MATURATION OF THE PERMANENT TEETH IN A WESTERN CAPE SAMPLE

BY

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DECLARATION

I .... declare that "Maturation of the permanent teeth in a Western Cape Sample" is my own work and that all the sources I have quoted have been indicated and acknowledged by means of references.

SIGNED: ....

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DEDICATION

This thesis is dedicated to four orthodontists whose endeavour and dedication made possible a postgraduate course in orthodontics at the Faculty of Dentistry, University of the Western Cape.

DR P DE WET

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OPSOMMING

Kennis van die ontwikkeling van die menslike gebit vind nie net toepassing in tandheelkunde en ortodonsie nie, maar ook op sulke uiteenlopende gebiede soos fisiese antropologie, endokrinologie, voeding en geregtelike odontologie. Navorsing het bewys dat daar minder afwyking is in tandveroudering dan in skeletveroudering. Gevolglik is daar by die vasstelling van liggaamlike ouderdom nou meer voorstanders van tandveroudering as skeletveroudering. Meer navorsing word nou toegespits op die vasstelling van norme vir tandontwikkeling van verskillende rasse en streke.

In hierdie studiestuk is die tandontwikkeling van Wes-Kaaplandse voorbeelde volgens die metode van Demirjian et al. (1973) ondersoek. 'n Totaal van 293 gevalle is as monster gebruik wat bestaan het uit 128 seuns en 165 meisies, die ouderdomme waarvan gewissel het vanaf 5 jaar tot 16 jaar. Die totale verouderingskerwe is bereken en die data van die geslagte is met mekaar vergelyk asook met data van Frans-Kanadese Kaukasiër-monsters. Derde kiestande is afsonderlik ondersoek. Die resultate is onderwerp aan die Chi-vierkantstoetse.

Die resultate het getoon dat tandveroudering meer gevorderd was by die vroulike geslag tot by die ouderdom van 14 jaar in die Wes-Kaapse gevalle. Vanaf 15-jarige ouderdom het die veroudering by meisies verlangsaam en is die proses later as by seuns voltooi. Die Wes-Kaaplandse voorbeelde was in beide manlik en vroulik merkwaardig gevorderd in vergelyking met die Frans-Kanadese Kaukasiër-voorbeelde. By die vroulike voorbeelde egter, is veroudering op 'n later stadium voltooi as by vroulike Frans-Kanadese voorbeelde.

Die derde kiestand het 'n onafhanklike ontwikkelingspatroon getoon met geen ras- of geslagsverbintenis nie. Hierdie feit kom dan ook ooreen met die ontwikkelingspatroon van die derde kiestand in ander rasse en streke.

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INTRODUCTION

The need for in-depth knowledge of dental emergence and calcification in orthodontic diagnosis and treatment planning cannot be disputed. Serial extractions, treatment timing, bite opening and closing, expansion and various other orthodontic procedures cannot be successfully executed without an in depth knowledge of the calcification and eruption of teeth. Besides its orthodontic implications, dental calcification and eruption plays a significant role in physical anthropology, forensic odontology, endocrinology and nutrition (Demirjian, 1978). Forensic scientists are agreed that teeth constitute the most important and reliable means for determining age from approximately 10 week in utero to old age (Altini, 1983).

It is a generally accepted fact that there is no correlation between biological age and chronological age (Prahl-Andersen and Van der Linden, 1972; Demirjian, 1978), an aspect, which will be discussed in further detail later in the review of the literature. Biological age is seen to be a more accurate indicator of an individuals maturity than chronological age (Moorees et al, 1963; Prahl-Andersen and Van der Linden, 1973; Demirjian et al, 1973). However, allocating a biological age to an individual is not an easy exercise as no definite consensus has, to date, been reached regarding the best method of determining biological age (Moorees et al, 1963; Garn et al, 1967; Demirjian, 1978). Today, many different methods are being used to establish this, for example bone age, height, menarche, circumpubertal growth and dental age.

Research has shown that calcification and emergence of both deciduous and permanent teeth are remarkably independent of skeletal development (Meredith 1959; Lewis and Garn, 1960; Garn et al, 1967; Demirjian, 1978). This is not surprising since the teeth develop from ectoderm and the bone from mesoderm. Research has also shown that the variability in dental development is less than that in skeletal maturation (Lewis and Garn, 1960; Garn et al, 1967). Since dental calcification is genetically controlled (Lewis and Garn, 1960) and less susceptible to external influences than skeletal maturation, there has been a definite trend in recent years to use dental age as a criterion for somatic growth evaluation rather than skeletal maturational indicators (Demirjian, 1978). There are however, problems associated with the use of dental age rather than skeletal age. These problems arise as a result of:

a) The variation in dental emergence and calcification pattern between individuals, races and even areas (see review Demirjian 1978).

b) The lack of correlation between dental development and skeletal development which rules out the possibility of using the one indicator to evaluate the other.

c) The lack of correlation between dental development and the circumpubertal growth spurt and menarche.

d) The lack of sufficient longitudinal studies on dental maturational patterns in different groups of people, which would have made possible valid statistical correlations and the establishment of norms for dental development.

The need for research into the developmental pattern of the teeth in different race groups and in different geographical areas is now becoming essential as recent studies are indicating significant differences in dental maturation in different populations of the world (Demirjian et al, 1973; Krumholt et al, 1971; Debrot 1972; Garn et al, 1973; Frietas and Salzano, 1975; Loevy, 1983).

Whether emergence pattern or calcification pattern ought to used to determine dental age is still not fully resolved and remains controversial (Demirjian 1973; Hagg and Taranger, 1984). However, it is now accepted that calcification is largely under genetic control and is not influenced to any significant extent by environmental factors as does dental emergence (Lewis and Garn, 1960). Dental emergence can be hastened or retarded by various environmental influences, one example of which is the premature extraction of deciduous teeth. It was Gleiser and Hunt (1955) who first stated, in their well known study, that "the calcification of a tooth may be a more meaningful indication of somatic maturation than its clinical emergence". Since then, this concept has steadily been gaining acceptance among workers in the field of human dental biology (Nolla, 1960; Lewis and Garn, 1960; Moorees et al, 1963; Demirjian, 1973). Today many workers consider dental maturation or calcification, which is a continuous process, as a better measure of physiological maturity than a short lived and environmentally dependent phenomenon such as dental emergence (Demirjian, 1978).

Out of this new trend amongst workers to investigate calcification instead of emergence, arose various methods to break down the continuous process of dental calcification into stages. Numerous methods were evolved in a quest for the establishment of stages which were not only easily recognizable on X-ray, but which had no variation and did not lend themselves to examiner error. Out of this search for the best method to evaluate dental maturation arose two broad concepts. The one concept based maturation on length criteria (Nolla, 1960; Moorees et al, 1963) and the other concept based maturation on shape criteria (Lewis and Garn, 1960; Demirjian et al, 1973). The difficulty with using length criteria was its limitations when applied to cross-sectional studies. The use of shape criteria on the other hand is now gaining credibility and the method proposed by Demirjian et al (1973), which makes use of a unique biological scoring system, is gaining popularity. The advantage of this system is that it has its applicability in both longitudinal and cross-sectional studies.

To date, no studies have been undertaken to determine the pattern of maturation of the teeth or the bones in the Western Cape population group. Such a study is essential, in keeping with the worldwide trend of establishing norms for dental and skeletal maturation. This cross-sectional study of dental development in a so called "Coloured" population group of the Western Cape has been undertaken essentially to establish dental maturation trends. Obviously, longitudinal studies using large samples are most appropriate in establishing dental norms. However, cross-sectional studies, such as this, are valuable in establishing trends which would add to the pool of knowledge that is essential in establishing definite norms for dental development in South African population groups.

Dentists are presently still applying Caucasian norms derived by such workers as Schour and Massler (1940) and Hurme (1949) on all sections of the South African population. This demonstrates the lack of knowledge in this aspect of dentistry which is important not only in the field of orthodontics but also in general dental practice.

It was on this basis that a study on the so called "Coloured" population group in the Western Cape was undertaken. The objectives of this study were:

1. To investigate the pattern of calcification of all the teeth, including third molars.

2. To investigate sex differences in the maturation of the teeth.

3. To compare the dental maturation pattern of the Western Cape sample with a French Canadian (Caucasian) sample.

REVIEW OF THE LITERATURE

Introduction

Knowledge about the development of the dentition can be applied not only in dentistry and orthodontics, but also in such diverse fields as physical anthropology, endocrinology, nutrition and forensic odontology (Demirjian 1978). Only 40 years ago lack of knowledge of dental maturation and eruption actually resulted in the unjustified treatment of the thyroid gland in stocky and stout children. The latter were mistakingly thought to have some thyroid abnormality because of the delayed dental eruption pattern (Brauer et al, 1947).

It is now accepted that physiological or biological age, in contrast to chronological age, is more important in assessing an individual's growth and development (Prahl-Andersen, 1972; Demirjian 1973). The concept of physiological age is based on the degree of maturation of different tissue systems. Several biological ages have been developed: skeletal age, morphological age, secondary sex character age and dental age (Demirjian et al, 1973). These criteria can be applied separately or together to assess the degree of physiological maturity of a growing child.

The chronological age of children with uncertain birth records is often estimated by evaluating the individuals somatic maturity. However, owing to a comparatively low variability of tooth formation in relation to chronological age (Lewis and Garn, 1960), it seems that methods based on stages of tooth formation are more appropriate in assessment of chronological age than those based on other indicators of somatic development (Hagg and Matsson, 1985).

Various criteria are used in the evaluation of dental maturation, for example, eruption times, degree of calcification and exfoliation in the case of the deciduous dentition. However, the study of dental development, unlike that of skeletal development, has unfortunately not progressed to the stage where norms for dental maturity have been wholly clarified and standardized or reached a stage of universal acceptance (Demirjian, 1978).

The most commonly used parameter for assessing dental maturity has always been the term "eruption". This term is used to indicate the clinical appearance of the cusps of a tooth through the gingiva (Demirjian, 1978). The first use of eruption as an indicator of physical maturity occurred in England (Saunders, 1837) when the Factory Act stipulated that a child without a second permanent molar could not be allowed to work in the factories. Later, the dental criteria, as a maturity indicator, was used for school entrance purposes.

Up until the 1940's, data on dental development were based on histological sections from very small samples. Errors from this unreliable approach persist to the present day (Demirjian, 1978). Schour and Massler (1940) published the "Chronology of Growth of Human Teeth", which was based predominately on histological sections and included both deciduous and permanent teeth. This developmental "norm", persisted for many years and proved inconclusive from a view of serial growth and development of the individual as a whole. According to Todd (1931), a dead child is a defective child, unless the death has been caused by accident or acute illness. Studies of dental development should, therefore, utilize healthy living skulls.

Today, studies of dental maturity try to use and correlate histological, radiological and clinical data. The prenatal phase of deciduous dental development is still the histological approach. Postnatal dental maturation, however, is studied both radiologically (formation) and clinically (emergence). It must be remembered that formation and eruption are essentially two different processes which can be influenced by genetic, environmental and hormonal factors (Demirjian, 1978).

A great deal of research has been done on the chronology and timing of dental emergence. These studies have been conducted in order to establish population standards for clinical, anthropological, medico-legal and other purposes. Several such standards have been used as criteria for the determination of biological (dental) age.

CALCIFICATION OR FORMATION AS OPPOSED TO ERUPTION OR EMERGENCE OF TEETH

According to Demirjian (1978) the word "eruption" is an erroneous term used to denote the appearance of a tooth in the oral cavity. According to this author, the correct term for the piercing of the gingiva is referred to as "clinical emergence" or "emergence". Similarly, piercing of the alveolar bone, as seen on the radiographic image, is termed "alveolar emergence". Eruption is actually a dynamic movement of the tooth, both before and after actual emergence.

The concept of tooth calcification in contrast to clinical emergence as a meaningful indicator of somatic maturation, is steadily gaining acceptance among workers (Garn et al, 1958; Nolla, 1960; Moorees et al, 1963a; Prahl-Anderson, 1972; Demirjian et al, 1973) for the following reasons:

a) The clinical emergence of a tooth is a fleeting event and its exact emergence time is very difficult to determine (Dale, 1985). There is no clear cut definition of the word "eruption" in the literature.

b) The emergence of a tooth is disturbed by different exogenous factors, for example, infection, premature extraction of deciduous teeth, crowding and injury. The rate of eruption may be decreased by deficiency of vitamin A or D, hypothyroidism and sickness, or it may be due to semi-starvation, hyperthyroidism, cortisone administration, and increased activity (Graber and Swain 1985).

c) That if the emergence of a tooth is taken as a maturity indicator, then each tooth has to be considered individually. The overall picture of the dentition cannot be assessed unless the total count of the teeth are dealt with. This means that the evaluation of maturity becomes a very crude measurement (Demirjian, 1978).

d) The use of clinical emergence as a maturity indicator is limited to certain ages as the human dentition consists of two sets of teeth which emerge during two periods separated by several years. It is thus impossible, with emergence data alone, to assess the dental maturity of a child between the ages of 2½ and 6 years, and after 12 years of age, as there is no clinical emergence of teeth at those time periods (Demirjian, 1978; Prahl-Andersen, 1972).

For all the above reasons, dental formation or calcification, which is a continuous developmental process, seems to be a better measure of physiological maturity than clinical emergence

(Lewis and Garn, 1960; Nolla, 1960; Moorees et al, 1963a; Liliequist and Lundberg, 1971; Prahl-Andersen, 1972; Demirjian, 1978; Nanda, 1983; Dale, 1985).

Hagg and Taranger (1981), in their study on the relationship between dental development and pubertal growth spurt, categorized dental "eruption" into "dental emergence stages". Dental emergence stage I (DES-I) was defined as the emergence of the crowns of 1 to 7 incisors through the gingiva. Similarly, DES-2 referred to the stage when all the incisors emerged. Acknowledging the effects of factors that delayed or accelerated emergence, they made systematic adjustments to the times of emergence of the teeth.

The fact that emergence and calcification did not follow the same pattern was illustrated in a study by Garn and Lewis (1957). The workers noted the following:

a) 21 out of 22 children with P2, M2 (second premolar, second molar) sequence of formation (calcification) continued to be P2M2 in eruption or emergence sequence.

b) Half of 14 children with M2P2 (second molar, second premolar) sequence of formation shifted to P2M2 sequence of eruption. This suggested that even though the second molar was advanced in its early stages of calcification, it was, however, overtaken in its maturation and eruption by the second premolar. This phenomenon applies to certain population groups only.

Garn et al, (1958) undertook another study on the calcification and emergence of the second premolar and second molar using radiographs. Alveolar emergence and occlusal attainment were assessed. Clinical emergence was not assessed. The authors found that the sequence of calcification and emergence alternated in 55% of the subjects. From this study, they concluded that a stage of calcification, for example, could not be a prediction criterion for a stage of eruption. Tooth calcification and eruption processes are independent of each other (Garn et al, 1958, 1960).

