2	R 1/2	M_3	Ri	R 1/4	R ½
20.5 years	1	M^3	R 1/2	R 1/2	R 1/2	M_3	(NA)	(NA)	(NA)
21.5 years	2	M^3	R 3/4	R ¾	A 1/2	M_3	(NA)	(NA)	(NA)

Table 4.6. Tooth stage chart of Group 2 individuals (All Sexes)

Maxilla						Mandible			
			Tooth Formation Stage				Tooth Formation Stage		
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
6 months	13	i^1	R 1/4	R ½	R 3/4	i_1	R 1/4	R 3/4	R ¾
		i^2	Ri	R ½	R 3/4	i_2	R 1/4	R 1/2	R ½
		c'	Cr 3/4	Crc	R 1/2	c,	Cr 3/4	Crc	R ¼
		m^1	Cr 3/4	R ½	R 1/2	m_1	Cr 3/4	R 1/4	R ½
		m^2	Cr 1/2	Crc	Ri	m_2	Cr 1/2	Cr 3/4	Crc
		I^1	Cco	Coc	Cr 1/2	I_1	Coc	Coc	Cr ½
		I^2	-	-	-	I_2	Ci	Ci	Cr ½
		C'	Ci	Ci	Coc	C,	Ci	Ci	Coc
		M^1	Cco	Cco	Coc	M_1	Cco	Cco	Coc
1 year	12	i^1	R 1/2	Rc	A 1/2	i_1	R 1/2	Rc	A ½
		i^2	R 1/2	R ¾	Rc	i_2	R 1/4	R 3/4	Rc
		c'	Crc	R ½	R 3/4	c,	Crc	R 1/2	R ¾
		m^1	R 1/2	R ¾	Rc	m_1	R 1/2	R 3/4	Rc
		m^2	Crc	R ¼	R 1/2	m_2	Cr 3/4	R 1/4	R ½
		I^1	Cr 1/2	Cr ½	Cr 1/2	I_1	Cr 1/2	Cr 1/2	Cr ½
		I^2	-	Ci	Coc	I_2	Cr 1/2	Cr 1/2	Cr ½
		C'	Coc	Coc	Cr 1/2	C,	Coc	Coc	Cr ½
		M^1	Coc	Coc	Cr 1/2	M_1	Coc	Coc	Cr ½
1.5 years	10	i^1	Rc	Rc	Ac	i_1	Rc	A 1/2	Ac
		i^2	R 3/4	Rc	Ac	i_2	R 3/4	Rc	Ac
		c'	R 1/2	R ½	R 3/4	c,	R 1/2	R 3/4	R ¾

		m^1	R 3/4	Rc	Rc	m_1	R 3/4	R 3/4	Rc
		m^2	R 1/4	R ½	R 3/4	m_2	R 1/4	R 1/2	R ¾
		I^1	Cr 1/2	Cr 1/2- Cr ¾	Cr 3/4	I_1	Cr 1/2	Cr 1/2- Cr 3/4	Cr ¾
		I^2	Ci	Coc	Cr 1/2	I_2	Coc	Cr 1/2	Cr ¾
		C'	Coc	Cr ½	Cr 1/2	C,	Coc	Cr 1/2	Cr ½
		P^1	-	-	Cco	P_1	-	Ci	Cco
		M^1	Coc	Cr ½	Crc	M_1	Coc	Cr 1/2	Crc
2.5 years	8	i^1	Rc	Ac	Ac	i_1	Ac	Ac	Ac
		i^2	Rc	A ½	Ac	i_2	Rc	Ac	Ac
		c'	R 3/4	Rc	Ac	c,	R 3/4	Rc	Ac
		m^1	R 3/4	Rc	Ac	m_1	Rc	Rc	Ac
		m^2	R 3/4	Rc	Ac	m_2	R 3/4	Rc	Ac
		I^1	Cr 1/2	Cr ¾	Ri	I_1	Cr 1/2	Cr 3/4	Crc
		I^2	Coc	Cr ½	Crc	I_2	Cr 1/2	Cr 3/4	Crc
		C'	Cr 1/2	Cr ½	Cr 3/4	C,	Coc	Cr 1/2	Cr ¾
		P^1	Ci	Cco	Coc	P_1	Ci	Cco	Cr ½
		P^2	-	-	Cco	P_2	-	-	Cco
		M^1	Cr 1/2	Crc	Crc	M_1	Cr 1/2	Crc	Ri
		M^2	-	-	Cco	M_2	-	-	Cco
3.5 years	12	i^1	Rc	Ac	Res 1/4	i_1	Rc	Ac	Res ¾
		i^2	Rc	Ac	Res 1/4	i_2	Rc	Ac	Res ½
		c'	Rc	A 1/2- Ac	Ac	c,	Rc	Ac	Ac
		m^1	Rc	Ac	Ac	m_1	Rc	Ac	Ac
		m^2	Rc	A 1/2- Ac	Ac	m_2	Rc	A 1/2-Ac	Ac
		I^1	Cr 3/4	Cr ¾	Crc	I_1	Cr 3/4	Crc	Ri
		I^2	Cr 1/2	Cr ¾	Crc	I_2	Cr 1/2	Crc	Crc

		C'	Cr 1/2	Cr ¾	Crc	C,	Cr 1/2	Cr 3/4	Crc
		P^1	Cco	Cr ½	Cr 3/4	P_1	Cco	Cr 1/2	Cr ¾
		P^2	-	Cco	Coc	P_2	-	Cco	Cr ½
		M^1	Cr 3/4	Crc	R 1/4	M_1	Crc	Crc	R ¼
		M^2	-	Cco	Coc	M_2	-	Ci	Coc
4.5 years	9	i^1	Ac	Ac	Ac	i_1	Ac	Res 1/4	Res ½
		i^2	Ac	Ac	Ac	i_2	Ac	Ac	Res ¼
		c'	A 1/2	Ac	Ac	c,	A 1/2	Ac	Ac
		m^1	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	Crc	Crc	R 1/4	I_1	Ri	Ri	R ¼
		I^2	Cr 3/4	Crc	Ri	I_2	Crc	Ri	R ¼
		C'	Cr 3/4	Cr ¾	Crc	C,	Cr 3/4	Crc	Crc
		P^1	Cr 1/2	Cr ¾	Crc	P_1	Cr 1/2	Cr 3/4	Crc
		P^2	Cco	Cr ½	Cr 3/4	P_2	Coc	Cr 1/2	Cr ¾
		M^1	Crc	R ¼	R 1/2	M_1	R 1/4	R 1/4	Crc
		M^2	Ci	Coc	Crc	M_2	Ci	Coc	Crc
5.5 years	7	i^1	Res 1/4	Res ½	Res 1/2	i_1	Res 1/4	Res 1/4	Res ½
		i^2	Ac	Ac	Res 1/2	i_2	Ac	Res 1/4	Res ¾
		c'	Ac	Ac	Ac	c,	Ac	Ac	Ac
		m^1	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	Ri	R ¼	R 1/4	I_1	Ri	R 1/4	R ½
		I^2	Crc	Ri	R 1/4	I_2	Ri	R 1/4	R ¼
		C'	Crc	Crc	Ri	C,	Crc	Crc	Ri
		P^1	Cr 3/4	Crc	Ri	P_1	Cr 3/4	Crc	Ri
		P^2	Coc	Cr ¾	Crc	P_2	Coc	Cr 3/4- Crc	Crc
		M^1	R 1/4	R ½	R 3/4	M_1	R 1/4	R 1/2	R ¾
		M^2	Coc	Cr ¾	Crc	M_2	Coc	Cr 1/2- Cr 3/4	Crc

6.5 years	2	i^1	Res 3/4	-	-	i_1	-	-	-
		i^2	Res 1/2	Res ½	-	i_2	Res 1/2	Res 1/2	-
		c'	Res 1/4	Res ¼	Res 1/4	c,	Ac	Ac	Ac
		m^1	Res 1/4	Res ¼	Res 1/4	m_1	Res 1/4	Res 1/4	Res ¼
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	R 1/4	R 1/4-R ½	R 1/2	I_1	R 1/2	R 1/2	R ½
		I^2	Ri	Ri-R ¼	R 1/4	I_2	R 1/4	R 1/4	R ¼
		C'	Crc	Crc-Ri	Ri	C,	Ri	Ri	Ri
		P^1	Crc	Crc	Crc	P_1	Crc	Crc-Ri	Ri
		P^2	Cr 3/4	Cr 3/4-Crc	Crc	P_2	Cr 1/2	Crc	Crc
		M^1	R 3/4	Rc	Rc	M_1	R 3/4	R 3/4-Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
7.5 years	3	i^1	Res 3/4	-	-	i_1	-	-	-
		i^2	Res 1/2	-	-	i_2	Res 1/4	-	-
		c'	Ac	Ac	Res 1/2	c,	Ac	Ac-Res 1/4	Res ½
		m^1	Res 1/4	Res ¼	-	m_1	Res 1/4	Res 1/4	-
		m^2	Ac	Ac	Res 1/2	m_2	Ac	Ac	-
		I^1	R 1/4	R ¾	Rc	I_1	R 1/2	R 3/4	A ½
		I^2	R 1/4	R ½	R 3/4	I_2	R 1/4	R 3/4	Rc
		C'	Ri	R ¼	R 1/4	C,	Ri	R 1/4	R ¼
		P^1	Ri	Ri-R ¼	R 1/2	P_1	R 1/4	R 1/4	R ½
		P^2	Ri	Ri	R 1/4	P_2	Ri	Ri	R ½
		M^1	Rc	Rc	Rc	M_1	Rc	Rc	Rc
		M^2	Crc	Crc	R 1/4	M_2	Crc	Crc	R ¼
		M^3	-	-	Ci	M_3	-	-	-
8.5 years	3	i^2	-	-	-	i_2	-	-	-
		c'	Res 1/4	Res ¼	Res 3/4	c,	Res 1/4	Res 1/4-Res 3/4	Res ¾

		m^1	Res 1/4	Res ¼	Res 1/2	m_1	Res 1/4	Res 1/4-Res 3/4	Res ¾
		m^2	Ac	Ac	Res 1/4	m_2	Ac	Ac	Res ¾
		I^1	R 3/4	Rc	Rc	I_1	Rc	A 1/2	A ½
		I^2	R 3/4	Rc	Rc	I_2	Rc	Rc	A ½
		C'	R 1/4	R ½	R 1/2	C,	R 1/2	R 1/2	R ½
		P^1	R 1/2	R ½	R 3/4	P_1	R 1/2	R 1/2	R ½
		P^2	R 1/4	R ¼	R 1/2	P_2	R 1/4	R 1/4	R ½
		M^1	Rc	Rc	A 1/2	M_1	Rc	Rc	A ½
		M^2	R 1/4	R ¼	R 1/4	M_2	Ri	R 1/4	R ½
		M^3	Ci	Ci-Cco	Cr 1/2	M_3	-	Ci	Cr ½
9.5 years	6	c'	Ac	Res ¼	Res 3/4	c,	Res 1/4	Res 3/4	-
		m^1	Ac	Res ¼	Res 1/2	m_1	Res 1/4	Res 1/4	Res ½
		m^2	Ac	Ac-Res ¼	Res 3/4	m_2	Ac	Res 1/4	Res ¾
		I^1	Rc	A ½	Ac	I_1	Rc	A 1/2	Ac
		I^2	R 3/4	Rc-A ½	Ac	I_2	R 3/4	Rc - A 1/2	Ac
		C'	R 1/2	R 1/2-R ¾	R 3/4	C,	R 1/4	R 3/4	Rc
		P^1	R 1/4	R ½	Rc	P_1	R 1/4	R 3/4	Rc
		P^2	R 1/4	R ½	R 3/4	P_2	Ri	R 1/2	R ¾
		M^1	Rc	A 1/2 – Ac	Ac	M_1	Rc	A 1/2-Ac	Ac
		M^2	R 1/4	R ¼	R 3/4	M_2	R 1/4	R 1/4 - R 1/2	R ¾
		M^3	-	Coc	Cr 3/4	M_3	-	Cco-Coc	Cr ¾
10.5 years	1	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	A 1/2	A ½	A 1/2	I_1	Ac	Ac	Ac

		I^2	A 1/2	A ½	A 1/2	I_2	Ac	Ac	Ac
		C'	R 3/4	R ¾	R 3/4	C,	A 1/2	A 1/2	A ½
		P^1	Rc	Rc	Rc	P_1	Rc	Rc-A 1/2	A ½
		P^2	R 3/4	R ¾	R 3/4	P_2	Rc	Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	R ½	R 1/2	M_2	R 3/4	R 3/4	R ¾
		M^3	Coc	Coc	Coc	M_3	Coc	Coc-Cr 1/2	Cr ½
11.5 years	5	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	Ac	-	-	m_2	Res 3/4	-	-
		I^1	A 1/2	Ac	Ac	I_1	A 1/2	A 1/2-Ac	Ac
		I^2	Rc	Ac	Ac	I_2	A 1/2	Ac	Ac
		C'	R 3/4	Rc-A ½	Ac	C,	R 3/4	Rc-A 1/2	A ½
		P^1	Rc	Rc	Rc	P_1	R 3/4	Rc	A ½
		P^2	R 3/4	Rc	Rc	P_2	R 3/4	Rc	Rc
		M^1	A 1/2	Ac	Ac	M_1	A 1/2	Ac	Ac
		M^2	R 1/2	Rc	Rc	M_2	R 1/2	Rc	Rc
		M^3	Coc	Crc	Ri	M_3	Cco	Crc	Ri
12.5 years	3	c'	Res 3/4	-	-	c,	-	-	-
		m^1	-	-	-	m1	-	-	-
		m^2	-	-	-	m_2	Res 1/2	-	-
		I^1	A 1/2	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	A 1/2	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	Rc	A 1/2	C,	Rc	A ½	Ac
		P^1	Rc	Rc	A 1/2	P_1	Rc	A ½	A ½
		P^2	Rc	Rc	A 1/2	P_2	R 3/4	Rc	A ½
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac

		M^2	R 3/4	Rc	Rc	M_2	R 3/4	Rc	Rc
		M^3	Cr 3/4	Cr 3/4-Crc	Crc	M_3	Cr 3/4	Crc	Crc
13.5 years	6	I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	A ½	Ac	C,	Rc	A ½	Ac
		P^1	Rc	A ½	Ac	P_1	A 1/2	A ½	Ac
		P^2	Rc	Rc	Ac	P_2	Rc	Rc	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	Rc	Ac	M_2	Rc	Rc	A ½
		M^3	Cco	Ri	Rc	M_3	Crc	Crc-Ri	R ¾
14.5 years	1	C'	Ac	Ac	Ac	C,	A 1/2	A ½	A ½
		P^1	Ac	Ac	Ac	P_1	A 1/2	A ½	A ½
		P^2	Rc	Rc-Ac	Ac	P_2	A 1/2	A ½	A ½
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Rc	Rc	M_2	Rc	Rc-A ½	A ½
		M^3	R 1/4	R ¼	R 1/4	M_3	R 1/4	R ¼	R ¼
15.5 years	7	C'	A 1/2	Ac	Ac	C,	A 1/2	Ac	Ac
		P^1	Rc	Ac	Ac	P_1	A 1/2	Ac	Ac
		P^2	Rc	Ac	Ac	P_2	Rc	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Ac	Ac	M_2	Rc	Ac	Ac
		M^3	Ri	R ¼	R 1/2	M_3	Ri	R 1/4-R 1/2	R ½
16.5 years	9	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Rc	Ac	Ac	M_2	Rc	Ac	Ac
		M^3	Crc	R ¾	Rc	M_3	Crc	R ¾	Rc
17.5 years	7	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R ½	Rc	M_3	R 1/4	R 1/2-R 3/4	Rc
18.5 years	12	M^3	R 1/2	R 3/4-Rc	Ac	M_3	R 1/2	Rc	Ac
19.5 years	19	M^3	R 1/2	A ½	Ac	M_3	R 1/4	Rc	Ac

20.5 years	10	M^3	Rc	Rc	Ac	M_3	Rc	Rc	Ac

When compared to the London Dental Atlas, there are some differences in tooth stage variation, but nothing that is extremely different. The figures do indicate the third molar is highly variable in its development, beginning at age 7 when the third molar first begins to appear in some individuals. In Group 1, it is not until age 21 that a third molar develops past the stage of R ½, but in Group 2, some individuals are past the R ½ stage by age 16. However, no other teeth appear to be as variable in their development as the third molar. When comparing the two figures together, the only noticeable trend is that the chart for Group 2 reveals that the maximum stage reached for most teeth is one stage higher than that of their counterparts in Group 1.

BMI as a factor in dental development

Individuals in Group 2 were divided into categories based on sex and by classification as either obese or non-obese (Table 4.5). The BMIs of the individuals from either sex were then divided into yearly age categories and averaged, and this average BMI was then rated as either obese or non-obese, dependent upon age and sex (Figure 4.4). As BMI alone is meaningless without appropriate context, an additional figure (Figure 4.5) was made which depicts individuals divided by classification as obesity and by sex to provide visualization as to patterns in the sample.

