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Kelmendi, Jeta

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Jeta Kelmendi

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DOCTORAL DISSERTATION

Zagreb, 2019.

Sveučilište u Zagrebu

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Supervisors:

Associate Professor Marin Vodanović DDM, PhD

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DOKTORSKI RAD

Mentori:

Izv.prof.dr.sc Marin Vodanović, dr.med.dent

Izv.prof.dr.sc Ferit Koçani, dr.med.dent

Zagreb, 2019.

This thesis was prepared at the University Dentistry Clinical Centre of Kosova, Kosova; Department of Radiology and University of Zagreb, School of Dental Medicine, Croatia; Department of Dental Anthropology.

The committee for defense of the Dissertation:

- prof.dr.sc. Hrvoje Brkić, *(Committee chair)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia
- assoc.prof.dr.sc. Jelena Dumančić, *(Member)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia
- prof.dr.sc. Sandra Anić Milošević, *(Member)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia
- prof.dr.sc. Mario Šlaus, *(Member)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia
- prof.dr.sc. Marina Lapter Varga, *(Member)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia
- Doc.dr.sc. Ivana Savić Pavičin, *(Substitue member)*

  University of Zagreb, School of Dental Medicine, Republic of Croatia

Date of thesis defence: 07 June 2019.

Supervisors: Associate Professor Marin Vodanović DDM, PhD
Department of Anthropology
School of Dental Medicine, University of Zagreb
University Hospital Centre Zagreb
Croatia

Associate Professor Ferit Koçani DDM, PhD
University of Prishtina' Hasan Prishtina'
Department of Endodontics and Restorative Dentistry
University Dental Clinic
University Dentistry Clinical Centre of Kosova, Prishtina
Kosova

Lector of English language: Lidija Štefić, MA
Senior lecturer
School of Dental Medicine,
University of Zagreb
Croatia

Lector of Croatian language: Lidija Štefić, MA
Senior lecturer
School of Dental Medicine
University of Zagreb
Croatia

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Jeta Kelmendi

Summary

AGE ESTIMATION OF CHILDREN AND ADOLESCENTS IN KOSOVO POPULATION BY DIFFERENT DENTAL METHODS

The aim of the study was to apply different dental age estimation methods such as the Demirijan's, Williems', Moorree's and Cameriere's method to Kosovar population aged 6-24 years in order to compare the accuracy of these methods, and to correlate chronological age with dental age. Also, the aim was to develop a specific maturity chart and formula to estimate age in a sample of children from Kosovo.

The sample of orthopantomographs was selected from 1952 healthy people aged 6 to 24 years old. The radiographs taken from the files of a radiography unit of the University Dentistry Clinical Center of Kosovo in Pristina were retrospectively reviewed. The radiographs from patients who did not have all seven left mandibular teeth, blurry images, were not included in this study. Chronological age has been calculated as the difference between the date when panoramic radiographs were taken and the birth date, with age groups based on one-year increments. Radiographs were collected by one examiner and rated after three months. Dental maturity was calculated using the Demirijan's, Willems' Moorrees' and Cameriere's regression formula.

It has been observed that mineralization was completed after the age of 16 in a large majority of individuals. Intra-class correlation coefficients were 0.858 for intra-rater agreement. For a majority of tested methods, a statistically significant difference was found between chronological age and dental age. In males, the most accurate methods were those using four teeth Dem76IN2. In females, dental age was the most accurate for the Willems method. The mean absolute difference between DA and CA were between 0.74 years for the Willems, 0.77 for Dem73, 0.83 for Cameriere. The results showed that only I3M statistically significantly contributed to discriminating adults and minors. ROC analysis showed that the cut-off value of I3M < 0.08 was the best in discriminating adults and minors.

The mineralization of the mandibular teeth was ahead in females in most stages. The Willems method was the most accurate method for estimating dental age if all seven mandibular teeth were available for analysis. Therefore, these methods were recommended for age estimation of Kosovar children. Also, this research has found the effectiveness of I3M in estimating 18 years of age in Kosovar children and adolescents.

Key words: Age estimation methods; Dental age estimation; Kosovar children and adolescence; Cut-off value.

Sažetak

ODREĐIVANJE DOBI NA UZORKU POPULACIJE DJECE I ADOLESCENATA S KOSOVA POMOĆU RAZLIČITIH DENTALNIH TEHNIKA

Ciljevi rada: Procjena dentalne dobi se vrši iz raznih razloga u nekoliko kliničkih i znanstvenih disciplina koje uključuju ortodonciju, dječju stomatologiju, forenzičku stomatologiju, arheologiju i paleostomatologiju. Procjena dentalne dobi, danas postaje sve važnija u forenzičnoj stomatologiji budući da postoji sve veći broj ilegalnih imigranata koji putuju bez odgovarajućih dokumenata na temelju kojih ih je moguće identificirati, odnosno pojedinaca s nestalim ili nepreciznim podacima o datumima rođenja. Dentalna dob je pokazatelj biološke zrelosti djece. Određivanje dentalne dobi koje se zasniva na analizi razvoja zuba smatra se preciznijim i korisnijim od ostalih pokazatelja zrelosti, jer je manje uvjetovana prehrambenim čimbenicima i endokrinim statusom. Valjanost različitih metoda procjene dobi može se potvrditi testiranjem istih na različitim populacijskim skupinama. Najbolje metode za procjenu dobi su one koje su testirane na različitim populacijama, one koje su prikladne i lako primjenjive, brze i jeftine, a ne nužno one metode s nižim standardnim odstupanjima.

Cilj je ovog rada bio primijeniti različite metode za određivanje dentalne dobi (metode po Demirjianu, Williemsu, Moorresu, Camerierеu) na uzorku kosovske populacije u dobi od 6 do 24 godine kako bi se usporedila točnost tih metoda i korelirala kronološka dob sa dentalnom dobi, te razvila specifična formula za procjenu dobi u populaciji djece s Kosova.

Materijali i postupci: Istraživanje je napravljeno na 1952 ortopantomograma zdravih osoba u dobi od 6 do 24 godine. Ortopantomogrami pripadaju Zavodu za radiologiju Sveučilišnog stomatološkog bolničkog centra u Prištini na Kosovu i snimljeni su ranije za potrebe drugih dijagnostičkih i terapijskih zahvata koji nisu imali veze s ovim istraživanjem. Za svaki ortopantomogram biio je poznat datum rođenja, spol, datum snimanja i kratka povijest bolesti. U istraživanje nisu bili uključeni ortopantomogrami osoba koje nisu bile zdrave (na temelju povijesti bolesti) i koje nisu imali svih sedam donjih zuba na lijevoj strani. Kronološka je dob (KD) djece izračunata kao razlika između datuma snimanja ortopantomograma i datuma rođenja (zaokruženo na dva decimalna mjesta), s dobnim skupinama na temelju jednogodišnjih prirasta. Dentalna dob (DD) se određivala pomoću metoda i regresijskih formula po Demirjianu, Willemsu, Moorreesu i Camerierеu. Uzorak je podijeljen u dvije dobne skupine, od 6 do 16 i 17 do 24 godine te je bio razvrstan prema spolu.

Rezultati: Za većinu ispitivanih metoda pronađene su statistički značajne razlike između kronološke dobi i dentalne dobi. Kod muških su ispitanika bile najtočnije one metode koje su koristile četiri zuba Dem76IN2, te Dem76PM1. U djevojčica je dentalna dob bila najtočnija kod Willemsove metode, potom za Dem76 i Dem73. Prosječna apsolutna razlika između DD i KD bila je između 0,71 godina za metodu po Willemsu, 0,78 godina za Dem76 u dječaka i 0,72 godine za metode po Dem73 do 0,72 godina, te za metodu po Willemsu u djevojčica. Skup podataka za vježbu je korišten da bi se dobio model logističke regresije, dok je skup podataka za testiranje korišten za proučavanje performanse modela. Indeks zrelosti trećeg kutnjaka (*third molar maturity index – I3M*) i spol kao neovisna varijabla i dob odrasle osobe (≥ 18 godina) ili dob maloljetnika (< 18 godina) kao zavisna varijabla su korišteni za analizu logističke regresije. *Receiver operating curve* (ROC) je korištena za određivanje specifične vrijednosti odstupanja I3M-a da bi se predvidjela dob odrasle osobe. Rezultati su pokazali da je samo I3M statistički i značajno doprinijela razlikovanju odraslih od maloljetnih osoba. ROC analiza je pokazala da je vrijednost odstupanja od I3M < 0.08 bila najbolja za razlikovanje odraslih osoba od maloljetnika. Performansa vrijednosti odstupanja I3M-a < 0.08, za razlikovanje odraslih od maloljetnika, je analizirana putem tablica nepredviđenih slučajeva za oba spola. Kod muškaraca, točna klasifikacija (Acc) je bila 0,968 (95% CI, 0,926 do 0,985), osjetljivost (Se) je bila 0,962 (95% CI, 0,925 do 0,978), i specifičnost (Sp) was 0,976 (95% CI, 0,929 do 0,995). Bayes-ov test vjerojatnosti nakon ispitivanja (Bayes PTP) je bio 0,975 (95% CI, 0,905 do 1,00). Kod djevojčica, Acc je bio 0,909 (95% CI, 0,870 to 0,917), Se i Sp su bili 0,826 (95% CI, 0,787 do 0,834) odnosno 0,991 (95% CI, 0,953 do 1,00), dok je Bayes-ov PTP bio 0,989 (95% CI, 0,926 do 1,00).

Zaključak: Kod djevojčica se mineralizacija mandibularnih zuba odvijala ranije u većini faza. Za procjenu dentalne dobi bila je najtočnija metoda po Willemsu ako su svih sedam mandibularnih zuba bili dostupni za analizu. Isto tako, pronađena je slična točnost metoda Dem76PM1 i Dem76IN2. Stoga se njihova upotreba za procjenu dobi može predložiti za procjenu dentalne dobi kosovske djece. Također, ovo je istraživanje utvrdilo učinkovitost I3M u procjeni 18 godina stare kosovske djece i adolescenata. Daljnje bi znanstvene studije trebale ukazivati na korisnost ove metode i specifično odstupanje za različite populacije adolescenata. Ovo istraživanje je pokazalo da metoda po Moorreesu nije prikladna za kosovsku populaciju nakon dobi od 11 godina.

Ključne riječi: Metode procjene dobi; Procjena dentalne dobi; Kosovo; forenzična stomatologija; djeca; adolescenti

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THE LIST OF ABBREVIATIONS

BV	Blood vessels
C	Mandibular Canine
CA	Chronological Age
DA	Dental Age
Dem73	Demirjian original 7-tooth system 1973
Dem76	Demirjian revised 7-tooth system 1976
Dem76IN$_2$	Alternate 4-tooth incisors approach
Dem76PM$_1$	4-tooth method based on premolars and molars
DF	Dental Follicle
DL	Dental Lamina
DP	Dental Papilla
EM	Ectomesenchyme
I$_1$	First mandibular incisor
I$_2$	Second mandibular incisor
I$_3$M	The third molar maturity index
KAS	Kosovo Agency of Statistics
LR	The likelihood ratio
M$_1$	First mandibular molar
M$_2$	Second mandibular molar
NPV	The negative predictive value
OD	Odontoblast layer
OE	Oral Epithelium
OPG	Orthopanthomographs
PM$_1$	First mandibular premolar
PM$_2$	Second mandibular premolar
PPV	The positive predictive value
Se	Sensitivity
Sp	Specificity
UDCCK	University Dentistry Clinical Centre of Kosova

1. INTRODUCTION

The evidence of age is very important and valuable for all human beings. Human age is a measure, expressed mainly in years, the period lived since birth. Hence, the undisputed registration of birth date is necessary to determine chronological age of an individual. Age may also be a measure of biological, psychological and social changes occurring over time. Age estimation according to human teeth has been employed by numerous researchers who were seeking better and more convenient methods to determine the age of an individual.

The sequence of tooth formation and eruption is well documented. Teeth formation is influenced by nutrition and oral hygiene, as well as inheritance. It is less depended on behavioural factors than on dental aging and degeneration (1-3). Tooth mineralization stages are much less affected by variation in endocrine and nutritional status if compared with bone mineralization, and developing teeth, therefore, it provides a more certain indication of chronological age. Tooth formation is often used to assess maturity and predict the age of humans.

Within clinical dentistry, this piece of information aids in diagnosis and treatment planning, especially when patients are referred to orthodontic treatment, particularly because certain stages of pubertal growth spurt may benefit the treatment of some types of malocclusion associated with skeletal disorders. In addition, age estimation is also important in pediatric and forensic dentistry (4).

In forensic odontology and archaeology, age estimation methods can aid in the identification of age at death of a deceased child and can also provide important information with regard to past populations. Furthermore, the estimation of age has also proved to be valuable when birth data are missing or suspected in the management of immigration since it can help determine physiological age (5-7).

Moreover, the use of radiographic guidelines to predict a patient's skeletal maturation is a routine practice for healthcare workers that adopt an integrated approach to examinations. Using these findings, the pubertal or adolescent growth spurt may be assessed to define whether it is imminent, present or complete (8, 9).

1.1 Tooth development

Teeth are formed in the alveolar process of the jaws which comes from the first pharyngeal arch. The first pharyngeal arch is itself subdivided into maxillary and mandibular processes

which subsequently develop in mandibular and maxillary jaws. Teeth start to develop by early migration of neural crest cells into the mandibular and maxillary processes where they stay below the oral ectoderm (10). The sequence of the formation follows a chronological pattern and begins on the sixth to seventh intra-uterine week with the development of buds in the dental lamina. The development of the teeth occurs in stages starting from the crown and progressing towards the root. The following are the stages of tooth development: 1. Bud stage. 2. Cap stage. 3. Bell stage (Figure 1) followed by appositional growth, calcification and eruption. For the primary dentition, the bud stage occurs at the beginning of the eighth week of prenatal development. This stage is mainly characterized by the appearance of a tooth bud without a clear arrangement of cells (11). The tooth bud stage itself is the group of cells at the periphery of the dental lamina. The stage actually begins once epithelial cells proliferate into buds, into the ectomesenchyme of the jaw. Together with the mesenchyme, each of these buds from the dental lamina will be converted into a tooth germ. The important point to note is that only the proliferation of the two tissues occurs during this stage. At the end of the bud stage, the dental papilla, the dental follicle and the enamel organ are considered to be the tooth germ (12). The cup stage for the primary dentition occurs between the 9th and the 10th week of prenatal development during the fetal period. This stage is characterized by the continuation of the growth of the oral epithelium into mesenchyme. This stage marks the beginning of histodifferentiation. In the cap stage, calcification and mineralization of the future crown cusp tips or incisal tooth edge proceed continuously layer by layer until the apical root ends of the developing teeth are closed. Next stage is the bell stage where the morph differentiation starts. This stage occurs for primary dentition between the 11th and the 12th week of prenatal development. It is characterized by the continuation of the process of proliferation, differentiation and morphogenesis. The ectodermal cells and underlying neural crest derived epithelial cells form the enamel organ and dental papilla, respectively. The inner cells of the enamel organ differentiate into ameloblasts and secrete enamel, while the dental papilla cells differentiate into odontoblasts and secrete dentin. Initially, there is a deposition of tissue matrix and subsequent precipitation of inorganic calcium minerals. As growth proceeds, through various molecular interactions, the teeth take their characteristic shapes. Early calcification starts at the tips of the cusps and forms one of the earliest stages that can be identified on radiographs during age estimation (13, 14). Medical imaging can specify the mineralization process in the living organisms (15). As the teeth grow within the jaw bones, they are enclosed in dental crypts which can be recognized on radiographs, initially, as radiolucent areas which later become radiopaque as the teeth develop and calcify (14, 16). To

quantify the timing of this maturation sequence, the chronological age at which a tooth developed into an arbitrarily chosen stage is registered (14).

The thresholds between stages are reflected in specific tooth traits such as calcification commencement, crown completion, root completion, or the root and tooth fractions used to divide the maturing process in consecutive stages. A particular stage occurring in the tooth maturation process is the eruption of a tooth through the alveolar bone and gums into the mouth.

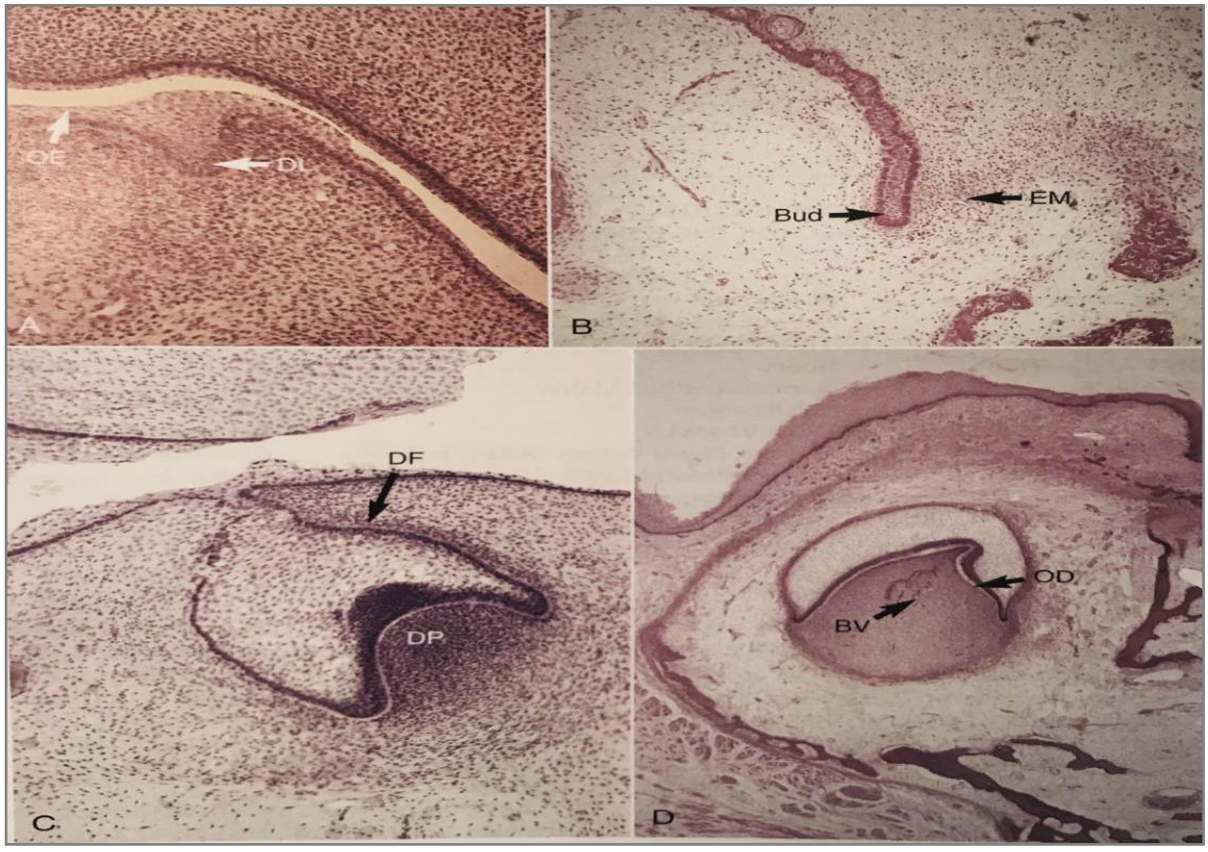

Figure 1 Histology of the human tooth development (12)

A, Earliest stage of tooth development. The invagination of the dental lamina (DL) from the oral epithelium (OE). **B**, Bud stage of tooth formation. The beginning of ectomesenchyme (EM) to condense around the tooth germ. **C**, The cup stage of tooth formation. The dental lamina (DL) is the condensed ectomesenchyme inside the invagination. Around the tooth germ begin to be formed dental follicle (DF). **D**, Early bell stage of tooth formation. The appearance of odontoblast (OD) and blood vessels (BV).

Source: Torabinejad M., Walton E. R. Endodoncia: Parimet dhe praktika. Dragash: ALB-MED Publisher; 2016. p. 2.

The maturation quantification is used for age estimations based on certain tooth types, a specific tooth position or a group of teeth (17). While the crown formation is completed, vascular and sensory neural elements start to migrate into the pulp from the future root apex in a coronal direction (18). At that time, the root is still growing at its apical tip, and the cells from dental papilla are being recruited to become dentin-forming odontoblasts. At this stage, the internal epithelium of the enamel still stimulates the development of odontoblasts with the subsequent formation of dentin, but the subsequent differentiation of the epithelium into the ameloblasts that produce the enamel does not participate in root formation (19). Cylindrical odontoblasts form dentin adjacent to the basal side of the opposing inner enamel epithelium mobility, thus inhibiting root resorption (20). Eruption of the teeth occurs before completion of root development and proceeds through a well predetermined sequence with a specific timing for each tooth. Formation of the tooth continues from prenatal life up to early adult life resulting into two sets of teeth, namely, the deciduous and permanent dentition. As a result, dental age can be assessed up to early adult life (21). The formation of the tissues surrounding the teeth is also very important for the development of the root. The tissue arises from the dental follicle, differentiate when the root sheet fragments and ectomesenchymal cells of the dental follicle penetrate between the epithelial fenestrations and become opposed to the newly formed dentin of the root. Some cells become cementum forming cells on the tooth root surface and some will take part in the mineralized organic matrix of the supporting bone. Periodontal ligament fibers are inserted into cementum and the supporting bone to anchor the teeth into the arches (22).