EMERGENCE OF THE DECIDUOUS DENTITION

The emergence of deciduous teeth spans over a relatively short period namely from 6 to 30 months of age, as compared to permanent teeth which span from about 6 years to approximately 18 years of age. Studies on deciduous dentition maturation have been done on emergence stages rather than on degrees of calcification. Moorrees et al, (1963b), nevertheless, utilized the "Fels" material to make a longitudinal radiographic study on the development of the deciduous canine and molars. They presented normative data on this work. Weighted estimates of the mean attainment age for each stage were obtained by using a standard deviation of 2.042 log conceptional - age units. A graphic representation of the chronology of tooth formation and root resorption was provided for each tooth. However, the author cautioned that "standard score ratings for the various teeth should be presented preferably as a range of maximal and minimal deviate. They should not be averages, in recognition of the individuality of each tooth".

(i) Eruption Sequence

According to Moyers (1973), the initial calcification of the various primary teeth is as shown in Table 1.

TABLE 1 INITIAL CALCIFICATION TIMES (IN UTERO)

Teeth	Weeks (in utero)
Central incisors	14
First molars	15½
Lateral incisors	16
Canines	17
Second molars	18

Hatton (1955) listed the eruption times of the primary teeth as follows:

At 6 months - onen third have one or more teeth;

At 9 months - Mean:3 teeth; 80% have between 1 and 6 teeth.

At 12 months - Mean:6 teeth; 50% have between 4 and 8 teeth.

At 18 months - Mean:12 teeth; 85% have between 9 and 16 teeth.

At 24 months - Mean:19 teeth; 60% have between 15 and 18 teeth.

At 30 months - 19 teeth; 70% have between all primary teeth.

There is a great deal of variation in the eruption of deciduous teeth. However, the most frequent pattern as stated by Moyers (1973) and Leighton (1977) is:

$\overline{A}$, $\underline{A}$, $\underline{B}$, $\overline{B}$, $\underline{D}$, $\overline{D}$, $\underline{C}$, $\overline{C}$, $\overline{E}$, $\underline{E}$, The table below illustrates the mean eruption ages in months of deciduous teeth of 84 subjects investigated by Leighton (1977)

TABLE 2 MEAN ERUPTION AGES IN MONTHS OF DECIDUOUS TEETH AMONG 84 SUBJECTS

Tooth	Male n = 39		Female n = 45		Total n = 84	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Upper Central Incisor	8.92	± 0.22	9.40	± 0.23	9.18	± 2.10
	10.19	± 0.26	10.87	± 0.20	10.55	± 2.58
Upper Canine	17.51	± 0.33	18.73	± 0.35	18.17	± 3.21
Upper First Molar	14.55	± 0.29	14.87	± 0.21	14.72	± 2.29
Upper Second Molar	26.28	± 0.52	26.33	± 0.33	26.31	± 3.27
Lower Central Incisor	6.75	± 0.20	7.57	± 0.23	7.28	± 2.00
Lower Lateral Incisor	11.06	± 0.31	11.97	± 0.31	11.55	± 2.86
Lower Canine	17.78	± 0.36	18.70	± 0.36	18.27	± 3.32
Lower First Molar	14.69	± 0.26	14.96	± 0.19	14.83	± 2.05
Lower Second molar	25.60	± 0.52	25.82	± 0.39	25.72	± 4.11

ii) Sex Difference

Demirjian (1978) in his review noted that many authors were unanimous in reporting no differences in the emergence of the deciduous dentition between boys and girls. However, there is still lack of consensus, as some investigators found an earlier emergence pattern in boys (Leighton, 1977; Baghdady and Ghose, 1981) while

while other investigators found a delayed emergence pattern in boys (Bambach 1973). Infante (1974) concluded from his study on Black and White children from a lower socio economic level in South Eastern Michigan, that boys of both races began deciduous tooth emergence at earlier ages than girls. However, girls surpassed boys in tooth emergence at approximately 15 months of age and remained advanced through to completion. Lavelle (1975) stated that deciduous tooth eruption times are more variable than is stated in the majority of orthodontic texts, a feature which must be taken into account in the treatment of the deciduous dentition.

iii) **Racial difference:**

Most studies found a trend towards early emergence of the deciduous teeth in White American, British and French samples when compared to Blacks, Indians and Chinese (Demirjian 1978). Magnusson (1982) found that Icelandic children displayed a significantly earlier emergence of the deciduous dentition than their Swedish, Hungarian and American counterparts. However, by 2 years of age, the Black, Indian and Chinese groups caught up with the white groups and the initial delay was thus overcome. Friedlander and Bailit (1969) came to the conclusion that the emergence of the deciduous dentition was complete by the end of the 29th month of life, regardless of ethnic origin or race, or at which age the first tooth appeared.

iv) **Socioeconomic Status:**

Bambach et al (1973) found no significant correlation between deciduous tooth emergence and socio-economic conditions. Lavelle (1975) also found no significant differences in the socio-economic distributions between the various samples he investigated.

v) **Genetics:**

The emergence of deciduous dentition seems to be more influenced by genetic and hereditary factors than by environmental or socioeconomic situations (see review Demirjian, 1978). Prenatal dental development is characterized by at least as much sexual dimorphism, developmental variability, bilateral asymmetry and sequence variability as has been reported in the postnatal development of the deciduous and permanent dentitions (Moyers, 1973).

vi) **Nutrition:**

In general terms, no correlation has been found between nutrition and the emergence of the deciduous teeth (Infante and Owen 1973). Dental emergence might be delayed only in cases of severe Protein Calorie Malnutrition (P.C.M.). With the information currently available, emergence and formation patterns of the deciduous dentition seemed "programmed" in foetal life (Jellife and Jellife, 1973).

vii) **Birth Weight, Stature:**

Low birth weight and prematurity are two factors which have been linked to delayed emergence of the deciduous teeth (Demirjian, 1983).

Advanced emergence has also been correlated to height in both sexes and to head circumference in boys (Infante and Owen, 1973). Some workers reported the timing of tooth eruption as being correlated to physique, whilst other workers (see review Demirjian, 1978) concluded that eruption timing is independent of stature or body weight. Lavelle (1975), in his study on the timing of deciduous tooth eruption found no significant relationship between eruption, and the distribution of body weight or stature between the various population samples that he examined.

Many workers found no correlation between deciduous dental emergence and skeletal maturity (Robinow, 1973; Billewicz et al, 1973) Since there are so few definitive correlations between deciduous tooth emergence and other physiological parameters such as skeletal maturation, size and sex., it can be concluded that the deciduous dentition is remarkably independent of other morphological processes (Demirjian, 1978).

MATURATION AND EMERGENCE OF THE PERMANENT TEETH

1) TIMING OF ERUPTION AND ITS ORTHODONTIC SIGNIFICANCE

In orthodontics, it is of interest to be able to predict the ultimate size and rate of maturation of the jaws, the ultimate size, rate of maturation, and emergence of the teeth into the oral cavity, and the ultimate treatment result.

As far as emergence is concerned, the following are generally accepted (Moorees et al, 1963; Dale, 1985):

a) The unerupted permanent tooth is literally "standing still" until half of its root is formed. If the preceding deciduous tooth is extracted too early, that is, before half of the root is formed, emergence is delayed.

b) The teeth emerge into the oral cavity when about three quarter of their roots are formed.

c) It requires approximately 2½ years for the canine root to develop from one quarter to one half of its length and about 1½ years to grow from one half to three quarters.

d) It requires approximately 1¾ years for the first premolar root to grow from one quarter to one half of its length and about 1½ years to grow from one half to three quarters.

e) The last quarter of root development and apical closure lasts from six to eight months.

Root development is speedier in some children and slower in others. According to Moorees et al (1963), the only way to estimate the velocity of root development is by repeated observations (that is, by means of a longitudinal study). Eruption, according to Demirjian (1978), is the continuous movement of a tooth occlusally, and the rate of this movement, according to Feasby (1981), has not, to date, been thoroughly investigated. The latter author, in his longitudinal radiographic study of eruption using the lower border of the mandible as a reference plane, noted the following:

i) After complete crown formation, the teeth moved towards the occlusal plane at a uniform rate.

ii) There was a pre-occlusal eruption surge of 4 to 7mm per year.

iii) The rapid eruption phase does not correlate with root length increase in which eruption exceeded root growth by as much as 4.6mm per year.

iv) A significant eruption rate was demonstrated at age 14 years.

v) The mandibular second molar continued to erupt at approximately three times the rate of the mandibular canines.

Because of the variation among individuals in the amount of root formation at clinical emergence, it is not possible to predict the exact time of emergence from root length, even when considering the skeletal age as an additional measure of physiologic age (Moorees et al, 1963). However, findings (Moorees et al, 1963) infer that deciduous molars should not be extracted before at least one quarter of the premolar root length has been attained.

Extraction of a deciduous tooth at a stage when the root of the succeeding permanent tooth is more than half completed will hasten the eruption of the permanent successor. However, this premature loss of the deciduous tooth does not affect the rate of formation of the roots of the permanent successor (Dale, 1985).

Information regarding the developing maxillary incisors can be used to guide the timing of partial multiband treatment and interceptive procedures. Information associated with the second premolars and second molars can also be used in the initiation of multi-banded mechanotherapy and permanent dentition treatment. Multibanded appliances are inserted when the maxillary permanent canines and mandibular second premolars have erupted sufficiently. In deep overbite malocclusions, the placement of bands is delayed until the permanent second molars have emerged (Dale, 1985).

Knowledge of the development of the dentition and the sequence of eruption is important when embarking on a serial extractions programme. Three factors may be applied by the clinician in deciding the optimum time for the removal of teeth in the guidance of occlusion (Dale, 1985).

1) The effect of extraction of the primary tooth on the eruption of its permanent successor.

2) The amount of root formation at the time of emergence.

3) The length of time for the attainment of various stages of root development.

The relative eruptive rates of the permanent canine and first premolars influence the decision as to which primary teeth should be extracted. Dental age, assessed particularly by root length, is an essential requirement when deciding on a serial extractions programme or when contemplating interceptive or definitive multibanded orthodontic treatment. A knowledge of root development, relative eruptive rates and the emergence of permanent teeth, together with root resorption of the primary teeth and the factors that influence these processes, is mandatory in the timing of serial extractions (Moorees *et al*, 1963; Dale, 1985).

2) STUDIES ON THE EMERGENCE OF THE PERMANENT TEETH:

Numerous cross-sectional and longitudinal studies have been undertaken on the emergence of the permanent teeth, primarily to establish norms (see review Demirjian, 1978). Means and standard deviations of the emergence times of each tooth have been derived from data gathered from these cross-sectional and longitudinal. Cumulative incidence curves have been constructed showing the percentage of children in whom a certain tooth has emerged at a given age (Tanner, 1962; Demirjian, 1978).

Current standards of eruption of teeth are made mostly on the basis of cross-sectional studies, whilst few longitudinal studies have been undertaken (Savara and Steen, 1978). These cross-sectional and longitudinal studies, nevertheless, provide a source of information for the establishment of norms. Workers who attempted to establish norms from cross-sectional studies of eruption include Cohen (1928), Hurme (1949), Billewicz and McGregor (1975), De Melo et al (1975), and Ballew (1976). Workers who have undertaken longitudinal studies in their attempt to establish norms include Nanda (1960), Knott and Meredith (1966), Moorees and Kent (1977), Filipsson (1975), Hagg and Taranger (1984).

Hurme (1949), while working at the Forsyth infirmary, published an extensive study on the emergence of teeth based on 93,000 children throughout the world. This was a cross-sectional study incorporating 100 years of publications on the subject in eight different countries. From this data Hurme published his famous chart depicting emergence of the permanent teeth, with the variability and sex difference listed.

Later studies adopted the probit transformations as the best method for analysing cross-sectional data on eruption/emergence patterns (Monk, 1974, Hoffding et al, 1984). Hagg and Taranger (1981), in their longitudinal study, used the probit analysis to calculate the mean age at the occurrence of each dental emergence stage (DES).

Recently, a new set of norms for dental emergence has been proposed by Moorees and Kent (1977)(Figure 1)

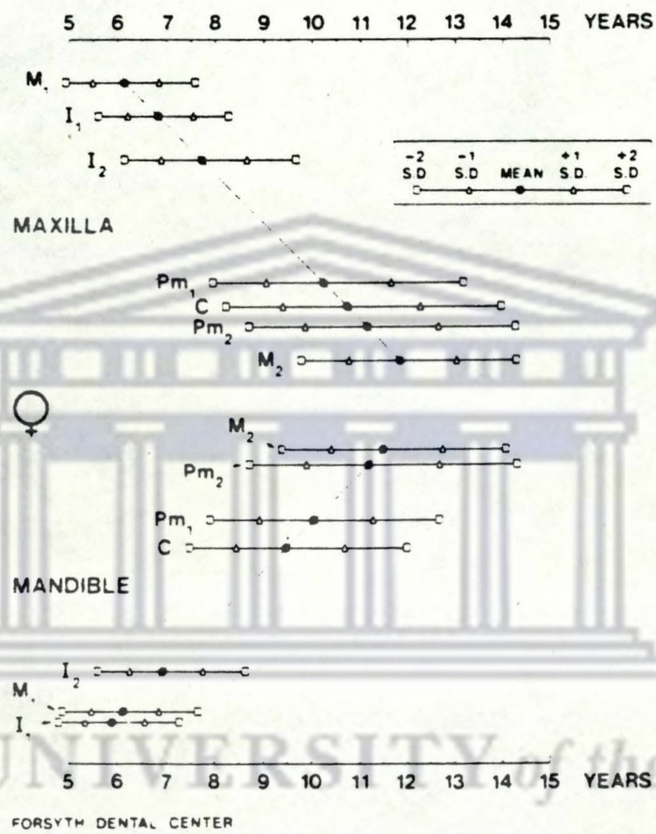


Fig. 1 Assessment of dental age by tooth emergence.

In their proposal, the median ages for emergence of the permanent maxillary and mandibular teeth are depicted, and these could be used to calculate the dental age.

A further development to these emergence charts are the "step function" charts. The "step function" charts can be used to predict the time of eruption of certain permanent teeth by applying the "goodness of fit" technique (Filipson, 1975, Moorees and Kent, 1977).

Gustafson and Kock (1974) constructed the "tooth development diagram", which is a culmination of all the data from studies extending as far back as 1909 to as recently as 1970. They investigated the following 4 stages in both primary and permanent teeth:

Stage I - commencement of mineralization

II - completion of crown

III - eruption (the cusp(s) penetrating the gingiva)

IV - completion of root(s)

These stages were represented schematically on graph paper. On one axis was the age from conception to 15 years of age and the other axis had the second quadrant deciduous and permanent teeth. Triangles were constructed to represent each stage. The base of the triangle was the range and the peak represented the mean age.

3) **SYMMETRY OF EMERGENCE OF PERMANENT TEETH:**

It is now widely accepted that there is symmetry in the emergence time between the teeth of the right and left sides (Demirjian, 1978; Hoffding et al, 1984). The emergence of the upper and lower teeth varies according to the individual tooth: the first toothemerge is always the lower central incisor. Frietas and Salzano (1975), in their study, observed no significant asymmetry in the eruption of permanent teeth in both white and black individuals.

4) **SEXUAL DIFFERENCES:**

Several authors have found significant differences between the two sexes in the emergence of the permanent dentition. Girls are usually 1 to 6 months ahead of boys for certain teeth such as canines (Garn et al, 1967; Melo et al, 1975; Savara and Steen, 1978; Demirjian and Levesque, 1980; Ghose and Bahdady, 1981; Garcia-Godoy, 1982; Hagg and Taranger, 1984; Hoffding et al, 1984). This difference can be as great as 11 months in some populations (Demirjian, 1978).