Table 4.7. Total amount of individuals listed as either obese or not obese, separated by sex

Weight	Male	Female	Total
Not Obese	41.7 %	52.6 %	46.9 %
Obese	58.3 %	47.4 %	53.1 %
Number of individuals	84	78	

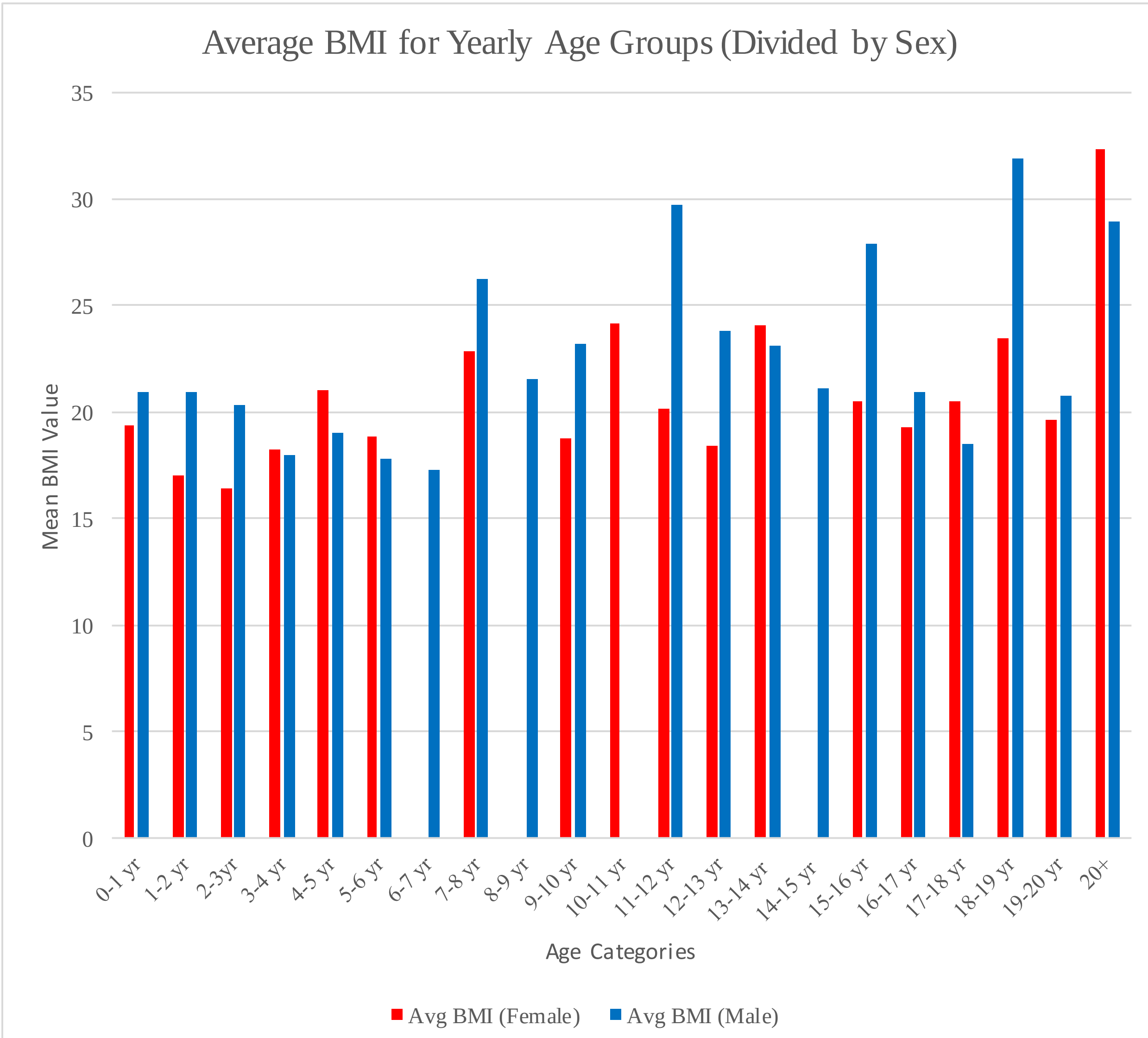

Figure 4.6. Average BMI for yearly age groups divided by sex

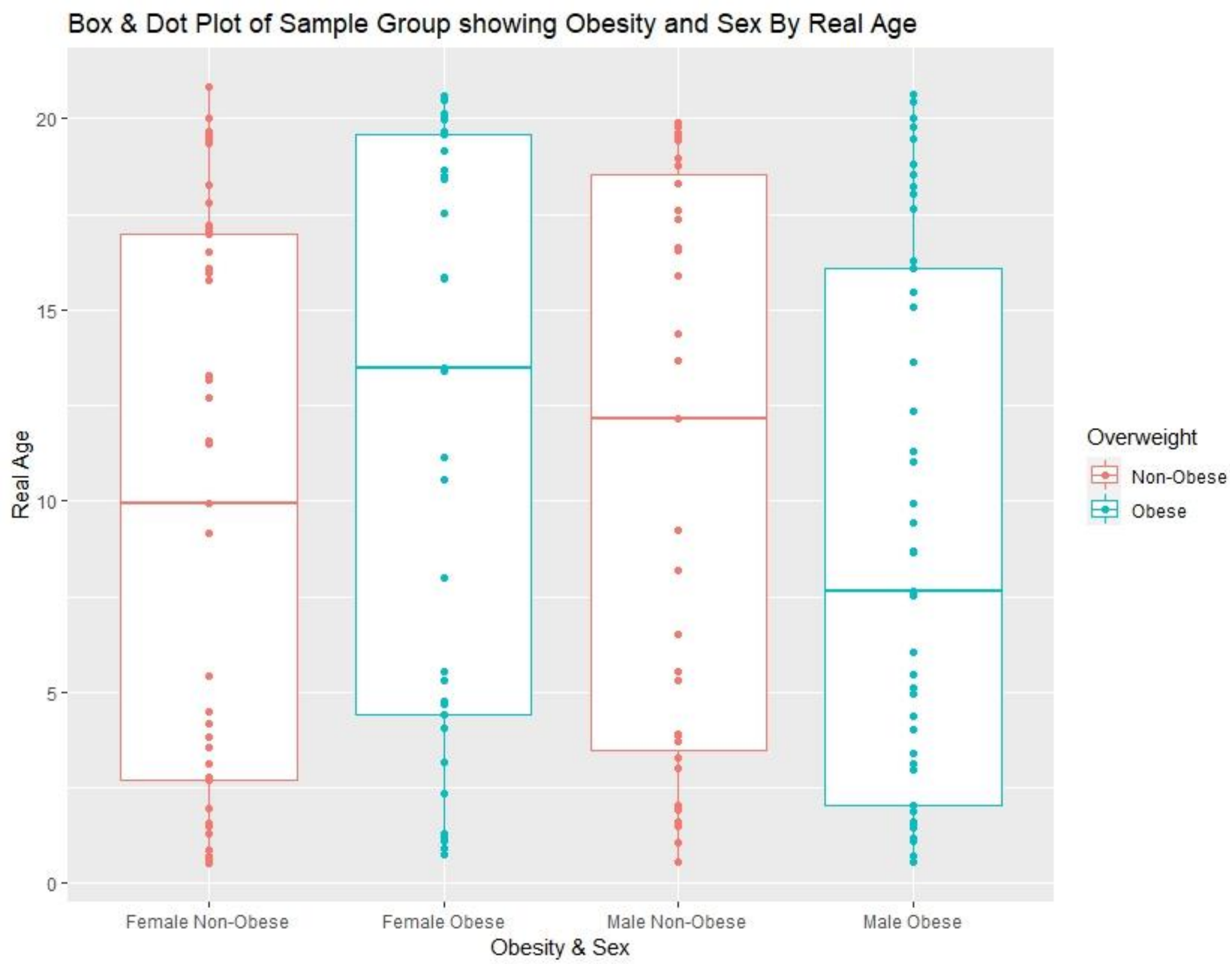

Figure 4.7. BMI values divided by sex and classification as overweight or not

Examination of Table 4.5 shows a near-even split between individuals who were classified as obese vs non-obese. More male individuals were found to be obese than females in Group 2. Obese males had a median age of around 10 years of age, while obese females had a median age of around 13 years, indicating that males tend to be more obese at younger ages compared to females (Figure 4.5). Between the ages of 14-20, the average BMI for females was 17.23, an average BMI not classified as overweight or obese. At age 20 and older, females had an average BMI of 32.34 while males had an average BMI of 28.92; both sexes had an average BMI classified as obese (Figure 4.4). Figure 4.4 also shows that as an individual's age increases, so too does their BMI.

Following an analysis of the general rates of obesity based on age and sex in the sample, a paired t-test compared Group 2's mean real ages and their mean estimated ages. The estimated mean age of Group 2 was 10.73 years, while the mean real age was 10.23, creating a Delta Age of .5 years, or six months. The resulting p-value was 0.0003, which demonstrated a significant difference in the Delta Age.

Linear regression analysis was then used to evaluate if obesity, as represented by BMI, is a variable that impacts the 0.5-year Delta Age obtained in this sample using the London Dental Atlas. Figure 4.6 provides a scatterplot for the Delta Age vs BMI percentiles. An additional linear regression excluding individuals over the age of 17 was done to account for the variability in the development rates of the third molars. Figure 4.7 displays the scatter graph of this analysis. Overall, there is not a significant relationship between BMI and Delta Age.

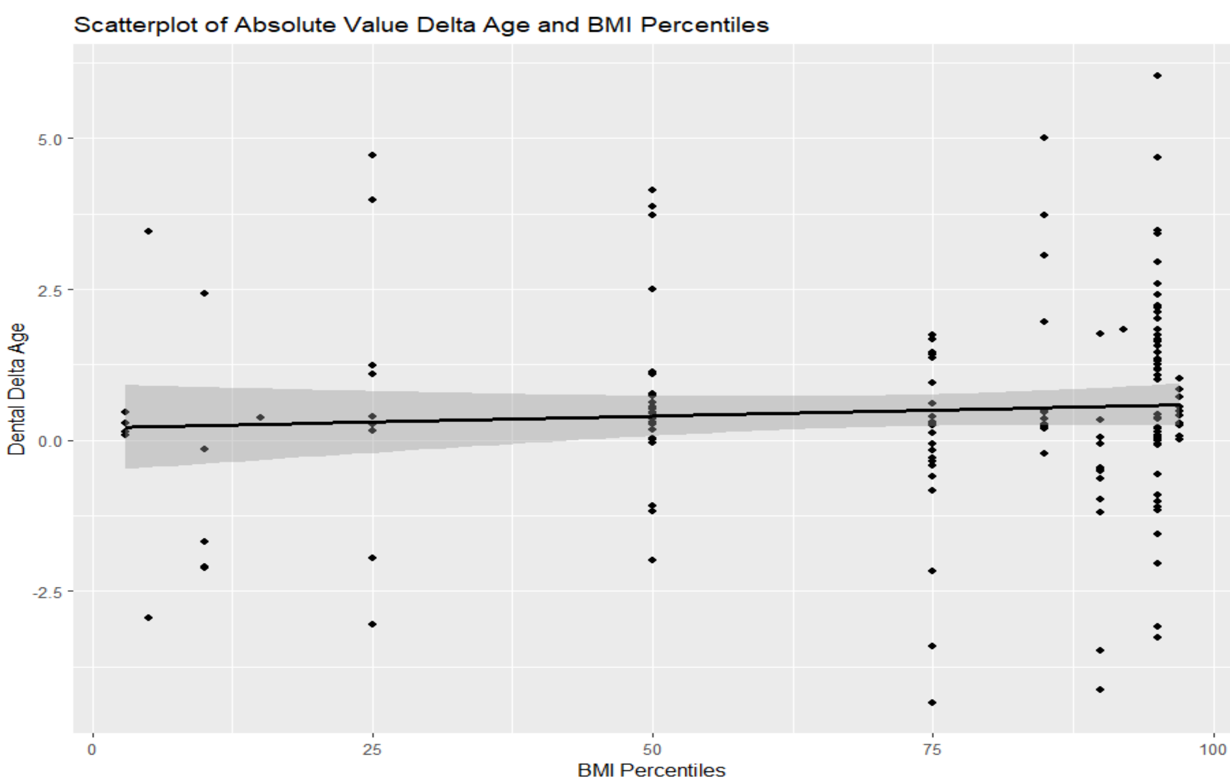

Figure 4.8. Scatterplot of delta age and BMI percentiles

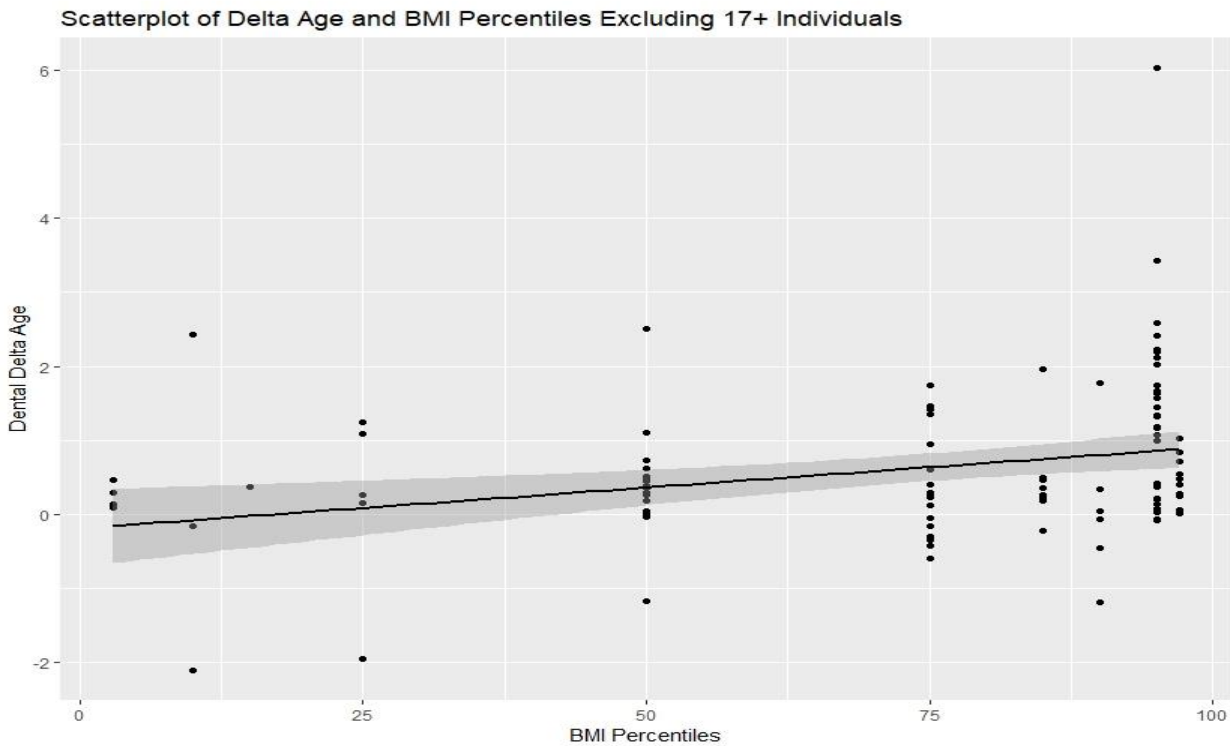

Figure 4.9. Scatterplot of delta age and BMI percentiles excluding 17+ individuals

Intra-observer error results

The results of the Cohen's Kappa values suggest that intra-observer reliability in my scoring of dental development (by tooth) is overall strong for both Group 1, the Economides Collection, and Group 2, the OMI Collection. For Group 1, the average Cohen's Kappa score was 0.76, indicating substantial reliability. For Group 2, the average Cohen's Kappa score was 0.85, indicating significant agreement with the sample reliability. Combining the average Cohen's Kappa scores for both groups produced a value of 0.81, indicating significant overall sample reliability in the retesting. For a list of Cohen's Kappa results for each tooth, see Tables A.1-A.4 for Group 1, and Tables A.5-A.8. for Group 2, all of which can be found in the Appendix.

Chapter 5: Discussion

This thesis compared the accuracy of the London Dental Atlas (AlQahtani et al., 2010), Ubelaker's dental charts (1978), and Moorrees et al. Dental Charts (1963a, 1963b), in estimating the age of Native American children and adolescents. I compared by taking the average Delta Age of each sample group with each method to determine whether each method overestimated or underestimated the average age for each group, and by how much. Furthermore, I also examined how factors such as sex, generation of birth, and weight might affect an individual's dental development, and thereby estimated ages, in two groups (an orthodontic sample and a contemporary pediatric autopsy sample). I tested five different hypotheses that were mentioned at the beginning of this thesis: 1. Which of the three age estimation methods is the most accurate when applied to a Native American population? 2. Are there differences in dental development between males and females? 3. Are certain teeth more prone to being under or over-developed compared to other teeth? 4. Is there evidence of secular change in dental development between Group 1 and Group 2? 5. What is the relationship between body mass index (BMI) and an individual's dental development?

This thesis is one of the first studies to test how the accuracy of these methods on age estimation of Native American individuals with known ages. The results of this thesis have important consequences for individuals doing archaeological research, and perhaps even more importantly, to those conducting forensic investigations. Of the methods tested, I found that the London Dental Atlas (AlQahtani et al., 2010) is the most accurate for age estimation of contemporary Native American infants, children, and adolescents. In addition, I found that females and males do not show significant differences in dental development until around age 7, where females began to have their ages overestimated more than males. For individuals aged 17 and older, however, males were more often overestimated regarding their ages compared to females, especially in Group 2, the contemporary pediatric sample.

Accuracy of the three chosen dental methods tested

The London Dental Atlas (AlQahtani et al., 2010) is the most accurate dental age estimation method that I tested, having overestimated the average groups' ages of both groups by approximately six months. However, this was more accurate than Ubelaker’s dental charts (1978), which consistently underestimated both sample groups by around seven to eight months below the two groups’ real average ages. The least accurate method was the Moorrees dental charts (1963a & 1963b), underestimating the average real ages of both groups by around 3 years.

