A radiographic study of the impact of race and sex on 1st and 2nd molar development

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A RADIOGRAPHIC STUDY OF THE IMPACT OF RACE AND SEX ON 1ST AND 2ND MOLAR DEVELOPMENT

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Master of Arts

in

The Department of Geography and Anthropology

By
Suzanne Price
B.A., Drew University, 2002
August 2005
Dedication

This thesis is dedicated to my parents, Bobby Joe and Barbara Price. Since before I was old enough to attend school, my parents stressed to me the value of education. My parents sacrificed a great deal to send my sister and me to Catholic school, sometimes working two jobs each to make ends meet. When their sacrifices should have lessened, they actually increased, as they supported me fully while I attended a small, private liberal arts college. The sacrifices my parents made were always done with a smile and motivated me to push myself past what I thought was my best. They instilled in me values that are the core of who I am and have shown me that the best kind of success does not involve financial gain.

My parents are the reason I was able to attend LSU and are a large part of the completion and success of this project. In addition to paying for gas to travel to New Orleans countless times, they encouraged me and inspired me in so many ways. My father struggled through a difficult recovery after triple bypass surgery toward the end of my second semester and throughout the summer. Even though his recovery was unsure at the end of the semester and I wanted to come home, both my parents insisted I finish the term because it was so important to both of them. Their strength is in everything I do, and this thesis is for them.
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# Table of Contents

Dedication ........................................................................................................................... ii

Acknowledgments .............................................................................................................. iii

List of Tables ..................................................................................................................... vi

List of Figures ................................................................................................................... vii

Abstract ............................................................................................................................ viii

Chapter 1: Introduction ....................................................................................................... 1

Chapter 2: Review of Literature ........................................................................................ 4
  Normal Dental Development .......................................................................................... 4
  Variation in Dental Development and Its Factors ........................................................... 5
  Racial Variation in the Dentition .................................................................................. 10
  Sex Differences in Teeth ............................................................................................... 14
  Age Standards and Variation in Formation Between Groups ....................................... 17
  The Race Debate ........................................................................................................... 25

Chapter 3: Materials and Methods .................................................................................... 31
  Sample ........................................................................................................................... 31
  Methodology .................................................................................................................. 32

Chapter 4: Results ............................................................................................................ 36
  Descriptive Statistics ..................................................................................................... 36
  First Molar (M1) ........................................................................................................... 38
  Second Molar (M2) ....................................................................................................... 39
  Secular Change ............................................................................................................. 44

Chapter 5: Discussion ....................................................................................................... 47

References Cited ............................................................................................................... 54

Appendix: Institutional Review Board Approval ............................................................ 57

Vita .................................................................................................................................... 60
List of Tables

Table 1: Number of x-rays gathered for each race ........................................................... 32
Table 2: Age range distribution by race............................................................................ 36
Table 3: Distribution of x-rays taken in each decade ....................................................... 37
Table 4: Mean age for each sex in sample, where 0 = female and 1 = male ............... 37
Table 5: Mean age for each race analyzed, where 1 = white and 2 = black .......... 37
Table 6: Univariate analysis of variance for LM1, sex, race, and interactions...... 38
Table 7: Mean age in months for stages of left 2nd molar development.................... 40
Table 8: Univariate analysis of variance for newlm2, sex, race, and interactions........ 40
Table 9: Mean ages for each stage of LM2 development for sex,
   0 = female, 1 = male ........................................................................................... 42
Table 10: Mean ages for each stage of LM2 development for race,
   1 = white, 2 = black .......................................................................................... 42
Table 11: Mean ages for each stage of LM2 development for each race, 1=white,
   2=black interacting with each race, 1=white, 2=black ...................................... 43
Table 12: Univariate analysis of variance for decade and newlm2 interactions....... 44
Table 13: Mean ages at each LM2 stage of development for each decade, 1= 1980s,
   2=1990s, 3=2000-present...................................................................................... 45
List of Figures

Figure 1: Demirjian et al. (1978) stages of permanent dental development with X-ray examples from sample. (Descriptions taken from Demirjian et al. 1978:221-226)........... 34
Abstract

Age standards exist within physical anthropology for many aspects of human development. They are important throughout the discipline, especially in its forensic application, which often aims to produce a complete biological profile (including a specific age range) of an unidentified individual. The assessment of child development requires standards in order to compare an apparent physiologic age to an actual chronological age. In assessing chronological age of an individual, the use of multiple indicators is ideal and important in determining age at death. For individuals under the age of about 21 years, dental development is the most reliable indicator of age.

Research aimed at understanding the variation in tooth formation due to race and sex will help to more accurately determine the age at death of remains of subadult individuals. This project examined the impact of race, sex, and time period on first and second molar development. The sample gathered consisted of 303 panorex radiographs of individuals ranging in age from four years to 14 years. Each radiograph was of an individual whose age, sex, and racial affinity were known. The results of statistical analyses revealed no significant difference in timing of dental development between race, sex, or decade groups. Mean comparisons did show some slight differences, especially with regard to sex and decade differences. Girls have an earlier average age at each stage of second molar development than boys. A directional change from the 1980s to the 1990s shows an increase in average age at each stage of development, suggesting that at least some secular change has occurred in recent years.
Chapter 1: Introduction

Age standards exist within physical anthropology for many aspects of human development. They are important throughout the discipline, especially in its forensic application which often aims to produce a complete biological profile (including a specific age range) of an unidentified individual. The assessment of child development requires standards in order to compare an apparent physiologic age to an actual chronological age. In assessing chronological age of an individual, the use of multiple indicators is ideal in determining age at death. For individuals under the age of about 21 years, dental development is the most reliable indicator of age.

The development of the dentition has two main aspects: the eruption of the teeth, which is the full emergence of the occlusal surface (past the point at which a tooth breaks through the gum surface), and the formation of the tooth (crown and root structure) which can only be seen in living individuals through the use of x-rays. While both aspects of dental development follow a predictable schedule, formation has been shown to be less affected by environmental factors and more resistant to nutritional factors than eruption (Smith 1991). Eruption has been known to be influenced by such factors as caries, premature tooth loss, and malnutrition (Smith 1991). For these reasons, tooth formation is superior to tooth eruption in both reliability and accuracy of determining age (Byers 2002, Maki et al. 1999).

As is true for tooth size and morphology, the formation of teeth in their schedule and pattern is extremely heritable, and the stages of formation show less variation than stages in skeletal development. Low correlations have been found between tooth formation and physical attributes of individuals, whereas high correlations exist between
such attributes and skeletal development. Also, while studies have explored a possible secular trend in age of tooth emergence, no clear trends have been seen (Liversidge and Molleson 2004). Such findings in light of clear trends for increased stature through secular change suggest that dental development is much less affected by the environmental influences that cause secular change in the skeleton.

Because tooth formation has been shown to be reliable, accurate, and relatively resistant to secular change, meaningful variation between groups (if it exists) should be explored. Standards of tooth formation should be examined in order to ascertain whether they are accurate for different groups. Also, the possibility of secular change should be explored in more detail to determine if changes have occurred over time. Change which has occurred after age standards were developed will necessarily influence the accuracy of age assessment. Research aimed at understanding the variation in tooth formation due to race and sex will help to more accurately determine the age at death of remains of subadult individuals. Often, juveniles may be assigned race or sex using nonskeletal indicators, as skeletal indicators are generally not helpful in determining race and sex for children. Understanding group differences will help to provide a more focused and precise age range of the individual. In turn, a narrower age range will help to provide a more accurate profile of an unidentified individual.

In addition to forensic uses, such research has practical implications for archaeological studies. Teeth, or often only tooth crowns, are sometimes all that is left of an individual at an archaeological site. The adaptation of the dentition has resulted in its evolving into a tissue of extreme hardness and density, which, along with its resistance to degradation, has allowed it to survive in the fossil record better than skeletal material.
(Smith 1991). Analyzing the stage of formation of these teeth may likely be the only method available to estimate the individual’s chronological age (Hillson 1986). Having a modern sample with which to compare these teeth is important. Using a modern sample to evaluate standards developed in the past will aid in the understanding of variability and secular change between as well as within populations.
Normal Dental Development

Humans have two sets of dentition, the deciduous and the permanent. The deciduous teeth are lost and subsequently replaced by permanent teeth in a predictable pattern. During the period of change from primary to permanent dentition, a complement of the two types exists in the dental arcade. This complementary set of teeth is called the transitional dentition (Shaw et al. 1978).

Both deciduous and permanent teeth develop in the same fashion, regardless of each tooth’s morphology. Tooth formation begins with mineralization of the cusps of the crown of the tooth. The cusps join and begin to form the entire crown of the tooth. The pulp chamber develops after the occlusal surface has formed, followed by the beginning development of a root structure. The roots are the last to form, although eruption often occurs before the apex of the root has closed. As teeth can erupt before they have completed formation, an early loss of a deciduous tooth may trigger the earlier eruption of a permanent tooth, though formation will still proceed on schedule (Shaw et al. 1978).

The development of the deciduous teeth begins well before birth. Mineralization begins early in the second trimester of pregnancy, with crowns being partially complete in most teeth by birth (Smith 1991). The total formation of deciduous teeth takes place over two to three years. Eruption of these teeth takes place over about a one-year period, the bulk of which occurs during the second year after birth.

The permanent dentition begins formation within the first year of life, and complete formation of each tooth takes place over eight to twelve years (Smith 1991). The formation of these teeth occurs in clusters, with the last of the teeth beginning
formation around age ten. The first molar (M1, or six-year molar) is one of the teeth that begins formation within the first year of life. The two anterior incisors and the canines also begin formation during this time. Between the ages of about two years to four years, the premolars and second molar begin formation (M2, or twelve-year molar). Each tooth has a specific age range at which it emerges. The first molar and second molar (with which this study is concerned) erupt at around age six and age 12, respectively (Smith 1991).