It is well documented that girls, in general are more advanced than boys as far as calcification of teeth is concerned (Nolla, 1960; Lewis and Garn, 1960; Fanning, 1961; Demirjian and Levesque 1980). It is generally agreed that there is a close similarity in the early stages of dental calcification in boys and girls. In older age groups, girls are always ahead of boys (Demirjian and Levesque, 1980). In a survey of a French-Canadian sample by Demirjian and Levesque (1980), it was found that the time of maturation is similar for both sexes up to stage "C" of crown formation. However from stage "D" onwards girls are consistently more advanced than the boys.

According to Hagg and Taranger (1984), there is a difference of approximately 3 months between the sexes for the first permanent tooth to emerge. This difference is about 10 months for the 13th and 14th tooth. It is then decreased to approximately 6 months for the 28th tooth. Females are earlier in all cases.

A cross sectional survey of Japanese children revealed the following (Hoffding et al 1984):

a) The sequence of emergence in the mandible was concordant with the tooth number. In the maxilla, the canine emerged after the first premolar in girls and after the second premolar in boys.

b) The mean emergence times of teeth in girls preceded those of the boys. The posterior teeth in girls emerged about six months ahead of the corresponding teeth in boys.

c) The greatest difference in the emergence was found for the canines in the maxilla (0.7 years) and the mandible (0.8 years).

An interesting finding of Savara and Steen (1978), in their longitudinal study, was the extent of variation in the sequence of eruption of the first seven permanent teeth. They listed 16 different variations with the commonest sequence being:

Girls
- maxilla: 6,1,2,4,3,5,7
- mandible: 1,6,2,3,4,5,7

Boys
- maxilla: 6,1,2,3,4,5,7
- mandible: 1,6,2,3,4,5,7

Individual variability in tooth formation can be demonstrated radiographically well before their emergence. Sequential variability in permanent tooth calcification has been shown to exist prenatally when some of the permanent teeth begin to form (Garn et al, 1975). The most common order of prenatal permanent tooth development was M1, I1, I2,C. This sequence was modal in both maxilla and mandible (Garn et al, 1975).

5) **RACIAL AND GENETIC FACTORS:**

The emergence as well as the calcification of the permanent dentition is influenced to a considerable degree by genetic and racial factors. Garn et al (1960) made sibling and twin comparisons of tooth formation using serial radiographs. These comparisons revealed cross-sex and like sex sibling correlations, with excellent monozygotic twin correspondences. From this study Garn et al (1960) deduced that the greater proportion of interpersonal variance in timing in tooth formation and also in tooth emergence were due to genetic influences. Tobias (1958) made observations of skeletal and dental maturation and eruption patterns and concluded that, of all the normal anatomical features of the body, the morphology of the teeth came closest to blood groups and other serological factors in the sense of being determined almost entirely by genes.

If the details of tooth emergence are analysed tooth by tooth, and with samples of adequate size, at least three generalizations could be made concerning dental "maturation" (Garn and Bailey, 1978), namely:

a) That there is a socio-economic effect, albeit small, with the more affluent being advanced in tooth emergence and the poor being slightly delayed.

b) That there is a very clear genetic effect, as shown by twin and sibling correlations. Eighty-five to ninety percent of emergence variability can be explained in genetic terms in samples where dental caries and premature loss of deciduous teeth and some permanent teeth are not a complicating factor.

c) That there are real population differences in tooth emergence timing as in well as in calcification sequence. The later emerging deciduous teeth and all permanent teeth appear to be more advanced in American Blacks over their White counterparts. Indeed, it would appear that tooth emergence and dental "maturity" is advanced in most groups of Asiatic, Amerindian, and African origin or ancestry as compared with Europeans or Americans of European descent. Sometimes, African Blacks are as much as 1½ years more advanced in dental development than their European counterparts (Krumholt et al, 1971). Numerous other workers also reported advanced maturation and eruption patterns amongst Blacks as compared to Europeans (Debrot 1972, Garn et al, 1973; Frietas and Salzano, 1975; Loevy, 1983).

Differences in maturation and eruption of teeth are also evident between certain White groups, although these difference are not as substantial as that which is noted between White and Black groups. Loevy (1983) and Sapoka and Demirjian (1971) observed that French Canadian children showed a slower maturation pattern than White children in other parts of North America.

Differences in emergence and maturation of teeth in other ethnic groups can be listed as follows:

i) Latino children in the U.S.A. are more advanced than Whites (Loevy, 1983).

ii) Zulus are more advanced than Europeans and American Whites (Suk, 1949).

iii) Iraqi children have the same eruption times as Asians, but are slightly more advanced than Europeans and Americans (Ghose and Baghdady, 1981).

iv) Southeastern Dominican schoolchildren are, in general,more advanced in dental emergence than United States Whites and Blacks and South African Whites. Garcia-Godoy et al (1982) also noted that their sample showed a delayed emergence of only the maxillary first molar and the mandibular central incisor and first molar when compared to United States Whites. They attributed this "delayed" eruption in the U.S. White groups to genetic influences. The South Eastern Dominicans are a mixture of Blacks and Spanish (Mulattoes).

v) South African Whites show a slightly advanced emergence age as compared to the United States Whites (Monk, 1974).

vi) Frietas and Salzano (1975) did not find any great differences in emergence times between the Brazilian Whites and Blacks. Although the Black subjects were generally more precocious at the beginning of the process, * these dissimiliarities disappeared by nine and twelve years of age.

vii) The timing of the emergence of the anterior and the posterior segments of dentition is different for Lima Indians, Hong Kong children, American and British children (Demirjian 1978). The difference could be due to the fact that the posterior teeth emerged earlier in a population subject to premature shedding of the deciduous molars.

viii) The racial difference is greatest for the mandibular lateral incisor and least for the teeth of the canine area (Garn et al, 1973).

*notably in girls as far as the upper and lower incisors were concerned

6) **SOCIOECONOMIC INFLUENCES:**

Socioeconomic conditions are known to have a definite effect on general body growth, but several investigators (Houpt et al, 1967; Garn et al, 1973; Garcia-Godoy et al, 1982) concluded that there is no impact on permanent tooth emergence, or, at most, only an insignificant one, as compared to the effect on general somatic growth. The Ten-State Nutrition Survey (1972) in the United States showed that white children from high and low income states did not differ significantly in the age of emergence of the permanent teeth; Black children, however, showed an emergence pattern that was earlier in the higher income states (Demirjian, 1978).

Urban and rural differences are also small and insignificant (Helm and Siedler, 1974). Consequently, many workers have come to the conclusion that population differences in tooth emergence exceed socio-economic differences (Garn et al, 1973; Demirjian, 1978; Garcia-Godoy, 1982).

7) **EFFECTS OF NUTRITION:**

Both nutritional status, as measured by fatness and per-capita income, affect tooth formation and emergence timing, but far less than is true for ossification timing and skeletal ("bone") age (Garn and Stephen, 1978).

Grossner and Mansfeld (1983), in their study of children from third world countries adopted by Swedish families, found no retardation of dental development due to nutritional factors.

It is true that severe undernutrition will affect the skeletal and dental systems, but the latter to a lesser degree; even statistically significant correlations remain low (Demirjian 1978).

8) **HORMONAL EFFECTS:**

Few studies have been done on the role of hormones in the process of dental emergence or dental development. In their longitudinal study of two children with pituitary insufficiency, Cohen and Wagner (1948) came to the conclusion that,because of different developmental patterns and different origins (ectodermal and mesodermal), the bony structures (maxilla and mandible) and teeth showed independent growth patterns and were affected differently. Because of the lack of synchronization between bone and dental tissues, positional arrangements, such as changes in vertical dimension and overbite, became more complicated.

According to Garn et al (1967), tooth formation responds to endocrine therapy, and an overtreated cretin, for example, will tend to be advanced dentally as well as skeletally. Interestingly, tooth formation may be advanced, in some cases dramatically so, in certain of the chromosomal deletions and reduplications, even when skeletal development is normal or retarded.

Some workers have reported slight advanced dental maturation with endocrine precocities (for example, adrenocortical hyperplasia) whilst other workers (Garn et al, 1965a) reported slightly delayed dental emergence with hypo-functional endocrine glands (for example, hypothyroidism). However, according to Demirjian (1978); Garn and Stephen (1978) even serious endocrinopathies, which severely retard somatic growth and maturation, exert only a minor effect on the dentition.

In experimental studies on male monkeys, injections of large doses of testosterone accelerated the emergence of all permanent canines. However, the effect of testosterone on the emergence of the canine and other teeth in human males has not been established (Hagg and Taranger 1984). Hagg and Taranger (1983a) found that the emergence of only one specific tooth, the mandibular canine, was significantly correlated to a testosterone dependent pubertal event, the voice change.

SECULAR TREND IN DENTAL MATURITY

Several researchers have investigated secular trends in puberty, height, weight and general growth, over a period of several decades. During recent decades, stature such as head or upper arm circumference, weight has increased more than other measurements, (Tanner, 1962).

It has been assumed that the dental system, being an inherent part of the body, must be influenced by this trend, although perhaps to a lesser degree. Whether the early shedding of the deciduous teeth advances the emergence of the permanent ones, or the reverse, where the permanent teeth develop early and cause the deciduous teeth to shed early, is still to be proven (Demirjian 1978).

Butler (1962), however, argued that there is no evidence that the early shedding of the deciduous teeth is the major cause for the early emergence of the permanent teeth; rather, he attributed the phenomenon to advanced human growth and development generally, as observed during this century. He thus supports a secular trend theory in dental maturity. Hoffding et al, (1984), in their cross-sectional studies on Japanese, demonstrated a secular trend in the emergence of permanent teeth. Monk (1974) found an earlier emergence of most of the permanent teeth in a 1974 White South African cross-sectional sample when compared to a similar 1951 sample. However, Monk attributed this finding to a difference in statistical methods employed. He used the "Hellman" method in 1951 and the Probit analysis in 1974.

Brook (1973) favoured the theory that the earlier emergence of permanent teeth parallels early puberty and an increase in height and weight, as noted in the last two decades.

The secular trend in general growth is attributed to improved environmental conditions, including better nutrition. Although teeth are influenced by environmental factors, they do not follow the same pattern as general growth, and their maturational process is relatively independent. To prove the existence of a secular trend in dentition, one must conduct studies in which the ethnic origin of the sample, methodology, and statistical treatment of the data are carefully controlled. Only then can we positively detect the existence of such a trend in dental development (Demirjian 1978).

EVALUATION OF DENTAL MATURITY BY DEVELOPMENTAL STAGES

1. Calcification of the tooth is a gradual and continous process from crypt formation to closure of the root apex, and many workers (Nolla, 1960; Moorees et al, 1963; Demirjian, 1973) have tried to catagorize this continous process into stages based on the appearance of characteristic developmental features like cusp formation, crown formation and root formation. The use of calcification instead of clinical emergence, to estimate "dental age" is steadily gaining acceptance among workers (Nolla, 1960; Moorees et al, 1963a; Garn et al, 1967; Liliequist and Lundberg, 1971; Prahl Andersen and Van der Linden, 1972; Demirjian 1973). Some workers have combined calcification stages and emergence stages to establish norms for tooth development (Garn and Lewis, 1960; Gustafson and Koch, 1974).

2. Just as there is symmetry in the emergence of teeth on the right and left sides, so is there a high degree of correlation in the calcification of the teeth on the right and left sides (Nolla, 1960; Moorees et al 1963a; Liliequist and Lundberg 1971; Demirjian 1973). As a result, it is possible to study only one side of the arch.

Most investigators have also preferred to limit their observations to the mandibular teeth and the maxillary incisors, because of the clearer view of these parts on the Xray (Moorees et al, 1963; Lilliequist and Lundberg 1971; Demirjian 1973). Nolla (1960), in his study on dental maturation used both the jaws - but one side only. Demirjian (1973), however, used only the mandibular left segment, as he felt that this view was most clear and served the purposes of standardization.

3. Dental maturity from Xrays has been assessed in a number of ways. Basically, two criteria have been used namely, root length and levels of calcification of the tooth from cusp calcification to closure of the root apex. Using these two criteria, authors (Moorees et al,1963a; Demirjian 1973) have devised various combinations to break down the process of calcification, and development of the tooth, into stages. Many workers have allocated scores to these stages and thereby established norms for the calculation of dental age.

Gleiser and Hunt (1955) described 13 different stages of maturity from calcification of the tip of the cusp to closure of the apex. The description of the stages is based on length criteria, corresponding to, for example, ½ of the crown or ¾ of root formation completed.

Garn et al (1958) described 5 stages of development of the second premolar and second molar. Three of these stages were for calcification and two were for eruption. All assessments of the calcification stages as well as the alveolar emergence and occlusal attainment, were made from radiographs. In this study, clinical emergence was not assessed. In another paper, Garn et al (1967) described 8 stages of dental development and labelled these from A to H, ranging from the earliest appearance of the follicle to closure of the apices. Percentile standards were established for boys and girls.

Nolla (1960) described another technique for the evaluation of the development of the permanent dentition, based on 10 length stages, such as 1/3 of the crown or 2/3 of the root. A score of 1-10 was assigned to each stage, starting from the presence of the crypt without calcification, to the completion of the apical end. The scores which were noted for each tooth and subsequently added for all the mandibular and maxillary teeth. Thus there was a specific score for each age group and for each sex.

Fanning (1961) applied Gleiser and Hunts' 13 stages of dental development to all mandibular and maxillary incisors. For greater precision, she added a total of seven more stages: two initial stages, two for cleft formation in the molars, and three to describe the different degrees of apex closure. These 20 stages served only to detract from the precision of the method. It proved to be too difficult to differentiate between successive stages, and measurements became little more than subjective estimates.

Moorees et al (1963a) studied the developmental pattern of eight mandibular and two maxillary incisor permanent teeth. The incisors were assessed from intra-oral radiographs of 134 Boston children, while uniradicular and multiradicular posterior teeth were assessed from lateral radiographs of 246 children from the Fels sample. The results of this study are presented in chart form. The mean developmental stage of each tooth is depicted on the chart with two standard deviations. The development was based on length criteria, ranging from degrees of crown completion to degrees of root development. They are "designed specifically for determining the dental maturity of an individual child, for each tooth separately".

The usefulness of this system can be very well appreciated in orthodontic clinics, where formative stages of individual teeth and their emergence are very important for treatment planning purposes.

Following a study of 287 children, Liliequist and Lundberg (1971) published a system of evaluation for dental development based on the radiographic assessment of the mandibular teeth (excluding the third molars), upper incisors, and cuspids. The upper bicuspids and molars were not examined because of the difficulty of obtaining a clear image of these teeth on Xrays. Eight developmental stages were defined between the non-calcified crown and the completion of root development

On assessing the methods described above it should be noted that all these systems have been based on absolute values for the lengths of the teeth, crowns or roots. If dental radiographs from longitudinal studies are not available, such a system is difficult to apply. Even an experienced investigator can have trouble distinguishing between such criteria as ¼ or 1/3 of a root length.

Moreover, absolute lengths of teeth can be highly variable from individual to individual (Demirjian 1978). On the other hand, the assessment of dental maturity, like skeletal maturity, should be based on biological criteria rather than on length or width measurements alone. The latter are really estimates of growth, as distinct from maturity (Demirjian 1973).