However, my examination of the estimated age for both groups revealed that the largest errors (either over- or under-estimates) were in individuals where age relied on the third molar. In cases where third molars were absent (either congenitally or surgically removed), the maximum age estimate that could be obtained was 16 years. In cases where the third molar is present, an individual could have a real age of 21, but their third molar development suggests an age of just 16, a potential five-year underestimation. Thus, additional analysis was conducted on the average ages versus estimated ages of both groups but excluded individuals over the age of 17 to avoid the problems these issues present.

The results of this additional analysis indicate that Ubelaker’s dental charts are the most accurate method, although it still underestimated the average ages of both sample groups. This suggests that Ubelaker's dental charts might be the more accurate method for more general use in estimating age. These results provide support to my earlier hypothesis (hypothesis 1), that Ubelaker's dental charts would be more accurate due to its use of a Native American group similar to this thesis, at least when excluding individuals over the age of 17.

My results compare favorably with other published works regarding the accuracy of the three tested age estimation methods. AlQahtani et al. (2014), found that Ubelaker's dental charts consistently underestimated the average mean real age for their sample around 0.80 years, similar to this thesis' results. The results of AlQahtani et al. (2014) accuracy in aging by the London Dental Atlas differ slightly from the results of this thesis in that their results have the London Dental Atlas mean difference underestimate or match the samples' real age, while I found the London Dental Atlas consistently overestimated the average ages of the sample groups. However, the London Dental Atlas is the most accurate method for estimating age when accounting for all teeth and not excluding any.

When reviewing the results obtained using the Moorrees et al. chart, Martínez Gutiérrez & Ortega-Pertuz (2017) found that it underestimated their sample between 0.5 – 6.64 years depending on the age group of the individuals measured. The results of this thesis are similar; age estimation for younger individuals using the Moorrees et al. chart are highly accurate, but in older individuals, this chart underestimates age by up to six years. Alkandiri et al. (2021) found that of three dental age estimation techniques, the London Dental Atlas, the Moorrees et al. chart, and the simple average method (SAM), the London Dental Atlas was the most accurate when applied to a sample of 180 Kuwaiti juveniles. In that paper, the Moorrees et al. chart underestimated the average ages of the males and females by around one year, while the London Dental Atlas overestimated by 0.60 years for females and 0.14 for males (Alkandiri et al., 2021).

For younger individuals, the Moorrees et al. chart was accurate, but not for older individuals due to a lack of more consistent aging for all teeth and their development making age estimates far lower than an individual's real age. Furthermore, as the Moorrees method only utilizes mandibular teeth except for the maxillary incisors, if remains are found that lack the mandible, the method was not created to work around such an issue. In addition, the Moorrees et al. method utilizes a sample group of adolescent American individuals of European descent for use in developing their charts. Thus, there is a fundamental difference between the sample group used by Moorrees et al. and the group of individuals studied in this thesis and the lack of accountability for teeth in the maxillary jaw makes it the least accurate age estimation method in this thesis.

Ubelaker's dental charts were fairly accurate, but they consistently underestimated age for all individuals, but especially individuals between the ages of 15-21. For older individuals, this is due to the lack of clarity regarding age association with third molar growth, as the third molar is the only tooth still viable for aging in individuals older than 16. In general, the age ranges used in Ubelaker's dental charts allow for arguably greater forgiveness in age estimation, but the results might not be as precise compared to other methods. In some instances, the lack of precision is acceptable, but in medical or forensic cases, age estimates need to be both accurate and precise.

Sex differences in age estimation

As previous sections of this thesis discussed; I hypothesized that females would show more advanced rates of dental development when compared to males. This hypothesis was influenced by earlier studies by individuals like Demirjian & Levesques (1980), and others who found evidence that females mature faster concerning dental development. The results of this thesis indicate that males and females tend to be somewhat similar in their dental development at younger ages, but that the average estimated ages for females between the ages of 10-15.99 were consistently overestimated by a greater amount when compared to males in both the London Dental Atlas and Ubelaker's dental charts. For individuals 16 and older, the overestimates of the average estimated ages were more common in males than females in several age groups; but this is possibly due to variation in third molar development rather than sexual dimorphism.

The findings regarding age estimation for males and females utilizing the third molar support the findings of Demirjian & Levesque (1981), whose research showed that males tended to reach third molar maturity earlier than females. More specifically, females' third molars typically grow faster than males up until the stage of crown completion (Coc). During main root development however, males' third molars develop faster than females by a median age of 1.5 years (Demirjian & Levesque, 1981). This finding supports the results of this thesis in that males had their ages overestimated more than females when examining ages 16 and older, as the third molar would have been the main tooth used for age estimation.

Variations in tooth development

My findings indicate that there are no abnormal variations in tooth development in either of my sample groups when compared to standards set by a method like the London Dental Atlas. In looking at variation patterns in specific teeth, the third molar remains the most variable tooth in its development. In Group 1, the Economides collection, third molars never reached beyond the stage of R ½ development, even at age 21. However, in Group 2, the OMI collection, individuals under 18 years of age were seeing third molar growth beyond stage R ½ of development. No other tooth in the dentition has the same amount of variation in its development patterns. My findings reaffirm the high variability in third molar growth, while also revealing that there are no differences in the overall development patterns of other teeth in my population than other populations like the ones used in the London Dental Atlas.

Secular change

The results of this thesis suggest that there is no evidence of secular change between Group 1, individuals likely born between 1960 and 1990, and Group 2, individuals born between 1990-2017. This is likely due to a combination of a relatively small sample size and the lack of precise measurement of the secular difference between the birth years of individuals in both sample groups. Additionally, the chronological difference between the two groups might not be large enough to properly identify secular change, as some individuals' birth years might overlap with individuals from another group.

The results of this thesis seem contradictory to those of other researchers who have studied the phenomenon of secular change in dental development. However, the limitations listed in the previous paragraph should be considered when viewing these results. Heuzé & Cardoso (2008) found that in comparing a sample of juvenile skeletal remains from a Lisbon population who died between 1913 to 1972, the Libson population was consistently delayed by around one year compared to a modern 21st-century population. However, this study also has a small sample size regarding the Libson population, consisting of just 40 individuals in total. This small sample size, similar to this thesis' results, could have affected the results.

Vucic et al. (2014), found that from a sample of 753 Dutch children from three different cities, individuals born in 2003 were more dentally mature by around 1.5 years compared to similarly aged individuals born in 1963. This study avoids some of the potential issues with previous studies by including a larger sample size while also limiting all the individuals in the study to one geographic area.

The findings of this thesis indicate that there should be no issues with using a modern dental age estimation method on Native American populations from the past 100 years. This allows for greater confidence in areas such as historic archaeology, where archaeologists might attempt to estimate the age of deceased individuals on tribal land or in other areas of the United States. However, future researchers might wish to conduct further research into secular change in dental development for Native Americans who lived in the Americans before European arrival.

BMI and dental development

The results of this thesis suggest that obesity, as measured through BMI, does not have an impact on dental development. The linear regression scatterplots and the correlation coefficients conducted on Group 2 (as Group 1 was not used in BMI testing) suggest that BMI and obesity are not the causes of the Delta Age results between the groups' real and estimated ages. These results seem to contradict previous studies which suggest that individuals classified as obese are found to have more advanced rates of dental development compared to non-obese individuals (Salazar, 2021; Garn et al., 1965; Nicholas et al., 2018). While not specific to a Native American population, these studies consistently found that obese individuals' estimated ages were higher than a year or more compared with their real ages. In the specific case study examinations involved in this thesis, individuals in Group 2 who were classified as obese occasionally had their ages underestimated using the London Dental Atlas.

One issue of note when using BMI is that although it is meant to refer to weight to identify signs of obesity, BMI does not account for muscle mass and other factors which contribute to an individual's weight. In other words, a 17-year-old football player who is 6'1 and 225 pounds would be classified as overweight by measuring BMI alone. However, it would not account for the fact that an individual could have large muscle mass that adds to their weight, increasing their BMI and causing it to be classified as overweight or obese. For the individuals in Group 2, it is still unknown whether an individual is classified as obese or not due to their weight being made of either fat or muscle. Furthermore, the data available does not track whether an individual at the time of death was consistently obese for months or years leading up to their death, or whether they might have even lost weight before their death but have been chronically obese throughout their life. A longitudinal study by Nicholas et al. (2018), suggests, that chronic obesity in early life leads to accelerated dental development later in life. From that, it could be stated that the results of the BMI analysis would indicate that individuals around the age of puberty (13-15) who are obese would show signs of consistent overestimation.

From the results of the linear regression analyses using both normal Delta Age values as well as their absolute values, it does not appear that Group 2 follows the standard trend other researchers have seen regarding BMI and dental age estimation. The initial hypothesis was that individuals in this sample with a BMI classified as obese would have an advanced rate of dental development compared to similarly aged individuals with what the CDC considers a normal and healthy body weight. Linear regression analyses of the absolute values of the Delta Ages provide similar results: the relationship was weak and little of the variation was explained. When excluding individuals over 17, the results still indicated a very weak relationship with little of the variation in the sample being explained by obesity when represented by BMI. Thus, it can be concluded obesity through BMI does not affect age estimation in any significant manner for this sample group.

Chapter 6: Conclusions and Final Thoughts

One of the main goals of this thesis was to determine which of the three chosen dental age estimation methods; 1. The London Dental Atlas (Alqahtani et al., 2010), 2. Ubelaker's dental charts (Ubelaker, 1978), 3. The Moorrees Dental Chart (Moorrees et al., 1963a; 1963b), was the most accurate in estimating the age of two groups of contemporary Native Americans (1960-2019) from New Mexico. The initial hypothesis was that Ubelaker's dental charts would be the most accurate due to similarities in the group of individuals used in his charts and the groups included in this thesis. However, the analysis of the corresponding Delta Ages from both groups in this thesis for each method revealed that the London Dental Atlas was the most accurate method of the three. Ubelaker's dental charts were only more accurate when excluding third molars, but it is not always possible to exclude third molars from age estimation, as it would arbitrarily affect age estimates for older individuals.

After identifying which of the three dental age estimation methods was the most accurate, the rest of this thesis was dedicated to understanding how factors such as sex, secular change, tooth variation, and BMI might affect age estimates using dental development as a source. My research shows that up to the age of 16, females ages were more consistently overestimated when compared to males, supporting the findings of past researchers. However, when examining the differences between males and females at the age of 16 and above, where age estimation becomes reliant on the third molar, I found that males ages were more consistently overestimated compared to females, a finding supported in other publications (Demirjian & Levesque, 1981).

I also examined whether secular change might impact dental development in Native American children. A possible concern is that using dental age estimation methods which were made using data from contemporary populations might not be as effective in accurately aging individuals from past populations. This concern has been addressed in some studies, which suggest that there are differences in rates of development between past and contemporary populations. I created plotted figures that overlayed the number of teeth from individuals in both groups and their average tooth stage of development with the median stage of development listed in the London Dental Atlas (AlQahtani et al., 2010). Overall, I found some variation in tooth stages between Group 1 and Group 2, but my results do not provide definitive evidence of secular change between the two groups.

I also examined variations in dental development among the varying tooth types. Third molars are highly variable in their development and eruption into the jaw, and this does not even include whether the third molars are present or not (Liversidge & Marsden, 2010). I assessed whether any other teeth were as equally variable in their development. This was achieved by creating tables that mirrored those found in the London Dental Atlas, displaying the minimum, median, and maximum tooth stages of each tooth present at varying age groups and divided by group and sex. Overall, there was some slight variation in tooth stage development between the two groups and the London Dental Atlas, but nothing to suggest any drastic differences with the minor variation present still falling in acceptable rates of development. The third molar remained the most variable tooth of all the teeth in the dentition.

The final goal of this thesis was to examine the effect that obesity, as measured through an individual's body mass index (BMI), might have on dental development. Studies conducted in the past have provided evidence that states that obese juveniles with high BMIs have more advanced dental development rates compared to non-obese individuals. Using a combination of an unpaired t-test and linear regression analysis, I determined that BMI was not the cause of the difference between the average estimated ages of the sample groups and their average real ages. This suggests that another factor, such as genetics/epigenetics, socioeconomic status, chronic illness, or some other biological or social factor, may be the cause of the age difference I observed between the two groups' average estimated ages and their average real ages.

Directions for Future Research

The results of this thesis show that modern dental age estimate methods, such as the London Dental Atlas and Ubelaker's dental charts, can be used to estimate the ages of Native American children and adolescents with a high degree of accuracy overall. However, there are still concerns that other possible factors could artificially influence the age estimates. One of the biggest issues that necessitate future research is to examine how health factors outside of BMI might affect dental development. Chronic diseases like cancer and chronic renal failure affect the biological development of juvenile individuals afflicted with such diseases (Alamoudi et al., 2020; Campisi et al., 2007; Jaffe et al., 1990; Proctor et al., 2005). For researchers studying archaeological populations which likely suffered from chronic health conditions, special focus must be placed on how these diseases might have delayed the development of individuals so that the proper adjustments can be made during the creation of age estimates.

Although my research states that obesity, as represented through BMI, does not affect dental development in a meaningful capacity, there should be future research into examining how other aspects of health could possibly impact dental development. Several past studies have recorded that obesity does affect dental development (Salazar, 2021; Garn et al., 1965; Nicholas et al., 2018), but it is possible that my sample size was too small to properly detect this issue. My research did not examine the relationship between dental development and being underweight; but being underweight could cause a delay in dental development. While some research suggests being underweight does affect dental development (Hedavati & Khalafinejad, 2014; Kumar et al., 2013), additional research can only help to clear up this confusion, especially as it might be due more to malnutrition rather than just being under a healthy weight.

The possibility of malnutrition slowing dental development also merits more attention. The existing literature shows mixed results, with some research suggesting that it has no effect (Elamin & Liversidge, 2013) and other studies claiming that it leads to a delay in dental development (Alvarez & Navia, 1989). Malnutrition status was not available in this study; therefore, I call for other anthropologists to determine if dental development is resistant to malnutrition, or if the process may be delayed due to the lack of essential vitamins and minerals that accompany a status of being malnourished. Another avenue of examination is the amounts of visceral adipose tissue and subcutaneous adipose tissue and how the presence and amount of such tissues could affect dental development, which this thesis did not examine.

Beyond looking at health and weight factors and their effects on dental development, future research needs to further examine the idea of secular change and its relationship with dental development. Although the results of my thesis suggest that there is no evidence of secular change between my two sample groups, there was a lack of clarification in the overall year of birth difference between the two samples. Future researchers should collect data on larger samples with clearly stated years of birth with a minimum age difference of fifty years to begin determining if the generation of one's birth affects dental development. The few studies done on the subject have at minimum a fifty-year age gap, so I believe that would be a safe minimum for any future study (Sasso et al., 2013; Vucic et al., 2014). I expect that researchers will find the most obvious evidence between sample groups with a difference of around 200 years, where diet and medicine drastically differed compared to modern living, but research needs to be conducted to support this hypothesis.

The process of creating age estimates is incredibly important to biological anthropologists, archaeologists, and medical professionals relying on accurate age estimates to make proper identifications. This thesis, and the work of numerous other researchers, have made it clear that using dental development to create age estimates is possible and highly accurate. A plethora of methods exist which use dental development to create age estimates, and this thesis tested three of them; 1. The London Dental Atlas (Alqahtani et al., 2010), 2. Ubelaker's dental charts (1978), 3. The Moorrees Dental Chart (Moorrees et al., 1963a & 1963b). Ultimately I found that the London Dental Atlas is the most accurate, and found that factors such as BMI and secular change have relatively little influence on natural dental development. Lastly, future research should identify other factors which could influence dental age estimates to make age estimates as accurate as possible. Identifying these factors and learning exactly how they might affect dental development will allow for the most accurate age estimates possible to be obtained, even with said factors affecting natural dental development.

<u>Bibliography</u>

Adams, D. M., Ralston, C. E., Sussman, R. A., Heim, K., & Bethard, J. D. (2019). Impact of population-specific dental development on age estimation using dental atlases. *American Journal of Physical Anthropology, 168*(1), 190-199. https://doi.org/10.1002/ajpa.23735

Alamoudi, N. M., Alsadat, F. A., El-Housseiny, A. A., Felemban, O. M., Al Tuwirqi, A. A., Mosli, R. H., & Saadah, O. I. (2020). Dental maturity in children with celiac disease: A case-control study. *BMC Oral Health, 20*(1), 311-311. https://doi.org/10.1186/s12903-020-01316-y

Alkandiri, F., Karimi, A., Draft, D., Lucas, V. S., & Roberts, G. (2021). Dental age estimation: A comparison of three methods of estimating dental age in a population of Kuwaiti children and adolescents. *Forensic Science International. Reports, 3*, 100214. https://doi.org/10.1016/j.fsir.2021.100214

Almonaitiene, R., Balciuniene, I., Tutkuviene, J. (2010). Factors influencing permanent teeth eruption: Part one- general factors. *Baltic Dental and Maxillofacial Journal, 12*: 67-72.