Occasionally, tooth formation is totally completed, over the time it undergoes ageing by regressive changes such as recession of the periodontium. The secondary dentin is laid down throughout life. As a result, both pulp chamber and root canals become smaller, sometimes to that point that they are no longer visible on radiographs (12). Also, great anatomical changes are reflected in dentin staining, apical tooth resorption and tooth wear by attrition, abrasion or erosion. Tiny or microscopic regressive changes are found as well as the apposition of secondary dentin and cementum in the extracted teeth. The various changes which occur in teeth have found use in age estimation of adults (12, 23, 24). Developmental histological changes in teeth are also useful in fetal age assessment. As previously explained, during the mineralization phase of the enamel, the ameloblasts produce the enamel matrix at a rate of approximately 4μm/day; however, there is a rhythmic variation in the calcification process every 4 days. Consequently, incremental growth lines known as *striae* of Retzius

microscopically appear within the enamel. In cross-section, these lines resemble concentric bands parallel to the dentoenamel junction (25, 26). Any time a systemic disturbance occurs, the enamel mineralization process is interrupted and the currently developing *striae* will appear darker. The darkest and largest incremental growth line seen in the deciduous teeth is called the neonatal line and is caused by the stress and physiologic changes at birth. When present, the neonatal line can be used to distinguish whether a child died before or after birth (26). For the European and a small number of other populations, in spite of their location in different geographical areas, tooth formation has been shown to occur approximately at the same time. The common finding that has been observed and is worth mentioning is that dental maturity for female is usually ahead of that of males, hence age estimation studies usually present data for females and males separately (17, 27, 28).

1.2 Timing of deciduous and permanent dentition

Since embryonic tooth development begins early in fetal development, human dentition is a great indicator of age soon after conception and the degree of morphologic enamel mineralization is radiographically easily viewed. Table 1, provides approximate times of the initial mineralization, completed crown development, and completed root development for the primary and permanent human dentition (29). The times of initial primary tooth mineralization are expressed in terms of weeks in utero during which the growth of the primary crown and the root is completed. There are three initial mineralization times worth of special mention: the earliest initial dental mineralization occurs in the primary maxillary and mandibular incisors at about 14 weeks in utero, all primary teeth have begun mineralization by the 19th week. The mineralization of the first permanent molar begins at about birth as it is shown in the Table 1 (30).

Teeth are a goldmine of information for an osteologist and human anthropologist, as they can show the gender, age, geographical origin and diet of the individual to whom they belong (31). The 32 permanent human teeth, located in the upper and lower jaw, each holding 16 teeth, are resilient to chemical and physical degradation (32).

1.3 The importance of age estimation in orthodontic

Maturation is known as the development process that completes physical growth, and its stages can be evaluated and graphically represented in many simple ways (33). The physical maturation stage in adolescence provides useful information for orthodontic treatment planning and progression, also, for decisions on retention type and duration. Such decisions should be based on the evaluation of occlusal stability after treatment, which may be completed before the end of the growth spurt peak (33, 34). The evaluation of an individual's level of maturation can be assessed by the interpretation of some clinical and radiographic signs. Additionally, some physiological parameters are included as well as chronological, skeletal and dental ages, gender, sexual development, genetic factors and ethnicity (14, 33, 35).

Table 1. Stages of development of human teeth (29)

Deciduous Dentition	**Central Incisor**	**Lateral Incisor**	**Canine**	**First Molar**	**Second Molar**		
Maxillary							
Initial mineralization	14 w	16 w	17 w	15.5 w	19 w		
Crown formation completed	1.5 m	2.5 m	9 m	6 m	11 m		
Root formation completed	1.5 y	2 y	3.5 y	2.5 y	3 y		
Mandibular							
Initial mineralization	14 w	16 w	17 w	15.5 w	18 w		
Crown formation completed	2.5 m	3 m	9 m	5.5 m	10 m		
Root formation completed	1.5 y	1.5 y	3.25 y	2.5 y	3 y		
Permanent Dentition	**Central Incisor**	**Lateral Incisor**	**Canine**	**First Bicuspid**	**Second Bicuspid**	**First Molar**	**Second Molar**
Maxillary							
Initial mineralization	14 w	10-12 w	4-5 m	1.5-2 y	2-2.25 y	At birth	2.5-3 y
Crown formation completed	1.5 m	4-5 y	6-7 y	5-6 y	6-7 y	2.5-3 y	7-8 y
Root formation completed	1.5 y	11 y	13.15 y	12.13 y	12-13 y	9-10 y	14-15 y
Mandibular							
Initial mineralization	3-4 m	3-4 m	4-5 m	1.5-2 y	2-2.25 y	At birth	2.5-3 y
Crown formation completed	4-5 y	4-5 y	6-7 y	5-6 y	6-7 y	2.5-3 y	7-8 y
Root formation completed	9 y	10 y	12-14 y	12-14 y	13-14 y	9-10 y	14-15 y

w- weeks; m-months; y-years. Source: Data adopted from Manual of Forensic Odontology 5th Edition by David R.Senn and Richard A. Weems p.218

In general, chronological age alone may not be used as a valid parameter to estimate growth velocity or skeletal maturity (36). The hand wrist radiograph provides the best indication of skeletal maturation because it gives the visualization of several ossification points in a small area (37). The findings from aforementioned studies have direct clinical applications because they confirm the differences between genders regarding onset, duration and intensity of the maximum pubertal growth spurt. The possibility of exposing patients to X-rays several times is a reason for concern (34). A practical alternative is the use of lateral cephalometric radiographs which are usually demanded for orthodontic diagnoses. They may also be used for growth predictions by evaluating bones of the spinal column and the development of the frontal sinuses (38). Moreover, body, maxillary and, in particular, mandibular growth are not stagnant at the end of the maximum growth spurt, even in patients with Angle Class II or Class III malocclusion, which affects the prognosis of orthodontic treatment (39, 40).

From the scientific literature review, it has been observed that some studies on dental age found a strong positive correlation between root mineralization of mandibular canines before apical closure, usually at the same time as it erupts in the mouth and the onset of pubertal growth spurt, at a degree similar to that of the sesamoid bone calcification (8). When the dental apex is closed, the finger epiphyses and diaphysis are usually already fused, and growth spurt peak has already been achieved (41). Girls usually mature earlier, with the mean difference of two years for the onset of pubertal growth spurt (33). Boys not only reach maturation later, but the magnitude of their growth velocity peak is also considerably greater than that of girls (33). Likewise, there are remarkable differences in the distribution of tooth calcification and mineralization phases between genders (8). Girls usually begin and end their dental development earlier than boys (42). These differences point to the need to start orthodontic treatment earlier in girls than in boys (33). Consequently, in some cases, panoramic images can be used to assess the physiologic maturation stage of the patient to avoid the excessive radiological-exposure.

1.4 The importance of age estimation in forensic dentistry

According to the suggestions made by the Study Group on Forensic Age Diagnostics, a forensic age estimation of a living person for the purpose of criminal prosecution should consist of the following: a physical examination that also records anthropometric data, any age relevant developmental disorders and signs of sexual maturation; an X-ray examination of

the left hand; and a dental examination that records dentition status and evaluates a panoramic image (43). Age estimation plays an important role in forensics, not only to identify dead victims, but also for crimes and accidents (44-46). In addition, chronological age is important in most societies for school attendance, employment, social benefits, and marriage. In adulthood, teeth are subject to time-related changes that represent biological aging, and many studies have shown that several aging characteristics can be used to determine age (47, 48). The legal consequences related to an individual's particular age make a human a subject for forensic age estimation when no or suspicious age documentation is available (49).

1.5 Dental age estimation

Human teeth can be stored in better ways than other parts of the body, thus giving a better indication of age. Dental age estimation has application in establishing the identity of living or dead persons. It also has application in living individuals whose chronologic age is under deliberation. Teeth are harder than any other substances in the human body, which is why they remain long after all other parts have decayed (50). Victims of fires are often identified by their teeth, which can withstand temperatures of more than 1,093 degrees Celsius. Teeth that have passed through particularly intense heat are very fragile and can shrink. Nevertheless, they can be lacquered and used for identification as they are carefully treated (51). The literature on dental age estimation gives broad and extensive information about different methods, their technical performance and fundamental mechanisms (52).

The age of an individual is estimated on the basis of the transformation of age-related markers to chronological age. The age-related markers are variables in biological, psychological and social appearance (53). Human biological age-related variables are defined as human body parts that change over ages. The age predicting value of the variables considered depends on its correlation with age. In a human body, the consummate age-related variables have been revealed in the skeleton and were classified into two groups: the bone group and the dental group. Dental age estimations are specifically based on age variables that are observed in human teeth. Conversion of dental age changes variables into chronological age permits us to establish an age prediction.

The main characteristics associated with age recorded in dental variables are changes in dental development or morphology and modification in dental biochemistry (54). Parallel to the classification of variables, the estimation of dental age of a child is sorted in relation to the

corresponding age category of an individual. Thus, methods based on tooth development are applied to children and sub-adults. The methods based on tooth morphology are suitable for adults, whereas those based on tooth biochemistry are suitable during the entire lifetime. In forensic dentistry, dental age estimation methods are often combined with methods based on non-dental variables (55).

1.5.1 Dental age estimation methods

In general, there are two methods of dental age estimation: invasive and non-invasive methods (56). Age estimation methods are based on tooth development and are generally classified as methods based on third molar development and methods based on development of all the other teeth (57).

Due to the fact that development of the teeth can be observed from the sixth week, while crown calcification of the primary incisors and 1st molar begins as early as 13 – 15 weeks of embryonic life, the methods can be applied during both periods: the prenatal and postnatal period (21, 50). Dental development evaluation is made for person in the age group 16 to 25 (58). Age estimation methods that are based on developmental characteristics include histological approach through microscopic observation of incremental lines and gravimetric observation of mineral content of teeth (59). Further techniques include visual examination of the time of teeth eruption and radiographic examination of developing dentition. The time of teeth eruption and radiographic examination of developing dentition may be used to estimate dental age in children and adolescents (46). Previously in childhood life, environmental factors have less effects on tooth maturation and this can be observed between the time of birth and age 10 (7). Syphilis and hypopituitarism affect dental development to a quarter of the scale of the remaining skeleton (28, 42, 60). These factors can lead to a delayed or failed eruption of teeth. However, tooth calcification is not greatly influenced by these factors (23). Dental age estimation techniques for children can be subdivided into two categories: "atlas style", a diagrammatic representation of the developing tooth structures with their associated eruption pattern, and techniques that require some form of incremental staging of developing teeth. All techniques in both categories are based on analysis of OPGs (7).

Radiographical evidence of formation of the crown and root completion that has been utilized for this age group (Schour and Massler’s chart in 1941, and reproduced in 1944) was the first attempt on age estimation. Historically, this atlas has been the most cited atlas for dental age estimation (61). Unfortunately, it has been observed that estimation of dental maturation in

this chart was based on a very small sample size of institutionalized, chronically ill, and malnourished children (7). Therefore, some atlas style charts that were published later are considered to be more reliable. The atlases produced by Ubelaker (1978, 1989) and AlQahtani *et al.*, (2010) are more suitable for dental age estimation (60).

All atlas style techniques have some constitutional problems because they are not gender differentiated, which is resulting in a high degree of variability, particularly from midchildhood through adolescence. Additionally, there is not a sufficient number of ancestral and population specific studies and the most important problem is that atlas style techniques tend to have a large degree of inter-observer disagreement and a larger error rate than other tooth formation and development techniques (7). The techniques that involve tooth mineralization are more useful. Researchers face dilemmas such as how to create a staging chart that has enough detached intervals of tooth development easy to be used and to provide accurate and useful data. The two most commonly used staging systems nowadays are those of Moorrees *et al.*, and Demirjian *et al*., (26).

A number of authors have divided tooth development into different stages such as, 10 stages by Gleiser and Hunt (1955) and a modified classification by Kohler et al., (1994), 8 stages by Demirjian et al., (1973), 14 stages by Moorrees et al., (1963) and 10 stages by Nolla, (1960). Demirjian‘s (1973) tooth stages are more frequently used since they are easier to identify (44). The stages of tooth development have been modified by Willems et al., who developed the Willems model of age estimation. Due to population differences in dental growth, the authors such as Demirjian and Willems recommended testing of their methods in other populations in order to verify their applicability to other foreign populations (14, 62). Again, at the end of skeletal maturity, few age-markers remain for estimating age by progressive morphological methods (63). By age 14, the only remaining tooth undergoing growth and formation is the third molar. The third molar is the most developmentally variable tooth and age estimation is based on the average morphologic development, hence there are limitations to third molar age estimation techniques (7, 57, 63). However, the third molar is the most reliable biological indicator during adolescence, and in the early adulthood, and can easily and non- invasively be evaluated using dental radiographs. A multidisciplinary approach to determine the age of legal majority has been suggested by some authors such as Schmeling et al., (2004), who recommended combining the third molar age estimation with some techniques of age estimations using radiographs of the clavicle and the hand wrist for bone age estimation (6). Cameriere et al., (2004), have reported that the third molar age estimation

in combination with the pulp/tooth area ratio assessment of the second molar resulted in a more accurate age estimation of individuals who are 18 years of age or older 18 (64).

When mandibular third molars are used for age estimation, the stages of tooth development that have been identified on radiographs are measured. These radiographs show the absence or the presence of dental crypt in the alveolar process of the maxillary and mandibular jaw, the levels of crown and root formation/calcification and tooth apices that are either open or closed. Once the stages have been identified, different methods of age estimation can then be applied to convert the tooth stages into dental age (8, 26, 45).

Demirjian's methods. In 1973, Demirjian published the most widely used method for dental age estimation for children in which he described a procedure for estimation of developmental stages of seven first teeth on the left side of the lower jaw, excluding third molars, in French-Canadian ethnically Caucasian children. He defined 8 stages of development of the crown and the root of the teeth, and marked them from A to H. This technique requires the evaluation and staging of the entire mandibular left quadrant excluding the third molar (65). The mandibular arch was selected because of better clarity of radiographic images compared to maxillary imagery as a result of superimposing dental and maxillofacial anatomy (66). It is acceptable to evaluate a portion or the entire dentition on the mandibular right when the same tooth in the left quadrant is missing, malformed, rotated, or difficult to stage for any reason. At an earlier time when all teeth have been staged, each tooth was assigned a "self-weighted score". Its staging and the gender of an individual were also determined (65). Every developmental stage of each tooth corresponds to the correct number value. This method includes three steps whereby at step one, the developmental stage of the tooth is identified. In step two, the teeth are assigned maturity scores (Table 9), while in the final step, the scores are converted into age. The sum of the appropriate numerical values for all seven teeth is compared with comparative dental age tables ranging from 0 to 100, separately for girls and for boys (Figure 2, Table 2 and Table 3) (10,16). The study also provides graphical data that allow for the maturity score to express the age interval at the 10th and 90th percentiles (65).

In 1976, in the continuation of the research, Demirjian published a custom dental setting system based on three additional methods. The first is the method related to the same seven teeth on the left side of the lower jaw, the other on the four teeth (Dem76PM1 and Dem76IN2) (67). The accuracy of the Demirjian's method was tested on residents of different European countries and ethnic communities, and many studies have shown that chronological

age surpasses over years (68-70). The results point to some differences from the French children standard and the reasons for this are different unsupported statistical procedures, manual harmonization of population curves, as well as differences in lifestyle, environment and nutrition habits of population. It is clear that it is necessary to check the accuracy of French-speaking standard obtained by Demirjian's procedure or even adapted reference tables for each population in particular (71).

Although the Demirjian's method does have more population specific studies available, the technique can be problematic particularly in cases that involve fragmented remains or where a tooth is bilaterally missing or malformed (65).

Moorrees's method. The article written by Moorrees *et al*. provided chronological age estimation information of the permanent mandibular posterior teeth and later developmental stages of permanent maxillary and mandibular incisors (72). The incremental stages of permanent tooth development described by Moorrees *et al*., are shown in the schematic drawing and their associated descriptions are shown in Figure 4. This system of classification provides two separate development schemes, one for single rooted teeth illustrating 13 stages and the other for the molars having 14 stages of development. The difference is the addition of stage Cli representing the cleft formation in molars. The mean age and standard deviation were originally provided in a cumbersome and difficult to read graphical format for each tooth at every stage with separate graphs developed for males and females. The technique procedure requires to identify the tooth correctly, weigh up its proper stage of morphological development, subsequently to read the associated mean age and standard deviation from the gender-specific graph (65). In order to maintain examiner repeatability, it is recommended to record the highest stage of morphological development that has been attained and to avoid selecting the apparent closest stage when a tooth appears to be between stages (65). Careful tooth selection is an important factor affecting the result of accuracy. In cases where the third molar is the only tooth in an individual's dentition that is continuing to undergo maturation, adolescent third molar techniques should be considered. In addition, one needs to be aware of the fact that there is a greater variation in root development than in crown formation, and that some teeth inherently have a higher degree of developmental variation than others (73). Consequently, when selecting the teeth that are still undergoing the crown development and utilizing the teeth that are having smaller standard of deviations we should increase the accuracy of age estimation. Fortunately, the data from the original graphs have been translated into tables (Tables 4 through 5).

Similar studies have been carried out on other population specific groups in the United States and worldwide (74-76). An important finding of those studies was the order of variability in specific tooth development for males and females.

From the scientific literature, it has been observed that the first molar consistently provides the most accurate results (65). Since the data from the Anderson study refer to older children than the age estimation data in the Moorrees *et al*., study, this study is considered an alternative study to Moorrees *et al*., and should be considered when estimating the age of children in their later childhood and early adolescence. Moreover, the Moorrees's method also provides a full range of age estimation data beginning at birth, whereas most Demirjian's population studies begin to assess age between 2 and 3 years (65, 72, 77, 78).

Dental development was determined by inspecting radiographs and assigning a rating according to consecutive stages defined by Moorrees, Fanning and Hunt (1963) who scored all permanent teeth using 14 stages described by Moorrees *et al*., plus the crypt stage.

Subsequently, the mean ages, in units of logarithmic conception age, were transformed into chronologic age and the plus/minus one or two standard deviations of age limits were also calculated (69, 79, 80).

Willems's method. In order to improve the accuracy of the Demirjian's method (1973), Willems et al., 2001, modified the Demirjian's method to create a new method for dental age estimation based on a Belgian Caucasian reference population. The method uses the same A-H tooth staging technique of Demirjian et al., (1973), based on seven left mandibular teeth in order to generate a new scoring system for age estimation. However, Willems retained the staging technique that had been created by Demirjian et al., (1973), but he introduced new scores (69, 81). Tooth formation is divided into 8 stages and criteria of these stages for each tooth were given separately. Having noted all stages of teeth from central incisor to the second molar by the examiners, the developmental status of a particular tooth was calculated in years based on tables given by Willem's et al., shown in Table 6 (80). All of the values from central incisor to the second molar thus obtained were summed to obtain an overall maturity score, which will indicate the dental age of that particular patient. Developmental tooth stages with corresponding age scores expressed directly in years for each of the seven left mandibular teeth in boys and girls. Willems adopted the Demirjian's method by using weighted analysis of variance on a sample of OPGs from Belgian children and presented a tailored and simplified Demirjian's system, thus showing an increased accuracy of

determining chronological age based on dental age (69). According to some recent studies, the Willems's method was superior to Demirjian's (68, 78, 82, 83).

The Willem's method has been developed very well, which resulted in a mean age difference of 0.0 and 0.2 years for boys and girls respectively. The Demirjian's (1973) method had resulted in higher overestimation of 0.5 years for boys and 0.9 years for girls respectively (81). The Willem's method of age estimation has been tested in other populations and it has been found to perform better than the Demirjian *et al.*, (1973) method (68, 83, 84).

Cameriere**'s method.** Cameriere et al., (2006), took a completely different approach and published a mathematical formula for calculating dental age on teeth for some European countries. The method is based upon measuring the completeness of apical development by a computer method and all studies to date show a very strong correlation with chronological age. The Cameriere's method was based on the regression analysis of age as a dependent variable, and normalized measurements of open apices of the first seven mandibular teeth on the OPG, where gender and number of the teeth with finished maturation of root apices (No) are important dependent variables in calculating dental age (85). Furthermore, the teeth with uncompleted root development, and, therefore, with open apices, were considered. This method was applied as all teeth without completed root maturation should be analysed, and should measure the distance between the inner sides of open apices. The sum of the distances between the inner sides of the two open apices has to be calculated for teeth with two roots. The distances of open apices normalize by dividing them by the tooth length to minimize the effects of differences among X-rays in magnification and angulation (86). Age estimation is calculated by using the European regression formula (87). This method has been tested in several populations and the obtained results have shown that estimated dental age was significantly correlated with chronological age. Also, the results showed a significant difference among European countries, and for this reason this regression equation could not be applied to worldwide population such as the Indian population (88). In some countries, this method should be used together with other methods of age estimation to increase the accuracy (89). However, the Willems's method was slightly more accurate compared to the Cameriere's method, therefore, the authors recommend this method for practical application in clinical dentistry and forensic procedures (82, 86, 90).

