A PILOT STUDY TO ASSESS DENTAL AGE ESTIMATION IN BLACK SOUTH AFRICAN CHILDREN USING DEMIRJIAN'S METHOD

by

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Declaration

I, André Uys, hereby declare that this dissertation, submitted by me in partial fulfilment of the requirements for the degree MSc (Odont) Maxillofacial and Oral Radiology at the University of Pretoria, South Africa, has not been submitted for a degree at this or any other University.

André Uys

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ABSTRACT

The age estimation method as described by Demirjian is the most frequently used tool to estimate the sub-adult dental age in forensic dentistry. This technique has been shown to over or under estimate the chronological age of sub-adults when applied to specific population groups. The aim of this study was to compare a black South African population sample with the original French-Canadian model to determine if Demirjian's method accurately reflects the true chronological age of this population group.

A sample of panoramic radiographs from 279 boys and 325 girls between the ages of 6 and 16 was obtained from the School of Dentistry University of Pretoria, and from orthodontists in private practice in the Pretoria region. The panoramic radiographs were used to score the seven left mandibular teeth. The calculated maturity score was used to determine the Demirjian dental age. All panoramic radiographs were scored by one examiner. A subset of 20 panoramic radiographs was scored by a second examiner and reliability tested using a Wilcoxon Matched Pairs Test.

This research showed that black South African children have a more advanced dental age compared to French-Canadian children. Demirjian overestimated the age for boys by 0.8 years and for girls by 0.5 years.

The dental age assessment provided by Demirjian is not suitable for black South African children. As a result, new standards of dental age assessment should be established for this population.

Key words: Dental age estimation, Demirjian's method, panoramic radiographs, forensic dentistry

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A PILOT STUDY TO ASSESS DENTAL AGE ESTIMATION IN BLACK SOUTH AFRICAN CHILDREN USING DEMIRJIAN'S METHOD

Chapter 1

Introduction

Age estimation plays an important role in several dental disciplines. In forensic dentistry there is a frequent need to determine the age of unidentified skeletons or individuals who have no record/documentation of their chronological age.[1-3] The importance of accurately estimating the chronological age of suspects involved in serious crime necessitates the use of highly accurate age estimation techniques in the age groups 6 to 18 years. The critical ages for criminal liability in South Africa are 7 and 14 years. The law in South Africa states that a child who has not yet completed his or her seventh year lacks criminal capacity and cannot be held criminally responsible. At the age of 14 years, a child is regarded as an adult and creates no presumption of lack of capacity. The aim of determining age is to provide the forensic odontologist with an accurate age range within a biological profile. If the age range is too large it will not be helpful to accurately determine age in a certain age range. In order to be of the greatest possible value, the method used should have the lowest possible standard deviation and be validated for the individual's specific population group.[2] A study should cover the age range for the formation stages being assessed and should be representative so as to include both early and late developers. The degree of maturation of different tissue systems determines the physiological age. Numerous biological ages have been developed and these includes: skeletal age, morphological age, secondary sex character age and dental age.[4]

The method most frequently used in forensic dentistry was described by Demirjian *et al*.[4] The two ages important to us, namely 7 and 14 years can be evaluated and determined using Demirjian's method. It was recommended that adaptations would be necessary in order to use this technique in other population groups. The

maturity standards determined were based on samples of French Canadian origin.[4] This was confirmed by other authors who found Demirjian's technique less accurate in their specific populations, due to an over and underestimation of dental age in their populations groups. [2, 3, 5, 6, 7]

Several other methods have also been described to determine dental age; these cover the range of ages from 4 months to 21 years of age. One of these methods uses the time of eruption as a parameter. The time of eruption is the moment when the tooth perforates the gingiva/keratinized mucosa.[8] A disadvantage of this method is that it is difficult to determine accurately the exact time of emergence. Emergence may also be influenced by early loss of primary teeth. This method is only useful during the relatively short period of time when eruption takes place. Determination of emergence is dependent on the timing of observation. Third molars may be problematic because of the high incidence of variation in their emergence patterns and because third molars are absent in 20 per cent of all patients.[9]

Other methods use measurements from radiographs as an indicator of dental age. They determine the length of the tooth, crown or root.[10-12] Some of these methods show good validity but it is sometimes difficult to determine the exact length of a root from a radiograph.[13]

The method Demirjian *et al.*[4] described was based on simplified chronological age estimation by restricting the number of tooth development stages to 8 and scoring them from 'A' to 'H'. The eight stages represent the calcification of each tooth, from crown and root calcification to the closure of the apex. A score was derived for each tooth and each development stage, from the method Tanner *et al*.[14] described for skeletal maturity. The scoring was limited to the first seven teeth of the lower left quadrant and compared to a graphical representation of the developmental stages. Each developmental stage had specific criteria and for each stage there were one, two or three written criteria. When only one criterion was given, the criterion had to be met to reach that specific stage; if two criteria were given it was sufficient if only the first one was met; if three criteria were given the first two had to be met to consider the stage reached. By using statistical

analysis a maturity score was assigned for each of the seven teeth of each of the 8 developmental stages. Separate standards were calculated for boys and girls. It is important to distinguish gender when assessing dental age. It was found that individual teeth showed a common pattern during early stages of development for both sexes.[15]

Demirjian *et al*. used a tooth rating that was converted into a score using tables for boys and girls respectively. All the scores for each of the seven teeth were added and the maturity score was calculated. The maturity score was then converted into dental age by using the published conversion tables. A sample of panoramic radiographs of 1446 French Canadian boys and 1482 French Canadian girls ranging in age from three to seventeen were used.[4] The original method was soon updated and included a larger sample size with a wider age range. The newer standards were based on data derived from a sample of 4756 French-Canadian children, ranging in age from 2-20 years. The examinations took place at the Ste-Justine Hospital and Growth Centre in Montreal. All the children had parents and grandparents of French Canadian origin.[16]

Chapter 2

Overview of the literature

The validity of Demirjian's method has been tested for numerous population groups worldwide to determine if the dental age estimation is valid for their specific population group. Factors that could affect the timing and rate of development and cause a variation between specific population groups include genetic factors, variation in age, sex and race. Non-genetic and environmental factors may both play a role and have an influence on the timing and rate of development. Understanding these factors as well as the potential influence of these factors on dental development is important. These factors must be taken into account when studying and comparing specific population groups.

A summary follows of the studied population groups worldwide to demonstrate that differences exist between their specific population group and the original group from Demirjian. Factors that may cause variation between different populations will also be considered.

2.1 Studies done on different population groups

A study done by Phillips VM and van Wyk Kotze TJ, on three South African children samples, found that Demirjian's method of age estimation consistently overestimated the ages of the three samples. The authors then constructed the Phillips tables which incorporated the correction factors required to more accurately estimate the ages of the three groups. This study was however restricted to Zulu and Xhosa children, collectively grouped as Nguni. The sample consisted of 171 Zulu children form Durban, Kwazulu Natal and 65 Xhosa children form the Western Cape. The samples were however not separated into males and females.[17] In another study done by Phillips VM and van Wyk Kotze TJ, 91 black Zulu with an age range of between seven and 15 years were used. The results of this study demonstrated that Demirjian's method overestimated 90% of the ages.[18]

In a Belgian Caucasian sample using 2116 panoramic radiographs of 1029 boys and 1087 girls, the age ranged from 1.8 to 18.0 years for the boys and 2.1 to 18 years for the girls. Demirjian's method resulted in a significant overestimation in all of the 13 age classes. The sample revealed a median difference of 0.5 years for boys (mean: 0.4; standard deviation: 1.0) and a median difference of 0.6 years for girls (mean: 0.7; standard deviation: 1.0). The greatest overestimation was found in the age group of 9 to 10 years for boys and 9 to 10 and 10 to 11 years for girls. The study used a single-rank test to search for age differences between dental age and chronological age and the outcome was that the adapted scoring system resulted in higher accuracy.[3]

A Finnish study used 738 panoramic radiographs of 389 girls and 349 boys which ranged from 2.5 to 16.5 years. The Finnish population can be considered ethnically homogeneous. The results showed that Finnish children were more advanced in dental maturity compared with French-Canadian children. Boys demonstrated a difference of 4.5 months at the age of 5-10 years and 7 months at the age of 11-12 years. For the girls advancement was seen at the age 4 to 12 years. On average Finish girls were 3.5 months ahead of French Canadian girls at the age of 4-9 years and 9 months ahead at 10-14 years.The study concluded that dental maturity differences exist among white population groups.[19]