AlQahtani, S. J., Hector, M. P., & Liversidge, H. M. (2010). Brief communication: The london atlas of human tooth development and eruption. *American Journal of Physical Anthropology, 142*(3), 481-490. https://doi.org/10.1002/ajpa.21258

AlQahtani, S. J. (2012). The london atlas: Developing an atlas of tooth development and testing its quality and performance measures

AlQahtani J. S., Hector P. M., Liversidge M. H. (2014). Accuracy of Dental Age Estimation Charts: Schour and Massler, Ubelaker, and the London Atlas. *American Journal of Physical Anthropology*, *154*, 70-78. https://doi.org/10.1002/ajpa.22473

Alter, G. (2004). Height, frailty, and the standard of living: Modelling the effects of diet and disease on declining mortality and increasing height. *Population Studies, 58*(3), 265-279. https://doi.org/10.1080/0032472042000272339

Alvarez, J. O., & Navia, J. M. (1989). Nutritional status, tooth eruption, and dental caries: A review. *The American Journal of Clinical Nutrition, 49*(3), 417-426. https://doi.org/10.1093/ajcn/49.3.417

Arumugam, V., Doggalli, N. (2020). Different Dental Aging Charts or Atlas Methods used for Age Estimation-A Review. *Asian Journal of Basic Science and Research, 2*(3), 64-74. Doi: 10.38177/AJBSR.2020.2306

Bagherpour, A., Imanimoghaddam, M., Bagherpour, M. R., & Einolghozati, M. (2009;2010;). Dental age assessment among iranian children aged 6–13 years using the demirjian method. *Forensic Science International, 197*(1), 121.e1-121.e4. https://doi.org/10.1016/j.forsciint.2009.12.051

Balla, S.B., Banda, T.R., Galic, I., N, N.M., Naishadham, P.P. (2019). Validation of Cameriere's third molar maturity index alone and in combination with apical maturity of permanent mandibular second molar for indicating legal age of 14 years in a sample of South Indian children. *Forensic Science International, 297*, 243-248. https://doi.org/10.1016/j.forsciint.2019.02.009

Balwant R., Anand, S.C.. (2006). Tooth Developments: An Accuracy of Age Estimation of Radiographic Methods. *World Journal of Medical Sciences, 1*(2), 130-132. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.608.1704&rep=rep1&type=pdf

Baumann, T. (2004). Defining Ethnicity. *The SAA Archeological Record,* 12-14.

Bei, M. (2009). Molecular genetics of tooth development. *Current Opinion in Genetics & Development, 19*(5), 504-510. https:/doi.org/10.1016/j.gde.2009.09.002

Blumenfeld, Jodi. (2000). Racial identification in the skull and teeth. *Totem: The University of Western Ontario Journal of Anthropology, 8*(1). https://ir.lib.uwo.ca/totem/vol8/iss1/4

Bogin, B., & Rios, L. (2003). *Rapid morphological change in living humans: Implications for modern human origins.* Elsevier Inc. https://doi.org/10.1016/S1095-6433(02)00294-5

Brown, W. A. B. (1985). Identification of human teeth. *Bulletin of the Institute of Archaeology, University of London, 21*(21-22), 1-30.

Buckley, H. R. (2000). Subadult health and disease in prehistoric tonga, polynesia. *American Journal of Physical Anthropology, 113*(4), 481-505. https://doi.org/10.1002/1096-8644(200012)113:4<481::AID-AJPA4>3.0.CO;2-1

Cakan, D. G., Ulkur, F., & Taner, T. (2013). The genetic basis of dental anomalies and its relation to orthodontics. *European journal of dentistry, 7*(Suppl 1), S143–S147. https://doi.org/10.4103/1305-7456.119092

Cameriere, R., Flores-Mir, C., Mauricio, F., & Ferrante, L. (2007). Effects of nutrition on timing of mineralization in teeth in a peruvian sample by the cameriere and demirjian methods. *Annals of Human Biology, 34*(5), 547-556. https://doi.org/10.1080/03014460701556296

Campisi, G., Di Liberto, C., Iacono, G., Compilato, D., Di Prima, L., Calvino, F., Di Marco, V., Lo Muzio, L., Sferrazza, C., Scalici, C., Craxì, A., & Carroccio, A. (2007). Oral pathology in untreated coeliac [corrected] disease. *Alimentary Pharmacology & Therapeutics, 26*(11-12), 1529-1536.

Cardona Salazar, D. K. (2021). *Examining the link between dental development, BMI and diet*

Cardoso, H. F. V. (2007). Environmental effects on skeletal versus dental development: Using a documented subadult skeletal sample to test a basic assumption in human osteological research. *American Journal of Physical Anthropology, 132*(2), 223-233. https://doi.org/10.1002/ajpa.20482

Carter, K. E. (2016). *The evolution of third molar agenesis and impaction*

Centers for Disease Control and Prevention. (2022). *Other factors in weight gain.* Centers for Disease Control and Prevention. Retrieved October 13, 2022, from https://www.cdc.gov/healthyweight/calories/other_factors.html

Centers for Disease Control and Prevention. (Updated December, 2022). *Growth charts- CDC extended BMI-for-age growth charts.* Centers for Disease Control and Prevention. Retrieved September 7, 2023, from https://www.cdc.gov/growthcharts/extended-bmi.htm

Cleveland Clinic. (2022). *Obesity.* Cleveland Clinic. Retrieved October 13, 2022, from https://my.clevelandclinic.org/health/diseases/11209-weight-control-and-obesity

Cole, T.J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establshing a standard definition for child overweight and obesity worldwide: international survey. *BMJ, 320*(7244), 1240.

Correia, H., Balseiro, S., & De Areia, M. (2005). Sexual dimorphism in the human pelvis: Testing a new hypothesis. *Homo, 56*(2), 153. https://doi.org/10.1016/j.jchb.2005.05.003

Coquerelle, M., Bookstein, F. L., Braga, J., Halazonetis, D. J., Weber, G. W., & Mitteroecker, P. (2011). Sexual dimorphism of the human mandible and its association with dental development. *American Journal of Physical Anthropology, 145*(2), 192-202. https://doi.org/10.1002/ajpa.21485

Dahlberg, A. A., & Menegaz-Bock, R. M. (1958). Emergence of the permanent teeth in pima indian children: A critical analysis of method and an estimate of population parameters. *Journal of Dental Research, 37*(6), 1123-1140. https://doi.org/10.1177/00220345580370061201

Demirjian, A., Goldstein, H., & Tanner, J. M. (1973). A new system of dental age assessment. *Human Biology, 45*(2), 211-227.

Demirjian, A., & Goldstein, H. (1976). New systems for dental maturity based on seven and four teeth. *Annals of Human Biology, 3*(5), 411-421. https://doi.org/10.1080/03014467600001671

Demirjian, A., & Levesque, G. -Y. (1980). Sexual differences in dental development and prediction of emergence. *Journal of Dental Research, 59*(7), 1110-1122. https://doi.org/10.1177/00220345800590070301

Dhamo, B., Kragt, L., Grgic, O., Vucic, S., Medina-Gomez, C., Rivadeneira, F., Wolvius, E. B., & Ongkosuwito, E. M. (2018). Ancestry and dental development: A geographic and genetic perspective. *American Journal of Physical Anthropology, 165*(2), 299-308. https://doi.org/10.1002/ajpa.23351

Edgar, H. J. H., Daneshvari, S., Harris, E. F., & Kroth, P. J. (2011). Inter-observer agreement on subjects' race and race-informative characteristics. *PloS One, 6*(8), e23986-e23986. https://doi.org/10.1371/journal.pone.0023986

Elamin, F., & Liversidge, H. M. (2013). Malnutrition has no effect on the timing of human tooth formation. *PloS One, 8*(8), e72274-e72274. https://doi.org/10.1371/journal.pone.0072274

Finch, C. E. (2010). Evolution of the human lifespan and diseases of aging: Roles of infection, inflammation, and nutrition. *Proceedings of the National Academy of Sciences – PNAS, 107*(suppl 1), 1718-1724. https://doi.org/10.1073/pnas.0909606106

Ford, C. L., & Harawa, N. T. (2010). A new conceptualization of ethnicity for social epidemiologic and health equity research. *Social Science & Medicine (1982), 71*(2), 251-258. https://doi.org/10.1016/j.socscimed.2010.04.008

Ford, M. E., & Kelly, P. A. (2005). Conceptualizing and categorizing race and ethnicity in health services research. *Health Services Research, 40*(5p2), 1658-1675. https://doi.org/10.1111/j.1475-6773.2005.00449.x

Forshaw, R. (2014). Dental indicators of ancient dietary patterns: Dental analysis in archaeology. *British Dental Journal, 216*(9), 529-535. https://doi.org/10.1038/sj.bdj.2014.353

Garn, S. M., Lewis, A. B., Polacheck, D. L., & Koski, K. (1958). The sex difference in tooth calcification. *Journal of Dental Research, 37*(3), 561-567. https://doi.org/10.1177/00220345580370032801

Garn, S. M., Lewis, A. B., & Kerewsky, R. S. (1965). Genetic, nutritional, and maturational correlates of dental development. *Journal of Dental Research, 44*(1), 228-242. https://doi.org/10.1177/00220345650440011901

Geifman, N., Cohen, R., & Rubin, E. (2013). Redefining meaningful age groups in the context of disease. *Age, 35*(6), 2357-2366. https://doi.org/10.1007/s11357-013-9510-6

Gravlee, C. C. (2009). How race becomes biology: Embodiment of social inequality. *American Journal of Physical Anthropology, 139*(1), 47-57. https://doi.org/10.1002/ajpa.20983

Gustafson, G., & Kock, G. (1974). Age estimation up to 16 years of age based on dental development. *Odontologisk Revy, 25*(3), 297-306. (PDF) Age Estimation Up to 16 Years of Age Based on Dental Development (researchgate.net)

Haavikko, K. (1970). The formation and the alveolar and clinical eruption of the permanent teeth. an orthopantomographic study. *Suomen Hammaslaakariseuran Toimituksia, 66*(3), 103-170.

Harris, E. F. (2016). Odontogenesis. In J. D. Irish, & G. R. Scott (Eds.), *A companion to dental anthropology* (1st ed., pp. 142-158). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118845486

Hasan, L. S., Ahmad, F. T., Abdullah, E. H. (2016). Impacted wisdom teeth, prevalence, pattern of impaction, complications and indication for extraction: A pilot clinic study in iraqi population. *Tikrit Journal for Dental Sciences, 4*, 50-62.

Heathfield, L. J., Haikney, T. E., Mole, C. G., Finaughty, C., Zachou, A. M., & Gibbon, V. E. (2021). Forensic human identification: Investigation into tooth morphotype and DNA extraction methods from teeth. *Science & Justice, 61*(4), 339-344. https://doi.org/10.1016/j.scijus.2021.05.005

Hedayati, Z., & Khalafinejad, F. (2014). Relationship between body mass index, skeletal maturation and dental development in 6- to 15- year old orthodontic patients in a sample of iranian population. *Journal of Dentistry (Shiraz), 15*(4), 180-186.

Heinrich-Weltzien, R., Zorn, C., Monse, B., & Kromeyer-Hauschild, K. (2013). Relationship between malnutrition and the number of permanent teeth in filipino 10- to 13-year-olds. *BioMed Research International, 2013*, 205950-8. https://doi.org/10.1155/2013/205950

Hernández, C. (2011). *Development of dental maturity standards for hispanic children in texas*

Heuzé, Y., & Cardoso, H. F. V. (2008). Testing the quality of nonadult bayesian dental age assessment methods to juvenile skeletal remains: The lisbon collection children and secular trend effects. *American Journal of Physical Anthropology, 135*(3), 275-283. https://doi.org/10.1002/ajpa.20741

Higgins, D., & Austin, J. J. (2013). Teeth as a source of DNA for forensic identification of human remains: A review. *Science & Justice, 53*(4), 433-441. https://doi.org/10.1016/j.scijus.2013.06.001

Higgins, D., Rohrlach, A. B., Kaidonis, J., Townsend, G., & Austin, J. J. (2015). Differential nuclear and mitochondrial DNA preservation in post-mortem teeth with implications for forensic and ancient DNA studies. *PloS One, 10*(5), e0126935-e0126935. https://doi.org/10.1371/journal.pone.0126935

Hilgers, K. K., Akridge, M., Scheetz, J. P., & Kinane, D. F. (2006). Childhood obesity and dental development. *Pediatric Dentistry, 28*(1), 18-22.

Hillson, S. (1996). *Dental Anthropology*. Cambridge: Cambridge University Press. doi:10.1017/CBO9781139170697

Holman, D. J., & Yamaguchi, K. (2005). Longitudinal analysis of deciduous tooth emergence: IV. covariate effects in japanese children. *American Journal of Physical Anthropology, 126*(3), 352-358. https://doi.org/10.1002/ajpa.10420

Hutchinson, J., & Smith, A. D. (1996). *Ethnicity*. Oxford: Oxford University Press.

Jaffe, E. C., Roberts, G. J., Cahntler, C., & Carter, J. E. (1990). Dental maturity in children with chronic renal failure assessed from dental panoramic tomographs. *Journal of the International Association of Dentistry for Children, 20*(2), 54.

Jodlowska, A, Postek-Stefańska, L. (2021). Tooth development in the light of chemotherapy induced agenesis in cancer survivors. *Polish Dental Association, 74*, 1:28-33. https://doi.org/10.5114/jos.2021.104695

Johns Hopkins. (n.d.). *Anatomy and development of the mouth and teeth.* Johns Hopkins Medicine. Retrieved October 19, 2022, from https://www.hopkinsmedicine.org/health/wellness-and-prevention/anatomy-and-development-of-the-mouth-and-teeth

John Hopkins. (n.d.) *Malnutrition.* John Hopkins Medicine. Retrieved October 13, 2022, from https://www.hopkinsmedicine.org/health/conditions-and-diseases/malnutrition

Kadavy, K. D. (2017). *Longitudinal study of the relationship between childhood BMI and timing of dental development*

Kahl, B., & Schwarze, C. W. (1988). Updating of the dentition tables of I. schour and M. massler of 1941. *Fortschritte Der Kieferorthopädie, 49*(5), 432.

Krishan, K., Kanchan, T., & Garg., A.K. (2015). Dental evidence in forensic identification – an overview, methodology and present status. *The Open Dentistry Journal, 9*(1), 250-256. https://doi.org/10.2174/1874210601509010250

Kjær I. (2014). Mechanism of human tooth eruption: review article including a new theory for future studies on the eruption process. *Scientifica*, *2014*, 341905. https://doi.org/10.1155/2014/341905

Krieger, N. (1999). Embodying inequality: A review of concepts, measures, and methods for studying health consequences of discrimination. *International Journal of Health Services, 29*(2), 295-352. https://doi.org/10.2190/M11W-VWXE-KQM9-G97Q

Krieger, N. (2010). The science and epidemiology of racism and health: Racial/ethnic categories, biological expressions of racism, and the embodiment of inequality- an ecosocial perspective. In I. Whitmarsh, & D. S. Jones (Eds.), *What's the use of race?: Modern governance and the biology of difference* (pp. 225-255). MIT Press. https://doi.org/10.7551/mitpress/8360.001.0001

Kumar, V., Venkataraghavan, K., Krishnan, R., Patil, K., Munoli, K., & Karthik, S. (2013). The relationship between dental age, bone age and chronological age in underweight children. *Journal of Pharmacy & Bioallied Science, 5*(5), 73-79. https://doi.org/10.4103/0975-7406.113301

Larson, C.S. (2016). Foreword. In J. Irish & G. Scott (Eds.), *A companion to dental anthropology*. John Wiley & Sons, Inc.

Lease, L.R. (2016). Anatomy of individual teeth and tooth classes. In J. Irish & G. Scott (Eds.), *A companion to dental anthropology* (pp. 94-107). John Wiley & Sons, Inc.

Legros, C. H., Magitot, E. (1880). *The origin and formation of the dental follicle.* Chicago: Jansen, McClurg and Company.

Levesque, G. -., Demirjian, A., & Tanguay, R. (1981). Sexual dimorphism in the development, emergence, and agenesis of the mandibular third molar. *Journal of Dental Research, 60*(10), 1735-1741. https://doi.org/10.1177/00220345810600100201

Lewis, A. B., Garn, S. M. (1960). The relationship between tooth formation and other maturational factors. *The Angle Orthodontist, 30*(2), 70-77.

Liversidge, H. M., & Marsden, P. H. (2010). Estimating age and the likelihood of having attained 18 years of age using mandibular third molars. *British Dental Journal, 209*(8), E13-E13. https://doi.org/10.1038/sj.bdj.2010.976

Logan, W. G., & Kronfield, R. (1933). Development of the human jaws and surrounding structures from birth to the age of fifteen years. *The Journal of the American Dental Association, 20*(3), 379-429.

Maber, M., Liversidge, H. M., & Hector, M. P. (2006). Accuracy of age estimation of radiographic methods using developing teeth. *Forensic Science International, 159*(1), S68-S73. https://doi.org/10.1016/j.forsciint.2006.02.019

Manjunatha, B. S., & Soni, N. K. (2014). Estimation of age from development and eruption of teeth. *Journal of Forensic Dental Sciences, 6*(2), 73-76. https://doi.org/10.4103/0975-1475.132526

Manoilescu, I., Ion, A., & Ioan, B. G. (2015). Post-mortem changes in teeth forensic issues. *International Journal of Medical Dentistry, 5*(4), 249-252. Retrieved from http://umiss.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/post-mortem-changes-teeth-forensic-issues/docview/1786439322/se-2

Marec-Berard, P., Azzi, D., Chaux-Bodard, A. G., Lagrange, H., Gourmet, R., & Bergeron, C. (2005). Long-term effects of chemotherapy on dental status in children treated for nephroblastoma. *Pediatric Hematology and Oncology*, *22*(7), 581-588. https://doi.org/10.1080/08880010500198848

Martínez Gutiérrez, V. M., & Ortega-Pertuz, A. I. (2017). Comparison of nolla, demirjian and moorrees methods for dental age calculation for forensic purposes. *Revista Odontológica Mexicana, 21*(3), e151-e159. https://doi.org/10.1016/j.rodmex.2017.09.011

Meredith, H. V. (1946). Order and age of eruption for the deciduous dentition. *Journal of Dental Research*, *25*(1), 43-66. https://doi.org/10.1177/00220345460250010901

Mincer, H. H., Harris, E. F., Berryman, H. E. (1993). The A.B.F.O study of third molar development and its use as an estimator of chronological age. *Journal of Forensic Sciences, 38*(2), 379-390). https://doi.org/10.1520/jfs13418j

Mohammed, R. B., Sanghvi, P., Perumalla, K. K., Srinivasaraju, D., Srinivas, J., Kalyan, U. S., & Rasool, S. M. I. (2015). Accuracy of four dental age estimation methods in southern indian children. *Journal of Clinical and Diagnostic Research*, *9*(1), HC01-HC08. https://doi.org/10.7860/JCDR/2015/10141.5495

Moorrees, C. F. A. (1959). *The dentition of the growing child*. Harvard University Press.

