Third Molar Development in Somalis as Compared with Caucasians and a New Method of Classification of Third Molar Development

A Thesis
SUBMITTED TO THE FACULTY OF THE
GRADUATE SCHOOL OF THE
UNIVERSITY OF MINNESOTA
BY

Christine Colton Hammer

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

Mansur Ahmad, BDS, PhD

June 2015

Acknowledgements

Thank you to all of the faculty members and staff at the University of Minnesota Division of Orthodontics for your time, knowledge, support and guidance during my time in the residency program.

Thank you to my co-residents for your friendship and support. You helped to make these past two years so enjoyable. Thank you especially for helping to set the high standards that we all followed during our time here, and will take with us as we practice.

Thank you to everyone who played an active role in this research project, data collection and analysis, and thesis:

Scott Lunos, MS for his knowledge and expertise in data organization and analysis.

Nanci de Felippe, DDS, MS for inspiring this research project.

My committee members: Mansur Ahmad, BDS, PhD
Brent Larson, DDS, MS
Kim Mansky, PhD

A very special thank you to Dr. Mansur Ahmad for his dedication, time, never-ending support and advice throughout this project.

Dedication

This thesis is dedicated to my family. To my husband, Kyle, for encouraging me to pursue my goals and supporting me in every endeavor. To my parents, Steve and Jean L'Abbe, for the gift of education, teaching me the value of hard work, and emphasizing the importance of integrity and faith. To my sisters and best friends, Laura and Marie, for making me laugh and being there for me. To my Aunt Michelle and Uncle Dave, for being the best roommates ever over these past two years. I love you all.

Abstract

Background: The third molar has been suggested as a reliable and useful indicator in age estimation during late adolescence to determine if an individual of unknown age has reached the age of majority. It is known that the rate of dental development is influenced by ethnic origin, and thus it is of importance to develop population specific dental development standards. Little is currently known of the rate of third molar development in Somali people.

Aims: To compare the chronological ages at which third molar developmental stages are reached in American-born Somali and Caucasian individuals aged 10 to 20 years old, and to develop a reliable method of classifying third molar developmental stages.

Materials and Methods: A total of 217 third molars were analyzed from 57 panoramic images of 24 individuals. The developmental stages of all molars were determined by two examiners using both the Demirjian *et al.* (1973) methods and the method proposed in this study.

Results: Trends in the data suggest that Somali individuals reach each of the stages of third molar development at younger chronological ages than Caucasian individuals. Numbers of molars within each stage of development were not large enough to test for a significant difference between the two ethnicities. The new classification of third molar development was more reliable than the Demirjian *et al*. method when used to analyze this study's data.

Conclusions: Staging by both classification systems suggests that Somali third molars may develop at a younger age than Caucasian third molars. The classification system introduced here is more reliable than the widely-used Demirjian method.

Table of Contents

List of Tables

List of Figures

Introduction

Age estimation in children and young adults of unknown chronological age is often required in adoptions, immigration cases, and other legal scenarios. Assessments of various biological markers can be used in combination with one another to provide the most accurate estimation of chronological age possible. Dental development is one such marker that can be used to estimate chronological age in an individual of unknown birth date. It has been demonstrated that dental development correlates closely with chronological age (Demirjian, 1973). It is preferable to determine dental age by stages of tooth development rather than by eruption of the permanent tooth into the oral cavity. Eruption can be influenced by many factors such as ankylosis, early or delayed loss of the deciduous tooth, impaction, and crowding. It does not appear that formation of the permanent tooth is affected by such factors (Demirjian, 1973). Demirjian's eight stage classification of dental development has been widely used to estimate a developing person's chronological age (Blenkin, 2010; Maia, 2010; Moananui, 2008; Kasper, 2009; Prieto, 2005; Blankenship, 2007).

Many studies have demonstrated that dental development is influenced by factors such as gender and ethnicity, and that the rate of dental maturation in a given population can vary significantly from that established by Demirjian's study of French-Canadian children in 1973 (Blenkin, 2010; Maia, 2010; Moananui, 2008; Kasper, 2009; Prieto, 2005; Blankenship, 2007). Thus, it is necessary to have dental maturation norms specific to an individual's ethnicity.

It is especially difficult to determine chronological age for individuals in their late teenage and early adulthood years, as many biological markers have completed development. In terms of dental maturation, once the second molar has completed development around age 15, one must rely on the development of the third molar in determining chronological age for these individuals if dental records alone are to be used to estimate age. The third molar is a variable tooth, but its development has been shown to correlate with chronological age (Engström, 1983; Lewis, 2010; Kasper, 2009; Prieto, 2005). Lewis *et al.* (2010) stated that the use of third molar development is indeed a valid marker for determining whether or not an individual has reached the age of 18, the age of legal majority in the United States. Many methods of classifying the various stages of third molar development have been utilized (Demirjian, 1973; Gleiser, 1955; Gustafson, 1974; Harris, 1984; Kullman, 1992; Olze 2005). Several of the proposed methods vary according to number of developmental stages, clarity of written descriptions, and presence of diagrammatic and/or radiographic examples of each developmental stage. It is imperative to have a reliable method of estimating age in young adults in order to determine if that individual is of the age of majority in public, legal and educational situations.

The Minneapolis-St. Paul metropolis in Minnesota has become a major resettlement area for Somali refugees entering the United States (Williams, 2011). Many of these refugees do not know their birth year due to the circumstances of their birth or the lack of cultural emphasis placed on birth date, and age estimation by experts is often required in legal proceedings (Williams, 2011; Gorman, 2010). In the only known study

to date to examine dental development in Somalis, Davidson and Rodd (2001) showed Somali children in the United Kingdom to be significantly more dentally advanced than their Caucasian peers. For age estimation in late adolescence and early adulthood, the third molar has the potential to be a valuable age marker in Somali young adults that relocate to the United States to determine if a Somali immigrant has reached the age of legal majority.

Aims

The primary aim of the present study is to compare the chronological ages at which the various third molar developmental stages are reached in Somali and Caucasian children and young adults. A secondary aim is to develop a reliable classification of dental development that can be applied to determining the developmental stage of third molars and compare that classification to the well-known method proposed by Demirjian *et al* (1973).

Hypotheses

It is hypothesized that Somali individuals reach the various stages of third molar development at an earlier chronological age than Caucasian individuals. If this is the case, application of Caucasian norms to third molar development in Somali juveniles would overestimate that individual's chronological age and could have negative implications in legal or other settings. It is additionally hypothesized that the classification of third molar developmental stages as proposed in this study will exhibit

superior inter- and intra-examiner reliabilities to that published by Demirjian *et al*. (1973) when applied to the same sample of third molar radiographic images.

Therefore, the null hypotheses that were aimed to be tested are:

1. There is no significant difference between the chronological ages of Somali and Caucasian individuals at which the various stages of third molar development are attained.
2. There is no difference between the inter- and intra-examiner reliabilities of the third molar development assessment methods proposed by the authors of this study and that of Demirjian *et al* (1973).

A Review of the Literature

Many different biological ages exist that can be helpful in estimating the chronological age of an individual. These include skeletal age, morphological age, secondary sex characteristic age and dental age. These factors can be used in combination with one another or separately to best describe the physical maturity and estimate the chronological age of a growing child.

Forensic age estimation in unaccompanied minors and young living adults is of importance in many situations. It has become increasingly important in the United States and many European countries due to a greater number of immigrants who often do not have documents to prove their chronological age, or doubts exist as to the certainty of the alleged chronological age (Schmeling, 2011). Currently, forensic age estimation involves the collaboration of many different disciplines including forensic and physical

anthropology, dentistry, radiology, pediatric medicine, psychology, and others. Forensic age estimation is not a new field. In fact, government bodies have been attempting to estimate chronological age for a variety of purposes since the days of the ancient Roman Empire. The eruption of the second molar indicated that a young male was eligible to serve in the Roman army (Schmeling, 2011). In the 1800s, dentists commonly estimated age. The British Parliament actually considered tooth eruption as the most accurate method of determining a child's chronological age, especially following the publication of Edwin Saunders' "The Teeth a Test of Age" in 1837 (Schmeling, 2011). Age estimation was important to the British government during this time so as to regulate the age at which a child could begin working in the manufacturing industry. Employers were often putting children to work at much too young of an age, and the government wanted a method in which to assess whether or not that child was indeed of an age that was suitable for manual labor (Saunders, 1838).

After the discovery of the X-ray by Röntgen in 1895, skeletal markers could be used in addition to eruption of teeth for the purposes of age estimation in living individuals. Radiographic analysis of the hand and carpus became a regularly used method of age estimation in living persons. Radiographic images also allowed for use of methods of age estimation based on tooth development, both erupted and unerupted, rather than on eruption alone (Schmeling, 2011).

In cases where estimation of age of a living child or adolescent is necessary, many factors must be taken into account to provide the most accurate assessment of estimated age. If possible, an assessment should include a physical examination, a radiographic

examination of the hand and wrist, and a dental examination that includes evaluation of a panoramic radiograph (Schmeling, 2011). A physical examination should include height and weight measurements as well as evaluation of secondary sex characteristics. Marshall and Tanner (1969 & 1970) developed a method for estimating the stage of secondary sex characteristic development that includes breast development and pubic hair growth in girls, and pubic hair growth and development of the penis, scrotum and testes in boys.

