Forensic Age Estimation in a Chicago Pediatric Population

BY

MATTHEW STRUMPF
B.A., Northwestern University, 2012
D.M.D, Midwestern University in Illinois, 2017

THESIS

Submitted as partial fulfillment of the
requirements for the degree of Master of Science
in Oral Sciences in the Graduate College of the
University of Illinois at Chicago, 2019

Chicago, Illinois

Defense Committee:

Christina Nicholas, PhD, Chair and Advisor
Marcio A. da Fonseca, DDS, MS
Ian Marion, DDS, MS
Sakher AlQahtani, BDS, MClinDent, PhD, College of Dentistry,
King Saud University, Riyadh, Saudi Arabia

ACKNOWLEDGMENTS

I would like to firstly, and most importantly, thank my primary advisor, Dr. Christina Nicholas, for all of her guidance and support throughout this project. I appreciate that she did not seem to mind that I would visit her office, unannounced, many times to ask the many questions that I had throughout it. This project would definitely not have been possible without her.

I also would like to specifically thank Dr. Sakher AlQahtani for his help throughout the project. He responded quickly with any question or request I had even though we were on opposite sides of the world.

I would like to express appreciation to the other members of my committee, as well. Dr. da Fonseca was always available with much needed advice and improvements to the project throughout the entire process. Dr. Marion was very supportive and was always available when I had a quick question. All members of this committee were truly integral to its completion, and I believe this project would not have been successful without any one of them.

Finally, I would like to thank my wife, Sydney, for reading every draft involved with my research project. She was beyond supportive and made everything less stressful to allow me to complete this thesis.

MBS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Age estimation is an important tool for identifying an unknown child or remains in many criminal cases. This retrospective, cross-sectional study assessed the accuracy of using the Demirjian Method to estimate the ages of a diverse Chicago pediatric population across a range of body mass indexes. 281 panoramic radiographs of children aged six to twelve years of age were selected from the University of Illinois College of Dentistry Pediatric and Orthodontic database. Dental age was calculated using the Demirjian method to evaluate tooth development. Dental age was then subtracted from the patient's chronologic age, at the time of the radiograph, to obtain a ΔAge (difference in age). The ΔAge was then compared against sex, ancestry, and BMI group.

The Demirjian method was relatively accurate at estimating the age of the normal BMI group. There was no statistical difference between ancestral groups or between sexes. There was a statistically significant overestimation of age in the overweight and obese BMI groups by approximately six months. These findings indicate that the pediatric dentistry, orthodontics, and forensics communities ought to account for accelerated growth and development of overweight and obese children.

I. INTRODUCTION

I.1 Age Estimation

Age estimation is an important tool used in many scenarios when individuals are un-identifiable. It is extremely important when helping to identify children whether it is for a case of child abuse, human trafficking, kidnapping, or death.[1] It is also one of the only reliable methods for identifying children since normal methods of identification, such as existing dental restorations, tattoos, signs of trauma, and other growth markers are not applicable at young ages.[2] Additionally, the way in which age is estimated greatly differs between adults and children.[3]

Forensic anthropologists use multiple bony sites in the adult body to aid in age estimation. The sternal rib end, pubic symphyses, the auricular surface of the ilium, and the cranial sutures can be assessed for signs of resorption, deposition, and remodeling to place the un-identifiable person into an age group.[3] Unlike adults, those bony landmarks have not fully formed to distinguish between younger ages. The most widely used method for age estimation in children is analysis of panoramic radiographs. The average ages when teeth develop and erupt have been well established and are used to narrow the age range to which the un-identifiable child may belong.[4]

I.2 Dental Age

Dentists and orthodontists assess the "dental age" of their pediatric patients daily to formulate a personalized treatment plan. Abnormalities in dental eruption patterns, whether those abnormalities are changes in the timing or sequence of tooth eruption, have significant impacts on treatment decisions.[4] Orthodontic intervention, space maintenance, caries control, and many other aspects of dentistry are affected by the patient's growth and development. It is therefore extremely important to the field of dentistry to be able to accurately assess the pediatric patient using radiographic findings.

I.3 Nature vs. Nurture

There are many factors that are thought to affect the timing of tooth development and eruption in children. Genetic factors like ancestral lineage may alter eruption patterns. Research has compared dental developmental patterns in individuals of different ancestral backgrounds. Kanagartnam and Schluter (2012) concluded that Polynesian children have earlier tooth eruption than European, Chinese, and Indian children, while American Indian tooth emergence happens earlier than Caucasian and African American children.[5] Many other studies have found evidence that ancestry has an effect on dental development.[6-14] On the other hand, Liversidge (1999) and Mack et al. (2013) concluded that ancestry does not have an effect on dental development questioning the hypothesis that different populations of children will exhibit different dental growth. If ancestry is not a factor, there is the potential to formulate an age estimation method that could be used around the world, especially in diverse countries like the U.S.

The other main factor thought to affect the timing of tooth development is environmental influence, such as nutrition and diet. Obese children have accelerated patterns of tooth development relative to their normal weight counterparts but the reason is unknown.[4,12,15,16,17] Conversely, Bagherian and Sadeghi (2011) concluded that BMI is not associated with dental development.

There is some debate over whether malnutrition causes delays in dental development. Elamin and Liversidge (2013) found that severe malnutrition has no effect on tooth development. This finding brings into question if environmental factors can have an effect on tooth development since severe malnutrition has been shown to have large effects on other biological systems. However, it is important to note that other researchers have found associations between stunting/wasting and delayed dental eruption.[18]

I.4 Childhood Obesity

Childhood obesity is a condition that affects at least one in six U.S. children and has a higher prevalence in Hispanic children.[3] Obesity has many comorbidities that not only affect systemic health but the oral and emotional health of these children. Diabetes, heart disease, asthma, bone and joint problems, and depression are examples of systemic health problems associated with childhood obesity. Increased risk of caries, malocclusion, and sleep apnea are examples of oral health concerns associated with childhood obesity.[4] Obesity can also impact normal growth and development as obese girls exhibit irregular and early menses. Other growth disturbances are seen with increased vertical growth, increased risk of hyperandrogenism and polycystic ovary syndrome.[19]

According to the Consortium to Lower Obesity in Chicago (CLOCC), from 2011-2015, the national average of overweight children in the U.S. was 11.4%, 18.6%, and 15.4% for kindergarten, 6th grade, and 9th grade children, respectively. The national average of obese children in the U.S. is 12.7%, 20.4%, and 16.7% for kindergarten, 6th grade, and 9th grade children, respectively. The rates for overweight and obese children in Chicago are higher than the average rates in the U.S. The Chicago average of overweight children is 16.5%, 19.4%, and 19.3% for kindergarten, 6th grade, and 9th grade children, respectively. The Chicago average of obese children is 20%, 29.2%, and 25.4% for kindergarten, 6th grade, and 9th grade children, respectively.[20] These rates of childhood obesity highlight the importance of studying the effects that obesity has on normal child growth and development.

I.5 Demirjian Method

Demirjian et al. created a then-new method for age estimation in 1973 after finding that tooth formation is a more accurate measure of age estimation than eruption/gingival emergence. Specific tooth shapes were recorded and assigned into one of eight stages (A to H) that are clearly recognizable and consistent between all individuals during tooth formation. This method is one of two main methods of assessing age. The other method, the Atlas method, tries to best fit the individual to a “snapshot” of typical presentations (examples of atlases include: Shauer and Massler, Ubelaker, and the London Dental Atlas). The Demirjian method assesses the formation of each tooth, assigns a stage to that individual tooth, and then generates a score based on the values assigned to each stage. This score can then be converted to a dental age that would represent that individual.