Like the bones of the hand and wrist, teeth undergo different sequences of maturational. During these maturational stages, continous changes in size and shape of the teeth can be seen and each tooth follows the same sequence. Influenced by previous work, Demirjian (1973) decided that arbitrary stages should be selected from this continous developmental process, and should be fully described, so that the entire developmental process can be traced from beginning to end. He thus described eight stages of dental development, (see appedix I).

Following on the work of Tanner et al (1972), who assessed bone maturity by allocating biological scores to the different maturity stages, Demirjian (1973) devised a new approach for assessing dental maturity based on the same principle as the bone-age assessment of Tanner et al (1975). By this system which utilizes a new technique of panoramic radiographs, weighted scores are assigned to each of the seven left mandibular teeth. Scores for each of the stages have been worked out separately for each of the sexes, making use of a mathematical formula devised by Tanner et al (1975). These scores are added to give a final maturity score for that individual.

The concept of a maturity scale is different from that of a scale of height, in that all subjects pass through the same series of points on the scale, starting with a stage designated as "0"for "complete immaturity", and concluding with "100", corresponding to "complete maturity". Demirjian et al (1973) drew up centile curves for the sample that he investigated and, using the 50th percentile curve, he established norms for the dental maturation of his French-Canadian sample. Separate centile curves were drawn up for boys and girls, and these ranged from the 3rd percentile to the 97th percentile.

The third percentile indicated delayed maturation and the 97th percentile advanced maturation.

Demirjian (1978) devised two additional systems utilizing the two molars and two premolars (M2, M1, PM_2,PM_1), and, in those cases that have missing sixes, one molar, two premolars and one central incisor (M2, PM_2, PM_1, I_1). In all three systems, equal "biological" weights for each tooth have been used. The correlation among the 3 systems is quite high, the correlation coefficient being between 0.7 and 0.9 for each age group between 6 and 16 years. However, longitudinal studies using the latter two systems are necessary to discount the possibility that different aspects of maturity are being measured (Demirjian, 1978).

It must be remembered that the above scoring system using biological weights and the percentile charts derived are for a French-Canadian sample. It is not known, as yet how representative the results are of children generally. Demirjian (1978), however, conjectured that the scores for the 8 stages would not vary much between populations, but that the maturity standards might change appreciably in different populations. He also maintained that it was possible to study differences in the average maturity of different populations, employing his scoring system with relatively small samples.

Loevy (1983) in his study of the maturation of permanent teeth in Black and Latino kids, found the system developed by Demirjian (1973) to be easy to employ and to be very applicable to his study. Moreover, many investigators are now using this system (Prahl-Andersen and van der Linden, 1972; Chertkow, 1980; Loevy, 1983), especially for cross-sectional studies.

ACCURACY AND PRECISION OF METHODS USED TO MEASURE MATURATION

Hagg and Matsson (1985) investigated the accuracy and precision of three different methods for estimation of chronological age, namely the methods of Liliequist and Lundberg (1971), Demirjian et al, (1973); and Gustafson and Koch 1974. The following findings were noted:

1) A high accuracy was found when the method proposed by Demirjian et al (1973) was applied to 3.5 to 6.5 year old children. This method, however, showed a low accuracy in the older age groups.

2) The accuracy of the method devised by Liliequist and Lundberg (1971) was found to be low in all age groups, and age determination using this method resulted in systematic underestimation of age.

3) the accuracy of the method described by Gustafson and Koch (1974) was high when applied to boys but low when applied to girls.

4) the precision was found to be high for the methods developed by Demirjian et al (1973) and Liliequist and Lundberg (1971) but somewhat lower for the method described by Gustafson and Koch (1974).

5) estimation of age is preferably done during early childhood. Of the methods tested, the one proposed by Demirjian et al (1973) is most reliable at these ages, due to its comparatively high accuracy and precision.

Lavesque and Demirjian (1980) studied the inter-examiner variation in rating dental formation from radiographs using the eight stage system as described by Demirjian et al (1973). They found that the discrepancies between the examiners were generally of the order of approximately one stage in about 20-25% of the cases. The authors thus suggested the use of reference radiographs, which could be obtained from their institution, for the double purpose of ensuring a homogenous rating by two examiners or more, as well as for the assessment of eventual differences between populations.

CORRELATIONS BETWEEN DENTAL DEVELOPMENT AND OTHER MATURITY INDICATORS

Many cross-sectional and longitudinal studies have been conducted to establish possible correlations between the development of the dental system and other physiological indicators such as bone age, height, menarche, or circumpubertal growth (see review Demirjian 1978). Most such studies have used dental emergence of both the deciduous and/or permanent teeth as the maturity indicator: however some have investigated the formation or calcification pattern of the teeth in relation to certain physiological measures (Garn et al, 1960; Chertkow, 1980; Hagg and Taranger, 1984).

Demirjian (1978) in his review of the development of the dentition concluded that the skeletal system, as well as height and onset of puberty, develop largely independently of the dental system. He cites that this is probably due to the fact that bone is derived from mesoderm whilst teeth are derived from epithelium. Hagg and Taranger (1984), in a longitudinal study on dental emergence, found that the correlation between dental and somatic development was low in both sexes. However, there was a distinct sex-specific pattern in the relationship between dental development and somatic development at puberty. In girls, there was a consistent and statistically significant correlation between development of the entire permanent dentition and somatic development at puberty. In boys, on the other hand, dental development occurred almost independently of somatic development at puberty. Since it appeared well established that the two dental processes, namely emergence and calcification, are autonomous, most authors have elected to try to correlate tooth calcification with physiological maturity indicators (Demirjian 1978).

Lewis and Garn (1960) found less variability in dental development than in skeletal development and thus suggested that dental development can be a better criterion of biological maturation than ossification. The diagram below illustrates the relative variability of the different maturational events.

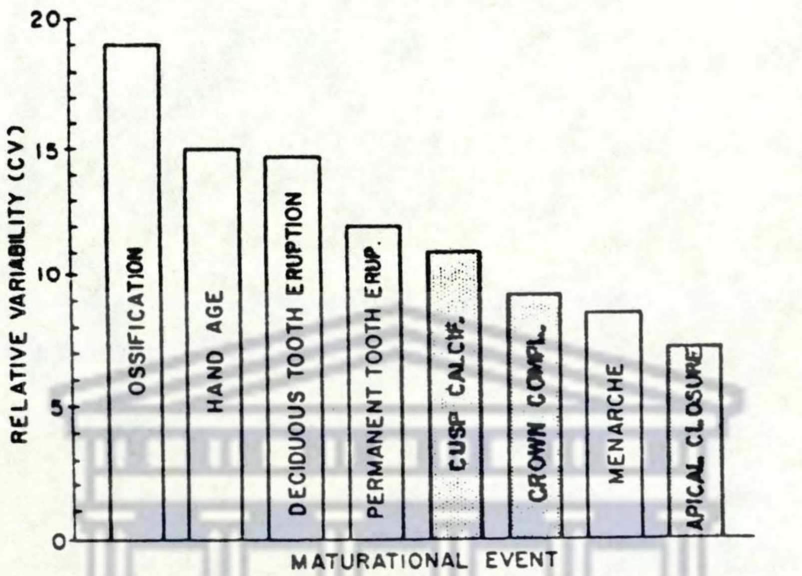


FIG. 2

Relative variability (CV) of different maturational events. (From Lewis, A.B., and Garn, S.M., 1960. The relationship between tooth formation and other maturational factors. Angle Orthod. 30: 70).

Many authors have noted the lack of correlation between dental development and skeletal development (see review Demirjian, 1978). In a longitudinal study of some 200 boys and girls at the Growth Centre of the University of Montreal, it was found that a very low correlation exists between dental age and skeletal age and/or stature (Demirjian 1978).

Meredith (1959) found only slight correlation between circumpubertal growth spurt and the eruption of the mandibular canine and, first and second molars. Chertkow (1980) in his study noted the following:

a) That there is a retardation of skeletal development among South African Black children compared to the Caucasoid peer group. This, however, is well documented in the literature (see review Chertkow, 1980).

b) That tooth development is accelerated among black children when compared to their Caucasoid peer group.

c) That little correlation has been shown to exist between the appearance of the above indicators and the overall maturational state of the dentition.

d) That a close relationship exists between calcification stage G* of the mandibular canine and other maturational indicators of the pubertal growth spurt among Caucasoid children. He thus advocated use of the mandibular canine as an indicator of the circumpubertal growth spurt.

However, according to Hagg and Taranger, (1984) Chertkow's judgement was based on the relationship between the above dental indicator and initial ossification of the adductor sesamoid bone in a biased sample. Firstly, the correlation between the ossification of the sesamoid bone and pubertal growth is only moderate. Secondly, only subjects with initial ossification of the sesamoid bone were included (Chertkow 1980), which did not guarantee that all subjects who were in a certain stage of dental development were included, and thirdly, the occurrence of a stage with short duration (initial ossification of the sesamoid bone) was related to being in, not attaining, a tooth formation stage of long duration (mean duration of G is about 2.7 years in both sexes (Demirjian and Levesque, 1980).

*G The walls of the root canals are parallel (distal root in molars) The apical ends of the root canal is completely closed (distal root and the apex.

THIRD MOLAR DEVELOPMENT

1) **GENESIS AND AGENESIS:**

Even in a normal population, the third molars vary widely in the timing of their calcification and eruption, and even in their morphology. Approximately 10-15% of the population may demonstrate agenesis (absence) of the maxillary and mandibular third molars (Nanda 1983). Thompson et al (1974) reported the proportion of subjects with one to four missing third molars to range from 9-35%. It is most common for two third molars to be absent, followed by one, four and three respectively (Gravely 1965). Other workers, on the other hand have shown the order of frequency to be one, two, three, four. There are more females than males with congenital absence of third molars in a ratio of 3:2 (Richardson 1980). Past surveys, however, show considerable variations in the methods of assessment used, in the ages of development of the third molar and in agenesis (Clow 1984).

Banks (1934) published a chart of third molar development based on a sample of 1000 American children of both sexes. He noted that crypts appeared between 5 and 14 years of age, and that 7 to 9 years were needed for complete development. Calcification of the maxillary third molar was generally earlier than that of the mandibular one, the difference being one to two years. According to Garn et al (1962), follicle formation of the third molar occurs on the average during the 8th year, but apical closure is not complete until the 20th year of life. In a substantial number of cases, the third molar requires even more than twelve years to complete its formation.

Richardson (1980) indicated that if third molar formation was delayed beyond the age of 10 years, the possibility of all four third molars developing was reduced by about 50%. She also found no significant differences in the size of early and late developing third molars. Since the third molar may not begin its calcification until as late as 14 years of age, the diagnosis of agenesis cannot always be made with certainty in the mixed dentition.

The mandibular third molar forms in the ramus usually at a level higher than the occlusal plane but descends vertically below the occlusal plane of the other molars (Richardson et al 1984). The tooth then appears to upright itself and erupt towards its normal occlusal position.

2) **SEXUAL DIMORPHISM:**

According to Garn et al (1962), the third molar is exceptional in the absence of any demonstrable sex difference in calcification. However there was some tendency (though not significant) for girls to be later than the boys in third molar formation. Gravely (1965), in his study, also showed that there were no significant sex differences. In addition he found no difference of significance between the right and left sides and between the maxilla and mandible.

Lavesque et al (1981), made the following observations:

a) The occurrence of bilateral agenesis was about 9% without significant sexual differences.

b) The left and right third molars had the same pattern of crown and root development and emergence.

c) Girls were ahead of boys up to the second half of crown formation, but this sexual difference disappeared at the first stage of root formation. The root development course was faster in males than in females.

d) At apex closure, the sexual difference was much more marked for retarded cases (about 2.7 years) than for median (1.5 yrs) or advanced cases (0.4 yrs).

e) For alveolar and clinical emergence males were about six months ahead of females at the median level.

3) **GENETIC INFLUENCE:**

There is a low correlation between third molar development and general body development. In fact, the third molar has less in common with bodily development than does the adjacent second molar (Garn et al, 1962).

The third molar exhibits a considerable degree of internal consistency in its development, with early formation of this tooth heralding early completion and vice versa. Thus, children who are early in third molar calcification are correspondingly early in the movement of this tooth through the alveolar bone. Thus, the third molar has developmental autonomy and its formation and eruption or movement through the alveolus is primarily genetically determined (Garn et al, 1962).

Somatic and sexual maturation can be accelerated by hypernutrition during the growing period, but the third molar tooth appears to be largely independent of the rate of sexual maturation of growth-accelerating phenomena in general (Garn et al, 1962).

4) RACIAL DIFFERENCES IN THIRD MOLAR MATURATION

Hellman (1936), in a survey of skulls, found that there were differences in third molar presence. He reported a low incidence of agenesis in Tasmanians, and that only 2.6% of these teeth were missing in West African Negroes. In contrast, a high proportion were found to be missing in skulls from Hungary. In American Caucasians the incidence of third molar agenesis ranged from 3.6% to 14.4% (Clow, 1984).

There are also ethnic differences in the development of third molars. Finns acquire their third molars later than the middle American Whites. North American Negroes erupt third molars earlier than do Whites (Garn et al, 1963). In a longitudinal study by Richardson et al (1984) on North American Black Males the following were noted:

i) The occlusal surface of the third molar was identified at a mean age of 9.75 years.

ii) The third molars began to move towards an upright position between the ages of 14 to 16 years. Before 18 years of age, the occlusal surface of the third molar assumed a position almost parallel to the occlusal plane of the first and second molars.

THIRD MOLAR IMPACTIONS

In an elaborate study conducted by Dachi and Howell (1961), the following were noted:

a) The incidence of patients with at least one impacted tooth was 16.7%.

b) The teeth most often impacted, in order of frequency, were the maxillary third molars, the mandibular third molars, the maxillary canines, and the mandibular premolars. Of the total number of third molars present, 29.9% of the mandibular third molars were impacted.

According to Björk, (as cited by Bishara and Andreasen, 1983), three skeletal factors separately influenced third molar impaction, namely,

i) Reduced mandibular length, measured as the distance from chin point to condylar head.

ii) Vertical direction of condylar growth as indicated by the mandibular base angle.

iii) Backward directed eruption of the mandibular dentition determined by the degree of alveolar prognathy of the lower jaw.

Ricketts (1979) found a relationship between the angulation of the mandibular third molar and its ultimate impaction. He indicated that impaction of third molars could be predicted as early as seven to nine years of age. He also indicated that if the predicted distance (that is, taking growth into account) from Xi (centre of ramus of mandible) point to the distal aspect of the second molar was 30 mm or greater, then sufficient space existed for the lower third molar. On the other hand, if the predicted distance was 20 mm or less, the space was considered inadequate.

According to Richardson et al (1984), the wide buccal location of mandibular third molars is an important factor in their impaction. Moreover, in addition to genetic factors and availability of the anteroposterior space, other factors such as the buccinator muscle, dense bone of the internal oblique ridge, or pterygomandibular raphe also play a role in third molar impaction or eruption.

THIRD MOLAR TEETH AND CROWDING:

The influence of the third molars on the alignment of the anterior dentition is still controversial. There is no conclusive evidence to indict the third molars as being the major aetiologic factor in post-treatment changes in incisor alignment (Bishara and Andreasen 1983). There is also no conclusive evidence that the third molars cause post-pubertal crowding of the lower incisors. It has been shown that a strong tendency exists for occlusally directed forces produced during masticatory movement to tip the posterior teeth forward. Thus, with or without third molars, this mesial drift mechanism is present (Weinstein, 1971).