A study carried out at the University of Oslo, Norway showed that Norwegian children were slightly more advanced in dental maturity when compared with French – Canadian children. The study used 128 boys and 133 girls. Boys demonstrated a mean difference between dental age and chronologic age of 1.5 to 4.0 months. The girls had an increase with age, varying from 0 to 3.5 months in the younger age groups (5.5 to 9.0 years) and 4.5 to 7.5 months in the groups 9.5 years and older. The average dental age was not markedly different form the original French-Canadian sample. In the older age groups 95% of the estimates were within 2 years of the chronological age. The study concluded that the applied standards may be adequate to determine dental age in Norwegian children.[20]

In a Dutch study a total of 451 children including 226 boys and 225 girls were studied using Demirjian's method. Inclusion criteria were children between the age of 3 and 17 years and non-Caucasian patients were excluded. The results showed a significant difference between chronological age and dental age. Dutch boys were 0.4 years and the girls 0.6 years ahead of the French-Canadian standard. The French-Canadian standards were found not to be suitable for Dutch children. The study constructed new graphs using a logistic curve with the equation $Y=100*\{1/ (1+e^{-\alpha(x-x0)})\}$ as their basis.[21]

In Southwest Germany at the University of Freiburg a cross-sectional study was undertaken to assess the dental age of boys and girls between the ages of 2 and 20 years. They evaluated 1003 panoramic radiographs from 514 girls and 489 boys. The subjects were from German origin. Statistical evaluation revealed a correlation between the parameters chronological age and the score sum of r = 0.85 for girls and r = 0.89 for boys. The results revealed that dental age distribution in Southwest Germany is not correlated with that of a French-Canadian population. The score sum values for both sexes in relation to the chronological age were plotted as a log curve. Sexual dimorphism was found with the girls demonstrating accelerated growth.[22]

In an assessment of dental maturity of Western Chinese children, digital panoramic radiographs of 445 children were used; the ages of the 228 girls and 217 boys ranged from 8 to 16 years. The chronological and dental ages were compared using a paired *t*-test. The results demonstrated a more advanced dental age compared to the French-Canadian population. The mean difference between dental age and chronological age in each age group ranged from 0.0071 to 1.25 years in girls and from 1.00 to 1.30 years in boys. The conclusion was that the standards according to Demirjian for French-Canadian children were not suitable for Western Chinese children. A new logistic curve at the 50th percentile was drawn through all points to determine the mean age for each of the dental maturity scores for both boys and girls. Girls demonstrated a more advanced dental development and reached dental maturation earlier than boys.[6]

In a study form Central Poland, 994 panoramic radiographs were used to validate Demirjian's method for this population group. Children aged 6 to 16 were included. The results of the study demonstrated a considerable acceleration in the dental age using Demirjian's method. The greatest acceleration was observed in girls aged 11 and 12 and in boys 13 years old. In both sexes there was considerable acceleration of dental age for the 6-year old group. The study showed no statistically significant difference in dental age when boys and girls from Central Poland were compared with one another for any particular age group. The conclusion of the study was that it was necessary to establish new tables for this population.[7]

A South Australian study done on 615 South Australian children found that it was necessary to generate new standard curves to assess age. The study found that Demirjian's dental age coincides with chronological age in 34.7 per cent of males and 39.6 per cent of females. The study found that South Australian children are less advanced in the early years when compared to Demirjian's standard, but they become more advanced once they reach 15 years of age. Australian and non-Australian children showed no statistical difference when established dental age was compared with chronological age. The children with differences between established dental age and chronological age, showed no statistical significance between Australian born children with parents of Australian birth and children with either one or two parents of non-Australian decent. The reason for this would appear to be the multicultural nature of the Australian society.[23]

In a study done in New Zealand three ethnic groups namely Maori, European and Pacific Island children were studied and levels of dental maturation of each of the three populations groups were determined. The sample size consisted of 1383 panoramic radiographs (660 males, 723 females) and included 477 Maori, 762 Europeans and 144 Pacific Island children ranging in age between 3 and 14 years. When the differences in dental age between European and Maori, and European and Pacific Island children were determined, a population difference divergence was found in ages 9-11 years. The results demonstrate that Polynesian children mature earlier than European children. The study highlights the importance of using population specific standards.[24]

A British study done on 521 London children of Bangladeshi and white Caucasian (English, Welsh and Scottish) origin aged 4 to 9 years, found that the British children were dentally more advanced than the Canadian standards. In girls the mean difference was 0.51±0.79 years and boys was 0.73±0.73 years.The study also found no significant difference between the Bangladeshi and white Caucasian groups.[25]

In a study done in Malaysia, Demirjian's method overestimated the age by 0.75 years for boys and by 0.61 years for girls. The study only included Malays to ensure the sample was uniform in ethnicity. This was a cross-sectional study and involved 428 children between the age of 7 to 15 years (214 boys and 214 girls). The authors in this study found Demirjian's method to be inapplicable for their population group. They also tested the Willems method on the same sample group. This method also demonstrated an overestimation. For boys the overestimation was 0.55 years and for girls it was 0.41 years. Both of these values were statistically significant. The conclusion was that neither of the methods was appropriate for a Malay population and that specific population standards are needed.[1]

Dental maturity has also been compared in children of different ethnic origins. A study used 9577 panoramic radiographs from 8 countries and used Demirjian's method to determine dental maturity scores and established specific tables for each gender as well as development graphs. The study provided dental maturity standards when the ethnic origin was unknown and also compared the dental maturity of these different populations. The conclusion was that the dental developmental tables are very reliable and should be used when the ethnicity is unknown. They stated that these dental development tables were not as accurate as the tables calculated for a specific country.[2]

The results of the studies mentioned above generally question the suitability of Demirjian's method as a blanket age estimation technique for children aged 2-18 years, and support the need for population specific adjustments.

2.2 Genetic factors

Variations in growth between different individuals are the consequence of differences in protein synthesis of enzymes. These processes are a reflection of the genetic composition of each individual.[26] Genes play a very important role in the initiation and regulation of the different dental development stages. The regulation process can vary and has the potential to do so. Genetic control occurs as a result of a switch mechanism. The specific genes for development can be switched on or off; producing specific substances which are important for a specific cellular activity.[27] Variations in the timing of the initiation of these switching mechanisms may result in variation between development in individuals.

Tooth morphogenesis is regulated by chronological and mutual interactions between epithelium and mesenchyme. Paracrine signal molecules mediate cell communication. Most of the signal molecules belong to transforming growth factor β (TGF β), fibroblast growth factor (FGF), Hedgehog and Wnt families. The genes are regulated by signals from transcription factors and signal receptors.[28] A substantial proportion of the overall variability in tooth mineralization rate can be attributed to genetic effects. Research has shown that the size of somatic structures is genetically regulated and that the rate of development of these structures is under significant genetic control. Genetic factors can be responsible for up to 82% of the variation rate of dental development.[29]

2.3 Epigenetics

Epigenetic mechanisms, causing chromatin structure modifications, may also play a role in the variation we find between individuals and different population groups.

The epigenetic signature of each differentiated cell type reflects the cells genotype, developmental history and environmental influences. This will ultimately give rise to the phenotype of the cell or organism. During fetal development, major epigenetic reprogramming takes place. Periods like these are very sensitive.

Proper or improper handling of these sensitive periods may lead to short or long term effects for the individual or offspring.[30]

Epigenetic modifications include DNA methylation and histone post-transcriptional modifications. The histone post-transcriptional modifications include methylation, acetylation, ubiquitination and phosphorylation.[31]

The process of aging involves a series of changes the organism undergoes during its lifetime. These include anatomical, physiological, biochemical and genetic changes. Epigenetics can be one component of aging. Epigenetic factors are heritable and modulated by external factors. The external factors causing change represent a molecular link between environment and aging.[32]

Postnatal life DNA methylation patterns are not fixed. These patterns can change with aging and can involve various mechanisms.[30] Exogenous factors are a proposed reason for DNA methylation status change with age. These factors include diet and drugs. An excess or deficiency of a variety of dietary elements can be the cause of global methylation patterns. The exposure to toxins and chemicals in the environment may lead to chemical modification of cytosines.[30]

The epigenome is very vulnerable during embryogenesis due to the high DNA synthetic rate. Environmental factors may influence this proses. During these early development stages, normal tissue development is established. The environmental influence on epigenetic gene regulation may continue trans-generationally even if there is a lack of exposure in the 2nd, 3rd and 4th generations.[33]

The ‘Barker hypothesis’ may be another reason for growth pattern variation. The hypothesis states that any change in fetal nutrition and endocrine status may result in adaptions in the development. This may change structure, physiology and metabolism of the individual. Maternal under-nutrition reduces fetal growth during gestation.[34]

Epigenetics may be an important factor to consider when studying variation between populations. Population groups exposed to different environmental factors can ultimately lead to differences in the growth of the studied individual.