To create this method, Demirjian and colleagues assessed over 3000 children of French-Canadian descent aged 2 to 20 who did not have any growth disorder that would affect tooth number or normal development. They then assessed the seven left mandibular permanent teeth to create the stages and scores. See Appendix B and C for the original diagrams and descriptions of each stage.[21]

Multiple studies have been performed assessing the accuracy of the Demirjian method. Three studies found that the Demirjian method overestimates age by 6 months. [17,22,23] Maher et al. 2006 overestimates age by 3 months. Khorate et al. 2014 found that Demirjian method underestimates age by 2 years. In contrast, Liversidge et al. 2006 found Demirjian method to be accurate for their sample. Despite the studies that indicate a discrepancy, the Demirjian method remains one of the most commonly used methods for dental age estimation. For example, in a review of 19 papers that looked at dental development/eruption and childhood BMI, Nicholas and colleagues (2018) found that 12/19 studies employed the Demirjian method or a derivative of it.

The goal of the Demirjian method, and other age estimation tools, is to calculate a dental age that is close to the subject's chronologic age; thus, if the Demirjian method produces an "accurate" age assessment, the difference between dental age and chronologic age, ΔAge, should approach zero. When assessing the accuracy of the Demirjian method, a positive ΔAge would mean the Demirjian method overestimated the age of the subject, and a negative ΔAge would mean an underestimation of the age. Therefore, the terms accuracy and overestimation/underestimation are interchangeable when discussing the Demirjian method.

I.6 <u>Study Objectives</u>

This study has the following key aims:

1) To assess the accuracy of the Demirjian method of age estimation in a diverse Chicago pediatric population between the ages of 6

and 12 years who have sought care at the University of Illinois College of Dentistry (UIC)

2) To assess the differences in age estimation between patients of different ancestries, a proxy for population genetics

3) To assess the differences in age estimation between patients of differing BMI, a proxy for environment

4) To contribute to the forensics field to better identify missing or deceased children

I.7 Hypotheses

H_{01}: The Demirjian method is not accurate at age estimation in a diverse population in Chicago

H_{02}: There is no relationship between ancestry and altered dental development resulting in inaccurate age estimations

H_{03}: There is no relationship between BMI and altered dental development resulting in inaccurate age estimations

II. MATERIALS AND METHODS

II.1 Study Approval

This study was approved for exemption by the Institutional Review Board of the University of Illinois at Chicago (IRB # 2018-0283), Chicago, IL (Appendix A). No funding was required for this project.

II.2 Study Criteria

A retrospective cross-sectional chart review using UIC Pediatric and Orthodontic database of panoramic radiographs. Approximately 300 radiographs were selected by using inclusion and exclusion criteria and age, ancestry, BMI, and sex were obtained. Dental development was assessed from the panoramic radiographs using the Demirjian method (described above). BMI was calculated based upon recorded height/weight within 6 months of time of radiograph and BMI percentiles were derived from this using the CDC online "Child and Teen BMI Calculator".

Inclusion Criteria:

- Electronic patient records with panoramic radiographs obtained from January 2012 to April 16, 2018.
- Children of Hispanic, Euro-American, and African-American ancestry, aged 6-12 years at the time the radiographs were obtained

- Height and weight measurements available from within 6 months of the panoramic radiograph

<u>Exclusion Criteria:</u>

- Patients who have undergone orthodontic treatment and/or major oral surgery prior to obtaining panoramic radiographs to be used in the study
- Presence of pathology, altered number of teeth, and/or malformed teeth on panoramic radiograph
- Gross image distortion of the panoramic radiographic
- Patients with craniofacial anomalies, diseases or conditions, particularly endocrine diseases, that may affect dental development and/or tooth eruption patterns
- Patients who have undergone medical treatment that may affect dental development and tooth eruption patterns (e.g., chemotherapy, radiotherapy, etc)
- Multiple panoramic radiographs – no patient will be represented more than once if they have had multiple panoramic radiographs obtained at the UIC College of Dentistry.
- Diseases affecting the number of teeth i.e. presence of hypodontia, hyperdontia, etc.
- Diseases resulting in malformation of teeth i.e. taurodontism, germination, etc.

- Craniofacial anomalies affecting tooth development or eruption patterns i.e. Treacher-Collins, cleft palate/lip, etc.
- Patients who did not have their height and weight recorded in the electronic dental chart within 6 months the panoramic radiograph was obtained.

II.3 Methodology

Data was obtained from the UIC College of Dentistry electronic patient database from patients seen in the Pediatric Dentistry and Orthodontics Departments. A report was generated that included all patients, ages 6-12 years, who had a panoramic radiograph taken between January 2012 and April 2018. The principal investigator (PI) screened the list for subjects that fit the inclusion and exclusion criteria. Those records that fit the criteria were then exported to a secure folder and assigned an identification number. The identification number was linked to the panoramic radiograph; the subject's ancestry, sex, height, weight, BMI, and age at the time of radiograph were recorded. The age of the subject, chronologic age, was calculated by subtracting the subject's birthdate from the date the radiograph was obtained and reported in months.

The radiographs were then analyzed using the Demirjian method to calculate dental age. The seven mandibular permanent teeth on the right side were assigned into one of the eight stages as defined by Demirjian using both diagrams and written descriptions. Each tooth could only fall into a stage if the threshold for that stage was achieved. Teeth were not "rounded up" to the next stage and were always "rounded down" for consistency. A worksheet (created by Frucht and colleagues 2000, Appendix D) was used to document each record and to calculate the dental age of the patient.

II.4 Intra-examiner variability

Prior to the beginning of data collection, 10 randomly selected radiographs were scored twice by the PI in an interval of one week.

II.5 Statistical Analysis

Chronological age was subtracted from estimated dental age for each record to calculate ΔAge (difference in age). Positive results indicated an overestimation and a negative result indicated an underestimation. The mean difference and standard deviation for each BMI group, normal, overweight, and obese, was compiled. Standard non-parametric statistic tests, such as Kruskal Wallis and Spearman's correlation were run to assess the relationships between our variables of interest at $\alpha=0.05$.

III. RESULTS

III.1 Study Results

One thousand sixty-six charts were reviewed for selection. Three hundred and five charts fit the inclusion and exclusion criteria. Twenty-four radiographs were not diagnostic and were unable to be analyzed. The total number of radiographs included in the study was 281.

We ran an intra-class correlation analysis to assess intra-rater reliability. This yielded a kappa=0.854. Additionally, the variability between the two measurements was minimal and if incorrect, was off by no more than one stage.

The average chronologic age of the sample was 8.84 years.

TABLE I

POPULATION STATISTICS

TABLE I Population statistics in percentage of the selected radiographs (by patient sex, ancestry, and age)

Population Statistics (%of total)	
Sex	
Male	143 (51)
Female	138 (49)
Ancestry	
African American	47 (17)
Asian	14 (5)
Euro-American	29 (10)
Hispanic	191 (68)
Age (in years)	
6.00-6.99	24 (8.5)
7.00-7.99	59 (21.0)
8.00-8.99	70 (24.9)
9.00-9.99	65 (23.1)
10.00-10.99	34 (12.1)
11.00-11.99	29 (10.3)

TABLE II

BMI GROUP BY SEX

TABLE II Number and percentage of radiographs of children in the different BMI categories, as defined by the CDC, by sex

	Male	Female	Total
Underweight	5 (1.8)	5 (1.8)	10 (3.6)
Normal	74 (26.3)	74 (26.3)	148 (52.7)
Overweight	39 (13.9)	33 (11.7)	72 (25.6)
Obese	25 (8.9)	26 (9.3)	51 (18.1)

TABLE III

BMI GROUP BY ANCESTRY

TABLE III Number and percentage of radiographs of children in the different BMI categories, as defined by the CDC, by different ethnic groups