1.6 The use of panoramic radiography in dental age estimation

Panoramic images have been commonly used in age estimation. They show a single tomographic image of the facial structures that includes jaws, dentition and their supporting structures. They are useful for assessing the development of the dentition in children. They are used to reveal conditions such as the deciduous teeth root resorption, development of the permanent teeth and tooth eruption pathway. Moreover, they are used in assessing the presence or the absence of developmental abnormalities, ankylosed and impacted teeth, to diagnose the presence and grade of oral pathology and evaluation of traumatic injuries (91). At University Dentistry Clinical Centre of Kosova, children commonly undergo a panoramic examination in order to assess and monitor growth and development of the teeth.

American Dental Association Council on Scientific Affairs (2006), recommends panoramic images for children who have evidence of eruption of the first tooth of permanent dentition which may occur at 5 – 7 years (92). Also, this Council recommends periapical or panoramic radiographs for adolescents to assess development of third molars. Therefore, it is easy to find OPG being routinely done for children. However, it is evident in previous studies that age estimation through OPG of children may not routinely be request for panoramic images of very young children, those above and below 5 years of age, hence examinations of younger age groups were not commonly available (82).

The ethical standards of taking radiographs was supported by giving the consent form before exposure to radiation (93, 94). However, dental radiographies require a very low dose of radiation, which is comparable to natural radiation (95, 96).

2. THE AIM AND THE HYPOTHESIS

2.1 The aim of the study

1. To evaluate time of mineralization of the permanent teeth from the upper and lower jaw of left side by using developmental stages in children and adolescents from Kosovo aged between 6 to 24.

2. To compare the accuracy of three different age estimation methods which use first seven teeth from mandible in children participants from Kosovo.

3. To correlate chronological age with dental age by using different dental age estimation method.

4. To correlate chronological age with the development by stages and open apices of lower third molars (third molar maturity index or I3M) from the left side of lower jaw.

5. To evaluate the open apices approach on lower left third molars for accurate discriminating participants between 18 years of age and older (adolescence) or under 18 years (children).

2.2 The hypothesis

1. The timing of mineralization stages of permanent teeth is within age ranges of children and adolescents of Caucasian origin from Europe, according to a literature.
2. There is no difference between the dental age estimated by methods of Demirjian, Willems, and Cameriere.
3. There is no difference among correlations of Demirjian‘s, Willems’ and Cameriere’s methods and chronological age.
4. There is no difference among correlations of third molar development evaluated by Cameriere’s third molar maturity index and chronological age.
5. There is no difference in accuracy of Cameriere's method of the open apices in discriminating participants between 18 years of age and older (adolescence) or under 18 years (children).

3. MATERIALS AND METHODS

3.1 The study area

The study was conducted in the UDCCK which is located in Pristina, Kosovo. It serves as a referral centre for management of dental and oral pathology.

3.1.1 Study population and sampling method

From previous records, 4514 people had digital panoramic imaging stored in the UDCCK radiology unit from March, 2011 to August, 2015. The sample consisted of 1952 OPGs collected from male and female subjects aged 6-24 years, who had visited the radiology unit since the installation of digital panoramic imaging machine in 2008. OPGs were retrieved as digitalized images from the local database. They were exported to JPEG format using the Sidexis Next generation imaging software, version 2.4®, integrated with the I-Max Touch Line: 220-240V-7A 50/60Hz max exposure time: 15s, produced by Owandy (OWANDY 6, allée Kepler 77420 Champs-sur-Marne - FRANCE) ®. All radiographs that satisfied the inclusion criteria were included in the study (Figure 2). The sample size was calculated using the formula for sample size determination while estimating the mean in a finite population. The confidence level (Cl) was set at 95%. The standard deviation and the margin of error were assumed to be 0.5 and ±5% respectively (97). The digital images were subsequently analysed using Corel DRAW (Graphics Suite X7, United States). During the analysis, 'Magnify' and 'Ruler' tools were used. The personal data were collected as follows: date of birth, date of radiography and gender.

3.1.2 Selection criteria

The OPGs that had been taken some time before were retrospectively collected and selected. They had to be diagnostically acceptable and at least the images of the teeth on one side of the mandible had to be clear to allow estimation of developmental stages. Any blurred images that had lost normal tooth outline due to geometric distortion or technical errors were excluded. Besides, the radiographs which had bilaterally missing mandibular teeth as well as dentition with features of developmental anomalies were excluded. Furthermore, panoramic images of patients aged above 24.99 years and those below 6.00 years were also eliminated. Eventually, any other form of dental imaging which was found in the patient' file such as intraoral periapical was not collected. Inclusion criteria were: Kosovar origin; age between 6 and 24 years; all teeth in lower jaw present; no obvious dental pathology on panoramic radiology related to the lower jaw. Exclusion criteria for OPGs were: incomplete dental

records including the absence of the recorded date of birth and the date of radiography; low-quality radiographs, OPGs without accompanying subject's full dental records; lack of the date when the OPGs were taken; severe destruction, extraction or hypodontia of permanent teeth and those OPGs with missing third molars (in a sample between the ages 12 and 24).

3.1.3 Determination of chronological age

The date of birth and the date of OPG were entered on a Microsoft 2010 excel worksheet. Chronological age (CA) of children was calculated as the difference between the date on which the OPG was taken and the birth date (rounded off to two decimal places), with age groups based on one-year increments.

3.1.4 Type of study

This is a cross-sectional study. It is a type of retrospective observational study that analyses the data collected from a population.

3.1.5 Training and preparation for data collection

The Ph.D. candidate (JK) was trained and calibrated before data collection and analysis. JK was taught how to identify seven developmental stages as outlined by Demirjian *et al*., Moorres and Willems age scores by professor Ivan Galič, from the University of Split and by professor Roberto Cameriere, for Cameriere's methodology according to the training course on "Age Estimation Anthropological Possibilities and Perspective", held at the University of Split on 9th and 10th December in 2016. Pre-testing of data collection form was done to minimize errors. It was a blind analysis of radiographs and the observer was not aware of chronological age and gender of the patient.

3.2 Determination of tooth maturity

3.2.1 Demirjian's methods

Each panoramic image was coded and given Arabic numerals, any patient identifiers were eliminated and radiographs were saved in one folder. All radiographs were estimated by the Ph.D. candidate and tooth maturity was determined by assessing the morphological appearance of teeth on OPGs. The stages of dental development were evaluated on the seven permanent teeth from the left side of the mandible, except third molars, according to Demirjian et al. (67). Briefly, dental development of permanent teeth was divided into eight mineralization stages (A to H), from cone-shaped calcifications of the upper portion of the crypt or stage A to fully closed apices or stage H. Subsequently, they were staged according to the Demirjian (1973) maturity chart and tooth description that are shown in Figure 2 and Figure 3. Demirjian classified the development of teeth into 8 stages and he created an age estimation method (67). Based on developmental stages, each tooth was given an appropriate score. The score assigned for each of the 8 teeth is added and a Total Maturity Score (S) was obtained as shown in Table 2 and Table 3 (98). The time mineralization of within stages of all evaluated teeth was presented as mean, standard deviation and additionally minimum age of last stage ‘H’ was recorded. Independent samples T test tested a possible difference in age between genders at each stage. For the Demirjian’s method from 1973 (Dem73), dental age was calculated by the specific self-weighted scores for dental stages to calculate the maturity score which was converted to dental age by using the conversion tables (82).

The specific maturity scores for dental stages were used for the three Demirjian’s methods from 1976 (83, 99). One method uses the same seven teeth (Dem76). Two methods use the sets of four teeth, one uses both premolars and both molars, PM2, PM1, M1, and M2, (Dem76PM2), and another uses both premolars, second molar and the first incisor, PM1, PM2, M2 and I1 (Dem76IN1) (30, 99).

All OPGs were examined by the blind approach, without the possibility to evaluate age and gender.

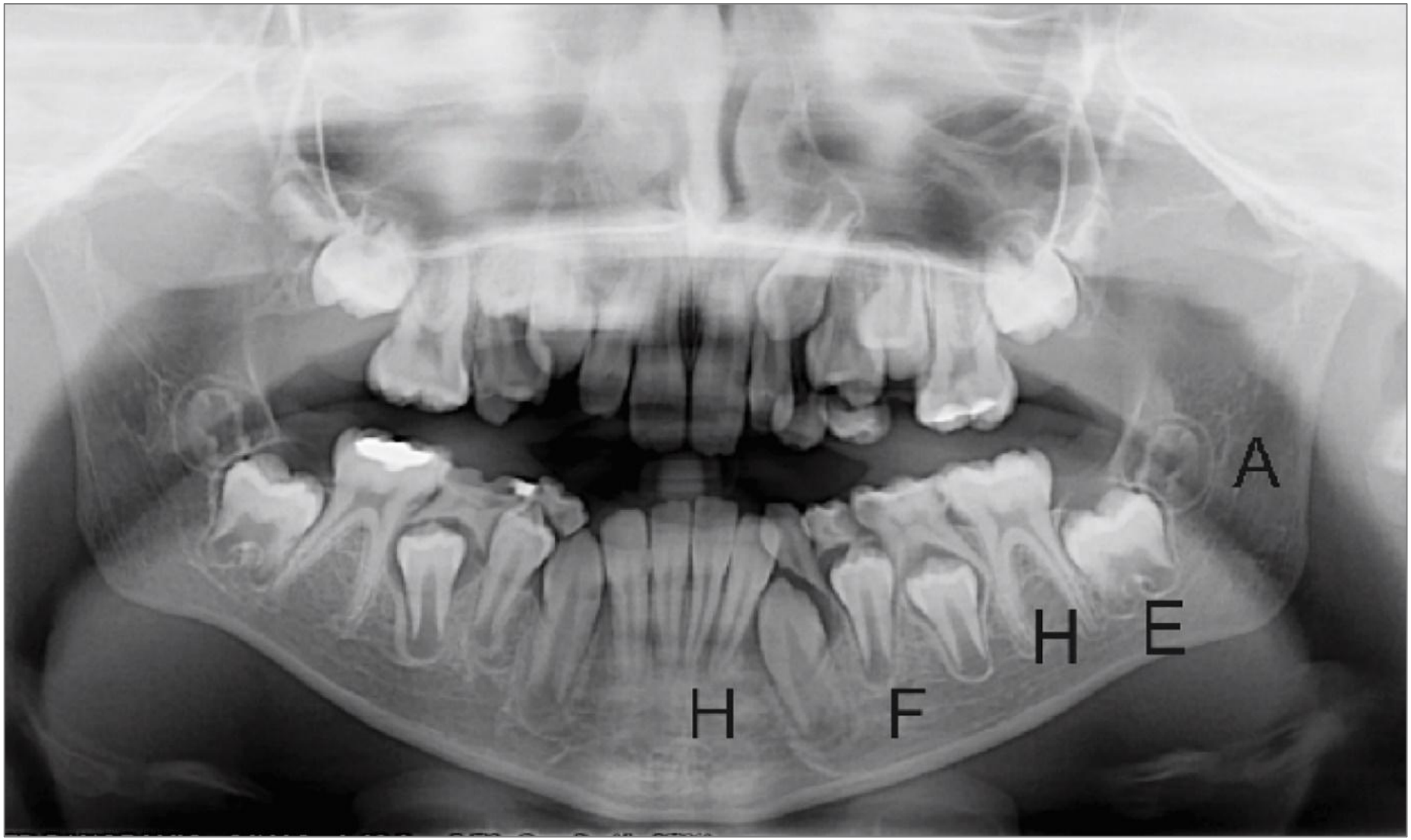

Figure 2. Demonstration of mineralisation A, E, F and H stages on orthopantomography by Demirjian's method

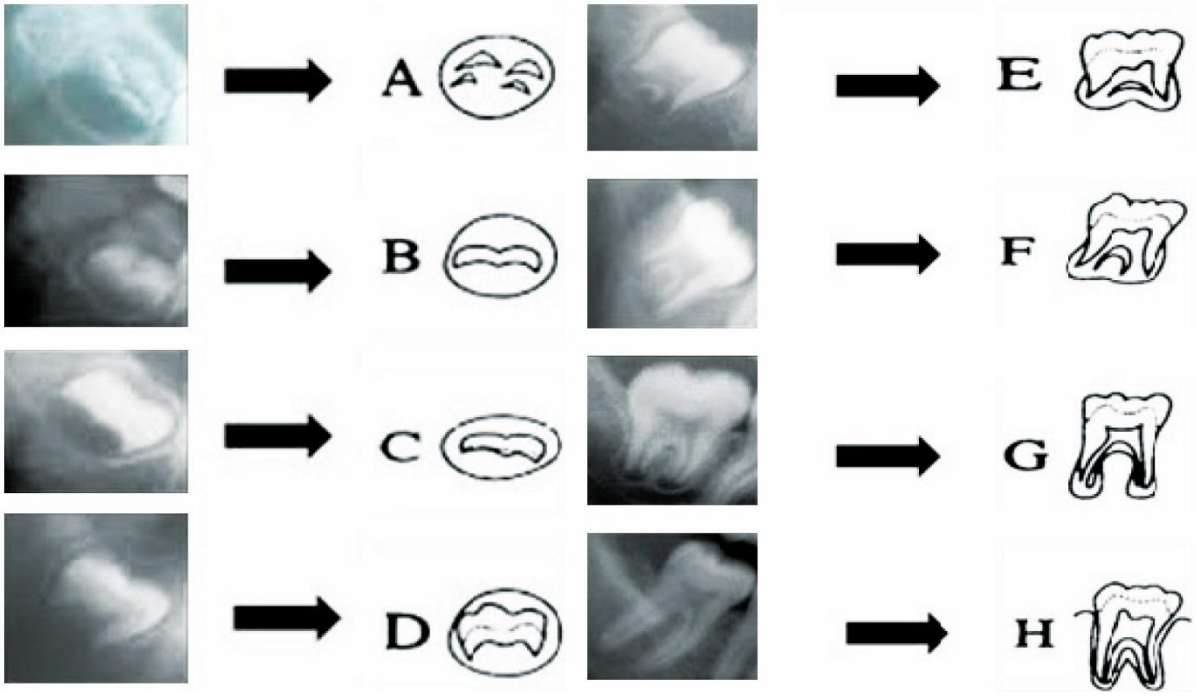

Figure 3. Demonstration of mineralisation stages by Demirjian's method. **Stage A:** Calcification of single occlusal points without fusion of different calcifications. **Stage B:** Fusion of mineralization points: the contour of the occlusal surface is recognizable. **Stage C:** Enamel formation has been completed at the occlusal surface, and dentine formation has commenced. The pulp chamber is curved, no pulp horns visible. **Stage D:** Enamel formation has been completed to the level of the amelocemental junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of pulp chamber remain curved. **Stage E**: The root length remains shorter than the crown height. The walls of pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stage. In molars, the radicular bifurcation has commenced to calcify. **Stage F:** The walls of pulp chamber now form an isosceles triangle, and the root length is equal to or greater than the crown height. In molars the bifurcation has developed sufficiently to give the roots a distinct form. **Stage G:** The walls of the root canal are now parallel, but the apical end is partially open. In molars, only the distal root is separated. **Stage H:** The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout (99).

Table 2. Conversion of maturity scores to dental age – girls (99)

Age	Score	Age	Score	Age	Score	Age	Score
3.0	13.7	**7.0**	51.0	**11.0**	94.5	**15.0**	99.2
.1	14.4	.1	52.9	.1	94.7	.1	99.3
.2	15.1	.2	55.5	.2	94.1	.2	99.4
.3	15.8	.3	57.8	.3	95.1	.3	99.4
.4	16.6	.4	61.0	.4	95.3	.4	99.5
.5	17.3	.5	65.0	.5	95.4	.5	99.6
.6	18.0	.6	68.0	.6	95.6	.6	99.6
.7	18.8	.7	71.0	.7	95.8	.7	99.7
.8	19.5	.8	75.0	.8	96.0	.8	99.8
.9	20.3	.9	77.0	.9	96.2	.9	99.9
4.0	21.0	**8.0**	78.8	**12.0**	96.3	**16.0**	100.0
.1	21.8	.1	80.2	.1	96.4		
.2	22.8	.2	81.2	.2	96.5		
.3	22.5	.3	82.2	.3	86.6		
.4	23.2	.4	83.1	.4	96.7		
.5	24.0	.5	84.8	.5	96.8		
.6	24.8	.6	84.8	.6	96.9		
.7	25.6	.7	85.3	.7	97.0		
.8	26.4	.8	86.1	.8	97.1		
.9	27.2	.9	86.7	.9	97.2		
5.0	28.0	**9.0**	87.2	**13.0**	97.3		
.1	28.9	.1	87.8	.1	97.4		
.2	29.7	.2	88.3	.2	97.5		
.3	30.5	.3	88.8	.3	97.6		
.4	31.3	.4	89.3	.4	97.7		
.5	32.1	.5	89.8	.5	97.8		
.6	33.0	.6	90.2	.6	98.0		
.7	34.0	.7	90.7	.7	98.1		
.8	35.1	.8	91.1	.8	98.2		
.9	36.8	.9	91.4	.9	98.3		
6.0	37.0	**10.0**	91.8	**14.0**	98.3		
.1	38.0	.1	92.1	.1	98.4		
.2	39.1	.2	92.3	.2	98.5		
.3	40.2	.3	92.6	.3	98.6		
.4	41.3	.4	92.9	.4	98.7		
.5	42.5	.5	93.2	.5	98.8		
.6	43.9	.6	93.5	.6	98.9		
.7	46.7	.7	93.7	.7	99.0		
.8	48.0	.8	94.0	.8	99.1		
.9	49.5	.9	94.2	.9	99.1		

Table 3. Conversion of maturity scores to dental age – boys (99)

Age	Score	Age	Score	Age	Score	Age	Score
3.0	12.4	**7.0**	46.7	**11.0**	92.0	**15.0**	97.6
.1	12.9	.1	48.3	.1	92.2	.1	97.7
.2	13.5	.2	50.0	.2	92.5	.2	97.8
.3	14.0	.3	52.0	.3	92.7	.3	97.8
.4	14.5	.4	54.3	.4	92.9	.4	97.9
.5	15.0	.5	56.8	.5	93.1	.5	98.0
.6	15.6	.6	59.6	.6	93.3	.6	98.1
.7	16.2	.7	62.5	.7	93.5	.7	98.2
.8	17.0	.8	66.0	.8	93.7	.8	98.2
.9	17.6	.9	69.0	.9	93.9	.9	98.3
4.0	18.2	**8.0**	71.6	**12.0**	94.0	**16.0**	98.4
.1	18.9	.1	73.5	.1	94.0		
.2	19.7	.2	75.1	.2	94.4		
.3	20.4	.3	76.4	.3	94.5		
.4	21.0	.4	77.7	.4	94.6		
.5	21.7	.5	79.0	.5	94.8		
.6	22.4	.6	80.2	.6	95.0		
.7	23.1	.7	81.2	.7	95.1		
.8	23.8	.8	82.0	.8	95.2		
.9	24.6	.9	82.8	.9	95.4		
5.0	25.4	**9.0**	83.6	**13.0**	95.6		
.1	26.2	.1	84.3	.1	95.7		
.2	27.0	.2	85.0	.2	95.8		
.3	27F	.3	85.6	.3	95.9		
.4	28.6	.4	86.2	.4	96.0		
.5	29.5	.5	86.7	.5	96.1		
.6	30.3	.6	87.2	.6	96.2		
.7	31.1	.7	87.7	.7	96.3		
.8	31.8	.8	88.2	.8	96.4		
.9	32.6	.9	98.6	.9	96.5		
6.0	33.6	**10.0**	89.0	**14.0**	96.0		
.1	34.7	.1	89.3	.1	96.7		
.2	35.8	.2	89.7	.2	96.8		
.3	36.9	.3	90.0	.3	96.9		
.4	38.0	.4	90.3	.4	97.0		
.5	39.2	.5	90.6	.5	97.1		
.6	40.6	.6	91.1	.6	97.2		
.7	42.0	.7	91.6	.7	97.3		
.8	43.6	.8	91.6	.8	97.4		
.9	45.1	.9	91.8	.9	97.5		

3.2.2 Moorrees 's method

Dental development was determined by inspecting radiographs and assigning a rating according to consecutive stages defined and shown in Figure 4 as follows: (a) for single-rooted teeth, and (b) for multiple-rooted teeth. According to Moorrees, Fanning and Hunt (1963), all permanent teeth were scored using 14 stages as described by Moorrees *et al*., plus the crypt stage.

