T.C.
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF PEDIATRIC DENTISTRY

EVALUATING AND COMPARING THE DENTAL AGE OF TURKISH AND LIBYAN CHILDREN AGED BETWEEN 7-14 YEARS USING THE DEMIRJIAN, WILLEMS AND CAMERIERE METHODS

Ph.D. THESIS

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated .... and numbered ....

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Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis represents my work done after registration for the degree of Ph.D. as appropriate at Yeditepe University and has not been previously included in a thesis or dissertation submitted to this or any other institution degree, diploma, or other qualifications.

I have read the University's current research ethics guidelines and accept responsibility for the procedures' conduct following the University's Committee on the Use of Human & Animal Subjects in Teaching and Research (HASC). I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and safety approval (where applicable), and acknowledged my obligations and the participants' rights.

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ABBREVIATIONS

AE: Age Estimation

AGFAD: A Study Group on Forensic Age Diagnostics

APA: Anterior Posterior Aspect

CA: Chronological Age

CI: Confidence interval

CM: Cameriere Method

DA: Dental Age

DM: Demirjian Method

DS: Dental Score

ICC: Intraclass correlation coefficients

IQR: Interquartile range

M: Mean value

MAT: Mean Appearance Time

OPTG: Orthopantomogram

RA: Real Age

RUS: Radius, ulnas, short bone

S.D.: Standard deviation

TIFF: Tagged Image File Format

TW2: Tanner and Whitehouse method for measuring skeletal age

WM: Willems Method

ABSTRACT

Almozughi M. The Demirjian, Willems, and Cameriere methods were used to evaluate and compare the dental age of Turkish and Libyan children aged 7-14 years. Ph.D. Thesis, Yeditepe University, Institute of Health Sciences, İstanbul, 2021.

Many changing human body parameters have been researched and compared to biological age in living humans, and human age prediction has been a subject of concern since documented history. Since it is applied to both the living and the deceased, age estimation is important in forensic odontology. In pediatric dentistry and orthodontics, the dental age (DA) is essential in determining the diagnosis and treatment plan. The aim of this study was to evaluate the accuracy of the Demirjian method (DM), Willems method (WM), and Cameriere method (CM) to Turkish and Libyan children because dental age assessment is considered appropriate in several countries. Compare Turkish and Libyan children's dental ages. A convenience sampling method was used in this retrospective cross-sectional observational study. The panoramic radiographs (ortopantographs) (OPTGs) of 300 Turkish children were selected from those who referred to Yeditepe University, Faculty of Dentistry, Pediatric Dentistry Clinics whose ages were between 7.0 and 14.9 years. The panoramic radiographs of 300 Libyan children were selected from the patient records who referred to the Pedodontic clinic at Al Hussein dental clinic in Tripoli, Libya whose ages were between 7.0 and 14.9 years. After a brief training phase, one examiner (M.A.) was responsible for the complete assessment of all radiographs. All mandibular teeth (except for the third molars) were scored using Demirjian et al system, as well as Willems and Cameriere's methods. All the recorded scores were statistically analyzed. The numerical variables were compared across two groups with using Mann Whitney U test or t-test, and three or more groups by Kruskal-Wallis test or ANOVA depending on their distribution. The assumption of normality was assessed with Shapiro Wilks' test in addition to visual inspections of QQ and PP plots. The Demirjian method overestimates the chronological age for both ethnicities. While Cameriere method underestimates the chronological age for Turkish group. Willlems method seems to have the closest estimate for chronological age for Turkish group. Willems seem to underestimate for Libyan while Cameriere seems to be the closest estimate for Libyan children. In conclusion the use of the Demirjian procedure to estimate dental age in Turkish children resulted in an overestimation of chronological age. The use of the Willems method for estimating dental age for Libyan children led to the finding that Willems dental age works reasonably well in estimating chronological age for both Libyan and Turkish children.

Key Words: Dental age, Demirjian, Willlems, Cameriere, chronological age

ÖZET

Almozughi M. Yaşları 7-14 arasında değişen Türk ve Libya'lı çocukların diş yaşlarının Demirjian, Willems ve Cameriere yöntemleri kullanılarak değerlendirilmesi ve karşılaştırılması. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, İstanbul, 2021.

Farklı insan vücudu parametreleri yıllardır araştırılmaktadır ve bu parametreler ile biyolojik yaş tahmini yapılmaya devam edilmektedir. Canlılarda ve ölülerde bu yaş tahminleri adli diş hekimliği açısından da oldukça önemlidir. Çocuk diş hekimliği ve ortodonti alanlarında diş yaşının bilinmesi özellikle tanı ve tedavi planının belirlenmesinde esastır. Bu çalışmanın amacı, diş yaşı belirlemek amacıyla kullanılan Demirjian yöntemi (DM), Willems yöntemi (WM) ve Cameriere yöntemlerinin (CM) Türk ve Libya'lı çocuklar için diş yaşı belirlemedeki uygunluğunun incelenmesi ve karşılaştırılmasıdır. Bu retrospektif kesitsel gözlemsel çalışmada fazla sayıda örnek incelenerek örnekleme yöntemi kullanıldı. Yaşları 7,0 ile 14,9 arasında değişen ve Yeditepe Üniversitesi, Diş Hekimliği Fakültesi, Çocuk Diş Hekimliği Kliniklerine başvuran 300 Türk çocuğunun panoramik radyografilerine (ortopantografları) (OPTG'ler) hasta kayıtlarından ulaşıldı. Yaşları 7,0 ile 14,9 arasında değişen ve Libya, Trablus'taki Al Hussein diş merkezi Pedodonti kliniğine başvuran 300 Libya'lı çocuğun panoramik radyografileri hasta kayıtlarından ulaşıldı. Kısa bir radyografi yöntemleri değerlendirme eğitimi aşamasından sonra, tüm radyografilerin üç arıy yöntemle değerlendirilmesi aynı tek araştırmacı tarafından (MA) gerçekleştirildi. Tüm alt çene dişleri (üçüncü büyük azı dişleri hariç) Demirjian, Willems ve Cameriere yöntemleri kullanılarak skorlandı. Kaydedilen tüm parametreler istatistiksel olarak analiz edildi. İki grup arasındaki sayısal değişkenler, Mann Whitney U testi veya t-testi kullanılarak, ikili veya daha fazla sayıdaki grup karşılaştırmaları dağılımlarına bağlı Kruskal-Wallis testi veya ANOVA kullanılarak analiz edildi. Normallik değerlendirmesi Shapiro Wilks testi ile ve ek olarak QQ ve PP grafiklerinin görsel incelemeleriyle değerlendirildi. Demirjian yöntemi, her iki etnik köken için kronolojik yaşı olduğundan fazla tahmin ediyor. Cameriere yöntemi Türk grubu için kronolojik yaşı olduğundan az hesaplamaktadır. Willlems yöntemi, Türk grubu için kronolojik yaş için en yakın tahmine sahip görünmektedir. Willems, Libyalı için hafife alırken, Cameriere Libyalı çocuklar için en yakın tahmin gibi görünüyor. Türk çocuklarında diş yaşını tahmin etmek için Demirjian yönteminin kullanılması, kronolojik yaşın fazla olarak tahmin edilmesine neden oldu.

Willems yönteminin kullanılmasının hem Libya'lı hem de Türk çocuklar için kronolojik yaşı tahmininde oldukça iyi sonuçlar verdiği saptandı.

Anahtar sözcükler: Diş yaşı, Demirjian, Willlems, Cameriere, kronolojik yaş

1 INTRODUCTION AND AIM

Human age prediction has been a source of controversy since recorded history, and many evolving human body standards have been studied and related to biological age of living people. In the second half of the twentieth century, a scientific approach to the subject emerged, leading to a plethora of reported age appraisal approaches that use either children or sub-adults. The explanation for this is that children's development and growth result in a property in which age-related laws are continually changing in different areas of the human body. Adults are less certain of these instructions, resulting in longer cycles of confidence (1).

In forensic odontology, age determination is crucial when it is seen on both the living and the dead. Where it comes to deceased bodies, age estimation helps recognize them and equate them to other individuals who have gone missing. Among the living, age determination may help determine one's legal status in cases including adoption, criminal responsibility, asylum, legal issues, and missing identification documents. Dental age (DA) is often used to measure and plan treatment in orthodontics and pediatric dentistry. Tooth structure is used in forensic branch to record the age (2).

Different standards have been established in different countries, and because dental age record is considered necessary, the aim of the present study was:

- To assess the accuracy of the Demirjian method (DM), Willems method (WM), and Cameriere method (CM) to Turkish and Libyan children.
- Compare the difference between the Dental age of Turkish children and Libyan children.

2 LITERATURE REVIEW

2.1 Growth-Pattern, Variability and Timing concept

You must have a detailed comprehension of growth concepts to grasp the basic mechanism. A complex set of proportions has its proportionality inverted by the sequence. To put it another way, at any given time, the internal structure of the body is a pattern of spatially proportioned bits. It's the natural change of body proportions that happens during growth and development (1).

During embryonic growth, around the third month of IU progression, the head makes up around half of all body circumferences. In contrast to the face, the head is huge, including more than half of the brain, while the limbs and trunk are still underdeveloped. By the time a child reaches maturity, the trunk and stems have developed more than the ears and head, culminating in a 30% reduction in the ranges of the entire body concerned with the head, with a steady reduction in related average for the head to about 12% in adulthood. Legs account for one-third of total body length at birth and half through adulthood. Lower limbs grow quicker than upper limbs during the post-natal period. It indicates the existence of a growth axis that runs from the head to the bottom. The Cephalocaudal Development Gradient is what they're called. The second definition in growth and progression is variability. Since no two people are exactly alike, deciding whether anyone is at the extreme of natural variance or falling below the normal range is challenging but important. As a consequence, uncertainty may be measured (2,3).

The last principle to include in the study of development and change is timing. There is inconsistency in timing and the same event happens at different times for different participants. Examples may be used to clarify the concept of timing. Any babies, for example, mature and expand rapidly, placing them at the top of the developmental scale. Slow growers will lag behind, but with the emergence of catch-up growth, they can eventually catch up to and even surpass fast growers. Females go through the same mechanism as men. A girl who reaches menarche between the ages of 10 and 11 matures sooner than a girl who reaches menarche between the ages of 13 and 15 (1,3,4)

2.2 Differential Growth

Through time, the human body has changed and evolved to perform different functions. The concept of differential growth explains how various organs may vary in tempo, amounts, and even how they may have differing evolutions.

2.2.1 Scammon's curve

Scammon's model of tissue growth: The lymphoid, general, and neural tissue development occurs at varying paces, but they reach maturity at the same time. Using many studies of multiple organ sizes, tissue, and organ growth charts, Scammon's expressed the belief that formation of various tissues and processes could be condensed into four different curves. What these graphs reflect are really showing is how Scammon's development patterns are laid out in formation is called Scammon's growth curves. (Figure 1 as seen here.) It should be clear to you by now that if we expand these ideas a little we have a lot of words and a lot of avenues to choose from for inquiry. Scammon's model of tissue growth: The lymphoid, general, and neural tissue development occurs at varying paces, but they reach maturity at the same time. Using many studies of multiple organ sizes, tissue, and organ growth charts, Scammon's expressed the belief that formation of various tissues and processes could be condensed into four different curves. What these graphs reflect are really showing is how Scammon's development patterns are laid out in formation is called Scammon's growth curves. (Figure 1 as seen here.) It should be clear to you by now that if we expand these ideas a little we have a lot of words and a lot of avenues to choose from for inquiry. Scammon's model of tissue growth: The lymphoid, general, and neural tissue development occurs at varying paces, but they reach maturity at the same time. Using many studies of multiple organ sizes, tissue, and organ growth charts, Scammon's expressed the belief that formation of various tissues and processes could be condensed into four different curves. What these graphs reflect are really showing is how Scammon's development patterns are laid out in formation is called Scammon's growth curves. (Figure 1 as seen here.) It should be clear to you by now that if we expand these ideas a little we have [will have] a lot of words and a lot of avenues to choose from for inquiry (3).

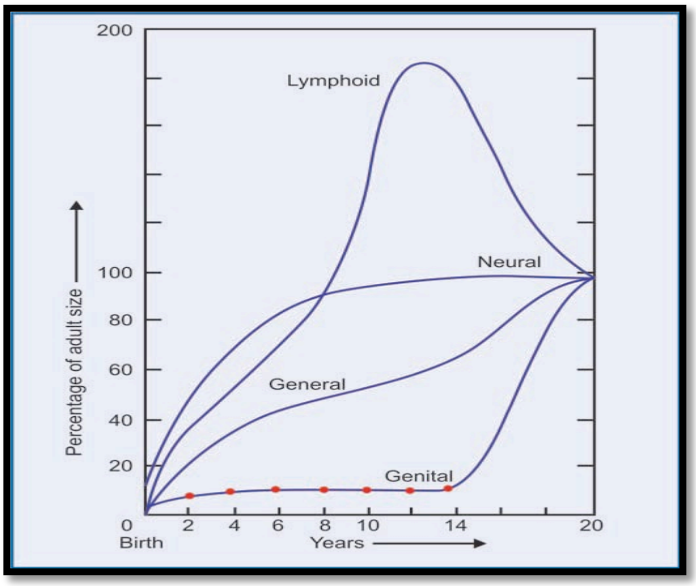


Figure 1. Scammon's curves

2.2.2 General Tissue

The curve report the body's growth as a total and its main parts, the growth way of stature, weight, and most outer forms of the body, consist of muscles, bones, and other organ systems. These describe an 'S' shaped curve with fast growth until the age of 2 to 3 years, followed by a slow period until the age of 10 years. The growth enters a fast way again at the age of 10 years until cut off at age of 18 to 20 years (1).

2.2.3 Neural Tissue

The neural curve reports the nervous system, brain's growth and related structures, as eyes, skull parts and the upper face. These parts have fast growth early in post-natal life. approximately 95 % of the sum percent in the central nervous system's size between up to twenty years of age is completed by the age of seven about. Grows very rapidly and reaches adult size by 6 to 7 years, and very little growth occurs after age of 7 years (1,3).

2.2.4 Genital Tissue

The genital development reports the growth way of both different sex aspects. The first one included that in females the fallopian tubes, ovaries, vagina, and uterus. The other one is the characteristics of breasts, pubic hair, and facial hair in girls and boys, as well as vocal cord growth in males and females are well-known and essential sex differences. exhibits only minimal growth prior to the age of maturity, then grows greatly in prominence throughout the teenage years (1,2).

2.2.5 Lymphoid Tissue

The lymphoid tissue represents the development of the thymus and lymph glands, appendix, tonsils. It increases so rapidly in late childhood and reaches around 200 % of its adult size because children are more susceptible to infections. At age of 18 years, the lymphoid tissue have involution to get the adult size (2).

2.3 Growth Spurts

- The phrase would not say that growth occurs all of the time, but more simply that growth is non-uniformity. But there still seem to be significant periods of stagnation where growth slows down. As described by this definition, a growth spurt may be defined as a steep of growth increase.
- The growth spurt in the prenatal period and the infantile period differ because they are more of a biological process involving the cells' division.
- On the other hand, the physiological change in hormonal secretion is responsible to cause underline growth associated with the pubertal period (1,3).

2.3.1 Timing of Growth Spurts

- Immediately prior to birth
- A year after the birth of the child
- Mixed dentition growth spurt
  - Boys between the ages of 8 and 11 years
  - Girls between the ages of 7 and 9 years
- Adolescent growth spurt at **Table (1):**
  - Boys between the ages of 14 and 16 years
  - Girls between the ages of 11 to 13 years

2.3.2 Prediction and Clinical Applications of Growth Spurts

The prediction of direction, amount, and timing of growth spurt is essential concerning orthodontic treatment. A growth spurt is the best time for interceptive orthodontics as growth can be modeled according to the desired effect **(Figure 2)**.

- Because girls develop an inch or two earlier than boys, girls' orthodontic therapy must begin earlier.
- The earlier the starting of puberty, the smaller is adult.
- Girls mature earlier and finish their growth sooner, leading to the difference in men and women's adult size.
- Growth spurts are also affected by environmental variations.
- Malocclusion requiring surgical correction should only be undertaken after the growth spurt is completed.
- Arch expansion can be done during growth spurts (1,3).

- Class III tendency with mandibular prognathism should be treated before a prepubertal growth spurt.
- Class II, III malocclusion should be treated during the growth spurt.
- If the jaw growth has to be accelerated, it must be done before the adolescent growth spurt in girls.
- In the timing of orthodontic treatment, clinicians have a tendency to treat girls too late and boys too soon.
- Forgetting the disparity in physiologic maturation, if the treatment delayed the opportunity to utilize the growth spurt missed. Therefore, it is indispensable to carefully assess the physiologic age while planning for orthodontic treatment (3).

Table 1. Adolescent growth spurt (1)

	Girls	Boys
First stage	▪ Occurs about the starting of a physical growth spurt. ▪ The development of breasts and growing pubic hair ▪ The peak of growth occurs after one years of age and this finishes the first stage.	▪ The first sign of sexual development in boys is a "fat spurt." ▪ The maturing boy gains weight, and there is feminine like fat distribution due to Leydig cells' estrogen production.

Second stage	▪ Secondary sexual characteristics begin to appear.	▪ occurs 1 year after first stage and coincides with starting of an increase in height ▪ Redistribution and decrease in fat. ▪ The growth of sexual organs also takes place in this stage.
Third stage	▪ This stage is between the age of one and one and a half years after second stage and menstruation usually occurs in this stage. ▪ At this stage, there is a more adult type of fat distribution occurs.	▪ Occurs during the first year of age after second stage and coincides with a peak velocity of gain in height. ▪ Axillary and facial hairs appear. ▪ The sexual organs reach adult size ▪ There is also a muscular growth spurt.
Fourth stage	None	▪ Occurs between 15 to 24 months after stage three. ▪ The growth in height ends. ▪ Hair appears on a full face. ▪ Increase in muscular strength.

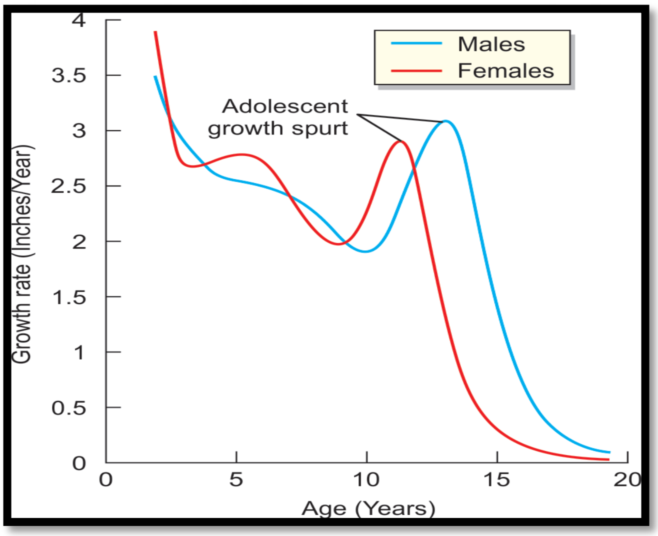


Figure 2. Graphical representation of growth in children (3)

2.4 Growth Trends

Tweed discerned a growth pattern by overlapping consequent cephalograms and termed it as growth trends (2).

ANB angle

• According to Sterner, it is the angle between (A point) on the maxilla and (B point) on the mandible.

• It is the Difference between SNA and SNB and indicates the magnitude of skeletal join discrepancies.

• The average value of the ANB angle is 2°.

• If it is less than 2°, then it indicates class II, and if it is more than 2°, then indicative of class III malocclusion **(Figure 3)**.

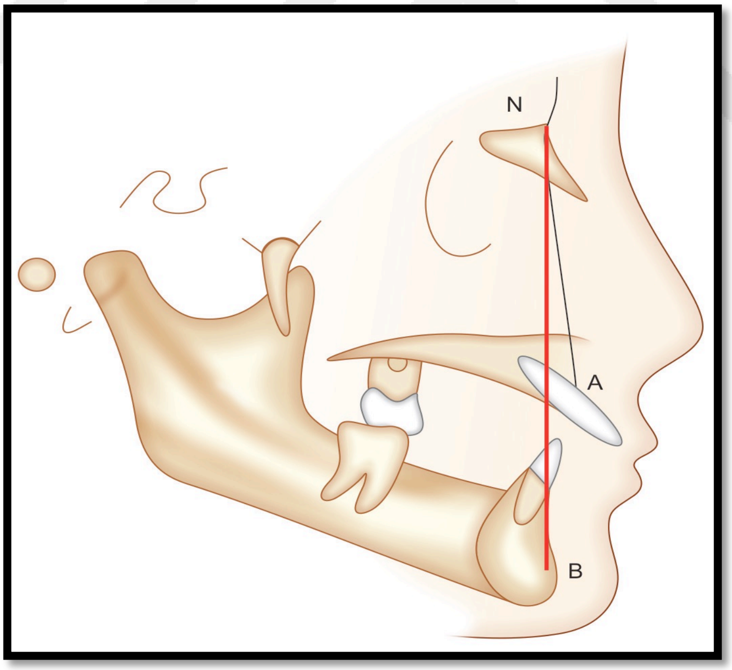


Figure 3. ANB angle (1)

2.4.1 Type A

▪ The maxilla and mandible grow together, and thus ANB angle remains the same.