Following a conference by the National Institute for Dental Research on November 28-30, 1979*, dedicated to third molars, 250 dentists present came to the consensus that crowding of lower incisors was produced by many factors which included tooth size, tooth shape, narrowing of the intercanine dimension, retrusion of incisors, and growth changes occurring in the adolescent stages of development. It was agreed that there is little rationale, based on present evidence, for the extraction of third molars solely to minimize present or future crowding of lower anterior teeth.

*see review Bishara and Andreasen, 1983.

PROPHYLACTIC THIRD MOLAR EXTRACTIONS:

There is a dichotomy of opinion regarding both the need and the consequences of early enucleation of third molars (Bishara and Andreasen, 1983). Opposition to extractions is based on the fact that:

i) At age 35 one in five Americans is wearing a full upper denture and has lost many lower teeth as well.

ii) During adolescence, some people develop severe dental caries and could lose first or second molars.

iii) Complications could arise during surgery.

Proponents of third molar extractions for prophylactic reasons base their arguments on the following:

i) Young adults between the ages of 18 and 22 experience problems with their third molars and at later ages pathologic changes often occur.

ii) Orthodontic treatment is enhanced, particularly when third molar extraction creates space for lower incisors or when, during anchorage preparation, distal movement of the first and second molars may be required.

iii) Removal of the third molar bud at age 7 and 10 years is surprisingly simple and relatively atraumatic.

METHODS USED TO ASSESS THIRD MOLAR MATURATION

Garn et al (1962) used a total of nine stages of calcification and movement in assessing the developmental course of the third molars. This number of stages was choosen in contrast to the smaller number of developmental stages previously recognized by Garn et al (1962), in order to take maximum advantage of the unusually long developmental course of the mandibular third molar tooth. For each child in the series, the earliest age at which each stage of third molar development had been attained was recorded as the "age-at-attainment".Cumulative frequency curves were then drawn from the recorded ages at attainment, and the 15th, 50th, and 85th percentiles were determined by interpolation from the curves.

Moorees et al (1963) assessed maturity of the third molar by means of the same method they employed to assess the maturity of the other teeth, namely crown and root length criteria. A chart was established for the third molar, showing the mean age at development of each of the thirteen stages, ranging from initial cusp formation to completion of apical closure.

Initial calcification of the cusps of mandibular third molars is at a mean age of about 9.4 years and apical closure is observed at a mean age of 23 years. Crown formation is completed at about 12 years of age.

Gravely (1965) described five stages in the development of the third molar. Stage one to stage four was concerned with crown development only. Stage five indicated crown completion and commencement of root formation.

Levesque and Demirjian (1981) assessed third molar maturation by assigning it eight developmental stages ranging from A to H. Stage 0 was the appearance of a crypt with no calcification. The age of attainment of each of the stages were noted and a mean age for each of the stages was established.

MATERIALS AND METHODS

1. RADIOGRAPHIC MATERIALS

Two hundred and ninety three 293 panoramic radiographs, taken the from the orthodontic files of patients who presented for orthodontic treatment at the Faculty of Dentistry, University of Western Cape, were examined for this study. From a total of 455 orthodontic files investigated, 162 radiographs were rejected because of:

a) the absence of certain teeth;

b) the presence of pathology in relation to teeth examined;

c) missing details in files for example sex of patient, date of birth;

d) a questionable patient category;

e) poor quality of x-rays for example lack of clarity in the incisor region.

The same machine *was used to take all the panoramic radiographs** examined. Though there is 3-10% enlargement on the left side of the mandible in panoramic radiographs (Sapoka and Demirjian 1971) this was not a serious drawback, because the rating system used here is based on shape criteria and relative values rather than on absolute lengths.

* General Electric Panelipse Machine
** Cronex 4 film with standard speed and intensifying screens

2. THE POPULATION SAMPLE

The Southern African population consists of four main and two smaller ethnic groups: Bantu speaking Negroes, Caucasians of European origin, Coloureds and Asians. The smaller groups are the Chinese and the Khoisan (Hottentots and Bushmen) (Thomas 1981, Dreyer 1978). According to Louw (1982) the Coloured population group is a heterogenous group consisting of the descendents of siblings from marriages between White and Black people and later infusion of Malay, Indian and Arabian blood. In his study, Louw (1982) defined the "Coloured" population of the Cape Peninsula as those who do not belong to:

a) the "Black" population group
b) the "White" population group
c) the South African Indian population who live in well defined areas of the Cape Peninsula.

The Western Cape area of South Africa, and particularly the Cape Peninsula is unique because all the population groups of the South African people are represented here in easily identifiable groups (Dreyer 1978). The "Coloured" population in the Cape Peninsula is an established group having its ethnic origins in the Western Cape. They are represented by three broad groups, namely, the Cape "Coloured", the Griqua and the Cape Malay (Dreyer 1978).

Although the Cape "Coloured" group are not genetically homogeneous, they are, nevertheless, regarded as an entity with their own unique features (Thomas 1981).

The "Coloured" population group of the Peninsula live in well defined areas under the following Municipalities (Louw 1982):

a) Cape Town

b) Bellville

c) Parow

d) Goodwood

e) Milnerton

f) Pinelands

g) Cape Divisional Council

h) Simonstown

i) Durbanville

The sample used in this study has been derived from the orthodontic patient list of the Faculty of Dentistry, University of the Western Cape. The majority of patients being treated at this faculty belong to the so called "Coloured" population group and our study was confined to this group.

The area covered by this sample was broad and encompassed practically all the municipalities and councils mentioned above. The reason for this is the lack of orthodontic services at all the other dental clinics run by the Department of Health, thus forcing the majority of the Coloured, Indian and Black patients to seek orthodontic services at the Dental Faculty of the University of the Western Cape.

The sample consisted of a total of 293 subjects ranging in age year from 5 years to 16 years. There were 128 males and 165 females (Table 3).

TABLE 3: AGE DISTRIBUTION OF SAMPLE EVALUATED

AGE(Yrs/Mnths)	BOYS	GIRLS	TOTAL
5:00 - 5: 11	1	3	4
6:00 - 6: 11	3	4	7
7:00 - 7: 11	9	8	17
8:00 - 8: 11	6	10	16
9:00 - 9: 11	12	22	34
10:00 -10: 11	15	16	31
11:00 -11: 11	11	17	28
12:00 -12: 11	24	24	48
13:00 -13: 11	12	17	29
14:00 -14: 11	18	15	33
15:00 -15: 11	9	13	22
16:00 -16: 11	8	16	24
	128	165	293

The lower left seven teeth were evaluated in 269 subjects ranging in age from 5 to 15 years. The reason for using only one side is that the development of teeth exhibits symmetry (Demirjian et al. 1973). For the evaluation of the third molar, 24 additional subjects in the 16 year old age category were used. This made the total sample 293.

METHOD

Two aspects of the dentition were evaluated namely:

a) The lower left quadrant, from the central incisor to the second molar.

b) The lower left third molar.

METHOD OF EVALUATION OF DENTAL MATURITY

1. SYSTEM OF EVALUATION OF DENTAL MATURITY

The choice of the lower left quadrant for investigation was based on the work of Demirjian et al (1973) who, amongst other workers have demonstrated symmetry in the maturation pattern of right and left sides.

a) Calcification Chart

The maturation level of each tooth was assessed according to the method advocated by Demirjian et al (1973) which made use of an eight stage calcification chart (Appendix I). The stages are based on shape criteria and are labelled from A to H. Since each stage on the chart depicted a particular shape only which did not pictorially convey the full range of charactistics of a stage, Demirjian et al (1973) backed each stage up with a written description that reduced or eliminated examiner error, especially in situations where an overlap of the stages occurred.

b) Scoring System

Unlike all previous studies on dental maturation, the study by Demirjian et al (1973) allocated a biologically weighted score to each stage for each tooth and for each sex for example, stage B for a second molar in a male has a score of 3.5 and stage D for a first molar in a female has a score of 4.5. These biologically weighted scores for each stage and for each tooth in the different sexes has been derived mathematically by Demirjian et al (1973), using the same formula that Tanner et al (1975) devised to assess skeletal maturity. For the purposes of our study the mathemathical derivation of this formula will be assumed to be correct and will not be further discussed.

A table of self-weighted scores for dental stages, used in this study, are given in appendix II. These scores were used by Demirjian et al. in 1973 on a French Canadian sample to establish norms for dental maturation. In a later study Demirjian (1978) increased his sample to include the extremes of the age groups (that is, 2 to 20 years) and this resulted in a revised table of biological scores for each of the stages. In this study, however, the "1973" table of scores were used because of the relatively small sample examined.

The method of giving scores to developmental stages was devised to rate biological maturation as such and, in the case of the teeth, these maturation scores ranged from "0" (no calcification) to "100" (closure of root apices of all the teeth except the third molars). The symbol "A" referred to initiation of calcification of a single tooth and the symbol "H" referred to the completion of root formation of that tooth. The biological scores allocated to each stage and for each tooth when added up, gave a score between "0" and "100". Zero ("0") indicated complete immaturity and "100" indicated complete maturity. A score in between "0" and "100" indicated the level of maturity of the dentition for the subject being investigated. It must be remembered that these maturity scores vary from individual to individual, for example, two ten year old males need not have the same maturity scores. This demonstrates the variability in the maturation of teeth.

c) Percentile Curves

Demirjian et al (1973) grouped the maturity scores into percentile values. He drew up centile curves, for boys and girls, to graphically demonstrate the number of subjects in the 10th, 50th, and 90th percentiles. The 50th percentile group formed the median values of dental maturity and this was taken as the norm for dental age in the French Canadian people. Either side of this 50th percentile demonstrated advancement or retardation of dental maturation (Appendix III).

In this study, the maturity scores (observed values) of the Western Cape sample were compared to the French Canadian scores of Demirjian et al (1973) at the different percentile levels.

2. EVALUATION PROCEDURE

The mandibular third molar was investigated separately and will be dealt with under a separate chapter. The primary objectives of this study is the investigation of the calcification pattern of the lower left seven teeth, from first incisor to second molar. This will be discussed under the following sub-headings:

1) Information about individual subjects:

Information about each subject was stored in cards. Details included in the cards were the name, date of birth, date of panoramic radiograph, age on date of X-ray and address of the subjcts (to establish group area).

2) The radiographic examination

Two hundred and sixty-nine (269) radiographs were examined by the researcher using a standard x-ray viewing box*. The examiner first familiarized himself with the method used by Demirjian et al. (1973) for assessing dental developmental stages as outlined in Appendix I.

Each radiograph was examined from the second molar (37) to the first incisor (31) and the stage of development was noted according to the chart of Demirjian et al (1973). A symbol was allocated to each tooth according to its stage of development.

*Dentaurum type LI viewing box

Where difficulty of differentiating between the stages was encountered, the examiner resorted to the written description of the stages. Where the radiographic image of a tooth was not clear or the tooth was missing then the same tooth on the opposite side of the arch was examined. This procedure was also adopted by Demirjian et al (1973) in their study.

In order to improve the validity of the radiographic examination when obtaining the maturity scores, an independent examiner was chosen to assess randomly selected radiographs. This procedure has been recommended by Demirjian et al. (1973). For this purpose, 15 panoramic radiographs were chosen from a sample of 269 without regard for age group or sex. The independent examiner was then requested to allocate the stage of development for each of the teeth examined according to the method described by Demirjian et al. (1973). The maturity scores obtained were then correlated with the scores obtained by the principal examiner using the Pearson's Product Moment Correlation Coefficient (r).

The developmental stages of each of the seven teeth being investigated were noted. A self-weighted biological score was then allocated to each stage, depending on the sex and tooth. The scores were obtained from a table of scores (see appendix II). The scores for the seven teeth were then added to give a total maturity score.

These scores were then matched with scores for similar ages in the work of Demirjian et al (1973) on French Canadian Caucasoids by locating the position of the score on their centile graphs (Appendix III). In this way, the number of scores (observed values) of the Western Cape sample below 10 percentile, above 90 percentile, between 10-50 percentile and between 50-90 percentile were noted. These scores were catagorized for males and females separately and each percentile group thus had a number of "observed" values.

3. STATISTICAL EVALUATION

A) Since this study is a comparison between the French Canadian sample of Demirjian et al (1973) and the Western Cape sample, the maturity scores were therefore put into four centile groups using the centile charts of Demirjian et al. (1973) as reference points (see appendix III). The scores were grouped as follows:

i) Number of scores below 10% ($<$ 10 percentile)

ii) Number of scores between 10% - 50% (10-50 percentile)

iii) Number of scores between 50% - 90% (50-90 percentile)

iv) Number of scores greater than 90% ($>$ 90 percentile)

B) The number of scores obtained (observed values) were then subjected to the chi squared test with 3 degrees of freedom to determine if there were any significant differences between the French Canadian and Western Cape samples.

C) The student's "t" test was used to determine if there were any significant differences between the sexes at each of the age groups.

EVALUATION OF THE THIRD MOLAR TOOTH

A total of 293 panoramic radiographs were examined to assess the development of the lower left third molar. The method of assessment was the same as that used to assess the other seven teeth of the mandible, namely the stages of calcification from A to H as proposed by Demirjian et al (1973). However, in the case of the third molar no scores were allocated to the teeth because the third molar shows a unique and independent developmental pattern when compared to the rest of the dentition.

The developmental stage of each third molar was recorded according to the chart and written description by Demirjian et al (1973). A table recording the sum of the developmental stages in each age group was drawn up (Table 14). Many trends regarding third molar development in the Western Cape sample was extrapolated from this table of data.. Amongst these were:

1) age of initiation of third molar development.

2) ages at which the different stages are completed.

3) racial and sexual influences in third molar development.

4) cumulative percentage incidence of third molar calcification from age 5 years to 16 years.

RESULTS

Inter-examiner reliability

The 15 panoramic radiographs that were examined by the principal examiner as well as the independent examiner, revealed a correlation coefficient (r) of 0.97. This, according to Mulder (1982), indicates a very high correlation. Details by which the Pearson's Product Moment Correlation Coefficient (r) were calculated are given in Appendix IV.

The correlation between the principal examiner and the independent examiner was found to be significant at the 1% level (r 0.64)*. On the basis of the latter, all panoramic radiographs other than those listed above, were, therefore, examined only by the principle examiner.

*Critical values for r taken from Table K, in "Statistical Techniques in Education" by J.C. Mulder (1982)

2. THE PATTERN OF DENTAL MATURATION

The total maturity score for each subject was grouped according to age. These scores were separated according to sex and then rearranged in numerical order in each of the age groups so that the range, median, and first and third quartiles could be calculated. The results obtained are shown in Table 4.

From Table 4, the following trends were noted:

i) In the earlier years, that is, from 6 to 10 years, the range of maturity score values were high.

ii) From 10 years onwards, the range and quartile values decreased considerably.

iii) From 6 to 9 years, there was rapid maturation of the teeth. Thereafter, the rate of maturation decreased progressively until 15 years of age when the maturation of all the teeth, except third molars, was complete.

The results shown in Table 4 are further delineated into box plots (Figures 3 and 4).