Many methods have been used over the years for estimating chronological age based on bone development in the hand and wrist. One of the earlier methods was developed by T.W. Todd in 1937. In Todd's system, an age estimation was made by comparing the ossification nuclei of the 27 bones of the hand and wrist to representative radiographs from individuals of known age in Todd's *Atlas of Skeletal Maturation* (Schmeling, 2011). Greulich and Pyle later revised Todd's atlas by analyzing hand-wrist radiographs of a larger number of subjects. Greulich and Pyle's *Radiographic Atlas of Skeletal Development of the Hand and Wrist* is based on radiographs of 6,879 North American children (Schmeling, 2011). During World War II, R. Acheson further modified the Todd system in an attempt to increase accuracy. Acheson's system required one to stage the development of each individual bone in the hand and wrist. A bone was then assigned a score based on its developmental stage. A cumulative maturity score was ultimately determined by summing the scores of each of the bones (Schmeling, 2011). In 1983, Tanner and Whitehouse revised Acheson's system so that the final maturity score could be converted to a chronological age estimation through distribution tables. The two

most commonly used methods today are the atlas reference method based on Greulich and Pyle's atlas and the numerical maturity score method based on the Tanner-Whitehouse percentile distributions (Schmeling, 2011).

Numerous studies have been conducted to examine which factors may influence bone maturation of the hand and wrist. Ethnicity and socioeconomic factors are those most frequently studied. Ethnic and racial factors seem to play an inconclusive role in bone maturation, and several studies have reported conflicting results in reference to the same ethnic population. Gross *et al.* (1995) found that hand-wrist bone maturation in African Americans more closely followed the Greulich and Pyle reference atlas than Caucasian Americans. Two additional studies concluded that African Americans have advanced bone maturation compared to the Greulich and Pyle reference (Lodler, 1993; Ontell, 1996). In contrast, Gilsanz *et al*. (1998) found no significant difference between hand-wrist bone age and chronological age in African Americans and Caucasian Americans. Socioeconomic factors, on the other hand, appear to play a significant role in the rate of hand-wrist bone maturation according to more recent studies. Children in poverty exhibit significantly delayed bone maturation during the pre-pubertal years as demonstrated by Jahari *et al.* (2000) in an Indonesian population, Fleshman *et al.* (2000) in an African population, and Melsen *et al.* (1996) in Danish children adopted from foreign countries.

Dental age is a useful assessment in the estimation of chronological age because it can easily be determined by capturing a dental radiographic image of the developing individual in question. Previous studies have demonstrated that dental development does

indeed relate more closely to chronological age than skeletal, somatic or sexual development (Demirjian, 1985; Lewis & Garn, 1960). Assessment of the development of the permanent dentition has been utilized for estimating chronological age in children since as early as the 1940s, shortly after the pattern of calcification of the dentition was found to be a reliable indicator of growth (Blenkin, 2010). One of the first widely used systems for this assessment was proposed by Demirjian *et al*. in 1973. They proposed a method for calculating dental age based on stages of tooth formation rather than eruption or gingival emergence. Stages of tooth development are less influenced by environmental factors than tooth eruption. Tooth eruption can be affected by a variety of factors such as ankylosis, early or late loss of the deciduous tooth, crowding, and impaction. In determining useful stages of tooth development, it is important that the stage represents a point in development that each tooth will predictably pass through from initiation of calcification to completion of root development. The stages must be clearly defined and distinct so as to avoid confusion. At any point in its development, the radiographic image of the tooth must match the criteria of only one of the proposed stages. Demirjian *et al.* (1973) developed a classification consisting of eight developmental stages, A through H. Panoramic radiographs of children aged 2 to 20 of French Canadian origin were assessed using this classification system. The authors employed panoramic radiographs due to clinical ease of obtaining these in younger individuals. The inherent magnification in this type of radiograph is not an issue as the developmental stages are based on shape criteria and relative values rather than absolute measurements. The authors then assigned a developmental stage to each of the seven

teeth, excluding the third molar, in the left mandibular quadrant. Because the third molar is not included in the analysis, this method is often not useful in late adolescence because all of the assessed teeth have completed development. If a tooth was congenitally missing from this quadrant, then the stage of the same tooth in the right mandibular quadrant, if present, was substituted. The authors were unable to find a suitable solution if that tooth was missing from both mandibular quadrants. A tooth's stage also had a corresponding numerical score, and the numerical scores of all teeth in the quadrant were then added together to yield a dental maturity score. Demirjian *et al*. were able to develop charts that would allow one to convert dental maturity scores into an individual's dental age that is an estimation of the chronologic age. They propose that the same eight developmental stages can be utilized for any gender or ethnicity, but that the conversion of the maturity score to dental age must be treated differently for each population (Demirjian, 1973).

Many studies have been conducted to investigate whether or not Demirjian's system, which was based off of findings in French-Canadian children, could be applied to other populations. In 2010, Blenkin *et al.* sought to test the applicability of the Demirjian system to a population based in Sydney, Australia. The authors scored 3,261 panoramic radiographs of individuals aged 1 to 23 of unknown racial background who had attended public dental clinics in a region of Sydney, Australia. They found that the Demirjian standards were not applicable to the Australian sample of unknown racial compositions because they underestimated chronologic age by 0.6 years on average.

Demirjian's system has also been employed to estimate the dental age of northeastern Brazilian children (Maia, 2010). The northeast region of Brazil has a semi-

arid climate, and the drought in this region has forced the internal migration of the rural northeastern Brazilian population into urban areas. Many of the migrant children eventually become abandoned and are then provided legal protection by the government. The children of this region often do not know their birthdates due to the rural nature of their previous culture, and thus the Brazilian government relies heavily on age estimation to resolve legal matters pertaining to the abandoned youth. The authors of this study sought to test the accuracy of Demirjian's system for these northeastern Brazilian children so that dental maturity scores could be converted to dental age using a scale developed specifically for the population in question. Demirjian's staging criteria were applied to 1,484 panoramic images from northeastern Brazilian children aged 7 to 13 years old. The authors found that the subjects' dental ages were significantly advanced when compared to the subjects' reported chronological ages, with a mean advancement of 1.22 years for males and 1.30 years for females (Maia, 2010). This study again emphasizes that dental maturation scores and grading criteria be determined for individual populations.

In 2008, Moananui *et al*. explored the rate of dental development in the native Maori and Pacific Island population of New Zealand as compared to dental development in European children living in New Zealand. Previous studies had suggested that teeth erupt earlier in these Polynesian populations as compared to Europeans. Others have also observed that Polynesian children have accelerated somatic growth and maturation in comparison to the development of European children in New Zealand (Moananui, 2008). The authors applied Demirjian's stages of tooth development to the seven left mandibular

permanent teeth, excluding the third molar, of 1343 panoramic radiographs obtained from various hospitals and private clinics in New Zealand. The study consisted of Maori, Pacific Island, and European children aged 2.5 to 14 years. The ethnicity of the patients was based on self-declared information in the patients' records or by assumption of the ethnicity due to surname. This is a clear weakness of this study. One cannot simply assume a certain ethnicity based on surname. It is possible that the child was adopted and the adoptive parents are of a given ethnicity. It is also possible that the mother and father are of different ethnicities. If a patient is included in a specific ethnicity category for the purposes of this study, it is important that both parents are of that ethnicity. The authors found that both Maori and Pacific Island children were consistently advanced in dental age when compared to their European peers. This was the first study of its kind to compare dental maturation between three different ethnic groups. Interestingly, Pacific Island children were more dentally advanced than Maori children who were in turn more advanced than New Zealand children of European origin (Moananui, 2008).

The only study to date to investigate the interrelationship between dental age and chronological age in Somali children compared with that of Caucasian children was conducted in Sheffield, United Kingdom by L.E. Davidson and H.D. Rodd in 2001. As we have also seen in Minneapolis, the authors of this study noted that clinical observations have suggested that Somali children in the United Kingdom appear dentally advanced compared to their Caucasian peers. Davidson & Rodd (2001) analyzed panoramic radiographs of 162 individuals under 16 years of age that lived in Sheffield, United Kingdom. The sample was approximately equally distributed among Caucasian

and Somali individuals. The method described by Demirjian in 1973 was employed to calculate a dental age for each individual. This dental age was then compared to the chronological age of the individual at the time of the radiograph, as calculated based on the individual's reported date of birth. Somali boys were found to be dentally advanced 1.01 years beyond their reported chronological age, whereas Caucasian boys were only 0.19 years advanced when compared with the French-Canadian based Demirjian standards. Somali girls were 1.22 years advanced, which was significantly greater than the 0.52 year advancement found for Caucasian girls. A weakness of this study is that the authors based chronologic age off of the reported birthdate of individuals. If the Somali children included in the study were not born in the United Kingdom, it is highly possible that reported birthdate is inaccurate. Ten Somali children were found to have discrepancies of three or more years between dental age and chronological age, drawing suspicions as to the validity of their reported birthdates (Davidson, 2001). This encouraged the exclusion of individuals born outside of the United States in the present study. The results of this study also emphasized the importance of our present study, as overestimating an individual's chronological age could have serious implications in many situations.

As previously stated, a limitation of the Demirjian method is that it is not useful for age estimation in late adolescence and early adulthood. This is because all of the teeth assessed have typically completed development with closure of the root apex or apices by late adolescence. However, age estimation during this period is of the utmost importance as it is during late adolescence that an individual reaches the age of majority

of 18 years of age in the United States. The third molar is the only tooth still developing during late adolescence, and therefore serves as an important tool in age assessment during this time period despite it being the most variable tooth with respect to size, shape, eruption timing and likelihood of congenital absence (Blankenship, 2007). The lower third molar has been found to have a strong correlation with chronological age (Engström, 1983). Any method used to employ third molar development for the purposes of age estimation when attempting to determine if an individual is of legal age or minor status should avoid overestimation of chronological age so as to avoid classifying an actual minor as someone of legal age (Schmeling, 2011).