2.4 Gender effects on age determination

It is important to distinguish gender when assessing dental age. Within any given population there is a difference in the rate of development between boys and girls. For somatic growth girls are generally more advanced than boys up to the pre-adolescent years.[15] It was found that individual teeth showed a common pattern during early stages of development for both sexes. There was no difference in the chronology of dental mineralization between boys and girls for stage A, B and C; - different stages representing crown formation of teeth. Girls were more advanced by an average of 0.35 year for stage D (completion of crown development). Stages E, F, G and H represent root development. During the stages of root development the mean difference between sexes was 0.54 year for all teeth. The canine presented with the largest difference, 0.90 years. The data demonstrates the importance of sexual dimorphism particularly during the stages of root development.[15] When assessment of dental maturation is done, gender differences must be taken into account. In Australian children there were no statistical differences between genders in the lower age groups. This however changed for the 11 to 12.9 year group with a significant difference between the two sexes for estimated dental age. The age group 13 to 14.9 years demonstrated a significant difference in variance but not in the mean value. The 15 to 16.9 age groups showed similar results with significant variance of the established dental age but no difference in the mean value.[23] In a study done in New Zealand they used quantile regression analysis to show differences between boys and girls across the age groups investigated. They found that knowledge of the sex does not increase the accuracy of estimating age because the magnitude of the error of estimating age is greater than the difference between the sexes.[24] A British study showed that the mean age of completion of tooth development stages was earlier in girls. The related stage of each individual tooth related to stage M_1 was investigated for both sexes. Only one tooth showed a sex difference related to the

M_1 formation stage but this did not affect the related stage. The canine formation when M_1 was at stage E, F and G was meaningfully advanced for girls when compared to boys. This indicates that girls begin their development earlier but also advance through the particular stages more rapidly.[35] Until 18 years of age girls are always more advanced in dental maturity. At the ages of 12 to 13 years boys do start to catch up in growth. At the level of inter-population variability the girls' maturity acceleration and the catch up growth for boys are less obvious. The dimorphism of the adolescent period is less conforming due to the fact that the population variability is higher than the variability of the gender. The greatest degree of sexual dimorphism occurs during the root formation stages and the difference during the crown formation stages are negligible.[2]

2.5 Race influence on age determination

Between individuals we find genetic variation. Groups of similar geographical and racial origins do show differences in growth and development. It is therefore important to identify the racial background of the population being studied.

During a symposium hosted in 2007 at the University of New Mexico[36] on the topic "Race Reconciled" the delegates agreed on the following points:

- That a considerable variation exists between individuals in a specific population.
- Biological variations exist between individuals from different populations.
- Patterns in group variation have been largely influenced by their culture, ecology and geography.
- That variation has important research implications.

For forensic practice the following conclusions may be drawn. Studies on skeletal maturation for populations of all major ethnic groups, are available. It was found that all the populations studied demonstrated identical and defined stages for skeletal maturation. Secondly it was determined that time related differences when passing through skeletal maturation were not affected by ethnicity and X-ray

standards. The conclusion is that forensic age estimation may be applied to ethnic groups which are different to the reference population.[37]

It was shown that there was no statistical difference between Australian and non-Australian children with respect to the differences between established dental age and chronological age. No statistical difference between Australian born children with parents of Australian birth and those with one or both non-Australian parents could be found with respect to the differences between established dental age and chronological age. No obvious relationship to country classification was detected for children with a large difference between established dental age and chronological age. A multicultural society would appear to be the reason.[23]The dental development of two ethnic groups (Caucasian and Bangladeshi children) living in London demonstrated no differences in dental maturation.[25, 35]

Dental development has a special status within the development processes of the human body. All the other processes used to measure maturity react to malnutrition, disease and mental stress but the timing of dental formation remains relatively unaffected. Strong evidence exist to indicate that odontogenesis is under strong genetic control and gives a very high correlation with the chronological age.[38, 39]

It was proposed that the southern Bantu speaking group can be considered a homogeneous population.[40] Geometric morphometric studies demonstrated that southern African Bantu-speaking populations are very strongly related but did show population specific features. The more traditional distribution of these groups is however disappearing because of intermarriage.[41]

Differences observed between racial groups are not only of genetic origin. Growth can be affected by both genetic and environmental factors and these factors do not act independently. Environmental factors include nutrition and socio-economic status. Genetically dissimilar populations respond differently to the same environmental factors they are being exposed to.[42] Malnutrition affects skeletal and dental systems but the latter is effected to a lesser degree. Statistically significant correlations between dental emergence and nutrition remain low.[9]

Statistically significant varying rates of development have even been found within the same racial groups. A sample from one region in Finland, with developed predictive tables, was applied to another region in the same country. The population in Finland is considered to be fairly homogenous racially. Statistically significant differences in predicted age were found between the reference sample from Helsinki and the rural community of Kuhmo in the north eastern part of Finland. The northern sample were dentally more advanced.[43]

Chapter 3

3.1 Aim

To determine the statistical adjustment needed when dental age is determined using Demirjian's method for a black South African population sample.

3.2 Hypothesis

The standards of dental age assessment determined by Demirjian for French-Canadian children may not be suitable for a black South African population sample. An underestimation of dental age is expected when Demirjian's method is used on a black South African population sample.

Chapter 4

Materials and Method

4.1 Selection criteria and subjects

In this study, panoramic radiographs and clinical records of 604 black South African children of known chronological age and gender were obtained from the School of Dentistry University of Pretoria, and from orthodontists in private practice in the Pretoria region. The children were from Pretoria and surrounding areas in the Gauteng region. For this study a total of 279 boys and 325 girls ranging in age from 6 to 16 years were used. Both film and digital panoramic radiographs were used.

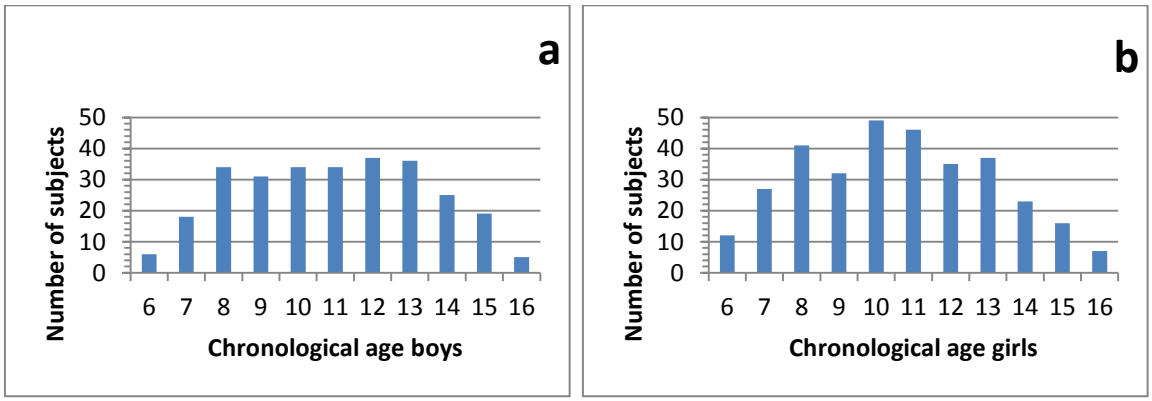


Table 1.*The number of subjects and age distribution of the black South African (a) boys and (b) girls.*

The panoramic radiographs were collected from patients attending the dental clinics and all radiographs formed part of the patient's routine dental treatment. No panoramic radiographs were taken primarily for this research project. Exclusion criteria included the following: age above 16.9 years and under 6 years at the time the panoramic radiograph was taken; non South African children; presence of systemic diseases; presence of congenital anomalies; unclear panoramic radiographs, and aplasia of at least two corresponding teeth bilaterally in the mandible. The subjects were divided into eleven groups. In age group 10, the patients ranging in age from 10 to 10.9 were included and so on. The

chronological age was converted to a decimal age using the date on the panoramic radiograph and the patient's date of birth.