BMI by Ancestry (% of total)

	African American	Asian	Euro-American	Hispanic	Total
Underweight	2 (0.7)	0 (0)	3 (1.1)	5 (1.8)	10 (3.6)
Normal	27 (9.6)	12 (4.3)	17 (6.0)	92 (32.7)	148 (52.7)
Overweight	10 (3.6)	2 (0.7)	3 (1.1)	57 (20.3)	72 (25.6)
Obese	8 (2.8)	0 (0)	6 (2.1)	37 (13.2)	51 (18.1)

TABLE IV

BMI GROUP BY AGE

TABLE IV Number and percentage of radiographs of children in the different BMI categories, as defined by the CDC, by age

	BMI by Age in years (% of total)						
	6.00-6.99	7.00-7.99	8.00-8.99	9.00-9.99	10.00-10.99	11.00-11.99	Total
Underweight	0 (0)	0 (0)	2 (0.7)	5 (1.8)	1 (0.4)	2 (0.7)	10 (3.6)
Normal	15 (5.3)	34 (12.1)	33 (11.7)	30 (10.7)	22 (7.8)	14 (5.0)	148 (52.7)
Overweight	7 (2.5)	15 (5.3)	22 (7.8)	16 (5.7)	6 (2.1)	6 (2.1)	72 (25.6)
Obese	2 (0.7)	10 (3.6)	13 (4.6)	14 (5.0)	5 (1.8)	7 (2.5)	51 (18.1)

The data was analyzed to assess if it was normally distributed. A Shapiro-Wilk test was run on all variables: BMI, BMI percentile, Age (Chronologic) and ΔAge (the difference between dental and chronologic age). All variable were not normally distributed: BMI ($P<0.001$), BMI percentile ($P<0.001$), age ($P<0.001$), and ΔAge ($P=0.011$)

We calculated the average ΔAge for each BMI group and found that the normal BMI group showed relatively accurate age estimation (mean= -0.009 years, SD=1.110). The underweight group (mean= 0.056 years, SD=1.182) also showed relative accuracy in age estimation; however the sample size for the underweight group was small (n=10). The overweight group (mean= 0.471 years, SD=1.247) and the obese group (mean= 0.489 years, SD=1.019) showed a general overestimation of approximately 6 months. The total for all groups (mean= 0. 208 years, SD=1.137) showed an average overestimation of approximately 2.5 months.

TABLE V

ΔAGE by BMI GROUP

TABLE V shows the average ΔAge and SD of each BMI group and the total for all groups.

ΔAge by BMI group

	Underweight	Normal	Overweight	Obese	Total
Mean ΔAge (years)	0.056	-0.009	0.471	0.489	0.208
SD	1.182	1.110	1.247	1.019	1.137

Since the data was not normally distributed, non-parametric tests were run to compare variables that would affect the accuracy of the Demirjian method to calculate age by using the measurement, ΔAge. The first test was a Spearman rank correlation between BMI percentile and ΔAge. There was a statistically significant positive relationship between increasing BMI percentile and increasing ΔAge (P<0.001) but weak correlation (Rho=0.231; in Figure 1).

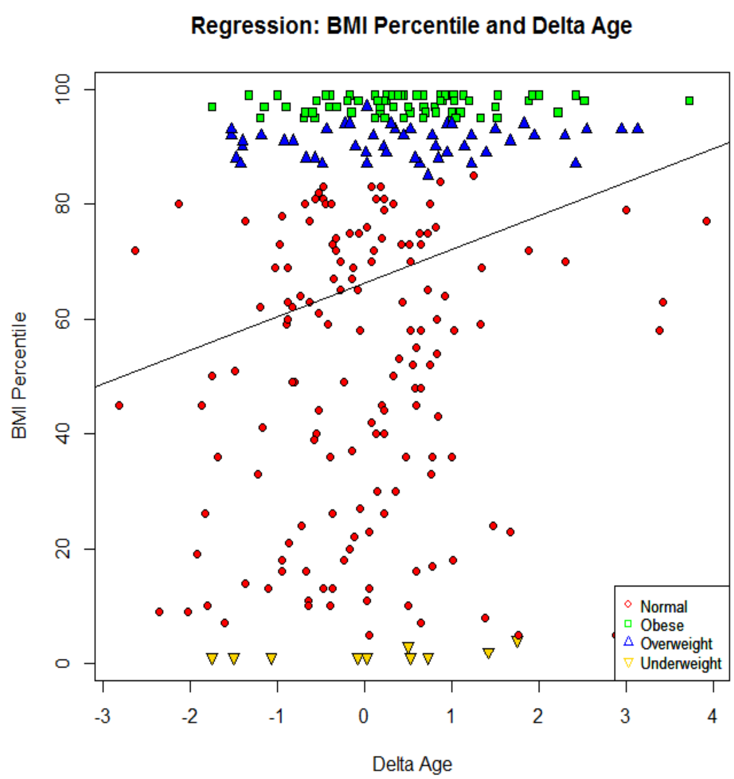


Figure 1. Scatterplot depicting the relationship between BMI percentile and ΔAge. The best-fit line demonstrates the significant (p=0.001) but weak positive relationship between the two variables, whereby as BMI percentile increases, ΔAge also increases. (Yellow triangles = Underweight; red circles = normal weight; blue triangles = overweight; green squares = obese)

A Kruskal-Wallis rank sum test was used to compare ΔAge against BMI category groups (underweight, normal, overweight, and obese). We found a statistically significant relationship (P=0.001) when including all four groupings, but elected to exclude the Underweight sample from further analyses due to the fact that it was much smaller in size than the other three subgroups. There was a statistically significant (P<0.001) difference between the three remaining groups; the heavier BMI groups, overweight and obese, had a higher ΔAge than the normal group. To confirm if there were other relationships, a Dunn's test was run to compare each pair of groups. Statistically significant differences were found between the obese and normal groups (P=0.002) and the overweight and normal group (P=0.024). All other pairs were found to not have a statistically significant difference.