Variation in Dental Development and Its Factors

While the development of the dentition is one of the most reliable indicators of chronological age, individual and normal group variation (regional, between populations) is significant. Compared to the stages of skeletal development, individual variation is only moderate, but it can be high enough to cause difficulties in ascertaining whether significant variation exists between groups (such as in the present study). Individual variation has been noted by many to be higher for eruption than for tooth formation. “There is continuous variation within populations. Consistent differences in the distribution of timing exist between the sexes and in man between ethnic groups” (Hillson 1986:181). Several studies have explored variation in dental development, perhaps due to problematic presentation in literature of dental eruption and formation as being minimally variable.

Simpson and Kunos (1998) argue that there is a significant degree of normal variation in the timing of dental development. This normal variation exists both within and across samples. Their research involved about three hundred individuals ranging in age from three months to eighteen years and examined the development of mandibular
permanent teeth. They found the canine tooth to be the most variable in its formation times and that it was affected by the status of health and hormones. As for the other teeth, the researchers found them to be resilient relative to the canine. Overall, the results of the sample were more variable than the researchers expected (Simpson and Kunos 1998).

The results implied to the researchers that a broader definition is needed of normative dental development. In order to accurately evaluate dental development, appreciation and consideration must be given for the normal variation in formation times. The authors state that the various dental schedules that have been established, including their own, vary significantly. The variation could be due to statistical analyses, sample composition, or population variation. Whatever the reason, the authors argue that the variation seen among researchers has important implications for the use of many dental schedules. The authors suggest that a good dental development schedule should be consistent and have a broad age range (Simpson and Kunos 1998). A broader age range for tooth stages necessarily impacts the exactness of a chronological age estimation; however, when taken with scored stages of several other teeth, such a range may actually provide a more accurate assessment.

Variation in formation and eruption of deciduous teeth has been studied by Liversidge and Molleson (2004). The researchers documented this variation using 182 modern individuals and 133 individuals represented by skeletal remains from the medieval period. Both mandibular and maxillary teeth were assessed and analyzed, and the researchers claim that the results obtained for crown completion (for canine, 1st molar, and 2nd molar) are similar to those of previous studies, but that timing of apex completion was later than what had been seen in the past. Though some variation did
occur between the modern and medieval populations, no significant difference existed between groups for either formation or eruption of teeth (Liversidge and Molleson 2004). These findings imply a lack of secular change occurring between the two samples.

The authors (Liversidge and Molleson 2004) argue that the development of deciduous teeth is in many ways different from the development of the permanent teeth. Deciduous teeth appear to have a much faster rate of formation with regard to both the enamel and dentine than the permanent teeth. This is not surprising, as normal deciduous tooth development occurs over a shorter period of time than does permanent tooth development (Smith 1991). Deciduous teeth also appear to have faster root growth, “reflected in the smaller root-cone angle in deciduous teeth compared with permanent teeth” (Liversidge and Molleson, 2004:174). The differences shown in deciduous tooth development imply a likelihood of higher accuracy of age prediction using them as opposed to using permanent teeth. Less variation occurs with a shorter time span of development. The authors do argue, however, that in order to better understand patterns between and within teeth, a view of the entire tooth formation continuum as a whole should be taken (Liversidge and Molleson, 2004).

Rajic et al. (1999) examined tooth eruption times in a large sample of Croatian children. The researchers found an average period of eruption (time needed for each tooth to fully erupt) to be 14.35 months. This average is later from one to about two months than the other studies cited by the authors. One study mentioned in their review found second molar eruption termination to be six months later than all previous studies, but the authors found their sample’s termination to be even later than that. Overall, they found
central incisors and second molars of the mandible emerged earlier. In the maxilla, the rest of the teeth emerged earlier (Rajic et al. 1999).

While tooth formation and eruption schedules are highly heritable, they are also influenced by other factors (formation much less than eruption), such as health and nutrition. Variation due to such factors must be addressed in research like the present study.

With regard to the deciduous dentition, severe malnutrition can delay eruption significantly. Non-eruption of primary teeth may also cause increased malnutrition, as teeth are an important part of the digestive process. Infants with malnutrition may suffer a delay in tooth eruption, but this delay is usually small. Additionally, its effect is not nearly as significant as the effect on height, weight, and overall skeletal development (Eveleth and Tanner 1990).

Infant size compared with gestational age has also been seen to influence age of eruption. A study noted by Eveleth and Tanner (1990) found that the most influential factor of the number of teeth erupted at twelve months of age was the infant’s weight and height. Infants with the lowest weights and heights had the least number of teeth erupted at that age.

Eveleth and Tanner (1990) have compiled data on tooth emergence from several populations around the world, illustrating the high degree of variability between populations (not necessarily ethnically distinct). At six months of age, the data show a range of populations having from 0.2 to 2.0 teeth. At one year of age the range is from 4.0 teeth to 9.0 teeth. These data show a significant decrease in variability between populations by age three (Eveleth and Tanner 1990). With regard to the permanent
dentition, less variability was seen between populations, but it was still significant. These
data showed significant overlap of each population’s age ranges of eruption. The overlap
indicated to the authors that variability was likely due to factors other than ethnicity
(Eveleth and Tanner 1990).

While no difference was seen in relatively wealthy countries (such as Finland and
England) between social classes with regard to eruption, a large difference was seen in
poorer countries. Economic circumstance was a large influence on number of teeth
emerged at each age in Nigeria. Rural villages were noted to average five teeth erupted
at one year of age, while the elite and wealthy averaged nine teeth at the same age. The
authors noted that this population showed perhaps the largest economic difference
possible between the two classes in a single population (Eveleth and Tanner 1990).

A study conducted in Finland explored the variation in eruption times of
permanent first molars and incisors as possibly influenced by premature birth (Harila-
Kaera et al. 2003). This study examined 328 prematurely born children compared with
1804 control children to determine the effect of premature birth on dental development.
Those children born prematurely showed a significantly earlier tooth eruption than the
control group. The authors suggest that pre-term birth affects the eruption process
because these teeth have gone through a sensitive period around the time of birth. The
teeth of preterm children had begun tooth formation “under the influence of various
neonatal systemic factors and accelerated growth period (catch-up growth) with related
unknown mechanisms, which may influence the eruption of the permanent incisors and
first molars in prematurely born children (Harila-Kaera 2003:293).”
These studies do well to illustrate the trend of significant within and between population variability in dental development. In most cases, the variability was noted to be much higher than expected. These studies also point to the idea mentioned previously that a higher variability is seen with eruption (and there are many factors that affect it) than with tooth formation. Variability as discussed here and its factors are important to consider when conducting research on groups differences in dental development.

Racial Variation in the Dentition

Exploring racial differences in dental development is at the forefront of the present study, and, therefore, racial differences in all aspects of the dentition should be discussed. Previous studies exploring racial differences in dental development have not all agreed about the nature of such differences. There has been a relative consensus among dental anthropologists about racial differences in tooth size and morphology. Several groups have been seen to possess distinct characteristics in tooth morphology when compared to other hereditary population groups. Such distinct characteristics are not said to occur only in the population with which they are identified, but are most commonly found in that population, with others exhibiting the traits only minimally. Overlapping does occur between populations. For tooth size, overlap occurs to the extent that labeling one group with the largest or smallest tooth size is difficult (Hillson 1986). While populational overlap does occur and is significant, generalizations of a population’s dental characteristics can be made and are useful in forensic and physical anthropology.

Australian Aborigines have been well documented in their dental characteristics, which have tended to be notably distinct from other ethnic groups. Haines (1972) noted
that this group tends to have a large, well formed dental arch. The tooth size in this group appeared to be the largest among all known races. This large size compared to other populations may be due in part to the extended isolation of this group from others, and may reflect a difference in diet. The difference may also merely reflect a lack of gene flow occurring between this group and others. Rogers (1988) also remarked that Australian Aborigines are a large toothed race (along with Melanesians and American Indians) with wide crowns. With regard to shape, the central incisors of Australian Aborigines are spatula shaped and usually broad (Haines 1972). The pulp cavities in this population are also large, and the presence of a Carabelli’s cusp is rare. In addition, individuals in this population tend to have a diastema at the midline. The formation of the third molar is usually rudimentary, although its absence is common (Haines 1972).

Southern African dental characteristics were investigated by several scientists in the first half of the past century. Descriptions included a tendency of teeth to have a large body below the crown with an equally large pulp cavity (Haines 1972). Short individual roots are also common. Overall tooth size is larger than European populations, but smaller than Australian Aborigines and Melanesians (Haines 1972). In addition, “the upper first premolars almost invariably have two distinct and well formed roots, and sometimes three, unlike many other races (Haines 1972:133).” The lower premolars are usually folded or U-shaped in their root structure. The third molar is usually present, well formed, and highly functional (Haines 1972). This population also commonly has a midline diastema (Haines 1972).

Mongoloid dental characteristics are based mostly on studies of Chinese and Mongol populations. Shovel shaped incisors is the most commonly cited feature of
Mongoloid populations, though it also occurs in American Indian groups as well. This trait is a form of incisor, most commonly maxillary incisors, where pronounced lingual margins contrast with a depressed inner surface, making the lingual side of the tooth appear like a shovel (Rogers 1988). The roots of canines and incisors are usually short in Mongoloid populations (Rogers 1988). The average size of teeth is noted to be larger than Europeans, but smaller than the populations already discussed (Haines 1972). Lower molars most commonly have three roots in these populations, a trait which is rare in European populations (Haines 1972). A wide and deep pulp cavity is also common, and Carabelli’s cusp is rare. Third molars are commonly absent, and, more notably, lower incisors are as well (Haines 1972). Such a trait is extremely rare in other populations.

American Indian populations also commonly have shovel shaped incisors as well as a midline diastema (Haines 1972). Large crowns and small roots are common, as well as increased size of molar crowns from the first to the third molars (Haines 1972). The reverse is true for most European individuals (Haines 1972). About one third of the population investigated exhibited rotated upper central incisors (Haines 1972). In this population, a Carabelli’s cusp is rare (Haines 1972).