- Should be accompanied by a Class I relationship pattern and ANB does not exceed 4.5°, no treatment indicates.
- Represent more than 25 percent.

Type A Subdivision

- The maxilla is protruding with an ANB angle of more than 4.5°.
- The treatment is to allow the mandible to catch up while restricting the growth of the maxilla
- The prognosis is good but may sometimes require the extraction of premolars.

2.4.2 Type B

- Mandible and maxilla grow forwards and downwards, with the maxilla's growth exceeding that of the mandible.
- Poor prognosis and indicates that point B will not catch up with point A.
- Vertical Growth direction of the middle and lower face is predominant.

Type B Subdivision

The **ANB** angle is large and continues to grow to indicate a negative growth trend.

2.4.3 Type C

The maxilla and mandible grow forwards and downwards, with the mandible growing forward more rapidly.

The **ANB** angle is seen to be decreasing with the mandible catching up with the maxilla. Indicates a favorable trend, and no treatment is required until the eruption of canine.

Type C Subdivision

- The mandible is growing more forward than the maxilla; with this, the mandible incisors touch the lingual surface of maxillary incisors.
- Therefore mandibular incisors are tipped lingually, and maxillary incisors are tipped labially (1–3).

2.5 Growth assessment parameters

The correct knowledge of facial age, developmental age, chronologic age, etc. is essential for formulating a treatment plan. These anthropometric measurements are also useful in the interdisciplinary evaluation of patients (1,4).

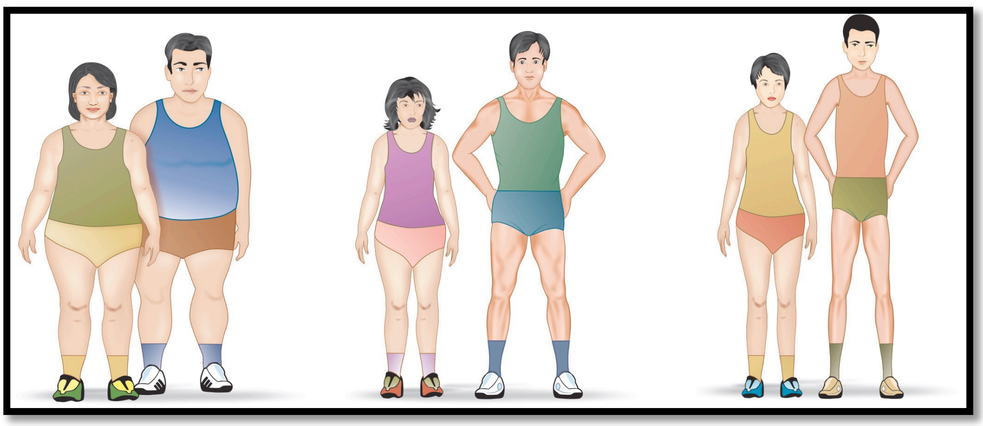
2.5.1 Somatotypic Age

Sheldon defines somatotype as a sequence of 17 anthropometric proportions unrelated to nutritional status **(Figure 4)** (4).

Endomorphs are short and stocky, with a lot of subcutaneous fat and well-developed digestive viscera. **Mesomorphs** have a number of fat, bone, and connective tissue and are tall, stout, and athletic. **Ectomorphs** are individuals who are tall, thin, and delicate, with very few subcutaneous fat and muscle tissue. A chronologic late mature is an ectomorph, whereas a chronologic early mature is an endomorph. Somatotype may reveal a child's developmental pattern, although it is not a good indicator of future success (4).

2.5.2 Chronologic Age

It is the most apparent and simple developmental age parameter, and it can be determined using the child's birth date. There could be a difference between children of the same chronological age due to differences in maturation, diseases, and various environmental factors. While its apparent simplicity, chronological age is neither an accurate indicator of progress nor a strong predictor of growth (5,6).



(A) **(B)** **(C)**

Figure 4. Somatotypic classification: **(A)** Endomorph **(B)** Mesomorph **(C)** Ectomorph (4)

2.5.3 Height and Weight Age

Height has been commonly employed as a determinant of development age. The standard growth curve widely employed to characterize a child's size compared to that of children of the same chronologic age is used to assess developmental age. Growth of all children up to puberty follows nearly the same curves, but the difference in adolescent growth spurts change the growth curves during and after puberty considerably. Because each child's height is related to environmental and genetic factors, it is clear that a single measurement is limited as a predictor of development age. If height age has to be considered, then the child's longitudinal height that expresses the child's growth curve is of more value. Weight and height age are correlated well with each other **(Figure5),** but weightage alone is a low indicator of growth or developmental age owing to a large number of variations (1,7).

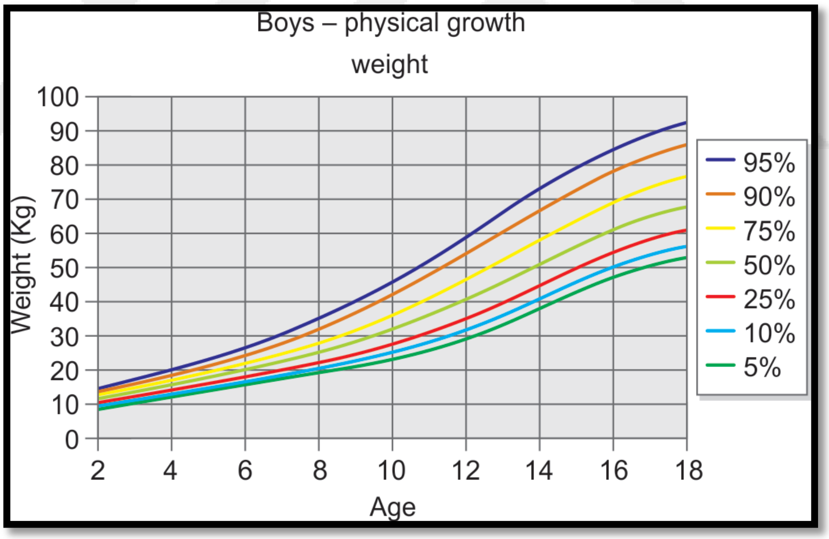


Figure 5. Height/Weight comparative chart for age assessment (1)

2.5.4 Sexual Age

At puberty, differential hormones actions yield characteristic body charges (8)

2.5.5 Facial Age

The ultimate goal of developmental growth assessment of children being evaluated for craniofacial intervention is facial age. The aim is to figure out where they are on the facial growth curve such that future growth can be expected. Various methods used to measure facial age and prediction of craniofacial development is an anthropometric measurement, facial growth velocity curve, and cephalometric radiographs (1).

2.5.6 Skeletal Age

Skeletal age is a popular diagnostic tool for endocrine, orthopedic, genetic, and renal disorders, as well as for determining children's growth capacity and monitoring response to medical therapy (9). The most widely used guide for estimation of bone age is the Greulich and Pyle reference atlas, which contains radiologic analyses of the hand (the left one) and the wrist for people at varying stages of skeletal formation (10).

The benefits of using skeletal age include the potential to recognise the distinct pattern of epiphyseal core ossification growth, the readily recognizable level of ossification, and the typical sequence of developmental changes that occur from birth to maturity (1).

Hand and Wrist Radiographs

The hand-wrist region includes a variety of very small bones that have a constant and expected appearance, ossification, and union from birth to adulthood. We may assess a patient's skeletal maturation status by comparing their radiograph to parameters that indicate different skeletal ages (1).

Anatomy of the hand-wrist area: The four types of bones that make up the hand-wrist region are the forearm, carpals, metacarpals, and phalanges **(Figure 6)**.

1. Distal parts of long bones of the forearm: The distal parts of the radius and ulna from the first group of bones. These give rise to distal projections on their respective sides called radial and ulna styloid.

2. Carpals: These include 8 small bones irregularly shaped organized in two ways.

• Proximal row: Scaphoid, lunate, triquetral, pisiform.

• Distal row: Trapezium, trapezoid, capitate, hamate.

3. Metacarpals: 5 small long bones making the skeletal framework of the palm. Each metacarpal ossifies from one primary and one secondary center.

4. Phalanges: These are small bones make up the fingers. These are 3 in number except for the thumb, which has 2; the three bones are proximal, middle, and distal.

• Sesamoid bone: Small bone nodular shaped usually seen in the tendonous region of thumb (10).

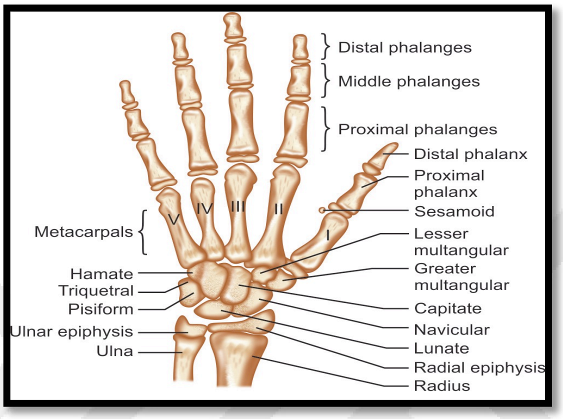


Figure 6. Tracing of male standard 13 years, six months hand-wrist radiograph (10)

Determination of skeletal age:

The APA view radiograph of the left hand and wrist is considered standard for determining skeletal age. The following are conventionally followed methods for skeletal age assessment:

- **Greulich** and **Pyle** published an atlas of standard hand wrist radiographs for males and females at various ages **(Figure 7)** (10).
- For skeletal age determination, one compares the radiograph of the left hand-wrist region of the child with the atlas standards beginning with the same-sex and nearest chronological date.
- The hand-wrist standard that superficially resembles the child's radiograph uses for a more detailed comparison.
- Both bones are tested, and each center is given a skeletal age that is considered natural. Following that, a general age is determined (10).

- The radius, ulnas, short bone (RUS) ranking, the carpal bone method, and the TW2 process (which ranks all the growth centers) are three methods suggested by **Tanner and Whitehouse** for measuring skeletal age by rating the maturity of individual bones (9).
- **Taranger et al.**: Mean appearance time (MAT) of bone stages (11).
- **Grave** and **Brown**: They further corroborated the evidence of Bjork and Helm and included more ossification centers. They divided skeletal development into nine stages, each representing a level of skeletal maturity **(Figure 8)** (3).

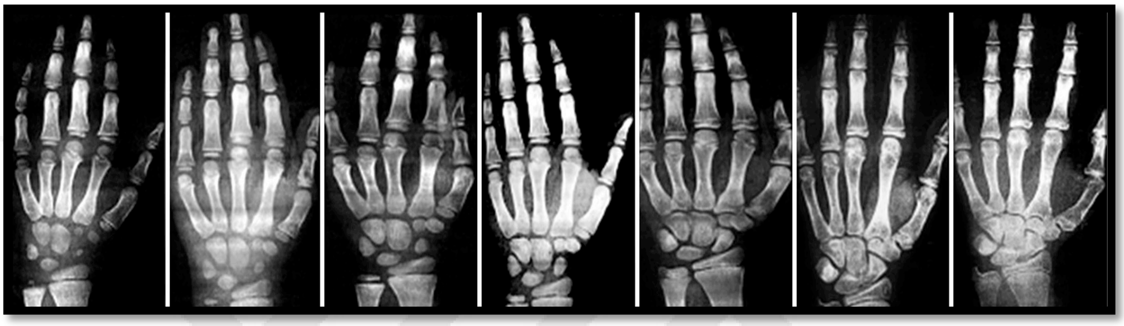


Figure 7. Hand-wrist radiograph of children ranging from 5–15 years (2)

2.5.7 Dental Age

In a traditional sequence, the last erupted tooth in the oral cavity is used to calculate dental age. It is the simplest but the least accurate method. It involves using dental eruption charts to classify the teeth that are clinically active in the oral cavity. The disadvantages of this technique are the wide variations in the eruption time, the effect of environmental and local factors, and the fact that no or a lot of teeth may erupt during the same time period (1).

Since mineralization is controlled by genes rather than environmental influences, it is advisable to estimate age in children based on dental development. Demirjian, Goldstein, and Tanner proposed the most widely used age estimating method, which they later modified (12,13). In 2006, Cameriere et al. suggested in the European community a procedure for estimating the chronological age the measurement of teeth's open apices. This procedure was said to be much more accurate than others. Radiographic age determination methods are easy, non-destructive, and reliable (14–16).

The age of a child's teeth has no bearing on his or her developmental status. A few methods give the development quotient a reasonably accurate level, signifying the close relationship between dental and chronologic age (13,16).

2.6 Forensic Dentistry

The discipline of applying dentistry to legal matters is classified as forensic dentistry, or forensic odontology. The forensic dentistry is an essential element of the USA legal procedures for more than 3 decades. In addition, forensic dentistry refers to a variety of investigative projects including the justice system and dentistry. This advanced dentistry sector, which is part of the larger field of criminalistics, involves gathering and analyzing dental and related data (17).

2.7 The Concept of Age

Generally speaking, when we use the term age, we refer to the chronological age of the individual or object that has elapsed since the person was born or since the item was made. From a forensic viewpoint, when we wish to know the age at the time of death, we ask for the chronological age, the time elapsed between the individual's birth and death. It is impossible to answer this question precisely without knowing the time of birth and time of death of the individual in question. Fortunately, in cases where this information is not available, an assessment of the age at the death's time can be made based on the body's biological maturity (1,2).

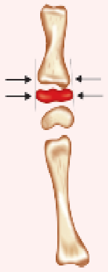
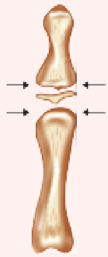
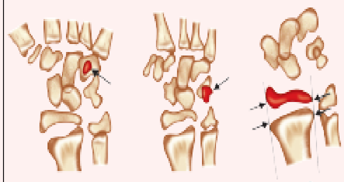
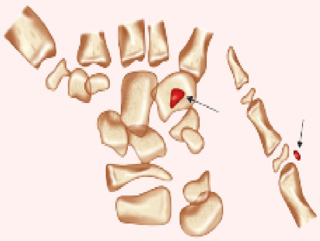
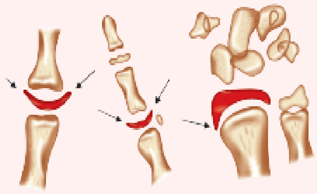
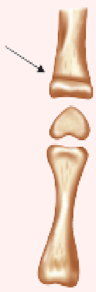
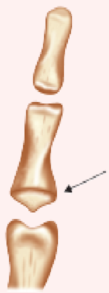
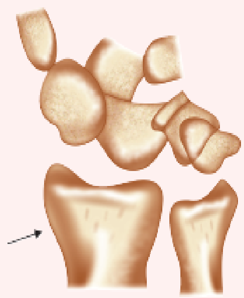
Stage 1	*Stage 2*	*Stage 3*
• Epiphysis and diaphysis of proximal phalanx of index finger are equal • 3 years before peak velocity of pubertal growth spurt • Males – 10.6 years; Females – 8.1 years 	• Epiphysis and diaphysis of middle phalanx of middle finger are equal • Males – 12.0 years; Females – 8.1 years 	• Characterized by areas of ossification viz. hamular process of hammate, ossification of pisiform • Males – 12.6 years; Females – 9.6 years 
Stage 4	*Stage 5*	*Stage 6*
• Marks the beginning of pubertal growth spurt • Increase mineralization of ulnar sesamoid in thumb • Increased ossification of hamular process of hammate • Males – 13.0 years; Females – 10.6 years 	• Peak of pubertal growth spurt • Epiphysis caps diaphysis in middle phalanx of 3rd finger, proximal phalanx of thumb and radius • Males – 14.0 years; Females – 11.0 years 	• End of pubertal growth spurt • Union of epiphysis and diaphysis of distal phalanx of middle finger • Males – 15.0 years; Females – 13.0 years 
Stage 7	*Stage 8*	*Stage 9*
• Union of epiphysis and diaphysis of • proximal phalanx of middle finger Males – 15.9 years; Females – 13.3 years 	• Fusion between epiphysis and diaphysis of middle phalanx of middle finger • Males – 16.9 years; Females – 13.9 years 	• Signifies end of skeletal growth • Fusion of epiphysis and diaphysis of radius • Males – 18.5 years; Females – 16.0 years 

Figure 8. Stages of skeletal development (3)

According to Frank, maturation is "a series of successive transitions over time" (18). He then states that this occurs until the adult state is achieved. A broader view of this process that is not limited by the adult state's achievement would seem more appropriate because biological maturation continues throughout life. The term maturity should be used as a general concept for any specified stage during this process (19).

Dental maturity has gotten a lot of attention and concern because of the importance in the study of developmental disabilities and therapeutic orthodontics. Since developing teeth are more controlled by genes and less affected by endocrine disturbances and environmental damage than other body tissues, dental development methods are suitable for evaluating a child's era (20,21).

There are various radiography techniques used in dental development to estimate the age. Demirjian method was also closely examined for its applicability to different cultures and age groups, according to the researchers. The Willems algorithm, which is also in its infancy, has proved to be a more accurate age predictor. Other methods, such as Cameriere's, have been used as well. Several tests evaluating the accuracy of all three methods have been conducted (13,14,22).

2.8 Methods for Age Assessment

In England, the first attempts to use teeth as an indicator of age were developed. In the early nineteenth century, child labor and violence were serious social problems, contributing to the industrial revolution's economic crisis. In 1837, a dentist called Edwin Saunders addressed the English parliament with a pamphlet titled "Teeth A Test of Maturity," which was the first to publish article regarding the dental consequences of age calculation (23).

The literature describes a number of methods for predicting adult age. The different methods are classified into three branches:

1. Methods of morphology

2. Biochemical procedures

3. Use of radiological techniques (24).

Radiology is critical in assessing an individual's age. The usage of radiological images for age estimate is one of the most significant techniques of forensic science diagnosis. It's an easy, non-invasive, and repeatable treatment that can be carried out on both living and undead individuals. Any of the radiographic images used in age identification include lateral oblique radiographs, intraoral periapical radiographs, panoramic radiographs, cephalometric radiographs, optical photography, and new imaging technologies (24).

Age estimation divides into three phases:

1. Prenatal, neonatal and post-natal

According to radiography, the mineralization of deciduous incisors starts in the 16th week of intrauterine life. The tooth germs will appear on the radiograph as radiolucent areas before they start to mineralize; subsequent radiographs of the mandible will reveal the deciduous teeth in various stages of mineralization based on the fetus's prenatal age (23)(24).

2. Children and adolescents

The pacing of tooth development in the oral cavity and tooth calcification is used to approximate children's and adolescents' dental ages. Radiographic analysis of the developing dentition, particularly when no clinical evidence is available (2.5-6 years), as well as clinical tooth emergence at various points, will help in age determination. To assess the age of children and adolescents, the Schour and Masseler scheme (1941), Nolla's process (1960), and Moore's, Fanning, and Hunt method (1963) are all used(24,25).

3. Adults

Permanent dentition development is achieved clinically with the eruption of the third molar between the ages of 17 and 21, when radiographic age assessment becomes difficult. The most common methods used are developing the third molar and assessing the volume of teeth (25).

2.9 Need for Accurate Methods in Forensic Dentistry

The need for unique age assessment methods has never been more significant than in the last two decades because of two major reasons related to current socio-political development. The first reason is the rise the number of unidentified corpses and human remains; the second reason is increase in the number of cases concerning the age estimation of living persons that may not have accurate proof of their birth date. This progress has also shown the importance of aging of both human remains and living humans (26).

Willems et al. argued in 2001 that a significant point of dental age estimation is that the investigator should incorporate several different approaches available and perform repetitive measurements and calculations to improve reproducibility and reliability of the age estimation. (27).

Using multiple dental strategies or combination of dental and skeletal or other methods as required. Because age estimation technology is in its early stages, forensic dentists who practice age estimation must maintain an eye on scientific literature and stay updated on new developments and validate or refute current techniques(17).

2.10 Methods of Age Assessment According to Tooth Development

Estimates of dental age dependent on the last tooth erupt in the oral cavity. While it is the simplest, it is often the least accurate. Many factors that affect somatic, sexual, and skeletal growth have little effect on dental development's start, speed, or series. Many academics have recognized the importance of age prediction systems that are based on normal tooth development over time. In 1935, Schour and Hoffman discovered that under standard conditions, the dentition pattern acts as an accurate development index. The mode of dental growth was quickly adopted as a method of determining age(28,29).

In its development, each tooth follows the same pattern. This is the list that can be arbitrarily divided into stages. Any such stages, according to Demirjian, should: Describe the major developmental stages of the tooth,

- Be clearly defined (not just based on length increases), and
- Be objective enough to be reproducible (30).

The relative precision of the tooth production process is a major contributing factor in the common use of these growth-based age prediction systems. Many other methods of calculating biological age of children younger than 14 years are outperformed by the gradual apices formation of teeth (31).