4.2 Dental age assessment

The assessment of dental age was performed according to Demirjian's method. All the panoramic radiographs were scored by the author using the criteria set by Demirjian *et al.* [4] without the knowledge of the patient's chronological age. The mandibular seven left teeth were scored excluding the third molar. Each tooth was rated on an 8-stage scale ranging from A to H depending on the stage of calcification. Each stage of the seven teeth was then allocated a score, and the sum of the scores gave a calculation of the subject's dental maturity.

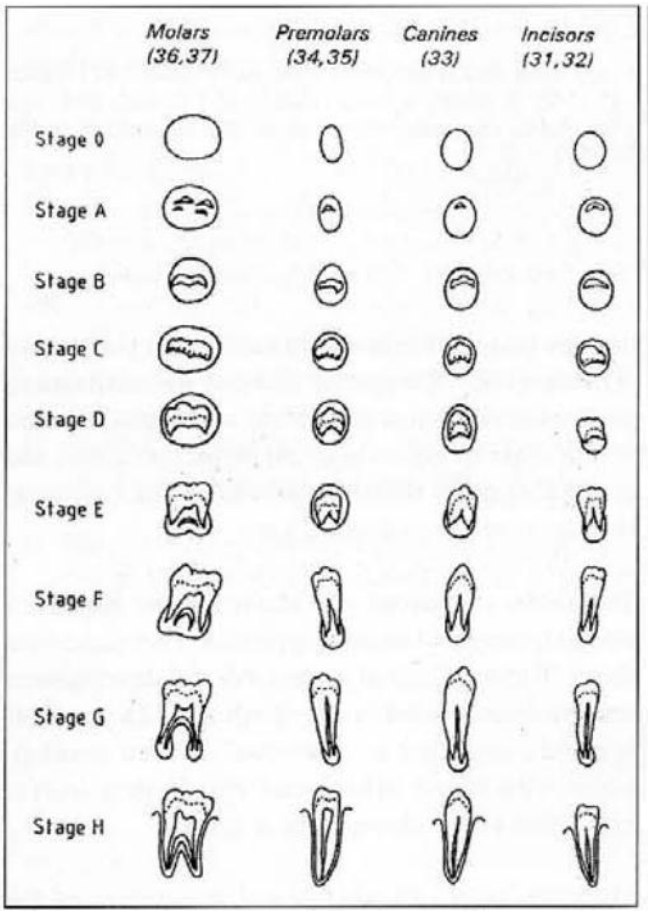


Figure 1. *Development stages as presented by Demirjian et al.*[4]

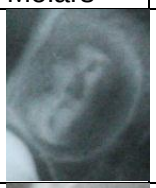
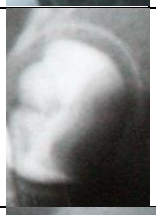
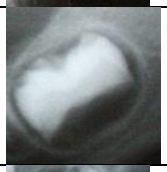
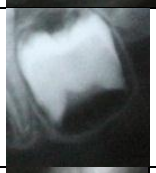
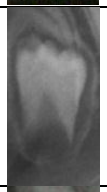
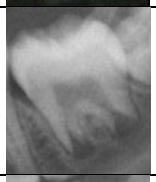
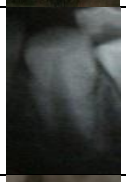
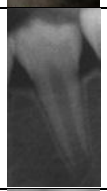
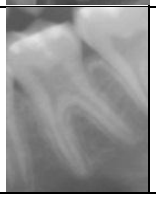
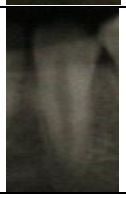
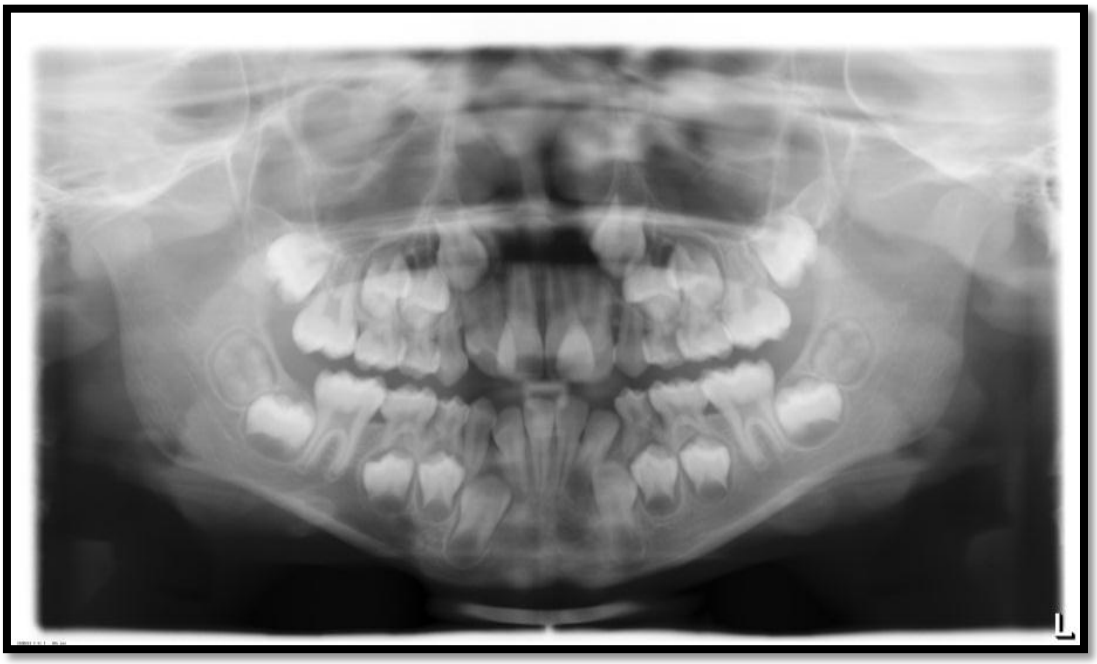
Stages	Molars	Bicuspids	Canines	Incisors
A				
B				
C				
D				
E				
F				
G				
H				

Figure 2. *Examples of developmental stages of the permanent dentition used in this study.*

Figure 3. *Example of two subjects used in the study.*

The chronological age was determined by subtracting the date of birth from the date the panoramic radiograph was taken. Demirjian's developmental stages and self-weighted score were used to allocate a tooth stage to the seven left mandibular teeth and the maturity scores calculated. Demirjian's conversion tables were used to convert the maturation score to a dental age.

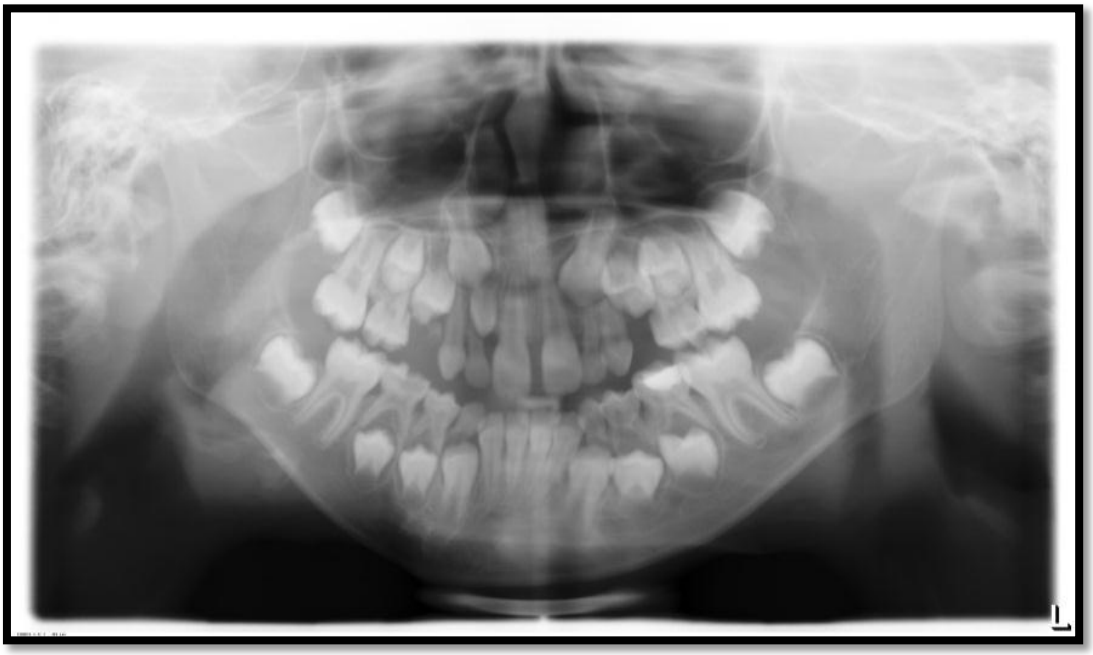
Example 1. A boy with a chronological age of 8.7 years.