Moorrees, C. F. A., Fanning, E. A., & Hunt, E. E. (1963). Age variation of formation stages for ten permanent teeth. *Journal of Dental Research*, *42*(6), 1490-1502. https://doi.org/10.1177/00220345630420062701

Moorrees, C. F. A., Fanning, E. A., & Hunt Jr, E. E. (1963). Formation and resorption of three deciduous teeth in children. *American Journal of Physical Anthropology*, *21*(2), 205-213. https://doi.org/10.1002/ajpa.1330210212

Müller, N. (1990). To determine the age of people with special attention to wisdom teeth. *Medical Thesis, Erlangen-Nuremberg, Germany*.

Munasinghe, V. (2018). Ethnicity in Anthropology. *John Wiley & Sons, Ltd.* DOI: 10.1002/978111892435.wbiea1948

Must, A., Phillips, S. M., Tybor, D. J., Lividini, K., & Hayes, C. (2012). The association between childhood obesity and tooth eruption. *Obesity (Silver Spring, Md.)*, *20*(10), 2070-2074. https://doi.org/10.1038/oby.2012.23

Nadler, G. L. (1998). Earlier dental maturation: Fact or fiction? *The Angle Orthodontist*, *68*(6), 535-538.

Nandlal, B., Patil, K., Ravi, S. (2014). Estimation of dental age by nolla's method using orthopantomographs among rural free residential school children. *International Journal of Medical Research and Health Sciences*, *3*(2), 273-277. Doi: 10.5958/j.2319-5886.3.2.059.

National Health Service. (2020). *Overview malnutrition.* National Health Service. Retrieved October 13, 2022, from https://www.nhs.uk/conditions/malnutrition/

Nicholas, C., Thalji, G., & Richter, A. (2018). Childhood obesity and accelerated timing of dental development: A critical review. *Forensic Anthropology, 1*(3), 170-179. https://doi.org/10.5744/fa.2018.0018

Nicholas, C. L., Kadavy, K., Holton, N. E., Marshall, T., Richter, A., & Southard, T. (2018). Childhood body mass index is associated with early dental development and eruption in a longitudinal sample from the iowa facial growth study. *American Journal of Orthodontics and Dentofacial Orthopedics, 154*(1), 72-81. https://doi.org/10.1016/j.ajodo.2017.10.033

Nolla, C.M. (1952). The Development of the Permanent Teeth. *Journal of Dentistry for Children, 27,* 254-266.

O'Donnell, L., & Edgar, H. J. H. (2020). Sociocultural determinants of health and wealth in historic african americans. *Biodemography and Social Biology, 66*(1), 69-89. https://doi.org/10.1080/19485565.2020.1833705

O'Donnell, L., Hill, E. C., Anderson, A. S., & Edgar, H. J. H. (2020). Cribra orbitalia and porotic hyperostosis are associated with respiratory infections in a contemporary mortality sample from new Mexico. *American Journal of Physical Anthropology, 173*(4), 721-733. https://doi.org/10.1002/ajpa.24131

Owsley, D. W., & Jantz, R. L. (1983). Formation of the permanent dentition in arikara indians: Timing differences that affect dental age assessments. *American Journal of Physical Anthropology, 61*(4), 467-471. https://doi.org/10.1002/ajpa.1330610409

Pahel, B. T., Vann, W. F., Divaris, K., & Rozier, R. G. (2017). A contemporary examination of first and second permanent molar emergence. *Journal of Dental Research, 96*(10), 1115-1121. https://doi.org/10.1177/0022034517716395

Parent, A., Teilmann, G., Juul, A., Skakkebaek, N. E., Toppari, J., & Bourguignon, J. (2003). The timing of normal puberty and the age limits of sexual precocity: Variations around the world, secular trends, and changes after migration. *Endocrine Reviews, 24*(5), 668-693. https://doi.org/10.1210/er.2002-0019

Pereira, C. P., Russell, L. M., De Pádua Fernandes, M., Da Silva, Ricardo Henrique Alves, & De Sousa Santos, Rui Filipe Vargas. (2019). Dental age estimation based on development dental atlas assessment in a child/adolescent population with systemic diseases. *Acta Stomatologica Croatica, 53*(4), 307-317. https://doi.org/10.15644/asc53/4/1

Proctor, R., Kumar, N., Stein, A., Moles, D., & Porter, S. (2005). Oral and dental aspects of chronic renal failure. *Journal of Dental Research, 84*(3), 199-208. https://doi.org/10.1177/154405910508400301

Puranik, M.P., Priyadarshini, C., Uma., S.R. (2015). Dental Age Estimation Methods: A Review. *International Journal of Advanced Health Sciences, 1*(12), 19-25. https://www.researchgate.net/publication/291343131_Dental_Age_Estimation_Methods_A_Review

Putri, A. S., Soedarsono, N., Nehemia, B., Atmadja, D. S., & Ubelaker, D. H. (2021). Age estimation of individuals aged 5-23 years based on dental development of the indonesian population. *Forensic Sciences Research, ahead-of-print*(ahead-of-print), 1-9. https://doi.org/10.1080/20961790.2021.1886648

Raitapuro-Murray, T., Molleson, T. I., & Hughes, F. J. (2014). The prevalence of periodontal disease in a romano-british population c. 200-400 AD. *British Dental Journal, 217*(8), 459-466. https://doi.org/10.1038/sj.bdj.2014.908

Ramirez, D. A.-M. and K. (2019). *The economic reality of Native Americans and the need for immediate repair.* NCRC. Retrieved February 3, 2023, from https://ncrc.org/the-economic-reality-of-native-americans-and-the-need-for-immediate-repair/

Rathee, M., Jain, P. (2022). *Embryology, Teeth*. StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560515/

Roberts, G. J., Parekh, S., Petrie, A., & Lucas, V. S. (2008). Dental age assessment (DAA): A simple method for children and emerging adults. *British Dental Journal, 204*(4), E7-E7. https://doi.org/10.1038/bdj.2008.21

Santana, S. A., Bethard, J. D., & Moore, T. L. (2017). Accuracy of dental age in nonadults: A comparison of two methods for age estimation using radiographs of developing teeth. *Journal of Forensic Sciences, 62*(5), 1320-1325. https://doi.org/10.1111/1556-4029.13434

Santos, R. V., Fry, P. H., Monteiro, S., Maio, M. C., Rodrigues, J. C., Bastos-Rodrigues, L., & Pena, S. D. J. (2009). Color, race, and genomic ancestry in brazil: Dialogues between anthropology and genetics. *Current Anthropology, 50*(6), 787-819. https://doi.org/10.1086/644532

Sasso, A., Špalj, S., Mady Maričić, B., Sasso, A., Ćabov, T., & Legović, M. (2013). Secular trend in the development of permanent teeth in a population of istria and the littoral region of croatia. *Journal of Forensic Sciences, 58*(3), 673-677. https://doi.org/10.1111/j.1556-4029.2012.02301.x

Saunders, E. (1847). The Teeth a Test of Age, Considered with Reference to the Factory Children. *The American Journal of Dental Science, 7*(4), 330.

Schmeling, A., Olze, A., Reisinger, W., & Geserick, G. (2001). Age estimation of living people undergoing criminal proceedings. *The Lancet (British Edition), 358*(9276), 89-90. https://doi.org/10.1016/S0140-6736(01)05379-X

Scheiwiller, M., Oeschger, E. S., & Gkantidis, N. (2020). Third molar agenesis in modern humans with and without agenesis of other teeth. *PeerJ (San Francisco, CA), 8*, e10367-e10367. https://doi.org/10.7717/peerj.10367

Schour L, Massler M. (1941). The development of the human dentition. *Journal of American Dental Association, 28*, 1153– 1160.

Schour I, Massler M. (1944). Development of human dentition chart, *2nd ed. Chicago: American Dental Association.*

Scott, G. R., & Irish, J. D. (2016). *A companion to dental anthropology.* John Wiley & Sons, Incorporated. https://doi.org/10.1002/9781118845486

Šindelárová, R., Žáková, L., & Broukal, Z. (2017). Standards for permanent tooth emergence in czech children. *BMC Oral Health, 17*(1), 140-140. https://doi.org/10.1186/s12903-017-0427-9

Steggerda, M., & Hill, T. J. (1942). Eruption time of teeth among whites, blacks, and native americans. *American Journal of Orthodontics and Oral Surgery, 28*(6), 361-370. https://doi.org/10.1016/S0096-6347(42)90608-2

Taranger, J., Lichtenstein, H., & Svennberg-Redegren, I. (1976). Dental development from birth to 16 years. *Acta Pædiatrica, 65*(S258), 83-97. https://doi.org/10.1111/j.1651-2227.1976.tb14763.x

Thesleff, I. (2006). The genetic basis of tooth development and dental defects. *American Journal of Medical Genetics Part A, 140A*(23), 2530-2535. https://doi.org/10.1002/ajmg.a.31360

Thevissen, P. W., Alqerban, A., Asaumi, J., Kahveci, F., Kaur, J., Kim, Y. K., Pittayapat, P., Van Vlierberghe, M., Zhang, Y., Fieuws, S., & Willems, G. (2010). Human dental age estimation using third molar developmental stages: Accuracy of age predictions not using country specific information. *Forensic Science International, 201*(1), 106-111. https://doi.org/10.1016/j.forsciint.2010.04.040

Toledo Avelar, L. E., Cardoso, M. A., Santos Bordoni, L., de Miranda Avelar, L., & de Miranda Avelar, J. V. (2017). Aging and sexual differences of the human skull. *Plastic and Reconstructive Surgery. Global Open*, *5*(4), e1297–e1297. https://doi.org/10.1097/GOX.0000000000001297

Tompkins, R. L. (1996). Human population variability in relative dental development. *American Journal of Physical Anthropology, 99*(1), 79-102. https://doi.org/10.1002/(SICI)1096-8644(199601)99:1<79::AID-AJPA5>3.0.CO;2-V

Trakinienė, G., Andriuškevičiūtė, I., Šalomskienė, L., Vasiliauskas, A., Trakinis, T., & Šidlauskas, A. (2019). Genetic and environmental influences on third molar root mineralization. *Archives of Oral Biology, 98*, 220-225. https://doi.org/10.1016/j.archoralbio.2018.11.026

Ubelaker, D. H. (1978). *Human skeletal remains: Excavation, analysis, interpretation.* Aldine Publishing Company

Ubelaker, D.H. (2006). Introduction to Forensic Anthropology. In: Schmitt, A., Cunha, E., Pinheiro, J. (eds) *Forensic Anthropology and Medicine Complementary Sciences From Recovery to Cause of Death*. Humana Press. https://doi.org/10.1007/978-1-59745-099-7_1

University of New Mexico. (n.d.). *Maxwell museum of anthropology orthodontics case file system.* University of New Mexico Health Sciences Center. Retrieved October 3, 2021, from https://searchorthodontics.health.unm.edu

U.S. Department of Health and Human Services. (February, 2018). *Factors affecting weight & health – NIDDK.* National Institute of Diabetes and Digestive and Kidney Diseases. Retrieved March 21, 2023, from https://www.niddk.nih.gov/health-information/weight-management/adult-overweight-obesity/factors-affecting-weight-health

U.S. Food & Drug Administration. (December, 2017). *Kids aren't just small adults – medicines, children, and the care every child deserves.* https://www.fda.gov/drugs/information-consumers-and-patients-drugs/kids-arent-just-small-adults-medicines-children-and-care-every-child-deserves#:~:text=Not%20all%20medicines%20are%20right%20for%20an%20infant,the%20right%20medicine%20and%20follow%20the%20directions%20exactly.

Vasconcelos, N. P. S., Caran, E. M. M., Lee, M. L., Lopes, N. N. F., & Weiler, R. M. E. (2008). Dental maturity assessment in children with acute lymphoblastic leukemia after cancer therapy. *Forensic Science International, 184*(1), 10-14. https://doi.org/10.1016/j.forsciint.2008.11.009

Vázquez-Nava, F., Vázquez, R. E. M., Saldivar, G. A. H., Beltrán, G. F. J., Almeida, A. V. M., & Vázquez, R. C. F. (2008). Allergic rhinitis, feeding and oral habits, toothbrushing and socioeconomic status. Effects on development of dental caries in primary dentition. *Caries Research, 42*(2), 141-147. https://doi.org/10.1159/000121438

Verma, M., Verma, N., Sharma, R., & Sharma, A. (2019). Dental age estimation methods in adult dentitions: An overview. *Journal of Forensic Dental Sciences, 11*(2), 57-63. https://doi.org/10.4103/jfo.jfds_64_19

Vodanović, M., Hrvoje, B., Mario, Š., & Željko, D. (2005). The frequency and distribution of caries in the mediaeval population of bijelo brdo in croatia (10th–11th century). *Archives of Oral Biology, 50*(7), 669-680. https://doi.org/10.1016/j.archoralbio.2004.11.014

Vodanović, M., Dumančić, J., Galić, I., Savić Pavičin, I., Petrovečki, M., Cameriere, R., & Brkić, H. (2011). Age estimation in archaeological skeletal remains: evaluation of four non-destructive age calculation methods. *The Journal of forensic odonto-stomatology*, *29*(2), 14–21.

Vucic, S., de Vries, E., Eilers, P. H. C., Willemsen, S. P., Kuijpers, M. A. R., Prahl-Andersen, B., Jaddoe, V. W. V., Hofman, A., Wolvius, E. B., & Ongkosuwito, E. M. (2014). Secular trend of dental development in dutch children. *American Journal of Physical Anthropology, 155*(1), 91-98. https://doi.org/10.1002/ajpa.22556

Weisensee, K. E., & Jantz, R. L. (2011). Secular changes in craniofacial morphology of the portuguese using geometric morphometrics. *American Journal of Physical Anthropology, 145*(4), 548-559. https://doi.org/10.1002/ajpa.21531

Worthman, C. M., Dockray, S., & Marceau, K. (2019). Puberty and the evolution of developmental science. *Journal of Research on Adolescence, 29*(1), 9-31. https://doi.org/10.1111/jora.12411

Wood, J. W., Milner, G. R., Lukacs, J. R., Mcgrath, J. W., Roth, E. A., Ubelaker, D. H., Wilkinson, R. G., Harpending, H. C., Weiss, K. M., Cohen, M. N., Eisenber, L. E., Hutchinson, D. L., Jankauskas, R., Cesnys, G., & Katzenberg, M. A. (1992). The osteological paradox: Problems of inferring prehistoric health from skeletal samples. *Current Anthropology, 33*(4), 343-370. https://doi.org/10.1086/204084

Organization, W. H., Organization, W. H., & UNAIDS. (2009). *WHO child growth standards: Growth velocity based on weight length and head circumference- methods and development.* World Health Organization.

Yahya, M., Rahman, S.A., Alam, M.K. (2013). Facial skeleton morphometry: a 3d study. *International Mecial Journal, 20*(6), 716-720.