Table 4 RANGE, MEDIAN AND QUARTILES OF MATURITY SCORES FOR MALES AND FEMALES

AGE GROUPS	MALES				FEMALES			
	RANGE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE	RANGE	FIRST QUARTILE	MEDIAN	THIRD QUARTILE
6.00:6-11	44 - 47.6	-	44	-	35.1 - 74.2	35.1	60.7	74.2
7.00:7-11	34.1 - 88.1	55.6	74.0	84.3	75.7 - 85	77.2	82.0	82.9
8.00:8-11	79.2 - 91.5	80.9	82.7	88.9	72.1 - 93.7	81.5	86.1	91.8
9.00:9-11	75.6 - 93.1	85.2	87.6	91.3	87.1 - 95.7	90.1	93.7	94.5
10.00:10-11	86 - 94.5	92.4	93.1	94.1	89.6 - 98.6	93.7	94.7	96
11.00:11-11	92.4 - 97	93.1	93.5	96.4	93.7 - 98.1	94.5	96	97.5
12.00:12-11	92.4 - 98.2	93.7	94.9	96	94.4 - 100	96.4	97.9	98.9
13.00:13-11	93.9 - 98.4	95.1	95.3	97.9	97.4 - 100	98.1	98.9	100
14.00:14-11	95.3 - 100	98.2	98.2	100	97.3 - 100	98	98.9	100
15.00:15-11	97 - 100	98.7	100	100	97.4 - 100	98.9	98.9	100

80

FIG 3

RANGE, QUARTILES AND MEDIAN VALUES OF MATURITY SCORES IN MALES N = 120

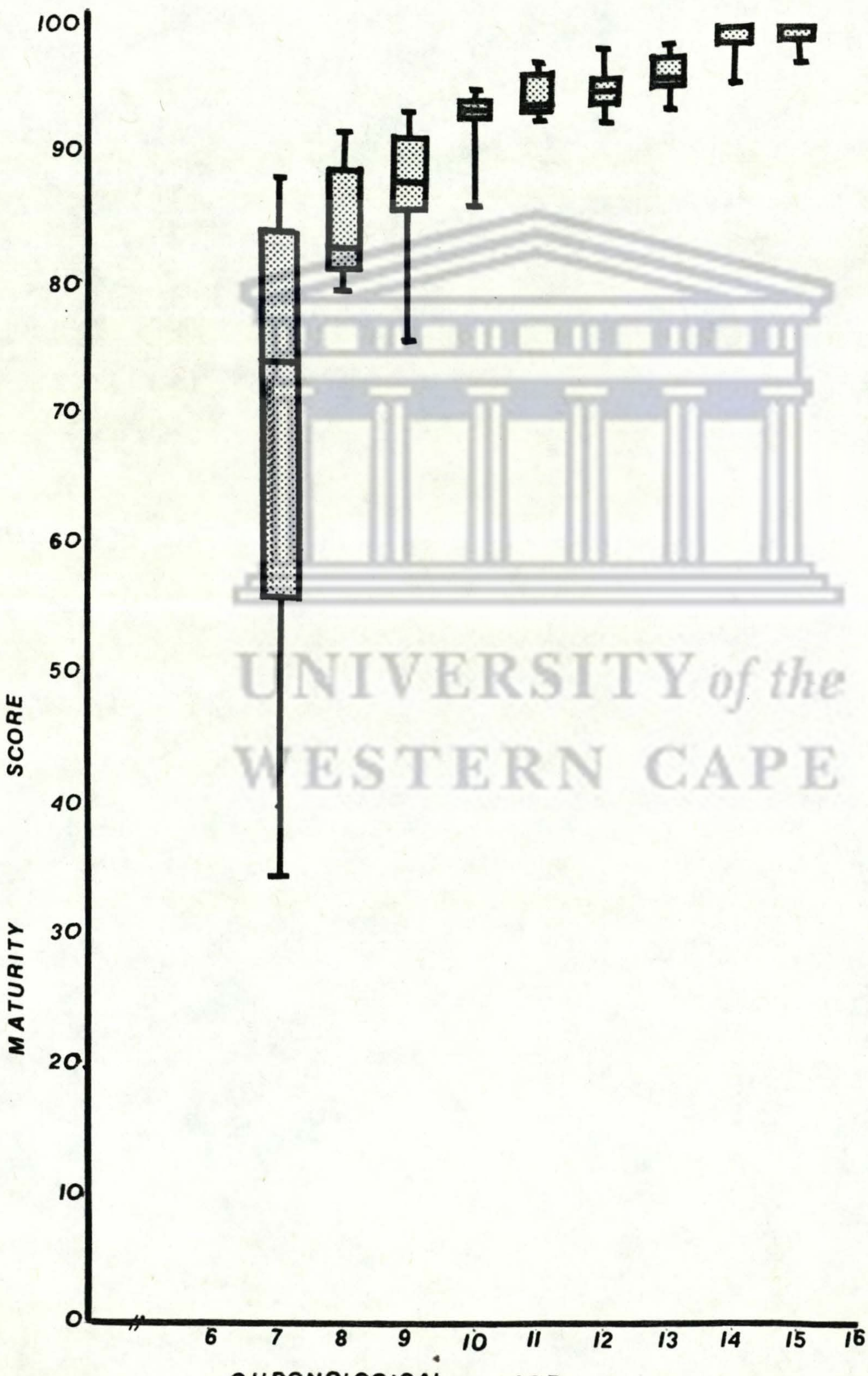
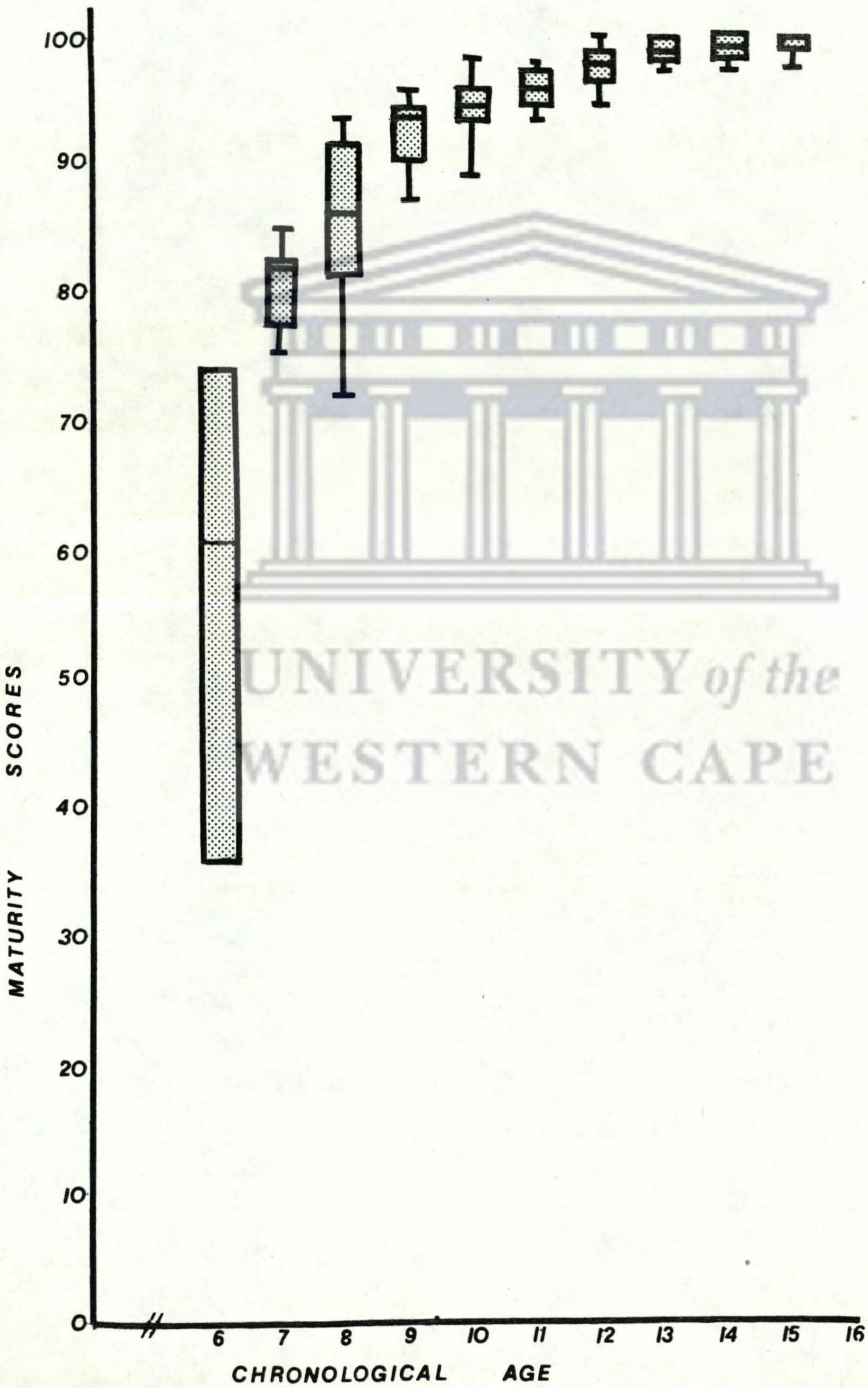


FIG 4

RANGE, QUARTILES AND MEDIAN VALUES OF MATURITY SCORES IN FEMALES N = 149



3. SEX DIFFERENCES IN THE DENTAL MATURATION PATTERN

The means and standard deviations of the maturity scores for each age group and each sex were calculated. The age groups considered here ranged from 7 to 15 years. The 5 year and 6 year old subjects were not included because their numbers were too few for valid statistical deductions.

The results obtained are shown in Table 5. The t-values and the level of significance are indicated in respect of each group.

From Table 5, it can be seen that the maturity scores were significantly different between males and females between the ages of 9 to 13 years of age. At ages 9, 11, 12 and 13, the maturity scores were significant at the 1% level and at age 10 years, it was significant at the 5% level. No significant differences in the maturity scores were seen at ages 7, 8, 14 and 15 years.

When median values were considered, it was found that females were advanced in their dental maturation for all ages except at age 15 years where they were overtaken by males in respect to completion of maturation (Figure 5).

TABLE 5. CALCULATION OF t-VALUES FOR MATURITY SCORES BETWEEN MALES AND FEMALES

Age Groups	Nx	MALES		Ny	FEMALES		t value	Level of Significance
		Mean (x)	Standard Deviation		Mean (y)	Standard Deviation		
7.00 - 7 : 11	9	68.98	18.10	8	80.84	3.30	1.719	No significance
8.00 - 8 : 11	3	84.26	4.63	4	85.40	6.59	0.352	No significance
9.00 - 9 : 11	12	87.50	4.85	22	92.25	2.75	3.542	1%
10.00 - 10 : 11	15	92.66	2.14	16	94.65	2.05	2.689	5%
11.00 - 11 : 11	11	94.24	1.65	17	96.09	1.45	3.018	1%
12.00 - 12 : 11	24	94.93	1.45	24	97.61	1.45	6.473	1%
13.00 - 13 : 11	12	96.12	1.56	17	98.92	0.98	5.714	1%
14.00 - 14 : 11	18	98.63	1.25	15	98.97	1.08	0.800	No significance
15.00 - 15 : 11	9	99.37	1.26	13	99.15	0.82	0.478	No significance

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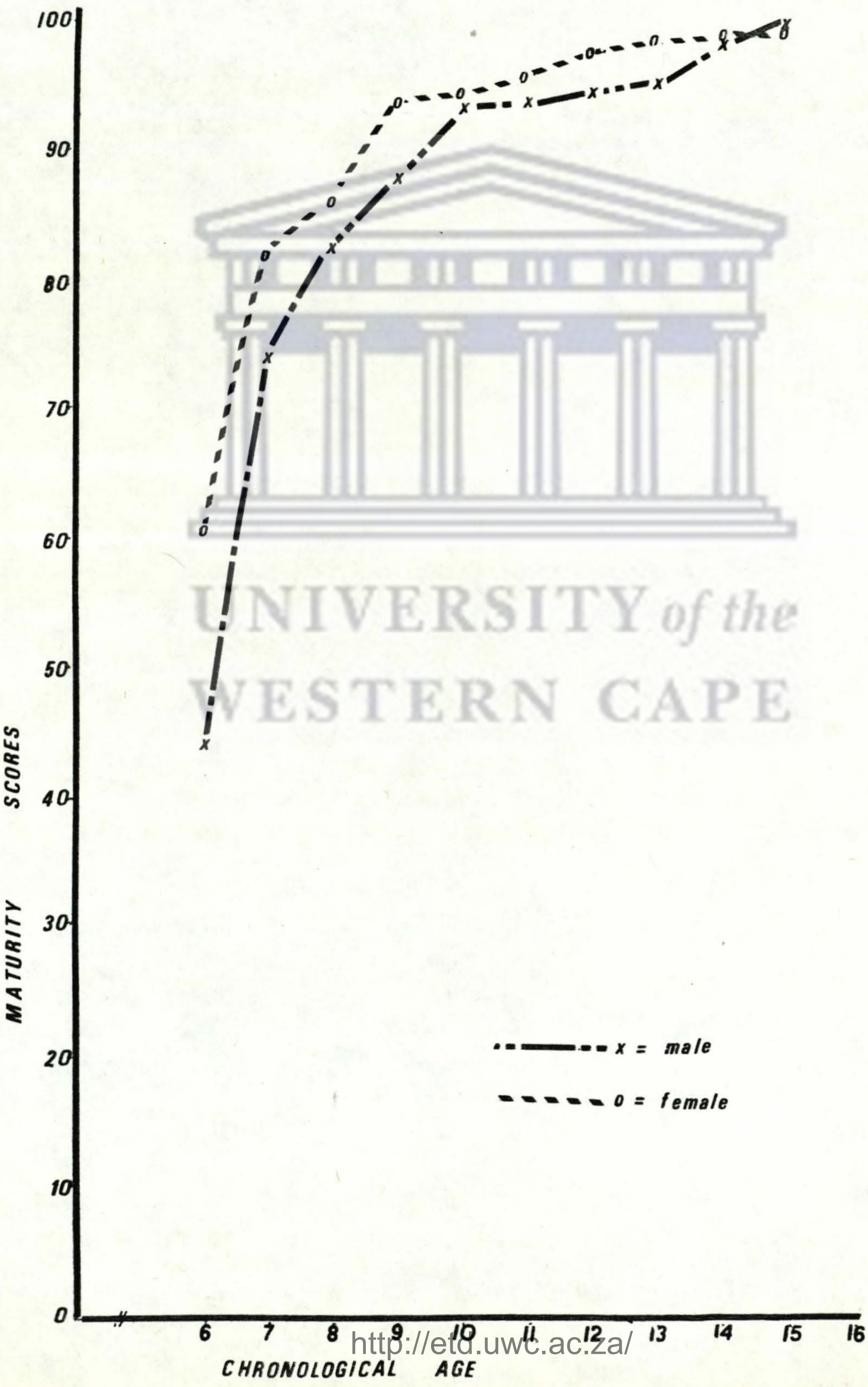
FIG 5

COMPARATIVE CURVES (MEDIAN) OF DENTAL MATURITY FOR BOYS AND GIRLS



4. COMPARISON OF WESTERN CAPE AND FRENCH CANADIAN SAMPLES

According to the centile curves of Demirjian et al (1973) maturity values above the 50 percentile curve indicated advanced dental maturity and values below this curve indicated retarded maturation.