Subsequently, these mean ages, in units of logarithmic conception age, were transformed into chronological age, and plus and minus one and two standard deviation age limits were also calculated.

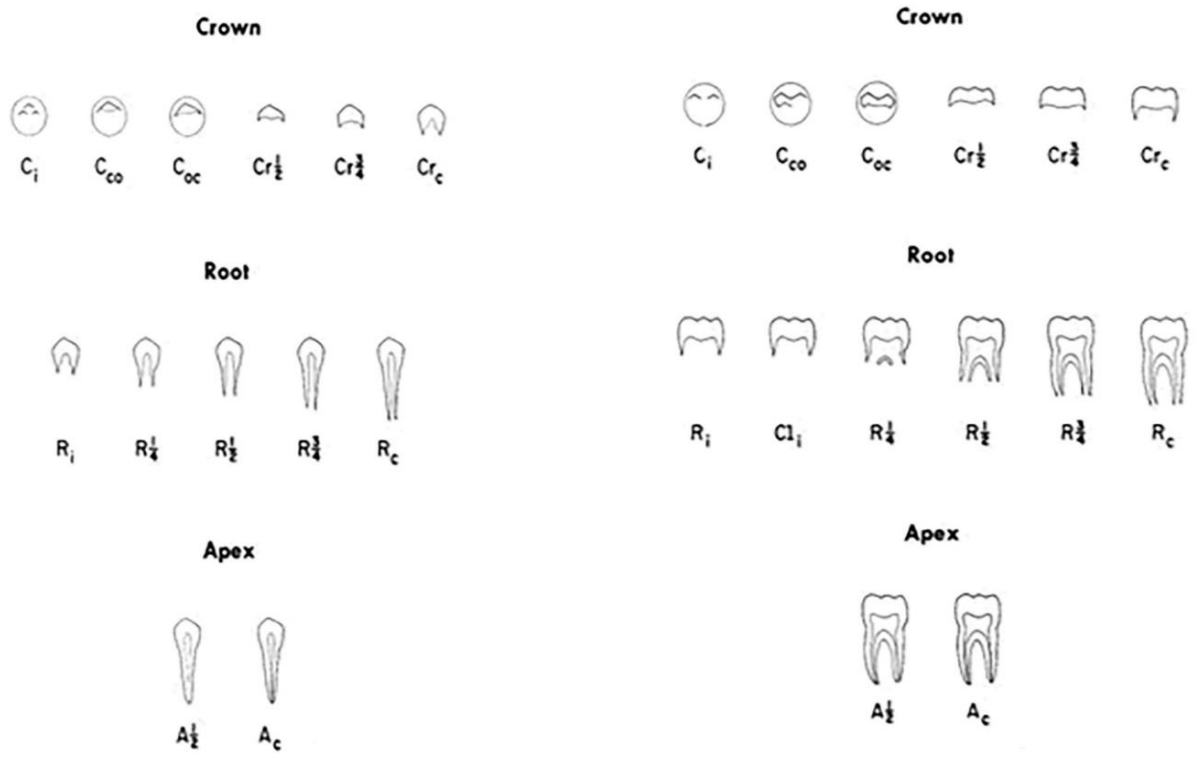

Figure 4. Tooth-formation stages and definition of abbreviations (72). **(a)** single rooted tooth, **(b)** multiple rooted tooth

C_i, initial cusp formation; **C_{CO}**, coalescence of cusps; **C_{OC}**, cusp outline complete; **$Cr_{1/2}$**, crown 1/2 complete; **Cr ¾**, crown 3/4 complete; **Cr_C**, Crown complete; **Ri**, Root - Initial root formation; **Cl_i**, Initial cleft formation; **$R_{1/4}$**, Root 1/4 length; **$R_{1/2}$**, Root 1/2 length; **$R_{3/4}$**, Root 3/4 length; **R_C**, Root length complete; **$A_{1/2}$**, Apex 1/2 closure; **A_C**, Apical closure complete.

Table 4. Mean age of attainment of developmental stages for girls (65)

STAGE	31		32		33		34		35		36		37		38		21		22	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ci					0.5	0.12	1.7	0.24	2.9	0.35	0.1	0.05	3.5	0.41	9.6					
Cco					0.7	0.15	2.2	0.28	3.5	0.40	0.2	0.09	3.8	0.43	10.1	1.05				
Coc					1.2	0.18	2.9	0.35	4.1	0.47	0.7	0.14	4.3	0.49	10.7	1.11				
Cr½					1.9	0.25	3.5	0.41	4.7	0.53	1.0	0.17	4.8	0.54	11.3	1.17				
Cr¾					2.9	0.35	4.2	0.49	5.3	0.59	1.4	0.20	5.4	0.59	11.7	1.20				
Crc					3.9	0.45	5.0	0.56	6.2	0.66	2.2	0.28	6.2	0.68	12.3	1.27	4.9	0.54	5.7	0.62
Ri					4.7	0.52	5.7	0.63	6.7	0.73	2.6	0.32	7.0	0.75	12.9	1.32				
Cli											3.5	0.41	7.8	0.83	13.5	1.39				
R¼	4.5	0.51	4.7	0.53	5.3	0.57	6.5	0.69	7.5	0.79	4.6	0.52	9.1	0.96	14.9	1.53	6.0	0.66	6.6	071
R½	5.1	0.57	5.9	0.65	7.1	0.75	8.1	0.86	8.7	0.92	5.1	0.57	9.8	1.01	15.8	1.62	6.6	0.71	7.2	0.76
$R^{2/3}$	5.6	0.62	6.3	0.68													7.1	0.76	7.7	0.82
R¾	6.1	0.66	6.7	0.72	8.3	0.88	8.8	0.97	10.0	1.05	5.5	0.60	10.5	1.09	16.4	1.67	7.6	0.81	8.3	0.87
Rc	6.6	0.72	7.6	0.80	8.8	0.93	9.9	1.03	10.6	1.12	5.9	0.63	11.0	1.13	17.0	1.71	8.2	0.86	9.1	
A½	7.4	0.79	8.1	0.86	9.9	1.03	11.0	1.15	12.0	1.24	6.5	0.71	12.0	1.23	18.0	1.82	8.9	0.93	9.6	0.99
Ac	7.7	0.82	8.5	0.89	11.3	1.18	12.1	1.26	13.6	1.40	8.0	0.85	13.8	1.43	20.1	2.01				

Source: Data adopted from Manual of Forensic Odontology Fifth Edition, edited by David R.Senn, Richard A. Weems, Age Estimation p.225

Table 5. Mean age of attainment of developmental stages for boys (65)

STAGE	31		32		33		34		35		36		37		38		21		22	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ci					0.5	0.11	1.8	0.24	3.0	0.37	0.0	0.09	3.7	0.41	9.2	0.98				
Cco					0.8	0.15	2.3	0.31	3.5	0.42	0.2	0.11	4.0	0.43	9.7	1.01				
Coc					1.2	0.19	2.9	0.36	4.2	0.48	0.5	0.11	4.8	0.49	10.3	1.07				
Cr½					2.1	0.27	3.6	0.43	4.7	0.53	1.0	0.17	5.1	0.54	10.9	1.14				
Cr¾					2.9	0.35	4.4	0.52	5.3	0.59	1.5	0.21	5.7	0.59	11.6	1.20				
Crc					4.0	0.46	5.2	0.58	6.2	0.69	2.1	0.29	6.5	0.68	12.0	1.24	5.3	0.59	5.9	0.64
Ri					4.8	0.55	5.8	0.64	6.9	0.74	2.7	0.34	7.1	0.75	12.7	1.32				
Cli											3.5	0.41	8.1	0.83	13.6	1.41				
R¼			5.3	0.60	5.7	0.63	6.8	0.74	7.8	0.83	4.7	0.53	9.3	0.96	14.6	1.50	6.3	0.68	6.9	075
R½	5.2	0.59	6.2	0.68	8.0	0.86	8.5	0.91	9.4	0.99	5.1	0.57	10.1	1.01	15.1	1.54	6.9	0.74	7.6	0.80
$R^{2/3}$	5.8	0.64	6.8	0.74													7.6	0.80	8.1	0.86
R¾	6.4	0.70	7.4	0.78	9.6	1.00	9.9	1.04	10.8	1.13	5.4	0.61	10.8	1.09	15.9	1.62	8.1	0.85	8.7	0.91
Rc	7.0	0.75	8.0	0.84	10.2	1.06	10.3	1.09	11.5	1.21	5.8	0.64	11.3	1.13	16.3	1.67	8.6	0.90	9.6	1.01
A½	7.7	0.81	8.5	0.90	11.8	1.23	11.9	1.24	12.7	1.30	6.9	0.75	12.2	1.23	17.6	1.79				
Ac	8.1	0.85	9.3	0.98	13.0	1.35	13.3	1.38	14.2	1.46	8.5	0.91	14.2	1.43	19.2	1.95				

Source: Data adopted from Manual of Forensic Odontology Fifth Edition, edited by David R.Senn, Richard A. Weems, Age Estimation; p. 226

3.2.3 Willems's method

The stages of tooth development that were previously identified were then assigned the corresponding age scores using the Willems age score tables shown in Table 6. It is worth mentioning that there are different scores for girls and boys. The scores for the seven teeth were summed up to give the estimated dental age for a particular individual. Having noted all stages of teeth from the central incisor to the second molar by examiners, the developmental status of a particular tooth was calculated in years based on tables given by Willems et al., (80). All the values from the central incisor to the second molar that were obtained in this manner were summed up to obtain an overall maturity score, which would indicate the DA of that particular patient. Developmental tooth stages with corresponding age scores were expressed directly in years for each of the seven left mandibular teeth in boys and in girls.

Table 6. Williams's dental maturity score for girls and boys (100)

Gender	Tooth	Stages							
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Girls	CI (31)*			1.83	2.19	2.34	2.82	3.19	3.14
	LI (32)				0.29	0.32	0.49	0.79	0.70
	C (33)			0.60	0.54	0.62	1.08	1.72	2.00
	P1 (34)	-0.95	-0.15	0.16	0.41	0.60	1.27	1.58	2.19
	P2 (35)	-0.19	0.01	0.27	0.17	0.35	0.35	0.55	1.51
	M1 (36)	-	-	-	0.62	0.90	1.56	1.82	2.21
	M2 (37)	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04
Boys	CI (31)			1.68	1.49	1.50	1.86	2.07	2.19
	LI (32)			0.55	0.63	0.74	1.08	1.32	1.64
	C (33)				0.04	0.31	0.47	1.09	1.90
	P1 (34)	0.15	0.56	0.75	1.11	1.48	2.03	2.43	2.83
	P2 (35)	0.08	0.05	0.12	0.27	0.33	0.45	0.40	1.15
	M1 (36)				0.69	1.14	1.60	1.95	2.15
	M2 (37)	0.18	0.48	0.71	0.80	1.31	2.00	2.48	4.17

*Tags according to Federation Dentaire International (FDI), CI- central incisor, LI- lateral incisor, C- canine, PM1-first premolar, PM2-second premolar, M1-first molar, M2-second molar

3.2.4 Cameriere's method

The Cameriere method was based on the regression analysis of age as a dependent variable, and normalized measurements of open apices of the first seven mandibular teeth on the OPG, where gender and number of teeth with finished maturation of the root apex are important dependent variables in calculating DA. All teeth without completed root maturation were analysed, and the distance between the inner side of the open apices (Ai, i=1… 5) was measured, which is shown in Figure 6.

The sum of the distances between the inner sides of the two open apices was calculated for teeth with two roots (Ai, i=6, 7). Distances of open apices were normalized by dividing by the tooth length (Li, i=1… 7) to minimize the effects of differences among X-rays in magnification and angulation, (Figure 5).

Firstly, dental age estimation was measured by using Cameriere's European regression formula:

Age = 9.402 - 0.879 × c + 0.663 × No - 0.711×s - 0.106 × s × No,

- C = variable boys (1) and girls (0), where
- No: teeth with apical ends of the roots completely closed.
- s: the sum of A/L ratio for every tooth at an open apex.

The above mentioned Cameriere's regression formula for a Kosovo sample underestimates dental age for about two years. For this reason, dental age has been estimated by the same predictors for the Kosovo sample but for all eight teeth on the left side of the lower jaw. The following regression formula was obtained:

Age = 7.396 - 0.517 × c + 0.943 × No - 0.078×s - 0.071 × s × No

with the determination coefficient R2 = 0.817 and 81.7%, respectively. Statistically significant are all coefficients of regression ($p < 0.001$), with the exception of the coefficient with "s" ($p = 0.203$). The greatest impact had "No" with standardized coefficient 0.793, with × No with standardized coefficient 0.121, and gender with standardized coefficient 0.108.

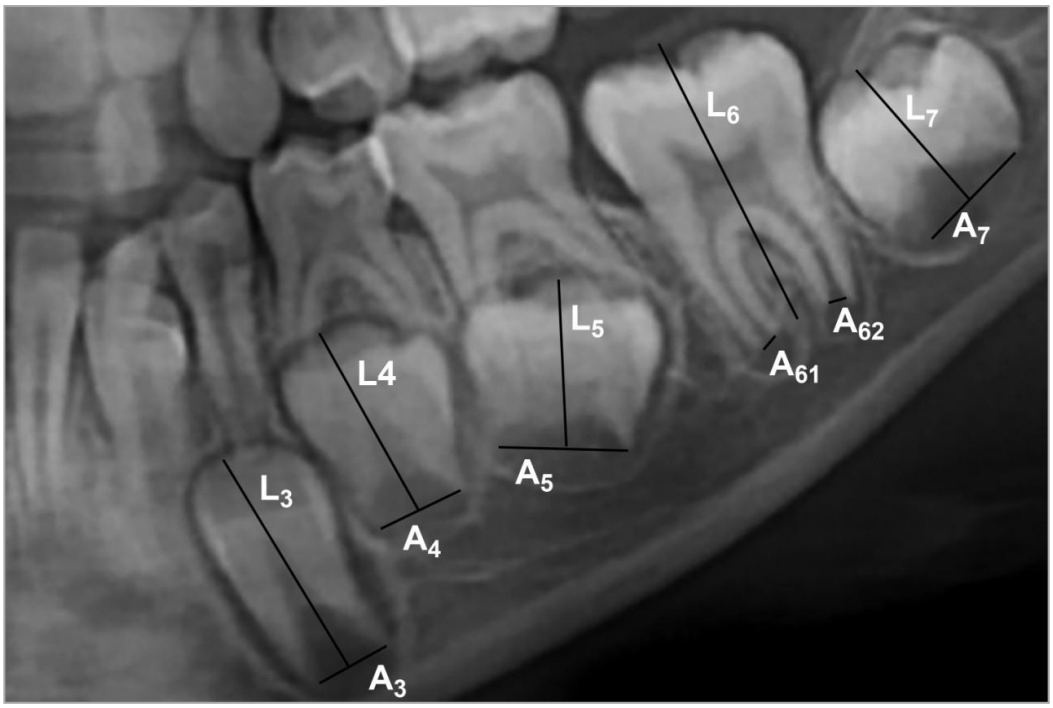

Figure 5. An example of tooth measurement. A=1, ..., 5 (teeth with one root), is the distance between the inner sides of the open apex; A6 (teeth with two roots), is the sum of the distances between the inner sides of the two open apices; and L=1, ..., 7, is the length of the seven teeth

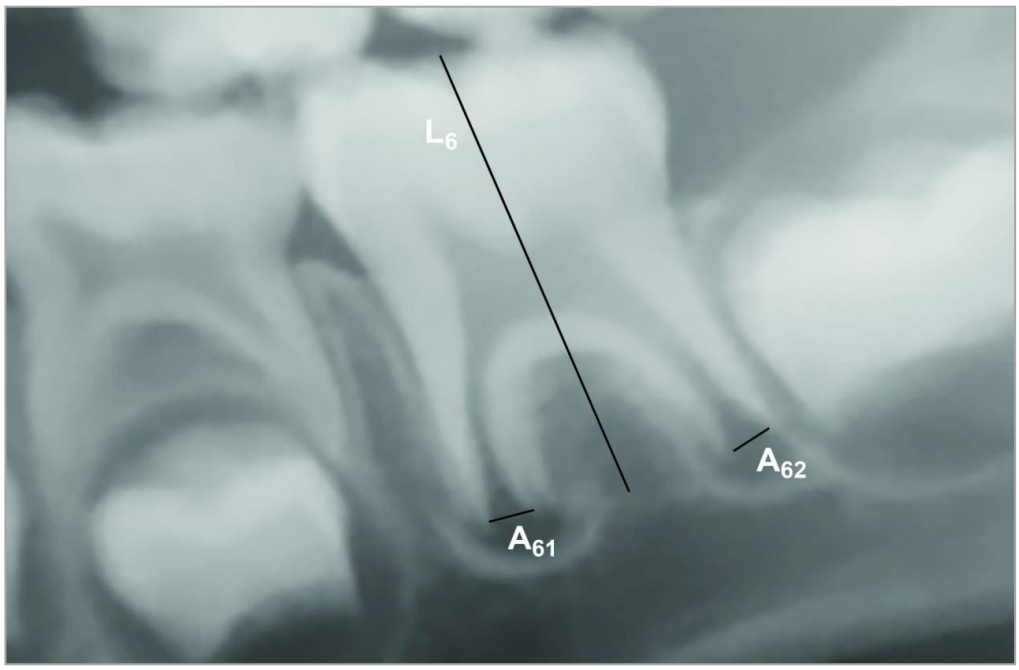

Figure 6. An example of measurement of a tooth with two roots. A6 is the sum of the distances (A6 = A61 + A62) between the inner sides of the two open apices, and L6 is the length of the first molar

The third molar maturity index by Cameriere's method

The developing lower left third molars on the OPG were analysed. Dental age estimation was performed according to the method of Cameriere et al.(101). Briefly, the projections of the apical end of the roots of the left lower third molar of the individual were measured. The I_3M was explained as follows: if the root development of the third molar is complete, i.e., there is no possibility to measure open apices on the projections on OPG, then I_3M is equal to 0.0. Then, I_3M is evaluated as the sum of the distances between the inner sides of the two open apices divided by the tooth length. I_3M is calculated in a similar way to the ratio Ai to Li, when i = 6,7, as described for the teeth with two roots in Cameriere et al. Both impacted and non-impacted third molars were included in this research, only if their roots were radiographically visible (64, 102, 103).

3.3 Data analysis

The calculation of results and statistical analysis were done using Microsoft Excel (MS Office 2010 Microsoft Corp., Redmond, WA, USA) and the Statistical Package for Social Science (SPSS) version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). The analysis was categorized as descriptive and inferential statistics. Time mineralization of stages of all evaluated teeth was presented as mean, standard deviation, median, minimum and maximum value. Inferential statistics consisted of CI, standard error, parametric and non-parametric tests. The statistical significance of the mean difference between chronological and estimated age was measured using the paired-samples t-test and 95% of CI. The difference between the corresponding antagonists as well the same type of teeth between gender was tested by the independent samples t-test. One sample t-test compared chronological age and dental age for Demirjian's, Willems's and Cameriere's methods independently for male and female Kosovar population between 6 and 24 years of age. Males and females were compared using the independent t-test. The Pearson's correlation coefficient was used to evaluate the correlation between dental age by Demirjian's, Willems's and Cameriere's methods and chronological age. The Spearman's correlation coefficient was used to evaluate the correlation between developmental stages by Demirjian, Moorrees, Willems and Cameriere and chronological age, whereas the third molar maturity index was evaluated by Pearson's coefficient. The A 2x2 contingency table was used to test the accuracy of classification, of specific Demirjian and Moorrees stages and previously tested cut-off value (I3M=0.08) for the third molar

maturity index, in participants: those who were 18 years of age and older or younger than 18 years. One-way ANOVA was used to compare different methods for dental age estimation.

3.4 Reproducibility test

Intra-observer reproducibility for mineralization stages of both staging methods, as well as measuring or open apices by Cameriere were assessed. A total of 50 OPGs, were randomly selected and assessed after a three-months interval between the first and second assessment by (JK) to find the intra-rater agreement and also were evaluated after two weeks from first evaluation by another examiner (IG) to find inter-rater agreement. The Cohen's kappa value for mineralization stages and the intra-class correlation coefficient (ICC) for the measures of the open apices were calculated (104).

3.5 Ethical considerations

The proposal was presented to the UDCCK's Ethics and Research Committee for approval by the request of Professor Ferit Kocani, PhD, on October 28, 2015. The approval was granted under the approval number 378 on November 4, 2016. The approval to carry out the study was sought from the Chairman of the Ethics Committee in University Dentistry Clinical Centre. Data were corrected retrospectively from clinical records that had already been consented to be used for research since UDCCK is a research and teaching hospital. The study did not involve examination of patients. The research was also approved by the Senate of the University of Zagreb, Class: 643-03/16-07/75, reference number: 380-130/134-16-2 Zagreb, 15 June 2016. Patients' parents or guardians had to sign an agreement with the University Dentistry Clinical Centre of Kosovo provided that dental records and radiographs could only be used for research and educational purposes without any possibility of jeopardizing their confidentiality and study was in agreement with the ethical standards imposed by the Declaration of Helsinki (105).