European populations are generally considered to be of moderate tooth size, falling into neither the large toothed race category nor the small toothed race category (Rogers 1988). Overall, the European dental arch is narrow compared with other populations (Haines 1972). The appearance of European teeth is often said to be crowded, which may account for misplaced teeth and/or an uneven arch (Haines 1972). The incisors in this population are rounded with smooth surfaces, showing little tendency
for shovel shaping (Haines 1972). Lateral incisors are often peg shaped and tend to be smaller in size than central incisors. A large cingulum is commonly found on upper incisor teeth (Haines 1972). European second molars tend to have four cusps rather than the five commonly seen in other populations. Impaction is common as is the congenital absence of a third molar (Haines 1972). A Carabelli’s cusp is common in Europeans (Haines 1972).

To distinguish between American Whites and Blacks with regard to dental characteristics requires attention to individual ancestry; however, some trends have been noted in these American populations. American Blacks tend to have large crown dimensions, and Carabelli’s cusp is rare. American Whites have notably smaller lateral incisors than central (as in European populations) (Rogers 1988). American Whites also tend to have a particular proportion of the mandibular second molar which involves a reduction in buccolingual diameter and a relative increase in mesiodistal diameter (Rogers 1988).

The racial characteristics described make evident the overlap of traits between populations, but also the differences commonly seen between them. While determining the race, or ancestry, of an individual from the dentition alone is not possible, understanding the characteristics that distinguish populations can be a useful step in identifying unknown individuals (Haines 1972). In addition, the many differences between populations with regard to dental form imply a possibility of differences also existing between populations with regard to dental development.
Sex Differences in Teeth

A consensus has existed for some time that sexual differences are present in the dentition. With regard to morphology, the nature of such differences is generally agreed upon, but with regard to development, studies have found conflicting results. The following discussion will review literature addressing sexual differences in tooth morphology.

Dental researchers have consistently found a low degree of sexual dimorphism in the crown dimensions of human teeth, but the degree has been high enough to be mentioned throughout the literature (Hillson 1986, Hillson 1996, Rogers 1988, Scott and Turner II 1997). Male teeth are noted to be somewhat larger than female teeth in absolute size (Hillson 1986, Hillson 1996, Rogers 1988, Scott and Turner II 1997). One of the first studies to explore sexual dimorphism in the teeth of children found the difference in size (mesiodistal diameter) to be about 4% on average (Garn et al. 1964). Sexual dimorphism in the canine was found to be the greatest, with a difference of 6% on average (Garn et al. 1964). Molars showed less dimorphism, followed by premolars, and incisors with the least dimorphism at 3% average difference in size (Garn et al. 1964). The differences found were small but consistent in the researchers’ sample of children from Ohio. In another study, buccolingual diameter showed more sexual dimorphism at 5.6%, with males being larger. Different teeth were affected than in the previous study, with second molars being the most affected (Hillson 1986). The two diameters were put together and used as an index, and showed males to be significantly different than females (Hillson 1986).
In overall crown dimensions, male teeth are usually from 2 – 6% larger than female teeth (Scott and Turner II 1997). Even though this difference is seemingly small, “discriminant function analysis of tooth size can correctly classify the sexes 86% of the time (Scott and Turner II 1997:105).”

Other differences are present between male and female teeth which are important to note. Hypodontia and hyperdontia frequencies show sexual dimorphism. Females show higher instances of missing teeth than do males, and males have a higher frequency of supernumerary teeth than females (Scott and Turner II 1997). Females also have been noted to show a larger difference in size between upper central and lateral incisors relative to males (Rogers 1988). In addition, females have more pointed and narrower canines than males (Rogers 1988).

With regard to crown traits, many studies have explored sexual dimorphism, but significant variability occurred in findings from one sample to another. In a study noted by Scott and Turner (1997), several crown trait expressions thought to be sexually dimorphic were investigated in two samples of Japanese children. The findings illustrate the irregularities commonly encountered when assessing sex differences in crown traits. In one sample, six of 24 comparisons showed a significant sex difference, while the other sample showed no sex difference in four of those six comparisons. Of all traits explored, only the Carabelli’s cusp showed a significant sex difference in both samples (Scott and Turner II 1997).

The sex differences shown here are at times only slight, so that the developmental mechanisms that influence them would be difficult to determine. Sex differences do imply differences in development; therefore, investigating sexual differences in the
development of the dentition is important and useful as well. Research has indicated that genes on sex chromosomes are involved in several aspects of dental ontogeny (Scott and Turner II 1997). “For example, the structural gene for amelogenin is located on the X and Y chromosomes (Scott and Turner II 1997:108).” Within enamel development, amelogenin plays an important role. This protein makes up about ninety percent of the organic component of the enamel matrix, the secretion of which is a main aspect of enamel development (Hillson 1996). Amelogenin in humans is produced by only one gene, which has two copies. One copy is on the X chromosome, while the other is on the Y chromosome. Both copies of the gene are said to be expressed, which implies differences in expression between males and females (Hillson 1996).

Amelogenesis, or the formation of enamel, may possibly have a sexual difference in its rate which may be related to these genetic differences (Butter and Joysey 1978). No data are available on exact rates of amelogenesis, but data showing that female teeth erupt and complete calcification earlier than males support the idea that the duration of amelogenesis is involved in the production of sexually dimorphic teeth (Butter and Joysey 1978). The longer amelogenesis of males (if this in fact is true) may be an important influence on the differing sizes of teeth such as the canine. The relationship of amelogenin with the sex chromosomes may be an important underlying mechanism.

Chromosomal abnormalities which involve the sex chromosomes also have an influence on dental ontogeny (Scott and Turner II 1997). Crown and root morphology are influenced in many ways when such abnormalities occur.

“As the X chromosome exerts its primary influence on enamel while the Y chromosome promotes both enamel and dentine growth, crowns and roots may follow a
different set of instructions from the sex chromosomes during development (Scott and Turner II 1997:108).” Despite these differing instructions, crown and root traits still show little, if any, sexual dimorphism in their expression (Scott and Turner II 1997). As has been noted, the differences found are usually inconsistent across samples.

Sex differences appear to be found in nearly all aspects of dental development, including the resulting morphology of teeth. The consensus of differences in size does appear to be upheld, but with regard to other traits and ontogeny, more research should be done to better understand these differences.

**Age Standards and Variation in Formation Between Groups**

Several studies in anthropology and in odontology have been conducted which address tooth eruption and formation as age estimators of subadult individuals. Fewer studies in forensic literature or in anthropological literature in general address variation in tooth formation between groups, whether they are race, region, or sex groups. Even fewer studies have addressed differences in molar teeth. This discussion will review literature addressing age standards for tooth eruption and formation, the reliability and accuracy of these indicators of age, and variation found in tooth eruption and formation between different groups.

One of the most commonly used methods of dental age assessment, and the method used in this study, was developed by Demirjian, Goldstein, and Tanner (1973). Several age standards had already been defined by many different researchers, but these authors felt a new system should be developed. “Useful stages must be easily recognizable, and such that a tooth always passes through the same stages in every individual (Demirjian et al. 1973:213).” They asserted that stages are indicators of
maturity rather than size, so absolute length measurements cannot define any particular stage. They adopted an eight stage system, which scores teeth from beginnings of calcification (stage A) to the completion of root formation and apical closure (stage H). This system of age assessment was based on the analysis of radiographs for equal numbers of girls and boys from Montreal, Canada. The researchers acknowledge that the dental maturity scores for a given chronological age will vary across populations according to level of dental advancement. The researchers assume, however, that the actual pattern of development of teeth will not vary much between different populations. For this reason, they believe the stages scored will be similar in all populations differences only arising when a dental age is calculated. This system is noted by the researchers to be valid as a scoring system for all populations (Demirjian et al. 1973).

A study by Ajmal et al. (2001) compared three commonly used methods of age assessment from teeth to determine which was the most accurate and reliable. The sample was 100 patients from Karnataka, India. The first method used was the Gustafson method, which has been used since 1950. This method scores six regressive changes in a tooth: attrition, secondary dentin, gingival recession, cemental apposition, root resorption, and root transparency. The second system, Kashyap’s method, modified the Gustafson method by omitting gingival recession and root resorption, and including objective measurements. This method showed a difficulty in measuring length of secondary dentin and width of cemental apposition. The third method was a clinical technique termed the average stage of attrition method. Each cusp of each molar was given a score, and the averages of all cusps were calculated. The researchers found that the most useful method was the average stage of attrition, as its standard error was the lowest. This method,
However, has limitations pertaining to the dietary habits of the population. All methods showed a standard error close to zero (Ajmal et al. 2001).

While studying the dental ages of juvenile skeletons in the Arikara Indian populations of South Dakota (time period ranging from A.D. 1600-1835), Owsley and Jantz (1983) found the application of the American white dental formation standards to be less than ideal. Their research involved the evaluation of a commonly used set of standards for dental age assessment against an archaeological sample of Arikara Indian remains. Their objective was to show the variation that occurs on age assessments of different teeth. Each tooth was aged on its own merit and then compared within individual values. As the standards used allow each tooth to be aged independently according to root and crown formation, the age determined by one tooth should be quite similar to that determined by another tooth. If such a similarity is not seen, a likelihood exists that the developmental schedules of this sample do not parallel the schedules found in whites (Owsley and Jantz 1983).

The researchers of this study found that ages obtained from first and second premolars and mandibular incisors closely approximated each other (Owsley and Jantz 1983). Those dental ages determined by maxillary incisors and mandibular second molars were older, from six months to 1.1 years. Third molars were assigned ages that were, on average, two years older than ages assigned by premolars and mandibular incisors. The significant variability found in this study suggests that more than just normal individual variability is occurring. Owsley and Jantz (1983) believe the variability seen shows the presence of significant differences in tooth formation timing.
between these populations. Such timing differences necessarily complicate the assessment of dental ages in studies on growth and demographics.

The authors argue that because accurate assessment of the ages of preadult skeletons is important in many fields of investigation, the lack of normative data available for populations other than white children is problematic. Comparison of the dentition of individuals of a non-white race with those standards based on white populations is potentially a significant source of error in age assessment.

Another study tested the accuracy of the same set of standards tested by Owsley and Jantz (1983), in addition to another set involving formation timing of the permanent dentition. Saunders et al. (1993) applied these standards to a group of subadult skeletal remains from a 19th century historic cemetery. Tooth formation was evaluated for 241 subadult individuals from this period. Historic records indicate that the majority of these individuals were of European descent. Each tooth was given an age based on the standards being tested. Overall age estimates were determined by several different combinations of the standards, permanent teeth, and deciduous teeth.