MALE SAMPLE

TABLE 6

COMPARISON OF FRENCH CANADIAN AND WESTERN CAPE MALES (N = 120)

PERCENTILES	OBSERVED VALUES	EXPECTED VALUES
<10	2	12
10-50	32	48
50-90	50	48
>90	36	12

The results indicated that the maturity scores between Western Cape Males and French Canadian males differed significantly at the 1% level ($x^2 = 61.7$; DF = 3).

It can, therefore, be noted that advanced dental maturation was a feature of Western Cape males when compared to the Canadian Caucasoid sample.

FEMALE SAMPLE

The study revealed that the majority of the subjects fell above the 50 percentile curve indicating advanced maturity of the Western Cape females when compared to the French Canadian sample. (Table 7).

TABLE 7

COMPARISON OF FRENCH CANADIAN AND WESTERN CAPE FEMALES (N = 149)

PERCENTILES	OBSERVED VALUES	EXPECTED VALUES
< 10	2	14.90
10-50	42	59.60
50-90	57	59.60
> 90	48	14.90

The difference in the maturity scores between the French Canadian and Western Cape female samples were found to be significant at 1% level (x^2 = 90 ; DF = 3).

5. COMPARISON BETWEEN CHRONOLOGICAL AGE AND DENTAL AGE IN THE WESTERN CAPE SAMPLE

Using Caucasian norms (Demirjian et al. 1973), the dental age of the Western Cape sample was determined (see conversion tables in Appendix II). These were compared with the median chronological age.

The median chronological age, as well as the dental age, for Western Cape males and females are indicated in Tables 8 and 9 respectively.

TABLE 8. COMPARISON OF DENTAL AGE AND CHRONOLOGICAL AGE IN FEMALES (MEDIAN VALUES)

CHRONOLOGICAL AGE (Median - Years)	DENTAL AGE (YEARS) (French Canadian Norms)
6.7	7.4
7.5	8.3
8.4	8.8
9.6	10.7
10.4	11.1
11.3	11.8
12.5	13.5
13.5	14.6
14.5	14.6
15.6	14.6

TABLE 9. COMPARISON OF DENTAL AGE AND CHRONOLOGICAL AGE IN MALES (MEDIAN VALUES)

CHRONOLOGICAL AGE - YEARS (Median Values)	DENTAL AGE - YEARS (French Canadian Norms)
6.1	6.8
7.7	8.1
8.5	8.9
9.5	9.7
10.6	11.5
11.6	11.7
12.5	12.6
13.2	12.9
14.5	15.8
15.6	16.0 +

It can be seen from the above tables that the dental age for both males and females was ahead of the chronological age in all age groups except in the 13 year age group in boys and the 15 year age group in girls.

MATURITY OF THE THIRD MOLAR TOOTH

Since no biological scoring system exists for the third molar, evaluation of its maturation pattern was based on the stages of development according to the method of Demirjian et al (1973). The stage of development of the lower third molar was noted in each subject and listed according to the age. The results of this aspect of the study are shown in Table 10.

TABLE 10

THE DISTRIBUTION OF THE STAGES OF MATURATION IN THE DIFFERENT AGE GROUPS

AGE	N*	A	B	C	D	E	F	G	H	CUMULATIVE PERCENTAGE DEVELOPMENT	MOST COMMON STAGE
6.00- 6:11	7	0	0	0	0	0	0	0	0	-	0
7.00- 7:11	17	2	1							17.6%	A
8.00- 8:11	16	2	3		1					37.5%	B
9.00- 9:11	34	2	11	3	1					50%	B
10.00-10:11	31	3	11	7						67.7%	B
11.00-11:11	28	1	6	13	5	1				92.8%	C
12.00-12:11	48	0	1	19	20	4				91.7%	C-D
13.00-13:11	29	0	0	9	11	6	2			96.5%	C-D
14.00-14:11	33	0	1	4	11	12	4			97%	D-E
15.00-15:11	22	0	0	2	2	6	8	1		86.3%	E-F
16.00-16:11	23	0	0	2	4	8	6	3		100%	E-F

*N = Number of subjects

From the above table, it can be noted that

third molar formation in the Western Cape sample was initiated between the ages 7 to 11 years. At age 16 years the most common stages of maturation were 'E' and 'F'. The former indicated the start of bifurcation formation and a root length less than the height of the crown, while the latter indicated a root length that was equal to or greater than crown height.

Cumulative incidence of calcification at 7 years was 17.6% and at age 16 years, this was 100%. This meant that 100% of 16 year old subject in the Western Cape sample exhibited some stages of third molar development.

DISCUSSION

In a study such as this, cognisance must be taken of the sample used. The so called "Coloured" population of the Western Cape has been defined by various workers as an entity on its own (Dreyer, 1978, Thomas, 1981; Louw, 1982). One problem encountered in this study was the delineation of the Indian and so called "Coloured" subjects. This separation was done entirely on a "group areas" basis and this in the authors opinion was not entirely correct as many "Indians" have adopted the "Coloured" identity and many "Coloureds" have adopted the "Indian" identity and live in Indian areas. Research is necessary to prove that Indians living in so called Indian areas of the Western Cape are of a "pure" stock. Nevertheless, to eliminate the possibility of any confusion in the sampling method, Indians from "Indian" areas and Africans from "African" areas were excluded from the study. The eventual sample of 293 ranged in age from 5 years to 16 years.

Since the sample was derived from the orthodontic patient list of the department of Orthodontics, University of Western Cape, the number of subjects in the 5 and 6 year age category was very limited. This prevented valid statistical deductions for these age groups but, nevertheless, helped in establishing the lower limit of the maturation scores.

The use of subjects from the orthodontic list broadened the sample base (as far as areas were concerned). In the evaluation process of the sample, addresses of the subjects were noted and, appraisal of this information revealed that subjects came from all areas in the Cape Peninsula (as listed by Louw, 1982). This is not surprising as the department of orthodontics of the University of the Western Cape provides the only orthodontic service to the so called "Coloured" community of the Western Cape.

The decision to use the method advocated by Demirjian et al (1973) to evaluate the maturation of the teeth was taken because of:

a) The cross-sectional sample that was investigated. The methods advocated by Garn et al (1960), Nolla (1960), Moorees et al (1963a) and Gustafson and Koch (1974) were more applicable to longitudinal studies.

b) The ease of application of the method that utilized biological scores and shape criteria.

c) The fairly high degree of accuracy in noting the different stages on the chart, which were backed up by a written description of each stage. The accuracy of the method was tested by Hagg and Taranger (1985) and they found the method to be relatively accurate.

d) The availability of dental age norms for comparison purposes of samples that used this method of investigation.

e) The increasing popularity of this method amongst researchers (Chertkow, 1980; Loevy, 1983). Using this method, therefore, made the data obtained in this study more amenable for comparison purposes between races, areas and sexes.

Demirjian et al (1973) used four examiners to test for inter-examiner and intra-examiner error. They found disagreements between the examiners in only 10% of the radiographs and this was never more than one stage. Based on the work of Demirjian et al (1973), who confirmed the accuracy of their method of assessment, only one additional examiner was used in this study to test for examiner error. The inter-examiner correlation in this study was very high (r = 0.97) and disagreements between the two examiners never exceeded one stage. It must be remembered, however, that any additional examiner has to be well acquainted with the charts and written descriptions before proceeding with the scoring.

This high correlation coefficient demonstrated that the method advocated by Demirjian et al (1973) for dental maturity evaluation, was not so prone to examiner error as some of the other methods (Garn et al, 1960; Nolla, 1960; Moorees et al, 1963a, Lilliquist and Lundberg, 1971 and Gustafson and Kock, 1974. This high inter-examiner correlation also reaffirms the greater accuracy of shape criteria as opposed to length criteria in the assessment of dental maturation.

The use of the lower left quadrant only (excluding third molars) as an indicator of total dental maturity has been extensively dealt with by Demirjian et al (1973). They found symmetry of maturation of the teeth on the right and left sides and the maturation of the lower left quadrant was representative of maturation of all the teeth except third molars. Other workers (Hoffding et al, 1984; Frietas and Salzano, 1975) also found symmetry of maturation. The use of the panoramic radiograph proved to be most appropriate for a study of this nature and the ease of substitution of teeth from the opposite side of the jaw, where necessary, proved efficient and convenient.

The pattern of dental development in the Western Cape sample showed close similiarities to the pattern of development in the French Canadian sample, except that the maturation was advanced . In the French Canadian sample, the maturation of the teeth was very rapid between the age of 6 to 10 years. A median maturity score of approximately 35 at age 6 years and approximately 85 at age 10 years indicated that almost 50% of the maturation took place in a 4 year time span from 6 to 10 years of age. This period of rapid maturation is actually the mixed dentition phase in the development of the dentition.

In the Western Cape Sample the median maturity score at age 6 years was approximately 60 and at age 10 years, it was approximately 95, indicating that 35% of maturation was completed in the 4 year span, as compared to the 50% of the French Canadian sample. This meant that by age 6 years, the Western Cape sample was already advanced in the maturation of the teeth. The phase of rapid maturation, as evident in the French Canadian sample, was also present in the Western Cape Sample, but this stopped at about age 9 years.

The advanced calcification pattern in the Western Cape sample, when compared to the French Canadian sample of Demirjian et al (1973), was a feature right upto age 16 years. This was also a feature in both males and females.

This pattern of advanced calcification was also noted by Loevy (1983) in his sample of Chicago Blacks, when compared to this same French Canadian Sample. Chertkow (1980), in his study on South African Blacks and Whites, noted an advanced dental maturation pattern amongst the Blacks. Garcia-Godoy (1982) noted an advanced dental maturation pattern in Mullatoes who are a mixture between Blacks and Spanish. The Western Cape sample thus seems to follow the same pattern of advanced dental maturation as the Blacks and Mullatoes mentioned above, although not to the same degree. Norms of dental maturation based on Caucasian values would, therefore, not apply in this Western Cape sample. Further longitudinal studies on larger samples is necessary to establish norms for dental development in the so called "Coloured" population group of the Western Cape.

A notable feature of the maturation pattern of the teeth in the Western Cape sample was the great deal of variation in calcification timing in the early years and the almost total lack of variation at age 16 years. The decrease in variation towards 16 years of age indicated that most of the subjects tended towards completion of their dental calcification at age 16 years irrespective of the fact that they were advanced or retarded in the earlier years. This meant that some individuals, who were delayed in the earlier years, caught up in development in later years. Those that were advanced in the earlier years, slowed down in later years. When compared to the French Canadian sample, the females were substantially advanced between the ages 9 to 13 years and surprisingly retarded at age 15 to 16 years. Males, on the other hand, were substantially advanced in the 14 to 16 year category. The age of completion of dental calcification (excluding third molars) thus seemed to be 16 years for both males and females of the Western Cape sample. This age of completion of calcification is the same for both the French Canadian and Western Cape samples.

Comparison of the sexes showed a consistently advanced maturation pattern in females, that is, when median values were considered. Males, however, tended to complete calcification very slightly earlier than the females. The median maturity score for males at 15 years of age was '100' and for females '98'. The sex differences found in the Western Cape sample followed a similar pattern to the French Canadian sample although maturation was advanced in both the Western Cape males and females.

The above sex comparisons were based on median values. When means and standard deviations were calculated for each sex and each age group, the following were noted:-

i) In the early years the standard deviations were large, indicating a great deal of variation (S.D. for males = 18.10).

ii) In later years, the standard deviations decreased considerably, so that at age 16 years, the standard deviation for males was ± 1.26, and for females, it was ± 0.82, indicating almost a total lack of variation.

iii) Significant male-female differences at the 1% level were noted at ages 9, 11, 12 and 13 and at the 5% level in the 10 year old group. In earlier years, the variation in calcification timing was too great to derive any statistically significant differences between males and females. The standard deviation for males at age 7 years was 18.10 and for females it was 3.30. At age 8 years the standard deviation was 4.63 and 6.59 respectively. In later years, the variation was low and the scores approximated each other closely.

As a result the differences noted between 9 to 13 years were no longer significant at 14 and 15 years of age. This trend is to some extent similar to the work of Demirjian and Lavesque (1980), who noted a close similarity in the early stages of dental calcification in boys and girls. In older age groups, girls were always ahead of boys. In a survey of a French Canadian sample by the above authors, it was found that the time of maturation is similar for both sexes up to stage "C" of crown formation. However, from stage "D" onwards, girls are consistently more advanced than boys. Sexual difference in this study, thus, seems to be prominent in the late mixed dentition stage.

Our study, being a cross-sectional study on a relatively limited sample, gives an insight into dental maturational trends in the so-called "Coloured" population group of the Western Cape. This trend indicates a definite advanced maturation pattern in the "Coloured" group when compared to Caucasian norms. The use of Caucasian norms to evaluate dental development in the so called "Coloured" population group of the Western Cape is, therefore, not very accurate. The actual degree of inacurracy can only be gauged once dental developmental norms for this population group have been established. In order to establish these norms, however, longitudinal studies on larger samples would be required.

It is interesting to note that while certain population groups show advanced dental maturation pattern when compared to Caucasoid norms (Loevy 1983; Chertkow, 1980), the reverse can be expected for skeletal maturation. Whilst dental maturation is advanced in Blacks (Loevy, 1983; Chertkow, 1980), skeletal maturation is delayed (Chertkow 1980). Therefore, as a follow-up to this study a further study is being undertaken in the department of Orthodontics, University of the Western Cape, to investigate the pattern of skeletal maturation in the same sample that was investigated for dental maturation. It would be interesting to note if the pattern of skeletal maturation of this Western Cape sample follow the Caucasian norms that have been established for skeletal development. Correlation of the data on skeletal maturation with the data on dental maturation would give valuable insight into the use of dental developmental norms to evaluate somatic maturation patterns in the Western Cape sample investigated.

THIRD MOLAR

Third molar formation was initiated between ages 7 to 11 years in the sample investigated. If a third molar was not present at age 12 years, then the third molar did not form at all. Crown formation was completed by age 12 years. At 16 years, half to three quarters of the root was formed. Unfortunately, the sample was restricted to age 16 years. Further research on a bigger sample over a wider age span is essential to make valid statistical deductions, especially in a cross-sectional study such as this.

The distribution of the stages in each of the age groups did not show any particular sexual predeliction. This lack of sex differences in third molar formation has been reported previously by other workers (Garn et al 1962, Gravely 1965, Clow 1984).

The cumulative frequency distribution of third molars as observed in this study on 293 subjects, was very much similar to that published by Gravely (1965) and Clow (1984) in that calcification was initiated at about 7 years and by 16 years, 100% of the sample had third molars at one stage or another (excluding missing third molars). The most common stages at age 16 was 'E' and 'F' and the most common stage at age 10 was 'B'. Therefore, it took approximately 6 years for third molar formation from fusion of calcified cusps to a root length that was equal to or greater than crown height.

In the work of Lavesque et al (1981) on a French Canadian sample, the median of attainment of stage A was 9.8 ± 0.2 years and that of stage "F" was 16.3 years. In this study the median age of attainment of stage A was 9 years and stage F about 16 years. Definite median ages could not be calculated because of the small number of subjects in each stage.