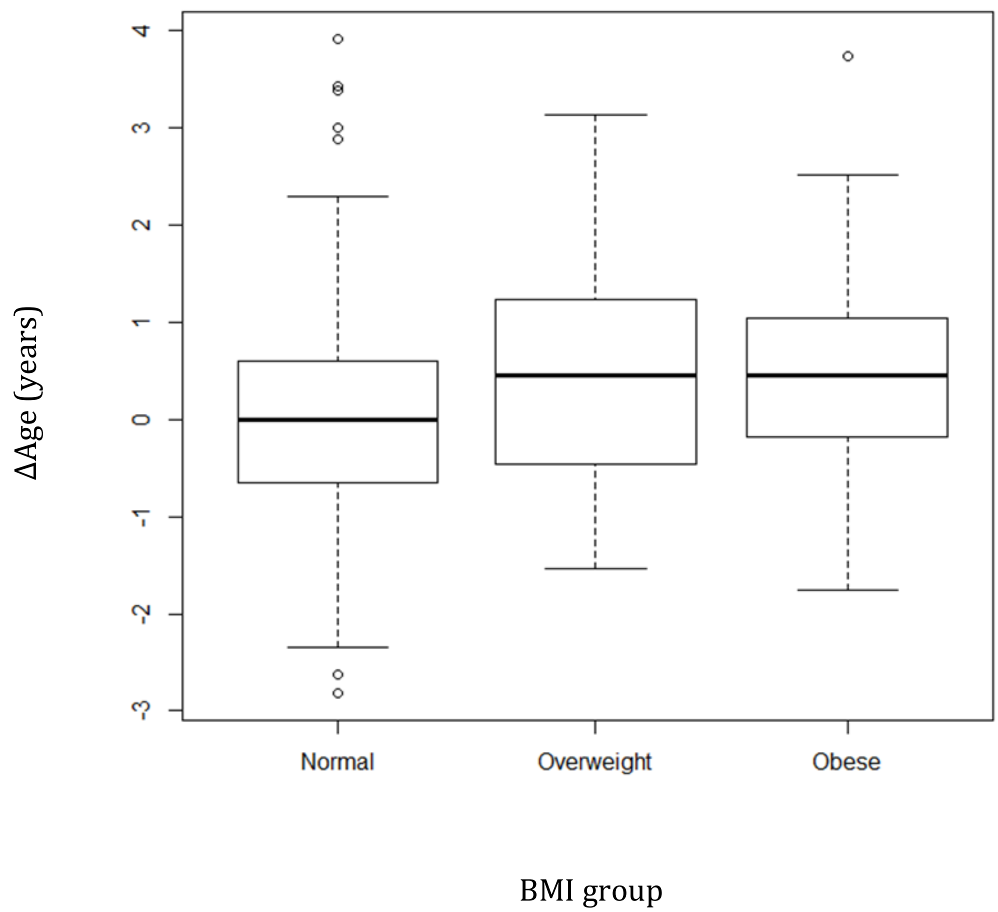


Figure 2. Boxplot depicting the Kruskal-Wallis test excluding the underweight category group since there were so few underweight subjects. The test shows the relationship between the higher BMI groups compared to the normal BMI group representing an overestimation of age in those higher BMI groups ($P<0.001$)

When further assessing for the relationship between ΔAge and BMI by separating the groups into male and female, it was found that females ($P<0.001$, Rho=0.271) showed a slightly stronger correlation than males ($P=0.021$, Rho=0.192). To ensure that sex was not a confounding factor when comparing ΔAge to BMI, a partial correlation analysis controlling for sex found that there was still a statistically significant relationship even when controlling for sex-relating differences (Cor=0.211, $P<0.001$).

Lastly, a Kruskal-Wallis rank sum test comparing ancestry to ΔAge found no statistically significant relationship($P=0.15$).

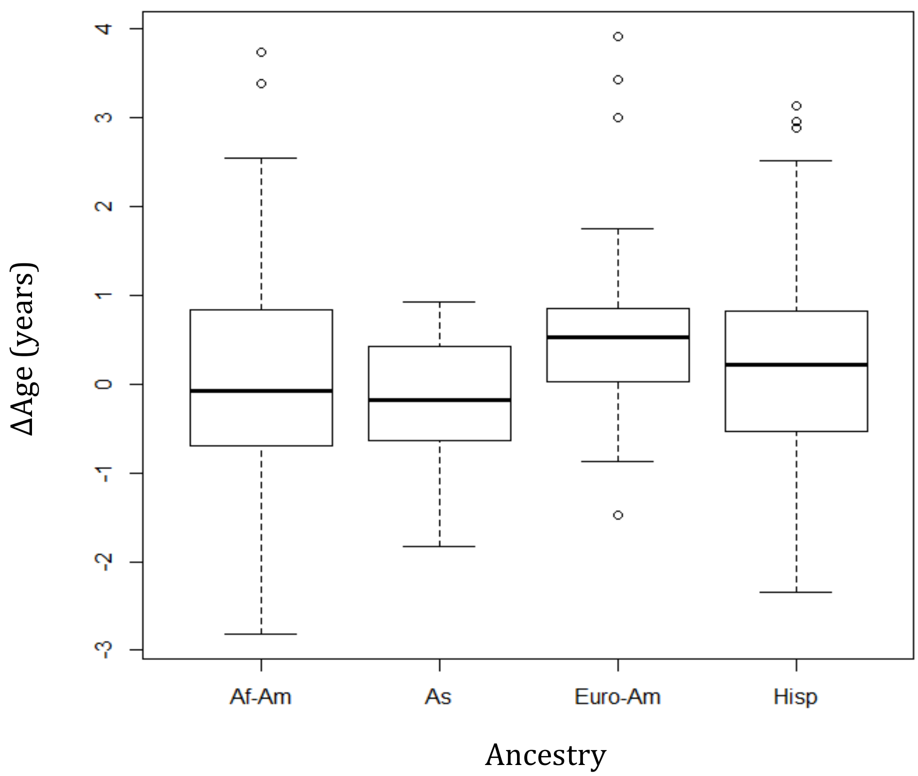


Figure 3.Boxplot depicting the Kruskal-Wallis test depicting the relationship between ancestry and ΔAge. The test shows there was no relationship between the ancestral groups and age estimation accuracy (P=0.15)

IV. Discussion

IV.1 Demirjian Method

The Demirijian method has been one of the most widely used techniques for estimating age using dental panoramic radiographs of unknown subjects. However, the validity and accuracy of estimating age using this method has been questioned in other studies. Using a population of pediatric patients from the College of Dentistry at the University of Illinois at Chicago (UIC), we hoped to expand on the accuracy and ease of using the Demirjian method to estimate age and the effects that BMI has on the resulting age estimate.

The Demirjian method was used to estimate sample ages by one examiner. It was found to overestimate age, on average, by 2.5 months. It was very accurate with children of normal BMI, underestimating by less than a week. It overestimated the age in the overweight group, 5.7 months, and in the obese group, 5.9 months.

Even though the Demirijian method was accurate at estimating the age of the normal BMI group, on average, the standard deviation of all the groups was plus or minus a little over one year. This may be attributable to a combination of biological variability and technical factors related to using the Demirjian method. While the Demirjian method is clearly defined with both a picture and description, there are only eight stages to describe tooth development. Between stages may be extended periods of growth and development that would widen the possible age range of the patient. Specifically, it was found that many teeth were coded as stage E, F, or G (See Appendix A) even though the teeth within each one of those stages may be at a relatively different stage of development. Due to the wide differences between certain stages and to follow the proper procedure, the primary examiner always “rounded down” to the last complete stage. However, it may have been more accurate to select the stage closest to the current tooth development. The Demirjian method also places a significant amount of emphasis on the development of the anterior teeth. This resulted in age estimation issues since the examiner noted that the anterior region of the panoramic radiographs was often the most difficult to analyze due to the superimposition of the spine.

Many previous studies have also questioned the accuracy of Demirjian method in estimating age. Sehrawat and Singh 2017 employed a systematic review and meta-analysis of fifteen studies to find that Demirjian overestimates age by approximately 6 months. Other studies also found the Demirjian method to overestimate age.[7,9,10,12,14,22] On the other hand, other studies found the Demirjian method to underestimate age.[1,6] Liversidge et al. 2006 found the Demirjian method to be good at estimating age. Maher et al. 2006, found the Demirjian method to overestimate the age by about 3 months, similar to the results found in the UIC pediatric population. We also found that it was most likely to overestimate age by about 2.5 months. Having a forensic age estimation tool that can approximate the age of an unknown child within 3 months is extremely useful. In general, the Demirjian method was an accurate predictor of chronological age for our sample. We therefore argue that it is a useful tool for estimating age for our Chicago population. However, while we found that the Demirjian method is relatively accurate on average, the estimate could overestimate or underestimate by as much as 2 years for an individual, which should be accounted for in forensic age estimations.

IV.2 <u>Sex and its effect on age estimation</u>

Our sample was split roughly even between sexes: male (51%) and female (49%). We found no differences in age estimation between sexes although there was a slightly stronger correlation for females between ΔAge and BMI (Rho=.271). These findings suggest that the Demirjian method accurately corrects for the growth disparities between sexes and can precisely estimate the age if the sex is known.