Appendix

Table A.1. Cohen's Kappa values for permanent maxillary teeth Group 1 recollection

Individual Tooth Stage Group 1	Cohen's Kappa Score
Maxillary RM3	0.47
Maxillary RM2	0.33
Maxillary RM1	0.69
Maxillary RPM2	0.55
Maxillary RPM1	0.40
Maxillary RC1	0.40
Maxillary RI2	0.47
Maxillary RI1	0.76
Maxillary LI1	0.89
Maxillary LI2	0.69
Maxillary LC1	0.69
Maxillary LPM1	0.69
Maxillary LPM2	0.69
Maxillary LM1	0.76
Maxillary LM2	0.21
Maxillary LM3	0.47

Table A.2. Cohen's Kappa values for permanent mandibular teeth Group 1 recollection

Individual Tooth Stage Group 1	Cohen's Kappa Score
Mandibular RM3	0.08
Mandibular RM2	0.89
Mandibular RM1	0.89
Mandibular RPM2	0.83
Mandibular RPM1	0.62
Mandibular RC1	0.47
Mandibular RI2	0.62
Mandibular RI1	0.89
Mandibular LI1	0.89
Mandibular LI2	0.83
Mandibular LC1	0.62
Mandibular LPM1	0.89
Mandibular LPM2	0.89
Mandibular LM1	0.76
Mandibular LM2	0.83
Mandibular LM3	0.33

Table A.3. Cohen's Kappa values for deciduous maxillary teeth Group 1 recollection

Individual Tooth Stage Group 1	Cohen's Kappa Score
Maxillary rm2	0.95
Maxillary rm1	0.89

Maxillary rc1	0.89
Maxillary ri2	1
Maxillary ri1	1
Maxillary li1	1
Maxillary li2	1
Maxillary lc1	0.83
Maxillary lm1	1
Maxillary lm2	0.95

Table A.4. Cohen's Kappa values for deciduous mandibular teeth Group 1 recollection

Individual Tooth Stage Group 1	Cohen's Kappa Score
Mandibular rm2	0.83
Mandibular rm1	0.89
Mandibular rc1	0.95
Mandibular ri2	1
Mandibular ri1	1
Mandibular li1	1
Mandibular li2	1
Mandibular lc1	0.95
Mandibular lm1	0.95
Mandibular lm2	0.89

Table A.5. Cohen's Kappa values for permanent maxillary teeth Group 2 recollection

Individual Tooth Stage Group 2	Cohen's Kappa Score
Maxillary RM3	0.69
Maxillary RM2	0.89
Maxillary RM1	0.89
Maxillary RPM2	0.83
Maxillary RPM1	0.95
Maxillary RC1	0.76
Maxillary RI2	0.76
Maxillary RI1	0.83
Maxillary LI1	0.83
Maxillary LI2	0.69
Maxillary LC1	0.76
Maxillary LPM1	0.95
Maxillary LPM2	0.89
Maxillary LM1	0.95
Maxillary LM2	0.83
Maxillary LM3	0.69

Table A.6. Cohen's Kappa values for permanent mandibular teeth Group 2 recollection

Individual Tooth Stage Group 2	Cohen's Kappa Score
Mandibular RM3	0.69
Mandibular RM2	1
Mandibular RM1	0.95
Mandibular RPM2	0.89
Mandibular RPM1	0.89
Mandibular RC1	0.89
Mandibular RI2	0.62
Mandibular RI1	0.83
Mandibular LI1	0.83
Mandibular LI2	0.62
Mandibular LC1	0.89
Mandibular LPM1	0.89
Mandibular LPM2	0.89
Mandibular LM1	0.89
Mandibular LM2	1
Mandibular LM3	0.62

Table A.7. Cohen's Kappa values for deciduous maxillary teeth Group 2 recollection

Individual Tooth Stage Group 2	Cohen's Kappa Score
Maxillary rm2	0.95
Maxillary rm1	0.76
Maxillary rc1	0.95
Maxillary ri2	0.830.82
Maxillary ri1	0.83
Maxillary li1	0.95
Maxillary li2	0.95
Maxillary lc1	0.95
Maxillary lm1	0.83
Maxillary lm2	0.95

Table A.8. Cohen's Kappa values for deciduous mandibular teeth Group 2 recollection

Individual Tooth Stage Group 2	Cohen's Kappa Score
Mandibular rm2	0.95
Mandibular rm1	0.76
Mandibular rc1	0.95
Mandibular ri2	0.83
Mandibular ri1	0.69
Mandibular li1	0.76
Mandibular li2	0.89
Mandibular lc1	0.95

Mandibular lm1	0.83
Mandibular lm2	0.89

Table A.9. Chi-Squared and Fisher's Exact p-value test results for the maxillary lateral incisors

7.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 R ½	1	1	2	1.333	1
UI2 Other	0	2	2	P-value	
Total	1	3	4	0.248	
8.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 R ¾	1	1	2	1.333	1
UI2 Other	0	2	2	P-value	
Total	1	3	4	0.248	
9.5 -year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 Rc	4	1	5	**4.41**	0.08
UI2 Other	1	5	6	**P-value**	
Total	5	6	11	**0.04**	
10.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 A ½	2	1	3	1.2	1
UI2 Other	3	0	3	P-value	
Total	5	1	6	0.273	
11.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 Ac	4	3	7	0.0524	1
UI2 Other	2	2	4	P-value	
Total	6	5	11	0.819	
12.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 Ac	7	2	9	0.1481	1
UI2 Other	0	1	1	P-value	

Total	7	3	10	0.7	
13.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UI2 Ac	2	6	8	NA	NA
UI2 Other	0	0	0	P-value	
Total	2	6	8	NA	

Table A.10. Chi-Squared and Fisher's Exact p-value test results for the maxillary canines

7.5-year-olds	Sample 1	Sample 2	Total	**Fisher's exact p-value**	
UC R 1/4	1	2	3	1	
UC Other	0	1	1		
Total	1	3	4		
8.5-year-olds	Sample 1	Sample 2	Total	**Fisher's exact p-value**	
UC R ¼	1	1	2	1	
UC Other	0	2	2		
Total	1	3	4		
9.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC R ½	3	3	6	0.07	1
UC Other	4	3	7	P-value	
Total	7	6	13	0.797	
10.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC R 3/4	2	1	3	1.5556	0.429
UC Other	4	0	4	P-value	
Total	6	1	7	0.21	
11.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC R 3/4	4	1	5	1.6555	0.293
UC Other	3	4	7	P-value	
Total	7	5	12	0.198	

12.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC Rc	5	2	7	0.0164	1
UC Other	3	1	4	P-value	
Total	8	3	11	0.898	
13.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC Rc	1	1	2	0.889	0.464
UC Other	1	5	6	P-value	
Total	2	6	8	0.346	
14.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC A 1/2	2	0	2	1.33	1
UC Other	1	1	2	P-value	
Total	3	1	4	0.248	
15.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC Ac	8	6	14	1.2245	0.467
UC Other	0	1	1	P-value	
Total	8	7	15	0.268	
16.5-year-olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UC Ac	6	9	15	NA	
UC Other	0	0	0	P-value	P-value
Total	6	9	15	NA	1

Table A.11. Chi-Squared and Fisher's Exact p-value test results for the maxillary third molar

8.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Ci	0	1	1	0.4444	1
UM3 Other	1	2	3	P-value	
Total	1	3	4	0.51	

9.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Coc	1	1	2	0.0141	1
UM3 Other	6	5	11	P-value	
Total	7	6	13	0.906	
10.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Coc	1	1	2	2.9167	0.286
UM3 Other	5	0	5	P-value	
Total	6	1	7	0.088	
11.5 year olds	Sample 1	Sample 2	Total	**Chi Squared**	**Fisher's exact p-value**
UM3 Cr 1/2	4	0	4	**4.287**	0.081
UM3 Other	3	5	8	**P-value**	
Total	7	5	12	**0.04**	
12.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Cr 3/4	2	1	3	0.0764	1
UM3 Other	6	2	8	P-value	
Total	8	3	11	0.782	
13.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Cr 3/4	1	0	1	3.4286	0.25
UM3 Other	1	6	7	P-value	
Total	2	6	8	0.064	
14.5 year olds	Sample 1	Sample 2	Total	**Chi Squared**	**Fisher's exact p-value**
UM3 R 1/4	0	1	1	**4**	0.25
UM3 Other	3	0	3	**P-value**	
Total	3	1	4	**0.046**	
15.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**

UM3 R 1/4	1	1	2	0.0103	1
UM3 Other	7	6	13	P-value	
Total	8	7	15	0.919	
16.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 R 1/2	3	1	4	2.7841	0.235
UM3 Other	3	8	11	P-value	
Total	6	9	15	0.095	
17.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 R 1/2	1	2	3	0.0227	1
UM3 Other	2	5	7	P-value	
Total	3	7	10	0.88	
18.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 R 3/4	1	1	2	2.4306	0.275
UM3 Other	1	11	12	P-value	
Total	2	12	14	0.119	
19.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 Rc	0	3	3	0.5485	1
UM3 Other	3	16	19	P-value	
Total	3	19	22	0.459	
20.5 year olds	Sample 1	Sample 2	Total	Chi Squared	**Fisher's exact p-value**
UM3 A 1/2	0	0	0	NA	NA
UM3 Other	1	10	11	P-value	
Total	1	10	11	NA	

Figure A.1. Tooth stage chart of Group 1 individuals (Females)

Maxilla							Mandible		
		Tooth Formation Stage					Tooth Formation Stage		
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
7.5 years	0	i^1				i_1			
		i^2				i_2			
		c'				c,			
		m^1				m_1			
		m^2				m_2			
		I^1				I_1			
		I^2				I_2			
		C'				C,			
		P^1				P_1			
		P^2				P_2			
		M^1				M_1			
		M^2				M_2			
		M^3				M_3			
8.5 years	0	i^2				i_2			
		c'				c,			
		m^1				m_1			
		m^2				m_2			
		I^1				I_1			
		I^2				I_2			
		C'				C,			
		P^1				P_1			
		P^2				P_2			
		M^1				M_1			
		M^2				M_2			
		M^3				M_3			
9.5 years	4	c'	Res 1/4	Res ½	-	c,	Res 1/4	Res ½	-
		m^1	Res 1/2	Res ½	-	m_1	Res 1/2	Res ¾	-
		m^2	Res 1/4	Res ½	-	m_2	Res 1/4	Res ½	-
		I^1	Rc	Rc	Ac	I_1	Ac	Ac	Ac
		I^2	R 3/4	Rc	Rc	I_2	Rc	A ½	A ½
		C'	R 1/2	R 1/2-R ¾	R 3/4	C,	R 1/2	R ½	R ¾

		P^1	R 1/4	R ½	R 1/2	P_1	R 1/4	R ½	R ¾
		P^2	Ri	R ½	R 1/2	P_2	Ri	R ¼	R ¾
		M^1	A 1/2	Ac	Ac	M_1	Rc	Rc-A ½	A ½
		M^2	Ri	R ¼	R 1/4	M_2	Ri	R ¼	R ½
		M^3	-	-	Coc	M_3	-	-	Cco
10.5 years	2	c'	Res 3/4	Res ¾	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	Res 1/2	Res 1/2-Res ¾	-	m_2	Res 1/2	Res ½	-
		I^1	A 1/2	A 1/2-Ac	Ac	I_1	A 1/2	A 1/2-Ac	Ac
		I^2	Rc	Rc-A ½	A 1/2	I_2	A 1/2	A 1/2-Ac	Ac
		C'	R 1/2	R 1/2-R ¾	R 3/4	C,	R 1/2	R 1/2-R ¾	R ¾
		P^1	R 1/2	R 1/2-R ¾	R 3/4	P_1	R 1/2	R 1/2-R ¾	R ¾
		P^2	R 1/4	R 1/4-R ¾	R 3/4	P_2	R 1/4	R 1/4-R ¾	R ¾
		M^1	A 1/2	A 1/2-Ac	Ac	M_1	A 1/2	A 1/2-Ac	Ac
		M^2	R 1/2	R ½	R 1/2	M_2	R 1/4	R 1/4-R ½	R ½
		M^3	-	-	-	M_3	Cco	Cr 1/2-Cr ¾	Cr ¾
11.5 years	7	c'	Res 1/2	Res ¾	-	c,	-	-	-
		m^1	-	-	-	m_1	Res 3/4	-	-
		m^2	Res 1/2	-	-	m_2	Res 1/4	Res ¾	-
		I^1	A 1/2	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Rc	A ½	Ac	I_2	Ac	Ac	Ac
		C'	R 1/2	R 3/4	Rc	C,	R 3/4	R 3/4-Rc	A ½
		P^1	R 1/2	R ¾	A ½	P_1	R 1/2	R 3/4-Rc	A ½
		P^2	R 1/2	R 1/2-R ¾	A ½	P_2	R 1/2	R ¾	Rc

		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	R ½	R ¾	M_2	R 1/2	R ½	R ¾
		M^3	Cr 1/2	Cr ½	Cr ¾	M_3	Coc	Cr ½	Cr ½
12.5 years	6	c'	Res 1/2	Res ¾	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	Rc	A ½	C,	Rc	A ½	A ½
		P^1	Rc	A ½	Ac	P_1	Rc	A ½	Ac
		P^2	Rc	Rc	Ac	P_2	Rc	Rc	A ½
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Rc	Rc	M_2	R 3/4	Rc	Rc
		M^3	Cr 1/2	Cr ¾	Crc	M_3	Coc	Cr 1/2-Cr ¾	Crc
13.5 years	2	I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	Rc	A 1/2	C,	Rc	Rc-A ½	A ½
		P^1	Rc	A ½	Ac	P_1	R 3/4	R ¾	A ½
		P^2	Rc	Rc-A ½	Ac	P_2	Rc	Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 3/4	R ¾	Rc	M_2	R 1/2	R 3/4-Rc	Rc
		M^3	Cr 1/2	Cr 1/2-Cr ¾	Cr 3/4	M_3	Cr 1/2	Cr ½	Cr ½
14.5 years	1	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		P^1	Ac	Ac	Ac	P_1	Ac	Ac	Ac
		P^2	Ac	Ac	Ac	P_2	Ac	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	A 1/2	A ½	A 1/2	M_2	A 1/2	A ½	A ½
		M^3	Ri	Ri	Ri	M_3	Ri	Ri	Ri
15.5 years	3	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		P^1	Ac	Ac	Ac	P_1	Ac	Ac	Ac
		P^2	Ac	Ac	Ac	P_2	Ac	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac

		M^2	Ac	Ac	Ac	M_2	A 1/2	Ac	Ac
		M^3	R 1/2	R ½	R 1/2	M_3	R 1/2	R ½	R ½
16.5 years	3	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/4	R 1/2	M_3	R 1/4	R ¼	R ¼
17.5 years	2	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/4-R ½	R 1/2	M_3	Ri	R ¼	R ¼
18.5 years	1	M^3	R 1/2	R 1/2	R 1/2	M_3	R 1/2	R ½	R ½
19.5 years	1	M^3	(NA)	(NA)	(NA)	M_3	R 1/4	R ¼	R ¼
20.5 years	1	M^3	R 1/2	R 1/2	R 1/2	M_3	(NA)	(NA)	(NA)
21.5 years	1	M^3	A 1/2	A 1/2	A 1/2	M_3	(NA)	(NA)	(NA)

Figure A.2. Tooth stage chart of Group 1 individuals (Males)

Maxilla						Mandible			
		Tooth Formation Stage				Tooth Formation Stage			
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
7.5 years	1	i^1	-	-	-	i_1	-	-	-
		i^2	-	-	-	i_2	-	-	-
		c'	-	-	-	c,	Ac	Ac	Ac
		m^1	Res 1/2	Res 1/2	Res 1/2	m_1	Res 1/2	Res ½	Res ½
		m^2	Res 1/4	Res 1/4	Res 1/4	m_2	Res 1/4	Res ¼	Res ¼
		I^1	R 1/2	R 1/2	R 1/2	I_1	Rc	Rc	Rc
		I^2	R 1/2	R 1/2	R 1/2	I_2	R 3/4	R ¾	R ¾
		C'	R 1/4	R 1/4	R 1/4	C,	Ri	Ri-R ¼	R ¼
		P^1	Ri	Ri	Ri	P_1	Ri	Ri-R ¼	R ¼
		P^2	Ri	Ri	Ri	P_2	Ri	Ri	Ri
		M^1	Rc	Rc	Rc	M_1	Rc	Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
		M^3	-	-	-	M_3	-	-	-
8.5 years	1	i^2	-	-	-	i_2	-	-	-
		c'	Res 1/4	Res 1/4	Res 1/4	c,	(NA)	(NA)	(NA)
		m^1	(NA)	(NA)	(NA)	m_1	Res 1/4	Res ¼	Res ¼
		m^2	Res 1/2	Res 1/2	Res 1/2	m_2	Ac	Ac	Ac
		I^1	Rc	Rc	Rc	I_1	Rc	Rc	Rc
		I^2	R 3/4	R 3/4	R 3/4	I_2	R 3/4	R ¾	R ¾
		C'	R 1/4	R 1/4	R 1/4	C,	R 1/4	R ¼	R ¼
		P^1	Ri	Ri	Ri	P_1	R 1/4	R ¼	R ¼
		P^2	Ri	Ri	Ri	P_2	R 1/4	R ¼	R 1/4
		M^1	Rc	Rc	Rc	M_1	R 3/4	R 3/4-Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc

		M^3	-	-	-	M_3	-	-	-
9.5 years	3	c'	Res 1/2	Res 1/2	-	c,	Res 1/2	-	-
		m^1	Res 3/4	Res 3/4	-	m_1	Res 3/4	Res ¾	-
		m^2	Res 1/2	Res 1/2	-	m_2	Res 1/4	Res ½	-
		I^1	A 1/2	A 1/2-Ac	Ac	I_1	A 1/2	Ac	Ac
		I^2	Rc	Rc-A 1/2	A 1/2	I_2	Rc	A ½	Ac
		C'	R 1/2	R 3/4	Rc	C,	R 1/2	R ½	R ¾
		P^1	R 1/2	R 1/2	Rc	P_1	R 1/2	R ½	R ½
		P^2	R 1/2	R 1/2	R 1/2	P_2	R 1/2	R ½	R ½
		M^1	Ac	Ac	Ac	M_1	Rc	A ½	Ac
		M^2	R 1/4	R 1/2	R 1/2	M_2	R 1/2	R ½	R ½
		M^3	-	-	Ci	M_3	-	Cco	Cco
10.5 years	4	c'	Res 1/2	Res ¾	-	c,	Res 1/4	Res ¾	-
		m^1	Res 1/2	-	-	m_1	Res 1/2	Res ½	-
		m^2	Res 1/4	Res ½	-	m_2	Res 1/4	Res ½	-
		I^1	Rc	Rc	Ac	I_1	Ac	Ac	Ac
		I^2	Rc	Rc	A ½	I_2	A 1/2	Ac	Ac
		C'	R 1/2	R ½	R ¾	C,	R 1/2	R ½	Rc
		P^1	R 1/4	R ½	R ¾	P_1	R 1/2	R ½	Rc
		P^2	R 1/4	R ½	R ½	P_2	R 1/4	R ½	R ½
		M^1	Ac	Ac	Ac	M_1	A 1/2	A ½	Ac
		M^2	R 1/4	R ¼	R ½	M_2	R 1/4	R 1/4-R ½	R ¾
		M^3	-	Coc-Cr 1/2	Cr ½	M_3	-	Cco	Cr ¾
11.5 years	3	c'	Res 3/4	Res 3/4	-	c,	-	-	-
		m^1	-	-	-	m_1	Res 3/4	-	-

		m^2	Res 3/4	-	-	m_2	Res 1/4	-	-
		I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Rc	A 1/2	Ac	I_2	Ac	Ac	Ac
		C'	R 1/2	Rc	Rc	C,	R 3/4	R 3/4-Rc	A ½
		P^1	R 1/2	R 3/4	Rc	P_1	R 3/4	R ¾	A ½
		P^2	R 1/2	R 3/4	Rc	P_2	R 1/2	R ¾	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	R 1/2	Rc	M_2	R 1/2	R ½	Rc
		M^3	Cco	Coc	Cr 1/2	M_3	Cco	Cco	Cr ½
12.5 years	3	c'	Res 3/4	-	-	c,	Res 3/4	-	-
		m^1	-	-	-	m_1	Res 3/4	-	-
		m^2	Res 1/2	-	-	m_2	Res 1/4	-	-
		I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	R 1/2	Rc	Rc	C,	R 1/2	Rc	A ½
		P^1	R 1/2	Rc	Rc	P_1	R 1/2	Rc	A ½
		P^2	R 1/2	R 3/4	Rc	P_2	R 1/4	R ¾	Rc
		M^1	Ac	Ac	Ac	M_1	A 1/2	Ac	Ac
		M^2	R 1/2	R 1/2	R 3/4	M_2	R 1/2	R ½	Rc
		M^3	Cr 1/2	Cr 1/2-Cr 3/4	Cr 3/4	M_3	Cco	Coc-Cr ½	Cr ¾
13.5 years	0	I^1	-	-	-	I_1	-	-	-
		I^2	-	-	-	I_2	-	-	-
		C'	-	-	-	C,	-	-	-
		P^1	-	-	-	P_1	-	-	-
		P^2	-	-	-	P_2	-	-	-
		M^1	-	-	-	M_1	-	-	-
		M^2	-	-	-	M_2	-	-	-
		M^3	-	-	-	M_3	-	-	-