Due to the interest in utilization of third molar development for age estimation in late adolescence and young adulthood, many classification systems have been proposed for assessing the mineralization of third molars. Each of these systems varies slightly in the number of stages proposed, the written descriptions given for each stage, and the graphic representation of each stage if provided. In 2005, Olze *et al.* examined and compared the validity of five such stage-based systems. The authors analyzed 420 panoramic radiographs of German females ages 12-25 years. The left mandibular third molar was staged according to the following five systems (Figures 1 – 5): Gleiser and Hunt (1955), Demirjian *et al.* (1973), Gustafson and Koch (1974), Harris and Nortje (1984) and Kullman *et al* (1992).

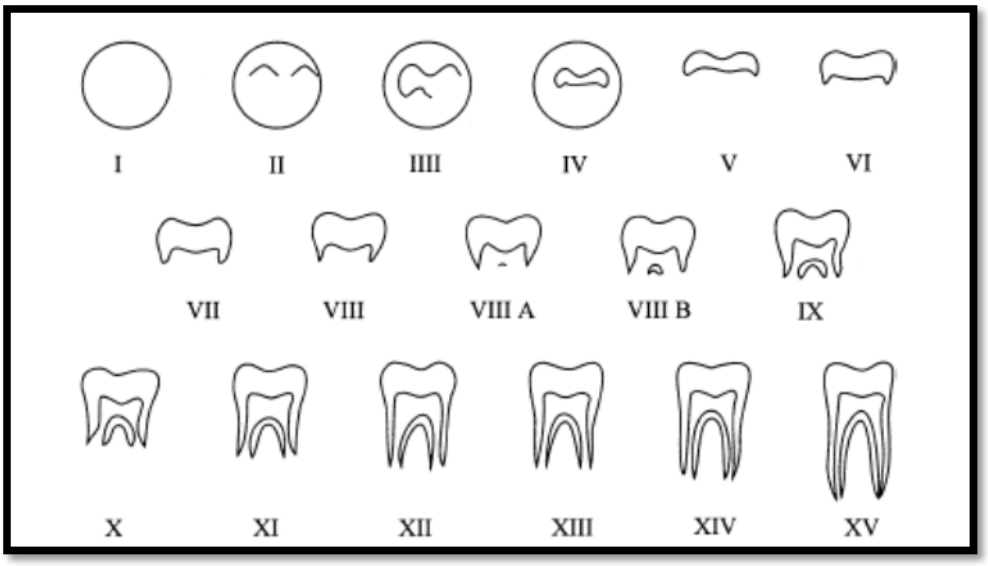


Figure 1. Diagrammatic representation of the fifteen-stage classification by Gleiser and Hunt (1955). Gleiser and Hunt provide written descriptions of each stage as well.

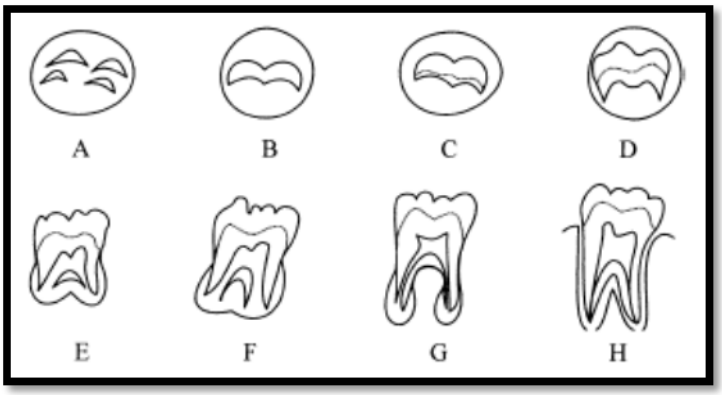


Figure 2. Diagrammatic representation of the eight-stage classification by Demirjian *et al* (1973). Written descriptions of each stage are also provided with this classification method.

- Stage 1: commencement of mineralization
- Stage 2: completion of crown
- Stage 3: eruption when the cusp(s) penetrate the gingiva
- Stage 4: completion of root(s).

Figure 3. Written description of 4-stage classification proposed by Gustafson and Koch (1974). No diagrammatic representation of the stages is given in this classification system.

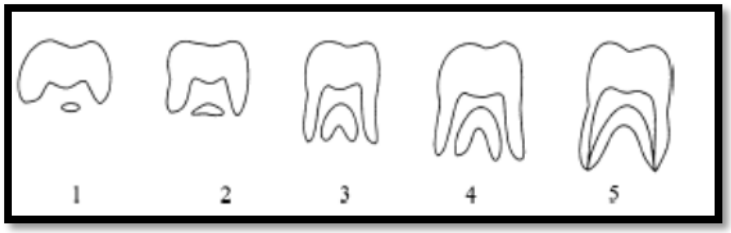


Figure 4. Diagrammatic representation of the five-stage classification by Harris and Nortje (1984). Written descriptions of each stage are provided with this classification method as well.

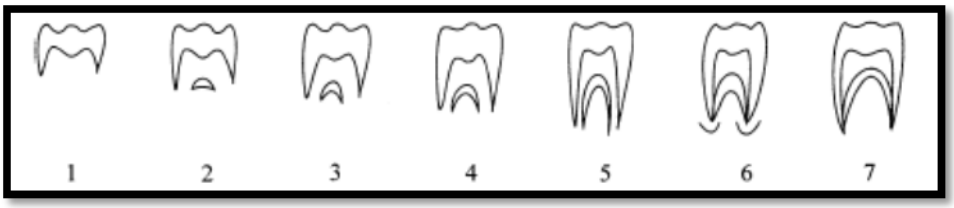


Figure 5. Diagrammatic representation of the seven-stage classification by Kullman *et al* (1992). Written descriptions of each stage are provided with this classification method as well.

Inter- and intra-observer agreements were calculated for all methods using a weighted kappa coefficient, and it was assumed that the classification method with the lowest assessment variability was the most appropriate method to be used in assessment of the third molar development for purposes of age estimation. Secondly, the authors compared the correlation between true chronological age and estimated chronological age based on the results obtained from the various classifications. The classification system that yielded maximum correlation was considered to be the superior method. Olze *et al.* (2005) concluded that the eight-stage classification system developed by Demirjian *et al*. (1973) was the best of the five methods reviewed as it produced the highest inter- and intra-observer agreements, and the strongest correlation between actual chronological age

and estimated chronological age based on the stages defined. The Gleiser and Hunt (1955) and Kullman *et al.* (1992) methods also produced good results, but the Gustafson and Koch (1974) and Harris and Nortje (1984) methods yielded poorer results in terms of observer agreement and correlation between true age and estimated age. These two classifications that did not perform as well also had the fewest number of stages, with the Gustafson and Koch classification having four stages and the Harris and Nortje method having five stages. Interestingly, Engström *et al.* (1983) developed a five-stage system to examine the relationship between chronological age and lower third molar development and found a high correlation between the two (Figure 6). They surmised that fewer dental stages in a system increases the ease of discriminating between the various stages. These conflicting studies suggest that the textual and visual descriptions of each stage may have more impact on the reliability and validity of a classification than the actual number of stages. It is speculated that the Gustafson and Koch method may also have performed worse due to the lack of diagrammatic representations of each stage.

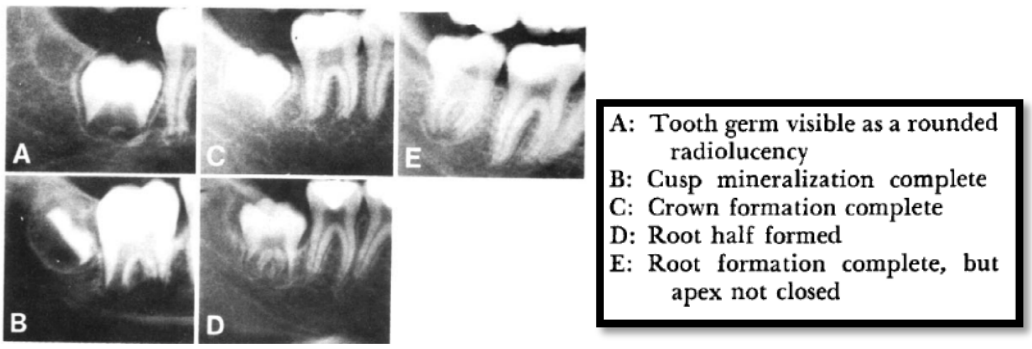


Figure 6. Radiographic representations and written descriptions of the five stages of third molar development as proposed by Engström *et al* (1983).