Tooth number	M_2	M_1	P_2	P_1	C	I_2	I_1	
Mandibular tooth stage	D	G	D	D	F	F	H	
Score	10.1	17.0	9.7	7.0	10.0	7.8	11.8	= 73.4

A score sum of 73.4 for boys translate into a dental age of 8.1 years.

Example 2. A girl with a chronological age of 8.7 years.



Tooth number	M_2	M_1	P_2	P_1	C	I_2	I_1	
Mandibular tooth stage	D	G	D	E	F	H	H	
Score	11.1	14.0	10.6	11.8	10.3	14.2	12.9	= 84.9

A score sum of 84.9 for girls translate into a dental age of 8.6 years.

4.3 Reliability

All assessment of tooth formation was done by the first author. Twenty radiographs were randomly selected and reassessed by another examiner after calibration. The dental ages for all twenty radiographs were calculated. The variations between the inter- and intra-examiners were tested using a Wilcoxon Matched Pairs Test.

Chapter 5

Results

The mean difference between the chronological age found in black South African children compared to the dental age found in French-Canadian children ranged from -1.35 to -0.29 in boys and from -0.89 to 0.74 in girls (Table 1).

Table 2. *t-Test demonstrating the mean difference between the chronological age and dental age for black South African boys and girls and French-Canadian children according to Demirjian. The P-value in the last column was determined using the Wilcoxon matched pairs test.*

Age	Mean chronological age (± SD)	Mean Dental age (± SD)	Mean difference	*P*-value	*n*
Boys					
6	6.38 (0.35)	7.73 (0.44)	-1.35	0.028	6
7	7.46 (0.31)	8.41 (0.85)	-0.95	0.001	18
8	8.41 (0.30)	8.97 (1.26)	-0.56	0.004	34
9	9.50 (0.28)	9.79 (1.02)	-0.29	0.165	31
10	10.53 (0.31)	11.11 (1.58)	-0.58	0.040	34
11	11.56 (0.31)	12.67 (1.53)	-1.11	0.000	34
12	12.49 (0.28)	13.50 (1.35)	-1.01	0.000	37
13	13.42 (0.30)	14.34 (1.51)	-0.92	0.001	36
14	14.32 (0.25)	15.02 (1.22)	-0.70	0.007	25
15	15.43 (0.32)	15.74 (0.74)	-0.31	0.010	19
16	16.32 (0.22)	16.00 (0.00)		0.043	5
Girls					
6	6.65 (0.15)	7.53 (0.53)	-0.88	0.002	12
7	7.43 (0.26)	8.09 (0.63)	-0.66	0.000	27
8	8.44 (0.31)	8.94 (0.82)	-0.50	0.000	41
9	9.47 (0.30)	10.23 (1.19)	-0.76	0.002	32
10	10.34 (0.28)	10.96 (1.17)	-0.62	0.001	49
11	11.44 (0.27)	12.18 (1.18)	-0.74	0.001	46
12	12.44 (0.27)	13.33 (0.99)	-0.89	0.001	35
13	13.42 (0.29)	14.19 (0.88)	-0.77	0.000	37
14	14.33 (0.28)	14.38 (1.09)	-0.05	0.346	23
15	15.47 (0.29)	15.68 (0.71)	-0.21	0.098	16
16	16.34 (0.31)	15.60 (0.68)	0.74	0.018	7

S.D.: standard deviation; $P<0.05$ is statistically significant; *n*: number of subjects.

In boys, all the age groups showed a negative mean difference. The negative values demonstrate that all the age groups from 6 to 15 were advanced in growth when compared to the French-Canadian children. For the boys there was a

statistically significant difference between the chronological age and the dental age compared to Demirjian's results for all the age groups except for age group 9 (Table 1). The greatest accelerated development is observed for age groups 6 and 11. Age group 16 for the boys was not analysed because all the children in the group reached a dental score of 100 and the dental age could not be computed.

In girls, age groups 6 to 15 showed a negative mean difference (advanced dental age), and age group 16 a positive difference (retarted dental age).There was a statistically significant difference between the chronological age and the dental age compared to Demirjian's results for all the age groups except for age groups 14 and 15. The highest acceleration is observed for age groups 6 and 12. On average black South African boys were 0.8 years and the girls 0.5 years ahead of the French-Canadian children.

Table 3. *Comparison of mean dental age of boys and girls in age groups.*

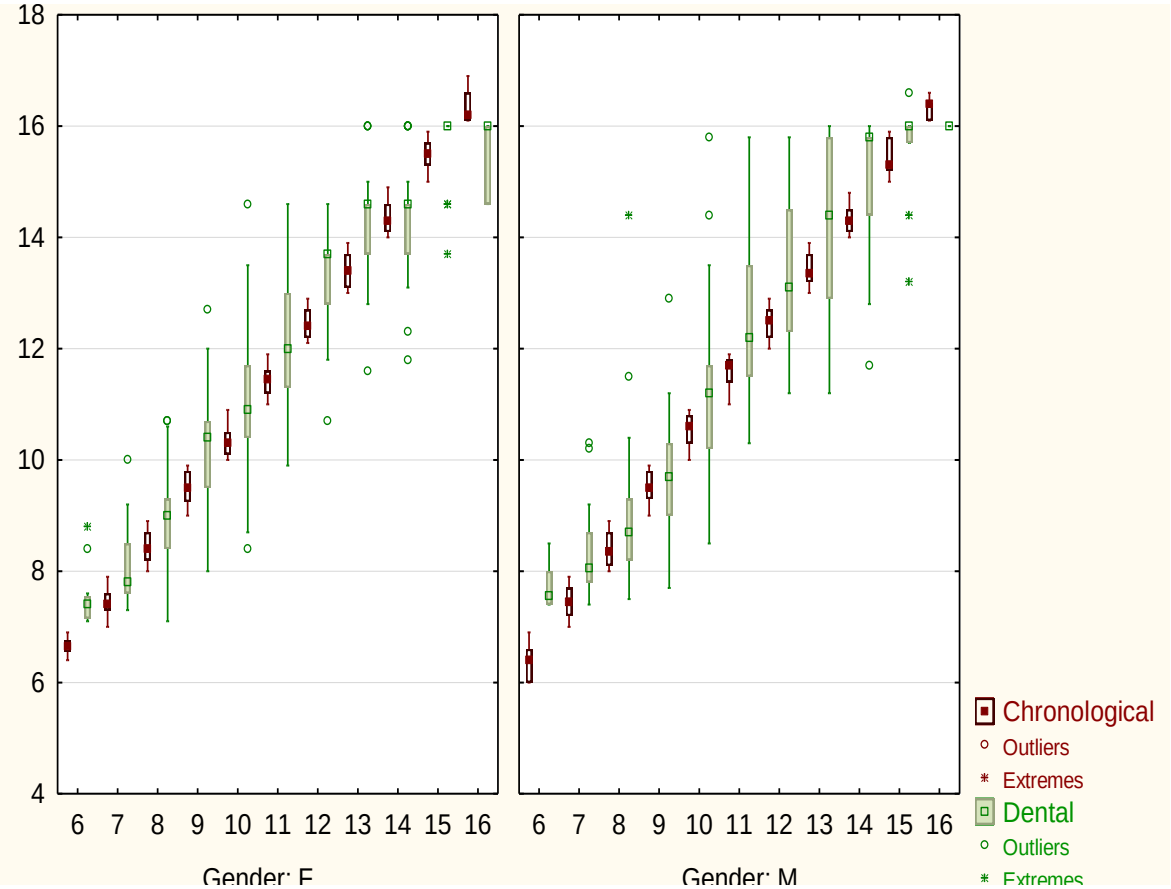
Age group	Dental age					
	Boys			Girls		
	Mean	S.D.	*n*	Mean	S.D.	*n*
6	7.73	0.44	6	7.53	0.53	12
7	8.41	0.85	18	8.09	0.63	27
8	8.97	1.26	34	8.94	0.82	41
9	9.79	1.02	31	10.23	1.19	32
10	11.11	1.58	34	10.96	1.17	49
11	12.67	1.53	34	12.18	1.18	46
12	13.50	1.35	37	13.33	0.99	35
13	14.34	1.51	36	14.19	0.88	37
14	15.02	1.22	25	14.38	1.09	23
15	15.74	0.74	19	15.68	0.71	16
16	16.00	0.00	5	15.60	0.68	7

S.D.: standard deviation*; n*: number of subjects.