2.10.1 Logan & Kronfeld

The study by Logan & Kronfeld in 1933 commenced in response to a practical problem. It had been noted that it was not uncommon for growth deformities and underdevelopment of the teeth and jaws to occur in the years following the surgical correction of congenital clefts of the maxilla and upper lip. The authors suggested a thorough understanding of the position, timing, and tooth development sequence was necessary if the Trans maxillary wires were to be surgically positioned without damage to unerupted teeth. Histological sectioning and radiographic examination is used to create a cross-sectional study of 0 to 6-month-olds. This age span was also extended to 2 years through the investigation, which is the window's endpoint for the surgical procedure of choice. Once the utility of this information to specialists and general dental practitioners alike was realized, the age range was then extended up to 15 years, which is the endpoint of developing the first seven permanent teeth. For their study, Logan and Kronfeld looked at 25 fresh postmortem specimens. However, 19 of them were under the age of two years old. After obtaining radiographs, serial histological sections were made. The writers published a detailed overview of the position and relative development of the human dentition. They saw no direct link between the degree of calcification and the infant's age, although they theorized that it was due to the children's chronic illnesses (32).

The observations of Logan & Kronfeld found that. The accuracy of the ages given for the various tooth development stages was up to ± 1.5 years with no sex differentiation. This study provided the day's dentists with the information required to judge the child's development level and measure it against expected norms (32).

2.10.2 Schour & Massler

In 1941, Schour and Massler published a significant paper on the evolution of the human dentition. The usage of a diagram showing the human dentitions development from birth to 35 years was notable in this study, and the graphic is still widely used today. The authors hoped to provide information on dentition development that would be "useful in normal dental work" for a general dentist. The distillation of this information into a pictorial or 'atlas type' chart provided the profession with a useful tool for determining an individual's age in everyday situations. By contrasting the radiographic image to a specific diagram, the child's average age is listed with the corresponding diagram (29). This chart is reproduced in **Figure (9, 10**).

Any of the advantages of using this system to measure an individual's age are as follows: It is non-destructive since it can be performed on radiographs of the jaws, it is straightforward and does not need advanced preparation to identify particular phases of growth, as many of the more recently developed systems do and it does not require the use of specialized equipment outside of a monitor, as many of the more recently developed systems do. One legitimate criticism of this method is that it is based on Logan and Kronfeld work and therefore suffers from the same sample size limitations, with one sample per age group up to 15 years. In the case of psychologically ill, institutionalized children, there was no difference between males and females. When assigning a different diagram to each year of growth, the mean age range can only be 6 months (32).

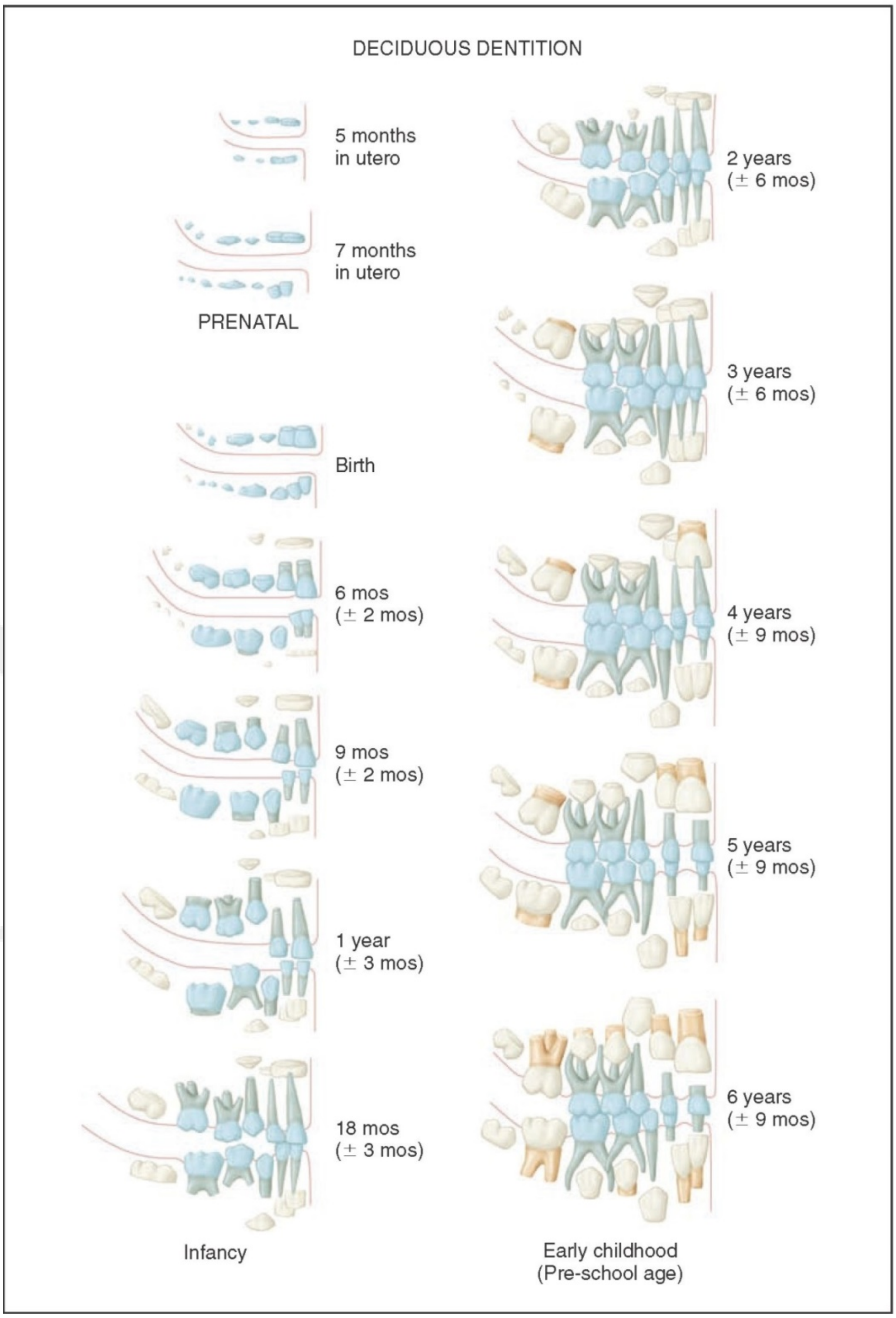


Figure 9. The sequence of formation of the human dentition (Schour and Massler)

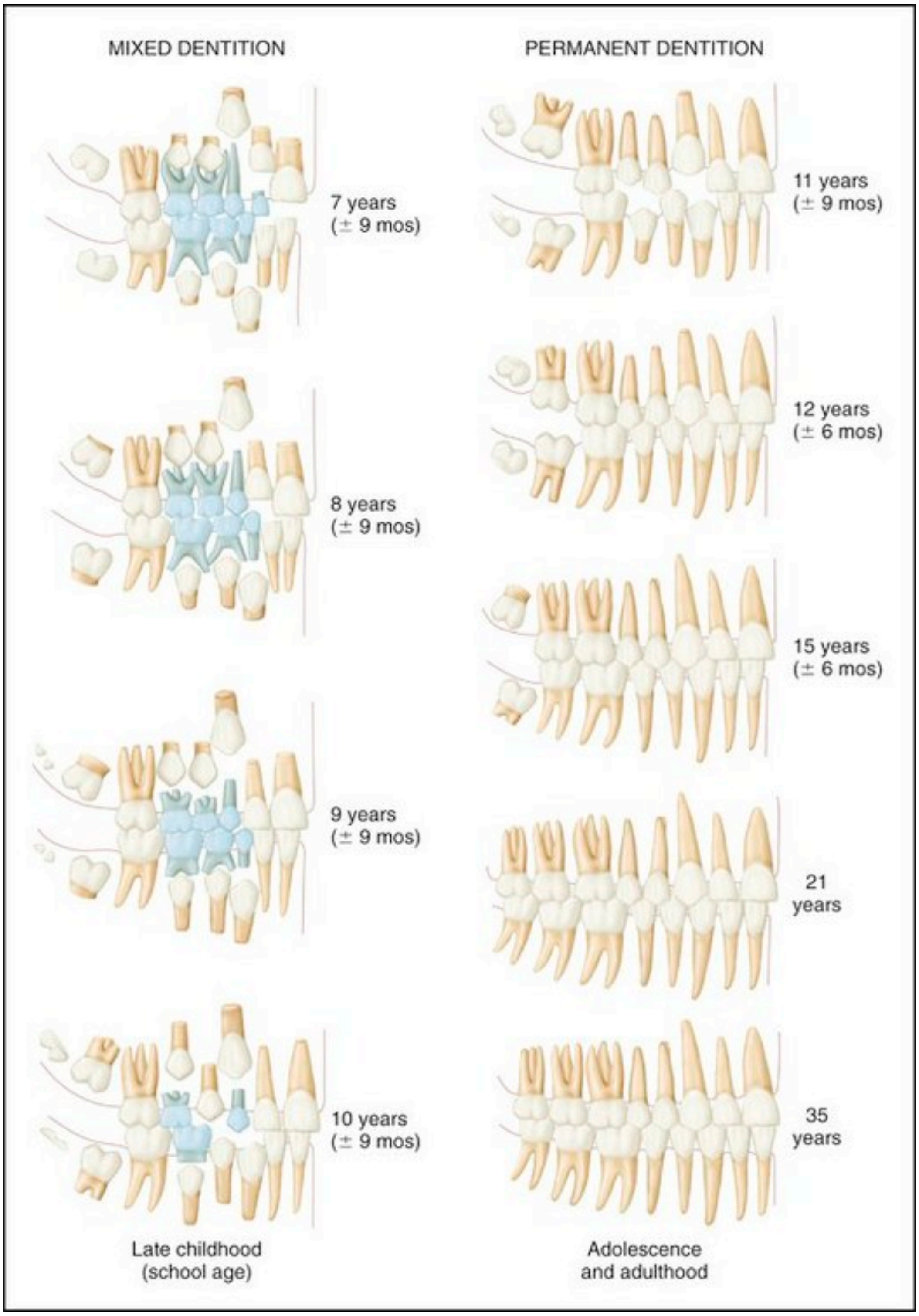


Figure 10. The sequence of formation of the human dentition (29)

2.10.3 Gleiser & Hunt

This study, undertaken in 1955, was a radiographic, longitudinal study that examined the development of the first permanent molar of 25 male and 25 female children. They divided the periods of development of this tooth into 16 stages. It is worth noting that the authors mention the use of 13 to 16 stages, depending upon which part of the article one refers to; they were; however, one of the first groups of researchers to divide the process of development of each tooth into many defined stages. Instead of estimating at what age a particular stage of development had commenced, the authors recorded every child's age in which a specific stage was observed. They then calculated the standard deviation of the age for each of the stages of tooth development. They noted a period of fast growth in the teeth' development during the 1/3 – 1/2 root length formations period. More importantly, they also noted an increasing sexual dimorphism in teeth development with increasing age but that the rate of growth was probably very similar (33). They said that in a study by Selmer-Olsen of 123 boys and 122 girls, the mean mesiodistal diameter of the girls teeth was 96% that of the boys teeth and that the mean root length of the girls teeth was 94% that of the boys teeth (34). Their study observed that teeth underwent a period of rapid growth during their development and that for girls, this period was 96% as long as that of the boys. They concluded that total incremental dental development rates are approximately the same for boys and girls. While the girls had a shorter period of rapid growth, they had a smaller unlimited size of the tooth to achieve, thereby completing the development in a shorter time frame. Gleiser and Hunt also concluded that emergence was not a good predictor of chronological age as the teeth' calcification (33).

This method's use is fast and simple because it relies on the analysis of just one tooth, but this is also its main disadvantage. If any growth abnormality has occurred with either (or both) of the mandibular first permanent molars, the system cannot be used accurately. Interestingly, the comparison between skeletal age, dental age, and chronological age from this study showed that where delays in skeletal maturity occurred, the effects were far less prolonged in the dental development of the same child (33,34).

2.10.4 Fanning

Fanning stated that chronological age could be misleading concerning dental maturity, in that they may not coincide if the child's growth is advanced or retarded for their age. Fanning undertook this qualitative study to provide norms for attaining specific stages of dental development and root resorption. It was the intention that these norms, including percentile bands, be used in conjunction with the known chronological age in clinical diagnosis and treatment planning by dentists and orthodontists. The study was planned to be long-term, with lateral skull radiographs taken and studied every three months during the first year of life, and every six months until the boy was eleven and a half years of age. The periapical radiographs of the upper and lower incisors were taken every six months from the ages of 4 to 11.5 years to provide functional photos of the anterior teeth. The subjects studied consisted of 48 males and 51 females. Fanning designated several development stages for each tooth based upon the fifteen stages described by Gleiser and Hunt. Fanning described up to twenty stages depending on tooth type: the development of the permanent incisors was covered in twelve stages; the permanent molars required all twenty to be used, while the deciduous teeth development was described by only seven stages (35).

Fanning derived the mean age for her sample at which each tooth reached each stage of development. This study was one of the first to study the pattern, timing, and dental development rate of a large sample. Consequently, the tables derived have been used to assessd the chronological age for the stage of dental maturity described even though this was not the author's original intention. This study proved useful for this purpose because it relies on development times and not emergence times. However, this study is limited in its application. It only spans the ages 0 to 11.5 years, an error of up to 3 years is possible, and there is no way to consolidate the results for each tooth to provide an overall assessment of chronological age.

Further, the allocation of one of up to twenty stages is very time consuming and is often difficult to apply consistently. Again it is important to note that the author did not intend that the results be used to estimate chronological age. Instead, she sought to aid in treatment planning and diagnosis (35).

2.10.5 Nolla

Nolla felt that it is essential that the dentist understands dentition development and undertook this study to provide information to help the dentist assess young patients' dental development. To do this, the author set out to create norms that displayed the average tooth growth for males and females at various ages, as well as tables that could be used to calculate chronological age based on visible dental production. Examining a collection of annual serial radiographs of 25 female and 25 male babies, totaling 1746 radiographs for the female sample and 1656 radiographs for the male sample, was one part of the procedure. According to Nolla, every tooth goes through one of the ten stages of dental growth. These are depicted in **Figure (11).**

Each point was also given a numerical ranking. After that, the permanent maxillary and mandibular teeth were inspected. To build a "sum of levels" rating, the scores were applied together. To define standards for the maturation of each permanent tooth, specific tooth scores were used.

On the other hand, the summed scores were used to define norms for the scored degree of dental growth at each age. A dentist could use a radiograph to determine a child's tooth growth periods, convert the stages to appropriate grades, and use the total of the scores to calculate the individual's age using the Nolla conversion tables. The same formula may be used to measure specific tooth ratings(36).

This method's advantages are that ten graphically described stages can be visually matched to a radiograph's developing teeth' appearance. As a consequence, no other specialized equipment is needed except x-ray machines, and the method is simple to use. These few advantages are unfortunately outweighed by the disadvantages, which include; the requirement for absolute and estimated measurements of the root formation - to measure '1/3 root formed' you need to evaluate how long the fully formed root will be; the racial mixture of the sample on which the study is based was not reported, and as such limits, its applicability; and finally, because of the format of 'expected norms' no prediction error values can be obtained for any estimates made.

A recent study by Bolzano's et al. proved quite successful despite these shortcoming(37). Using the Nolla standards, but with only three teeth, the researchers reported prediction errors of only ±1.3 to 1.4 years in cases aged under ten years. The error increased to just ±2 years at the 95% confidence interval (36,37).

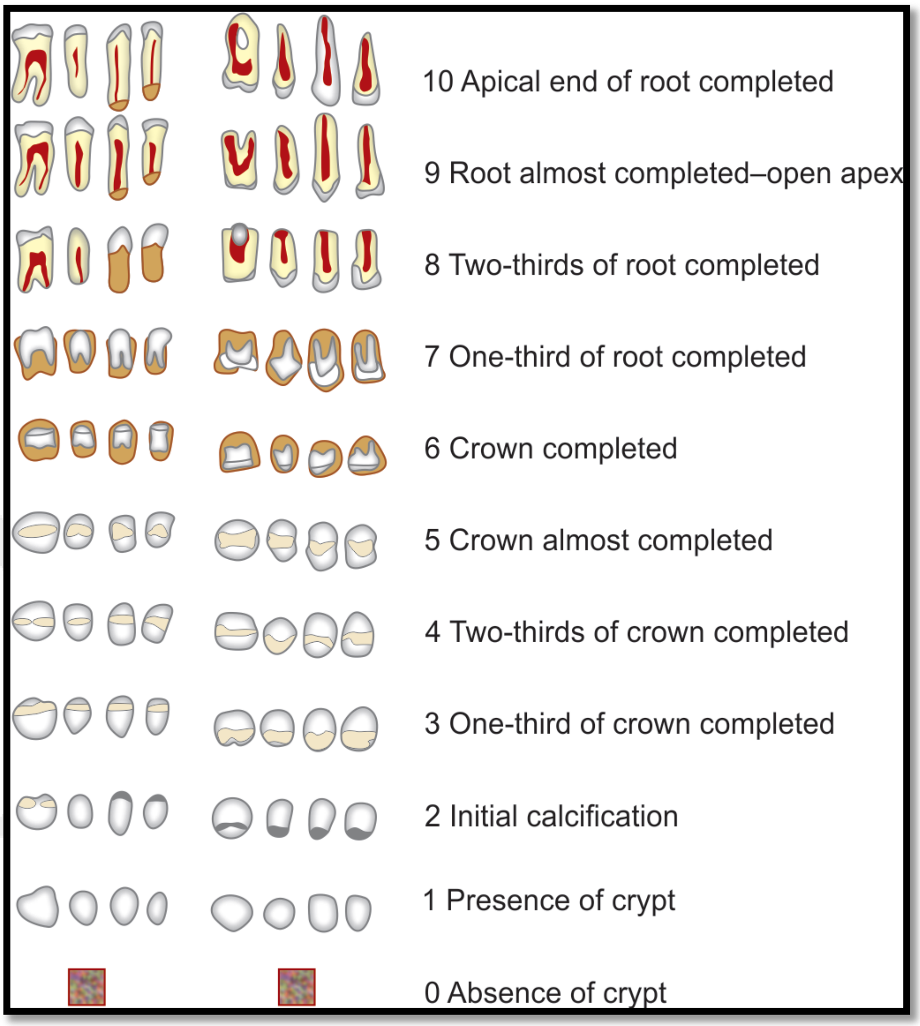


Figure 11. Diagram of tooth maturation showing the progression from the initial appearance of crypt through the last stage of apical root closure for the developing tooth (36)

2.10.6 Moorrees, Fanning & Hunt

In this study, the authors noted the usefulness of using dental maturity to estimate skeletal remains' age. Similar in design and building on Fanning's work, this longitudinal study sought to expand the age range covered up to 17-18 years and simplify the rating system by only using fourteen stages. Again, the aim was to create growth norms for each of the eight mandibular and maxillary incisor teeth at each of the 14 developmental stages. A separate analysis of 136 males and 110 females followed the development of the dentition to the final stages at about 18 years, with 48 and 51 females included for the age group up to about ten years. The authors graphed the results, which included two standard deviation age limits, and measured the mean age of attainment for each tooth level (20).

The advantages of using this system over earlier systems appear that the smaller number of stages and reported high intra-observer reliability make for a more consistent and easily applied rating system. Other researchers have used this method with exceptionally accurate results, predicting ages within ± 0.2 years (38). In this study by Moorrees Fanning and Hunt, the quoted intra-observer agreement figure of 75% for incisors and 90% for posteriors did not account for chance expected concurrence. As a consequence, there would be less intra-observer agreement. The system can be extended to the fullest range of conditions possible, from birth to adulthood, so the authors provided requirements for both deciduous and permanent dentitions (39).

One of the main disadvantages of using this technique relies on absolute measurements, such as root 1/4, 1/2, or 3/4 formed. To measure this accurately, one needs to know the final length of the particular root in question. Another disadvantage of using this system is, as the authors pointed out, that because of the problem of the applicability of these results to a given population and the variation between the maturity of each tooth as compared to the norms, it may not be possible to estimate a specific dental age (38,39).

2.10.7 Liliequist & Lundberg

The authors sought to determine whether or not the combination of methods of determining skeletal and dental maturity would give a more accurate estimate of chronological age than each method taken alone. The investigation focused on two main parts. Firstly, assessing the reliability of The Schmid & Moll method of estimating age from analysis of the developing wrist bones. Secondly, the authors sought to develop a means of evaluating the dental age with an associated numerical index that could be statistically processed. In this way, the authors could measure a continuum of development instead of the specific age stages depicted in the reference images. These two methods were then combined and simplified, and the correlation between the two methods was assessed. The sample consisted of 148 females and 139 males taken from a group of Swedish school children. For the development of the dental-based system, both intra-oral and extra-oral radiographs were taken of each child. The tooth development was divided into eight stages, each stage being allocated a numerical score between 0 and 6. Each of the maxillary and all mandibular teeth (except third molars) was assessed from the radiographs and assigned a score based on each tooth's development stage. These scores were totaled to give a maturity score. The mean value and standard deviation of each tooth's scores at each one-year age bracket were computed, as was the mean value and standard deviation for the summed maturity scores (40).