This is also important to note because there are times when identifying human remains that the sex is unknown. Sex is virtually un-identifiable in pre-pubertal remains and therefore can complicate the Demirjian method's ability to estimate age. Without knowing the sex, the

Demirjian method could return a very large age range that would not be as useful.

IV.3 <u>Ancestry and its effect on age estimation</u>

Our population of pediatric patients is made up of 17% African American, 5% Asian, 10% Euro-American, and 68% Hispanic. It is important to note, however, that the ancestry of the patients of the clinic were either self-reported or identified by the staff member registering them. Therefore, the accuracy of the ancestry data is questionable, even though it most likely is representative of this population.

Although the ancestry data cannot be verified, the Demirjian method found no statistically significant difference in age estimation between ancestral groups (P=0.15). This finding supports previous works, Cameriere et al. 2008, Liversidge 2009, and Liversidge 2011, that found that there was no association between ancestry and altered timing of dental eruption. However, many other previous works suspect ancestry to play a role in age estimation.[5,6,8,9,13,14] We argue that previous literature does not account for environmental factors that may override ancestry, such as groups tend to live in close proximity to each other and share similar diets. Liversidge et al. 2011 found similar results since British and Bangladeshi-British children showed similar development even though their ancestries differed.

IV.4 BMI and its effect on age estimation

The percent of overweight (25.6%) and obese (18.1%) children in our sample was 43.7%. According to Healthy Chicago 2.0 and the Consortium to Lower Obesity in Children, the overweight rate in Chicago between 2011-2015 for 6th graders (11-12 years) was 19.4% and the obesity rate was 29.2%. The overweight rate for kindergarteners (5-6 years) was 16.5% and the obesity rate was 20%. Therefore, the UIC population falls within the expected rates for Chicago and can therefore be considered representative of Chicago in terms of obesity.

Many other studies have had similar findings as was found using the Demirjian method. Hilgers et al. 2006 and Wendell and Hartsfield 2011 concluded that higher BMI leads to accelerated dental development and a resulting overestimation using age estimation methods. Mack et al. 2013 and Costacurta et al. 2012 also concluded that higher BMI leads to accelerated dental and skeletal development using alternate measures of development. On the other side, Eid et al. 2002 and Bagherian and Sadeghi 2011, conclude that BMI plays no effect on the accuracy of age estimation.

Higher BMI, which may be representative of environmental and local factors like nutrition and diet, had a statistically significant effect on the age estimation of the UIC population. Overweight and obese children exhibited accelerated development compared to their normal BMI counterparts. This finding is statistically significant ($P<0.001$). While it may not be understood what the underlying cause is for the acceleration, it is clear that obesity has some association with dental development. It is therefore important for the dentist to consider that while formulating treatment plans for this subset of patients. Additionally, the forensic odontology community needs to take into account this acceleration when identifying unknown remains. Knowing that there is a large percentage of the pediatric population that is in the overweight and obese BMI category and that they will be relatively accelerated dentally, the forensic odontologist may need to account for this when reporting an estimated age range for the un-identified remains. If possible, the forensic community can utilize this information with known missing children to narrow the search by broadly identifying BMI category and accounting for that in the age estimation.

IV.5 <u>Impact on dentistry and forensics</u>

It is clear that there is disagreement in the forensic and dental community on the factors affecting age estimation, including when using the Demirjian method. Ancestry, increased BMI, and other genetic and environmental factors may play a role in altering the timing of dental eruption and also tooth development. However, while dental age estimation of unknown remains may never be precise, our findings and a number of other studies have shown discrepancies when using the Demirjian method to estimate age in different populations of children. It therefore may be in the best interest of communities, whether they are on a small or large, to "calibrate" the Demirjian method to combat the effects of local environment to be most effective for their population. If unknown remains were found in Chicago, it may be beneficial to utilize this specific study in addition to integrating results from other pediatric populations. Thus, continuous assessment of age estimation methods should be performed throughout national communities to maintain accurate age estimation methods.

IV.6 Limitation of the Study

- Ancestral data was not consistently recorded and may not always be accurate
- Height and weight measurements were taken by multiple providers and not calibrated
- Panoramic radiographs were analyzed by only one investigator

IV.7 <u>Future Studies</u>

There is a lot of potential for many future studies related to these topics. In order to elicit the true relationship between ancestry, BMI, and tooth development, there needs to be a similar study with data on the diets of the children. This may be a better proxy for environment. Additionally, repeating this study in other cities or areas in the world will allow for comparison between Demirjian accuracy and may even show the effects that local factors have on a given population.

V. Conclusion

We can conclude that increased BMI, in the overweight and obese ranges, has an association with advanced timing of dental development Therefore, since obesity in the pediatric population is high and has been trending upward, it is important for the dental and forensic field to account for this effect.

The Demirjian method, on average, is a good age estimation method for unknown panoramic radiographs. However, due to the broad categories of tooth development, issues reading panoramic radiographs, and wide range of age estimates, the Demirjian method should not be used as the only method of age estimation.

There were no sex differences in age estimation, and there were no differences in the age estimation of the recorded ancestries within our population.

Appendix A

UIC

Approval Notice
Initial Review (Response To Modifications)

May 8, 2018

Matthew Strumpf
Pediatric Dentistry
Phone: (708) 917-9997

RE: **Protocol # 2018-0283**
"Forensic Age Estimation in a Pediatric Population: A Comparison of Environmental and Ancestral Factors"

Dear Dr. Strumpf:

Your Initial Review (Response To Modifications) was reviewed and approved by the Expedited review process on May 8, 2018. You may now begin your research

Please note the following information about your approved research protocol:

Protocol Approval Period: May 8, 2018 - May 7, 2021
Approved Subject Enrollment #: 2000
Additional Determinations for Research Involving Minors: The Board determined that this research satisfies 45CFR46.404, research not involving greater than minimal risk. Wards of the State may not be enrolled unless the IRB grants specific approval and assures inclusion of additional protections in the research required under 45CFR46.409. If you wish to enroll Wards of the State contact OPRS.
Performance Sites: UIC
Sponsor: None
PAF#: Not Applicable
Grant/Contract No: Not Applicable
Grant/Contract Title: Not Applicable
Research Protocol(s):

a) Forensic Age Estimation in a Chicago Pediatric Population: A Comparison between Environmental and Ancestral Factors, Version 1, 01/09/2018

Informed Consent(s):

a) Waiver of informed consent granted [45 CFR 46.116(d)] for retrospective review of data and radiographs previously collected for dental care purposes.

Assent(s):

a) Waiver of Child Assent granted [45 CFR 46.116(d)] for minors under the age of 18 for retrospective review of data and radiographs previously collected for dental care purposes.

Parental Permission(s):

a) Waiver of parental permission granted [45 CFR 46.116(d)] for retrospective review of data and radiographs previously collected for dental care purposes.

HIPAA Authorization(s):

a) Waiver of Authorization granted [45 CFR 164.512(i)(1)(i)] for retrospective review of data and radiographs previously collected for dental care purposes.

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific category(ies): **(5)** Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

Please note the Review History of this submission:

Receipt Date	Submission Type	Review Process	Review Date	Review Action
03/06/2018	Initial Review	Expedited	03/19/2018	Modifications Required
04/23/2018	Response To Modifications	Expedited	05/08/2018	Approved

Please remember to:

→ Use your **research protocol number** (2018-0283) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the guidance:

"UIC Investigator Responsibilities, Protection of Human Research Subjects"

(http://research.uic.edu/irb/investigators-research-staff/investigator-responsibilities)

Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 413-4060. Please send any correspondence about this protocol to OPRS via OPRS Live.