The researchers found that the combination of permanent and deciduous teeth is the best method to use in estimating dental age. One set of standards used, which has an original reference sample beginning at birth, was found to be more accurate than the other, which began at three years of age. Overall, the researchers found that the estimated tooth formation age for sub adults from either forensic or archaeological samples provide accurate age assessments for the individual and the population as a whole. Their findings also imply a lack of secular change occurring between samples.
These results, while at first appearing to contradict those obtained by Owsley and Jantz (1983), in fact do not. This study asserts that the standards based on white children for dental formation timing are accurate when applied to a sample of white sub-adults from a relatively recent time period. Owsley and Jantz (1983) found that these standards are not entirely accurate when applied to a non-white population. Together, both studies suggest that within populations of one race, dental formation is much less variable than that to be found between populations. These studies suggest that further research into population variation in tooth formation is needed.

While the previous studies mentioned involve the accuracy of tooth formation standards, one particular study involves the accuracy of x-rays, or radiographs, in deriving these standards. Beynon et al. (1998) researched the process of x-ray absorbance by mineralized tissues of developing teeth and the radiographic images obtained. The authors state that previous studies indicate that age at onset of the mineralization stage is overestimated, while the age at crown completion is underestimated using x-rays. Among other problems, the determination of the completion of crown growth is reliant upon the identification of the last formed enamel at the cervix. This determination is difficult to recognize for various reasons, which have a significant influence on imaging.

The authors argue that crown completion times as estimated by radiographs are based on the interpretations of approximal enamel completion, as exact enamel completion cannot be seen in most radiographs. This argument suggests that the human population standards which are currently being used to determine tooth stage are not accurately representative of true anatomical and chronological stages of crown
development. Because of this, researchers should be extremely careful when referring sub-adult individuals to these radiological standards (Beynon et al., 1998).

One of the first important studies that explored possible differences between the sexes with regard to dental development was Demirjian and Levesque’s (1980) study of French-Canadian children. The researchers looked at over five thousand panoramic radiographs of children between 2.5 and 19 years of age. Using the method previously developed by Demirjian et al. (1973), each tooth was evaluated individually for a stage of development. For each stage, comparisons were made between boys and girls. In the earlier stages of development (Demirjian’s eight stages from A through H), a chronological similarity was seen between boys and girls. As development advanced, girls also advanced over boys. Specifically, stages A, B, and C of crown development showed no sex difference for the majority of teeth. For stage D, which is the completion of crown development, girls were more developed than boys by an average of .35 years for four teeth. For the stages following stage D, the average difference between sexes was .54, with the canine showing the largest dimorphism at .90 years. The authors suggest that there is an importance of sexual dimorphism during the period of root formation rather than during crown formation (Demirjian and Levesque 1980).

Up to the age of five to six years, no significant difference was seen between boys and girls in the timing of dental development (Demirjian and Levesque 1980). In later ages, girls were always more developed than boys.

Mincer, Harris and Berryman (1993) provide age benchmarks for American whites from 14 to 24 years of age using the formation of maxillary and mandibular second molars. The researchers involved in this study used the same classification
system used by Liversidge and Speechly (2001). Within individuals, formation of the maxillary third molar appeared to be more advanced than the mandibular third molar. Results and statistical analyses indicate that the root formation of this tooth was significantly earlier in males than in females. While the third molar is generally considered to be the most variable in the dentition, there are situations in which it is the only usable piece of data for age estimation. Because of this, variability on formation timing of this tooth is important to understand (Mincer, et al. 1993).

One study previously mentioned (Rajic et al. 1999) looked at overall timing of dental emergence and development compared with other studies’ findings. In addition to looking at the dental schedule of the sample, the researchers also recorded and analyzed sex differences in the period of eruption and ages of eruption (Rajic et al. 1999). Comparison of the sexes showed what the researchers believe to be a clear tendency toward earlier eruption in boys; however, the average period of eruption was lower in girls (Rajic et al. 1999).

As mentioned previously, studies exploring tooth formation and eruption variation between racial groups are few, but that is not to say they are nonexistent. The Journal of Dentistry published a study by Maki et al. (1999) which researched the impact of race on tooth formation. The research consisted of samples of American white, Japanese, and Chinese individuals from five to twelve years of age. Mandibular first molars were examined and assigned a stage of development from seven stages. These teeth were chosen because previous studies have indicated a consistency in their development. In statistical analyses, girls in all racial groups formed their teeth significantly earlier than boys, especially with regard to later stages. Between racial groups, researchers found that
tooth formation in American white children was more advanced than either the Japanese or Chinese group. Tooth formation was not markedly different between Japanese and Chinese, most likely due to the fact that both are Asian populations. The authors argue that the results obtained show significant differences among the races, which suggests that tooth formation as a whole is affected by the racial factor (the concept of the “racial factor will be discussed later).

A study conducted by Liversidge and Speechly (2001) produced somewhat different findings with regard to racial variation. This study compared tooth formation of Caucasian children with Bangladeshi children. The mandibular first molars were also used in this research, and each tooth was classified into a particular stage (though different stage standards were used than those employed by the previous study). Results obtained in this research indicate (as Maki et al.’s results do) that attainment of tooth developmental stages occurs earlier in girls than boys. Furthermore, the data indicate that girls not only develop the tooth earlier than boys, they also advance through the different stages more rapidly (a consideration not addressed by Maki et al.). With regard to racial differences, this study did not show a significant difference in tooth formation between Bangladeshi and Caucasian children. The authors offer as an explanation the wide variation in age and small size of the sample (Maki et al. 1999).

A study conducted by Harris and McKee (1990) explores tooth development for blacks and whites of the middle southern United States. Maxillary and mandibular molars were assigned mineralization stages according to the Moorees, Fanning, and Hunt scheme (which has about five more stages than the Demirjian system). The results indicated that females develop more rapidly than males overall, with blacks being more
sexually dimorphic than whites. They also found overall dimorphism to be greater in the root than in the crown. Within sex groups, blacks achieved mineralization stages for all teeth earlier than whites by about 5%. Black males are earlier than white males by about 4%, while black females are earlier than white females by about 6%. The difference was most notable in later developing teeth such as the canine and third molar. In addition, the race difference was proportionately greater during the stages of crown development than during root development (Harris and McKee 1990).

The results of each of these studies indicate that variability in tooth formation is frequently seen, for some teeth more than others, between groups. Differing methods for determining stage of tooth formation may play a role in the varying results obtained by different researchers, and this should be taken into account when interpreting data on tooth formation variation. Reliability of x-rays in determining tooth formation stage, regardless of standard used, is less than perfect, and attention should be paid to this when conducting research using them. Overall, these studies imply that there is in fact variation in tooth formation which may be correlated with race and sex differences. I plan to address this variation in my research, taking into account the previous research that has been done.

The Race Debate

“Our subdivisions are not called races as we have no interest in entering the debate on whether or not human races exist (Scott and Turner II 1997:168).” This statement was made during a discussion of dental variation in The Anthropology of Modern Human Teeth. The authors discussed variation between groups in terms of geographic categories rather than race categories. These particular authors seem to
believe that to study racial variation as such automatically enters a researcher into the important and controversial debate about race that is at the forefront of modern anthropology. This researcher agrees, and since this study examines dental variation between races, the idea of race and its uses should be discussed.

While engaging in cross-cultural comparison, anthropologists may purposely or inadvertently classify people according to similarities and differences in order to better understand variation existing within and between cultures. This is not an unusual thing to do, and people in areas all over the world group individuals, and themselves, according to certain characteristics. However, anthropologists must be careful not to classify people in another culture according to standards of their own culture. This is because those characteristics used to classify people in one culture may be different from those used in another culture. Race is one example.

In a multi-ethnic country such as the United States, a person might classify any African-American, Caribbean-American, or individual with both a black and a white parent, as black. Skin color is a characteristic used, but classification into “black” as race might apply to individuals with varying skin shades. An individual classified as black in the United States could be considered white in Brazil, if his or her skin color was consistent with the definition of that “race” in that country (Bamshad and Olson 2003). The same individual might be classified by South Africans as either colored or black, two completely different categories not distinguished in the U.S. at all (Bamshad and Olson, 2003).

In anthropology, race is both a biological and a cultural term. The classification into races may differ by culture, but it is generally agreed upon that the term race,
whether defined biologically or culturally, refers in at least some way to physical characteristics of an individual. Physical anthropologists attempt to classify individuals (namely skeletal remains) into races by adhering to certain standards in biology that appear to put an individual into one group. The problem with this approach is that the classification determined by biology may be different from that determined by culture, which may also differ from the racial classification the individual gave him or herself. Individuals may identify themselves as one race, while biology may identify them as another.

Biological definitions of race do still have merit to some researchers, even if they differ from the cultural definitions. One example involves the propensities of some groups to have certain diseases. For instance, groups with African ancestry show a higher tendency to have sickle cell disease than other groups (Bamshad and Olson, 2003). In this way, an individual who does not classify himself as African, or black, might be defined so by a doctor who diagnoses him with sickle cell.

No single definition of race is entirely correct or agreed upon by all people (Goldberg, 1992). The physical and genetic characteristics that make some groups different from others are also not widely agreed upon. Research involved with understanding those physical characteristics that classify individuals into races is important in the understanding of the term race itself.

Some anthropologists, sociologists, and others have entered the race debate with the idea the race does not exist, at least in the way we know it. The notion held by many who take this side is that race is a social construct (Graves 2004). This idea has much evidence and support throughout the academic community. Perhaps the most noteworthy
attention to this debate (at least to anthropologists) came in the form of a statement on “race” put forth by the American Anthropological Association. In this statement, important evidence for the idea of race as a social construct is addressed.