14.5 years	2	C'	Rc	A 1/2	A 1/2	C,	A 1/2	A ½	A ½
		P^1	A 1/2	Ac	Ac	P_1	A 1/2	A ½	Ac
		P^2	Rc	A 1/2	Ac	P_2	Rc	Rc-A ½	A 1/2
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	A 1/2	A 1/2	A 1/2	M_2	Rc	Rc	Rc
		M^3	Crc	Crc-Ri	Ri	M_3	Crc	Crc-Ri	Ri
15.5 years	5	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		P^1	Ac	Ac	Ac	P_1	Ac	Ac	Ac
		P^2	Ac	Ac	Ac	P_2	Ac	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	A 1/2	Ac	Ac	M_2	A 1/2	Ac	Ac
		M^3	Cr 3/4	R 1/4	R 1/2	M_3	R 1/2	R ½	R 1/2
16.5 years	3	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/2	R 1/2	M_3	R 1/2	R ½	R 1/2
17.5 years	1	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R 1/4	R 1/4	M_3	R 1/4	R 1/4-R ½	R 1/2
18.5 years	1	M^3	R 3/4	R 3/4	R 3/4	M_3	R 1/2	R ½	R 1/2
19.5 years	2	M^3	R 1/4	R 1/4-R 1/2	R 1/2	M_3	Ri	R ½	R 1/2
20.5 years	0	M^3	-	-	-	M_3	-	-	-
21.5 years	1	M^3	R 3/4	R 3/4	R 3/4	M_3	(NA)	(NA)	(NA)

Figure A.3. Tooth stage chart of Group 2 individuals (Females)

Maxilla						Mandible			
			Tooth Formation Stage				Tooth Formation Stage		
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
6 months	13	i^1	R 1/4	R ½	R 3/4	i_1	R 1/2	R 3/4	R 3/4
		i^2	Ri	R ½	R 3/4	i_2	R 1/4	R 1/2	R 1/2
		c'	Cr 3/4	Ri	R 1/2	c,	Cr 3/4	Crc	R 1/4
		m^1	Cr 3/4	R ½	R 1/2	m_1	Cr 3/4	R 1/4	R 1/2
		m^2	Cr 1/2	Crc	Ri	m_2	Cr 1/2	Cr 3/4	Crc
		I^1	Cco	Coc	Cr 1/2	I_1	Ci	Coc	Cr 1/2
		I^2	-	-	-	I_2	Ci	Cco	Cr 1/2
		C'	Ci	Ci	Coc	C,	Ci	Ci	Coc
		M^1	Cco	Cco	Cco	M_1	Cco	Cco	Coc
1 year	12	i^1	R 3/4	Rc	A 1/2	i_1	R 3/4	Rc	A 1/2
		i^2	R 3/4	R ¾	R 3/4	i_2	R 3/4	R 3/4	Rc
		c'	R 1/4	R ½	R 1/2	c,	R 1/4	R 1/2	R 1/2
		m^1	R 1/2	R ½	Rc	m_1	R 1/2	R 3/4	R 3/4
		m^2	Crc	R ¼	R 1/2	m_2	Cr 3/4	R 1/4	R 1/2
		I^1	Cr 1/2	Cr ½	Cr 1/2	I_1	Cr 1/2	Cr 1/2	Cr 1/2
		I^2	Ci	Ci	Coc	I_2	Coc	Cr 1/2	Cr 1/2
		C'	Coc	Coc	Cr 1/2	C,	Coc	Coc	Coc
		M^1	Coc	Coc	Cr 1/2	M_1	Coc	Coc	Cr 1/2
1.5 years	2	i^1	Rc	Rc	Rc	i_1	A 1/2	A 1/2	A 1/2
		i^2	Rc	Rc	Rc	i_2	Rc	Rc	Rc
		c'	R 1/2	R ½	R 1/2	c,	R 1/2	R 1/2	R 1/2

		m^1	Rc	Rc	Rc	m_1	R 3/4	R 3/4-Rc	Rc
		m^2	R 1/4	R ½	R 1/2	m_2	R 1/2	R 1/2	R ½
		I^1	Cr 1/2	Cr 1/2-Cr 3/4	Cr 3/4	I_1	Cr 1/2	Cr 1/2-Cr 3/4	Cr ¾
		I^2	Coc	Coc-Cr ½	Cr 1/2	I_2	Coc	Coc-Cr 3/4	Cr ¾
		C'	Coc	Coc-Cr ½	Cr 1/2	C,	Coc	Coc-Cr 1/2	Cr ½
		P^1	Cr 1/2	Cr ½	Cr 1/2	P_1	Cr 1/2	Cr 1/2	Cr ½
		M^1	Rc	Rc	Rc	M_1	A 1/2	A 1/2	A 1/2
2.5 years	3	i^1	Ac	Ac	Ac	i_1	Ac	Ac	Ac
		i^2	A 1/2	A ½	A 1/2	i_2	A 1/2	Ac	Ac
		c'	Rc	Rc	Rc	c,	Rc	Rc	Rc
		m^1	Rc	Rc	Rc	m_1	Rc	Rc	Ac
		m^2	R 3/4	Rc	Rc	m_2	R 3/4	Rc	A 1/2
		I^1	Cr 3/4	Cr ¾	Crc	I_1	Cr 1/2	Cr 1/2	Crc
		I^2	Cr 1/2	Cr ½	Cr 3/4	I_2	Cr 1/2	Cr 1/2	Cr 3/4
		C'	Cr 1/2	Cr ½	Cr 1/2	C,	Cr 1/2	Cr 1/2	Cr 1/2
		P^1	Cco	Cco	Coc	P_1	Cco	Cco	Coc
		P^2	-	-	Ci	P_2	-	-	Ci
		M^1	Crc	Crc	Crc	M_1	Crc	Crc	Crc
		M^2	-	-	-	M_2	-	-	-
3.5 years	5	i^1	Rc	Ac	Ac	i_1	Ac	Ac	Res 1/2
		i^2	Rc	Ac	Ac	i_2	A 1/2	Ac	Res 1/4
		c'	Rc	Ac	Ac	c,	Rc	Ac	Ac
		m^1	A 1/2	Ac	Ac	m_1	A 1/2	Ac	Ac
		m^2	Rc	Ac	Ac	m_2	Rc	Ac	Ac
		I^1	Cr 3/4	Crc	Crc	I_1	Cr 3/4	Crc	Crc
		I^2	Cr 1/2	Cr ¾	Crc	I_2	Cr 1/2	Crc	Crc

		C'	Cr 1/2	Cr ¾	Crc	C,	Cr 1/2	Cr 3/4	Cr 3/4
		P[1]	Coc	Cr ½	Cr 1/2	P_1	Coc	Cr 1/2	Cr 1/2
		P[2]	-	Cco	Coc	P_2	-	Ci-Cco	Coc
		M[1]	Crc	Ri	R 1/4	M_1	Crc	Crc-Ri	R 1/4
		M[2]	-	Cco	Coc	M_2	-	Ci-Cco	Cco
4.5 years	6	i[1]	Ac	Ac	Ac	i_1	Ac	Res 1/4	Res 1/2
		i[2]	Ac	Ac	Ac	i_2	Ac	Ac-Res 1/4	Res 1/4
		c'	A 1/2	Ac	Ac	c,	A 1/2	Ac	Ac
		m[1]	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m[2]	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I[1]	Crc	Crc	R 1/4	I_1	Ri	Ri	R 1/4
		I[2]	Cr 3/4	Cr ¾	Ri	I_2	Crc	Ri	R 1/4
		C'	Cr 3/4	Cr ¾	Crc	C,	Cr 3/4	Crc	Crc
		P[1]	Cr 1/2	Cr ¾	Crc	P_1	Cr 3/4	Cr 3/4	Crc
		P[2]	Cco	Cr ½	Cr 3/4	P_2	Cr 1/2	Cr 1/2	Cr 3/4
		M[1]	R 1/4	R ¼	R 1/4	M_1	R 1/4	R 1/4	R 1/4
		M[2]	Ci	Cco-Coc	Cr 1/2	M_2	Cco	Cco-Coc	Cr 1/2
5.5 years	3	i[1]	Res 1/4	Res 1/4-Res 1/2	Res 1/2	i_1	Res 1/4	Res 1/4	Res 1/4
		i[2]	Ac	Ac-Res ¼	Res 1/4	i_2	R 3/4	Ac	Res 3/4
		c'	Ac	Ac	Ac	c,	Ac	Ac	Ac
		m[1]	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m[2]	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I[1]	R 1/4	R ¼	R 1/4	I_1	Ri	R 1/4	R 1/2
		I[2]	Ri	Ri	R 1/4	I_2	Ri	R 1/4	R 1/4
		C'	Crc	Ri	Ri	C,	Crc	Ri	Ri
		P[1]	Cr 3/4	Crc	Ri	P_1	Cr 3/4	Crc	Ri

		P^2	Cr 1/2	Crc	Crc	P_2	Cr 1/2	Cr 3/4-Crc	Crc
		M^1	R 1/2	R ½	R 3/4	M_1	R 1/2	R 1/2	R 3/4
		M^2	Coc	Cr ¾	Crc	M_2	Coc	Cr 3/4	Crc
6.5 years	0	i^1	-	-	-	i_1	-	-	-
		i^2	-	-	-	i_2	-	-	-
		c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	-	-	-	I_1	-	-	-
		I^2	-	-	-	I_2	-	-	-
		C'	-	-	-	C,	-	-	-
		P^1	-	-	-	P_1	-	-	-
		P^2	-	-	-	P_2	-	-	-
		M^1	-	-	-	M_1	-	-	-
		M^2	-	-	-	M_2	-	-	-
7.5 years	3	i^1	-	-	-	i_1	-	-	-
		i^2	-	-	-	i_2	-	-	-
		c'	Res 1/2	Res 1/4-Res 1/2	Res 1/2	c,	Res ½	Res 1/2	Res 1/2
		m^1	Res 3/4	Res ¾	-	m_1	Res ¾	Res 3/4	-
		m^2	Res 1/2	Res 1/2	Res 1/2	m_2	Res 3/4	Res 3/4	-
		I^1	R 3/4	R ¾	R 3/4	I_1	R ¾	R 3/4	R 3/4
		I^2	R 1/2	R ½	R 1/2	I_2	R ¾	R 3/4	R 3/4
		C'	R 1/4	R ¼	R 1/4	C,	R 1/4	R 1/4	R 1/4
		P^1	R 1/4	R 1/4-R ½	R 1/2	P_1	R 1/4	R 1/4	R 1/2
		P^2	R 1/4	R ¼	R 1/4	P_2	Ri	Ri	R 1/2
		M^1	Rc	Rc	Rc	M_1	Rc	Rc	Rc
		M^2	R 1/4	R ¼	R 1/4	M_2	Crc	Crc	R 1/4
		M^3	Ci	Ci	Ci	M_3	-	-	-
8.5 years	0	i^2	-	-	-	i_2	-	-	-
		c'	-	-	-	c,	-	-	-

		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	-	-	-	I_1	-	-	-
		I^2	-	-	-	I_2	-	-	-
		C'	-	-	-	C,	-	-	-
		P^1	-	-	-	P_1	-	-	-
		P^2	-	-	-	P_2	-	-	-
		M^1	-	-	-	M_1	-	-	-
		M^2	-	-	-	M_2	-	-	-
		M^3	-	-	-	M_3	-	-	-
9.5 years	6	c'	Ac	Res ¼	Res 3/4	c,	Res 1/4	Res 3/4	-
		m^1	Ac	Res ¼	Res 1/2	m_1	Res 1/4	Res 1/4	Res 1/2
		m^2	Ac	Ac-Res ¼	Res 3/4	m_2	Ac	Res 1/4	Res 3/4
		I^1	Rc	A ½	Ac	I_1	Rc	A 1/2	Ac
		I^2	R 3/4	Rc-A ½	Ac	I_2	R 3/4	Rc - A 1/2	Ac
		C'	R 1/2	R 1/2-R ¾	R 3/4	C,	R 1/4	R 3/4	Rc
		P^1	R 1/2	R 1/2-R 3/4	Rc	P_1	R 1/4	R 3/4	Rc
		P^2	R 1/4	R ½	R 1/2	P_2	Ri	R 1/2	R 3/4
		M^1	Ac	Ac	Ac	M_1	Rc	A 1/2-Ac	Ac
		M^2	R 1/4	R 1/4-R 1/2	R 1/2	M_2	R 1/4	R 1/4 - R 1/2	R 3/4
		M^3	-	Cco-Coc	Coc	M_3	-	Cco-Coc	Cr 3/4
10.5 years	1	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	A 1/2	A ½	A 1/2	I_1	Ac	Ac	Ac
		I^2	A 1/2	A ½	A 1/2	I_2	Ac	Ac	Ac
		C'	R 3/4	R ¾	R 3/4	C,	A 1/2	A 1/2	A 1/2
		P^1	Rc	Rc	Rc	P_1	Rc	Rc-A 1/2	A 1/2
		P^2	R 3/4	R ¾	R 3/4	P_2	Rc	Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac

		M^2	R 1/2	R ½	R 1/2	M_2	R 3/4	R 3/4	R 3/4
		M^3	Coc	Coc	Coc	M_3	Coc	Coc-Cr 1/2	Cr 1/2
11.5 years	3	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	Ac	-	-	m_2	Res 3/4	-	-
		I^1	A 1/2	Ac	Ac	I_1	A 1/2	Ac	Ac
		I^2	A 1/2	Ac	Ac	I_2	A 1/2	Ac	Ac
		C'	Rc	A ½	Ac	C,	Rc	A 1/2	A 1/2
		P^1	Rc	Rc	Rc	P_1	Rc	Rc	A 1/2
		P^2	R 3/4	Rc	Rc	P_2	R 3/4	Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	Rc	Rc	M_2	R 1/2	Rc	Rc
		M^3	Crc	Crc-Ri	Ri	M_3	Crc	Crc-Ri	Ri
12.5 years	3	c'	Res ¾	-	-	c,	-	-	-
		m^1	-	-	-	m1	-	-	-
		m^2	-	-	-	m_2	Res 1/2	-	-
		I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	A 1/2	A 1/2	A 1/2	C,	Rc	A 1/2	Ac
		P^1	A 1/2	A ½	A 1/2	P_1	Rc	A 1/2	A 1/2
		P^2	Rc	Rc-A ½	A 1/2	P_2	R 3/4	Rc	A 1/2
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Rc	Rc	M_2	R 3/4	Rc	Rc
		M^3	Crc	Crc	Crc	M_3	Cr 3/4	Crc	Crc
13.5 years	4	I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	A ½	Ac	C,	Rc	A 1/2	Ac

		P^1	Rc	Rc-A ½	Ac	P_1	A 1/2	A 1/2	Ac
		P^2	Rc	Rc	Ac	P_2	Rc	Rc	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 1/2	Rc	Ac	M_2	Rc	Rc	Ac
		M^3	Cco	Ri	Rc	M_3	Crc	Crc-Ri	R 3/4
14.5 years	0	C'	-	-	-	C,	-	-	-
		P^1	-	-	-	P_1	-	-	-
		P^2	-	-	-	P_2	-	-	-
		M^1	-	-	-	M_1	-	-	-
		M^2	-	-	-	M_2	-	-	-
		M^3	-	-	-	M_3	-	-	-
15.5 years	4	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		P^1	Ac	Ac	Ac	P_1	Ac	Ac	Ac
		P^2	Ac	Ac	Ac	P_2	Ac	Ac	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	Ri	R ½	R 1/2	M_3	Ri	R 1/2	R 1/2
16.5 years	3	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Rc	Ac	Ac	M_2	Rc	Ac	Ac
		M^3	Crc	R ½	R 1/2	M_3	Crc	R 1/2	R 3/4
17.5 years	4	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 1/4	R ½	R 1/2	M_3	R 1/4	R 1/2	Rc
18.5 years	5	M^3	R 1/2	R 1/2	Ac	M_3	R 1/2	R 3/4	Ac
19.5 years	10	M^3	R 1/2	R 3/4	Ac	M_3	R 1/4	Rc	Ac
20.5 years	7	M^3	Rc	Rc	Ac	M_3	Rc	Rc	A 1/2