Sincerely,

Erik Schuster, MA
IRB Coordinator, IRB # 1
Office for the Protection of Research Subjects

cc: Marcio Da. Fonseca, Pediatric Dentistry, M/C 850
Christina Nicholas, M/C 841

UNIVERSITY OF ILLINOIS AT CHICAGO
Office for the Protection of Research Subjects
201 AOB (MC 672)
1737 West Polk Street
Chicago, Illinois 60612
Phone (312) 996-1711

Appendix B

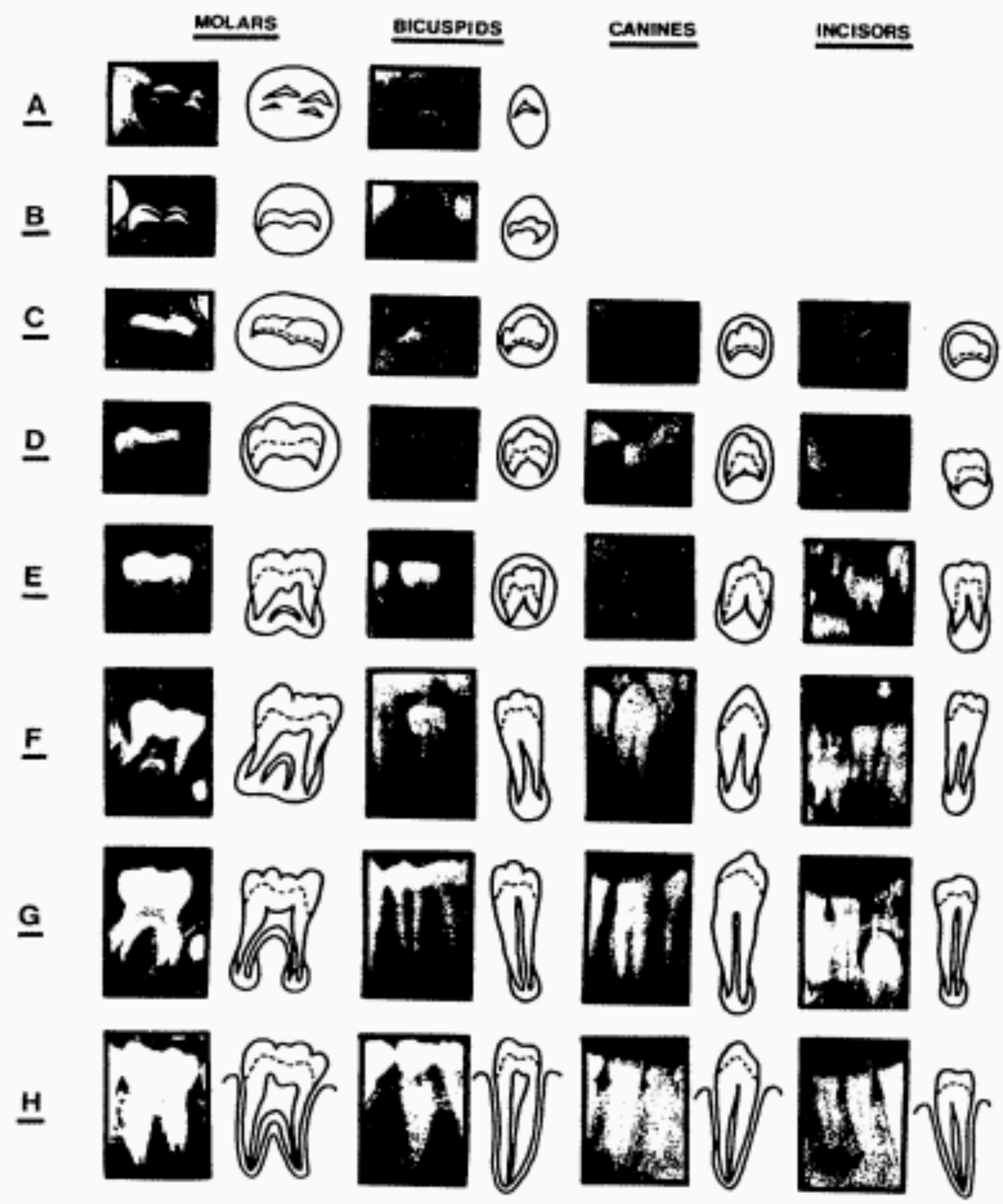


FIG. 1. Developmental stages of the permanent dentition.

Radiographic and pictographic representation of tooth stages as defined by Demirjian et al. (1973)

Appendix C

STAGE *DESCRIPTION*

A In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points.

B Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.

C
- a. Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen.
- b. The beginning of a dentinal deposit is seen.
- c. The outline of the pulp chamber has a curved shape at the occlusal border.

D
- a. The crown formation is completed down to the cemento-enamel junction.
- b. The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns if present, gives an outline shaped like an umbrella top. In molars the pulp chamber has a trapezoidal form.
- c. Beginning of root formation is seen in the form of a spicule.

E

Uniradicular teeth:
- a. The walls of the pulp chamber now form straight lines, whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage.
- b. The root length is less than the crown height.

Molars:
- a. Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semi-lunar shape.
- b. The root length is still less than the crown height.

F

Uniradicular teeth:
- a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.
- b. The root length is equal to or greater than the crown height.

Molars:
- a. The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings.
- b. The root length is equal to or greater than the crown height.

G
- a. The walls of the root canal are now parallel and its apical end is still partially open (Distal root in molars).

H
- a. The apical end of the root canal is completely closed. (Distal root in molars).
- b. The periodontal membrane has a uniform width around the root and the apex.

Written descriptions of tooth stages as defined by Demirjian et al. (1973)

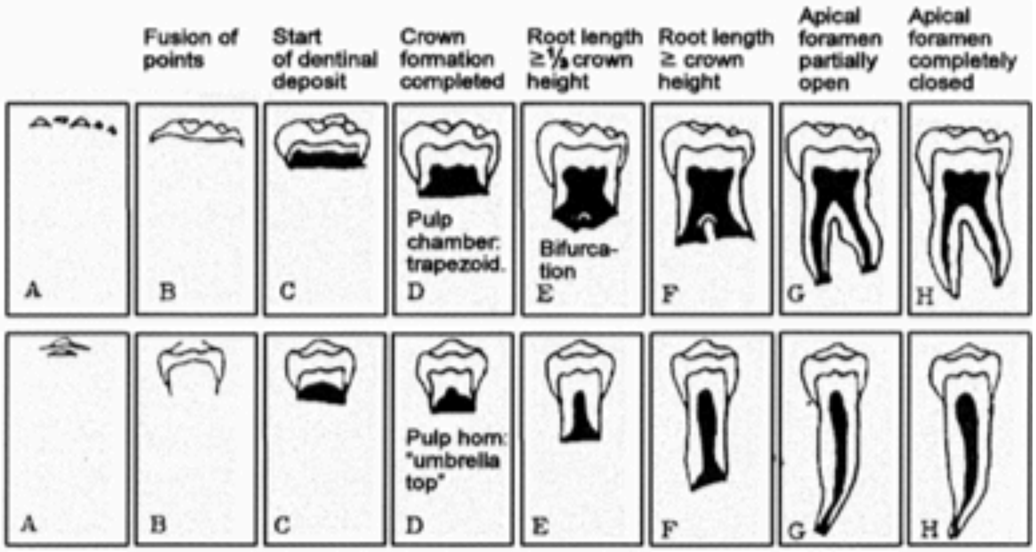
Appendix D

PATIENT NAME

BIRTH DATE

X - RAY DATE

CHRONOLOG. AGE in years



	M_2	M_1	P_2	P_1	C	I_2	I_1	
MAND. TOOTH STAGE								Score sum
SCORE	+	+	+	+	+	+	=	.