4. RESULTS

4.1 Samples and reliability of measurements

The overall sample consisted of 1952 OPGs belonging to children and adolescents from a Kosovo population aged 6 to 24 years. Since the suggested methods of age estimation evaluate only the data up to 16 years of age, the sample was divided into two age groups, from 6 to 16 and 17 to 24 years of age. The distribution of OPGs by age and gender is given in Table 7. In addition to frequencies, the number of OPGs, in which the mineralization of the first seven teeth on the left side of the lower jaw is completed, is expressed in brackets. It can be observed that mineralization is completed after 16 years of age in the most majority of subjects. According to the Chi-Square test, the proportion of genders in chronological age is similar for both groups of OPGs: for a total sample of 6 to 24 years, the Chi-Square = 25.819, df = 18, p = 0.104 and for a sample of 6 to 16, the Chi-Square = 7.552, df = 10, p = 0.673.

Table 7. Panoramic radiographs from Kosovo, number in parenthesis represent samples with completed mineralization of seven mandibular teeth from the left side

Age groups	Gender					
	Females		Males		Total	
6	15		12		27	
7	21		31		52	
8	47		49		96	
9	51		47		98	
10	63		49		112	
11	65		58		123	
12	61	(1)	48	(0)	109	(1)
13	66	(2)	66	(2)	132	(4)
14	70	(15)	64	(11)	134	(26)
15	52	(34)	54	(18)	106	(52)
16	52	(47)	65	(34)	117	(81)
Total	563	(99)	543	(65)	1106	(164)
17	67	(62)	56	(37)	123	(99)
18	69	(67)	55	(34)	124	(101)
19	60	(60)	47	(42)	107	(102)
20	66	(66)	56	(53)	122	(119)
21	33	(33)	59	(56)	92	(89)
22	26	(26)	45	(45)	71	(71)
23	54	(54)	44	(44)	98	(98)
24	54	(54)	55	(55)	109	(109)
Total	429	(422)	417	(366)	846	(788)
Grand total	992	(521)	960	(431)	1952	(952)

Inter and intra-observer repeatability of the estimation of development stages according to the Demirjian's method, the Moorrees's method and by Cameriere's method was performed on a randomized sample of 50 OPGs by the Ph.D. candidate, which was repeated after three months by the author, also after two weeks of first assessment the randomized sample was preformed from another examiner (IG). Repeatability of assessment of development stages was carried out using a kappa coefficient.

In Table 8, there are Kappa coefficients for each tooth and average rates for all seven teeth. According to Altman, the coefficients of 0.600 to 0.800 are good repeatability scores, which is the case in this research.

Table 8. Intra-observer repeatability of the estimation of developmental stages according to the Demirjian, Moorrees and Camerier methods for 47 OPGs

Methods	**Tooth***							**Mean**
	31	**32**	**33**	**34**	**35**	**36**	**37**	
Demirjian's methods	0,787	0,857	0,643	0,696	0,622	0,783	0,790	0,740
Moorrees's methods	0,743	0,782	0,638	0,665	0,595	0,617	0,703	0,678
Camerier's methods	0.87	0.96	0.89	0.82	0.79	0.70	0.70	0.82
Inter observer (kappa)	0.82	0.78	0.82	0.88	0.80	0.72	0.82	0.81

* Tags by Federation Dentaire International (FDI)

4.2 Dental age estimation by Demirjian's methods with dental maturity scores for French Canadian population

An estimation of dental age of young people from the Kosovo population was made according to the Demirjian's method published in 1973 for the French Canadian population (67). According to this method, a maturity score was assigned to each of the first seven teeth of the lower jaw, particularly for female and male subjects (OPGs), according to the stage of development of the tooth, shown in Table 9. The total number of these scores (OPGs) gives the Demirjian maturity score for girls and boys.

Table 9. Demirjian's maturity scores for girls and boys (81)

Gender	Tooth	Stages							
		A	B	C	D	E	F	G	H
Girls	M2 (37)*	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
	M1 (36)			0.0	4.5	6.2	9.0	14.0	16.2
	PM2 (35)	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
	PM1 (34)		0.0	3.7	7.5	11.8	13.1	13.4	14.1
	C (33)			0.0	3.8	5.6	10.3	11.6	12.4
	LI (32)			0.0	3.2	5.6	8.0	12.2	14.2
	CI (31)				0.0	2.4	5.1	9.3	12.9
Boys	M2 (37)	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
	M1 (36)			0.0	8.0	9.6	12.3	17.0	19.3
	PM2 (35)	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
	PM1 (34)		0.0	3.4	7.0	11.0	12.3	12.7	13.5
	C (33)			0.0	3.5	7.9	10.0	11.0	11.9
	LI (32)				3.2	5.2	7.8	11.7	13.7
	CI (31)				0.0	1.9	4.1	8.2	11.8

*Tags by FDI, CI- central incisor, LI- lateral incisor, C- canine, PM1-first premolar, PM2-second premolar, M1-first molar, M2-second molar

Conversion of maturity score to dental age was made with using the scores from Tables 2 and Table 3, which were also published in the cited article by Demirjian and colleagues, for boys and girls, respectively (81).

The distribution of the maturity score of Kosovo sample subjects, estimated according to maturity scores for the French Canadian population by the Demirjian's method, is chronologically shown by scatter plots, particularly by gender, in Figure 7. The same distribution of estimated dental age is shown in Figure 8.

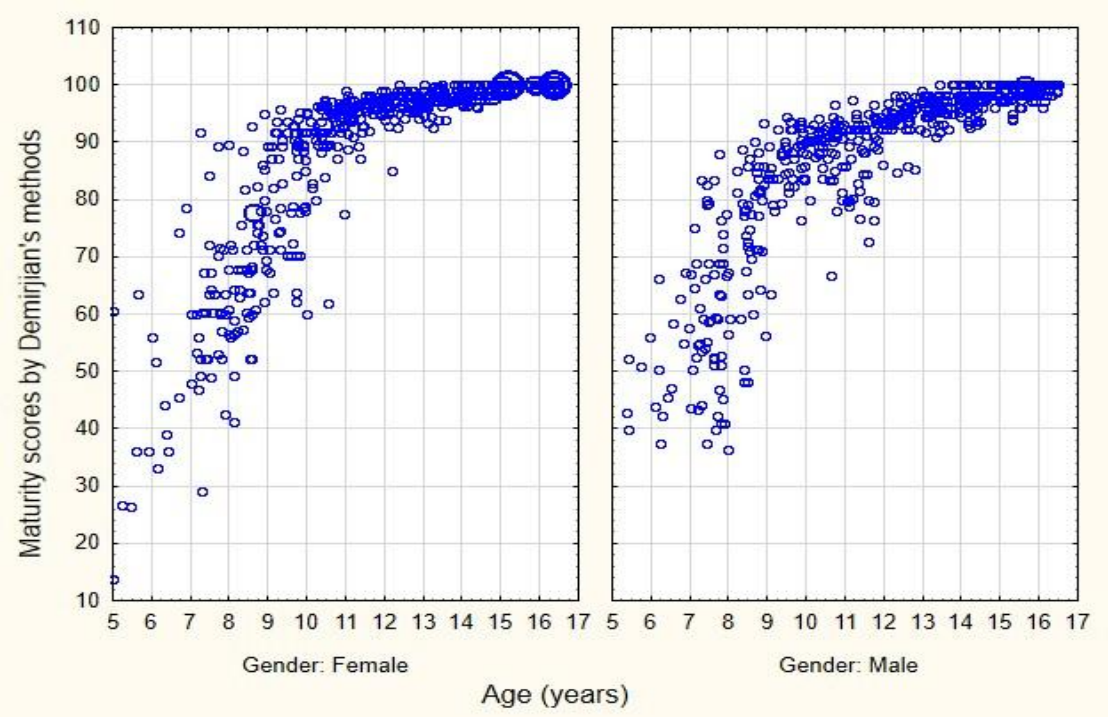

Figure 7. Scatterplot of the dental maturity scores by the Demirjian's method with maturity scores for a French Canadian population by age, according to gender

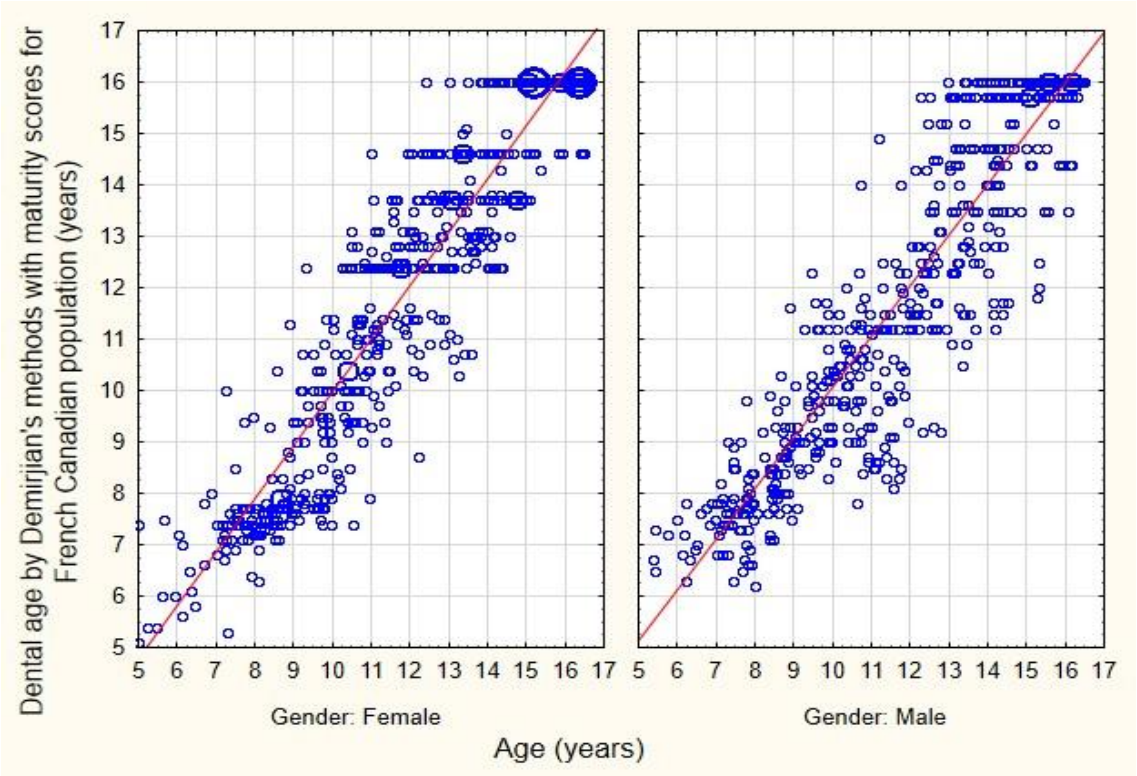

Figure 8. Scatterplots of dental age by the Demirjian's method with maturity scores for a French Canadian population by age, according to gender

The size of the circles in Figure 7 and Figure 8 indicate the frequency in the respective age group.

The Spearman's correlation coefficient of dental age according to Demirjian's maturity score for the French Canadian population with chronological age is for girls 0.926 ($n = 563$, $p < 0.001$) and 0.918 ($n = 543$, $p < 0.001$) for boys. Accordingly, the estimation of dental age of a Kosovo sample by maturity score for the French Canadian population shows a high correlation with chronological age for both genders despite noticeable individual deviations (Figure 8).

The distribution of dental age by the Demirjian's method according to the Kolmogorov-Smirnov test does not follow a normal distribution, which is clearly visible in Figure 9. The differences between the chronological age and dental age, estimated by the Demirjian's method with maturity scores for the French Canadian population, have not been found in either individual age or total age. For this reason, only basic parameters of these two key variables of this research (N, Mean, SD) are shown in Table 10. From the average values themselves, it is clear that there is a great correspondence among the average values between genders overall years of life.

The coefficients of variation are ranged from very low, 2.65% to moderate, 15.41% for individual age groups. Obviously, the total amount of the sample, in both genders is significantly higher, about 26%.

The basic aim of this study was to explore several methods for evaluating dental age and to check their correlation with chronological age and the correlation between them. This was done by examining the differences between them pair by pair.

Dental age differences obtained using the Demirjian's method with maturity scores for the French Canadian population and chronological age are on appearance an acceptable normal distribution (Figure 9). However, according to the results of the Kolmogorov-Smirnov's test, the hypothesis on normality of distribution is valid only for a female sample ($K\text{-}S\text{-}Z = 0.772$, $p = 0.591$), whereas it is valid for a male sample only visually ($K\text{-}S\text{-}Z = 1.399$, $p = 0.040$).

For this reason, in subsequent tests, the used parameter methods can be checked with appropriate boot strap methods that are not sensitive to the normality of distribution. As for the individual deviations of girls, it ranges from -3.51 to 3.60 years, and in boys almost the same, from -3.59 to 3.73 years.

Table 10. Summary statistics of chronological age (CA) and dental age (DA) by the Demirjian's method with dental maturity scores for a French Canadian population according to age groups and gender

Age group	Gender	N	CA		DA(D)		
			Mean	SD	Mean	SD	CV (%)
6	Female	15	5.64	0.61	6.22	0.84	13.50
	Male	12	5.86	0.47	7.03	0.45	6.40
7	Female	21	7.20	0.24	7.36	0.87	11.82
	Male	31	7.18	0.27	7.64	0.62	8.12
8	Female	47	8.02	0.29	7.53	0.59	7.84
	Male	49	8.01	0.32	7.83	0.80	10.22
9	Female	51	8.98	0.29	8.46	1.18	13.95
	Male	47	8.97	0.29	9.06	1.01	11.15
10	Female	63	10.01	0.30	9.67	1.49	15.41
	Male	49	10.01	0.29	10.11	0.94	9.30
11	Female	65	10.99	0.27	11.21	1.38	12.31
	Male	58	11.01	0.29	10.40	1.41	13.56
12	Female	61	12.01	0.30	12.61	1.30	10.31
	Male	48	12.01	0.30	11.63	1.78	15.31
13	Female	66	13.04	0.28	13.34	1.30	9.75
	Male	66	13.05	0.31	13.39	1.70	12.70
14	Female	70	14.01	0.27	13.99	1.31	9.36
	Male	64	14.07	0.26	14.38	1.52	10.57
15	Female	52	15.02	0.28	15.32	0.98	6.40
	Male	54	15.00	0.30	15.26	1.16	7.60
16	Female	52	16.08	0.27	15.87	0.42	2.65
	Male	65	15.97	0.29	15.74	0.58	3.68
6-16	Female	563	11.73	2.77	11.76	3.10	26.36
	Male	543	11.83	2.89	11.86	3.12	26.31

CA – chronological age, DA(D) – dental age by Demirjian's methods with dental maturity scores for French Canadian population, SD – standard deviation, CV – coefficient of variation (%)

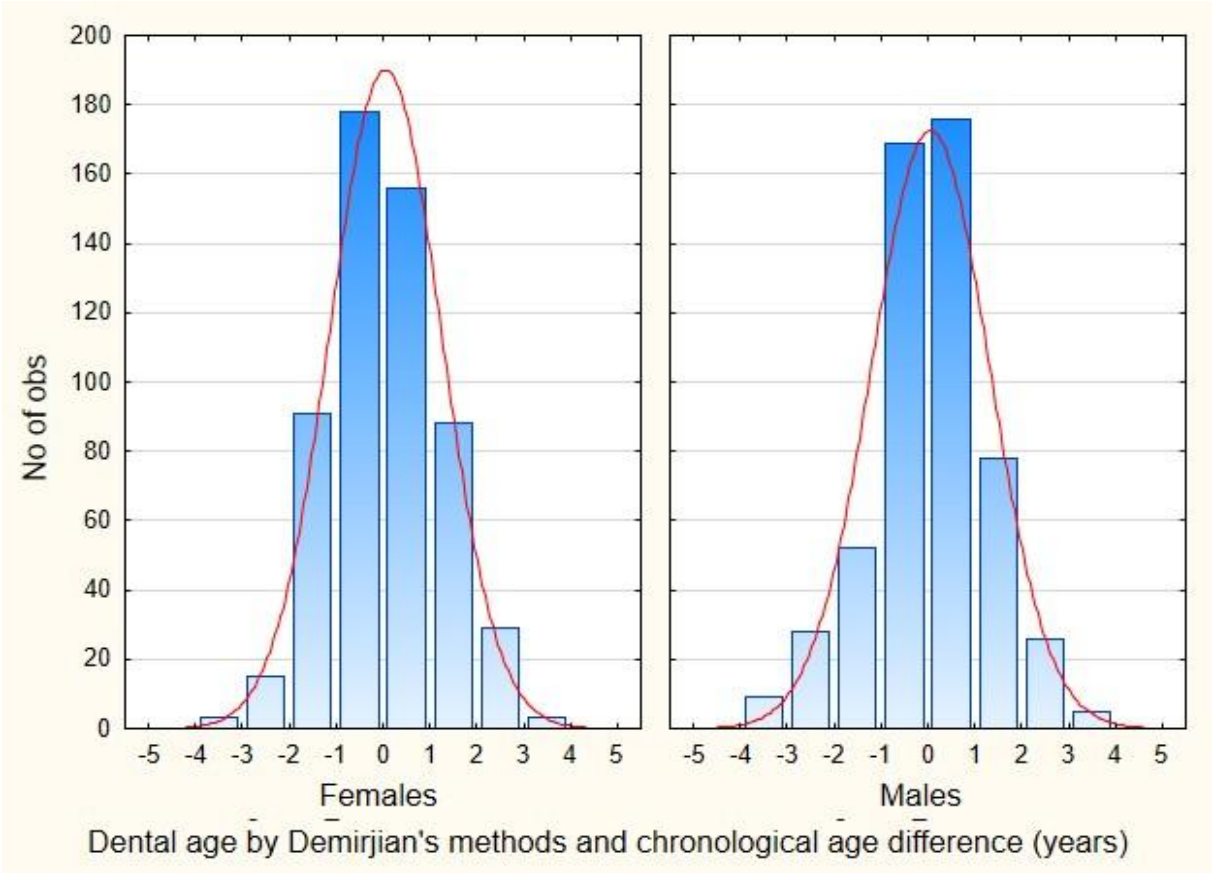

Figure 9. Distribution of the difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and chronological age, according to gender

As can be seen from the data in Table 11, statistically significant differences are found in both genders in groups of 6 and 16 years old. Other statistically significant differences are found in girls in groups of 8, 9, 12 and 15 years old, and in boys in groups of 7 and 11 years old. These data are illustrated in Figure 10 in which these differences are clearly noticed because the 95% of CIs are completely or almost entirely within the range below or above the line denoting the same values of dental and chronological age (0.0 value highlighted by thick line).

Table 11. Mean of dental age by the Demirjian's method with dental maturity scores for French Canadian population and chronological age and difference between age and gender

Age group	Gender	N	DA(D) – CA						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	df	p
6	Female	15	0.58	0.96	0.05	1.11	2.333	14	**0.035**
	Male	12	1.16	0.69	0.73	1.60	5.879	11	**<0.001**
7	Female	21	0.16	0.88	-0.24	0.56	0.823	20	0.420
	Male	31	0.46	0.60	0.24	0.68	4.275	30	**<0.001**
8	Female	47	-0.50	0.63	-0.68	-0.31	-5.391	46	**<0.001**
	Male	49	-0.18	0.76	-0.40	0.04	-1.664	48	0.103
9	Female	51	-0.52	1.08	-0.82	-0.22	-3.432	50	**0.001**
	Male	47	0.09	0.91	-0.18	0.35	0.649	46	0.520
10	Female	63	-0.34	1.36	-0.68	0.00	-1.983	62	0.052
	Male	49	0.11	0.92	-0.16	0.37	0.810	48	0.422
11	Female	65	0.22	1.36	-0.11	0.56	1.332	64	0.187
	Male	58	-0.62	1.42	-0.99	-0.24	-3.307	57	**0.002**
12	Female	61	0.59	1.30	0.26	0.93	3.574	60	**0.001**
	Male	48	-0.38	1.62	-0.85	0.09	-1.618	47	0.112
13	Female	66	0.30	1.29	-0.02	0.62	1.986	65	0.062
	Male	66	0.34	1.65	-0.06	0.75	1.679	65	0.098
14	Female	70	-0.01	1.24	-0.31	0.28	-0.093	69	0.927
	Male	64	0.31	1.51	-0.07	0.68	1.626	63	0.109
15	Female	52	0.30	0.89	0.05	0.55	2.451	51	**0.018**
	Male	54	0.26	1.19	-0.07	0.58	1.591	53	0.117
16	Female	52	-0.21	0.53	-0.36	-0.06	-2.887	51	**0.006**
	Male	65	-0.23	0.61	-0.38	-0.08	-3.042	64	**0.003**
6-16	Female	563	0.03	1.18	-0.07	0.12	0.535	562	0.593
	Male	543	0.03	1.26	-0.08	0.14	0.540	542	0.589

DA(D) – CA – difference of dental age by Demirjian's methods with maturity scores for French Canadian population and with maturity scores for Kosovo sample, SD – standard deviation, 95% CI – confidence interval of the difference, p - probability of the difference of null hypothesis that is obtained by one sample t-test

The results of the above analysis were also verified by an appropriate boot strap method that confirmed the results obtained by the parametric method.