Comparison of the mean dental age of boys and girls demonstrate a more advanced mean dental age for the boys for all the age groups except for age

group nine (Table 2). On average girls reached dental maturity 0.12 years ahead of boys when mean dental age is compared.

Figure 4. *Box plots demonstrating the chronological and dental age of black South African children for females and males. The mean values are indicated by the squares, the rectangles indicate standard deviation and the thin lines indicate the total ranges. The outliers and extremes are indicated with ° and * respectively.*



Chronological age (years)

The p value determined with the Wilcoxon Matched Pairs Test for examiner reliability was 0.740368. This value is not significant and operator calibration considered reliable.

Chapter 6

Discussion

This study showed that the eight-stage system of Demirjian *et al*.[4] is a simple and convenient method to use when assessing tooth development. The influence of geographic location and nutritional status in different population groups does necessitate the evaluation of each individual population group so as to determine the correction factor required for an accurate chronological age estimation. This study is in agreement with the authors from numerous studies who demonstrated that correction factors be used on different population groups.[1,2,3,6,7,17,18,19,20,21] The ease of use and the fact that the method of assessment is easily repeatable make it a very advantageous method.[4]

This study showed that black South African children revealed a more advanced dental age when compared to French-Canadian children from Demirjian's study.[4] The mean difference between chronological age and dental age were 0.8 years in boys and 0.5 years in girls.

In a recent study conducted by Liversidge[44], the method of Demirjian was found to be suitable without correction factors in a sample consisting of 4710 males and 4661 females (age 2-18). The outcome was that most adapted curves from all the world regions fell well within the 95% confidence intervals at the 50th percentile. They found that the curves for the average age/score lying close to the edge usually do not demonstrate raw data scores, and the sample size and raw data used to construct these curves and included small sample sizes and complex equations.[44]

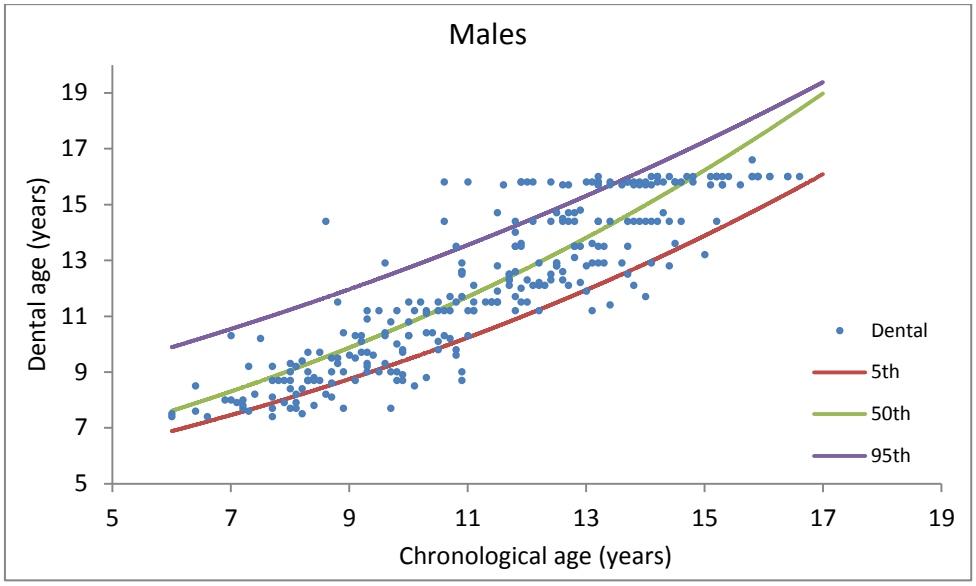
In contrast to Liversidge's work this study showed a statistically significant difference in boys aged 6, 7, 8, 10, 11, 12, 13, 14, and 15 at the $p<0.05$ level. All these ages indicated that boys reached dental maturity earlier. For age group 9 no statistical significant difference was found. A possible explanation for this can be that the data set of 31 boys used for age group 9 was unreliable or the individuals in this group could be classified as dentally average.

In girls statistically significant differences were found in age groups 6, 7, 8, 9, 10, 11, 12, 13 and 16 at the $p<0.05$ level. The girls were more advanced for all these ages and reached dental maturity earlier. For age groups 14 and 15 there were no statistical significant differences found. A possible explanation could be that the French-Canadian girls caught up to the black South African girls during these ages, or black South African girls develop fast from age 6 to 13 but slow down when they reach age 14 and 15 years. The number of subjects for age group 14 and 15 were 23 and 16 respectively, making these datasets less reliable. A statistically significant difference was present for age group 16 years. This result does not fit into the trend and this could be due to the dataset consisting out of only seven girls. Small datasets can be non- representable and thus unreliable. No individuals were discarded from the results regarded as 'outliers'. This was to include all the children with advanced, normal and delayed ages.

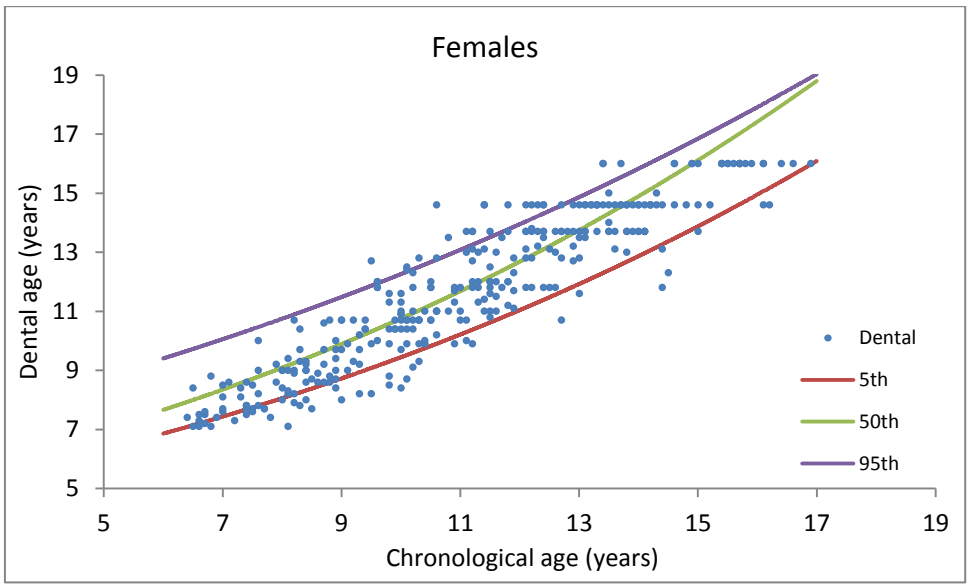
The scatterplots constructed with our data (figure 5) demonstrates a broader band between the 5th and 95th percentile lines for boys when compared to the girls. This represents a greater variation in dental age for the boys, and this variation was present for the entire age range. Biological differences between boys and girls are the likely cause for the larger variation. A larger variation for other parameters has been found for boys. These development parameters include height and age.[45] Most of our subjects fell within the 95th percentile range. For boys most of the outliers were between the ages of 10 and 13 years and for girls between the ages of 9 to 14 years.

Figure 5. *Scatterplots to demonstrate the calculated dental age by actual chronological age for black South African children (a) boys and (b) girls. The 5th, 50th and 95th percentile lines are drawn.*

a



b



A more advanced mean dental age for the boys compared to the girls were found for all the age groups except for age group nine (Table 2). On average girls reached dental maturity 0.12 of a year ahead of the boys. These values are however statistically not significant. When dental age is calculated using Demirjian's method one must keep in mind that the correction was made in the original research. To compare the dental age of boys with girls, new conversion tables specific to that population group should be formulated. This finding is in accordance with earlier maturation of other parameters of development in girls. Girls demonstrate an earlier maturation of parameters such as height, sexual maturation and skeletal age.[45] To accurately compare sexual dimorphism a large sample size should be used.

Reproducibility of any age estimation technique is essential. The researcher or different researchers should be able to determine and obtain the same age estimates for the same cases. The variations between the inter- and intra-examiner for this study indicated that the level of agreement was very high and the method is thus reliable. Disagreement between examiners occurred primarily in teeth 44 and 45 in stages G and H. The reason why particular stages of teeth are more difficult to assess may centre on the qualitative assessment required by this method. The given stages allow for variation in interpretation and assessment. Qualitative assessment in the outer ranges of each formative stage creates difficulties in this method.