Boys	0	A	B	C	D	E	F	G	H
M_2	0.0	1.7	3.1	5.4	8.6	11.4	12.4	12.8	13.6
M_1				0.0	5.3	7.5	10.3	13.9	16.8
PM_2	0.0	1.5	2.7	5.2	8.0	10.8	12.0	12.5	13.2
PM_1		0.0	4.0	6.3	9.4	13.2	14.9	15.5	16.1
C				0.0	4.0	7.8	10.1	11.4	12.0
I_2				0.0	2.8	5.4	7.7	10.5	13.2
I_1				0.0	4.3	6.3	8.2	11.2	15.1
Girls									
M_2	0.0	1.8	3.1	5.4	9.0	11.7	12.8	13.2	13.8
M_1				0.0	3.5	5.6	8.4	12.5	15.4
PM_2	0.0	1.7	2.9	5.4	8.6	11.1	12.3	12.8	13.3
PM_1		0.0	3.1	5.2	8.8	12.6	14.3	14.9	15.5
C				0.0	3.7	7.3	10.0	11.8	12.5
I_2				0.0	2.8	5.3	8.1	11.2	13.8
I_1				0.0	4.4	6.3	8.5	12.0	15.8

$$DA_{(♂)} = \frac{\ln[S : (100 - S)] - 3.056}{0.498} \quad \text{bzw.} \quad DA_{(♀)} = \frac{\ln[S : (100 - S)] - 3.318}{0.552}$$

NOTES

DENTAL AGE in years

Demirjian worksheet created by Frucht et al. (2000)

References

1. Khorate, M. M., Dinkar, A. D., & Ahmed, J. (2014). Accuracy of age estimation methods from orthopantomograph in forensic odontology: A comparative study. *Forensic Science International, 234*, 184.e8. doi:10.1016/j.forsciint.2013.09.020

2. Manigandan, T., Sumathy, C., Elumalai, M., Sathasivasubramanian, S., & Kannan, A. (2015). Forensic radiology in dentistry. *Journal of Pharmacy & Bioallied Sciences, 7*(Suppl 1), S264. doi:10.4103/0975-7406.155944

3. Priya, E. (2017). Methods of skeletal age estimation used by forensic anthropologists in adults: A review. *Foresic Research & Criminology International Journal, 4*(2) doi:10.15406/frcij.2017.04.00104

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

5. Warren, J. J., Fontana, M., Blanchette, D. R., Dawson, D. V., Drake, D. R., Levy, S. M., . . . Phipps, K. R. (2016). Timing of primary tooth emergence among U.S. racial and ethnic groups.*Journal of Public Health Dentistry, 76*(4), 259-262. doi:10.1111/jphd.12154

6. Moananui, R. T., Kieser, J. A., Herbison, P., & Liversidge, H. M. (2008). Advanced dental maturation in new zealand maori and pacific island

children. *American Journal of Human Biology : The Official Journal of the Human Biology Council, 20*(1), 43-50. doi:10.1002/ajhb.20670

7. MANI, S. A., NAING, L., JOHN, J., & SAMSUDIN, A. R. (2008). Comparison of two methods of dental age estimation in 7–15-year-old malays. *International Journal of Paediatric Dentistry, 18*(5), 380-388. doi:10.1111/j.1365-263X.2007.00890.x

8. Jayaraman, J., Wong, H. M., King, N. M., & Roberts, G. J. (2013). The french-canadian data set of demirjian for dental age estimation: A systematic review and meta-analysis. *Journal of Forensic and Legal Medicine, 20*(5), 373-381. doi:10.1016/j.jflm.2013.03.015

9. Sarkar, S., Kailasam, S., & Mahesh Kumar, P. (2013). Accuracy of estimation of dental age in comparison with chronological age in indian population--a comparative analysis of two formulas. *Journal of Forensic and Legal Medicine, 20*(4), 230-233. doi:10.1016/j.jflm.2012.09.007

10. Eid, R. M. R., Simi, R., Friggi, M. N. P., & Fisberg, M. (2002). Assessment of dental maturity of brazilian children aged 6 to 14 years using demirjian's method. *International Journal of Paediatric Dentistry, 12*(6), 423-428. doi:10.1046/j.1365-263X.2002.00403.x

11. Liversidge, H. M., Speechly, T., & Hector, M. P. (1999). Dental maturation in british children: Are demirjian's standards

applicable? *International Journal of Paediatric Dentistry, 9*(4), 263-269.

12. Weddell, L., & Hartsfield, J. (2011). Dental maturity of caucasian children in the indianapolis area. *Pediatric Dentistry, 33*(3)

13. Bagherian, A., & Sadeghi, M. (2011). Assessment of dental maturity of children aged 3.5 to 13.5 years using the demirjian method in an iranian population. *Journal of Oral Science, 53*(1), 37-42. doi:JST.JSTAGE/josnusd/53.37

14. Liversidge, H. M. (2010). Interpreting group differences using demirjian's dental maturity method. *Forensic Science International, 201*(1-3), 95-101. doi:10.1016/j.forsciint.2010.02.032

15. Mack, K. B., Phillips, C., Jain, N., & Koroluk, L. D. (2013). Relationship between body mass index percentile and skeletal maturation and dental development in orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopedics : Official Publication of the American Association of Orthodontists, its Constituent Societies, and the American Board of Orthodontics, 143*(2), 228-234. doi:10.1016/j.ajodo.2012.09.015

16. Costacurta, M., Sicuro, L., Di Renzo, L., Condo, R., De Lorenzo, A., & Docimo, R. (2012). Childhood obesity and skeletal-dental

maturity. *European Journal of Paediatric Dentistry : Official Journal of European Academy of Paediatric Dentistry, 13*(2), 128-132.

17. Liversidge, H. M., Smith, B. H., & Maber, M. (2010). Bias and accuracy of age estimation using developing teeth in 946 children. *American Journal of Physical Anthropology, 143*(4), 545-554. doi:10.1002/ajpa.21349

18. 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. DOI: 10.1093/ajcn/49.3.417

19. Leonibus, C., Marcovecchio, M., & Chiarelli, F. (2012). Update on statural growth and pubertal development in obese children. *Pediatric Reports, 4*(35) doi:10.4081/pr.2012.e135

20. Prevalence of Childhood Overweight and Obesity. (2019). *CLOCC*. www.clocc.net/about-childhood-obesity/prevalence/.

21. Demirjian, A. Goldstein, H. & Tanner, J. (1973). A New System of Dental Age Assessment. *Human Biology*. 45(2). 211-227.

22. Cameriere, R., Ferrante, L., Liversidge, H. M., Prieto, J. L., & Brkic, H. (2008). Accuracy of age estimation in children using radiograph of developing teeth. *Forensic Science International, 176*(2-3), 173-177. doi:S0379-0738(07)00715-3

23. Sehrawat, J. S., & Singh, M. (2017). Willems method of dental age estimation in children: A systematic review and meta-analysis. *Journal of Forensic and Legal Medicine, 52*, 122-129. doi:S1752-928X(17)30131-2

24. Nicholas, C., Thalji G., Richter, A. (2018). Childhood obesity and accelerated timing of dental development: A Critical Review. *Forensic Anthropology* 1(3), 170-179. Doi:10.5744/fa.2018.0018

25. Lewis, J. M., & Senn, D. R. (2015). Forensic dental age estimation: An overview. *43*(6), 315-319.

26. Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the united states, 2011-2012. *Jama, 311*(8), 806-814. doi:10.1001/jama.2014.732

27. Barlow, S. E. (2007). Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: Summary report.*Pediatrics, 120*(6), S164.

28. Liversidge, H. M., & Molleson, T. I. (1999). Developing permanent tooth length as an estimate of age. *Journal of Forensic Sciences, 44*(5), 917-920.