In the United States both scholars and the general public have been conditioned to viewing human races as natural and separate divisions within the human species based on visible physical differences. With the vast expansion of scientific knowledge in this century, however, it has become clear that human populations are not unambiguous, clearly demarcated, biologically distinct groups. Evidence from the analysis of genetics (e.g., DNA) indicates that most physical variation, about 94%, lies within so-called racial groups. Conventional geographic ‘racial’ groupings differ from one another only in about 6% of their genes. This means that there is greater variation within ‘racial’ groups than between them. In neighboring populations there is much overlapping of genes and their phenotypic (physical) expressions. Throughout history whenever different groups have come into contact, they have interbred. The continued sharing of genetic materials has maintained all of humankind as a single species (AAA 1998:1).

This statement summarizes well the arguments put forth by many in academia today, namely anthropology. History has shown that the idea of race has more meanings socially than it does biologically. The physical characteristics of a “race” are defined differently by different groups, do not always occur together, and overlap with many other groups. The American Anthropological Association (AAA) notes that those physical variations that are said to define a race have only the social meaning that humans put on them (AAA 1998). In addition, the AAA notes that races were constructed in order to provide a natural hierarchy supposedly established by God (AAA 1998). One may not be surprised to learn that the proponents of this hierarchy were at its highest level. Racism as the basis for the construction of race would not be too strong a statement according to this argument.
Researchers in anthropology have recently begun to explore the status of the race concept in physical anthropology as well as the other subfields. A 2003 issue of *American Anthropologist* devoted most of its content to exploring this issue from the varying viewpoints of several renown researchers. Jane Buikstra, et al. (2003), George Armelagos and Dennis Van Gerven (2003), and Rachel Caspari (2003) were among the researchers who explored the race concept in this issue. Research such as theirs is paramount to gaining a holistic understanding of the concept of race.

Regardless of whether a researcher believes that race is complex issue, that biological and social race differ dramatically, or that race does not exist at all, the arguments for each stance need to be noted when researching racial variation. In the present study, the noted races are Black, White, and Asian, categories that are clearly limiting with regard to geographic and ethnic diversity. These categories were used because each medical file provided a self-identified race (or parent identified) listed as such. The difference between biological and social race does impact the findings of this study for several reasons. First, admixtures are likely present throughout the sample. None was identified as such by his or her parent. Socially, these individuals may classify themselves or be classified as mixed, black, or even white. Such classifications are not able to be addressed in this study. Secondly, geographic variation is not accounted for. Individuals identified as black may have parents or ancestors from vastly different regions, such as the Caribbean, northern Africa, southern Africa, or the Pacific. The possibly wide geographic regions represented in this sample may result in large variability within the group. Lastly, the overall findings of this study likely do not apply to all individuals. Admixtures may not fall exactly into one category or another, and
some people may not agree with the terms “black”, “white”, and “Asian”. The hope of this researcher is that readers of this study will acknowledge the researcher’s understanding of the complex nature of the idea of race and the limitations of its use in studies such as this.
Chapter 3: Materials and Methods

Sample

For this study, a sample of radiographs was provided by the School of Dentistry at Louisiana State University. The sample consists of panorex radiographs obtained either as general screening radiographs for new patients, orthodontic screening radiographs to assess future orthodontic needs, or radiographs needed for diagnosis and treatment of specific problems such as infection. Individuals with chromosomal abnormalities, such as Down Syndrome, and individuals with developmental problems were not included. The sample includes individuals from southern Louisiana, mainly residing in Orleans Parish, Jefferson Parish, St. Bernard Parish, Plaquemines Parish, and a few other surrounding areas. Each radiograph is of an individual whose age, sex, and racial affinity are known. Due to the fact that all individuals were minors at the time of x-ray, such information was provided by a parent or guardian in the medical history section of the person’s file. These files were compiled beginning with the individual’s first visit to the clinic and included personal medical history information, demographic information, parental concerns, hygiene habits, and symptoms. Permission to use this sample was obtained by the Institutional Review Board (IRB) at Louisiana State University and LSU Health Sciences Center (Appendix A). In accordance with IRB protocol, any information that could be used to identify a participant was not used.

The socioeconomic status of the sample is generally lower middle class to upper lower class, as noted by Robert Barsley (personal communication, May 6, 2005). The sample gathered consisted of 303 radiographs of individuals ranging in age from four years to 14 years. Far fewer radiographs were found for individuals under the age of six.
years than for those of other ages. With regard to sex, a relatively equal distribution was obtained, with 153 females and 150 males. An attempt was made to gather x-rays in equal numbers of Asian, black, and white individuals, but significantly less Asian participants were found than for the other two categories. Table 1 shows the racial distribution of the sample.

Table 1: Number of x-rays gathered for each race

<table>
<thead>
<tr>
<th>Race</th>
<th>X-rays gathered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>12</td>
</tr>
<tr>
<td>Black</td>
<td>141</td>
</tr>
<tr>
<td>White</td>
<td>150</td>
</tr>
<tr>
<td>TOTAL</td>
<td>303</td>
</tr>
</tbody>
</table>

The date on which each x-ray was taken varies greatly. X-rays from closed files, or files of individuals who no longer visit the school of dentistry, were collected first. Such files range in date from the 1980s to 2004; however, many older files were missing demographic information and could not be used. For this reason, more recent files exist in greater numbers in this sample than earlier files. Active files were collected from the pediatric clinic at the LSU School of Dentistry.

Methodology

Each x-ray was catalogued and subsequently scanned into a computer file using a high resolution x-ray scanner provided by the school of dentistry. Adobe Photoshop was
used to adjust the brightness and contrast of those x-rays whose details were not clear
enough to ascertain an accurate stage classification.

The 1st and 2nd mandibular molars of each radiograph were classified into stages of development. Maxillary molars were unable to be used as the quality of a panorex x-ray distorts the details of the root structure for these teeth. Bitewing x-rays would be more appropriate for examining these teeth.

The method of classification used in this study is that developed by Demirjian et al. (1973) which describes eight distinct stages of development for molar teeth. The system provides detailed written criteria for each stage along with diagrams and x-ray examples of each stage. The accuracy of this technique may not be as high as some other methods, because it uses only eight stages of molar development over approximately ten or eleven years of development. Demirjian et al.’s (1973) method was chosen because it is widely used by clinicians and forensic practitioners, especially forensic odontologists (Mincer et al. 1993). In addition, this classification system is well designed and clear in its criteria, which allows non experts of dental development to stage teeth accurately.

Each 1st and 2nd mandibular tooth was examined and placed into a stage. Despite agreement in the field of dentistry that relative symmetry exists between left and right molars, both molars of both sides were scored independently. After the teeth were staged for the first time, recorded stages were set aside and the teeth were reanalyzed for stage. The second set of recorded stages was then compared to the first set, to ensure consistency in staging. Figure 1 illustrates the Demirjian et al. (1973) method of classification with x-ray examples provided by the data sample of this study.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>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.</td>
</tr>
<tr>
<td>B</td>
<td>Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.</td>
</tr>
<tr>
<td>C</td>
<td>Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen. The beginning of dentinal deposit is seen. The outline of the pulp chamber has a curved shape at the occlusal border.</td>
</tr>
<tr>
<td>D</td>
<td>The crown formation is completed down to the cementoenamel junction. In molars, the pulp chamber has a trapezoidal form. Beginning of root formation is seen in the form of a spicule.</td>
</tr>
<tr>
<td>E</td>
<td>Molars: Initial formation of the radicular bifurcation is seen in the form of a calcified point or a semi-lunar shape. The root length is still less than crown height.</td>
</tr>
<tr>
<td>F</td>
<td>Molars: 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. The root length is equal to or greater than crown height.</td>
</tr>
<tr>
<td>G</td>
<td>The walls of the root canal are now parallel and its apical end is still partially open (distal root in molars).</td>
</tr>
<tr>
<td>H</td>
<td>The apical end of the root canal is completely closed (distal root in molars). The periodontal membrane has a uniform width around the root and apex.</td>
</tr>
</tbody>
</table>

Figure 1: Demirjian et al. (1973) stages of permanent dental development with X-ray examples from sample used in present study. (Descriptions taken from Demirjian et al. 1978:221-226)
After all teeth were staged twice, data were quantified and entered into an SPSS (Statistical Package for the Social Sciences) file along with the individual’s age, sex, and race, and date of x-ray. The data were then analyzed statistically using SPSS to determine the significance of differences between sex, race, and decade groups. This was done with the help of a statistician and through the use of various descriptive statistics, univariate analyses of variance, and comparison of group means. Analyses of variance within each group were also performed to determine if the results obtained with each of these samples are representative of the larger population of each racial and sex group, and to assess the degree of within group variability.
Chapter 4: Results

Descriptive Statistics

Descriptive statistics were performed first to determine the distribution of the sample, and to ascertain whether or not the data needed to be restricted to perform analyses of variance. As shown earlier in Table 1, 303 x-rays were collected. Three cases from this collection were removed due to the poor quality of the x-ray. The edited racial distribution is seen in Table 2, under totals. Table 2 also illustrates the age distribution of the sample by race, using the category “new age” to represent age ranges of one year.

Table 2: Age range distribution by race

<table>
<thead>
<tr>
<th>New age</th>
<th>Race</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Asian</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Asian</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Asian</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Asian</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Asian</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Asian</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>2</td>
</tr>
<tr>
<td>Black</td>
<td>2</td>
</tr>
<tr>
<td>White</td>
<td>0</td>
</tr>
</tbody>
</table>

This table shows that both age and race distribution of the sample is severely skewed. The small number of Asian individuals prevented any accurate statistical analysis of that group, so they were eliminated from analyses of variance.

The distribution of number of x-rays per decade in which they were taken is shown in Table 3. Decade 1 represents the period from 1980 through 1989, decade 2
represents 1990 through 1999, and decade 3 represents 2000 through to the present day. The earlier decades show fewer x-rays in the sample, but the distribution is such that statistical analyses could be done to explore secular change in molar development.

Table 3: Distribution of x-rays taken in each decade

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>44</td>
<td>14.7</td>
<td>14.7</td>
<td>14.7</td>
</tr>
<tr>
<td>2</td>
<td>76</td>
<td>25.3</td>
<td>25.4</td>
<td>40.1</td>
</tr>
<tr>
<td>3</td>
<td>179</td>
<td>59.7</td>
<td>59.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>299</td>
<td>99.7</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Overall means were calculated for each subset of the two groups, sex and race, being analyzed. These means appear in Tables 4 and 5 respectively.