The advantages of this system are that: it recognizes that male and female dental development rates differ significantly, especially in the 8-12.5 year range – this allows for more accurate estimates of dental maturity; numerical values are given to the stages of development allowing for statistical analysis and easy comparison between groups; and importantly, the stages require relative measurements such as 'root longer/shorter than the crown.' These authors were one of the first groups to take this step. Many others were to follow. As such, the correlation between observers was high (0.92-0.99), which indicates a system that is 'well adapted for reported comparative investigations by different observers' (41).

The authors found a strong correlation between left and right maxillary tooth development (r=0.99) and also between maxillary and mandibular tooth development (r=0.99) when maturity scores were summed. The authors concluded that an adequate analysis could therefore be carried out on just one quadrant. The use of this system to estimate age has two disadvantages. Firstly, this was not the authors' intent. Secondly, there is no differentiation between males and females, despite the well-published sexual dimorphism that exists. The latter point may be a significant error source in applying this method (40,41).

2.10.8 Mörnstad, Staaf & Welander

The authors of this study sought to prepare a system of age assessment according to the degree of teeth development while minimizing the methodological variation inherent in so many other methods based on the subjective assessment of stages. To achieve this goal, they tested the degree to which metric measurements of teeth' radiographic images correlated with real age. Finding a significant correlation, the authors then developed a regression model to predict age from a given tooth measurement set. The study involved examining OPG radiographs of 270 male and 271 female children aged between 6 and 14. Each OPG was mounted on a digitizing tablet and direct measurements taken under a crosshairs cursor. The measures taken are detailed below in **Figure (12).** This system's advantages are that the measurements taken are absolute and objective; there is no room for subjective interpretation in systems that require classification into a predefined category or stage. The disadvantage of using this system is, like all previously reviewed systems, the lack of accuracy in the estimate of proper age, especially in those specific groups whose predictive models had a low coefficient of determination values. Finally, direct measurements mean that little or no training is required for a clinician to take the necessary measures accurately. Although not reported on, it is assumed that this last point would lead to a very high level of inter- and intra-examiner agreement (42).

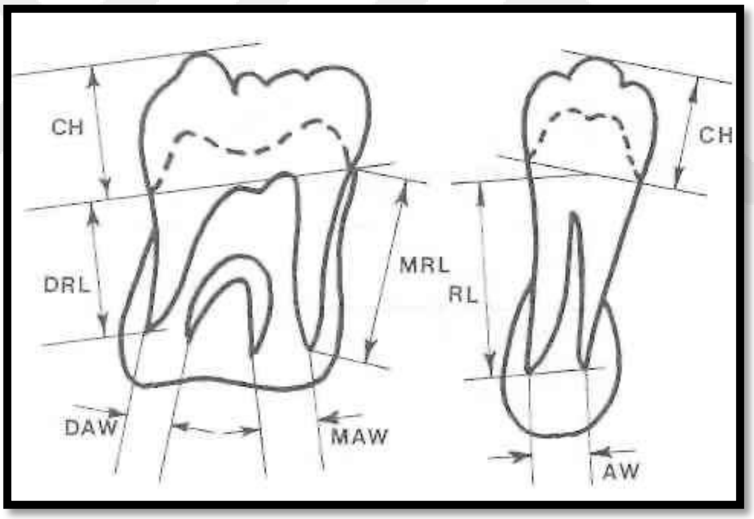


Figure 12. Distances are calculated for the landmarks. CH, Crown Height. DRL, Distal Root Length. MRL, Mesial Root Length. RL, Root Length for teeth with one root. DAW, Distal Apex Width. MAW, Mesial Apex Width. AW, Apex Width of for teeth with one root (42)

2.10.9 Demirjian, Goldstein & Tanner

After a systematic review of the literature, Demirjian, Goldstein, and Tanner concluded that tooth growth was a better indicator of dental age than tooth emergence. They needed to devise a method for calculating dental maturity based on a numerical value derived from the developmental stages depicted in each tooth. The authors intended to create centile charts that would convert the derived numerical 'maturity score' to the dental age. In clinical and forensic settings, this measurement may be used to assess dental maturity and calculate chronological age (43). The authors modified the defined system of stages previously published by Moorrees, Fanning, and Hunt. They simplified this system by defining only eight stages of development.

Further, the assessment of these stages relied on relative, not absolute measurements. The author represent of these stages were modified in a later study by Demirjian to clarify each stage's defining features (13). These stages and the updated descriptions are detailed in **Figure (13)**.

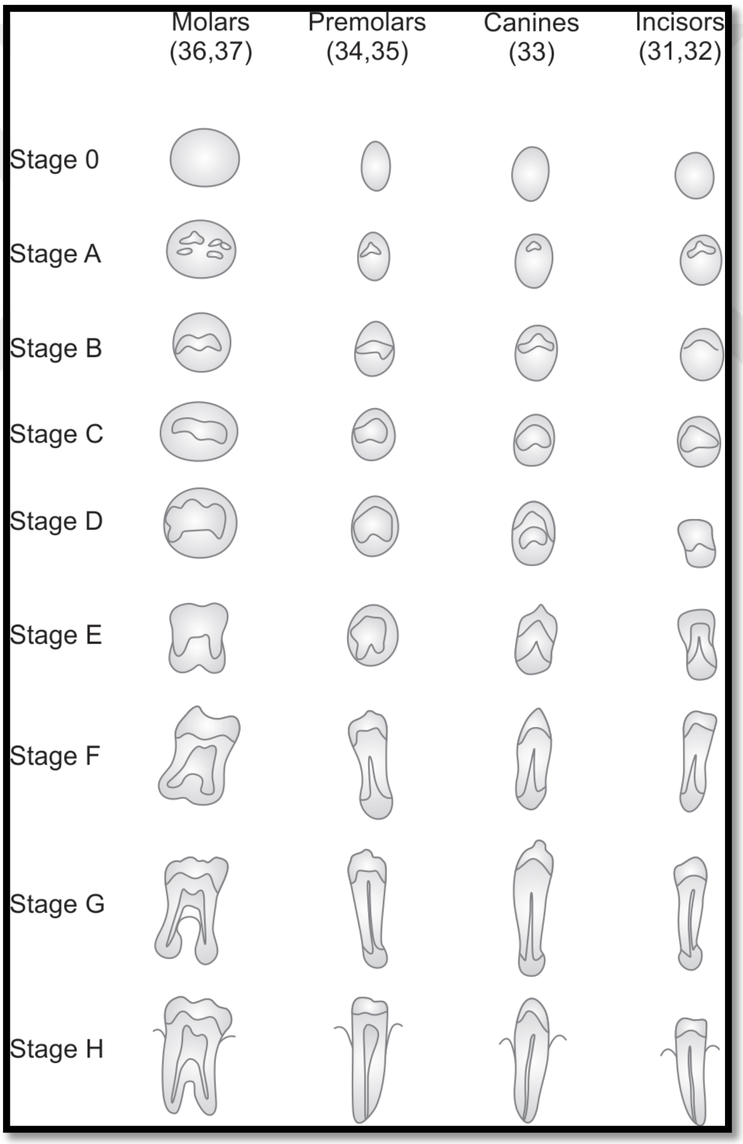


Figure 13. Stages of tooth growth as determined by the Demirjian system (1)

2.10.9.1 Dental Formation Stages

Stage (A): An inverted cone or cones may be seen in both uni-radicular and multi-radicular teeth at the crypt's superior stage, indicating the start of calcification. These calcified points haven't yet fused.

Stage (B): The calcified points fuse to form cusps (one or more), which fuse to form a normal-looking occlusal surface.

Stage (C):

a) Enamel production is finished at the occlusal area. Its development and convergence into the cervical area can be seen.

b) The beginnings of a dentinal deposit are visible.

c) The out features of the pulp chamber at the occlusal border has a curved shape.

Stage (D):

a) The formation of crown is finished under the cementoenamel junction.

b) The superior line of the pulp chamber in uni-radicular teeth has a distinct curved appearance. If the pulp horns are projecting, an umbrella-like outline is formed. In molars, the pulp chamber is trapezoidal in form.

c) Starting of root formation is visible in the form of a spicule.

Stage (E):

Uni-radicular teeth:

a) The pulp chamber walls now shape straight lines, which are interrupted by the inclusion of a greater pulp horn than in the previous stage.

b) The root length is less than the height of the crown. It does, however, exceed at least 1/3 of 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.

Stage (F):

Molars:

a) The calcified area of the bifurcation has progressed from its semi-lunar level, giving the roots a more definite and distinct outline with funnel-shaped endings.

b) The length of the roots is equal to or greater than the height of the crown.

Stage (G):

The root canal walls have now been parallel, and the apical end of the canal is only partly open (Distal root on molars).

Stage (H):

a) The root canal's apical end is fully sealed (Distal root on molars.

b) The periodontal membrane is the same diameter all the way across the root and apex (13,43).

In assigning ratings to the teeth as observed in the OPGs, Demirjian provided a set of rules as further guidance. These guidelines are:

1. The permanent mandibular teeth are arranged second molar, first molar, second bicuspid, canine, lateral incisor, and central incisor in this order.

2. All teeth are graded on a scale of A to H. The rating is calculated by comparing the tooth to the diagrams and x-ray images by carefully following the written instructions for each point. The diagrams can only be used as a starting point for more research, not as the sole source of data. There are one, two, or three written parameters for each point, labeled a), b), and c). If only one criterion is specified, it must be met for the stage to be considered complete; if two criterions are given, the first one must be met for the stage to be considered complete; and if three criterion are given, the first two must be met for the stage to be considered completed.

3. There should be no full samples obtained. A pair of dividers is all that is needed to compare the relative lengths (crown/root). The levels of apex closure may be determined

without the need of a magnifying glass. Without the use of a magnifying glass, the scores may be completed (43).

Demirjian's study involved 1446 men and 1482 women with French-Canadian descent, ranging in age from 2 to 20. Figure took OPGs in each case, and the teeth 37 to 31 inclusive were graded from A to H based on their developmental stage (with 0 indicating no calcification) by **Figure (13).**

The population was divided into males and females due to the well-known prevalence of sexual dimorphism in dental development. The authors choose the right mandibular teeth to study for a variety of reasons. For practical reasons, the mandibular teeth were preferred over the maxillary teeth: the maxilla's bony structures often obstruct radiographic views of the permanent teeth, particularly within the first six years of life. Many of the reports reviewed above have focused their research on the mandibular teeth for the same purpose (20,36,41). In comparison, the mandible teeth are clearly visible in an OPG, with the possible exception of older type OPGs in which the cervical spine is superimposed over the mandibular anterior teeth. Many experiments have shown a close connection between the developmental phases of the teeth on the left and right sides of the maxilla, when it comes to the decision to only use teeth on one side of the mandible (44–47).

The assigned ratings (0-H) were assessed and used to schedule the study' next phase. It was a new twist on the system, focusing on Tanner, Whitehouse, and Healy's employment. He invented a system for calculating age based on skeletal maturity, in which each bone was given a numerical rating that was weighted (48).

According to Demirjian, this method's modification is used to generate 'self-weighted' numerical values for each tooth stage. Male and female characters are distinguished by the writers. In a subsequent article, Demirjian revisited and updated these figures (13).

Table 2. Demirjian Scores for Dental Stages (Males)

Tooth	Stages								
	0	A	B	C	D	E	F	G	H
M2		2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M1				0.0	8.0	9.6	12.3	17.0	19.3
PM2		1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM1				3.4	7.0	11.0	12.3	12.7	13.5
C					3.5	7.9	10.0	11.0	11.9
I2					3.2	5.2	7.8	11.7	13.7
I1						1.9	4.1	8.2	11.8

For each case tested, Demirjian used the Tables to convert the attributed stage for each tooth to a self-weighted numerical score **Tables (2, 3)**. For example, if a male's tooth 37 was found to be in stage A, a score of 1.7 would be assigned; additionally, if a female's tooth 37 was found to be in stage A, a score of 1.8 would be assigned. This conversion produces a sequence of tooth points for each example, the number of which generates a summative 'Maturity Value' for that situation. Centile charts for both males and females were created using the tables in Appendix 1, allowing for the conversion of this total maturity score to dental age.

Table 3. Demirjian Scores for Dental Stages (Females)

Tooth	Stages								
	0	A	B	C	D	E	F	G	H
M2		2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M1					4.5	6.2	9.0	14.0	16.2
PM2		1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C					3.8	7.3	10.3	11.6	12.4
I2					3.2	5,6	8.0	12.2	14.2
I1						2.4	5.1	9.3	12.9

2.10.10 Willems method

In terms of methodology, Willems' method is similar to Demirjian's. Developmental tooth stages according to Demirjian's technique for equivalent age ratings expressed clearly in years for each of the seven left mandibular teeth for boys and girls using Willems sex-specific charts **Figure (14)**. All scores were added up using Willems' compare tables to offer dental age in years (22).

TABLE 1—*Developmental tooth stages according to Demirjian's technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in boys.*

Tooth	A	B	C	D	E	F	G	H
Central incisor	. . .	. . .	1.68	1.49	1.5	1.86	2.07	2.19
Lateral incisor	. . .	. . .	0.55	0.63	0.74	1.08	1.32	1.64
Canine	. . .	. . .	. . .	0.04	0.31	0.47	1.09	1.9
First bicuspid	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.4	1.15
First molar	. . .	. . .	. . .	0.69	1.14	1.6	1.95	2.15
Second molar	0.18	0.48	0.71	0.8	1.31	2	2.48	4.17

TABLE 2—*Developmental tooth stages according to Demirjian's technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in girls.*

Tooth	A	B	C	D	E	F	G	H
Central incisor	. . .	. . .	1.83	2.19	2.34	2.82	3.19	3.14
Lateral incisor	. . .	. . .	. . .	0.29	0.32	0.49	0.79	0.7
Canine	. . .	. . .	0.6	0.54	0.62	1.08	1.72	2
First bicuspid	−0.95	−0.15	0.16	0.41	0.6	1.27	1.58	2.19
Second bicuspid	−0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
First molar	. . .	. . .	. . .	0.62	0.9	1.56	1.82	2.21
Second molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

Figure 14. According to the Demirjian technique, developmental tooth stages with corresponding age scores expressed directly in years for each of the seven left mandibular teeth

2.10.11 Cameriere's method

Demirjian et al. first used a method for dental age estimation in 1973. They used eight different radiographic stages of the tooth crown and the root development (13). Willems et al. tested the Demirjian's method in 2001, and came up with a new ranking formula that became Demirjian's best adaptation (22). In 2006, Cameriere et al. proposed a procedure for estimating chronological age of children dependent on the relationship between age and the measurement of permanent teeth open root apices. The panoramic radiograph is processed using computer-aided drafting tools to calculate the ratio of the distance between the inner surfaces of the root apices and the length of the tooth to prevent the impact of differences in magnification within the radiographs. **Figure (15, 16).** AE (Age Estimation) is calculated using the proportion of the seven permanent left mandibular teeth (14).

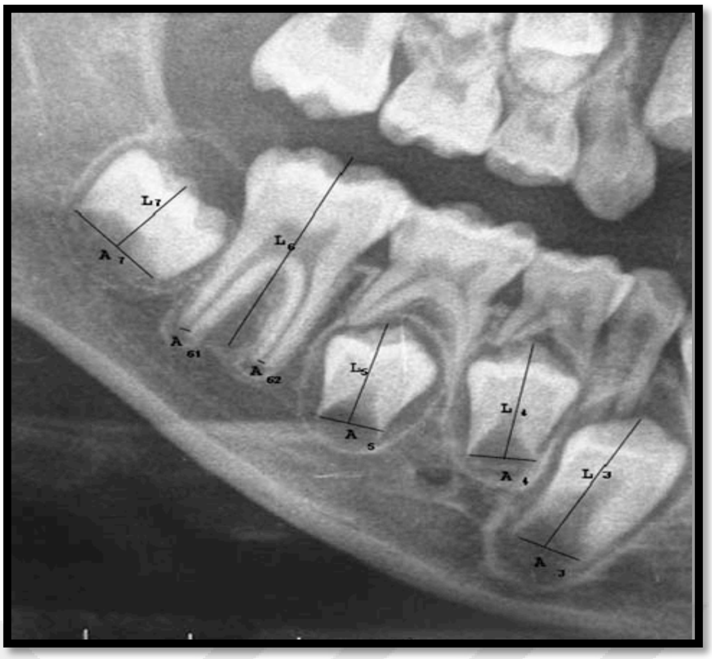


Figure 15. A tooth measuring example. The gap between the inner sides of the open apex is Ai, i=1,...,5 (teeth with one root); the number of the lengths between the inner sides of the two open apices is Ai, i=6, 7 (teeth with two roots); and the length of the seven teeth is Li, i=1,..7. (14)

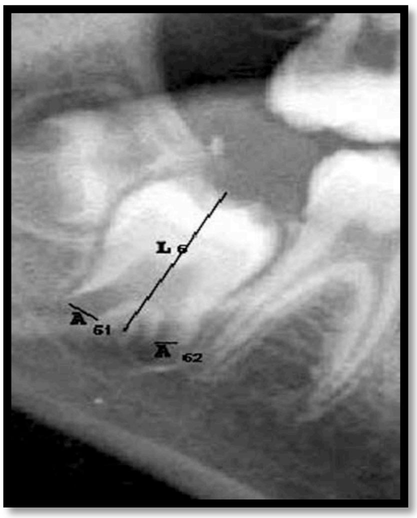


Figure 16. An example of a measurement of a tooth with two roots. A6 is the sum of the distances (A6 =A61 + A62) between the two open apices' inner sides, and L6 is the length of the second molar (14)

2.11 Tooth Development

The age of death can be calculated using a combination of methods dependent on dental results. For teens and young adults, dental age determination based on tooth development is now the most accurate age estimation method. The chronology of tooth formation, as well as the factors that affect the rate of development, will be investigated. The various age estimation methods that involve some kind of tooth growth assessment would be studied. In and by itself, dental development is a wide term. According to Capparelli, data on 'dental development' could have been dependent on one or more of the following areas:

- Histological premineralization sequences,
- Histological mineralization sequences,
- Incremental patterns of enamel and dentine formation,
- Emergence of teeth into the oral cavity and
- Gross mineralization sequences observed by either radiographic means or by direct observation of dissected developing teeth in situ or individually (49).

2.11.1 Chronology of Tooth Development

Prior to Logan and Kronfeld's landmark work in 1933, it was generally thought that all permanent teeth began calcification at the same period (32). Legros and Magitot's tables from 1893 were used to make this assumption (quoted in Logan and Kronfeld, 1933). In fact, several other studies at the time recorded the start of calcification of the teeth incorrectly as well. Depending on the teeth in question, dentition forming occurs at various stages during a child's growth. Because of the inherent biological variability of people, there is certain variation in the precise time, which is why ranges are used instead of distinct timings. Based on Fanning's earlier studies, Moorrees, Fanning, and Hunt published guidelines for the chronology of the growth of the deciduous and permanent dentition (20,50,51).

2.11.2 Variation in the Rate and Timing of Dental Development

Though small variations do exist, the above-mentioned tooth development pattern is reasonably consistent for all populations. The onset of tooth development and the rate, at which it progresses, on the other hand, varies considerably between people. Variations in age, sex, race, even population substructure have the most profound effect on the dental development of all the potential influences. Many non-genetic or environmental factors may result in minor yet sometimes significant alterations in dental development's timing and rate (20,50,51). Pelsmaekers et al. found that the non-genetic 'specific environmental factors' contributed less than 10% to dental maturation (47). Merwin and Harris showed that the genetic factors were responsible for about 84% of dental development (52).

3 MATERIALS AND METHODS

3.1 Materials

3.1.1 Selection of Sample

In this retrospective cross-sectional systematic study, convenience sampling was used. The panoramic radiographs (ortopantographs) (OPTGs) of 300 Turkish children were selected from those who referred to Yeditepe University, Faculty of Dentistry, Pediatric Dentistry Clinics whose ages were between 7.0 and 14.9 years. The panoramic radiographs of 300 Libyan children were selected from the patient records who referred to the Pedodontic clinic at Al Hussein dental clinic in Tripoli, Libya whose ages were between 7.0 and 14.9 years.

3.1.2 Selection criteria

The sample was derived from the archive-files of the Pediatric Dentistry Clinics at Yeditepe University, Faculty of Dentistry, for Turkish children. In contrast, the Libyan children's sample was derived from the Pedodontic clinic's archive-files at Al Hussein dental clinic Tripoli, Libya. Six hundred cases whose age were between 7 and 14 years randomly selected in total, whereas half of them were from Turkey and the other half were from Libya. Panoramic radiographs of these patients aged were included in this study and the groups were formed by consequent ages as 7-8 years, 8-9 years, and so on.

One investigator (M.A.) performed the full evaluation of all radiographs after an initial training period. All the mandibular teeth (except the third molars) were determined according to the system of Demirjian et al. Willems method and Cameriere's method. The subjects were all recorded with their surnames. As each case's racial background was not mentioned in the archive files, the patients' surnames were the only aid for detecting the patients' origin.

The files on the selected cases were obtained, and an OPTG, if present, was temporarily removed from the file for analysis. Following the acquisition of the available records, a number were excluded. The reasons for these exclusions were divided into three main areas, technical, patient factors, and incomplete information. The technical reasons for exclusion were based on the quality of the OPTG films and included:

- Image distortion due to either patient movement during exposure or malposition of the patient for exposure
- Incomplete image formation due to incorrect exposure techniques excluded.
- There is a loss of picture clarification due to under- or over-exposure, or under- or over-development of the film.