Just as dental maturation has been studied in various ethnicities for purposes of age estimation in children, third molar development has also been examined in many different populations for purposes of age estimation in adolescents. In 2007, Blankenship *et al.* investigated third molar development in the estimation of chronological age in African Americans as compared with Caucasian Americans. Maxillary and mandibular third molars of 1200 individuals aged 14 to 24.9 years were assigned a developmental stage according to Demirjian's eight-stage scheme. The authors found that the third molars of African Americans reached stages D through F much earlier, often at least one year earlier, than those of Caucasian subjects. Even though greater variability was seen with the later stage G, African Americans still reached this stage at an earlier chronologic age than Caucasians, although the difference was not as significant in males (Blankenship 2007). Kasper *et al.* (2009) later investigated the use of the third molar for age estimation in a Texas Hispanic population as compared with American Caucasians. Texas sees a large number unauthorized Mexican or Latin American individuals cross its borders each year, and age estimation in this population is useful in legal proceedings as the exact age of many of these individuals is unknown. Panoramic radiographs of 950 Hispanic individuals of known age and gender were evaluated in this study. Third molars were staged according to the eight-stage Demirjian method, which the authors supplemented with representative radiographic images of third molars at each stage of development (Figure 2). Mean ages of the subjects were calculated for each combination of gender, jaw and stage of third molar development. These were compared with the mean ages of American Caucasians from Mincer *et al* (1993). This appears to be a limitation of the

study. The study could be improved by analyzing a similar number of panoramic radiographs from a Texas Caucasian population with comparable age and gender distribution. Kasper *et al.* (2009) found that the third molars of Hispanic individuals reached the latter stages of development (Demirjian stages G and H) anywhere from 8 to 18 months earlier than the Caucasian reference population from Mincer's study. Thus, if Caucasian norms were used to estimate the chronological age of a Hispanic individual in Texas, there is a high likelihood that the chronological age would be overestimated and the individual may be classified as an adult when he or she is actually a legal minor. Overestimation of chronological age has negative implications in immigration cases, because an individual is treated differently based on adult or juvenile status (Kasper, 2009).

In 2010, Lewis and Senn published a review of third molar development in chronological age estimation (Lewis, 2010). The authors reviewed five studies all conducted in the United States that examined third molar development in relation to chronological age in different ethnic populations. All of the studies reviewed utilized the Demirjian staging method or a slight variation of the Demirjian system. From this review, it was concluded that a trend exists among various American populations. This trend is that American Hispanic third molar development is approximately six months advanced when compared to American Caucasian third molar development, and that African American third molar development is about six months ahead of that of Hispanic Americans. The reviewers also found that individuals with third molars classified as Demirjian's stage H, where closure of the root apex is complete, were all very likely to

have reached age 18. The authors thought that this technique would be valid for determining the legal age of majority in the United States. This review further highlights the need for population specific standards as to the rate of third molar development.

Demirjian's eight stages of tooth development were again utilized by Prieto *et al.* (2005) to evaluate the relationship between chronological age and third molar development in a Spanish population. The authors evaluated the mandibular third molars only in 1,054 digital panoramic radiographs of Spaniards aged 14 to 21 years using a modified representative diagram of Demirjian's eight stages of molar development. The authors found that on average Spanish women reach the Spanish age of majority (18 years old) in stage G of third molar development, and males reach 18 years of age in stage H. A stronger correlation was found between chronological age and third molar development for males ($r^2 = 0.54$) than for females ($r^2 = 0.45$). When comparing their results to those of previous studies, the authors found that third molar development occurs earlier in Spaniards than in French-Canadian, German, Japanese, and South African populations.

Rai *et al.* (2010) sought to determine the usefulness of third molar development in age estimation of Iranian individuals. The authors evaluated 1200 panoramic radiographs from Iranian individuals aged 10 to 27 years. All third molars were evaluated according to Demirjian's eight stage classification of dental development. Multiple regression analysis was used to obtain regression formulae for both males and females to allow for age estimation based on the developmental stage of maxillary and mandibular third molars. The authors claim that these regression formulae provide forensic experts a

scientific tool to utilize in estimating the chronological age of an individual of Iranian origin.

Third molar development in Somali individuals has yet to be studied. Only one study exists to date examining the rate of dental development in Somali children as compared to Caucasian children in the United Kingdom, and found Somali children to be significantly more dentally advanced than their Caucasian peers (Davidson, 2001). If the third molar development is to be used as a factor in age estimation of Somali individuals in late adolescence, it is critical to understand how the third molar development in Somalis compares to that in Caucasians so as to avoid potential overestimation of chronological age.

Research Methodology

The methodology employed in this study serves to accomplish the specific aims of comparing the chronological ages at which the various stages of third molar development are reached in Somali and Caucasian individuals and develop a reliable classification that can be applied to determining the developmental stage of third molars.

The target population included American-born Somali and non-Hispanic Caucasian individuals aged 10 to 20 years old who attend the orthodontic clinic of the University of Minnesota. It was necessary that subjects were born in the United States to avoid inconsistencies between reported and actual date of birth, an issue that was encountered in a previous study by Davidson *et al* (2001). Subjects with existing panoramic radiographs as part of their clinical management were included in the study.

Panoramic radiographs included in the study were either extracted from a cone-beam computed tomography (CBCT) image or were from a traditional two-dimensional digital panoramic x-ray. The purpose of the research project was explained to potential participants, and the subject was asked if they consented to having their radiographic images analyzed as part of the study. Subjects were asked to complete questionnaires to determine their heritage and birthplace (Figure 7). Subjects and their legal guardians (in the case of minors) were asked to complete informed consent, minor assent and HIPAA forms in order to have their radiographs included in the study. The methodology of this study was approved by the University of Minnesota Institutional Review Board.

Subjects were excluded from the study if they exhibited any syndrome or craniofacial anomaly or if their panoramic radiographs were of poor diagnostic quality. Subjects were also excluded from the study if both parents were not of either Somali or non-Hispanic Caucasian heritage, or if the subject was not born in the United States of America.

Questionnaire
Minor patient (10-17 years old)

We don't know much about when Somali people start having baby and adult teeth. We are requesting your permission to analyze your child's x-ray from before he/she received braces. This image will let us calculate his/her dental age as well as the development of his/her bones. We are also asking you to take a few minutes and answer these questions below:

1. Was your child born in the USA?
   ☐ Yes ☐ No
2. Is the child's mother from Somali inheritance?
   ☐ Yes ☐ No
3. Is the child's father from Somali inheritance?
   ☐ Yes ☐ No
4. Approximately how old was the child when his/her first baby teeth appeared in your mouth?
   _____ months ☐ I don't know

Hint: First teeth to erupt are usually the bottom front ones

5. Approximately how old was the child when his/her first adult teeth appeared in your mouth?
   _____ years ☐ I don't know

Hint: First teeth to erupt are usually the bottom front or back ones

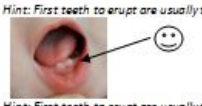
Thank you so much. We really appreciate your help!

Questionnaire
Minor patient (10-17 years old)

We don't know much about when Somali people start having baby and adult teeth, and we want to compare them to a group that we know a lot about. We are requesting your permission to analyze your child's x-ray from before he/she received braces. This image will let us calculate his/her dental age as well as the development of his/her bones. We are also asking you to take a few minutes and answer these questions below:

1. Was your child born in the USA?
   ☐ Yes ☐ No
2. Is the child's mother white non-Hispanic?
   ☐ Yes ☐ No
3. Is the child's father white non-Hispanic?
   ☐ Yes ☐ No
4. Approximately how old was the child when his/her first baby teeth appeared in your mouth?
   _____ months ☐ I don't know

Hint: First teeth to erupt are usually the bottom front ones



5. Approximately how old was the child when his/her first adult teeth appeared in your mouth?
   _____ years ☐ I don't know

Hint: First teeth to erupt are usually the bottom front or back ones

Thank you so much. We really appreciate your help!

Figure 7. Questionnaires completed by patients included in the study. Separate questionnaires exist for potential Somali and Caucasian participants. Questionnaires serve to determine if patients were born in the United States of America and to confirm their Somali or non-Hispanic Caucasian heritage.

The chronological age of each subject at the time of radiographic examination was determined from the subject's date of birth listed in his or her orthodontic record. The developmental stage of each third molar present in a subject's panoramic radiograph was determined blindly by both an orthodontic resident (CH) and an oral radiologist (MA) using the method described by Demirjian *et al.* (1973) as modified by Kasper *et al.* (2009) (Figure 8). The Demirjian staging system was utilized because it is the most widely used method, and has previously performed the best for correlation between estimated and true age (Prieto, 2005; Olze, 2005). Kasper's classification differs from the original Demirjian classification only in that it includes radiographic examples of each stage. Stage determination for each third molar was performed a second time by both examiners, at least two weeks from the initial assessment.

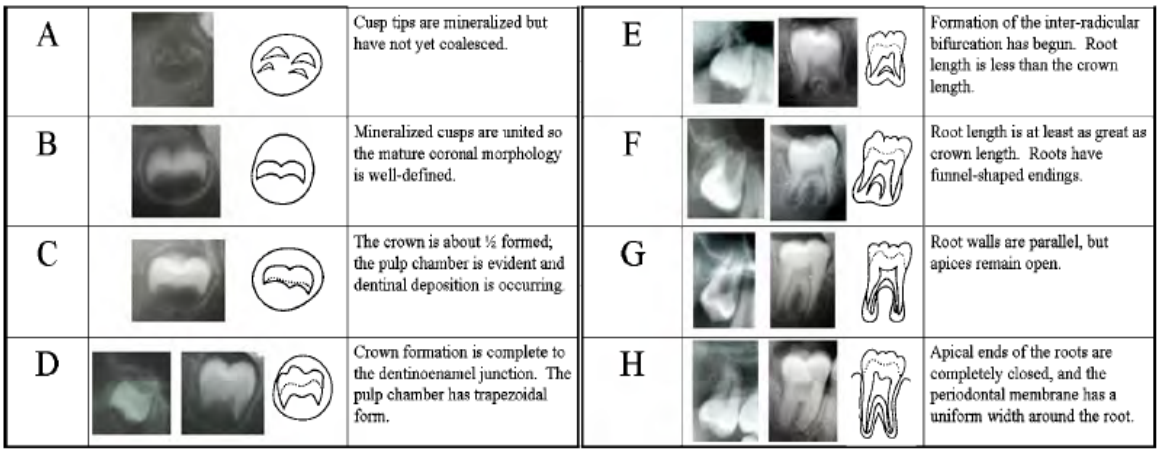


Figure 8. Demirjian's third molar developmental stages as modified by Kasper *et al*. with radiographic examples and written descriptions of each stage (Kasper, 2009).