Table 4: Mean age for each sex in sample, where 0 = female and 1 = male

<table>
<thead>
<tr>
<th>Dependent Variable: Age/mos</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>SexNum</td>
<td>Mean</td>
</tr>
<tr>
<td>0</td>
<td>115.320</td>
</tr>
<tr>
<td>1</td>
<td>118.842</td>
</tr>
</tbody>
</table>

Table 5: Mean age for each race analyzed, where 1 = white and 2 = black

<table>
<thead>
<tr>
<th>Dependent Variable: Age/mos</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>RaceNum</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>116.177</td>
</tr>
<tr>
<td>2</td>
<td>117.985</td>
</tr>
</tbody>
</table>

In sex, there is a mean difference in age of approximately 3 months, and in race, the mean difference is about 1 month.
First Molar (M1)

As seen in Table 2, the age distribution of the sample is skewed, with a minimal number of individuals under the age of seven. As the first molar, also known as the six-year molar, is usually completely formed before age 8, variability of stages for this tooth was minimal, with the majority of cases having achieved the stage of completion, or stage H. Despite the homogeneous nature of the sample for M1, a univariate analysis of variance was performed, the results of which are seen in Table 6. Relative symmetry was seen between left and right molars, so left molar 1, or LM1, was used for this analysis.

Table 6: Univariate analysis of variance for LM1, sex, race, and interactions

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>88569.622</td>
<td>17</td>
<td>5314.913</td>
<td>11.973</td>
<td>.000</td>
<td>.416</td>
</tr>
<tr>
<td>Interest</td>
<td>25601.208</td>
<td>1</td>
<td>25601.208</td>
<td>765.630</td>
<td>.000</td>
<td>.731</td>
</tr>
<tr>
<td>SexNum</td>
<td>59.698</td>
<td>1</td>
<td>59.698</td>
<td>.179</td>
<td>.672</td>
<td>.001</td>
</tr>
<tr>
<td>RaceNum</td>
<td>96.600</td>
<td>2</td>
<td>48.300</td>
<td>0.954</td>
<td>.347</td>
<td>.000</td>
</tr>
<tr>
<td>LM1</td>
<td>27969.700</td>
<td>4</td>
<td>6942.427</td>
<td>20.927</td>
<td>.000</td>
<td>.229</td>
</tr>
<tr>
<td>SexNum * RaceNum</td>
<td>602.711</td>
<td>2</td>
<td>251.356</td>
<td>.650</td>
<td>.466</td>
<td>.005</td>
</tr>
<tr>
<td>SexNum * LM1</td>
<td>102.477</td>
<td>3</td>
<td>34.159</td>
<td>.104</td>
<td>.957</td>
<td>.001</td>
</tr>
<tr>
<td>RaceNum * LM1</td>
<td>419.458</td>
<td>3</td>
<td>139.813</td>
<td>.420</td>
<td>.733</td>
<td>.005</td>
</tr>
<tr>
<td>SexNum * RaceNum * LM1</td>
<td>622.402</td>
<td>2</td>
<td>266.200</td>
<td>.614</td>
<td>.444</td>
<td>.008</td>
</tr>
<tr>
<td>Error</td>
<td>92204.108</td>
<td>282</td>
<td>326.955</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4470122.000</td>
<td>300</td>
<td></td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>1692747.950</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The above table shows the significance, or p value, of the difference in timing of LM1 development according to sex to be .957, which is much higher than the level needed for statistical significance (p< .05). This p-value indicates that no difference is seen between males and females in timing of LM1 development, or age at each tooth formation stage. With regard to timing of LM1 development for the race category, no
significance was found. The p value for this interaction was .733. In addition, no significance was seen for the interaction of sex, race, and LM1 development (p=.44).

From this table, the correlation of age with overall molar development is confirmed with the p value of LM1 being less than .000. This is to be expected, as development advances with age. In looking at the column of Partial Eta Squared, one can see the proportion of variability explained by each variable or interaction. While the values are extremely low for the categories examined (which showed no significant relationship), the value for LM1 is slightly higher, at .229. This shows that 22.9% of the variability in LM1 development can be explained by age. This leaves close to 80% of variability explained by other factors. The high number of individuals with stage H left virtually no variability in this category, so little can be said about the factors affecting LM1 development.

**Second Molar (M2)**

The left side (LM2) of this tooth was also used for variance analysis, as symmetry between sides was still seen, and to ensure consistency. In instances where the variablenewlm2 is seen, the variable LM2 has been changed to numerical values for better analysis. Due to the extremely small number of individuals exhibiting stages A, B, and H in this sample, these stages were removed in order to more accurately analyze the sample. In Table 7, the overall mean age in months is shown for each stage of development for the entire sample.
Table 7: Mean age in months for stages of left 2nd molar development

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mean</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>83.220</td>
<td>2.962</td>
<td>77.529</td>
<td>89.113</td>
</tr>
<tr>
<td>D</td>
<td>104.186</td>
<td>1.460</td>
<td>101.736</td>
<td>108.636</td>
</tr>
<tr>
<td>E</td>
<td>119.051</td>
<td>1.574</td>
<td>116.903</td>
<td>122.200</td>
</tr>
<tr>
<td>F</td>
<td>132.895</td>
<td>1.808</td>
<td>129.336</td>
<td>136.454</td>
</tr>
<tr>
<td>G</td>
<td>146.080</td>
<td>1.716</td>
<td>142.672</td>
<td>149.428</td>
</tr>
</tbody>
</table>

Table 7 shows also that stage C exhibits much more variability within the sample than do the other stages, with a standard deviation of 2.992.

Univariate analysis of variance was performed for newlm2 to determine its interaction with sex, race, and sex and race together. The results are illustrated in Table 8 below.

Table 8: Univariate analysis of variance for newlm2, sex, race, and interactions

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>103054.486</td>
<td>19</td>
<td>5439.096</td>
<td>32.898</td>
<td>.000</td>
<td>.705</td>
</tr>
<tr>
<td>Intercept</td>
<td>2661657.765</td>
<td>1</td>
<td>2661657.765</td>
<td>17357.13</td>
<td>.000</td>
<td>.995</td>
</tr>
<tr>
<td>SexNum</td>
<td>647.412</td>
<td>1</td>
<td>647.412</td>
<td>3.927</td>
<td>.049</td>
<td>.019</td>
</tr>
<tr>
<td>RaceNum</td>
<td>170.819</td>
<td>1</td>
<td>170.819</td>
<td>1.035</td>
<td>.310</td>
<td>.004</td>
</tr>
<tr>
<td>newlm2</td>
<td>90907.301</td>
<td>4</td>
<td>22726.978</td>
<td>137.840</td>
<td>.000</td>
<td>.679</td>
</tr>
<tr>
<td>SexNum * RaceNum</td>
<td>4.505</td>
<td>1</td>
<td>4.505</td>
<td>.027</td>
<td>.869</td>
<td>.000</td>
</tr>
<tr>
<td>SexNum * newlm2</td>
<td>531.514</td>
<td>4</td>
<td>132.878</td>
<td>.806</td>
<td>.522</td>
<td>.012</td>
</tr>
<tr>
<td>RaceNum * newlm2</td>
<td>781.228</td>
<td>4</td>
<td>195.307</td>
<td>1.185</td>
<td>.318</td>
<td>.018</td>
</tr>
<tr>
<td>SexNum * RaceNum * newlm2</td>
<td>829.476</td>
<td>4</td>
<td>207.369</td>
<td>1.266</td>
<td>.268</td>
<td>.019</td>
</tr>
<tr>
<td>Error</td>
<td>43031.392</td>
<td>281</td>
<td>153.600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>419050.000</td>
<td>281</td>
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<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>146085.117</td>
<td>280</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dependent Variable: AgeMths
a. Computed using alpha = .05
b. R Squared = .755 (Adjusted R Squared = .654)

Between subjects effects
This table shows that the mean age in months for each stage of new Lm2 development is not significantly affected (where \( p < .05 \)) by sex (\( p = .522 \)) or race (\( p = .318 \)). The interaction of race and sex with left molar 2 development is also not significant (\( p = .288 \)). This means that the average age in months at each stage of LM2 development is not significantly different for black females, white females, black males, or white males. In addition, the Partial Eta Squared values for these three factors ranges from .012 to .019, indicating that less than 2% of the variability in age at each stage of development can be explained by sex, race, or sex and race together.

A significant relationship was found with sex and age in months of the sample. The \( p \) value for SexNum is .49 which indicates that one sex in the sample is having x-rays taken at and earlier age than the other sex. Referring back to Table 4, one can see that the mean age for females is 115.32 months, where the mean age for males is 118.842 months. Partial Eta Squared, however, shows that only 1.5% of the variability is explained by sex, an amount comparable to the percentages explained by the non-significant values. The two values together suggest that females are having x-rays at a slightly earlier age than males, but also that the effect is slight with regard to how much variability is explained by sex.

Mean comparisons were made for average age in months of each race and sex at each stage of tooth development, and although statistical significance of mean differences has not been shown, these mean comparisons do illustrate a small degree of variation between groups. The average age in months for each stage of development for each sex is shown in Table 9.
Table 9: Mean ages for each stage of LM2 development for sex, 0 = female, 1 = male

<table>
<thead>
<tr>
<th>SexNum</th>
<th>newlm2</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>0</td>
<td>C</td>
<td>85.619</td>
<td>4.430</td>
<td>76.895</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>100.812</td>
<td>2.002</td>
<td>96.869</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>116.825</td>
<td>2.307</td>
<td>112.282</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>129.702</td>
<td>2.526</td>
<td>124.729</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>143.643</td>
<td>2.215</td>
<td>139.281</td>
</tr>
<tr>
<td>1</td>
<td>C</td>
<td>80.821</td>
<td>4.024</td>
<td>72.898</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>107.567</td>
<td>2.097</td>
<td>103.438</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>121.278</td>
<td>2.140</td>
<td>117.064</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>136.088</td>
<td>2.587</td>
<td>130.994</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>148.458</td>
<td>2.621</td>
<td>143.297</td>
</tr>
</tbody>
</table>

For all stages except stage C, females have an earlier average age at each stage of development than males by about 5 to 7 months. Again, stage C shows a much higher standard error than the other stages, suggesting more variability in the timing of that stage than others.