Cases excluded from this study if the patients had any:

- The possibility of significant tooth loss due to sickness or injury has been ruled out.
- A history of chronic illness, depression, or disease has been found to have a significant effect on dental growth.
- Medical background has been found to have a significant effect on dental growth.

3.2 Methods

3.2.1 Data Collection

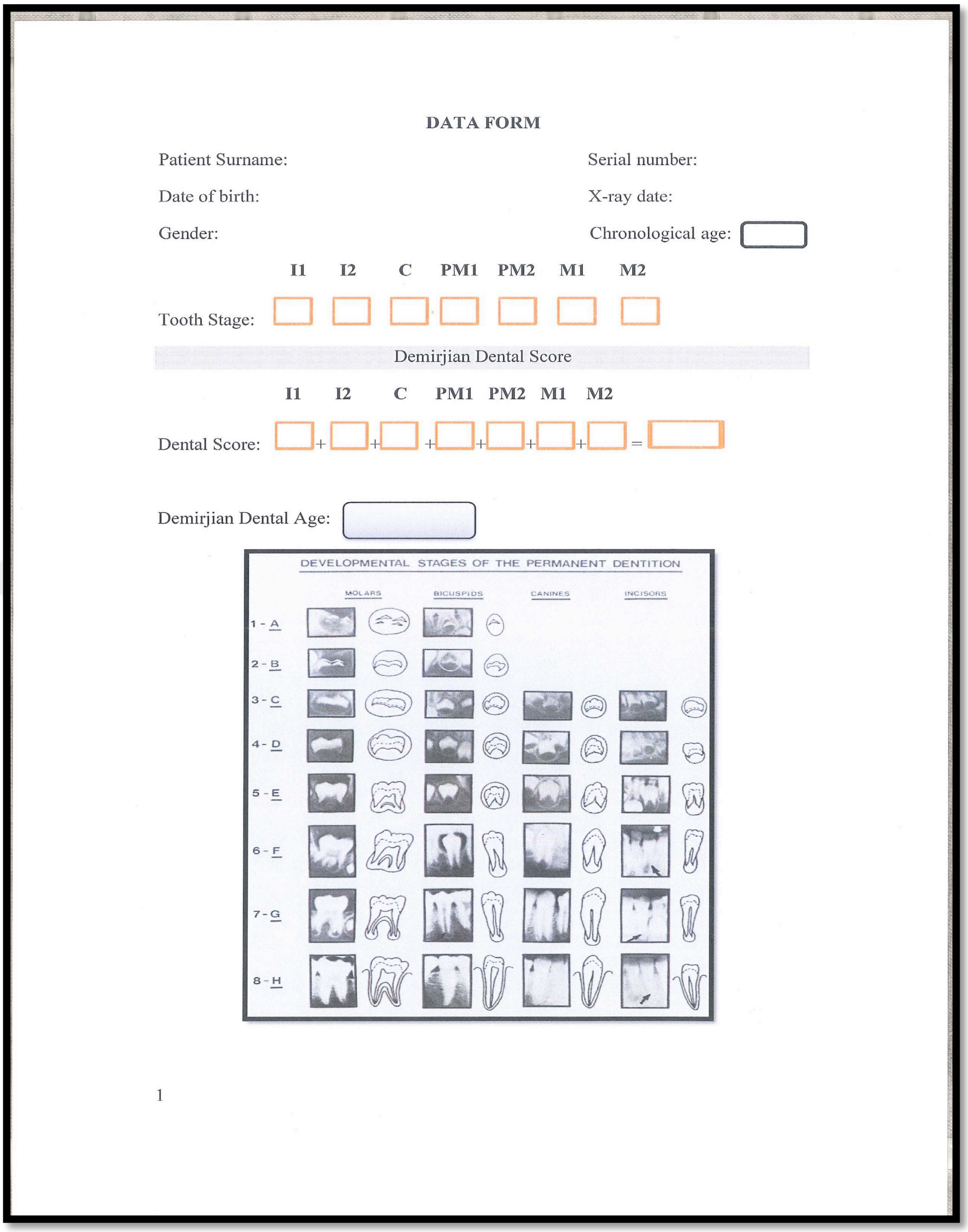
To collect the information, a special Data Sheet was designed for this study **Figure (17).**

Table 4. Distribution of the study sample (Turkish children) by gender and age.

Age Range	Total
7– 8	**22**
8 – 9	**63**
9 – 10	**58**
10 – 11	**56**
11– 12	**44**
12– 13	**49**
13– 14	**8**
14 – 15	**0**

Table 5. Distribution of the study sample (Libyan children) by gender and age

Age Range	Total
7– 8	52
8 – 9	49
9 – 10	47
10 – 11	39
11– 12	35
12– 13	27
13– 14	12
14 – 15	11



DATA FORM

Patient Surname: Serial number:

Date of birth: X-ray date:

Gender: Chronological age:

	I1	I2	C	PM1	PM2	M1	M2
Tooth Stage:							

Demirjian Dental Score

	I1	I2	C	PM1	PM2	M1	M2	
Dental Score:	+	+	+	+	+	+	=	

Demirjian Dental Age:

DEVELOPMENTAL STAGES OF THE PERMANENT DENTITION

MOLARS BICUSPIDS CANINES INCISORS

1 - A

2 - B

3 - C

4 - D

5 - E

6 - F

7 - G

8 - H

1

Figure 17. Special Data Sheet was designed for this study

3.2.2 Assessment of Attained Stages of Development

Each OPG was taken and placed on a radiograph viewing box and was then correctly oriented. In the third quadrant, the mandibular left side was the focus of the analysis. Each tooth in the 3rd quadrant was examined in turn and compared to the development stages described by Demirjian, Willems method, and Cameriere's method. For guidance, these stages are described both in written and pictorial form and detailed in the previous chapter. The alpha-numeric rating was assigned to that tooth and recorded in the appropriate box on the datasheet before the stage that best reflected the tooth's developmental stage was identified. For teeth 31 through 37, the process was repeated.

On the datasheet for that specific OPG, the assigned scores for each of the seven teeth were listed, along with the unique id for each case, their sex, date of birth, and date of OPG exposure. Figure 1 depicts the OPG and how the data for this study are collected **Figure (18).**

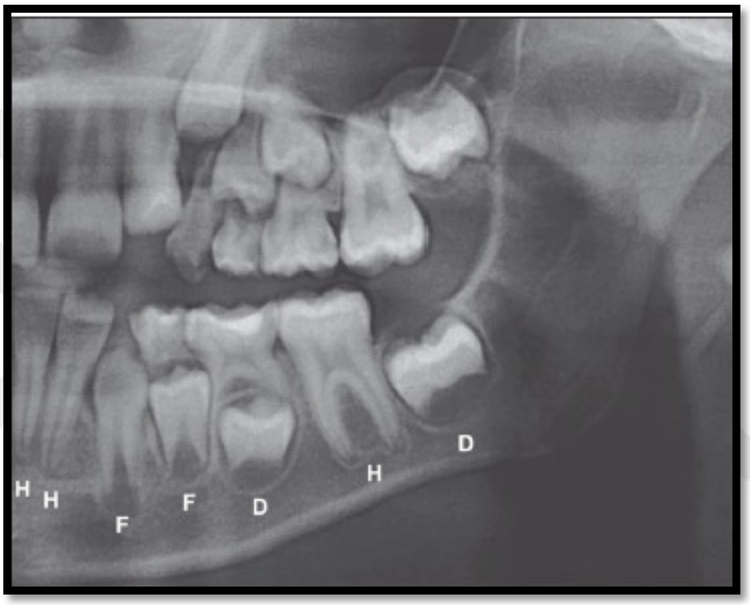
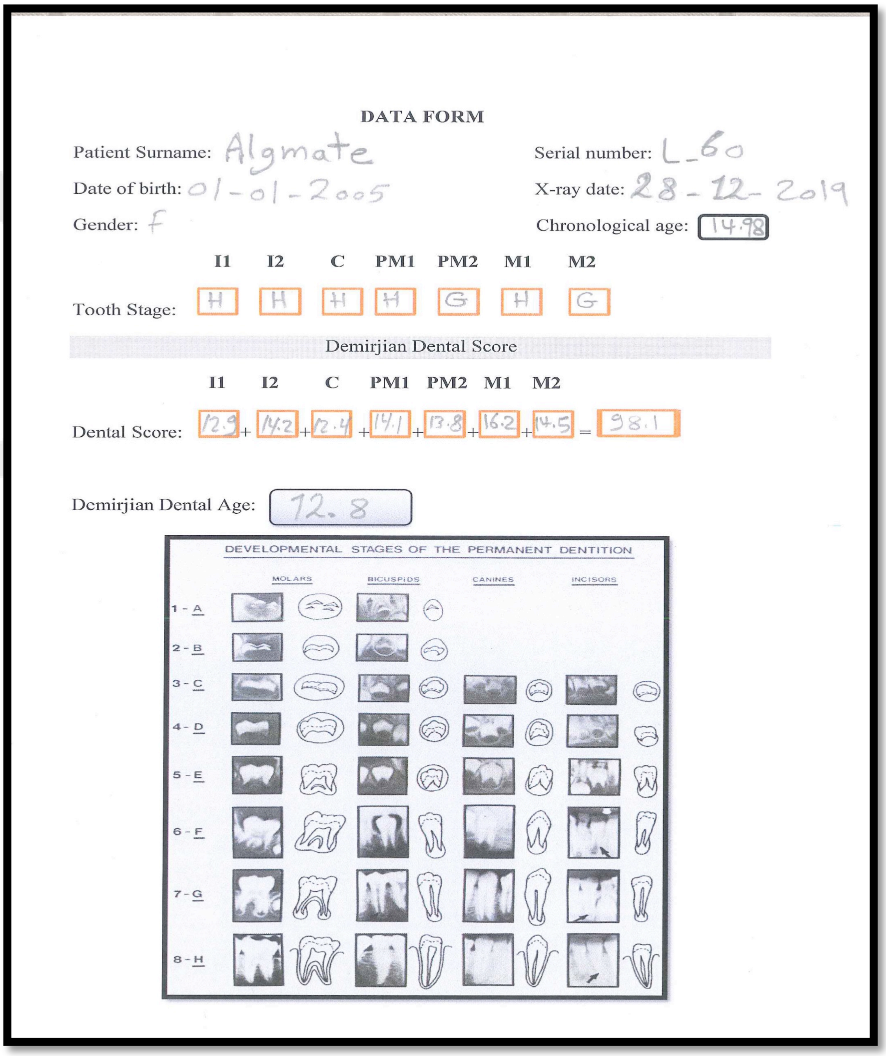


Figure 18. An example of OPG showing how the data was collected in this study

3.2.3 Conversion of Assessed Stages of Development to Dental Score (DS)

3.2.3.1 Conversion of Assessed Stages of Development to Demirjian Maturity Score (DS)

The numeric phases 0 to H are converted to a numerical score for each tooth in each case during the research (referred to as self-weighted scores). Demirjian's sex-specific tables, which are detailed in Tables, were used to do this, **Tables (1, 2).** The individual self-weighted scores for a given case were then totaled to present a Dental Score (DS). See **Figure (19)** showing an example of **(DM)** Data Sheet of a patient (13)(43).



DATA FORM

Patient Surname: Algmate Serial number: L_60

Date of birth: 01-01-2005 X-ray date: 28-12-2019

Gender: F Chronological age: 14.98

	I1	I2	C	PM1	PM2	M1	M2
Tooth Stage:	H	H	H	H	G	H	G

Demirjian Dental Score

	I1	I2	C	PM1	PM2	M1	M2	
Dental Score:	12.9 +	14.2 +	12.4 +	14.1 +	13.8 +	16.2 +	14.5 =	98.1

Demirjian Dental Age: 12.8

Figure 19. Showing an example of **(DM)** Data Sheet of a patient

3.2.3.2 Conversion of Assessed Stages of Development to Willems Maturity Score (DS)

Willems G. uses the Demirjian tooth mineralization stages to adjust scores. These scores were then converted into years using the Willems sex-specific tables **(14),** and the total number of years gave the dental age (22)**.**

3.2.3.3 Conversion of Assessed Stages of Development to Cameriere's Maturity Score (DS)

On the left hand, seven permanent mandibular teeth were valued. The number of teeth with completely developed roots and closed apical ends of roots (N0) was counted. Teeth with insufficient root development and therefore open apices were also considered. For teeth with one base, the distance (Ai, i=1,...,5) between the open apex's inner sides was determined **Figure (15)**. For teeth with two roots (Ai, i=6, 7), indicates the total of the lengths between the inner sides of the two exposed apices. **Figure (16)**. To account for possible differences in magnification and angulation inside x-rays, we standardized the measurements by dividing by the tooth length (Li, i=1,..7) (14).

In a dark space, the panoramic radiographs were examined on a widescreen monitor that was shot in TIFF format (Tagged Image File Format). Both measurements were taken by the same researcher using **Image J tools** at a magnification of 150 times.

3.2.4 Calculation of the Dental Age (DA) of Turkish and Libyan children

3.2.4.1 Calculation of the Dental Age (DA) by Demirjian method (DM)

The total maturity score (Dental Score DS) conversion to dental age according to Conversion tables– Demirjian Maturity Score to Dental age see **Tables in Appendix (2, 3)** Also see **Figure (19)** showing an example of **(DM)** Data Sheet of a patient.

3.2.4.2 Calculation of the Dental Age (DA) Willems method (WM)

3.2.4.3 Willems G. uses the Demirjian tooth mineralization stages to adjust scores. These scores were then converted into years by using the Willems sex-specific tables **Figure (14),** and the total number of years gave the dental age see **Figure (20)** showing an example of **(WM)** Datasheet of a patient.

Willems Dental Score

	I1		I2		C		PM1		PM2		M1		M2		
Dental Score:	3.14	+	0.7	+	2	+	2.19	+	0.55	+	2.21	+	2.09	=	12.88

Willems Dental Age: 12.88

TABLE 1—*Developmental tooth stages according to Demirjian's technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in boys.*

Tooth	A	B	C	D	E	F	G	H
Central incisor	...	...	1.68	1.49	1.5	1.86	2.07	2.19
Lateral incisor	...	...	0.55	0.63	0.74	1.08	1.32	1.64
Canine	...	...	...	0.04	0.31	0.47	1.09	1.9
First bicuspid	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.4	1.15
First molar	...	...	...	0.69	1.14	1.6	1.95	2.15
Second molar	0.18	0.48	0.71	0.8	1.31	2	2.48	4.17

TABLE 2—*Developmental tooth stages according to Demirjian's technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in girls.*

Tooth	A	B	C	D	E	F	G	H
Central incisor	...	...	1.83	2.19	2.34	2.82	3.19	3.14
Lateral incisor	...	...	...	0.29	0.32	0.49	0.79	0.7
Canine	...	...	0.6	0.54	0.62	1.08	1.72	2
First bicuspid	−0.95	−0.15	0.16	0.41	0.6	1.27	1.58	2.19
Second bicuspid	−0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
First molar	...	...	...	0.62	0.9	1.56	1.82	2.21
Second molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

Developmental tooth stages according to Demirjian technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth, (from Guy Willems 2001)

5

Figure 20. An example of **(WM)** Data Sheet of a patient

3.2.4.4 Calculation of the Dental Age (DA) by Cameriere's method (CM):

Normalized measures of the seven left permanent mandibular teeth (xi=Ai/Li, i=1,...,7), the total of the normalized open apices (s), and the amount (N0) of teeth with root growth full were used to assess dental maturity.

All of the morphological variables, xi, i=1,...,7, s, N0, and the gender of the participants were entered into an EXCEL file to be used as explanatory variables for age prediction in the statistical study that followed.

The data was adjusted using the following algorithm, which employs Cameriere's regression analysis.

Age = 8.971 + 0.375.g + 1.631.X5 + 0.674.N0 - 1.034.s - 0.176.s.N0,
(s): the sum of the Ai/Li of the open apices.
(N0): the number of teeth with complete root development.
(g): 1 for boys and 0 for girls.
(X5)=A5/L5.
CA was subtracted from the DA: A positive result indicated an overestimation, and a negative effect showed an underestimation of age.

3.2.5 Reproducibility of measurements

All 600 panoramic radiographs were re-evaluated after three weeks to assess this study's repeatability for defining the intra-observer error.

3.2.6 Calculation of the Chronological Age (CA)

Using a Microsoft Excel feature, the difference between the patient's recorded date of birth and the date the OPG was taken was determined, yielding the patient's chronological age at the time of the radiograph. This was then recorded on the Data Sheet as 'Chronological Age' in the related case.

Decimal ages were used for simplicity of statistical calculations, and ages were determined annually; for example, eight years three months was estimated as 8.25 years, and it was put in the age scale of eight years.

3.3 Data Analysis

Both categorical variables were summarized with frequencies and percentages based on their proportions, while numerical variables were summarized with mean and standard deviations (SD) or medians and interquartile range (Q1.Q3). The relationship between categorical variables (age and race versus ethnicities) was tested using the chi-square test or Fisher's exact test, depending on the cell frequencies.

Pearson correlations are calculated between chronological age and dental ages. Intraclass correlations (ICC) are calculated using two-way mixed design to measure absolute agreement between chronological age and dental ages. ICCs are calculated using the *irr* package in R.

For each dental age, a comparison between ethnicities (comparison of independent correlations by Fisher z test) and also for each ethnicity was performed. The comparison between different dental ages to determine which works well for each ethnicity (comparison of dependent correlations) and for all correlation comparisons, the *cocor* package in R were used.

The degree of association between radiographic dental age and historical age was determined using the Spearman correlation coefficient.

Additionally, Bland-Altman p plots were drawn using the blander package in R to demonstrate agreement between age estimation via either approach, and chronological age.

The numerical variables were compared across two groups with Mann Whitney U test or t-test and three or more groups by Kruskal-Wallis test or ANOVA depending on their distribution. The assumption of normality was assessed with Shapiro Wilks' test in addition to visual inspections of QQ and PP plots. The homogeneity of variance was assessed using Levene's test. Post hoc tests for each index are conducted by paired t-test with the Bonferroni correction. The significant group comparisons of numerical variables for three or more groups were followed by post-hoc tests. A mixed effect ANOVA analyses was used to determine whether chronological age using different dental age estimators for each ethnicity. Significant differences were followed by post-hoc tests. Pairwise comparisons were conducted using paired t-test or Mann-Whitney U test depending on the distribution where Bonferroni adjusted p values were evaluated. All the results were summarized using mean plots with 95% confidence intervals. R statix package was used for mixed effects models.

The p value smaller than 0.05 represents statistical significance. The R version 4.0.2 (2020-06-22) was employed for all analyses.

4 RESULTS

The aim of the present study was to determine the accuracy of the Demirjian method (DM). Willems method (WM). And Cameriere method (CM) for Turkish and Libyan children.

Thus, it was aimed to evaluate which of the methods for assessing the age of a patient through the evaluation of radiographs of the dental development is the most correlated with the chronological age of the child for Turkish and Libyan populations. The aim was also to determine the differences between the dental age of Turkish children and Libyan children with respect to gender and age groups.

In total, 600 cases were randomly selected. 300 from Turkish and 300 from Libyan children. The entire evaluation of all radiographs was done by one examiner (M.ALMOZUGHI) after an initial training period. All teeth of the lower left jaw except the third molar rated by the system of Demirjian method. Willems method and Cameriere's method.

Age groups were restricted from 7 to 13. because in the remaining groups the frequency is either very low or zero. Thus. I filtered out the age groups with zero or few observations. After filtering out the Age groups with zero or few observations there were 292 Turkish and 249 Libyan. totally 541 children left in the group.

The mean age for Turkish children is 10.14 (SD =1.65) where the minimum age is 7.08 and the maximum age is 12.97. The mean age for Libyan children is 9.61 (SD=1.71) where the minimum age is 7.00 and the maximum age is 12.99.

	Total (N=541)
Age.group	
[7,8)	74 (13.7%)
[8,9)	112 (20.7%)
[9,10)	105 (19.4%)
[10,11)	95 (17.6%)
[11,12)	79 (14.6%)
[12,13)	76 (14.0%)
Gender	
Female	279 (51.6%)
Male	262 (48.4%)
Ethnicity	
Libyan	249 (46.0%)
Turkish	292 (54.0%)

Figure 21. The distribution of the subjects by ethnicity. age group and gender

label	levels	Libyan	Turkish	p
Age.group	[7,8)	52 (20.9)	22 (7.5)	<0.001
	[8,9)	49 (19.7)	63 (21.6)	
	[9,10)	47 (18.9)	58 (19.9)	
	[10,11)	39 (15.7)	56 (19.2)	
	[11,12)	35 (14.1)	44 (15.1)	
	[12,13)	27 (10.8)	49 (16.8)	
Gender	Female	135 (54.2)	144 (49.3)	0.293
	Male	114 (45.8)	148 (50.7)	

Figure 22. The descriptive statistics for Gender and Age group versus Ethnicity table (The percentages are shown in paranthesis and they are column percentages) p values are Chi-square test p values. The numbers are frequencies and the numbers in paranthesis are percentages

The chi-square calculation was used to see if the number of boys and girls was comparable. The age ages between two minority groups are vastly different. The proportions of boys and girls in the two racial groups are not substantially different (p=0.086), according to the chi-square examination. As a consequence, the ethnicities are balanced by ethnicity, but the age groups are vastly different (p0.001).