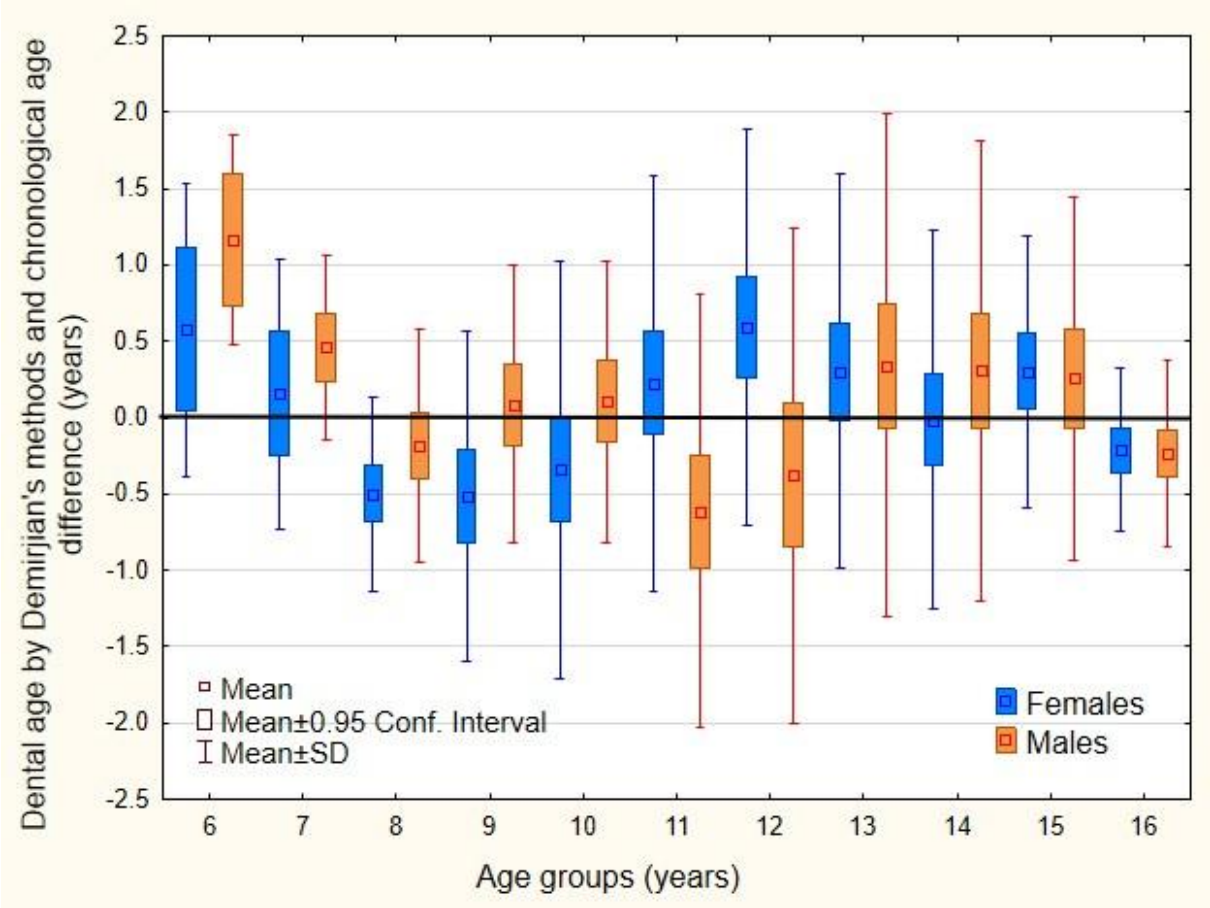

Figure 10. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a French Canadian population and chronological age (DA-CA). Box plot shows median and inter-quartile ranges, while whisker are lined extending from box to highest and lowest value, extending outliners

Girls and boys behave somewhat differently, except for groups of 11 and 12-year-olds. Namely, in these two age groups, dental age is subtracted for about 0.5 years in boys in relation to their chronological age, whereas the opposite is true for girls. Except for these two age groups, the estimation of dental age for girls is mostly greater or nearly equal to those relating to boys.

According to the t-test results for independent samples, the difference between dental age of girls and boys is statistically significant for age groups of 8 to 12 years old (Table 12).

Table 12. Gender difference of dental age by the Demirjian's method with dental maturity scores for the French Canadian population and the chronological age difference according to age groups

Age group	t statistics		
	t	df	p
6	-1.775	25	0.088
7	-1.480	50	0.145
8	-2.210	94	**0.030**
9	-2.984	96	**0.004**
10	-1.972	110	**0.041**
11	3.354	121	**0.001**
12	3.477	107	**0.001**
13	-0.154	130	0.878
14	-1.348	132	0.180
15	0.224	104	0.823
16	0.163	115	0.871
6-16	-0.034	1104	0.973

p - the probability of the hypothesis that gender difference is statically identical to the t-test for independent samples

The median absolute deviation of dental age estimations from chronological age, i.e. deviation, regardless to their gender, girls or boys, is shown in Table 13. The Table 13, shows that the median absolute deviation of dental age from chronological age ranges from 0.25 to 1.11 years, while this range is from 0.29 to 1.45 years for boys. The frequency of absolute deviation of dental from chronological age at half-year intervals, is shown in Figure 11. It is evident that, for both genders it is most likely to go up to 0.5 to one year, and then the frequency drops to a small number in the group of of 3.5 and 4 years.

Table 13. Mean absolute difference between dental age by the Demirjian's method and chronological age according to age group and gender

Age group	Gender	N	|DA(D) - CA|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.78	0.80	0.53	0.17	1.19
	Male	12	1.16	0.69	1.20	0.52	1.57
7	Female	21	0.53	0.71	0.25	0.09	0.76
	Male	31	0.61	0.45	0.49	0.21	1.02
8	Female	47	0.68	0.43	0.71	0.35	0.93
	Male	49	0.58	0.52	0.46	0.14	0.97
9	Female	51	1.04	0.58	0.99	0.74	1.41
	Male	47	0.64	0.65	0.44	0.15	0.86
10	Female	63	1.15	0.80	1.11	0.38	1.94
	Male	49	0.74	0.54	0.60	0.30	1.10
11	Female	65	1.13	0.77	1.10	0.55	1.49
	Male	58	1.15	1.02	0.91	0.16	1.84
12	Female	61	1.16	0.81	0.89	0.64	1.64
	Male	48	1.23	1.11	0.75	0.33	2.12
13	Female	66	1.09	0.74	1.00	0.49	1.57
	Male	66	1.41	0.91	1.34	0.58	2.26
14	Female	70	1.04	0.66	0.81	054	1.63
	Male	64	1.32	0.78	1.45	0.67	1.81
15	Female	52	0.87	0.34	0.86	0.64	1.10
	Male	54	0.99	0.69	0.84	0.61	1.14
16	Female	52	0.37	0.44	0.28	0.13	0.37
	Male	65	0.43	0.49	0.29	0.17	0.44
6-16	Female	563	0.95	0.70	0.81	0.36	1.38
	Male	543	0.94	0.83	0.70	0.29	1.41

|DA(D) - CA| - dental age by Demirjian's methods and chronological age absolute difference, SD – standard deviation

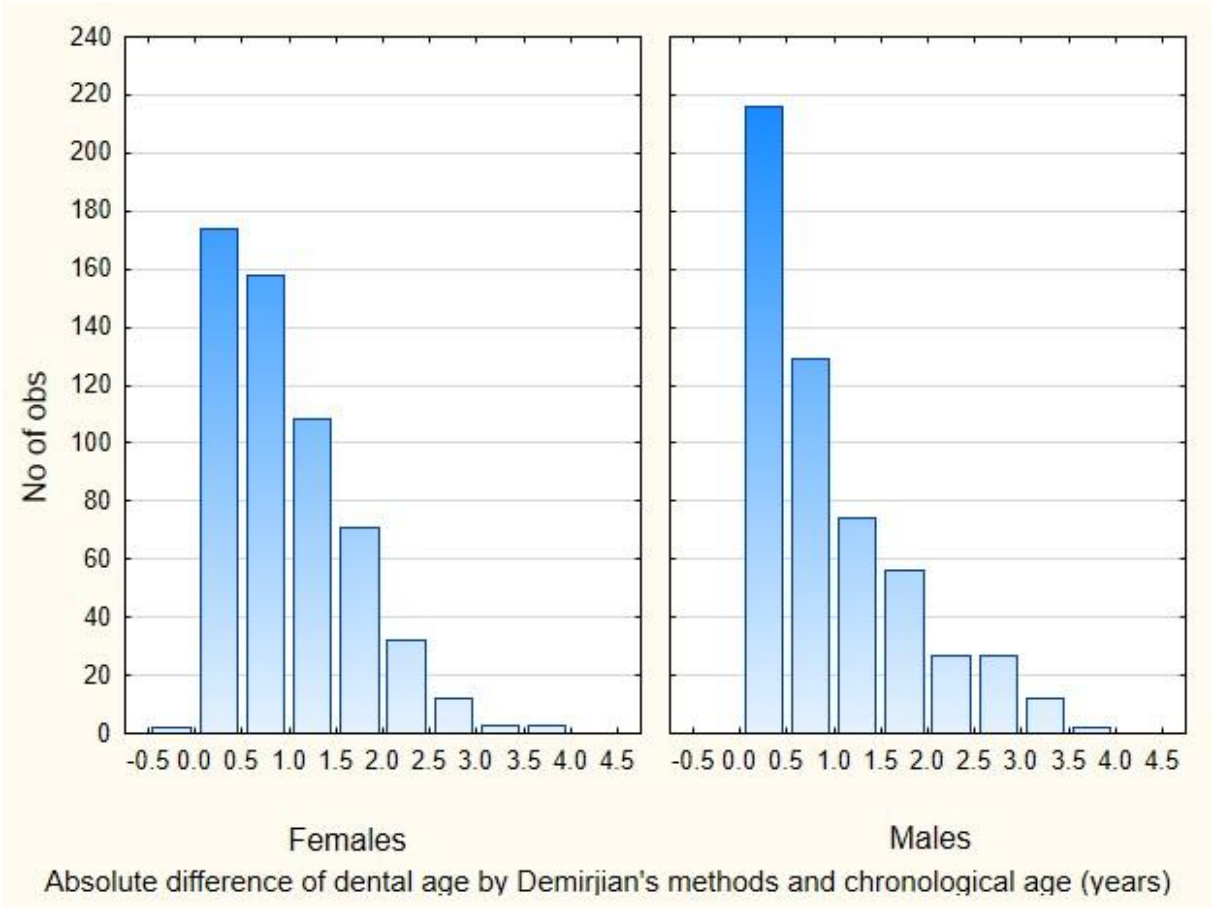

Figure 11. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and chronological age according to gender

4.3 Dental age estimation by Demirjian's methods with dental maturity scores for Kosovo population

The estimation of dental age of the Kosovo sample was performed by the Demirjian's method based on custom maturity scores. They were determined in such a way that for each tooth from 31 to 37 and the stage of maturity from A to H, an associated average chronological age was obtained on the basis of a sample of 1106 girls and boys, from the Kosovo population. The obtained scores are listed in Table 14.

For a Kosovo sample, the conversion of maturity scores into dental age was performed according to the Demirjian's method based on the average values of age groups interpolated with logistic function. The results with a corresponding chronological age, ranging from 6 to 16 years with a step of 0.1 year, are shown in Table 15 for girls and in Table 16 for boys.

Table 14. Demirjian's maturity scores for girls and boys from a Kosovo sample

Gender	Tooth	Stages							
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Girls	M2 (37)	4.9	7.4	8.3	9.5	10.6	12.0	13.3	15.3
	M1 (36)					5.9	5.8	8.5	12.6
	PM2 (35)	5.0	6.5	8.0	9.1	10.2	11.6	12.6	14.7
	PM1 (34)		4.8	7.4	8.3	9.7	11.0	12.1	14.3
	C (33)		5.5	6.1	7.9	8.7	10.1	12.1	14.1
	LI (32)				5.0	6.6	7.4	8.7	12.7
	CI (31)				5.2	6.6	6.7	7.7	12.2
Boys	M2 (37)		8.7	7.7	9.5	10.7	12.3	14.2	15.2
	M1 (36)					5.4	7.3	9.1	12.9
	PM2 (35)		8.5	7.4	8.2	9.7	11.6	13.5	14.8
	PM1 (34)			7.2	7.5	9.3	11.1	12.5	14.6
	C (33)			7.9	7.4	8.0	10.6	13.2	14.8
	LI (32)				8.4	7.1	8.2	9.2	13.1
	CI (31)					8.4	7.8	8.7	12.6

CI- central incisor, LI- lateral incisor, C- canine, PM1-first premolar, PM2-second premolar, M1-first molar, M2-second molar

The distribution of the maturity scores of the Kosovo sample, determined according to the maturity scores for the Kosovo sample subjects according to their chronological age using the Demirjian's method, which is shown in scatter plots in Figure 12, particularly those according to gender. The same distribution of the obtained dental age is shown in Figure 13.

Table 15. Conversion of maturity score for a Kosovo sample to dental age (7 teeth) for girls

Girls					
Age	**Score**	**Age**	**Score**	**Age**	**Score**
6.0	48.06	**10.0**	77.92	**14.0**	93.08
.1	48.89	.1	78.49	.1	93.30
.2	49.73	.2	79.05	.2	93.50
.3	50.57	.3	79.60	.3	93.70
.4	51.40	.4	80.14	.4	93.90
.5	52.24	.5	80.66	.5	94.09
.6	53.07	.6	81.18	.6	94.27
.7	53.91	.7	81.69	.7	94.45
.8	54.74	.8	82.18	.8	94.62
.9	55.56	.9	82.67	.9	94.79
7.0	56.39	**11.0**	83.14	**15.0**	94.95
.1	57.21	.1	83.60	.1	95.11
.2	58.03	.2	84.06	.2	95.26
.3	58.84	.3	84.50	.3	95.41
.4	59.65	.4	84.93	.4	95.56
.5	60.45	.5	85.36	.5	95.70
.6	61.25	.6	85.77	.6	95.83
.7	62.04	.7	86.17	.7	95.96
.8	62.82	.8	86.57	.8	96.09
.9	63.60	.9	86.95	.9	96.21
8.0	64.37	**12.0**	87.33	**16.0**	96.33
8.1	65.14	.1	87.69		
.2	65.89	.2	88.05		
.3	66.64	.3	88.40		
.4	67.38	.4	88.74		
.5	68.11	.5	89.07		
.6	68.83	.6	89.39		
.7	69.55	.7	89.70		
.8	70.25	.8	90.01		
.9	70.95	.9	90.30		
9.0	71.63	**13.0**	90.59		
.1	72.31	.1	90.87		
.2	72.97	.2	91.15		
.3	73.63	.3	91.41		
.4	74.27	.4	91.67		
.5	74.91	.5	91.93		
.6	75.53	.6	92.17		
.7	76.14	.7	92.41		
.8	76.75	.8	92.64		
.9	77.34	.9	92.86		

Table 16. Conversion of maturity score for a Kosovo population to dental age for boys

Boys					
Age	**Score**	**Age**	**Score**	**Age**	**Score**
6.0	45.46	**10.0**	79.58	**14.0**	94.80
.1	46.41	.1	80.20	.1	94.99
.2	47.37	.2	80.81	.2	95.17
.3	48.34	.3	81.40	.3	95.34
.4	49.30	.4	81.98	.4	95.51
.5	50.27	.5	82.54	.5	95.67
.6	51.23	.6	83.09	.6	95.83
.7	52.19	.7	83.62	.7	95.98
.8	53.15	.8	84.14	.8	96.13
.9	54.11	.9	84.65	.9	96.27
7.0	55.07	**11.0**	85.15	**15.0**	96.40
.1	56.02	.1	85.63	.1	96.54
.2	56.97	.2	86.10	.2	96.66
.3	57.91	.3	86.55	.3	96.78
.4	58.85	.4	86.99	.4	96.90
.5	59.78	.5	87.42	.5	97.02
.6	60.70	.6	87.84	.6	97.13
.7	61.62	.7	88.25	.7	97.23
.8	62.53	.8	88.64	.8	97.33
.9	63.43	.9	89.02	.9	97.43
8.0	64.32	**12.0**	89.40	**16.0**	97.53
8.1	65.20	.1	89.76		
.2	66.07	.2	90.10		
.3	66.93	.3	90.44		
.4	67.77	.4	90.77		
.5	68.61	.5	91.09		
.6	69.43	.6	91.40		
.7	70.25	.7	91.70		
.8	71.05	.8	91.98		
.9	71.83	.9	92.26		
9.0	72.61	**13.0**	92.54		
.1	73.37	.1	92.80		
.2	74.11	.2	93.05		
.3	74.85	.3	93.30		
.4	75.57	.4	93.53		
.5	76.27	.5	93.76		
.6	76.96	.6	93.98		
.7	77.64	.7	94.20		
.8	78.30	.8	94.41		
.9	78.95	.9	94.61		

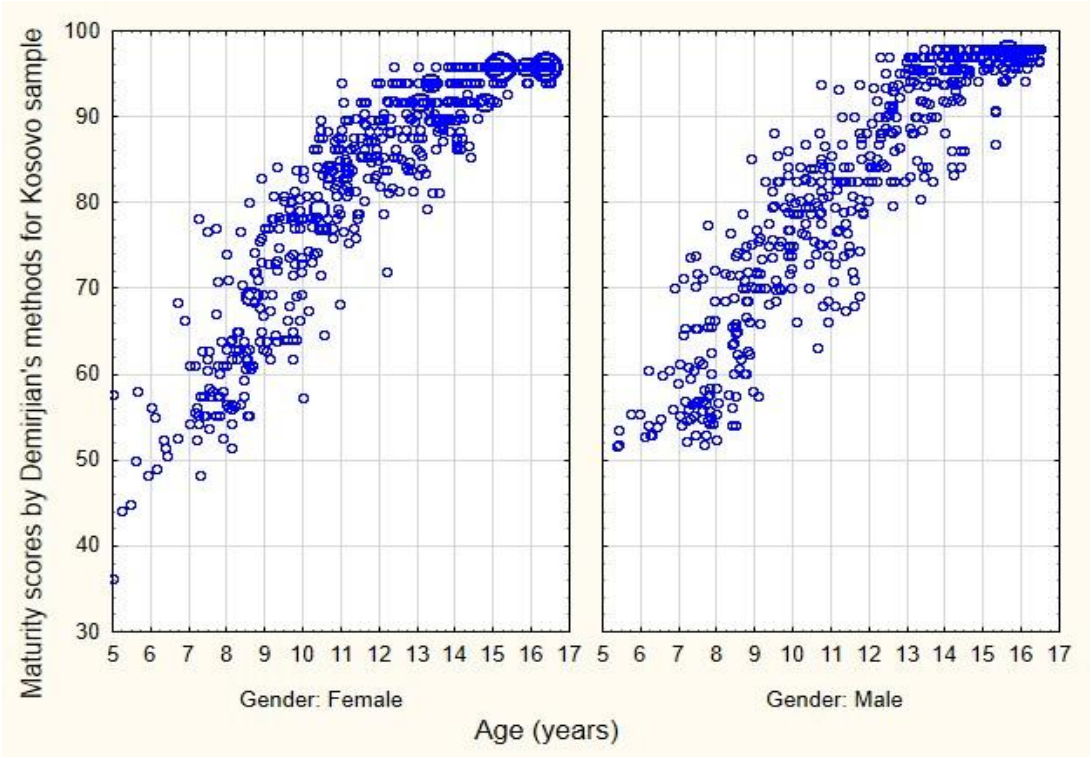

Figure 12. Scatterplot of the dental maturity scores by the Demirjian's methods for a Kosovo sample according to age and gender

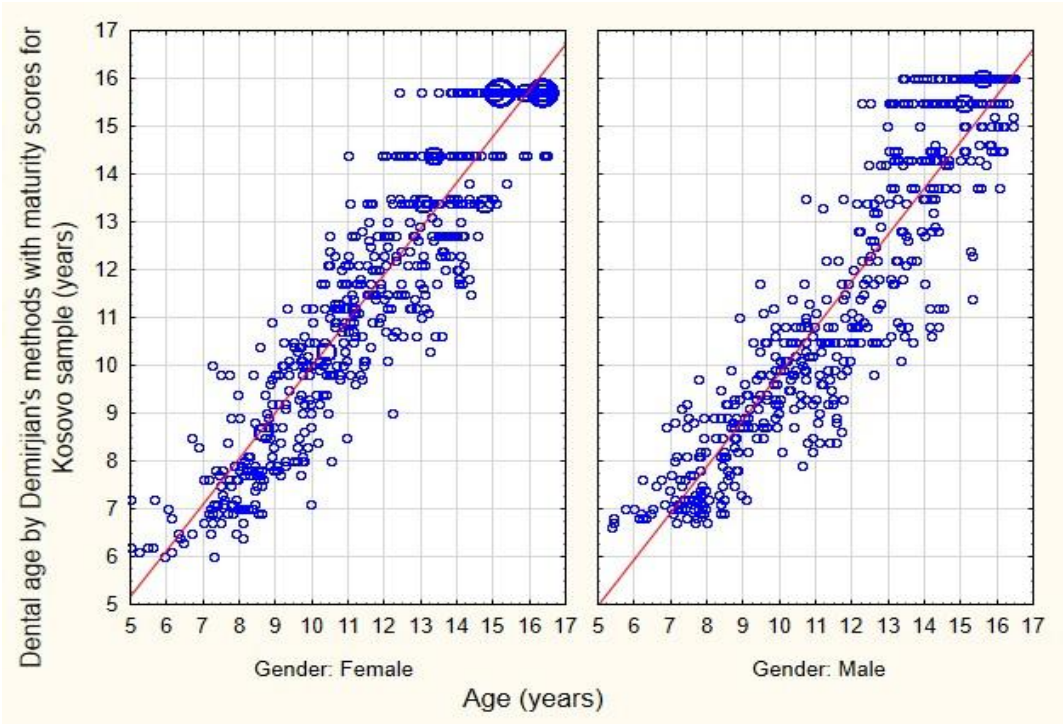

Figure 13. Scatterplot of the dental age by the Demirjian's method with maturity scores for a Kosovo sample according to age and gender

The size of the circles in Figures 12 and 13 indicate the frequency in the relevant age group. The Spearman dental age correlation coefficient according to Demirjian's maturity scores for a Kosovo sample with chronological age is 0.928 ($n = 563$, $p < 0.001$) for girls and it is 0.922 ($n=543$, $p < 0.001$) for boys. Therefore, the estimation of dental age for the Kosovo sample using its own maturity scoring shows a high degree of correlation of chronological age for both genders despite noticeable individual deviations (Figure 13). These correlation coefficients are identical to those with dental age estimation by means of the maturity scores for the French Canadian population.