It can be concluded that the development of the third molar in the Western Cape "Coloured" sample follows the same basic pattern of development as the third molar in other racial groups. No unique developmental pattern was observed. Development of the remaining lower left seven teeth were, however, advanced compared to the French Caucasoids. The third molar seemed to have an independent developmental pattern with no racial or sexual predeliction.

SUMMARY AND CONCLUSION

The following conclusions were drawn from this study:

1. The pattern of dental maturation in the so called "Coloured" population of the Western Cape was advanced when compared to a French Canadian Caucasoid norm for dental development. This advancement was noted in the 7 to 16 year age group and, for both males and females. Females,however, were retarded at the 15 to 16 year age category.

2. The advancement in dental maturation in the Western Cape sample was quite substantial in the 9 to 13 year age group in females and 14 to 16 year age group in males.

3. Males completed calcification of all the teeth (except third molars) at age 15.6 years. Females completed calcification later than males and later than the French Canadian Sample.

4. Sexual differences were quite significant in the 9 to 13 year age groups, with females being more advanced in dental maturation than males. Towards age 14 years, however, females became retarded and completed calcification at a later age than males.

5. Third molars have an independent developmental pattern in this Western Cape Sample and did not show any racial differences or sexual predelection.

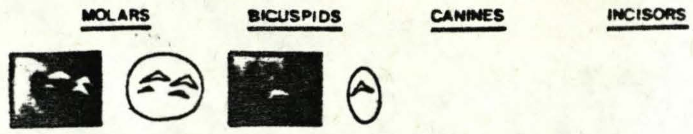
6. Further longitudinal studies on large samples is necessary to establish norms for dental maturation in the Western Cape.

A P P E N D I X

APPENDIX I

DEVELOPMENTAL STAGES OF THE PERMANENT TEETH (DEMIRJIAN ET AL 1973)

A

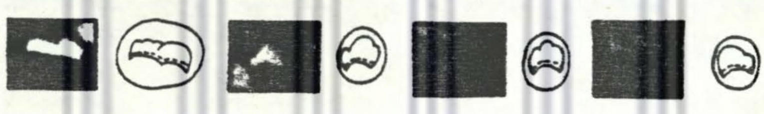


A In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points.

B

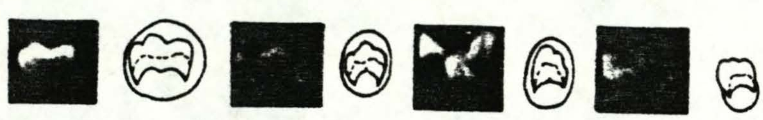
B Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.

C



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

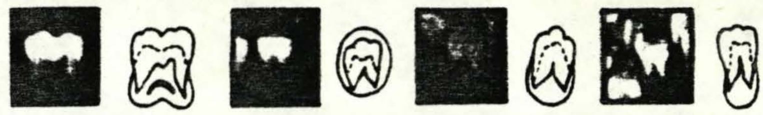
D



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

FIG. 6 DEVELOPMENTAL STAGES OF PERMANENT TEETH

E



E *Uniradicular teeth:*

a. The walls of the pulp chamber now form straight lines, whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage.

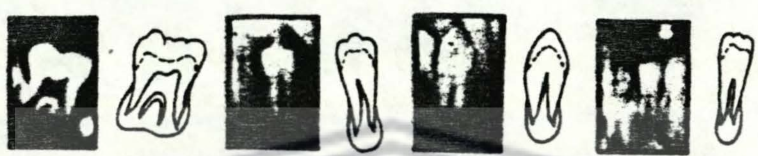
b. The root length is less than the crown height.

Molars:

a. Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semi-lunar shape.

b. The root length is still less than the crown height.

F



F *Uniradicular teeth:*

a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.

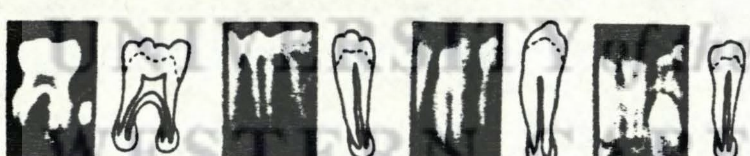
b. The root length is equal to or greater than the crown height.

Molars:

a. The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings.

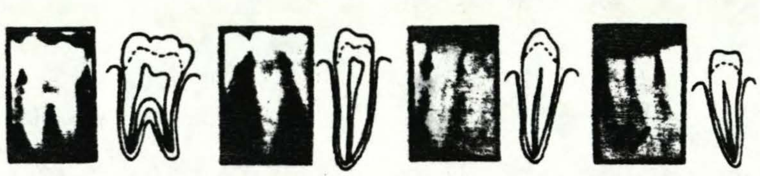
b. The root length is equal to or greater than the crown height.

G



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

H



H a. The apical end of the root canal is completely closed. (Distal root in molars).

b. The periodontal membrane has a uniform width around the root and the apex.

FIG. 6 (cont.) DEVELOPMENTAL STAGES OF PERMANENT TEETH

APPENDIX II

SELF WEIGHTED SCORES FOR DENTAL STAGES
(DEMIRJIAN ET AL 1973)

MATURITY SCORES

Table 11

Self-Weighted Scores for Dental Stages
7 Teeth (Mandibular Left Side)

	Boys								
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M_1				0.0	8.0	9.6	12.3	17.0	19.3
PM_2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM_1			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I_2				0.0	3.2	5.2	7.8	11.7	13.7
I_1					0.0	1.9	4.1	8.2	11.8
	Girls								
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M_1				0.0	4.5	6.2	9.0	14.0	16.2
PM_2	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM_1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I_2				0.0	3.2	5.6	8.0	12.2	14.2
I_1					0.0	2.4	5.1	9.3	12.9

NB: Stage 0 is no calcification

Table 12. CONVERSION OF MATURITY SCORE TO DENTAL AGE - GIRLS (7 TEETH)

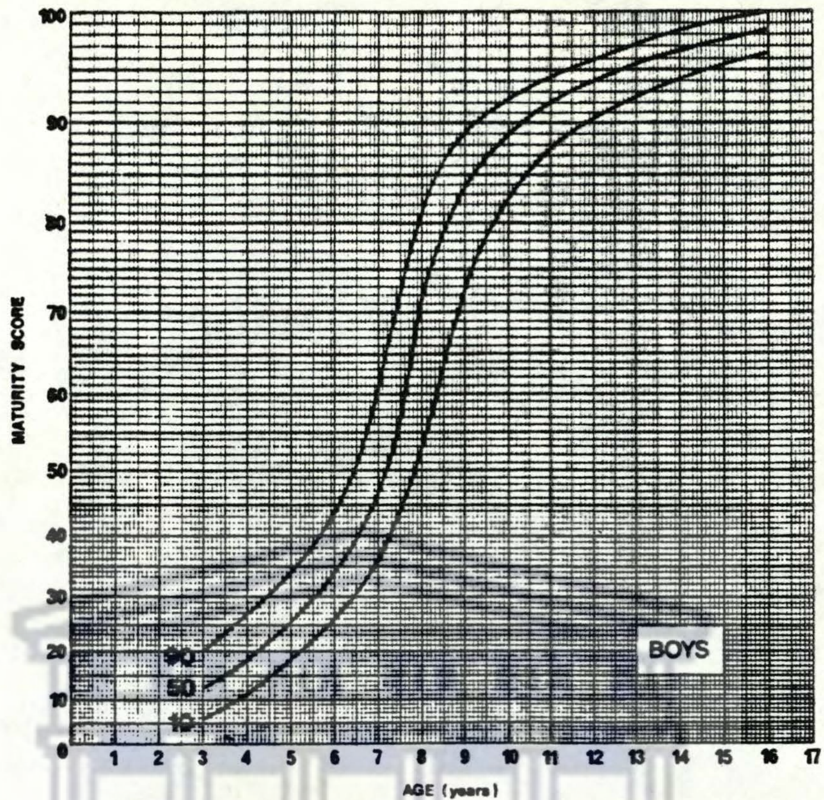
Age	Score	Age	Score	Age	Score	Age	Score
			Girls				
3.0	13.7	7.0	51.0	11.0	94.5	15.0	99.2
.1	14.4	.1	52.9	.1	94.7	.1	99.3
.2	15.1	.2	55.5	.2	94.9	.2	99.4
.3	15.8	.3	57.8	.3	95.1	.3	99.4
.4	16.6	.4	61.0	.4	95.3	.4	99.5
.5	17.3	.5	65.0	.5	95.4	.5	99.6
.6	18.0	.6	68.0	.6	95.6	.6	99.6
.7	18.8	.7	71.8	.7	95.8	.7	99.7
.8	19.5	.8	75.0	.8	96.0	.8	99.8
.9	20.3	.9	77.0	.9	96.2	.9	99.9
4.0	21.0	8.0	78.8	12.0	96.3	16.0	100.0
.1	21.8	.1	80.2	.1	96.4		
.2	22.5	.2	81.2	.2	96.5		
.3	23.2	.3	82.2	.3	96.6		
.4	24.0	.4	83.1	.4	96.7		
.5	24.8	.5	84.0	.5	96.8		
.6	25.6	.6	84.8	.6	96.9		
.7	26.4	.7	85.3	.7	97.0		
.8	27.2	.8	86.1	.8	97.1		
.9	28.0	.9	86.7	.9	97.2		
5.0	28.9	9.0	87.2	13.0	97.3		
.1	29.7	.1	87.8	.1	97.4		
.2	30.5	.2	88.3	.2	97.5		
.3	31.3	.3	88.8	.3	97.6		
.4	32.1	.4	89.3	.4	97.7		
.5	33.0	.5	89.8	.5	97.8		
.6	34.0	.6	90.2	.6	98.0		
.7	35.0	.7	90.7	.7	98.1		
.8	36.0	.8	91.1	.8	98.2		
.9	37.0	.9	91.4	.9	98.3		
6.0	38.0	10.0	91.8	14.0	98.3		
.1	39.1	.1	92.1	.1	98.4		
.2	40.2	.2	92.3	.2	98.5		
.3	41.3	.3	92.6	.3	98.6		
.4	42.5	.4	92.9	.4	98.7		
.5	43.9	.5	93.2	.5	98.8		
.6	45.2	.6	93.5	.6	98.9		
.7	46.7	.7	93.7	.7	99.0		
.8	48.0	.8	94.0	.8	99.1		
.9	49.5	.9	94.2	.9	99.1		

Table 13. CONVERSION OF MATURITY SCORE TO DENTAL AGE - BOYS (7 TEETH)

Age	Score	Age	Score	Age	Score	Age	Score
			Boys				
3.0	12.4	7.0	46.7	11.0	92.0	15.0	97.6
.1	12.9	.1	48.3	.1	92.2	.1	97.7
.2	13.5	.2	50.0	.2	92.5	.2	97.8
.3	14.0	.3	52.0	.3	92.7	.3	97.8
.4	14.5	.4	54.3	.4	92.9	.4	97.9
.5	15.0	.5	56.8	.5	93.1	.5	98.0
.6	15.6	.6	59.6	.6	93.3	.6	98.1
.7	16.2	.7	62.5	.7	93.5	.7	98.2
.8	17.0	.8	66.0	.8	93.7	.8	98.2
.9	17.6	.9	69.0	.9	93.9	.9	98.3
4.0	18.2	8.0	71.6	12.0	94.0	16.0	98.4
.1	18.9	.1	73.5	.1	94.2		
.2	19.7	.2	75.1	.2	94.4		
.3	20.4	.3	76.4	.3	94.5		
.4	21.0	.4	77.7	.4	94.6		
.5	21.7	.5	79.0	.5	94.8		
.6	22.4	.6	80.2	.6	95.0		
.7	23.1	.7	81.2	.7	95.1		
.8	23.8	.8	82.0	.8	95.2		
.9	24.6	.9	82.8	.9	95.4		
5.0	25.4	9.0	83.6	13.0	95.6		
.1	26.2	.1	84.3	.1	95.7		
.2	27.0	.2	85.0	.2	95.8		
.3	27.8	.3	85.6	.3	95.9		
.4	28.6	.4	86.2	.4	96.0		
.5	29.5	.5	86.7	.5	96.1		
.6	30.3	.6	87.2	.6	96.2		
.7	31.1	.7	87.7	.7	96.3		
.8	31.8	.8	88.2	.8	96.4		
.9	32.6	.9	88.6	.9	96.5		
6.0	33.6	10.0	89.0	14.0	96.6		
.1	34.7	.1	89.3	.1	96.7		
.2	35.8	.2	89.7	.2	96.8		
.3	36.9	.3	90.0	.3	96.9		
.4	38.0	.4	90.3	.4	97.0		
.5	39.2	.5	90.6	.5	97.1		
.6	40.6	.6	91.0	.6	97.2		
.7	42.0	.7	91.3	.7	97.3		
.8	43.6	.8	91.6	.8	97.4		
.9	45.1	.9	91.8	.9	97.5		

APPENDIX III

PERCENTILE CURVES OF FRENCH CANADIAN SAMPLES
(DEMIRJIAN ET AL 1973)



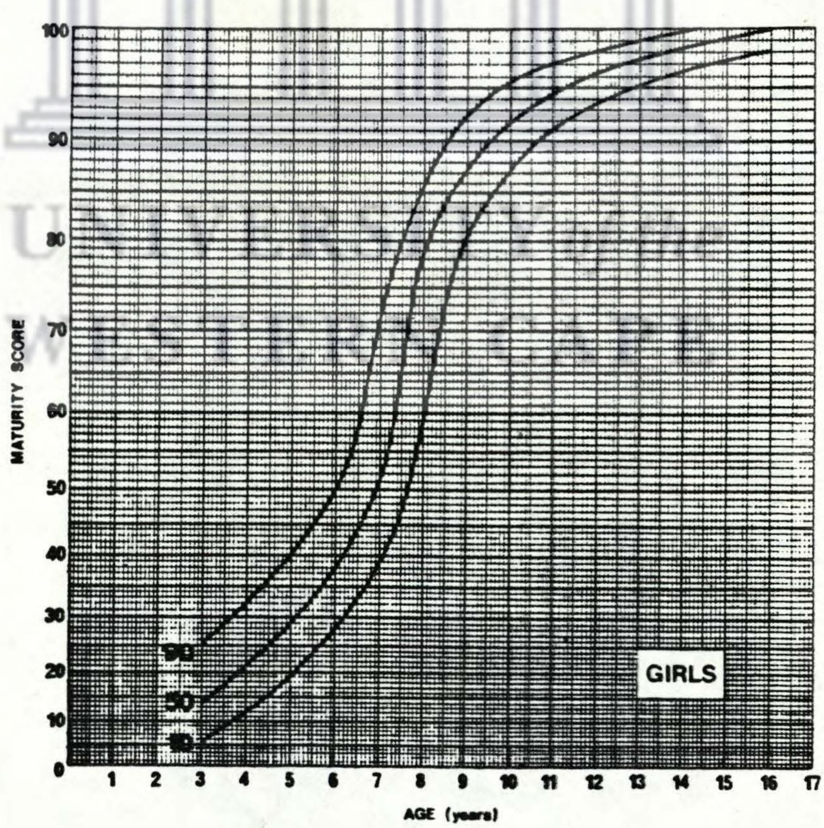


Fig. 7 a+b <u>DENTAL MATURITY PERCENTILES</u>

APPENDIX IV

STATISTICS

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