The percentage of Libyan children in (7.8) age group is 17.3% while it is 7.3% for Turkish children. The percentage of Libyan children in (12.13) age group is 9% while it is 16.3% for Turkish children. Also a t-test was conducted which revealed that Turkish children are significantly elder than the Libyan children (M=10.14(SD 1.57) versus M=9.61 (SD 1.71). p<0.001).

Age.group * Ethnicity

Data Frame: total

	Ethnicity		
Age.group	**Libyan**	**Turkish**	**Total**
[7,8)	52 (70.3%)	22 (29.7%)	74 (100.0%)
[8,9)	49 (43.8%)	63 (56.2%)	112 (100.0%)
[9,10)	47 (44.8%)	58 (55.2%)	105 (100.0%)
[10,11)	39 (41.1%)	56 (58.9%)	95 (100.0%)
[11,12)	35 (44.3%)	44 (55.7%)	79 (100.0%)
[12,13)	27 (35.5%)	49 (64.5%)	76 (100.0%)
Total	249 (46.0%)	292 (54.0%)	541 (100.0%)

Gender * Ethnicity

Data Frame: total

	Ethnicity		
Gender	**Libyan**	**Turkish**	**Total**
Female	135 (48.4%)	144 (51.6%)	279 (100.0%)
Male	114 (43.5%)	148 (56.5%)	262 (100.0%)
Total	249 (46.0%)	292 (54.0%)	541 (100.0%)

Figure 23. The descriptive statistics for Gender and Age group versus Ethnicity table (The percentages are shown in parenthesis and they are row percentages)

	Mean	Std.Dev	Min	Max	Median	IQR
Cameriere	9.88	1.58	6.22	14.1	10.0	2.27
Chronological.age	10.14	1.57	7.08	13.0	10.1	2.62
Demirjian	10.58	2.39	5.70	16.0	10.3	3.40
Willems	10.16	2.00	6.12	16.0	10.1	3.33

Figure 24. Descriptive statistics for dental ages of the Turkish Children

	Mean	Std.Dev	Min	Max	Median	IQR
Cameriere	9.57	1.76	6.40	13.2	9.79	2.71
Chronological.age	9.61	1.71	7.00	13.0	9.52	2.68
Demirjian	9.92	1.89	5.40	13.8	10.10	3.15
Willems	9.57	2.12	5.46	14.5	9.37	2.90

Figure 25. Descriptive statistics for dental ages of the Libyan Children

Correlations

The Fisher's z test was employed to compare the difference between two correlations based on two independent ethnicities (Cohen. Cohen. West. and Aiken (2003. p. 49)). From Fisher's z test results. the correlation between chronological age and Camemiere age for Turkish children is 0.86 while it is 0.90 for Libyan children. It can be concluded that Cameriere is a significantly better estimator for chronological age for Libyan than for Turkish children (95% CI for the difference between correlations=(-0.0840.-0.0004). p=0.0478). From Fisher's z test results. the correlation between chronological age and Demirjian dental age for Turkish children is 0.778 while it 0.867 for Libyan children. It can be concluded conclude that Demirjian is a significantly better estimator for chronological age for Libyan than for Turkish children (95% CI for the difference between correlations=(-0.146.-0.035). p= 0.0013). From Fisher's z test results. the correlation between chronological age and Willems dental age for Turkish children is 0.812 while it is 0.848 for Libyan children. It can be concluded that Willems dental age works equally for both Libyan and Turkish children to estimate chronological age (95% CI for the difference between correlations: (-0.089.0.0179), (p=0.1916)).

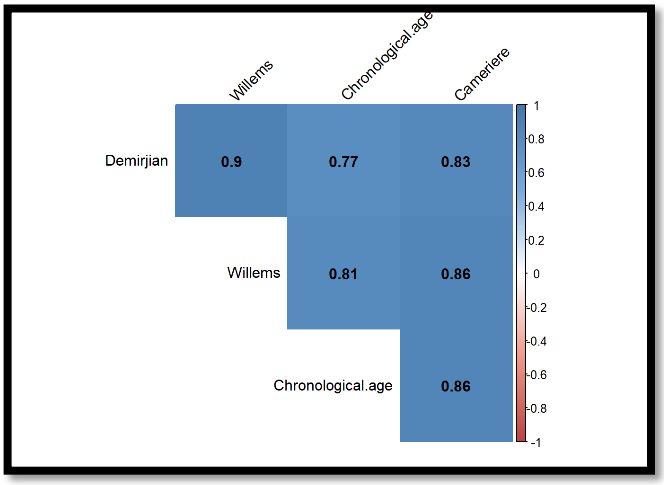


Figure 26. Correlations between dental ages of Turkish children

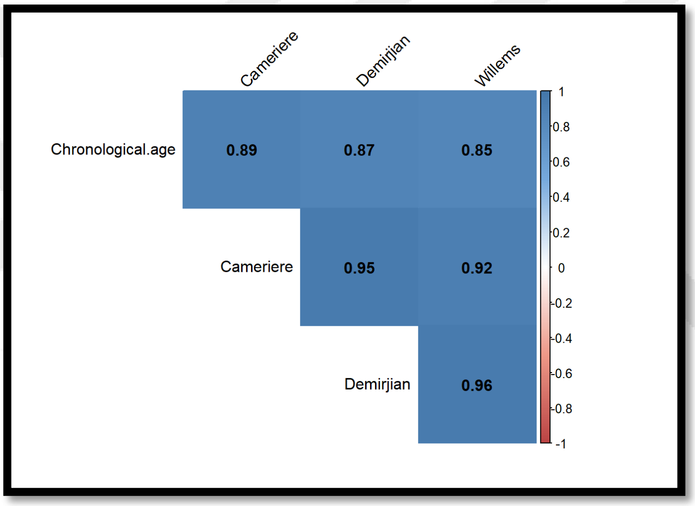


Figure 27. Correlations between dental ages of Libyan children

Agreement Analyses

Correlation measures the degree to which two variables are related. However, a strong correlation does not necessarily imply that the two systems are in sync. The correlation coefficient and regression analysis are often inadequate and misleading when measuring agreement. since they are just interested in the linear association between two sets of data Although correlations are useful for determining the relationship between two variables, they are often useful for determining the relationship between two variables. When deciding if a historical age and a dental age are in agreement, agreement checks are more helpful. Both babies are rated using all dental age methods. Intraclass correlation coefficients (ICC) are recommended for evaluating the reliability of measurement scales.

Intraclass correlation coefficients (two-way mixed effects model with single set raters) are used to see whether a historical era.

Repeatability outcome	Intervals	Further notes
	Ko and Li[8]	Cicchetti and Sparrow[9]
Poor	<0.50	<0.40
Fair	0.50-0.75	0.40-0.60
Good	0.75-0.90	0.60-0.75
Excellent	0.90-1	0.75-1

Figure 28. Common guidelines for the interpretation of the intraclass correlation coefficient

- The intra-class correlation coefficient between Chronological age and Cameriere dental age for Turkish population is 0.841 (95% CI: 0.789-0.878). for female 0.858 (95% CI: 0.806-0.896) and for male 0.826 (95% CI: 0.732-0.884).
- The intra-class correlation coefficient between Chronological age and Demirjian dental age for Turkish population is 0.699 (95% CI: 0.617-0.763). for female 0.717 (95% CI: 0.61-0.796) and for male 0.679 (95% CI: 0.574-0.761).
- The intra-class correlation coefficient between Chronological age and Willems dental age for Turkish population is 0.789 (95% CI: 0.741-0.829). for female 0.789 (95%CI: 0.726-0.848) and for male 0.784 (95% CI: 0.713-0.839).
- The intra-class correlation coefficient between Chronological age and Cameriere dental age for Libyan population is 0.892 (95% CI: 0.863-0.915). for female 0.883 (95% CI: 0.84-0.916) and for male 0.901 (95%CI: 0.859-0.931).
- The intra-class correlation coefficient between Chronological age and Demirjian dental age for Libyan population is 0.851 (95% CI: 0.795-0.890).The intra-class correlation coefficient between Chronological age and Demirjian dental age for Libyan female population is 0.856 (95% CI: 0.782-0.903).The intra-class correlation coefficient between Chronological age and Demirjian dental age for Libyan male population is 0.843 (95% CI: 0.773-0.892).
- The intra-class correlation coefficient between Chronological age and Willems dental age for Libyan population is 0.829 (95% CI: 0.786-0.864), for female 0.829 (95% CI: 0.786-0.864) and for male 0.811 (95% CI: 0.737-0.865).

Table 6. Correlation and intra correlation coefficients of dental ages with chronological age

	Turkish all		Turkish female		Turkish male	
	correlation	agreement	correlation	agreement	correlation	agreement
Cameriere	85.1	84	86.1	85.8	84.7	82.6
Demirjian	77.8	70	81	71.7	74.5	67.9
Willems	81.2	79	82.8	79.5	80.1	78.4
	Libyan all		Libyan female		Libyan male	
	correlation	agreement	correlation	agreement	correlation	agreement
Cameriere	89.2	89.2	88.3	88.3	90.4	90.1
Demirjian	86.7	85.1	87.4	85.6	85.6	84.3
Willems	84.8	82.9	86.3	84.5	83.6	81.1

Bland Altman Plot

The Bland–Altman map is a graphical technique for plotting the differential scores of two variables against the mean for each subject. The measurement of the mean difference and the design of agreement limits are the primary methods for accomplishing this. The main goal of the plot is to evaluate the negotiation intervals. It also makes no note of whether or not those restrictions are fair.

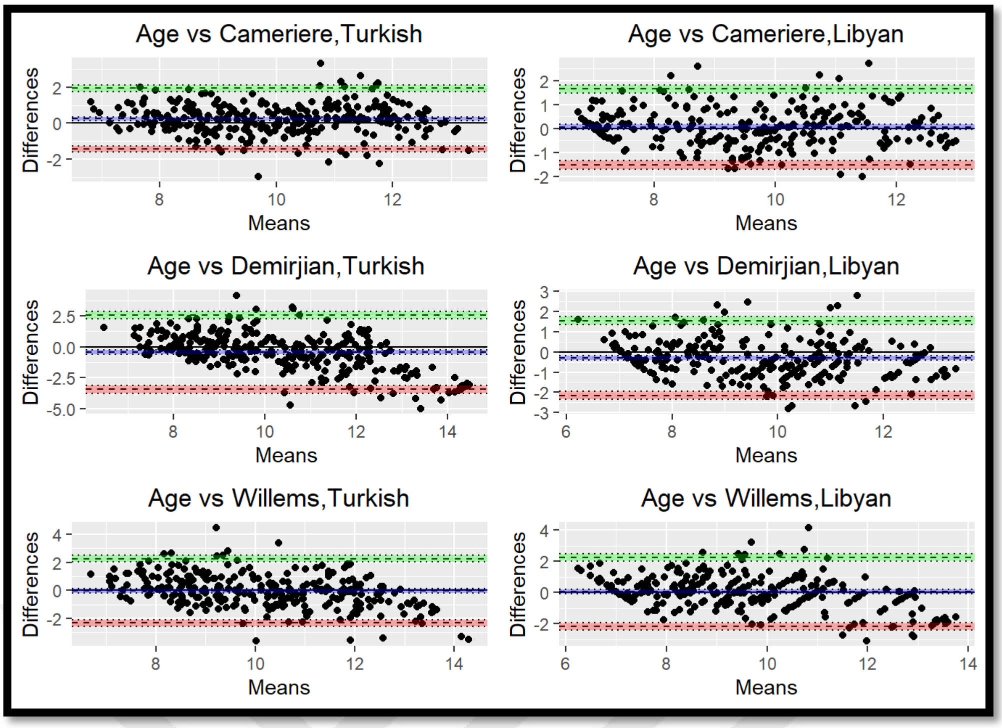


Figure 29. Evaluation of the limits of agreement, the Bland and Altman equations used the mean and standard deviation (SD) of the deviations between two scales.

From the Bland Altman plots it is seen that for both ethnicities all indexes have high agreement with chronological age since most of the points are inside the limits of agreement (green and pink lines). By looking at the blue line confidence interval in the plots.

Cameriere underestimates the chronological age. while Demirjian overestimates the chronological age for both ethnicities. Willems seems to make unbiased calculations for historical age of all ethnicities since the line of equity is above the confidence range of the mean distance.

Mean Plots

The graphs below show the mean values of dental ages in each group with 95% confidence intervals. While interperting the plots only vertical distances between points in each group should be compared because the error bars are shifted to prevent superposition.

Plots should be interpreted carefully since they are only visualizations of data summary. thus they should be supported by statistical tests.

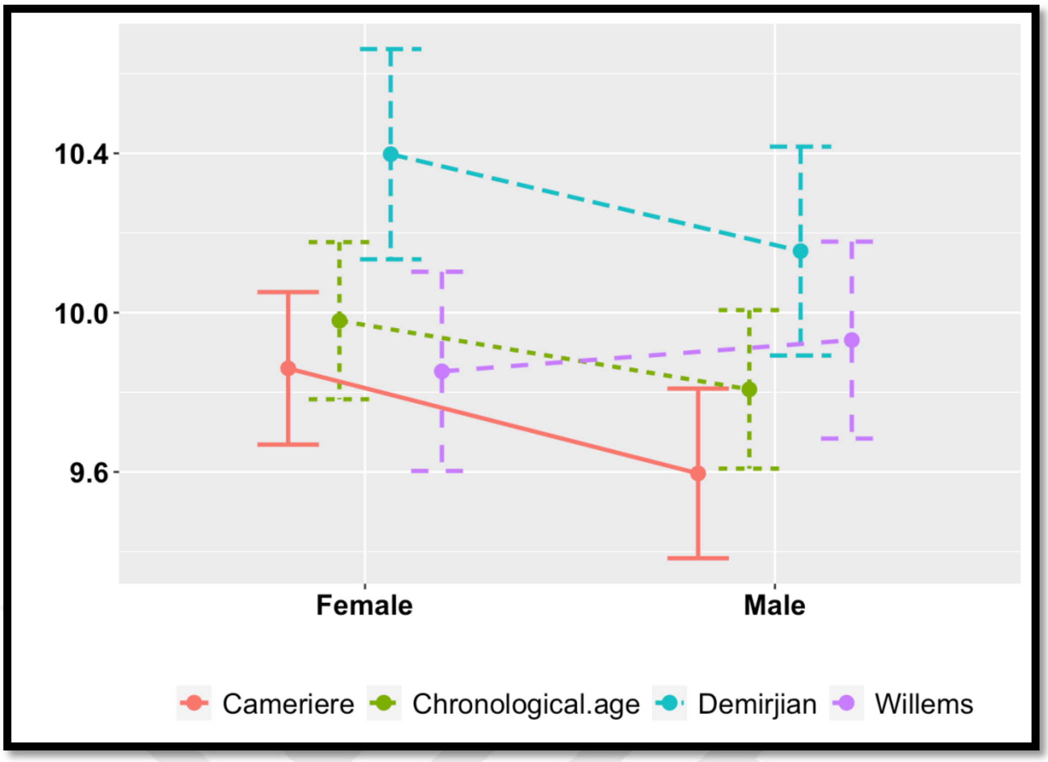


Figure 30. Mean plot of dental ages of all subjects for each gender (Points represent the mean values and error barsa re 95% confidence intervals)

In the above plot looking at the point estimates. Demirjian overestimates the chronological age. while Cameriere underestimates the chronological age. Willlems seems to have the closest estimate for chronological age for both genders.

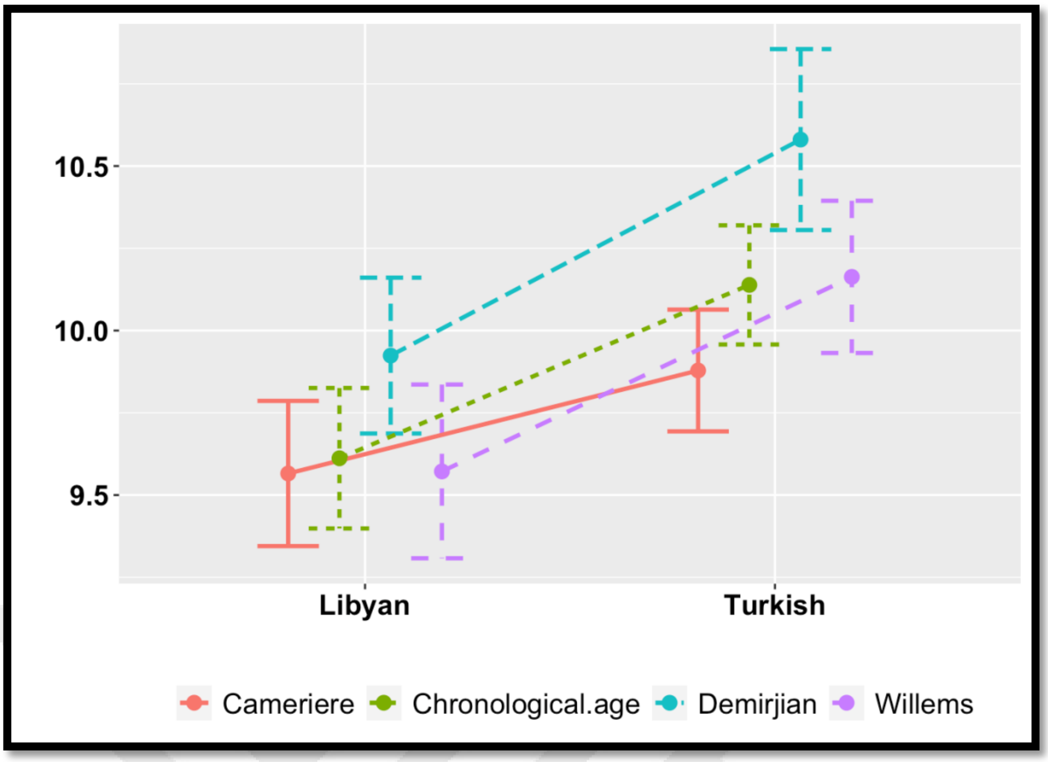


Figure 31. Mean plot of dental ages of all subjects for each ethnicity (Points represent the mean values and error bars are 95% confidence intervals)

In the above plot looking at the point estimates. Demirjian overestimates the chronological age for both etnicities. while Cameriere underestimates the chronological age for Turkish group. Willlems seems to have the closest estimate for chronological age for Turkish group. Willems seem to underestimate for Libyan while Cameriere seems to be the closest estimate for Libyan children. It should be noted that the confidence intervals coincide thus there might not be statistical significance betwen dental ages and chronological ages. statistical tests are required.

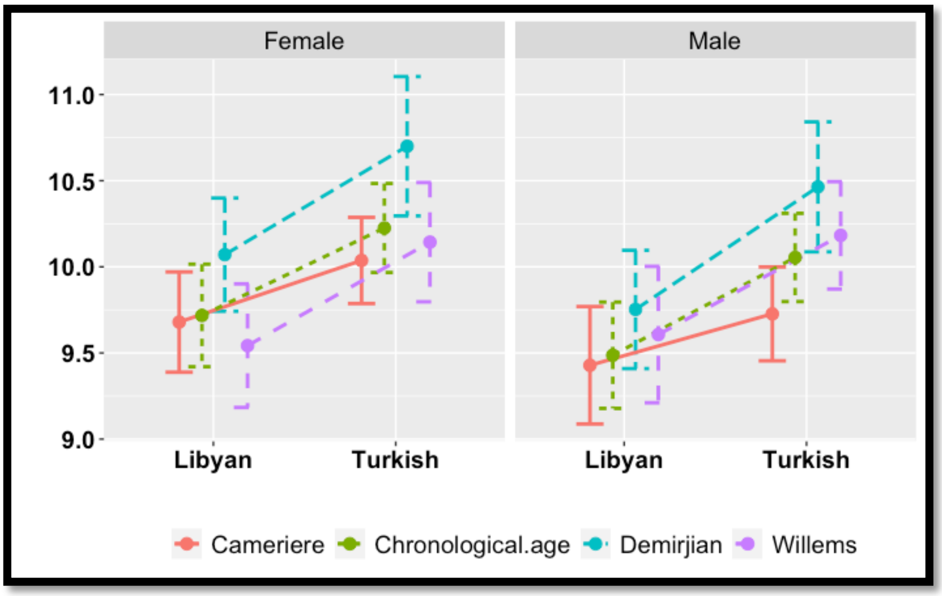


Figure 32. Mean plot of dental ages for each ethnicity and gender (Points represent the mean values and error bars are 95% confidence intervals)

For both Libyan females and males Cameriere provides the closest point estimate while for both Turkish females and males Willems provides the closest point estimate for the chronological age.