29. Kanagaratnam, S., & Schluter, P. J. (2012). The age of permanent tooth emergence in children of different ethnic origin in the auckland region: A cross-sectional study. *The New Zealand Dental*

Journal, 108(2), 55. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22788050

30. Elamin, F., & Liversidge, H. M. (2013). Malnutrition has no effect on the timing of human tooth formation. *PloS One, 8*(8), e72274. doi:10.1371/journal.pone.0072274 [doi]Maber, M., Liversidge, H. M., & Hector, M. P. (2006). Accuracy of age estimation of radiographic methods using developing teeth. *Forensic Science International, 159 Suppl 1*, 68. doi:S0379-0738(06)00076-4

31. Liversidge, H. M., Chaillet, N., Mornstad, H., Nystrom, M., Rowlings, K., Taylor, J., & Willems, G. (2006). Timing of demirjian's tooth formation stages. *Annals of Human Biology, 33*(4), 454-470. doi:UG0568V95NU71JN1

32. Liversidge, H. M. (2011). Similarity in dental maturation in two ethnic groups of london children. *Annals of Human Biology, 38*(6), 702-715. doi:10.3109/03014460.2011.609565

33. Liversidge, H. M. (2009). Permanent tooth formation as a method of estimating age. *Frontiers of Oral Biology, 13*, 153-157. doi:10.1159/000242409

34. 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. doi:10.1002/ajpa.21258

35. AlQahtani, S. J., Hector, M. P., & Liversidge, H. M. (2014). Accuracy of dental age estimation charts: Schour and massler, ubelaker and the london atlas. *American Journal of Physical Anthropology, 154*(1), 70-78. doi:10.1002/ajpa.22473

36. Alsaffar, H., Elshehawi, W., Roberts, G., Lucas, V., McDonald, F., & Camilleri, S. (2017). Dental age estimation of children and adolescents: Validation of the maltese reference data set*Journal of Forensic and Legal Medicine, 45*, 29-31. doi:S1752-928X(16)30158-5

37. Dean, M. C., & Liversidge, H. M. (2015). Age estimation in fossil hominins: Comparing dental development in early homo with modern humans. *Annals of Human Biology, 42*(4), 415-429. doi:10.3109/03014460.2015.1046488

38. Dean, M. C., Liversidge, H. M., & Elamin, F. (2014). Combining radiographic and histological data for dental development to compare growth in the past and the present. *Annals of Human Biology, 41*(4), 336-347. doi:10.3109/03014460.2014.922614

39. Kihara, E. N., Gichangi, P., Liversidge, H. M., Butt, F., & Gikenye, G. (2017). Dental age estimation in a group of kenyan children using

willems' method: A radiographic study. *Annals of Human Biology, 44*(7), 614-621. doi:10.1080/03014460.2017.1371794

40. Liversidge, H. M. (2012). The assessment and interpretation of demirjian, goldstein and tanner's dental maturity. *Annals of Human Biology, 39*(5), 412-431. doi:10.3109/03014460.2012.716080

41. Liversidge, H. M. (2015). Controversies in age estimation from developing teeth. *Annals of Human Biology, 42*(4), 397-406. doi:10.3109/03014460.2015.1044468

42. Liversidge, H. M., Buckberry, J., & Marquez-Grant, N. (2015). Age estimation. *Annals of Human Biology, 42*(4), 299-301. doi:10.3109/03014460.2015.1089627

43. Liversidge, H. M., Lyons, F., & Hector, M. P. (2003). The accuracy of three methods of age estimation using radiographic measurements of developing teeth. *Forensic Science International, 131*(1), 22-29. doi:S0379073802003730

44. Smith, D. W. (1977). Growth and its disorders: Basics and standards, approach and classifications, growth deficiency disorders, growth excess disorders, obesity. *Major Problems in Clinical Pediatrics, 15*, 1-155.

45. Sutphen, J. L. (1985). Growth as a measure of nutritional status. *Journal of Pediatric Gastroenterology and Nutrition, 4*(2), 169-181.

46. Frucht S., Schnegelsberg C., Schulte-Mönting J., Rose E., Jonas I. (2000). Dental age in southwest Germany. A radiographic study. *Journal of Orofacial Orthopedics*, 61(6), 318-329.

VITA

NAME: Matthew Strumpf

EDUCATION: B.A., Earth and Planetary Science, Northwestern University, Evanston, IL, 2012

D.M.D., Midwestern University, Downers Grove, IL, 2017

Certificate in Pediatric Dentistry, University of Illinois at Chicago, College of Dentistry, Chicago, IL, 2019

M.S., Oral Science, University of Illinois at Chicago, College of Dentistry, Chicago, IL, 2019

HONORS: Omicron Kappa Upsilon (OKU) Dental Honor Society, Midwestern University, Downers Grove, IL 2017

ISDS Clinical Science Winner at KAS Research Day, Midwestern University, Downers Grove, IL 2017

Best Student Researcher, Midwestern University, Downers Grove, IL 2017

PROFESSIONAL MEMBERSHIP:
American Academy of Pediatric Dentistry
American Dental Association
Illinois Society of Pediatric Dentistry
Chicago Dental Society
American Student Dental Association
Illinois Academy of General Dentistry

ABSTRACT: Strumpf M., da Fonseca M., AlQahtani S., Marion I., Nicholas, C. Forensic Age Estimation: A Literature Review Comparing Environmental and Ancestral Factors. University of Illinois at Chicago, College of Dentistry, Clinic and Research Day 2018.

Strumpf M., da Fonseca M., AlQahtani S., Marion I., Nicholas, C. Forensic Age Estimation in a Chicago Pediatric Population. University of Illinois at Chicago, College of Dentistry, Clinic and Research Day 2019.

Strumpf M., da Fonseca M., AlQahtani S., Marion I., Nicholas, C. Forensic Age Estimation in a Chicago Pediatric Population.

University of Illinois at Chicago, College of Dentistry, Clinic and Research Day 2019. American Academy of Pediatric Dentistry 2019 Annual Conference.

PRESENTATIONS:

Poster Presentation, Midwestern University, Kenneth A. Suarez Research Day, 2016
Title: Expression and Regulation of Zinc Transporter mRNA in a Human Adrenocortical Carcinoma Cell Line
Co-authors: H. Sharthiya, N. Surachaicharn, M. Harig, P.G. Kopf, K.E. Dineley, L.M. Malaiyandi

Poster Presentation, University of Illinois at Chicago, College of Dentistry, Clinic and Research Day, March 8, 2018
Title: Forensic Age Estimation: A Literature Review Comparing Environmental and Ancestral Factors
Co-authors: Marcio da Fonseca, Sakher AlQahtani, Ian Marion, Christina Nicholas

Poster Presentation, University of Illinois at Chicago, College of Dentistry, Clinic and Research Day, February 19, 2019.
Title: Forensic Age Estimation in a Chicago Pediatric Population
Co-authors: Marcio da Fonseca, Sakher AlQahtani, Ian Marion, Christina Nicholas

Poster Presentation, American Academy of Pediatric Dentistry (AAPD) 72nd Annual Session in Chicago, IL, May 24, 2019
Title: Forensic Age Estimation in a Chicago Pediatric Population
Co-authors: Marcio da Fonseca, Sakher AlQahtani, Ian Marion, Christina Nicholas

PUBLICATIONS:

Strumpf, M. (2016). Peer Education: Reviews of the Literature (PERLs). *Journal of Dental Education,* 80(4), 489-90.

da Fonseca, M., Strumpf, M. (2018) Dental local anesthesia for patients with pseudocholinesterase deficiency. *Special Care in Dentistry,* 38(2), 116.