A new classification of dental development was then developed by CH and MA in order to create a classification with more descriptive stages and superior reliability. The classification includes radiographic, line diagram and verbal descriptions of each stage (Figures 9 and 10, Table 1). Two months from the initial classification, the same set of

third molar images were again staged blindly by the same examiners using the new classification. The molars were staged on two separate occasions, with a one week period between readings.

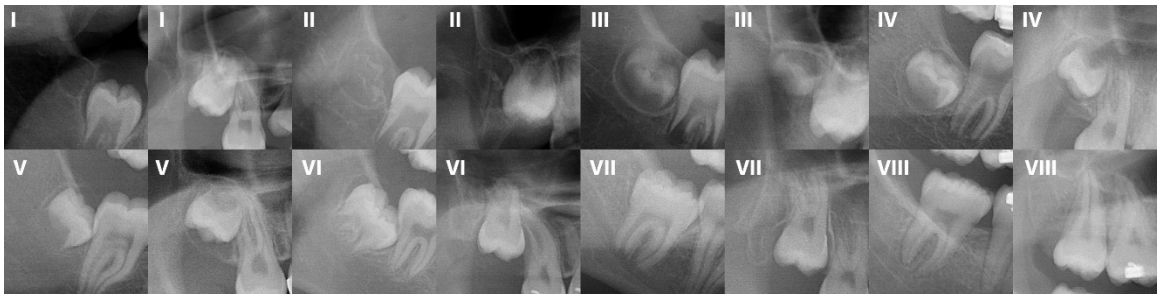


Figure 9. Radiographic representations of the eight stages of the classification of third molar developmental stages introduced in this study. Both maxillary and mandibular images are given for each stage. All images were taken from two dimensional digital panoramic images.

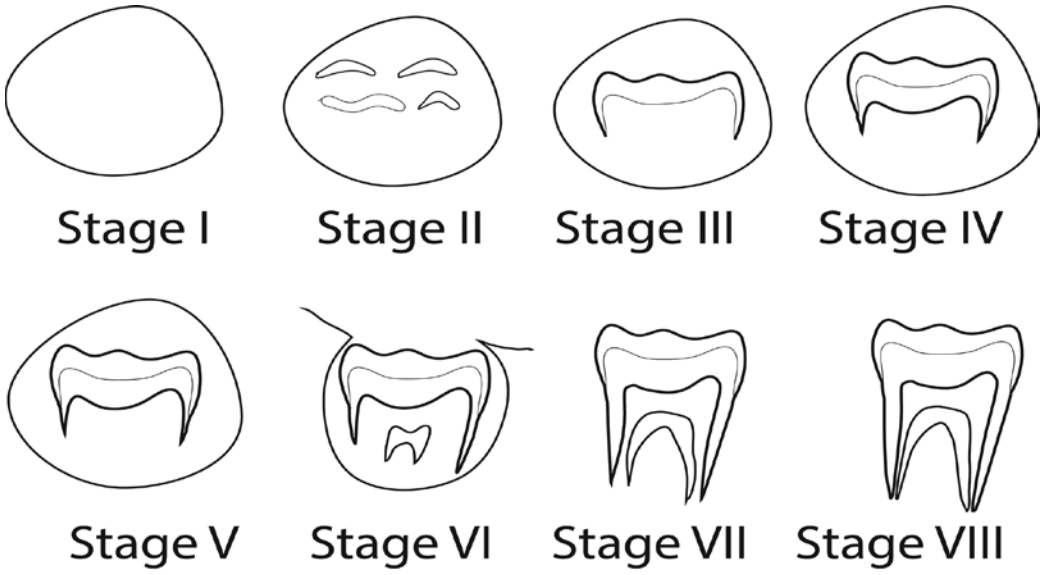


Figure 10. Diagrammatic representations of the eight stages of the classification of third molar development stages introduced in this study

Stage	Description
I	The dental follicle is apparent as a rounded radiolucency.
II	The cusp tip(s) have mineralized inside of the dental follicle present in Stage I. In teeth with multiple cusps, the cusp tips have not yet coalesced.
III	Coronal morphology is well-defined, but not yet complete. The cementoenamel junction (CEJ) is not yet evident. In teeth with multiple cusps, the cusp tips are united so that the mature coronal morphology is visible.
IV	Crown formation is complete. The CEJ is evident. If root formation has begun, root length is less than 2 mm where the maximum amount of root has formed.
V	In the area where maximum amount of root has formed, root length extends at least 2 mm beyond the CEJ but still remains less than crown height.
VI	In single rooted teeth, root length is equal to or greater than crown height and the root apex is open with divergent root walls. In multi-rooted teeth, the bifurcation has formed and root apices are open with divergent root walls.
VII	In single rooted teeth, root length is equal to or greater than crown height and the root apex is open with convergent root walls. In multi-rooted teeth, the bifurcation has formed and root apices are open with convergent root walls.
VIII	Root apices are closed.

Table 1. Descriptions of the characteristics of each of the eight stages of the third molar development classification system introduced in this study.

On all occasions, images were viewed in Microsoft Windows Photo Viewer ®. The examiners were allowed to enlarge the image in order to more closely view any anatomical structure of the third molar to determine which developmental stage the third molar should be classified as. For example, it was often necessary to magnify the radiographic image in order to determine closure of the root apex or apices.

Statistical Analysis

For purposes of the analysis, maxillary and mandibular third molars were considered separately. In cases where stages differed between the right and left quadrants

of the jaw, the two examiners ultimately came to a consensus stage for the maxillary or mandibular arch. Within an arch, the third molars never differed by more than one stage.

Descriptive statistics such as means, standard deviations, minimum values and maximum values were employed to characterize the data generated from the study.

Results

Sample

The total sample comprised 217 third molars from 57 panoramic images of 24 individuals. Many individuals had multiple panoramic images available from different time points. Twenty-four panoramic images from nine Somali subjects were viewed. Ten of these radiographs were from 2 Somali male subjects. The remaining 14 radiographs were from 7 Somali females. Thirty-three panoramic images came from 15 Caucasians. Seven Caucasian male subjects contributed 12 of the radiographs, while the remaining 21 images were from 8 Caucasian females. The distribution of third molars analyzed by ethnicity and dental arch is shown in Table 2.

Ethnicity	Maxillary	Mandibular	Total
Somali	48	44	92
Caucasian	60	65	125
Total (n = 217)	108	109	217

Table 2. Distribution of third molars analyzed by ethnicity and dental arch.

Third Molar Development in Somalis and Caucasians using the Demirjian et al. *(1973) Classification System*

For purposes of analysis, each subject was assigned a consensus maxillary third molar stage and a consensus mandibular third molar stage. In an individual subject, the stages of the contralateral third molars in a particular jaw were the same in the majority of the cases. In cases where the contralateral third molars were of different stages, the difference was never more than a single stage. In these cases, a stage was chosen that best represented both of the third molars in a given arch. Oftentimes, especially using the Demirjian staging method, a molar was between stages. For purposes of achieving a consensus stage for a given arch, a subjective decision was made by both examiners to classify that molar as the stage with which it shared the most criteria. Tables 3 and 4 display the distribution of the molars by consensus stage and ethnicity in both the maxillary and mandibular arches. The mean, median, minimum and maximum ages for which the various developmental stages were attained in both ethnicities are also included in these tables.

For developmental stage categories in which both Somali and Caucasian third molars were present, the difference between the mean ages for each group was calculated. The difference was calculated by subtracting the Somali mean age from the Caucasian mean age ($\text{Mean}_{\text{Caucasian}} - \text{Mean}_{\text{Somali}}$). Therefore, a positive number indicates that the Somali third molar reached the given developmental stage at an earlier chronological age than the Caucasian third molar. Maxillary third molars in stages C, D, E, and H were found for both Somali and Caucasian subjects. Somali third molars

attained these stages at a younger chronological age in three of these four stages: C, D, and H. The differences ranged from 7.7 months in Stage D to 21.6 months in Stage H. The Caucasian maxillary third molar reached stage E 5.1 months earlier than the Somali maxillary third molar.

Mandibular third molars from both Somali and Caucasian individuals were present in seven of the eight Demirjian developmental stages. Mandibular third molars of Somali individuals reached these stages at an earlier chronological age than those of Caucasians in all but stage F. As was seen in the maxillary third molars, the greatest difference in chronological age between the two groups was seen in the latter stages of development. Somali maxillary third molars reached stage H an average of 21.6 months earlier than Caucasians, and their mandibular third molars reached stage G 46.8 months earlier than Caucasians.

Mx Stage	Race	N	Mean Age (months)	Std Dev (months)	Median (months)	Minimum (months)	Maximum (months)	$Mean_{Cauc} - Mean_{Somali}$ (months)
A	C	1	156.5	.	156.5	156.5	156.5	-
B	S	2	120.6	9.1	120.6	114.2	127.0	-
C	C	10	147.1	15.5	149.4	121.0	165.0	10.1
	S	5	137.0	7.2	134.9	128.9	146.8	
D	C	11	169.0	13.7	169.0	152.3	192.2	7.7
	S	10	161.3	15.1	161.4	137.2	182.1	
E	C	6	163.5	20.5	163.8	136.5	189.7	-5.1
	S	2	168.6	10.0	168.6	161.5	175.6	
F	S	1	167.6	.	167.6	167.6	167.6	-
G	S	1	187.2	.	187.2	187.2	187.2	-
H	C	3	214.9	12.0	210.4	205.7	228.5	21.6
	S	3	193.3	10.1	197.8	181.7	200.3	

Table 3. Distribution of maxillary third molars by ethnicity and Demirjian *et al.* stage (1973).