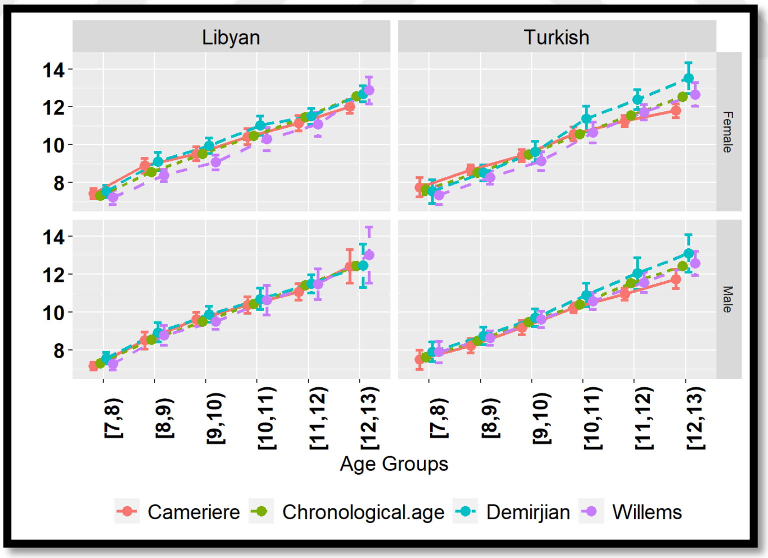
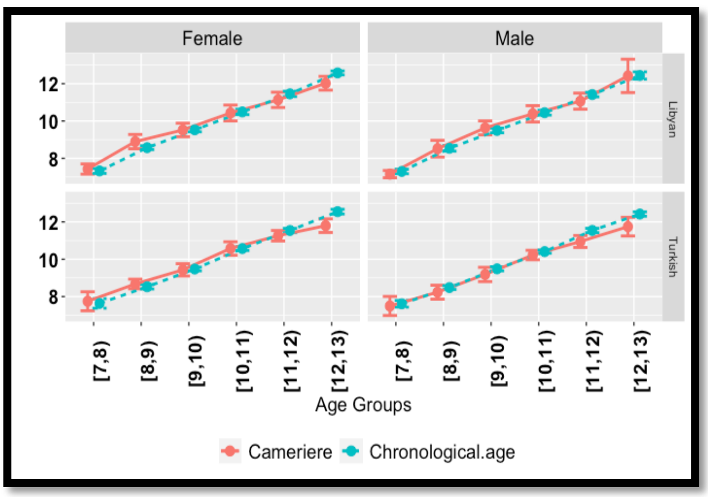


Figure 33. Mean plot of dental ages for each ethnicity. gender and age group (Points represent the mean values and error bars are 95% confidence intervals)

For Libyan children. Cameriere. Demirjian and Willems are all very close to each other and are good estimates for all gender and age group combination. however, for Turkish children the dental age estimates dissociates for older ages (11.12). (12.13). Especially it is seen that Demirjian overestimates the chronological age for Turkish children at older ages (11.12). (12.13)

These discrepancies can be further investigated in the following three graphs where a separate plot is drawn for each dental age.



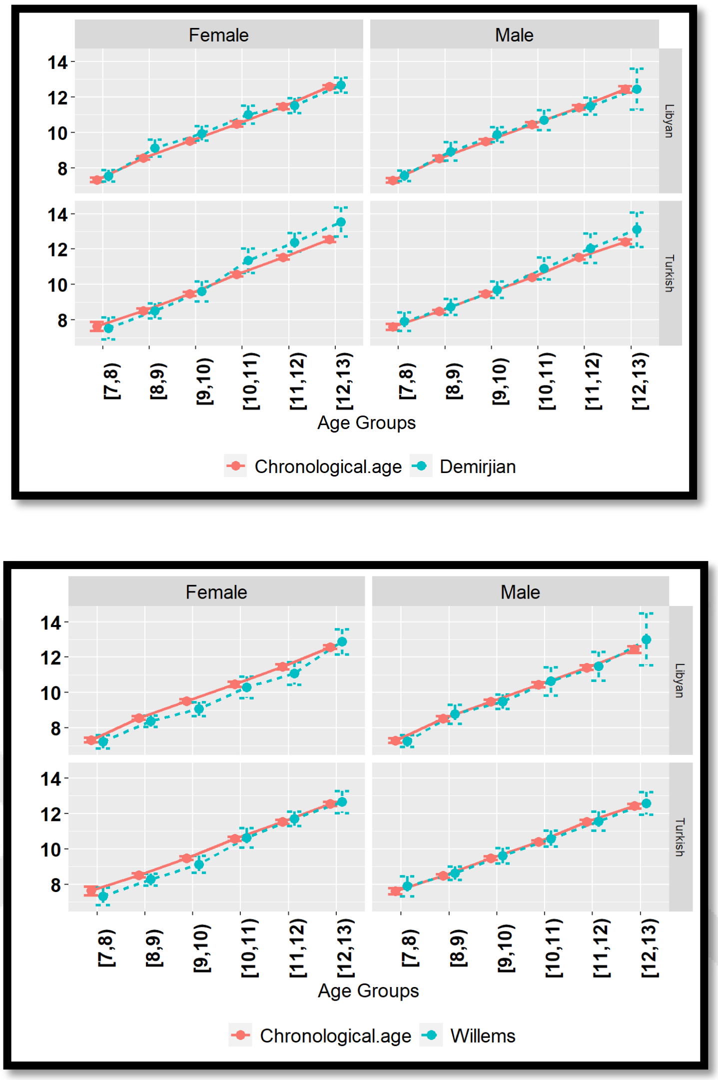


Figure 34. Three graphs where a separate plot is drawn for each dental age method comparing to Chronological age.

I also provided box plots for dental ages for each combination.

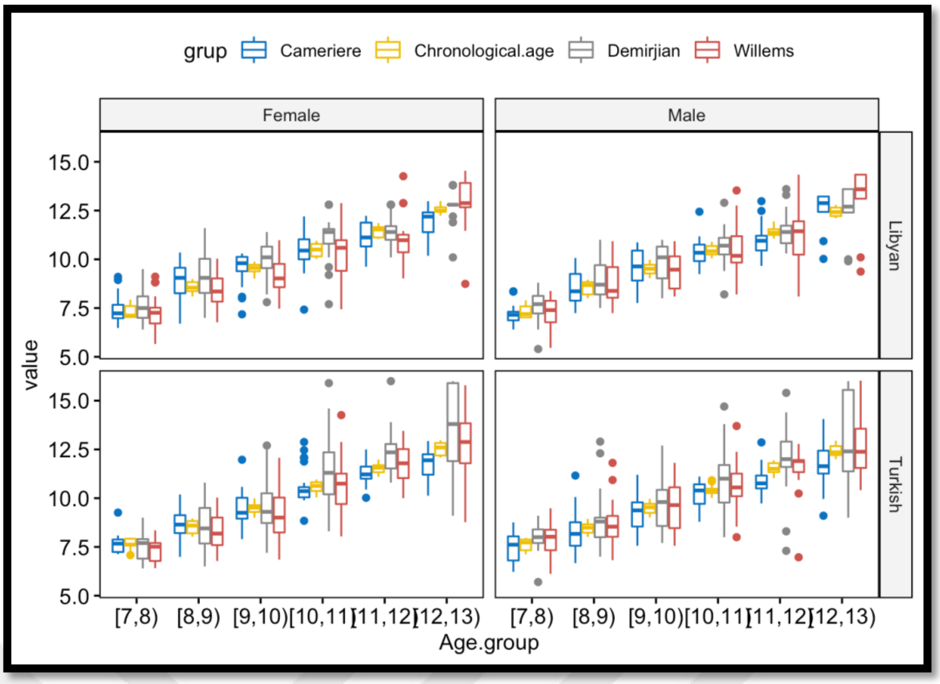


Figure 35. Box plots for ethnicity. age group and gender combination

The center lines within each box plot rectangle reflects the median values. The two ends of the rectangle represent the upper and lower quartiles, respectively. The upper whisker reaches above the upper quartile to the highest value within 1.5 times the interquartile radius, whilst the lower whisker extends below the lower quartile to the lowest value within 1.5 times the interquartile range. The points above or below the upper or lower whisker show the outlier findings.

Comparison of dental ages for each ethnicity, gender and age group

Statistical Comparisons

For both ethnicities, age and gender group. we compare chronological age with Cameriere. Demirjian. Willems. The repeated measures were used ANOVA test because we have 4 different measurements (chronological age. Cameriere. Demirjian. Willems) on each child.

There were three between subjects factors which are age group (7.8) (8.9) (9.10). [10.11). [11.12). (12.13). gender (Male. Female) and ethnicity (Turkish. Libyan) and one within subjects' factor which is dental age group (Chronological age. Cameriere. Demirjian. Willems). For the following analyses all of Chronological age, Cameriere, Demirjian, Willems as dental age groups were named for simplicity although chronological age is not a dental age.

A full model analysis were conducted where it may be employed a four-way mixed ANOVA model. The mixed effects ANOVA makes the following assumptions about the data:

No significant outliers in any cell of the design.

Normality: the outcome (or dependent) variable should be approximately normally distributed in each cell of the design.

Homogeneity of variances: the variance of the outcome variable should be equal between the groups of the between-subjects factors.

Assumption of sphericity: within-subjects group differences can vary in a similar way. This can be checked using Mauchly's sphericity measure.

The homogeneity of covariances is calculated using Box's M. The cells formed by the between-subjects factors should have equal covariance matrices.

The model's assumptions are nearly all right, as seen in the results of the four-way mixed effects ANOVA model.

Table 7. Full model mixed effects ANOVA results

Effect	DFn	DFd	F	p	p<.05
Gender	1	502	0.036	0.851	
Ethnicity	1	502	0.737	0.391	
Age.group	5	502	394.254	<0.001	*
Dental age group	2.22	1113.38	40.994	<0.001	*
Gender:Ethnicity	1	502	0.058	0.81	
Gender:Age.group	5	502	0.336	0.891	
Ethnicity:Age.group	5	502	1.372	0.233	
Gender: Dental age group	2.22	1113.38	6.998	0.0006	*
Ethnicity: Dental age group	2.22	1113.38	3.762	0.02	*
Age.group: Dental age group	11.09	1113.38	3.273	<0.001	*
Gender:Ethnicity:Age.group	5	502	0.315	0.904	
Gender:Ethnicity: Dental age group	2.22	1113.38	1.04	0.36	
Gender:Age.group: Dental age group	11.09	1113.38	1.061	0.39	
Ethnicity:Age.group: Dental age group	11.09	1113.38	2.35	0.007	*
Gender:Ethnicity:Age.group: Dental age group	11.09	1113.38	0.416	0.95	

* represents statistically significant effects at 0.05 significance level

There is a three-way interaction between ethnicity. age group and dental age group (Chronological. Cameriere. Demirjian. Willems) (F (11.09. 1113) = 2.35. p=0.007).

Post-hoc tests

Since there is a significant three-way interaction effect between ethnicity. age group and dental ages (Chronological. Cameriere. Demirjian. Willems). we can decompose it into:
* Simple two-way interaction: run two-way interaction at each level of third variable.
* Simple main effect: run one-way model at each level of second variable. and
* Simple pairwise comparisons: run pairwise or other post-hoc comparisons if necessary.

Simple two-way interaction

We have considered the simple two-way interaction of dental age group and age group and at each level of Ethnicity.

Table 8. Simple two-way interaction

Ethnicity	Effect	DFn	DFd	F	p	p<.05
Libyan	Age.group	5	968	679.31	<0.001	*
Libyan	Dental age group	3	968	7.94	<0.001	*
Libyan	Age.group: Dental age group	15	968	1.346	0.168	
Turkish	Age.group	5	1133	485.686	<0.001	*
Turkish	Dental age group	3	1133	17.209	<0.001	*
Turkish	Age.group: Dental age group	15	1133	2.168	0.006	*

There was a statistically significant simple two-way interaction of age group and dental age group (chronological and dental) for Turkish. $F(15. 1133) = 2.17$. $p = 0.006$. but not for Libyan. $F(15. 968) = 1.35$. $p = 0.168$. There was also a statistically significant difference between dental age group for Libyan. $F(3. 968) = 7.94$. $p <0.001$.

Compute simple main effects for Turkish

Simple key results should be used to pick up on a statistically important simple two-way relationship. As a result of our model, the impact of dental age may be examined on age at any level of age group or the effect of dental age on age at any level of age group.

Table 9. Compute simple main effects for Turkish

Ethnicity	Age.group	DFn	DFd	F	p	p<.05
Turkish	[7, 8)	1.94	38.85	0.416	0.657	
Turkish	[8, 9)	1.85	111.06	1.549	0.218	
Turkish	[9, 10)	1.87	104.88	2.893	0.063	
Turkish	[10, 11)	2.19	118.17	8.307	<0.001	*
Turkish	[11, 12)	1.95	79.81	11.182	<0.001	*
Turkish	[12, 13)	1.91	84.19	12.425	<0.001	*

There was a statistically significant simple main effect of dental age for Turkish at age groups [10,11), [11,12) and [12,13) with $F(2.19, 118.27) = 8.307$, $p < 0.001$, $F(1.95, 79.81) = 11.182$, $p < 0.001$ and $F(1.91, 84.19) = 12.425$, $p < 0.001$ respectively.

Pairwise comparisons for Turkish

Multiple pairwise comparisons may be used to evaluate which category means are distinct after a statistically relevant basic key result.

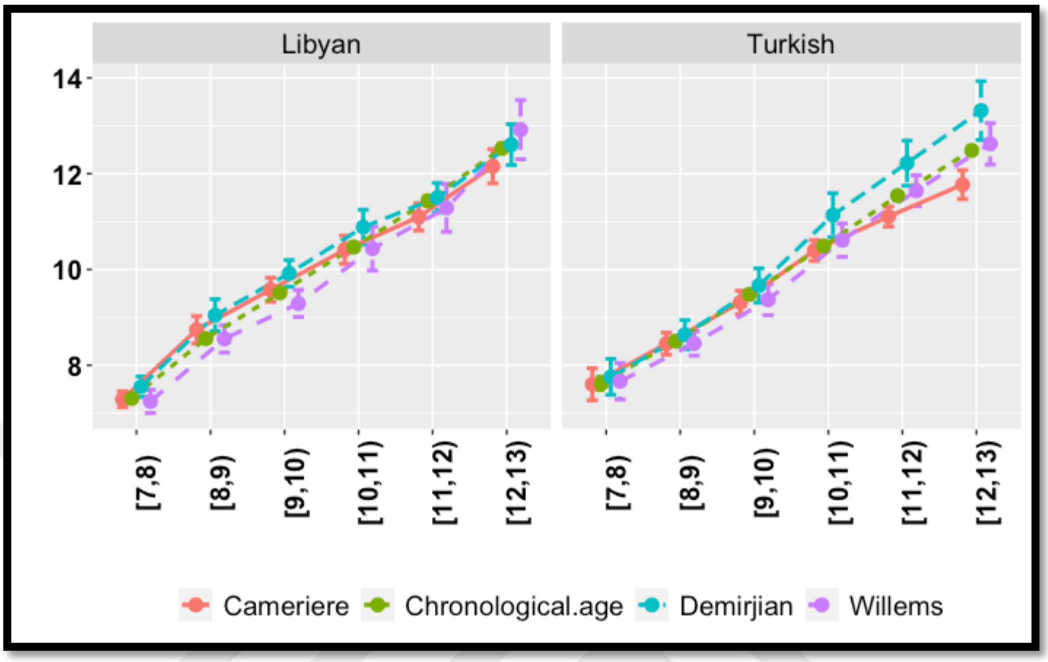


Figure 36. Pairwise comparisons

Pairwise comparisons for Libyan

Multiple pairwise comparisons may be used to evaluate which category means are distinct after a statistically relevant basic key result.

Table 10. Pairwise comparisons for Libyan

group1	group2	n	mean_1	sd_1	mean_2	sd_2	Mean difference	p.adj
Cameriere	Chronological age	249	9,57	1,76	9,61	1,71	-0,05	1
Cameriere	Demirjian	249	9,57	1,76	9,92	1,89	-0,36	<0.001
Cameriere	Willems	249	9,57	1,76	9,57	2,12	-0,01	1
Chronological age	Demirjian	249	9,61	1,71	9,92	1,89	-0,31	<0.001
Chronological age	Willems	249	9,61	1,71	9,57	2,12	0,04	1
Demirjian	Willems	249	9,92	1,89	9,57	2,12	0,35	<0.001

The Demirjian method overestimated chronological age (p0.001) for Libyan adolescents, while the Cameriere method underestimated chronological age (p=1). For Libyans, the Willems method and chronological age do not vary substantially (p=1).

5 DISCUSSION

This is the first study to compare and contrast the dental ages of Turkish and Libyan children aged 7 to 14. The Demirjian, Willems, and Cameriere methods were used to measure and compare the dental ages of Turkish and Libyan children aged 7 to 14. CA may be measured in three ways, according to the Study Group on Forensic Age Diagnostics (AGFAD). These procedures include physical testing, radiographic examination of the left eye, and dental examination. I used measures to assess dental development phases in this research because teeth are held longer than bones and dental growth is less affected by environmental and genetic factors than skeletal development (53). The complicated tooth development process continues from early fetal life to 20 years (54).

In forensic and legal dentistry, dental age assessment is one of the most precise measurements of biological age (55). Dentists, especially pedodontists and orthodontists, benefit from dental maturity for diagnosis and recovery planning (56,57). Up to now, many methods for determining dental development in different cultures were used (12,16), (22,29).

Various forms of dental radiographs have been used to measure dental development. Panoramic radiographs have been used to assess dental age by many researchers due to their affordability and capacity to see all of the teeth (58). Since intraoral radiographs are difficult to obtain without causing image distortion, panoramic radiographs are often the most reliable tool for determining the dental age (59). Thus the panoramic radiographs were used in this present study.

Many methods have been used to determine the dental age. Among all methods used to evaluate dental age, the methods of Demirjian et al. (43), Willems et al. (22), and Cameriere et al. (14) are commonly used in clinical and teaching field. These three methods were the apparent methods for this study.

5.1 Dental age of Turkish children

Demirjian's method

The eight-stage Demirjian procedure is the most widely used methods for determining dental age. It is one of the most fundamental, practical, and widely used techniques (57).

According many studies (57,60–63) have represented that Demirjian's initial method overestimates dental age when applied to communities other than the one of which it is based. To a lesser grade, underestimation has also been recorded (63,64).

A variety of studies have utilized and updated this technique on their own communities. Demirjian's technique has been used in populations of diverse ethnic groups and geographical areas, and there have been differences in dental formation among these societies (46,65–71). Therefore, one of the objectives of this study was to see whether Demirjian's method could be used to measure dental maturation in Turkish children. Several experiments have been done, however, to see if the Demirjian method for estimating dental age in Turkish children is accurate.

According to **Tunç and Koyukuk (2007)**, the average age difference between chronological and dental ages in Northern Turkish children ranged from 0.36 to 1.43 years for males and 0.50 to 1.44 years for females (57).

In Northwestern Turkish children, **Mentes et al. (2000)** discovered delayed dental maturity (68). However, **Nur et al. (2012)** discovered significant differences between northeastern Turkish children and French Canadian children in almost all groups (58). **A. P. Erdem et al. (2013)** showed that the Northwestern Turkish children aged 5–13 years had significantly delayed dental competence, The mean difference between chronological age and dental age was 1.08 to –0.84 years in boys and 0.69 to –0.66 years in girls (72).

In comparison to French-Canadian standards, **Karataş et al. (2012)** discovered significantly delayed dental maturity in the Southwest Eastern Anatolia region. The average delay in females was 0.33 years, while it was 0.48 years in people (73). For the southern Turkish study, **Gungor et al. (2015)** discovered statistically significant differences in the numerical and dental ages determined by Demirjian's method. Females in the 10–11 year age groups were slightly over-predicted, while males in the 13–15 year age groups were significantly under-predicted (74).

Celikoglu et al. (2011) found that in Turkey's Eastern region, the mean difference between chronological and dental ages ranged from 0.4 to 1.3 years in males and 0.2 to 1.9 years in females (75).

In another Turkish study, **Kirzioglu and Ceyhan (2012)** discovered that the Demirjian method overestimated male and female ages by 0.52 and 0.75 years, respectively (76).

In a study of Turkish children aged 5 to 15.90 years, **Apaydin and Yasar (2018)** discovered that DM overestimated the mean DA by 0.304 years (0.300 years for girls and 0.310 years for boys, varying from -0.19 to 0.98 years), except for the 9-year-old category, which was underestimated by 0.19 years (77). These results show that the Turkish population's growth occurs later than in the French/Canadian population sample represented by **Demirjian et al.**

In the present study, the use of the Demirjian procedure to estimate dental age in Turkish children resulted in an overestimation of chronological age. Demirjian often exaggerates Turkish children's chronological age as they get older (11.12). (12.13).

In agreement with the previous results (57, 58, 68, 72-77, the Demirjian method for dental age evaluation for Turkish children represent the overestimates the chronological age.

Willems method

Willems et al. (2001) used the DM in Belgian children and simplified it; they calculated chronological age with marginal errors (a median of 0.1 years for males and 0.2 years for females), but these were not statistically significant. In estimating age, Willems' method was found to be more successful than Demirjian's (22). And according to **Liversidge et al**., the WM showed more detailed results in estimating DA. (66) Because of that, I used the WM in this study. Although some studies are assessing the validity of the Willems method for dental age estimation for Turkish children.