A possible explanation for the advanced growth for the black South African population can relate to the short formation times for enamel and dentine.[46] The process of enamel and dentine formation is an extremely regulated process. A study done on the count of enamel increments using histological analysis to determine the duration of crown and root formation do show similarities between different population groups. Crown formation times for anterior teeth were consistently shorter in southern Africans compared to that of northern Europeans.[46] The formation of molar enamel found to be even less different from one another and that these differences are very small. The first molar protoconid formation times for a southern African group were shorter when compared to a northern European group. The paracone formation time for the third molar is

however greater in southern Africans than in northern Europeans but are both exceeded by a North American sample. The difference in mean enamel formation times for groups, sharing a close genetic origin, are as great as those from a more diverse genetic origin.[46] The differences between these diverse genetic groups are very small. The enamel formation of southern Africans seems to be shorter when compared to northern Europeans; this might explain the overestimation of dental age for our population group. Radiographic studies are able to record both the sequence of tooth mineralization and the timing of the various stages of tooth mineralization of individual teeth.[47] One disadvantage is that radiographs do not have the resolution to differentiate between microscopic changes in tooth growth.[48]

The numbers of children in each of the study age groups were different. For the younger and older age groups fewer panoramic radiographs were available. Small numbers make the data less reliable. The numbers in the remaining age groups were sufficient to compare with Demirjian's population but not to establish accurate new maturity scores for our population. Numerous published studies used very small sample sizes with varying age ranges to adapt their maturity scores. The usefulness of these studies must be questioned. Any tooth stage demonstrates a wide age variation. To describe tooth formation at the population level necessitates a sufficient sample size as well as a wide age range. All the children with an advanced, normal and delayed age should be included when establishing new maturity scores.[44] Using inappropriate sample sizes will result in inaccurate results.

It is uncertain to us why there is a difference between chronological age and dental age. It is however important to remember that the score for dental maturity represents the sum of weighted scores of 43 individual tooth stages and these were determined using correspondence analysis with end point restrictions. If one analyses the self-weighted scores for dental stages you will find that some scores have zero weight especially in the early ages. In boys and girls stage, H of M_1 carry the most weight namely 19.3 and 16.2 respectively[4]. At the end of dental maturity fewer stages contribute more and this can cause a single stage to lead to a large jump in dental age.[5] Unfortunately these weighted score values do not

have any biological meaning. 792 tooth stage sequences were found to be present in seven year olds and the most common sequences was only found in less than five percent of these children. The unique combinations for the seven year olds exceeded one hundred. The large amount of different sequences might add to the discrepancy we find between average chronological and dental age.[46] One disadvantage of Demirjian's method is the fact that a limit exist and that one tooth is able to predict age for the oldest child. The tooth in question is the second molar and an addition of the third molar is advised to improve accuracy until the age of eighteen. Demirjian's method is not useful after the age of sixteen and cannot be used to accurately predict age beyond age eighteen.[2]

The only other study done on a South African sample is the study done by Phillips VM and van Wyk Kotze TJ.[17] When these two studies are compared, a few important differences are noted. The sample size used in this study included 604 black children (279 boys and 325 girls) compared to a selected sample of 236 Nguni children (combined sexes) from the Phillips VM and van Wyk Kotze TJ study. The number of children in each age group used in the Phillips VM and van Wyk Kotze TJ study make the validity of the results for certain age groups questionable. For this study new dental age related tables were not prepared because statistically our population sample of 604 individuals was too small. Dental age related tables were however prepared by the Phillips VM and van Wyk Kotze TJ study using only 236 individuals. The validity and accuracy of the age related table should be questioned when such a small sample was used to construct the table. In the Phillips VM and van Wyk Kotze TJ study the boys and girls for the Nguni group were combined to generate generic tables. This study is in agreement and found no statistical difference between the two sexes when boys and girls are kept as separate entities. This study agrees that even though there are slight differences between the two sexes it is not significant enough to influence age estimation. The reliability of the analysis quality of this study was tested by inter- and intra-examiner assessment. The author of the Phillips VM and van Wyk Kotze TJ study was the only observer. Being the only observer could lead to continues misinterpretation of certain age stages, which in turn could lead to inaccurate results. This study however confirms the results from the Phillips VM and van Wyk Kotze TJ study that the Demirjian method over estimates dental age.

A larger study, in which all Black population groups are included, needs to be carried out, to accurately determine the correction factor needed in a Black South African population.

Panoramic radiographs are still considered the best method of estimating age in children.[49] Quality panoramic radiographs are however necessary to accurately determine the amount of crown, root and apex formation. Technically inferior radiographs make optimal interpretation difficult and in some cases impossible. Aspects influencing the diagnostic capability include underexposed, overexposed, poorly positioned patients and poor developing methods. Panoramic radiographs are produced using tomography and this can result in teeth being out of the focal trough. Structures out of the focal trough can lead to unequal magnification and geometric distortion making accurate assessment difficult. The patients chin and occlusal plane must be properly positioned to avoid any distortion in the anterior region. If the chin is lifted to high, the hard palate will be superimposed on the roots of the maxillary teeth. When the chin is positioned to low the anterior teeth becomes severely overlapped. Misestimation can easily take place if the teeth are inclined in a buccolingual direction.[50] Patients allowed to slump during positioning can cause a large radiopaque artefact in the midline. The artefact will be superimposed over the anterior teeth. Air present in the mouth during the procedure can cause poor visualization of the apices of the maxillary teeth. When viewing radiographs the proper environment should be available. All radiographs should be viewed on a bright and evenly illuminated light box. Digital panoramic radiographs were easier to read and the images clearer leading to more accurate interpretations. Digital panoramic radiographs also have the software facility to change lightness and contrast. This makes assessment of poorer quality radiographs easier and in my opinion more accurate.

The differences between the black South African and French Canadian children might be a secular trend.[51] Biological variation may also be a contributing factor for the differences found in a black South African population group. The differences found in this pilot study call for a larger population sample to be evaluated and to establish new maturity scores for black South African children.

Chapter 7

7.1 Conclusion

1. The results from this study have shown that Demirjian's method has some limitations when used to determine the estimated dental age of black South African children. The results demonstrated that Demirjian's method produced significant differences between dental age and chronological age in the studied group. This study is in agreement with a study from Phillips VM and van Wyk Kotze TJ done on a similar population group that Demirjian's age estimation method overestimates dental age.
2. Accelerated growth was observed for both boys and girls when compared with Demirjian's group.
3. The mean difference between chronological age and dental age were 0.8 years in boys and 0.5 years in girls.
4. In boys, statistically significant differences were observed in age groups 6, 7, 8, 10, 11, 12, 13, 14, and 15.
5. In girls, statistically significant differences were observed in age groups 6, 7, 8, 9, 10, 11, 12, 13 and 16.
6. Development standards used by Demirjian are not suitable for a black South African population group.

7.2 Recommendations for future research.

1. Increasing the sample size of all the age ranges to establish new maturity scores and logistic curves for the studied population group.
2. Testing the validity of the Willems *et al*.[3] method on our population group.
3. Comparison with other black South African children in rural communities found in other regions in South Africa.
4. The comparison of dental age between different racial groups found in South Africa using Demirjian's method.
5. The comparison of dental age between different black ethnic groups found in South Africa using Demirjian's method.

References

1. Mani S, Naing L, John J, Samsudin A. Comparision of two methods of dental age estimation in 7-15 year-old Malays. Int J Paediatr Dent. 2008; 18: 380-388.

2. Chaillet N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: International maturity curves for clinicians. J Forensic Sci. 2005; 50: 1164-1174.

3. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci. 2001; 46: 893-895.

4. Demirjian A, Goldstein H, Tanner J. A new system of dental age assessment. Hum Biol. 1973; 45: 211-221.

5. Maber M, Liversidge H, Hector M. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int. 2006; 159: S68-S73.

6. Chen J, Guo J, Zhou J, Liu R, Chen T, Zou S. Assessment of dental maturity of western Chinese children using Demirjian's method. Forensic Sci Int. 2010; 197: 119e1-119e4.

7. Rozyło-Kalinowska I, Kiworkowa-Raczkowska E, Kalinowski P. Dental age in Central Poland. Forensic Sci Int. 2008; 174: 207- 216.

8. Filipsson R. A new method for assessment of dental maturity using the individual curve of number of erupted permanent teeth. Ann Hum Biol. 1975; 2: 13-24.