Mn stage	Race	N	Mean Age (months)	Std Dev (months)	Median (months)	Minimum (months)	Maximum (months)	$Mean_{Cauc} - Mean_{Somali}$ (months)
A	C	2	128.5	10.6	128.5	121.0	136.0	7.9
	S	2	120.6	9.1	120.6	114.2	127.0	
B	C	10	151.8	15.2	151.6	125.4	174.9	5.0
	S	1	146.8	.	146.8	146.8	146.8	
C	C	10	160.7	14.2	160.1	136.5	192.2	6.1
	S	6	154.6	17.0	158.4	128.9	177.6	
D	C	5	172.4	19.4	184.4	147.1	189.7	17.6
	S	5	154.8	16.8	152.1	137.2	173.3	
E	C	3	177.8	25.7	172.5	155.1	205.7	6.1
	S	4	171.7	9.0	171.6	161.5	182.1	
F	C	1	179.8	.	179.8	179.8	179.8	-7.4
	S	1	187.2	.	187.2	187.2	187.2	
G	C	1	228.5	.	228.5	228.5	228.5	46.8
	S	1	181.7	.	181.7	181.7	181.7	
H	C	1	210.4	.	210.4	210.4	210.4	

Table 4. Distribution of mandibular third molars by ethnicity and Demirjian *et al.* stage (1973)

Plots and trendlines were generated that represent the mean chronological ages at which the Demirjian third molar developmental stages were attained for both ethnicity groups. For purposes of comparison, Somali and Caucasian third molar data were plotted together for both maxillary and mandibular third molars (Figures 11 and 12). The trendlines demonstrate that one would expect Somali individuals to reach each developmental stage at a younger chronological age than Caucasians. The difference is most pronounced in mandibular third molars at stages G and H.

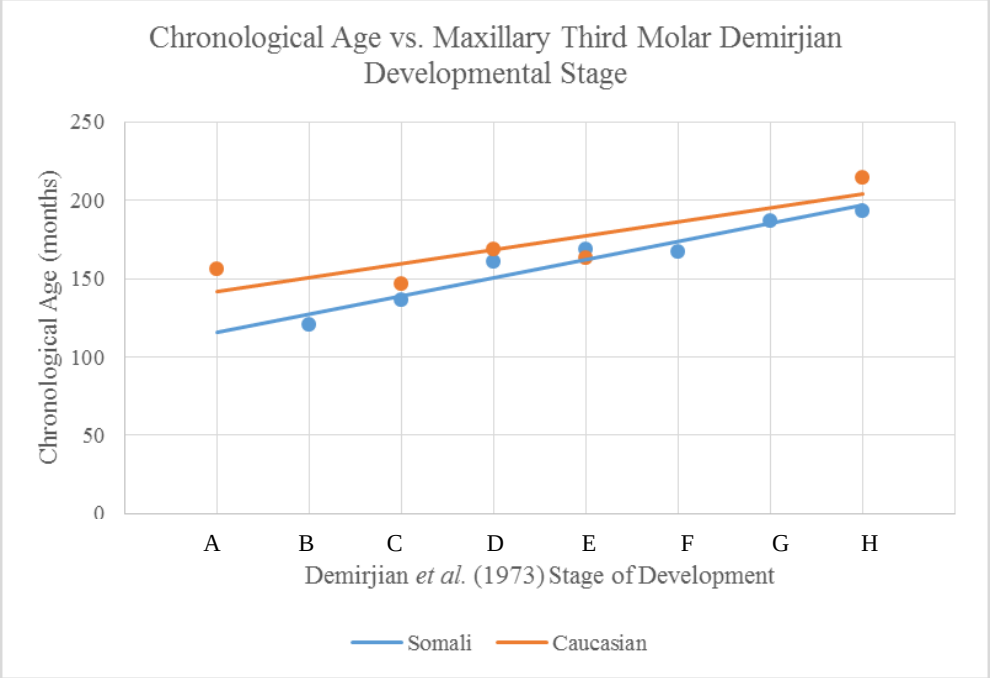


Figure 11. Trendlines comparing mean chronological ages at which each of Demirjian's eight stages of third molar development are reached in maxillary third molars of Somali and Caucasian individuals.

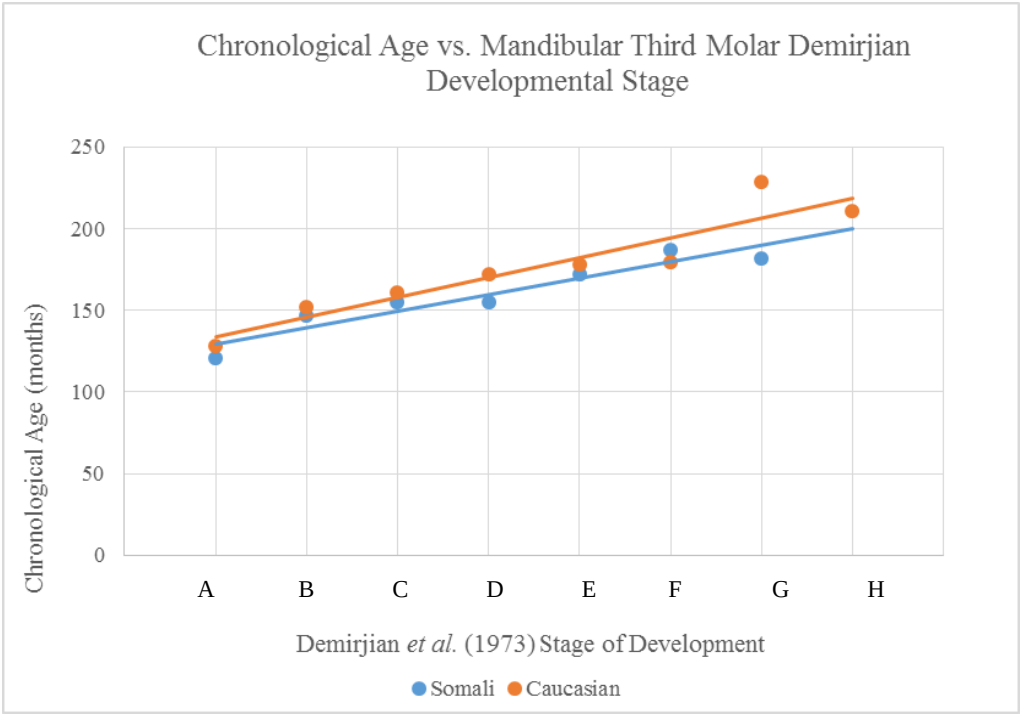


Figure 12. Trendlines comparing mean chronological ages at which each of Demirjian's eight stages of third molar development are reached in mandibular third molars of Somali and Caucasian individuals.

Third Molar Development in Somalis and Caucasians using the Newly Proposed Classification System

The same sample of third molars was again analyzed using the developmental classification system proposed in this paper as previously described. Descriptive statistics as well as differences between the mean ages of both groups at each stage are seen in Tables 5 and 6. Maxillary third molars were present for each ethnicity group in stages III, IV, V, VII, and III. The differences in chronological age ranged from 7.4 months at stage IV to 23.1 months at stage VIII. Stage V was the only stage in which the Caucasian maxillary third molar mean chronological age was less than the Somali chronological age.

Mx stage	Race	N	Mean Age (months)	Std Dev (months)	Median (months)	Minimum (months)	Maximum (months)	$Mean_{Cauc} - Mean_{Somali}$ (months)
II	C	1	156.5	.	156.5	156.5	156.5	-
III	C	3	146.8	18.6	155.5	125.4	159.4	22.2
	S	3	124.6	9.4	127.0	114.2	132.6	
IV	C	9	152.9	17.6	159.7	121.0	174.9	7.4
	S	9	145.5	11.8	141.9	128.9	162.5	
V	C	12	162.8	16.8	158.2	136.5	192.2	-8.5
	S	5	171.2	11.5	173.3	152.1	182.1	
VI	C	3	180.7	8.6	179.8	172.5	189.7	12.1
	S	2	168.6	10.0	168.6	161.5	175.6	
VII	S	1	167.6	.	167.6	167.6	167.6	-
VIII	C	3	214.9	12.0	210.4	205.7	228.5	23.1
	S	4	191.8	8.8	192.5	181.7	200.3	

Table 5. Distribution of maxillary third molars by ethnicity and stage as proposed by this study.

With the exception of stage VIII, all mandibular third molar stages contained teeth from both Somali and Caucasian individuals. Somalis attained each stage at a younger chronological age, indicating a consistent third molar development advancement compared to Caucasians. The greatest difference in chronological age was seen at stages IV and VII, with the Somalis being 19.7 months younger than Caucasians on average (Table 5).