Akkaya et al. (2015) found that the differences between chronological and estimated age for females and males are 0.15 and 0.07 years, respectively, in a survey of Turkish teenagers. Willems' strategy was more effective than Demirjian's (78).

Altan et al. (2016) investigated the Willems protocol in the Turkish population and found that girls were more accurate than boys in a survey of Turkish children aged 5–14.99 years (79).

Apaydin and Yasar (2018) discovered that WM underestimated the DA by 0.060 years (0.062 years for girls and 0.056 years for boys), varying from -0.68 to 0.32 years, in a survey of Turkish children aged 5 to 15.90 years. WM's results were the most accurate (77).

Hatice Cansu Kış et al. (2020) discovered that the Willems treatment overestimated the dental age relative to the chronological age in all age groups for boys and girls in all age groups in a survey of Turkish children aged 8–14 years (80).

The Willems, Demirjian, and Nolla methods' accuracy in Turkish children has been evaluated in studies from different regions of the country; the Willems method has been described as a highly accurate method in Turkish children (76–80) .

In the present study, the use of Willems' method for estimating dental age in Turkish children yielded the most precise estimate of chronological age for both genders. Willems seems to make unbiased calculations for historical age of all ethnicities since the line of equity is above the confidence range of the mean distance.

In agreement with the previous results (72,74,76–81), the WM showed the most accurate results for dental age assessment for Turkish children.

Cameriere method

Many researchers have used Demirjian, Willems, and Cameriere methods for diverse populations. Certain studies have used only the Demirjian or Willems or Cameriere method, while the three techniques have also been used and compared in others. Some have reported the Cameriere as more accurate, while others have reported the WM more accurately (75,77,78,80–82). According to recent studies, the Willems and Cameriere approaches have the highest accuracy in the Turkish culture. As a consequence, for the current analysis, The Cameriere method was selected. Just one previous study in the Turkish culture looked at the Demirjian, Willems, and Cameriere approaches (77). They simplified that WM and DM for evaluating age are accurate and recommended for Turkish children ranging in age from 5 to 15. WM showed the most accurate results.

Gülşah et al. became the first in the Turkish world to examine the Cameriere procedure's accuracy **(2015)**. While the writers argued that the technique was more accurate for girls than for boys, the methodology was found to be entirely compatible with the Turkish culture in that study. Girls' older prepubertal and pubertal development changes, which occur between the ages of 8 and 15, can explain this finding (82).

According to **Apaydin and Yasar (2018)**, the CM underestimated the DA by 0.580 years (0.550 years for girls and 0.603 years for boys), with a range of -1.99 to 0.34 years. In the CM, the underestimations in the 13, 14, and 15-year-old grades were more than a year. The difficulty in measuring small apex openings showed the difficulty in measuring small apex openings in this age group. Furthermore, the CM was more accurate of determining age in younger students. The differences were statistically significant for both sexes in most age groups (77).

Ozveren et al. (2019) compared the Willems and Cameriere approaches in the Thrace area, which represents a subgroup of the Turkish population. A total of 636 students, ranging in age from six to fifteen years, were included in the study (319 males and 317 females). According to the findings, both the Willems and Cameriere methods may be used for forensic age determination in the Turkish culture (81).

According to **Cansu Kış et al. (2020)** it was the first study to examine the Willems and Cameriere approaches using two large sample groups and two associated centers. It's perhaps the first-time regression analysis has been used to examine Turkish people's results. While the Turkish community accepts both methods, the modified Cameriere method could be best for forensic purposes, while the Willems approach is better for medicinal purposes. Both methods were more accurate in females than in males (80).

In the present study, the use of the Cameriere method for dental age evaluation for Turkish children showed underestimates the chronological age for both genders.

In agreement with the previous results (76,80,81), the Cameriere method for dental age evaluation for Turkish children resulted underestimates the chronological age.

5.2 Dental age of Libyan children

The Demirjian, Willems, and Cameriere methods are being used for the first time on the Libyan citizens. This allows the results to be compared with other population studies that take into account regional differences. Therefore, the results obtained here should be considered as preliminary results.

Using the same investigators to measure the dental ages of two separate demographic groups has the advantage of reducing assessor error. Furthermore, using the same set of parameters provides a common platform for assessing and evaluating data from all populations at the same time, regardless of whether the requirements are unique to the populations under study. As a result, these methods were incorporated into the present study in order to include a more detailed overview of two ethnic communities with no established dental developmental requirements for their populations.

Although meta-analysis of results from previous studies may be used to compare dental sophistication across age types, such reports are more likely to reveal general trends rather than substantive differences. This is the first study to compare the dental development of two communities using three techniques in one study (Demirjian, Willems, and Cameriere methods).

Demirjian's method

This is the first investigation into the applicability of the Demirjian approach to the Libyan citizens. One of the more pressing questions regarding age estimation from dental radiographs is whether evidence from one ethnic group can be used to compare people from other ethnic groups. Despite the fact that some researchers claim Demirjian's system is fairly reliable for European descendants (67,83,84), recent inquiries using this method on a variety of communities have shown a number of ethnic differences (30,46,65,85). The significance of establishing a representative reference data collection for each group is highlighted in these studies. One of the objectives of this cross-sectional study was to evaluate Demirjian's age estimation method for Libyan children and, if necessary, to establish special dental age maturity function formulae.

According to **Al-Emran (2008)** examined Saudi Arabian children aged from 8.5 years to 17 years of age and found that boys were 0.3 years and girls 0.4 years ahead of French-Canadian children used in the standards (85).

According to **Qudeimat and Behbehani (2009),** there is a difference in dental maturation between Kuwaiti children and French-Canadian norms, as calculated by dental age, with a tendency for delayed dental development. Kuwaiti children have a 0.69-year-old total dental age (86).

Al-Tuwirqi et al. (2011) represented much larger mean increases in dental ages of 0.71 years for KSA boys and 0.74 years for KSA girls. Besides provided the first dental value for Saudi Arabian children in the age group 5-6 years (87).

Abesi et al. (2013) found that the Demirjian method may be used to assess dental age in girls and boys before puberty in children aged 7 to 15 years old in Babol, Iran (88).

Abdrhman Azzawi et al. (2016) discovered that dental maturation in the Egyptian female population was 0.528 years faster than in the Egyptian male population in a sample of 400 children aged 5–13 years residing in Tanta district, Egypt. Children in Tanta city might not be required to follow Demirjian norms. The differences in their observations and those of Demirjian may be attributed to the passing of time as well as shifts in social conditions for specific populations, such as better diets and the absence of childhood disease (89).

Moness Ali et al. (2019) found that the age was overestimated for all subjects with an accuracy range from 0.18 to 1.19 years for males and from 0.08 to 0.87 years for females, except for two age subgroups (9–10-year-old males and 10–11-year-old females, for which the mean difference values were −0.06 and −0.008 years, respectively). The Demirjian's method may be unsuitable for Egyptian children living in Minia city (90).

Maktoom Alqadi and Amal Abuaffan (2019) observed that the Demirjian method was more successful for females than for males when comparing CA to DA in a sample of children from Sana'a, Yemen. The Demirjian method underestimated the CA of both sexes, with males seeing a larger variance. As a result, Yemeni children seem to be behind the times in terms of dental sophistication when opposed to children in other areas of the world (91).

In the present study, the use of the Demirjian method for dental age evaluation for Libyan children resulted Demirjian is a significantly better estimator for chronological age for Libyan than for Turkish children (95% CI for the difference between correlations=(-0.146.-0.035) p= 0.0013). While Demirjian overestimates the chronological age for both ethnicities and for both genders.

Willems method

Willems et al. (2001) used residual errors to calculate chronological age (a median of 0.1 for males and 0.2 for females), but the variations were not significant. In estimating age, Willems' method was found to be more successful than Demirjian's. The WM produced more detailed DA estimate results, according to Liversidge et al. As a consequence, in this study, I used the WM. The relevance of the Willems method for estimating dental age in Arabic children has been investigated in many studies. This is, nevertheless, the first review of the Willems method's applicability to Libyans (27,30).

El-Bakary et al. (2010) observed that the Willems protocol culminated in an average age overestimation of 0.14 years for girls and 0.29 years for boys in a sample of Egyptian children aged 5 to 16 (92).

In the whole analysis, **Antoine Saade et al. (2017)** found that Willem's solution produced a statistically marginal difference as compared to CA. Demirjian's method generated a higher mean value than Willem's in a survey of Lebanese students of both genders (93).

According to **Yasser Souror and Harshkant Gharote (2019)** The Willems method's mean age was lower than the chronological age of all adolescents, including boys and girls. Comparisons between all three mean ages of boys and girls were considered to be statistically insignificant in a study of Saudi Arabian children aged 5 to 13. For a study of Saudi Arabian children aged 5 to 13, it was discovered that the age calculated by Willems method was underestimated as compared to the age calculated by Demirjian method (94).

The use of the Willems method for estimating dental age for Libyan children led to the finding that Willems dental age works reasonably well in estimating chronological age for both Libyan and Turkish children (95 percent CI for the difference between correlations: (-0.089.0.0179). p=0.1916). Willems seems to make unbiased calculations for historical age of all ethnicities since the line of equity is above the confidence range of the mean distance.

Cameriere method

According to recent studies, the Willems and Cameriere methods provide the highest accuracy in a number of communities. As a consequence, for the current analysis, the

Cameriere method was selected. This is the first investigation into the applicability of the Cameriere approach to the Libyan citizens. Several studies have looked at using the Cameriere method to estimate dental age of other Arabic children.

In a survey of Egyptian children aged 5 to 16, **El-Bakary et al. (2010)** used the Cameriere method to measure dental age, observing an average age underestimation of 0.26 years for girls and 0.49 years for boys (92).

Dara Alsudairi, Sakher J. AlQahtani (2018) discovered that the mean difference between Estimated Age (EA) and Real Age (RA) for Cameriere's procedure was (0.89 years) with a standard deviation of (1.14 years) when extended to a sample of Saudi Arabian children aged 16 to 15.99 years (95).

The Cameriere method for estimating dental age for Libyan children was found to be a far better indicator of chronological age for Libyan children than for Turkish children (95 percent confidence interval for the difference between correlations= (-0.0840.-0.0004). p=0.0478) p=0.0478) p=0.0478) p= In the other side, the Cameriere method overestimates chronological age through ethnicities and genders.

6 CONCLUSIONS

Many methods have been used to record the dental age. Among a lot of method used to evaluate dental age, the methods of Demirjian et al. (43), Willems et al. (22), and Cameriere et al. (14) are commonly used in clinical and teaching field. This is the first study to compare and contrast the dental ages of Turkish and Libyan children aged 7 to 14. The Demirjian, Willems, and Cameriere methods were used to measure and compare the dental ages of Turkish and Libyan children aged 7 to 14.

The use of the Demirjian procedure to estimate dental age in Turkish children resulted in an overestimation of chronological age. Demirjian often exaggerates Turkish children's chronological age as they get older (11.12). (12.13). While for Libyan children resulted Demirjian is a significantly better estimator for chronological age for Libyan than for Turkish children (95% CI for the difference between correlations= (-0.146.-0.035) p= 0.0013). While Demirjian overestimates the chronological age for both ethnicities and for both genders.

The use of Willems' method for estimating dental age in Turkish children yielded the most precise estimate of chronological age for both genders. The use of the Willems method for estimating dental age for Libyan children led to the finding that Willems dental age works reasonably well in estimating chronological age for both Libyan and Turkish children (95 percent CI for the difference between correlations: (-0.089.0.0179). p=0.1916). Willems seems to make unbiased calculations for historical age of all ethnicities since the line of equity is above the confidence range of the mean distance.

In agreement with the previous results (76,80,81), the Cameriere method for dental age evaluation for Turkish children resulted underestimates the chronological age. While the use of Cameriere method for estimating dental age for Libyan children was found to be a far better indicator of chronological age for Libyan children than for Turkish children (95 percent confidence interval for the difference between correlations= (-0.0840.-0.0004). p=0.0478) p=0.0478) p=0.0478) p= In the other side, the Cameriere method overestimates chronological age through ethnicities and genders.

Ethnic differences, environment diet, socioeconomic status, sample size, and observational methods may all explain the wide variety of disparities observed in many studies from various countries. The reasonable age gap between two people in forensic science is the DA and CA is reported as ± 1.00 year for children until adolescence (96,97).

In conclusion, the use of the Demirjian procedure to estimate dental age in Turkish children resulted in an overestimation of chronological age. The use of the Willems method for estimating dental age for Libyan children led to the finding that Willems dental age works reasonably well in estimating chronological age for both Libyan and Turkish children.

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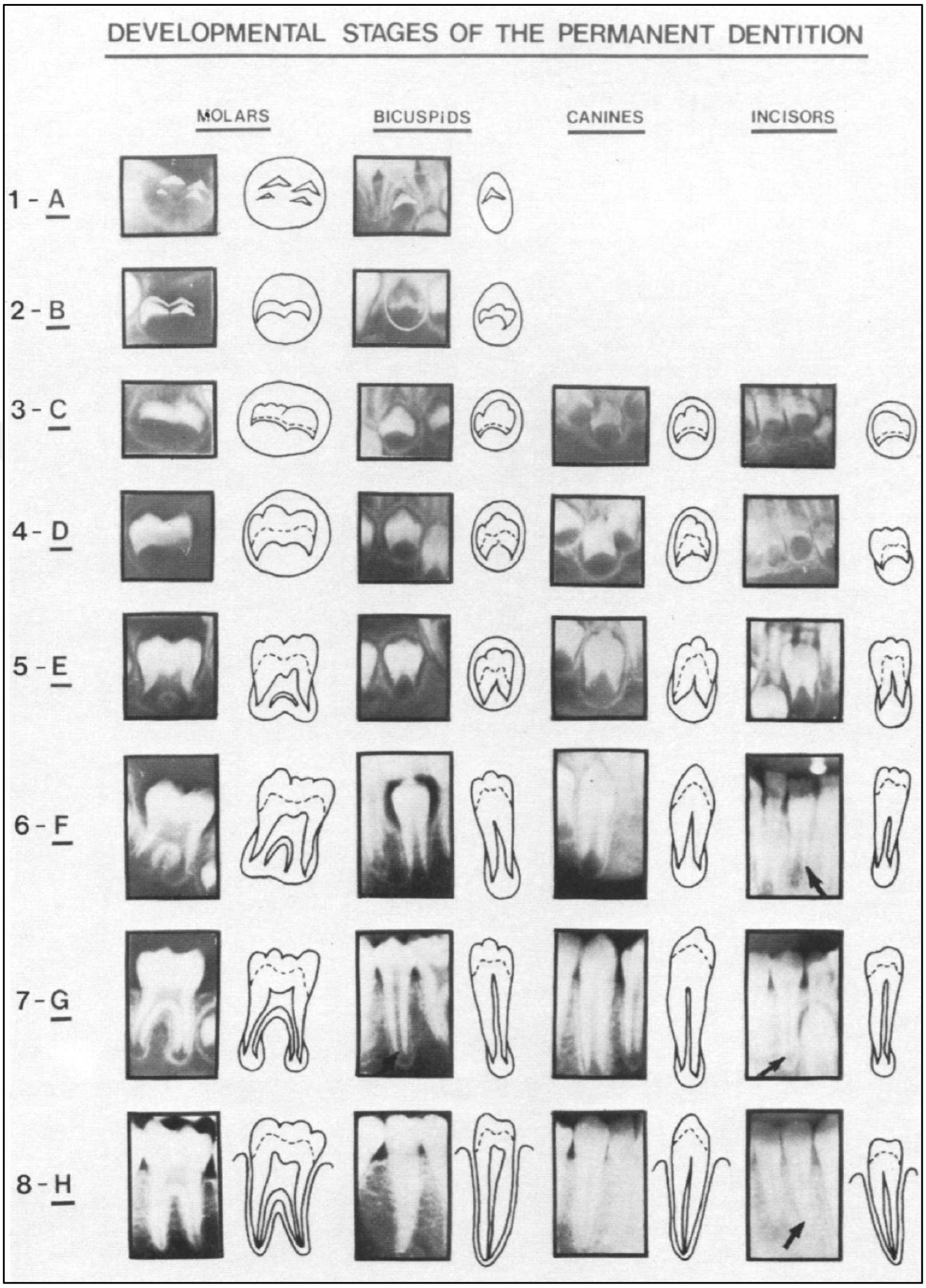
8 APPENDICES

Appendix 1



Appendix 2

Conversion of Maturity Score to Dental Age (7 teeth) Boys					
Age	**Score**	**Age**	**Score**	**Age**	**Score**
5.0	**32.0**	**9.0**	**82.4**	**13.0**	**97.4**
.1	33.3	.1	83.4	.1	97.5
.2	34.6	.2	84.0	.2	97.6
.3	35.4	.3	84.7	.3	97.7
.4	36.1	.4	85.0	.4	97.82
.5	37.0	.5	86.0	.5	97.95
.6	37.9	.6	86.6	.6	98.15
.7	38.6	.7	87.0	.7	98.3
.8	40.0	.8	87.7	.8	98.45
.9	40.8	.9	88.0	.9	98.6
6.0	**42.0**	**10.0**	**88.8**	**14.0**	**98.8**
.1	43.1	.1	89.4	.1	98.82
.2	44.2	.2	89.7	.2	98.85
.3	45.0	.3	90.0	.3	98.9
.4	46.2	.4	90.5	.4	98.95
.5	47.4	.5	91.0	.5	99.0
.6	48.2	.6	91.3	.6	99.08
.7	49.6	.7	91.9	.7	99.18
.8	51.0	.8	92.2	.8	99.25
.9	52.0	.9	92.6	.9	99.3
7.0	**53.3**	**11.0**	**93.0**	**15.0**	**99.4**
.1	55.0	.1	93.3	.1	99.45
.2	56.2	.2	93.8	.2	99.5
.3	58.0	.3	94.2	.3	99.55
.4	59.8	.4	94.4	.4	99.62
.5	61.5	.5	94.6	.5	99.7
.6	63.1	.6	94.8	.6	99.8
.7	65.0	.7	95.0	.7	99.9
.8	67.4	.8	95.3	**15,8-17**	**100**
.9	69.2	.9	95.7		
8.0	**72.0**	**12.0**	**95.9**		
.1	74.0	.1	96.2		
.2	75.0	.2	96.4		
.3	76.3	.3	96.55		
.4	77.2	.4	96.6		
.5	78.3	.5	96.65		
.6	79.2	.6	96.8		
.7	80.0	.7	97.0		
.8	81.0	.8	97.2		
.9	81.8	.9	97.25		

Appendix 3

Conversion of Maturity Score to Dental Age (7 teeth) Girls

Age	Score	Age	Score	Age	Score
5.0	**32.9**	**9.0**	**85.2**	**13.0**	**98.3**
.1	34.0	.1	86.3	.1	98.36
.2	35.0	.2	86.9	.2	98.4
.3	35.8	.3	87.5	.3	98.45
.4	36.8	.4	88.19	.4	98.48
.5	38.0	.5	88.65	.5	98.5
.6	39.25	.6	89.2	.6	98.65
.7	40.5	.7	89.8	.7	98.72
.8	41.7	.8	90.0	.8	98.83
.9	42.8	.9	90.09	.9	99.0
6.0	**45.0**	**10.0**	**91.0**	**14.0**	**99.1**
.1	45.9	.1	91.5	.1	99.15
.2	47.0	.2	92.0	.2	99.18
.3	49.0	.3	92.8	.3	99.19
.4	50.0	.4	93.0	.4	99.20
.5	52.0	.5	93.4	.5	99.25
.6	53.0	.6	93.8	.6	99.30
.7	55.0	.7	93.9	.7	99.45
.8	57.0	.8	94.2	.8	99.60
.9	59.0	.9	94.8	.9	99.87
7.0	**61.0**	**11.0**	**95.0**	**15-17**	**100**
.1	63.15	.1	95.25		
.2	66.0	.2	95.65		
.3	68.0	.3	95.92		
.4	69.0	.4	96.0		
.5	71.0	.5	96.25		
.6	72.4	.6	96.5		
.7	73.7	.7	96.75		
.8	75.0	.8	96.9		
.9	75.9	.9	97.0		
8.0	**76.8**	**12.0**	**97.2**		
.1	77.9	.1	97.3		
.2	78.85	.2	97.4		
.3	80.0	.3	97.5		
.4	81.0	.4	97.6		
.5	82.0	.5	97.7		
.6	82.6	.6	97.75		
.7	83.2	.7	97.8		
.8	84.1	.8	97.9		
.9	85.0	.9	98.2		

9 CURRICULUM VITAE

Personal Information

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Place of Birth	Tripoli	Date of Birth	30-09-1983
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E-mail	Abo.aoab@yahoo.com	Phone	00905459657086

Educational Background

Degree	Branch	Graduated From	Graduation Year
DDS	Dentistry	Tripoli university	2006
High School	-	Alasma school	1999

Foreign Languages	Foreign Language Examination Grade
Turkish-English	Very good

Computer Skills

Program	Ability to Use
Microsoft Office	Good