The distribution of dental age by the Demirjian's method with maturity scores for a Kosovo sample, according to the Kolmogorov-Smirnov test, does not follow a normal distribution. The differences between the genders regarding dental age, estimated by the Demirjian's method with maturity scores for the Kosovo sample, were found only for 6, 11 and 12 years old. These differences can be read from the data shown in Table 17. Since the central question for this research is the accuracy of dental age estimation compared to chronological age, the differences need to be thoroughly investigated.

The variation coefficients are ranged from very low 2.50% to moderate 13.73% for individual age groups. Obviously, an amount of the total sample of both genders is significantly higher, about 25-26%, as well as in the case of the dental age estimation by the Demirjian maturity scores method for a French-Canadian population.

The differences between dental age obtained using the Demirjian's method with maturity scores for a Kosovo sample and chronological age are on appearance acceptable normal distributions (Figure 14). This is confirmed by the Kolmogorov-Smirnov test: a female sample ($KSZ = 0.660$, $p = 0.777$), and a male sample ($KSZ = 0.914$, $p = 0.374$).

Table 17. Summary statistics of chronological age (CA) and dental age (DA) by the Demirjian's method with dental maturity scores for a Kosovo population according to age groups and gender

Age group	Gender	N	CA		DA(DK)		
			Mean	SD	Mean	SD	CV (%)
6	Female	15	5.64	0.61	6.48	0.42	6.48
	Male	12	5.86	0.47	6.91	0.25	3.62
7	Female	21	7.20	0.24	7.43	1.02	13.73
	Male	31	7.18	0.27	7.65	0.73	9.54
8	Female	47	8.02	0.29	7.63	0.79	10.35
	Male	49	8.01	0.32	7.72	0.78	10.10
9	Female	51	8.98	0.29	8.88	1.04	11.71
	Male	47	8.97	0.29	8.87	0.94	10.60
10	Female	63	10.01	0.30	9.85	1.17	11.88
	Male	49	10.01	0.29	9.76	0.77	7.89
11	Female	65	10.99	0.27	10.99	1.08	9.83
	Male	58	11.01	0.29	10.11	1.10	10.88
12	Female	61	12.01	0.30	12.24	1.26	10.29
	Male	48	12.01	0.30	11.27	1.57	13.93
13	Female	66	13.04	0.28	13.03	1.29	9.90
	Male	66	13.05	0.31	13.01	1.66	12.76
14	Female	70	14.01	0.27	13.65	1.37	10.04
	Male	64	14.07	0.26	14.12	1.64	11.61
15	Female	52	15.02	0.28	15.04	0.97	6.45
	Male	54	15.00	0.30	15.06	1.17	7.77
16	Female	52	16.08	0.27	15.58	0.39	2.50
	Male	65	15.97	0.29	15.49	0.67	4.33
6-16	Female	563	11.73	2.77	11.64	2.87	24.66
	Male	543	11.83	2.89	11.61	3.05	26.27

CA – chronological age. DA(DK) – dental age by Demirjian's methods with maturity scores for Kosovo sample. SD – standard deviation, CV – coefficient of variation (%)

As for individual deviations, they are in the range of -3.21 to 3.38 years for girls and almost in the same range for boys, from -3.90 to 3.24 years. The range of dental age estimations by the Demirjian's method with maturity scores for a Kosovo sample is smaller than that for the French Canadian population, especially the range related to girls. Namely, the estimated dental age range in girls by maturity scores for the French Canadian population is 7.11 years

and with maturity scores of 6.59 years for the Kosovo population. In the boys group, the difference is approximately the same (7.32 and 7.14 years), but it is still smaller for the estimation with maturity scores of their own sample.

As can be seen from the data in Table 18, statistically significant differences are found in both genders in the groups of 6, 8 and 16 years old. Other statistically significant differences are primarily found in boys, in the groups of 7, 10, 11 and 12 years old, and in girls in the age group of 14 years. These data are illustrated in Figure 15 in which these deviations are clearly notable because the 95% of CIs are completely or almost entirely below or above the line denoting equal values of dental and chronological age (0.0 value).

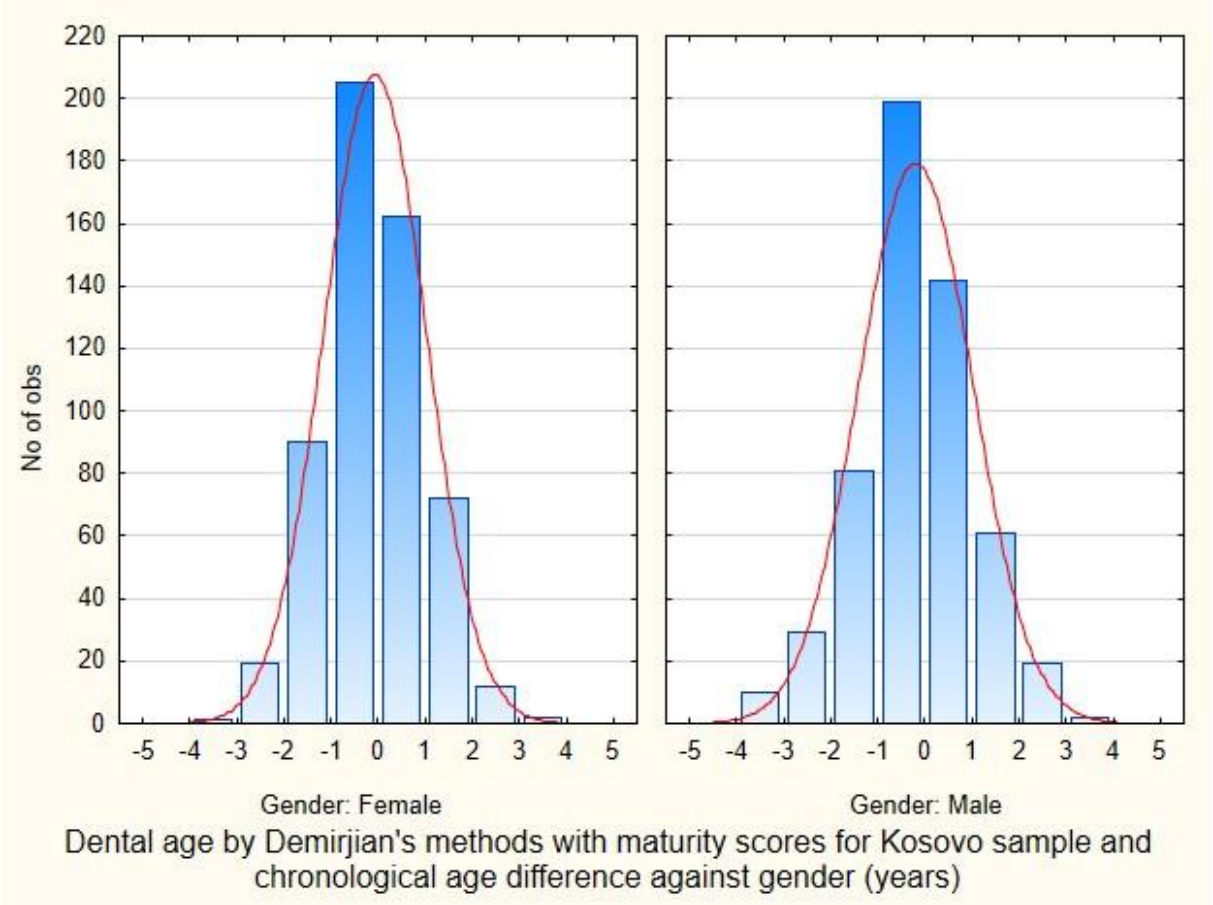

Figure 14. Distribution of the difference between dental age by the Demirjian's method with maturity scores for a Kosovo population and chronological age, according to gender

Table 18. Mean age of dental age by the Demirjian's method with dental maturity scores for a Kosovo population and chronological age and difference between age group and gender

Age group	Gender	N	DA(DK) – CA						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	Df	p
6	Female	15	0.84	0.76	0.42	1.26	4.297	14	**0.001**
	Male	12	1.05	0.48	0.74	1.35	7.624	11	**<0.001**
7	Female	21	0.23	1.04	-0.25	0.70	.996	20	0.331
	Male	31	0.47	0.73	0.20	0.73	3.565	30	**0.001**
8	Female	47	-0.40	0.81	-0.64	-0.16	-3.383	46	**0.001**
	Male	49	-0.29	0.75	-0.51	-0.07	-2.703	48	**0.009**
9	Female	51	-0.10	0.94	-0.36	0.16	-.757	50	0.453
	Male	47	-0.10	0.83	-0.34	0.15	-.812	46	0.421
10	Female	63	-0.16	1.07	-0.43	0.11	-1.213	62	0.230
	Male	49	-0.25	0.75	-0.46	-0.03	-2.301	48	**0.026**
11	Female	65	0.00	1.07	-0.26	0.27	.034	64	0.973
	Male	58	-0.91	1.13	-1.20	-0.61	-6.117	57	**<0.001**
12	Female	61	0.22	1.25	-0.10	0.54	1.397	60	0.168
	Male	48	-0.74	1.40	-1.15	-0.33	-3.655	47	0.001
13	Female	66	-0.01	1.28	-0.32	0.31	-.059	65	0.953
	Male	66	-0.03	1.58	-0.42	0.35	-.178	65	0.859
14	Female	70	-0.35	1.30	-0.66	-0.04	-2.271	69	**0.026**
	Male	64	0.05	1.62	-0.36	0.45	.242	63	0.810
15	Female	52	0.02	0.88	-0.23	0.26	.147	51	0.883
	Male	54	0.05	1.19	-0.27	0.38	.328	53	0.744
16	Female	52	-0.50	0.51	-0.64	-0.36	-7.161	51	**<0.001**
	Male	65	-0.48	0.66	-0.65	-0.32	-5.865	64	**<0.001**
6-16	Female	563	-0.10	1.08	-0.18	-0.01	-2.084	562	**0.038**
	Male	543	-0.22	1.21	-0.32	-0.12	-4.251	542	**<0.001**

DA(D) – CA – difference of dental age by Demirjian's methods with maturity scores for French Canadian population and with maturity scores for Kosovo sample, SD – standard deviation, 95% CI – confidence interval of the difference, p - probability of the difference of null hypothesis that is obtained by one sample t-test

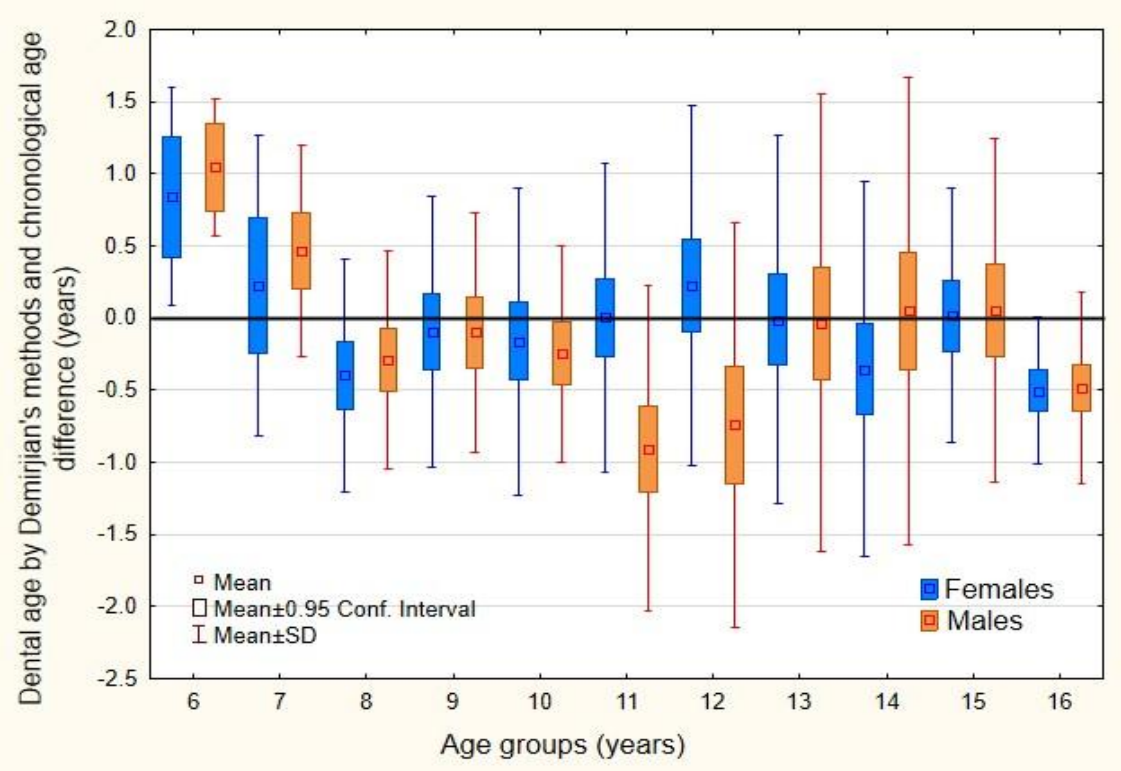

Figure 15. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a Kosovo population and chronological age (DA-CA). Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners.

A more accurate illustration of deviations from the zero difference is shown in Figure 15. Girls and boys behave somewhat differently, except for the groups of 11 and 12-year-olds. Specifically, in these two age groups, dental age is underestimated for about 0.5 years in boys with respect to their chronological age, whereas the opposite is true in girls. Except for these two age groups, the estimation of dental age in girls is mostly greater or almost equal to that in boys.

If we compare Figure 10 and Figure 15, we can clearly see that the dental age estimation according to the Demirjian's method corresponds to a great extent to maturity scores in the French Canadian population and maturity scores in a Kosovo sample. A greater difference is found only in groups of 9 and 10 years old.

According to the results of the t-test for independent samples, the difference between the dental age of girls and boys, estimated according to their own sample, is statistically significant for the age groups of 11 and 12 years old (Table 19).

Table 19. Gender difference between dental age by the Demirjian's method with dental maturity scores for a Kosovo population and chronological age according to age group

Age group	t statistics		
	t	df	p
6	-0.829	25	0.415
7	-0.987	50	0.329
8	-0.670	94	0.505
9	-0.004	96	0.997
10	0.464	110	0.643
11	4.586	121	**<0.001**
12	3.788	107	**<0.001**
13	0.102	130	0.919
14	-1.592	132	0.114
15	-0.173	104	0.863
16	-0.184	115	0.541
6-16	1.819	1104	0.069

p - the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

The median absolute deviation of dental age estimation from chronological age, also deviation, regardless to their gender, for girls and boys, is shown in Table 20. From this table, it is seen that the median value, the deviation of dental age from the chronological age for girls ranges from 0.45 to 1.14 years, while for boys this range is from 0.44 to 1.35 years. These values are similar or slightly lower than in the case of dental age estimations with maturity scores for a French Canadian population.

Table 20. Mean absolute difference between dental age by the Demirjian's method with maturity score for Kosovo population and chronological age according to age group and gender

Age group	Gender	N	|DA(DK) - CA|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.86	0.73	0.74	0.14	1.54
	Male	12	1.05	0.48	1.13	0.60	1.36
7	Female	21	0.73	0.75	0.45	0.24	0.86
	Male	31	0.66	0.56	0.48	0.21	0.92
8	Female	47	0.76	0.48	0.71	0.37	1.11
	Male	49	0.68	0.42	0.58	0.37	0.96
9	Female	51	0.77	0.54	0.77	0.26	1.15
	Male	47	0.63	0.55	0.44	0.25	0.94
10	Female	63	0.86	0.64	0.73	0.31	1.34
	Male	49	0.64	0.45	0.62	0.24	0.93
11	Female	65	0.82	0.68	0.65	0.32	1.19
	Male	58	1.19	0.81	0.86	0.61	1.71
12	Female	61	0.99	0.78	0.87	0.36	1.47
	Male	48	1.32	0.87	1.28	0.62	1.76
13	Female	66	1.05	0.71	1.01	0.52	1.53
	Male	66	1.32	0.87	1.20	0.57	2.14
14	Female	70	1.15	0.70	1.14	0.52	1.60
	Male	64	1.32	0.92	1.31	0.50	1.81
15	Female	52	0.76	0.44	0.64	0.44	1.08
	Male	54	0.90	0.77	0.74	0.50	1.00
16	Female	52	0.51	0.50	0.42	0.17	0.66
	Male	65	0.62	0.54	0.41	0.25	0.88
6-16	Female	563	0.87	0.66	0.73	0.33	1.20
	Male	543	0.96	0.77	0.77	0.35	1.30

|DA(DK) - CA|- dental age by Demirjian's methods with maturity scores for Kosovo sample and chronological age absolute difference, SD – standard deviation

The relationship between dental age estimation using the Demirjian's maturity score method for the French Canadian population and maturity scores tailored to the Kosovo sample can be investigated in the simplest way by finding the differences between them. These differences had to include age groups and, especially, gender.

The distribution of dental age difference by Demirjian's maturity score estimates for the French Canadian population and with the maturity scores for Kosovo sample is shown in Figure 16, separately for girls and boys. According to the Kolmogorov-Smirnov test, these distributions do not follow a normal distribution: Z = 5.926, p <0.001 for girls, whereas for boys it is Z = 2.624, p <0.001.