Figure A.4. Tooth stage chart of Group 2 individuals (Male)

Maxilla						Mandible			
			Tooth Formation Stage				Tooth Formation Stage		
Age	Number of Individuals	Tooth	Min.	Median	Max.	Tooth	Min.	Median	Max.
6 months	5	i^1	R 1/2	R ½	R 3/4	i_1	R 1/4	R 1/2	R ¾
		i^2	R 1/4	R ½	R 1/2	i_2	R 1/4	R 1/4	R ½
		c'	Cr 3/4	Crc	Crc	c,	Cr 3/4	Crc	Crc
		m^1	R 1/4	R ½	R 1/2	m_1	R 1/4	R 1/4	R ¼
		m^2	Cr 3/4	Crc	Crc	m_2	Cr 3/4	Cr 3/4	Crc
		I^1	Cco	Coc	Coc	I_1	Cco	Coc	Coc
		I^2	-	-	-	I_2	Ci	Ci	Ci
		C'	Ci	Ci	Ci	C,	Ci	Ci	Coc
		M^1	Cco	Cco	Cco	M_1	Cco	Cco	Cco
1 year	6	i^1	R 3/4	R 3/4-Rc	Rc	i_1	R 1/2	Rc	A ½
		i^2	R 1/2	R ¾	Rc	i_2	R 1/2	R 3/4	Rc
		c'	R 1/4	R ½	R 3/4	c,	Ri	R 1/2	R ¾
		m^1	R 3/4	R ¾	Rc	m_1	R 1/2	R 3/4	Rc
		m^2	R 1/4	R ¼	R 1/2	m_2	Ri	R 1/4	R ½
		I^1	Cr 1/2	Cr ½	Cr 1/2	I_1	Cr 1/2	Cr 1/2	Cr ½
		I^2	-	Cco	Coc	I_2	Cr 1/2	Cr 1/2	Cr ½
		C'	Coc	Coc	Cr 1/2	C,	Coc	Coc	Cr ½
		M^1	Coc	Coc	Cr 1/2	M_1	Coc	Coc	Cr ½
1.5 years	8	i^1	Rc	Rc	Ac	i_1	Rc	Rc-A 1/2	Ac
		i^2	R 3/4	Rc	Ac	i_2	R 3/4	Rc	Ac
		c'	R 1/2	R 1/2-R 3/4	R 3/4	c,	R 1/2	R 3/4	R ¾

		m^1	R 3/4	Rc	Rc	m_1	R 3/4	R 3/4	Rc
		m^2	R 1/4	R ¾	R 3/4	m_2	R 1/4	R 1/2	R ¾
		I^1	Cr 1/2	Cr 1/2-Cr 3/4	Cr 3/4	I_1	Cr 1/2	Cr 1/2-Cr 3/4	Cr 3/4
		I^2	Cco	Cr ½	Cr 1/2	I_2	Cr 1/2	Cr 1/2	Cr ¾
		C'	Coc	Cr ½	Cr 1/2	C,	Coc	Cr 1/2	Cr ½
		P^1	-	-	Cco	P_1	-	Ci	Cco
		M^1	Coc	Cr ½	Crc	M_1	Coc	Cr 1/2-Cr 3/4	Crc
2.5 years	5	i^1	Rc	Rc-Ac	Ac	i_1	Ac	Ac	Ac
		i^2	Rc	Ac	Ac	i_2	Rc	Ac	Ac
		c'	R 3/4	Rc	Ac	c,	R 3/4	Rc	A ½
		m^1	Rc	Ac	Ac	m_1	Rc	Rc-Ac	Ac
		m^2	R 3/4	Rc	Ac	m_2	R 3/4	Rc	A ½
		I^1	Cr 1/2	Cr ¾	Ri	I_1	Cr 1/2	Cr 3/4	Crc
		I^2	Coc	Cr ½	Coc	I_2	Cr 1/2	Cr 3/4	Coc
		C'	Cr 1/2	Cr ½	Cr 3/4	C,	Coc	Cr 1/2	Cr ¾
		P^1	Ci	Cco	Coc	P_1	Ci	Cco	Cr ½
		P^2	-	-	Cco	P_2	-	-	Cco
		M^1	Cr 1/2	Crc	Crc	M_1	Cr 1/2	Crc	Ri
		M^2	-	-	Cco	M_2	-	-	Cco
3.5 years	7	i^1	A 1/2	Ac	Res 1/4	i_1	Ac	Ac	Res ½
		i^2	Rc	Ac	Ac	i_2	Rc	Ac	Res ½
		c'	Rc	A ½	Ac	c,	Rc	Ac	Ac
		m^1	Rc	Ac	Ac	m_1	Rc	Ac	Ac
		m^2	Rc	A ½	Ac	m_2	Rc	A 1/2	Ac
		I^1	Cr 3/4	Cr ¾	Crc	I_1	Cr 3/4	Crc	Ri
		I^2	Cr 1/2	Cr ¾	Crc	I_2	Cr 3/4	Crc	Crc
		C'	Cr 1/2	Cr ¾	Cr 3/4	C,	Cr 1/2	Cr 3/4	Crc

		P^1	Coc	Cr ½	Cr 3/4	P_1	Cco	Cr 1/2	Cr ¾
		P^2	-	Cco	Cr 1/2	P_2	Ci	Coc	Cr ½
		M^1	Cr 3/4	Crc	R 1/4	M_1	Crc	Crc	R ¼
		M^2	-	Cco	Coc	M_2	-	Ci	Coc
4.5 years	3	i^1	Ac	Ac	Ac	i_1	Ac	Res 1/4	Res 1/2
		i^2	Ac	Ac	Ac	i_2	Ac	Ac	Ac
		c'	Ac	Ac	Ac	c,	Ac	Ac	Ac
		m^1	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	Crc	Crc	R 1/4	I_1	Ri	Ri	R ¼
		I^2	Crc	Crc	Ri	I_2	Ri	Ri	Ri
		C'	Cr 3/4	Cr ¾	Crc	C,	Cr 3/4	Crc	Crc
		P^1	Cr 1/2	Cr ¾	Cr 3/4	P_1	Cr 1/2	Cr 3/4	Cr ¾
		P^2	Coc	Cr ½	Cr 1/2	P_2	Coc	Cr 1/2	Cr ½
		M^1	Crc	R ¼	R 1/2	M_1	Crc	R 1/4	R ½
		M^2	Coc	Coc	Crc	M_2	Coc	Coc	Crc
5.5 years	4	i^1	Res 1/4	Res ½	Res 1/2	i_1	Res 1/4	Res 1/4	Res ½
		i^2	Ac	Ac	Res 1/2	i_2	Ac	Res 1/4	Res ¾
		c'	Ac	Ac	Ac	c,	Ac	Ac	Ac
		m^1	Ac	Ac	Ac	m_1	Ac	Ac	Ac
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	Ri	Ri	R 1/4	I_1	R 1/4	R 1/4	R ½
		I^2	Crc	Crc	Ri	I_2	Ri	R 1/4	R ¼
		C'	Crc	Crc	Crc	C,	Crc	Crc	Ri
		P^1	Cr 3/4	Cr 3/4-Crc	Crc	P_1	Cr 3/4	Crc	Crc
		P^2	Coc	Cr ¾	Cr 3/4	P_2	Coc	Cr 3/4-Crc	Crc
		M^1	R 1/4	R 1/4-R 1/2	R 3/4	M_1	R 1/4	R 1/4-R 1/2	R ¾
		M^2	Coc	Cr 1/2-Cr 3/4	Crc	M_2	Coc	Cr 1/2	Crc

6.5 years	2	i^1	Res 3/4	-	-	i_1	-	-	-
		i^2	Res 1/2	Res ½	-	i_2	Res 1/2	Res 1/2	-
		c'	Res 1/4	Res ¼	Res 1/4	c,	Ac	Ac	Ac
		m^1	Res 1/4	Res ¼	Res 1/4	m_1	Res 1/4	Res 1/4	Res ¼
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	R 1/4	R 1/4-R 1/2	R 1/2	I_1	R 1/2	R 1/2	R ½
		I^2	Ri	Ri-R ¼	R 1/4	I_2	R 1/4	R 1/4	R 1/4
		C'	Crc	Crc-Ri	Ri	C,	Ri	Ri	Ri
		P^1	Crc	Crc	Crc	P_1	Crc	Crc-Ri	Ri
		P^2	Cr 3/4	Cr 3/4-Crc	Crc	P_2	Cr 1/2	Crc	Crc
		M^1	R 3/4	Rc	Rc	M_1	R 3/4	R 3/4-Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
7.5 years	2	i^1	Res 3/4	Res 3/4/ -	-	i_1	-	-	-
		i^2	Res 1/2	Res 1/2/ -	-	i_2	Res 1/4	Res 1/4/ -	-
		c'	Ac	Ac	Ac	c,	Ac	Ac	Res ¼
		m^1	Res 1/4	Res ¼	Res 1/4	m_1	Res 1/4	Res 1/4	Res ¼
		m^2	Ac	Ac	Ac	m_2	Ac	Ac	Ac
		I^1	R 1/4	R ¼	Rc	I_1	R 1/2	R 1/2-A 1/2	A ½
		I^2	R 1/4	R 1/4-R 3/4	R 3/4	I_2	R 1/4	R 1/4-Rc	Rc
		C'	Ri	Ri-R ¼	R 1/4	C,	Ri	Ri-R 1/4	R ¼
		P^1	Ri	Ri	R 1/4	P_1	R 1/4	R 1/4	R ¼
		P^2	Ri	Ri	Ri	P_2	Ri	Ri	Ri
		M^1	Rc	Rc	Rc	M_1	Rc	Rc	Rc
		M^2	Crc	Crc	Crc	M_2	Crc	Crc	Crc
		M^3	-	-	-	M_3	-	-	-
8.5 years	3	i^2	-	-	-	i_2	-	-	-
		c'	Res 1/4	Res ¼	-	c,	Res 1/4	Res 3/4	-

		m^1	Res 1/4	Res ¼	Res 1/2	m_1	Res 1/4	Res 3/4	-
		m^2	Ac	Ac	Res 1/4	m_2	Ac	Res 1/4	-
		I^1	R 3/4	Rc	Rc	I_1	Rc	A 1/2	A ½
		I^2	R 3/4	Rc	Rc	I_2	Rc	Rc	A ½
		C'	R 1/4	R ½	R 1/2	C,	R 1/2	R 1/2	R ½
		P^1	R 1/4	R ½	R 1/2	P_1	R 1/2	R 1/2	R ½
		P^2	R 1/4	R ¼	R 1/2	P_2	R 1/4	R 1/4	R ½
		M^1	Rc	Rc	A 1/2	M_1	Rc	Rc	A ½
		M^2	R 1/4	R ¼	R 1/4	M_2	Ri	R 1/4	R ½
		M^3	Ci	Ci-Cco	Cr 1/2	M_3	-	Ci	Cr 1/2
9.5 years	4	c'	Ac	Res 1/4/ Res 1/2	Res 3/4	c,	Res 1/4	Res 3/4	Res ¾
		m^1	Ac	Res ¼	Res 1/4	m_1	Res 1/4	Res 1/4	Res ¼
		m^2	Ac	Ac	Res 3/4	m_2	Ac	Res 1/4	Res ¾
		I^1	Rc	Rc-A ½	Ac	I_1	Rc	A 1/2	Ac
		I^2	R 3/4	R 3/4-A 1/2	Ac	I_2	R 3/4	Rc-A 1/2	Ac
		C'	R 1/2	R ½	R 3/4	C,	R 1/4	R 1/2	Rc
		P^1	R 1/4	R ½	Rc	P_1	R 1/4	R 1/2	Rc
		P^2	R 1/4	R ½	R 3/4	P_2	Ri	R 1/2	R ¾
		M^1	Rc	A ½	Ac	M_1	Rc	Rc-A 1/2	Ac
		M^2	R 1/4	R ¼	R 3/4	M_2	R 1/4	R 1/4-R 1/2	R ¾
		M^3	-	Cco-Cr 1/2	Cr 3/4	M_3	Ci	Cco-Cr 3/4	Cr ¾
10.5 years	0	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	-	-	-
		I^1	-	-	-	I_1	-	-	-
		I^2	-	-	-	I_2	-	-	-
		C'	-	-	-	C,	-	-	-

		P^1	-	-	-	P_1	-	-	-
		P^2	-	-	-	P_2	-	-	-
		M^1	-	-	-	M_1	-	-	-
		M^2	-	-	-	M_2	-	-	-
		M^3	-	-	-	M_3	-	-	-
11.5 years	2	c'	-	-	-	c,	-	-	-
		m^1	-	-	-	m_1	-	-	-
		m^2	-	-	-	m_2	Res 3/4	-	-
		I^1	A 1/2	A 1/2-Ac	Ac	I_1	A 1/2	A 1/2	A ½
		I^2	Rc	A 1/2-Ac	Ac	I_2	A 1/2	A 1/2-Ac	Ac
		C'	R 3/4	R 3/4-Rc	A 1/2	C,	R 3/4	R 3/4-Rc	A 1/2
		P^1	Rc	Rc	Rc	P_1	R 3/4	R 3/4-Rc	Rc
		P^2	R 3/4	Rc	Rc	P_2	R 3/4	R 3/4-Rc	Rc
		M^1	Ac	Ac	Ac	M_1	A 1/2	A 1/2-Ac	Ac
		M^2	R 1/2	R 1/2-Rc	Rc	M_2	R 1/2	R 1/2-Rc	Rc
		M^3	Coc	Coc-Crc	Crc	M_3	Cco	Cco-Crc	Crc
12.5 years	2	c'	Res 3/4	-	-	c,	-	-	-
		m^1	-	-	-	m1	-	-	-
		m^2	-	-	-	m_2	Res 1/2	Res 3/4	-
		I^1	A 1/2	A 1/2-Ac	Ac	I_1	Ac	Ac	Ac
		I^2	A 1/2	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	Rc	Rc	C,	Rc	Rc-A 1/2	A 1/2
		P^1	Rc	Rc	Rc	P_1	Rc	Rc-A 1/2	A 1/2
		P^2	Rc	Rc	Rc	P_2	R 3/4	R 3/4-Rc	Rc
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	R 3/4	R 3/4-Rc	Rc	M_2	R 3/4	R 3/4-Rc	Rc
		M^3	Cr 3/4	Cr 3/4	Cr 3/4	M_3	Cr 3/4	Cr 3/4-Crc	Crc

13.5 years	2	I^1	Ac	Ac	Ac	I_1	Ac	Ac	Ac
		I^2	Ac	Ac	Ac	I_2	Ac	Ac	Ac
		C'	Rc	A ½	A 1/2	C,	A 1/2	A 1/2-Ac	Ac
		P^1	A 1/2	A ½	A 1/2	P_1	A 1/2	A 1/2	A 1/2
		P^2	Rc	Rc	Rc	P_2	Rc	Rc-A 1/2	A 1/2
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Rc	A 1/2	M_2	Rc	Rc-A 1/2	A 1/2
		M^3	Cr 1/2	Crc-Ri	R 1/4	M_3	Crc	Crc-R 1/4	R 1/4
14.5 years	1	C'	Ac	Ac	Ac	C,	A 1/2	A 1/2	A 1/2
		P^1	Ac	Ac	Ac	P_1	A 1/2	A 1/2	A 1/2
		P^2	Rc	Rc-Ac	Ac	P_2	A 1/2	A 1/2	A 1/2
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Rc	Rc	Rc	M_2	Rc	Rc-A 1/2	A 1/2
		M^3	R 1/4	R 1/4	R 1/4	M_3	R 1/4	R 1/4	R 1/4
15.5 years	3	C'	A 1/2	Ac	Ac	C,	A 1/2	A 1/2-Ac	Ac
		P^1	Rc	Rc	Ac	P_1	A 1/2	A 1/2	Ac
		P^2	Rc	Rc-Ac	Ac	P_2	Rc	Rc	Ac
		M^1	Ac	Ac	Ac	M_1	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Rc	Rc-A 1/2	Ac
		M^3	Ri	R 1/4	R 1/2	M_3	Ri	R 1/4	R 1/2
16.5 years	6	C'	Ac	Ac	Ac	C,	Ac	Ac	Ac
		M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 3/4	R 3/4	Rc	M_3	R 3/4	R 3/4	Rc
17.5 years	3	M^2	Ac	Ac	Ac	M_2	Ac	Ac	Ac
		M^3	R 3/4	R 3/4-Rc	Rc	M_3	R 3/4	R 3/4-Rc	Rc
18.5 years	7	M^3	R 1/2	Rc- Ac	Ac	M_3	R 3/4	R 3/4- Rc	Rc

19.5 years	9	M^3	Rc	Ac	Ac	M_3	R 1/2	A 1/2- Ac	Ac
20.5 years	3	M^3	Ac	Ac	Ac	M_3	Ac	Ac	Ac

VITA

Cal McGehee was born in Tupelo, Mississippi on June 18th 1999 to parents Bruce and DeAnna McGehee. From kindergarten to his senior year of high school, he attended Myrtle Attendance Center, graduating in May 2017. His first semester of college was at Ittawamba Community College, before transferring to Northeast Community College his next two semesters. His final five semesters of undergraduate studies were completed at the University of Mississippi, where he was on the Dean's list for his second semester, and the Chancellor's list for his final three semesters. He graduated from the University of Mississippi in May 2021 with a bachelor's degree in Anthropology and a minor in Psychology. He continued his education at the University of Mississippi by attending graduate school at the University of Mississippi Department of Sociology and Anthropology, obtaining a Masters of Arts in May 2023. His focus in his graduate studies include dental anthropology, age-estimation, Native American studies, and human anatomy.