Mn Stage	Race	N	Mean Age (months)	Std Dev (months)	Median (months)	Minimum (months)	Maximum (months)	$Mean_{Cauc} - Mean_{Somali}$ (months)
II	C	3	137.5	17.3	136.0	121.0	155.5	16.9
	S	2	120.6	9.1	120.6	114.2	127.0	
III	C	11	151.9	14.5	152.3	125.4	174.9	18.1
	S	2	133.8	1.6	133.8	132.6	134.9	
IV	C	9	166.5	17.7	162.2	136.5	192.2	19.7
	S	8	146.8	11.9	144.4	128.9	162.5	
V	C	3	168.6	21.3	169.0	147.1	189.7	0.1
	S	4	168.5	11.3	172.2	152.1	177.6	
VI	C	4	172.3	23.7	164.2	155.1	205.7	0.6
	S	4	171.7	9.0	171.6	161.5	182.1	
VII	C	2	204.2	34.4	204.2	179.8	228.5	19.7
	S	2	184.5	3.9	184.5	181.7	187.2	
VIII	C	1	210.4	.	210.4	210.4	210.4	-

Table 6. Distribution of mandibular third molars by ethnicity and stage as proposed by this study.

Trendlines were also created from the data obtained through staging third molar development using the development classification system proposed in this study. Mean chronological ages as found in Tables 5 and 6 were graphed as a function of third molar developmental stage, and a line of best fit was added to the plot. Figures 12 and 13 show chronological age as a function of maxillary and mandibular third molar developmental

stage using the classification system proposed in this study. Similarly to the trends seen in Figures 11 and 12 when Demirjian's classification of third molar development is used, Figure 13 and 14 demonstrate that Somali third molar development appears to occur at younger chronological ages than Caucasian third molar development.

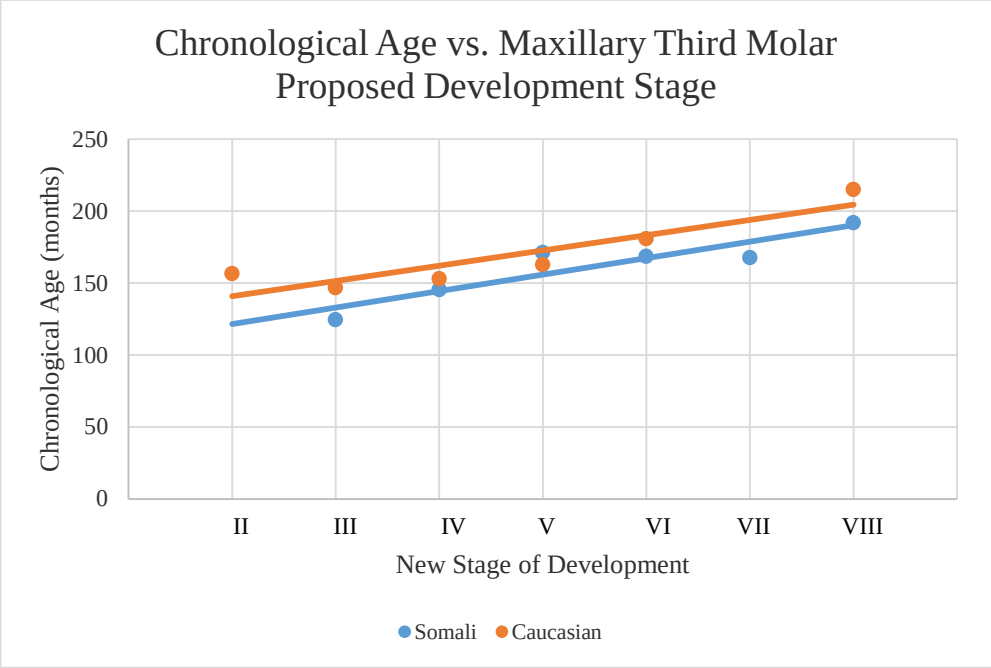


Figure 13. Trendlines comparing mean chronological ages at which each of the eight stages of third molar development proposed in this study are reached in maxillary third molars of Somali and Caucasian individuals.

It is important to note that statistical significance cannot be concluded from any of the data presented in this study due to the small sample size in each group. The descriptive data in Tables 3 through 6 indicate that many third molar development stages only contain one third molar that was analyzed. For this reason, the data is presented in terms of descriptive measures and trends.

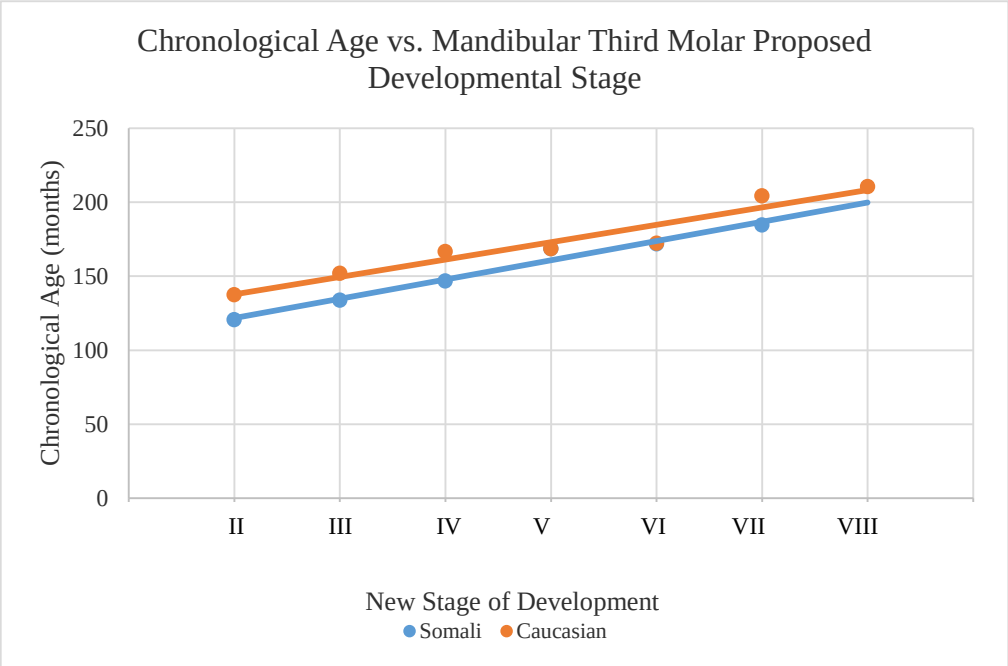


Figure 14. Trendlines comparing mean chronological ages at which each of the eight stages of third molar development proposed in this study are reached in mandibular third molars of Somali and Caucasian individuals.

A Comparison of Examiner Reliability using the Demirjian et al. *(1973) Method and the New Method (presented in this paper) of Third Molar Development Classification*

In order to assess inter- and intra-examiner reliability, each of the two examiners staged all of the third molars on two separate occasions as described previously. This was done for both the widely used Demirjian *et al.* (1973) classification of third molar development as well as the classification system proposed in this study. The reliabilities were found using a GEE model for binary outcome. This model takes into account potential within subject correlation, which was necessary as many third molars analyzed were from the same individual at different timepoints. The classification method

proposed in this paper has improved inter- and intra-examiner reliabilities when compared to the Demirjian *et al.* method (Table 7).

Classification Method	**Overall Intra-examiner Reliability (95% CI)**	**Inter-examiner Reliability (95% CI)**
Demirjian *et al.* (1973)	74.6% (67.6%, 80.5%)	63.0% (56.1%, 69.4%)
CH & MA	84.4% (80.3%, 87.7%)	68.5% (62.2%, 74.1%)

Table 7. A comparison of the overall intra-examiner and inter-examiner reliabilities determined by evaluating this study's sample using both the Demirjian *et al.* (1973) method and the method proposed in this paper by CH and MA for the classification of third molar development.

It is interesting to note that the two examiners in this study had noticeably different intra-examiner reliabilities, especially when the classification method proposed here was used (Table 8). The orthodontic resident (CH) was approximately 10% more reliable than the oral radiologist (MA) when the Demirjian *et al.* method was utilized, and almost 20% more reliable when the second method was used.

	Intra-examiner Reliability by Examiner (95% CI)	
Method	**CH**	**MA**
Demirjian *et al.* (1973)	79.2% (70.2%, 86.0%)	69.4% (57.6%, 79.0%)
CH & MA	98.6% (95.9%, 99.5%)	69.7% (61.6%, 76.7%)

Table 8. A comparison of the intra-examiner reliabilities of the two examiners in this study, CH (orthodontic resident) and MA (oral radiologist) using both the Demirjian *et al.* (1973) method and the method proposed in this paper by CH and MA for the classification of third molar development.

Discussion

Chronological age estimation is of additional importance in late adolescents in determining whether or not an individual is considered a minor or adult from a legal perspective. The third molar is one of the few remaining biological markers that is still undergoing development during late adolescence, and thus is a useful tool in chronological age estimation in individuals of unknown age. Previous studies have shown a correlation between third molar development and chronological age (Engström, 1983; Lewis, 2010; Kasper, 2009; Prieto, 2005).

As previously discussed, many classification methods of third molar developmental stages have been proposed previously. The method based upon Demirjian's classification system (1973) is the most widely used. This study set out to develop an improved classification of third molar development in terms of inter- and intra-examiner reliability.

Comparison of Third Molar Development in Somali and Caucasian Individuals

Rate of third molar development has been found to vary depending upon ethnicity (Blankenship, 2007; Kasper, 2009; Lewis, 2010; Prieto, 2005; Rai, 2010). This highlights the need for population specific standards for estimating chronological age based on the stage of third molar development. Only one study to date has investigated dental development in Somali children as compared to Caucasian children, and found Somali children to be dentally advanced in comparison to their Caucasian peers (Davidson, 2001). Limitations of the Davidson and Rodd (2001) study are that the

sample included only children younger than 16 years old, and the reported chronological ages of the subjects were questionable at times. The present study is the first to examine third molar development in Somali individuals as compared to Caucasian individuals, and ensure accuracy of the subjects' chronological ages by only including individuals born in the United States.