Table 10 shows the average ages of each stage for each race, black and white.

Table 10: Mean ages for each stage of LM2 development for race, 1 = white, 2 = black

<table>
<thead>
<tr>
<th>RaceNum</th>
<th>newlm2</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>1</td>
<td>C</td>
<td>84.536</td>
<td>4.024</td>
<td>76.612</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>102.044</td>
<td>2.082</td>
<td>97.945</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>118.283</td>
<td>2.244</td>
<td>113.864</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>129.095</td>
<td>2.526</td>
<td>124.122</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>146.929</td>
<td>2.323</td>
<td>142.354</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>81.905</td>
<td>4.430</td>
<td>73.181</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>106.335</td>
<td>2.018</td>
<td>102.361</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>119.819</td>
<td>2.206</td>
<td>115.476</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>136.695</td>
<td>2.587</td>
<td>131.601</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>145.173</td>
<td>2.526</td>
<td>140.199</td>
</tr>
</tbody>
</table>
For stages C and G, blacks have an earlier mean age at achievement of the stage, by only about one to three months. For the other stages, whites have an earlier mean age at achievement of each stage by one month to seven months. The greatest difference is seen in stage F where whites have an earlier mean age at attainment by seven months.

The average ages at attainment of each LM2 molar stage were also reported for the interaction of sex and race, and those means are seen in Table 11.

Table 11: Mean ages for each stage of LM2 development for each race, 1=white, 2=black interacting with each sex, 0=female, 1=male

<table>
<thead>
<tr>
<th>SexNum</th>
<th>RaceNum</th>
<th>newlm2</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>C</td>
<td>87.571</td>
<td>4.853</td>
<td>78.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>97.154</td>
<td>2.518</td>
<td>92.195</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>117.400</td>
<td>3.315</td>
<td>110.872</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>123.833</td>
<td>3.707</td>
<td>116.535</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>146.857</td>
<td>2.802</td>
<td>141.340</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C</td>
<td>83.667</td>
<td>7.413</td>
<td>69.069</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>104.471</td>
<td>3.114</td>
<td>98.338</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>116.250</td>
<td>3.210</td>
<td>109.929</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>135.571</td>
<td>3.432</td>
<td>128.814</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>140.429</td>
<td>3.432</td>
<td>133.671</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>C</td>
<td>81.500</td>
<td>6.420</td>
<td>68.858</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>106.933</td>
<td>3.315</td>
<td>100.405</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>119.167</td>
<td>3.026</td>
<td>113.207</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>134.357</td>
<td>3.432</td>
<td>127.600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>147.000</td>
<td>3.707</td>
<td>139.701</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C</td>
<td>80.143</td>
<td>4.853</td>
<td>70.587</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>108.200</td>
<td>2.568</td>
<td>103.143</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>123.389</td>
<td>3.026</td>
<td>117.430</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>137.818</td>
<td>3.871</td>
<td>130.195</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>149.917</td>
<td>3.707</td>
<td>142.618</td>
</tr>
</tbody>
</table>

Dependent Variable: Age/mos

Examining these mean differences reveals no clear patterns as to whether black females achieve stages earlier or later than white females, or whether black males achieve
stages earlier or later than black males. The direction of the mean differences changes with each stage of development, suggesting more variability exists within groups than between them.

Secular Change

The idea that timing of molar formation may be changing over recent years was explored with an analysis of variance. Referring back to Table 3, one can see that although the distribution of x-rays taken in each decade was skewed, enough examples exist in each time period to explore change over time. Despite decade 3 (2000 through the present day) only being about half completed, enough examples were provided from these years to explore possible trends of this period. The results of the variance analysis for decade and LM2 development with age in months are seen in Table 12.

Table 12: Univariate Analysis of Variance for decade and newlm2 interactions

<table>
<thead>
<tr>
<th>Source</th>
<th>Type II Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>110760.590</td>
<td>20</td>
<td>5530.030</td>
<td>32.963</td>
<td>.000</td>
<td>703</td>
</tr>
<tr>
<td>Intercept</td>
<td>600904.288</td>
<td>1</td>
<td>600904.288</td>
<td>3573.132</td>
<td>.000</td>
<td>928</td>
</tr>
<tr>
<td>decade</td>
<td>197.115</td>
<td>2</td>
<td>98.558</td>
<td>8.575</td>
<td>.004</td>
<td>004</td>
</tr>
<tr>
<td>newlm2</td>
<td>62430.303</td>
<td>7</td>
<td>8918.768</td>
<td>53.682</td>
<td>.000</td>
<td>572</td>
</tr>
<tr>
<td>decade * newlm2</td>
<td>3311.323</td>
<td>11</td>
<td>301.084</td>
<td>1.792</td>
<td>.055</td>
<td>066</td>
</tr>
<tr>
<td>Error</td>
<td>48765.404</td>
<td>278</td>
<td>180.006</td>
<td>1.728</td>
<td>.055</td>
<td>066</td>
</tr>
<tr>
<td>Total</td>
<td>4463066.000</td>
<td>296</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>157466.000</td>
<td>296</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Computed using alpha = .05
b. R Squared = .703 (Adjusted R Squared = .682)

The interaction of decade and newlm2 development shows a p value of .055, which is close to statistical significance (p<.05). Referring to Partial Eta Squared for this interaction, 6.6 % of the variability in age at stage of molar development can be
explained by decade. This percentage is fairly large for a data sample such as this, suggesting that at least some important change in age at stage of molar development has occurred over time. Looking at the mean age in months for each stage of development per decade, one can see that the direction of this change is somewhat unclear. These means are seen in Table 13.

<table>
<thead>
<tr>
<th>Decade</th>
<th>Stage</th>
<th>Mean (Age/mos)</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
<td>50.00</td>
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There is a somewhat clear trend in stages D through G for later development from decade 1 to decade 2, from one month to 13 months, with the greatest differences
occurring in the later stages of LM2 development. This suggests that individuals whose x-rays were taken in the 1990s achieve the later stages of development at a later age, which in turn suggests that the entire formation of LM2 has taken longer to complete in this decade on average, than in the 1980s. Stressing the indication of the p-value and Partial Eta Squared of the variance analysis that these results are not statistically significant is important. These mean comparisons do indicate some directional change from the 1980s to the 1990s, but the significance of such change is relatively low. In addition, the mean ages at stage attainment for decade 3 do not continue this pattern, being variable in whether mean ages are earlier or later for this group. Sample size of both decade 1 and decade 2 should be increased to further explore the significance of these mean differences.
Chapter 5: Discussion

Three important factors were examined with regard to permanent molar development in this study: sex, race, and decade of examination. The exploration of race and sex differences in timing of dental development has been undertaken by many researchers (Demirjian et al. 1980; Harris and McKee 1990; Liversidge and Molleson 2004; Liversidge and Speechly 2001; Maki et al. 1999; Mincer et al. 1993; Owsley and Jantz 1983). The studies exploring these group differences have not achieved highly similar results with regard to the nature of such differences. In addition, the exact mean ages at stages of development are difficult to compare across studies due to varying classification systems used. Despite the apparent limitations, this discussion will examine the results of the present study in the light of previous studies.

Little can be said about the results for left molar 1, as the age distribution did not allow for a meaningful analysis of the formation of this tooth. For an accurate assessment of this tooth, panoramic radiographs must be collected in larger numbers for individuals under seven years of age. Even with the lack of variability in this analysis, a high correlation was found between stage of molar development and age. This supports the idea that dental age is correlated with chronological age.

For left molar 2, the overall mean ages at each stage (Table 7) were somewhat later than the median ages reported by Demirjian and Levesque (1980) who first explored sex differences in tooth formation. Only median ages were reported for this study, so averages may differ quite dramatically. The median ages for both boys and girls in Demirjian and Levesque’s (1980) study were about one year earlier than the mean ages for the same groups in the present study. Variability is likely to exist between the
population of French-Canadian children used for their study and the Southern Louisiana population used for the present study. In addition, the population used in Demirjian and Levesque’s (1980) study was significantly earlier than the bulk of this study’s population.

In looking at the standard deviations of the mean ages at each stage (Table 7 and Table 9), significant variability is shown within this sample. Overall standard deviation ranges from about 1.4 to 1.8 months, with stage C showing a 2.99 month standard deviation. Mean ages by sex show a range of deviation from 2.2 to 2.6 months, with stage C showing a 4.0-4.4 month standard deviation. These values illustrate a high variability throughout the sample with regard to timing of dental development. Stage C shows about twice the variability as the other stages, suggesting that more variability exists as to the timing of this stage, or perhaps that intermediate stages are not accounted for with Demirjian’s et al. (1973) system of classification. In their study on sex differences in tooth formation, Demirjian and Levesque (1980) noted that sex differences were not seen in stages A or B, but that differences began to become evident following these stages. The high variability seen in stage C would seem to support the notion that group differences emerge around this time.

Sex differences in the timing of molar 2 development were not statistically significant (Table 8). This finding may be due in large part to sample size, as many studies exploring these differences used samples of more than 1000 radiographs. Despite the lack of statistical significance, sex differences were seen and should be discussed. The proportion of variability explained by sex for LM2 development was 1.2%. While this may seem low, it is still a large enough proportion to suggest that sex does have some effect on the timing of LM2 development. If mean ages of attainment for each sex are
subsequently examined, one can see that girls consistently (with the exception of stage C) show an earlier age at each stage than boys. The difference between means is about five to six months. These differences support those found in other studies which revealed girls forming teeth earlier than boys for the later stages of development (Demirjian and Levesque 1980; Liversidge and Speechly 2001; Maki et al. 1999).