9. Demirjian A. Dentition. In: Falkner F, Tanner J M (eds) Human growth, Postnatal growth. Plenum Press, New York.1978; 2: 413-444.

10. Gleiser I, Hunt E. The permanent mandibular first molar: its calcification, eruption and decay. Am J Phys Anthropol.1955; 13: 253-281.

11. Grøn A . Prediction of tooth emergence. J Dent Res. 1961; 41: 573-585.

12. Lilliequist B, Lundberg M. Skeletal and tooth development. Acta Radiol. 1971; 11: 97-111.

13. Mörnstad H, Reventlid M, Teivens A. The validity of four methods for age determination by teeth in Swedish children: a multicentre study. Swed Dent J. 1995; 19: 121-130.

14. Tanner J, Whitehouse R, Healy M. A new system for estimating skeletal maturity from hand and wrist, with standards derived from a study of 2600 healthy British children. Centre International de l'Enfance, Paris. 1962.

15. Demirjian A, Levesque G. Sexual differences in dental development and prediction of emergence. J Dent Res. 1980; 59: 1110-1122.

16. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol. 1976; 3: 411-421.

17. Phillips V, van Wyk Kotze T. Dental age related tables for children of various ethnic groups in South Africa. J Forensic Odontostomatol. 2009; 27:2: 29-44.

18. Phillips V, van Wyk Kotze T. Testing standard methods of dental age estimation by Moorrees, Fanning and Hunt and Demirjian, Goldstein and Tanner on three South African children samples. J Forensic Odontostomatol. 2009; 27:2: 20-28.

19. Nyström M, Haataja J, Kataja M, Evälahti M, Peck L, Kleemola-Kujala E. Dental maturity in Finnish children, estimated from the development of seven permanent mandibular teeth. Acta Odontol Scand. 1986; 44: 193-198.

20. Nykänen R, Espeland L, Kvaal S I, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand. 1998; 56: 238-244.

21. Leurs I, Wattel E, Aartman I, Etty E, Prahl-Andersen B. Dental age in Dutch children. Eur J Orthod. 2005; 27: 309-314.

22. Frucht S, Schnegelsberg C, Schulte-Mönting J, Rose E, Jonas I. Dental age in Southwest Germany, a radiographic study. J Orof Orthop. 2000; 61: 318-329.

23. McKenna C, James H, Taylor J, Townsend G. Tooth development standards for South Australia. Aus Dent J. 2002; 47: 223-227.

24. TeMoananui R, Kieser J, Herbison G, Liversidge H. Estimating age in Maori, Pacific Island, and European children from New Zealand. J Forensic Sci. 2008; 53: 401-404.

25. Liversidge H, Speechly T, Hector M. Dental maturation in British children: are Demirjian's standards applicable? Int J Peadiatr Dent. 1999; 9: 263-269.

26. Roberts D. Genetics of growth. Brit Med Bull. 1981; 37: 239-246.

27. Thesleff I. The genetic basis of normal and abnormal craniofacial development. Acta Odontol Scand. 1998; 56: 321-325.

28. Thesleff I. Epithelial-mesenchymal signalling regulating tooth morphogenesis. J Cell Sci. 2003; 116: 1647-1648.

29. Merwin D, Harris E. Sibling similarities in the tempo of human mineralization. Arch Oral Bio. 1998; 43: 205-210.

30. Nafee T, Farrell W, Carroll W, Fryer A, Ismail K. Epigenetic control of fetal gene expression. BJOG. 2008; 115: 158-168.

31. Junewein T, Allis C. Translating the histone code. Science. 2001; 293: 1074-1080

32. Calvanese V, Lara E, Khan A, Fraga M. The role of epigenetics in aging and age related diseases. Ageing Res Rev. 2009; 8: 268-276.

33. Dolinoy D, Weidman J, Jirtle R. Epigenetic gene regulation: linking early developmental enviroment to adult disease. Reprod Toxicol. 2007; 23: 297-307.

34. Gluckman P, Hanson M. Living with the past: evolution, development, and patterns of disease. Science. 2004; 305:1733-1736.

35. Liversidge H, Speechly T. Growth of permanent mandibular teeth of British children aged 4 to 9 years. Ann Hum Biol. 2001; 28: 256-262.

36. Heather J, Hunley K. Race Reconciled?: How biological anthropologists view human variation. Am J Phys Anthropol. 2009; 139: 1-4.

37. Schmelling A, Reisinger W, Loreck D, Vendura K, Markus W, Geserick G. Effects of ethnicity on skeletal maturation: consequences for forensic age estimations. Int J Legal Med. 2000; 113: 253-258.

38. Gandini P, Rizzo S, Renzi P. Dental age and skeletal age: correlation study. Mondo Orthod. 1989; 14: 207-210.

39. Grøn A. Prediction of tooth emergance. J Dent Res. 1962; 41: 573-585.

40. de Villiers H. 1968a. The skull of the South African Negro: a biometrical and morphological study. Johannesburg: Witwatersrand University Press.

41. Franklin D, Freedman L, Milne N, Oxnard CE. Geometric morphometric study of population variation in indigenous southern African crania. Am J Hum Biol. 2007; 19: 20-33.

42. Marshall W. Geographical and ethnic variations in human growth. Brit Med Bull. 1981; 37: 273-279.

43. Nyström M, Ranta R, Kataja M, Silvola H. Comparisons of dental maturity between the rural community of Kuhmo in northeastern Finland and the city of Helsinki. Community Dent Oral. 1988; 16: 215-217.

44. Liversidge H. Interpreting group differences using Demirjian's dental maturity method. Forensic Sci Int.2010; doi:10.1016/j.forsciint.2010.02.032.

45. Venrooij-Ysselmuiden M, Ipenburg A. Mixed longitudinal data on skeletal age from a group of Dutch children living in Utrecht and surroundings. Ann Hum Biol. 1978; 5: 359-380.

46. Reid D, Dean M. Variation in modern human enamel formation times. J Hum Evol. 2006; 50: 329-346.

47. Tompkins R. Human population variability in relative dental development. Am J Phys Antropol. 1996; 99: 79-102.

48. Beynon A, Clayton C, Ramirez Rozzi F, Reid D. Radiological aspects of the developing dentition in modern humans and great apes. J Hum Evol. 1998; 35: 351-370.

49.Farah C, Booth D, Knott S. Dental maturity of children in Perth, Western Australia, and its application in forensic age estimation. J Clin Forensic Med.1999; 6: 14-18.

50. Wood R. Forensic aspects of maxillofacial radiology. Forensic Sci Int. 2006; 159: S47-S55.

51. Nadler G. Earlier dental maturation: fact or fiction? Angle Orthod. 1998; 68: 535-538.

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Faculty of Health Sciences Research Ethics Committee
Fakulteit Gesondheidswetenskappe Navorsingsetiekkomitee

DATE: 26/08/2010

PROTOCOL NO.	**146/2010**
PROTOCOL TITLE	Dental Age Assessment Of Black South African Children Using Demirjian's Method
INVESTIGATOR	**Principal Investigator:** Dr. A.Uys
SUBINVESTIGATOR	None
SUPERVISOR	Prof. H. Bernitz
DEPARTMENT	**Dept:** Oral Pathology and Oral Biology **Phone:** 012-3192342 **Fax:** 012-321 2225 **E-Mail:** andre.uys@up.ac.za **Cell:** 0844301805
STUDY DEGREE	MSc (Odont) Maxillofacial and Oral Radiology
SPONSOR	None
MEETING DATE	**25/08/2010**

The Protocol and Informed Consent Document were approved on 25/08/2010 by a properly constituted meeting of the Ethics Committee subject to the following conditions:

1. The approval is valid until the end of December 2012 period, and
2. The approval is conditional on the receipt of 6 monthly written Progress Reports, and
3. The approval is conditional on the research being conducted as stipulated by the details of the documents submitted to and approved by the Committee. In the event that a need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

Members of the Research Ethics Committee:

Prof M J Bester	(female)BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc(Biochemistry); PhD (Medical Biochemistry)
Prof R Delport	(female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education
Prof VOL Karusseit	MBChB; MFGP(SA); MMed(Chir); FCS(SA) - Surgeon
Prof JA Ker	MBChB; MMed(Int); MD – Vice-Dean (ex officio)
Dr NK Likibi	MBBCh – Representing Gauteng Department of Health)
Prof TS Marcus	(female) BSc(LSE), PhD (University of Lodz, Poland) – Social scientist
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