Due to small sample size, statistical significance between the chronological ages at which Somali and Caucasian third molars reached the various stages of development could not be determined. However, trends do indicate that Somali third molars develop at a younger chronological age. The difference is often striking. For example, one Somali individual had a mandibular third molar that reached Demirjian's stage G almost 4 years earlier than the Caucasian individual (Table 4). If that Somali individual were analyzed according to Caucasian third molar development in this study, her age would be significantly overestimated and she could be determined to be an adult rather than a minor. The current study highlights the need for future studies with larger sample sizes in order to be able to determine if the differences seen in this study are of significance.

A Comparison of Examiner Reliability using the Demirjian et al. *(1973) Method and the Newly Proposed Method of Third Molar Development Classification*

The method proposed in this study had superior inter- and intra-examiner reliabilities when compared to those obtained using the Demirjian *et al.* method of classifying third molar development. The orthodontic resident's (CH) reliability improved most noticeably when using the method introduced in this study (Table 8). It is

possible that this is due to the fact that CH had a more involved role in developing this classification system, and had a greater understanding of the differences between the stages despite the two examiners reviewing the criteria for each stage in detail prior to assigning stages to the third molars analyzed in this study.

The classification system proposed here gave the examiner many aids to help in correct stage determination. These included written descriptions of the criteria of each stage, a drawn schematic representing each stage, and a radiographic example of each stage proposed. The method described in this study has the same number of stages as the widely used Demirjian *et al.* (1973) classification. This suggests that it is not only the number of stages that determines the reliability of a classification system, but also the quality of the descriptions provided and a distinct separation between each developmental stage.

Future Studies

The present study emphasizes the need for further research into the dental development of Somali and Caucasian individuals. Particularly the differences in third molar development should be explored with a larger sample size, as this has much use in chronological age estimation. With a growing number of Somali immigrants in certain United States metropolitan areas such as the Minneapolis-St. Paul area in Minnesota, it is useful in legal proceedings to have a population-specific standard to employ in age estimation so as to avoid the negative effects of overestimating chronological age. With

a larger sample, it will also be possible to examine differences in male and female third molar development.

Due to the improved reliability, the third molar development classification method proposed in this study should be further investigated. It should be applied to larger sample sizes and different populations, and should be used by examiners other than those who developed it to validate the superior reliabilities found in the present study. The stages could also be adapted to incisor and premolar teeth so that the system could be used in the chronological age estimation of children, similarly to the Demirjian method in which dental maturity scores are converted into an estimated age.

Conclusions

1. Trends indicate that third molars of Somali individuals develop at a younger chronological age than those of Caucasian individuals, according to both the Demirjian classification system and the system proposed in the present study. Due to small sample size, this cannot be drawn as a conclusion due to the lack of statistical significance.

2. For the examiners in this study, the newly proposed method of third molar development classification had improved inter- and intra-examiner reliabilities compared to the widely used classification of Demirjian *et al* (1973).

References

Blankenship, JA, Mincer, HH, Anderson, KM, Woods, MA, & Burton, EL. (2007). Third Molar Development in the Estimation of Chronologic Age in American Blacks as Compared with Whites. *J Forensic Sci, 52*(2), 428-433. doi:10.1111/j.1556-4029.2006.00356.x

Blenkin, MRB & Evans, W. (2010). Age Estimation from the Teeth Using a Modified Demirjian System. *J Forensic Sci, 55*(6), 1504-1508. doi:10.1111/j.1556-4029.2010.01491.x

Davidson, LE & Rodd, HD. (2001). Interrelationship between dental age and chronological age in Somali children. *Community Dental Health, 18*, 27-30.

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

Demirjian, A, Buschang, PH, Tanguay, R, & Kingnorth Patterson, D. (1985). Interrelationships among measures of somatic, skeletal, dental, and sexual maturity. *American Journal of Orthodontics, 88*, 433-438.

Engström, C., Engström, H., & Sagne, S. (1983). Lower Third Molar Development in Relation to Skeletal Maturity and Chronological Age. *Angle Orthodontist, 53*(2), 97-106.

Fleshman, K. (2000). Bone age determination in a pediatric population as an indicator of nutritional status. *Trop Doct, 30* (1), 16-18.

Gilsanz, V, Skaggs, DL, Kovanlikaya, A, Sayre, J, Loro, ML, Kaufman, F, & Korenman, SG. (1998). Differential effect of race on the axial appendicular skeletons of children. *J Clin Endocrinol Metab, 83* (5), 1420-1427.

Gleiser, I & Hunt, EE. (1955). The permanent first molar; its classification, eruption and decay. *Am J Phys Anthropol, 13*, 253-284.

Gorman, A. (2010, January 1). New Year's birthdays aplenty. *Los Angeles Times*. Retrieved from http://articles.latimes.com/2010/jan/01/local/la-me-jan1-2010jan01.

Gross, GW, Boone, JM, & Bishop, DM. (1995). Pediatric skeletal age: determination with neural networks. *Radiology, 195*(3), 689-695.

Gustafson, G & Koch, G. (1974). Age estimation up to 16 years of age based on dental Development. *Odontol Rev, 25*, 297-306.

Harris, MJP & Nortje, CJ. (1984). The mesial root of the third mandibular molar: A Possible indicator of age. *J Forensic Odontostomatol, 2*, 39-43.

Jahari, AB, Haas, J, Husaini MA, & Pollitt, E. (2000). Effects of an energy and micronutrient supplement on skeletal maturation in undernourished children in Indonesia. *Eur J Clin Nutr, 54*(supplement 2), S74-79.

Kasper, KA, Austin, D, Kvanli, AH, Rios, TR, & Senn, DR. (2009). Reliability of Third Molar Development for Age Estimation in a Texas Hispanic Population: A Comparison Study. *J Forensic Sci, 54*(3), 651-657. doi: 10.1111/j.1556-4029.2009.01031.

Kullman, L, Johanson, G. & Akesson, L. (1992). Root development of the lower third molar and its relation to chronological age. *Swed Dent J, 16*, 161-167.

Lewis, AB, & Garn, SM. (1960). The relationships between tooth formation and other maturational factors. *Angle Orthodontist, 30*, 70-77.

Lewis, JM & Senn, DR. (2010). Dental age estimation utilizing third molar development: A review of principles, methods, and population studies used in the United States. *Forensic Science International, 201*, 79-83.

Lodler, R, Estle, DT, Morrison, K, Eggleston, D, Fish, DN, Greenfield, ML, Guire, KE. (1993). Applicability of the Greulich and Pyle skeletal age standard to black and white children of today. *Am J Dis Child 147* (12), 1329-1333.

Maia, MCG, Marins, MA, Germano, FA, Beto, JB, da Silva, CAB. (2010). Demirjian's system for estimating the dental age of northeastern Brazilian children. *Forensic Science International, 200,* 177.e1-177.e4.

Marshall, WA & Tanner, JM. (1969). Variations in the pattern of pubertal changes in girls. *Arch Dis Child, 44*(235), 291-303.

Marshall, WA & Tanner, JM. (1970). Variations in the pattern of pubertal changes in boys. *Arch Dis Child, 45*(239), 13-23.

Melsen, B, Wenzel, A, Miletic, T. (1986). Dental and skeletal maturity in adoptive children: assessment at arrival and after one year in the admitting country. *Ann Human Biol, 13*(2), 153-159.

Mincer, HH, Harris, EF, & Berryman, HE. (1993). The A.B.F.O. study of third molar Development and its use as an estimator of chronological age. *J Forensic Sci, 38*(2), 428-433.

Moananui, RT, Kieser, JA, Herbison, P, Liversidge, HM. (2008). Advanced Dental Maturation in New Zealand Maori and Pacific Island Children. *American Journal of Human Biology, 20*, 43-50. doi: 10.1002/ajhb.

Ontell, FK, Ivanovic, M, Ablin, DS, & Barlow, TW. (1996) Bone age in children of diverse ethnicity. *Am J Roentgenol, 167*(6), 1395-1398.

Olze A, Bilang D, Schmidt S, Wernecke KD, Geserick G, & Schmeling A. (2005). Validation of common classification systems for assessing the mineralization of third molars. *Int M Leg Med, 119*, 22- 26.

Prieto, JL, Barberia, E, Ortega, R, & Magaña, C. (2005). Evaluation of chronological age based on third molar development in the Spanish population. *Int J Legal Med, 119*, 349-354. doi:10.1007/s00414-005-0530-3.

Rai, B, Kaur, J, & Jafarzadeh, H. (2010). Dental age estimation from the developmental stage of the third molars in Iranian population. *Journal of Forensic and Legal Medicine, 17,* 309-311.

Saunders, E. (1837). The Teeth a Test of Age, Considered with Reference to the Factory Children. In J. Forbes M.D. F.R.S. & J. Conolly M.D. (Eds.), *The British and Foreign Medical Review of Practical Medicine and Surgery, 5,* 205-206.

Schmeling, A, Garamendi, PM, Prieto, JL, & Landa, MI. (2011). Forensic Age Estimation in Unaccompanied Minors and Young Living Adults. In Vieira, DN (Ed.), *Forensic Medicine – From Old Problems to New Challenges* (pp. 77-120). ISBN: 978-953-307-262-3, InTech, DOI: 10.5772/19261

Williams, C. (2011, October 27). New census data: Minnesota Somali population grows. *Star Tribune*. Retrieved from http://www.startribune.com/132670583.html.