Race differences in the timing of LM2 development were also not significant (Table 8). Sample size is likely a reason here as well. A higher proportion of the variability for LM2 was explained by race than by sex, with 1.8% variability explained. This percentage suggests that race does have some effect on the timing of LM2 development, but this effect is less clear in the results than that of sex. Blacks achieve stages C and G earlier than whites (Table 10), but only minimally (with stage C being highly variable). Whites achieve the other stages of LM2 development earlier than blacks by about four to five months on average. These results contrast to those found by Harris and McKee (1990) which indicated that blacks achieve stages earlier than whites consistently by about 5%.

Examining the race and sex interaction does not seem to provide a clearer understanding of the direction of mean difference in this sample. The impact of this interaction has a lower p value (Table 8) than either race or sex alone and shows that 1.9% of the variability in LM2 development is explained by race and sex interacting. At times, mean differences show black females achieving stages earlier than white females, and other times, the opposite is true. A similar situation exists for males in the sample. Clearly, a larger sample needs to be examined in order to properly explain the difference between race groups in timing of LM2 development.
As mentioned previously, a statistically significant relationship was found between sex and age of sample, suggesting that females are having panoramic x-rays taken at a significantly earlier age than males. Reasons for the sex difference at age of exam could be many, and are only speculations at this point in time. Girls are known to develop faster than boys in many ways (Eveleth and Tanner 1990) and the earlier intervention on their dentition may reflect their earlier development. If eruption of teeth is occurring earlier, parents may seek dental consultation at an earlier age. In opposition to this hypothesis, the sex difference in age of exam may merely reflect the differential treatment of girls and boys by guardians in this sample.

Differences between decades of exam for LM2 development were not statistically significant. The p value for this analysis, however, was close to significant at .055, with 6.6% of the variability in LM2 being explained by decade. The relationship of decade and LM2 with age is the most significant one found in this study, and indicates that changes have occurred over time in schedule of LM2 development. The mean differences indicate that the 1990s sample achieved stages at a later age on average than the 1980s sample. For most stages mean ages at attainment were earlier in the post-2000 sample than in the 1990s. The clearest mean differences occurred from the 1980s to the 1990’s, suggesting a secular trend for later development of LM2. This finding is in contrast to the suggested trend mentioned in Liversidge and Speechly’s (2001) study which indicated an advancement in dental maturation over time. These results do indicate that some secular change is occurring with regard to tooth formation. Such a statement challenges the widely held notion that tooth formation is strongly resistant to environmental influence. The possibility of populational change

50
Many factors influenced the results of this study, not the least of which was sample size. While the overall sample size of about 300 radiographs is large enough for accurate statistical analyses, the size of each subgroup (whether it be sex, race, or stage of development) was relatively small. Due to time constraints, a larger sample for this study was not possible. The results of mean comparisons do indicate that a larger sample would yield more significant results, especially with regard to sex differences. Despite the sample size, the results of this study indicate that more analyses of this population would provide useful information about the factors affecting tooth formation. In addition to sample size, the variability of the population also affected the results. A much higher variability existed throughout this sample than was anticipated, challenging ideas about the regularity of tooth formation. As much, if not more, variability existed within each subgroup than between subgroups, suggesting that timing of tooth formation is more variable than previously thought.

The results of this study support the idea that tooth formation is only minimally affected by race, sex, and time period. This study, compared with several others, supports claims that a much smaller difference between sex and race with regard to tooth formation exists than with regard to eruption, as greater significance has been found in eruption studies (Nystrom et al. 2001, Rajic et al. 1999). More research with diverse populations and large samples should be done to more accurately understand the impact of race, sex, and time period, on molar development. In examining group differences in
dental development, the entire dental arcade should be examined. Many studies have examined differences between groups for all teeth in the arcade, and this provides a more holistic understanding of the impact of race and sex on dental development. In addition, when providing an age assessment for an unknown individual, all factors should be examined, including all teeth available. While this study only examined the factors affecting mandibular first and second molars, this research can be combined with research on other teeth to properly assess group differences.

Future research should also endeavor to standardize one method of tooth stage classification for use in studies such as this. While all accepted methods of determining tooth calcification stages are useful and relatively accurate, the use of so many different methods in similar research studies limits the comparability of one study to the next.

Variation in many aspects of human growth has been well documented in many studies, including skeletal development (Evelth and Tanner 1990). Usually, age assessment of skeletal elements is done with either one or two methods of assessment, ensuring consistency in methodology. Many studies have been done on dental formation and eruption, but comparisons are complicated at best, by the lack of conformity seen in methods used (Liversidge and Speechly 2001). This lack of conformity refers not only to the system of classification used, but also to the methods of statistical analysis. Some researchers use only mean comparisons, while others rely on a certain degree of statistical significance. If researchers truly endeavor to accurately understand the factors influencing timing of dental development, and, if they want to provide the most accurate age estimations for unknown individuals, they must standardize their methods. The
ability of researchers to accurately compare their studies on this subject would be invaluable to the advancement of knowledge about dental development.

In conclusion, the impact of race and sex on first and second molar development is not completely understood, and more research should be done to explore it. This study has shown that while differences appear to be slight, they do exist and should be explored in more detail. The importance of providing an accurate age at death of subadult individuals necessitates understanding any factor that may influence an age estimate. The standards used for dental age assessment are nearly all based on samples collected prior to 1980, and, if secular change is occurring, the nature of such change should be explored to make standards as accurate as possible.
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Appendix: Institutional Review Board Approval

LSU Institutional Review Board Exemption

IRB #: _______ LSU Proposal #: _______ Revised: 03/24/2004

LSU INSTITUTIONAL REVIEW BOARD (IRB) for
HUMAN RESEARCH SUBJECT PROTECTION
Office: 203 H-1 David Boyd Hall
578-8692; FAX 6792

APPLICATION FOR EXEMPTION FROM INSTITUTIONAL OVERSIGHT

Unless they are qualified as meeting the specific criteria for exemption from institutional review board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or sampled human tissue and/or data, directly or indirectly, with or without their consent, must be approved or exempted from review by the LSU IRB. This form helps the PI determine if a project may be exempted, and is used to request IRB exemption.

Instructions: Complete this form.
If it appears that your study qualifies for exemption send:
(A) Two copies of this completed form,
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts A & B),
(C) Copies of all instruments to be used. If this proposal is a part of a grant proposal include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study

to: ONE screening committee member (listed at the end of this form) in the most closely related department/discipline or to IRB office.

If exemption seems likely, submit it. If not, submit regular IRB application. Help is available from Dr. Robert Mathews, 578-8692, irb@lsu.edu or any screening committee member.

Principal Investigator: Suzanne Price
Student?: Y/N
Ph: 749-5463 E-mail: spence37@ehu.edu Dept/Unit: Anthropology
If Student, name supervising professor: Mary Manheim Ph: 518-6064
Mailing Address: 4325 Highland Rd. Baton Rouge, LA 70808
Project Title: A Psychogenic Study of the Impact of Race and Sex on Motor Development
Agency expected to fund project: Robert C. West Fund

Subject pool (e.g. Psychology Students): Children between ages 3-13

Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

I certify my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted.

PI Signature: Suzanne Price Date 3/20/04 (no per signatures)

Screening Committee Action:
Exempted ___ Not Exempted ___ Category/Paragraph __

Reviewer: Mathews Signature Date 5/7/04

57
LSUHSC Institutional Review Board Approval

EXPEDITED APPROVAL
LOUISIANA STATE UNIVERSITY HEALTH SCIENCES CENTER
(Assurance Number FWA00002762)

FROM: LSUHSC Institutional Review Board

TO: Joseph Moerschbaecher, Ph.D.
    Vice Chancellor for Academic Affairs

RE: IRB Application By: Robert E. Barsley, DDS, JD
    Dept. of Dental Health Resources


This is to document review and approval of the above research protocol. In the judgment of this Board, the procedures delineated in said application conform to the pertinent DHHS and FDA rules and regulations regarding use of human subjects. This procedure is authorized by 45 CFR 46.110 and 21 CFR 56.110 as published in the Federal Register September 19, 1998. Records regarding action of the Board, referable to said project, are on file in the Office of the Chairman. This study is expected under 46.110 category #5 of 45 CFR Part 46.

THE INVESTIGATOR agrees to report to the Committee any emergent problems, serious adverse reactions, or procedural changes that may affect the status of the investigation, and that no such change will be made without Board Approval, except where necessary to eliminate apparent immediate hazards. The investigator also agrees to periodic review of this project by the Board at intervals appropriate to the degree of risk to assure that the new project is being conducted in compliance with the Board's understanding and recommendation, and this interval will not exceed one year.

*PLEASE NOTE: 1. Any advertisement to recruit subjects for this study must be approved by the IRB prior to posting, publication and/or distribution.

2. Other institutional approvals may be required before the study can be initiated.

3. Written notification (at the time this study is completed/canceled) must be sent to the Office of the Chairman.


Approval Period: 7/29/04 - 7/28/05

Principal Investigator

DATE: 7/15/04

Kenneth E. Kratz, Ph.D., Chairman

DATE: 7/29/04
Waiver of HIPAA Authorization

A waiver of authorization has been granted to:

IRB#6062: A Radiographic Study of the Impact of Race and Sex on 1st and 2nd Molar Development.

by the LSUHSC- New Orleans Institutional Review Board, Reg.#00000177. This study meets the waiver criteria described in 45 CFR 164.512 (i) (2) (ii).

The request for this waiver was reviewed using the EXPEDITED procedure approved by the LSUHSC Institutional Review Board, and as required by 45 CFR 164.512 (i) (2) (iv).

This waiver pertains to Protected Health Information (PHI) as described in the study protocol.

With a waiver of authorization, investigators and other covered entities must keep a record of the subjects from whom Protected Health Information has been gathered and to whom this PHI is disclosed. This information must be provided to the subject upon request.

Approval Date: 7/29/04

Approved By LSUHSC IRB Chairman: [Signature]

Acknowledgement of Principal Investigator: [Signature]

Date: 7/30/04
Vita

Suzanne Price was born and raised in southern New Jersey. She attended a large, liberal Catholic high school before studying for her Bachelor of Arts in anthropology and psychology at Drew University in Madison, New Jersey. After taking a year off, she began pursuing her interests in physical anthropology. She will be continuing her studies in dental anthropology and evolutionary morphology in the doctoral program at New York University.