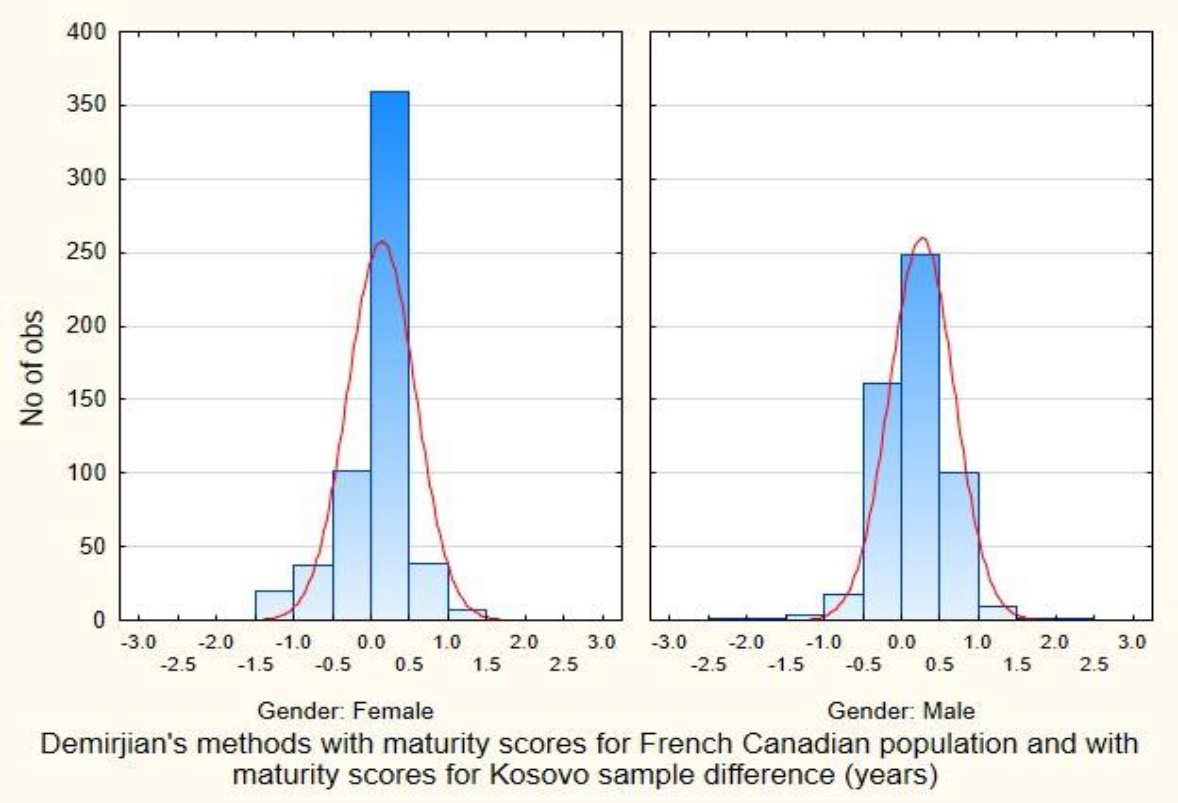

Figure 16. Distribution of the differences between dental age by the Demirjian's method with maturity scores for a French Canadian population and with maturity score for a Kosovo population according to gender

As can be seen from the data in Table 21, a statistically significant deviation of 0.0 value is found in both genders in almost all age groups according to the results of the One Sample T-Test. Due to the absence of normality distribution, the differences in t test results are checked and confirmed by the boot strap method. The differences close to the zero difference were found in the groups of 6, 7, and 8 years old. These data are illustrated in Figure 17 in which these deviations can be clearly seen because the 95% of CIs are completely or almost entirely within the range below or above the line denoting equal values of dental and chronological

age. As for individual deviations, they are within the range of -1.40 to 1.20 years in girls, and somewhat larger, from -2.10 to 2.20 years in boys.

Table 21. Mean age of dental age by the Demirjian's method with dental maturity scores for a French Canadian population and with maturity score for a Kosovo population and difference between age group and gender

Age group	Gender	N	DA(D) – DA(DK)						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	df	p
6	Female	15	-0.26	0.46	-0.52	0.00	-2.170	14	**0.048**
	Male	12	0.12	0.30	-0.07	0.31	1.356	11	0.202
7	Female	21	-0.07	0.41	-0.25	0.12	-.747	20	0.464
	Male	31	0.00	0.32	-0.12	0.11	-.056	30	0.956
8	Female	47	-0.10	0.37	-0.21	0.01	-1.852	46	0.070
	Male	49	0.11	0.29	0.03	0.19	2.657	48	**0.011**
9	Female	51	-0.42	0.51	-0.56	-0.28	-5.913	50	**<0.001**
	Male	47	0.19	0.28	0.10	0.27	4.499	46	**<0.001**
10	Female	63	-0.18	0.49	-0.30	-0.05	-2.857	62	**0.006**
	Male	49	0.35	0.29	0.27	0.44	8.454	48	**<0.001**
11	Female	65	0.22	0.49	0.10	0.34	3.627	64	**0.001**
	Male	58	0.29	0.48	0.16	0.42	4.571	57	**<0.001**
12	Female	61	0.37	0.30	0.29	0.45	9.551	60	**<0.001**
	Male	48	0.36	0.50	0.21	0.51	4.955	47	**<0.001**
13	Female	66	0.31	0.28	0.24	0.38	9.114	65	**<0.001**
	Male	66	0.38	0.53	0.24	0.51	5.728	65	**<0.001**
14	Female	70	0.34	0.15	0.30	0.38	19.116	69	**<0.001**
	Male	64	0.26	0.34	0.17	0.34	6.145	63	**<0.001**
15	Female	52	0.28	0.05	0.27	0.30	41.017	51	**<0.001**
	Male	54	0.20	0.37	0.10	0.30	4.073	53	**<0.001**
16	Female	52	0.29	0.03	0.28	0.30	70.344	51	**<0.001**
	Male	65	0.25	0.48	0.13	0.37	4.256	64	**<0.001**
6-16	Female	563	0.12	0.44	0.09	0.16	6.619	562	**<0.001**
	Male	543	0.25	0.42	0.21	0.28	13.951	542	**<0.001**

DA(D) – DA(DK) – difference of dental age by Demirjian's methods with maturity scores for French Canadian population and with maturity scores for Kosovo sample, SD – standard deviation, 95% CI – confidence interval of the difference, p - probability of the difference of null hypothesis that is obtained by one sample t-test

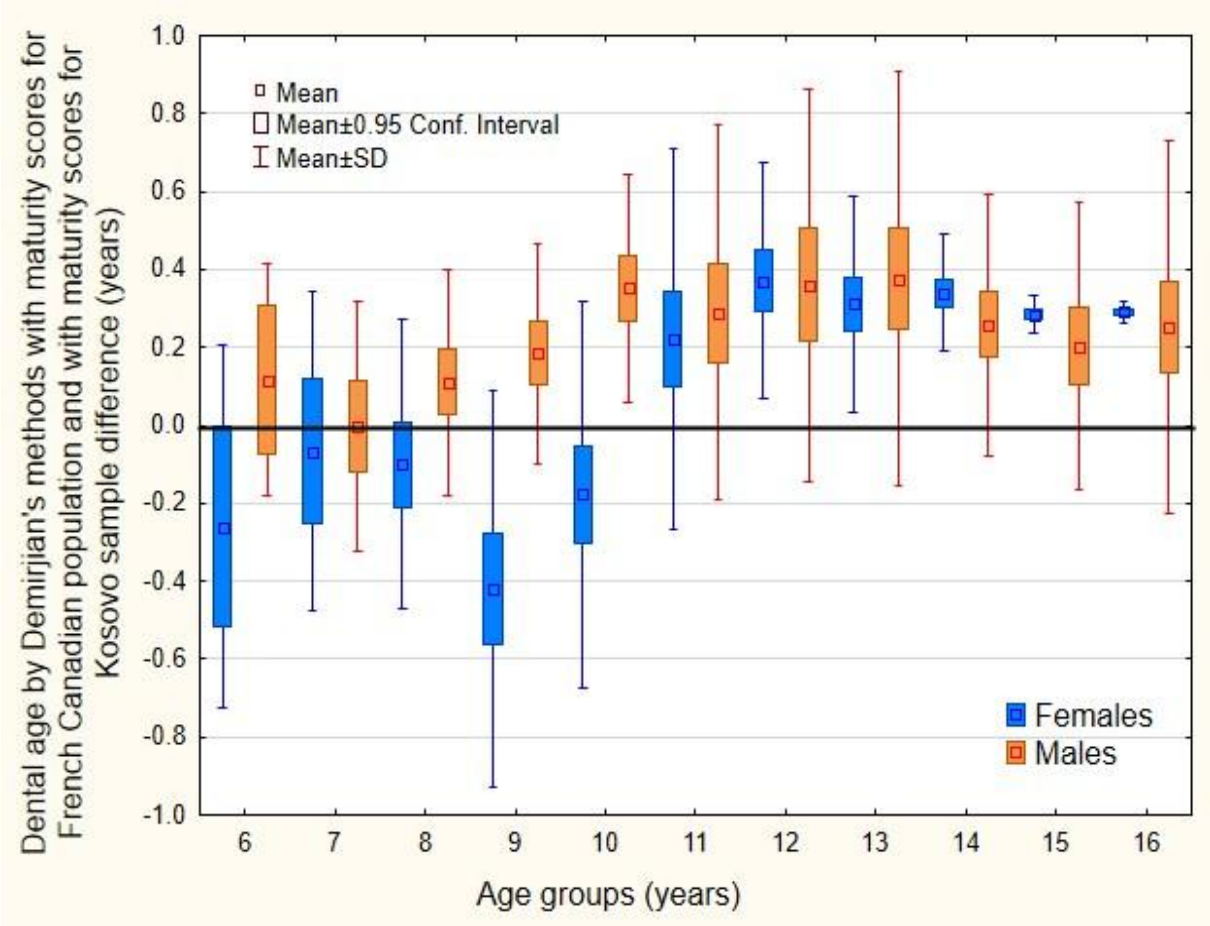

Figure 17. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a French Canadian population and with maturity scores for a Kosovo population, DA(D) – DA(DK). Box plot shows median and inter-quartile ranges, while whisker are lined extending from box to highest and lowest value, extending outliners

A more accurate figure of the deviation from the zero difference is shown in Figure 17. Regarding the deviation difference from the 0.0 value, girls and boys behave in a similar way, except in the groups of 6, 8, 9, and 10-year-olds. Namely, dental age with maturity scores for Kosovo sample is overestimated in girls, whereas it is underestimated in boys compared to the dental age estimation with maturity scores for the French Canadian population. From the 11th year onwards, dental age with its own maturity scores is evenly estimated for both genders with respect to the French Canadian population.

Table 22. Gender difference between dental age by the Demirjian's methods with maturity scores for a French Canadian population with maturity scores for a Kosovo population according to gender

Age group	t statistics		
	t	df	p
6	-2.434	25	**0.022**
7	-0.625	50	0.535
8	-3.104	94	**0.003**
9	-7.214	96	**<0.001**
10	-6.665	110	**<0.001**
11	-0.794	121	0.429
12	0.129	107	0.897
13	-0.881	130	0.380
14	1.859	132	0.065
15	1.573	104	0.119
16	0.573	115	0.568
6-16	-4.981	1104	**<0.001**

p – the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

According to the results of the t-test for independent samples, the difference between the age-related differences between girls and boys, estimated by the maturity scores for the French Canadian population, by the scores for their own sample, is statistically significant for age groups of 6, 8 to 10 year olds and overall (Table 22).

Absolute deviation of dental age difference evaluated by the Demirjian's maturity score method for the French Canadian population from the estimation by its own maturity score, i.e. the deviation regardless to the gender, girl or boy, is shown in Table 24. From Table 24, it is apparent that the median, that is, the value dividing the sample in half, of the deviation from chronological age is within the range from 0.29 to 0.51 years for girls, whereas it is within the range of 0.25 to 0.54 years for boys.

Table 23. Mean absolute difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and with maturity scores for a Kosovo population according to age group and gender

Age group	Gender	N	|DA(D) – DA(DK)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.41	0.33	0.30	0.20	0.70
	Male	12	0.25	0.19	0.20	0.10	0.48
7	Female	21	0.30	0.28	0.20	0.20	0.30
	Male	31	0.25	0.19	0.20	0.10	0.40
8	Female	47	0.30	0.23	0.20	0.20	0.30
	Male	49	0.26	0.16	0.20	0.10	0.40
9	Female	51	0.51	0.41	0.40	0.20	0.80
	Male	47	0.27	0.20	0.20	0.10	0.40
10	Female	63	0.40	0.34	0.30	0.20	0.50
	Male	49	0.40	0.22	0.40	0.27	0.60
11	Female	65	0.41	0.34	0.30	0.20	0.60
	Male	58	0.47	0.31	0.50	0.30	0.70
12	Female	61	0.41	0.25	0.30	0.20	0.50
	Male	48	0.54	0.30	0.60	0.30	0.70
13	Female	66	0.35	0.23	0.30	0.20	0.40
	Male	66	0.51	0.41	0.40	0.20	0.70
14	Female	70	0.34	0.15	0.30	0.20	0.40
	Male	64	0.30	0.30	0.20	0.10	0.47
15	Female	52	0.28	0.05	0.30	0.30	0.30
	Male	54	0.26	0.33	0.20	0.00	0.20
16	Female	52	0.29	0.03	0.30	0.30	0.30
	Male	65	0.28	0.46	0.00	0.00	0.20
6-16	Female	563	0.37	0.27	0.30	0.20	0.40
	Male	543	0.36	0.33	0.30	0.10	0.50

\|DA(D) - CA\|- dental age by Demirjian's methods with maturity scores for French Canadian population and with maturity scores for Kosovo sample absolute difference, SD – standard deviation

The frequency of the median absolute deviation of dental age difference with the Demirjian's method with maturity score for the French Canadian population from the estimation of its own maturity score at intervals of 0.2 years is shown in Figure 18. It can be observed that the

greatest deviations are found in both genders from 0.2 years and up to one year, subsequently the frequency drops sharply down to the groups just under 2.2 years of age.

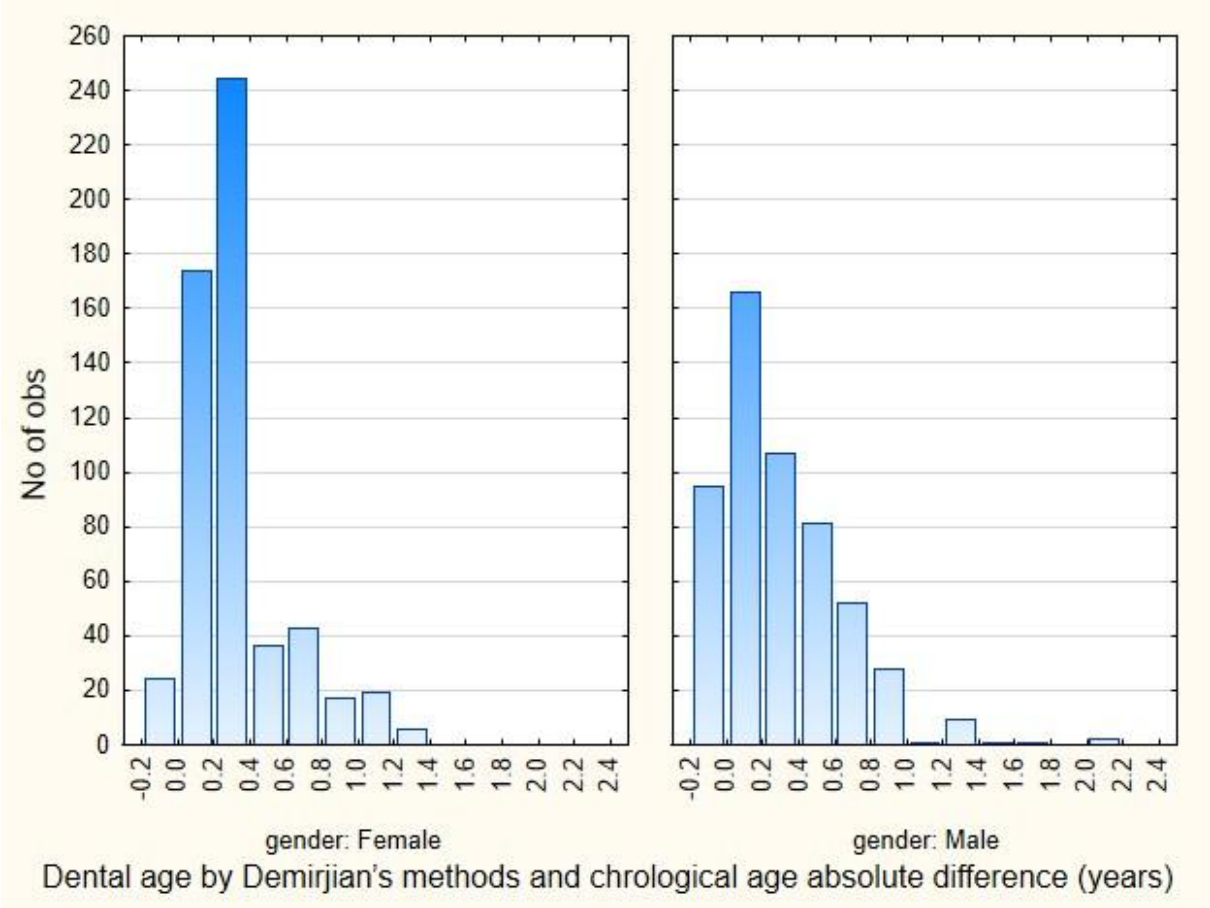

Figure 18. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and with maturity scores for a Kosovo population according to gender

The relationship between the maturity scores for the French Canadian population and the Kosovo sample is illustrated in Figure 19. It is noticeable that dental maturity of the French Canadian population in girls between 7.5 and 13 years of age, and in boys between 7.5 and 12 years of age, is considerably higher compared with dental maturity in a Kosovo sample beginning around age 6 and peaking around age 7 and vice versa.

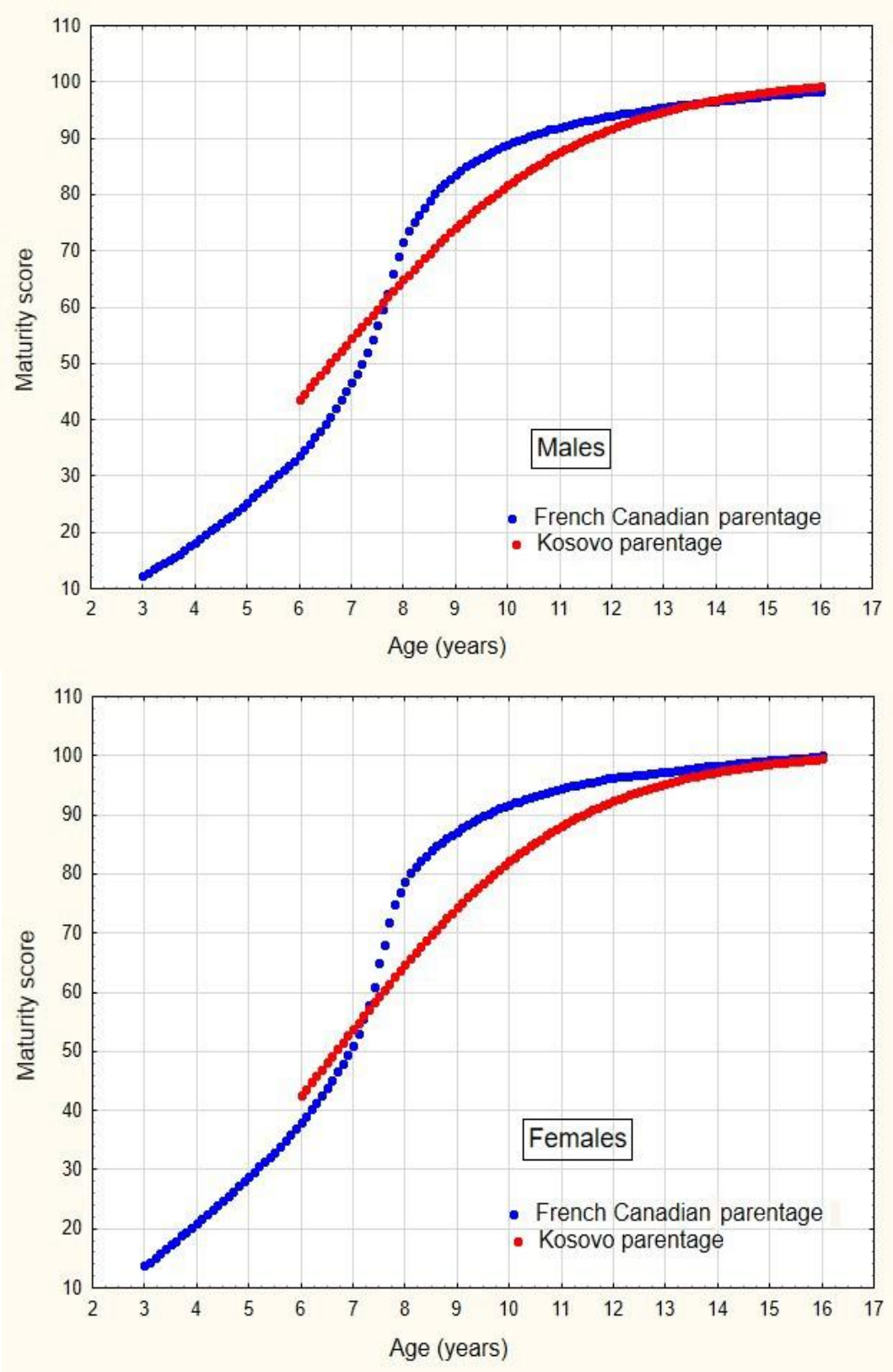

Figure 19. Dental maturity scores (medians) for females and males of a French Canadian and Kosovo origin according to chronological age

The correlation between dental age estimated by the Demirjian's method with maturity scores for the French Canadian population and maturity scores for the Kosovo population estimated by the nonparametric method (Spearman's rho) is 0.997 (n = 563, p <0.001) for girls and 0.988 (n = 543, p <0.001) for boys. The scatterplot in Figure 20 illustrates accurately this correlation.

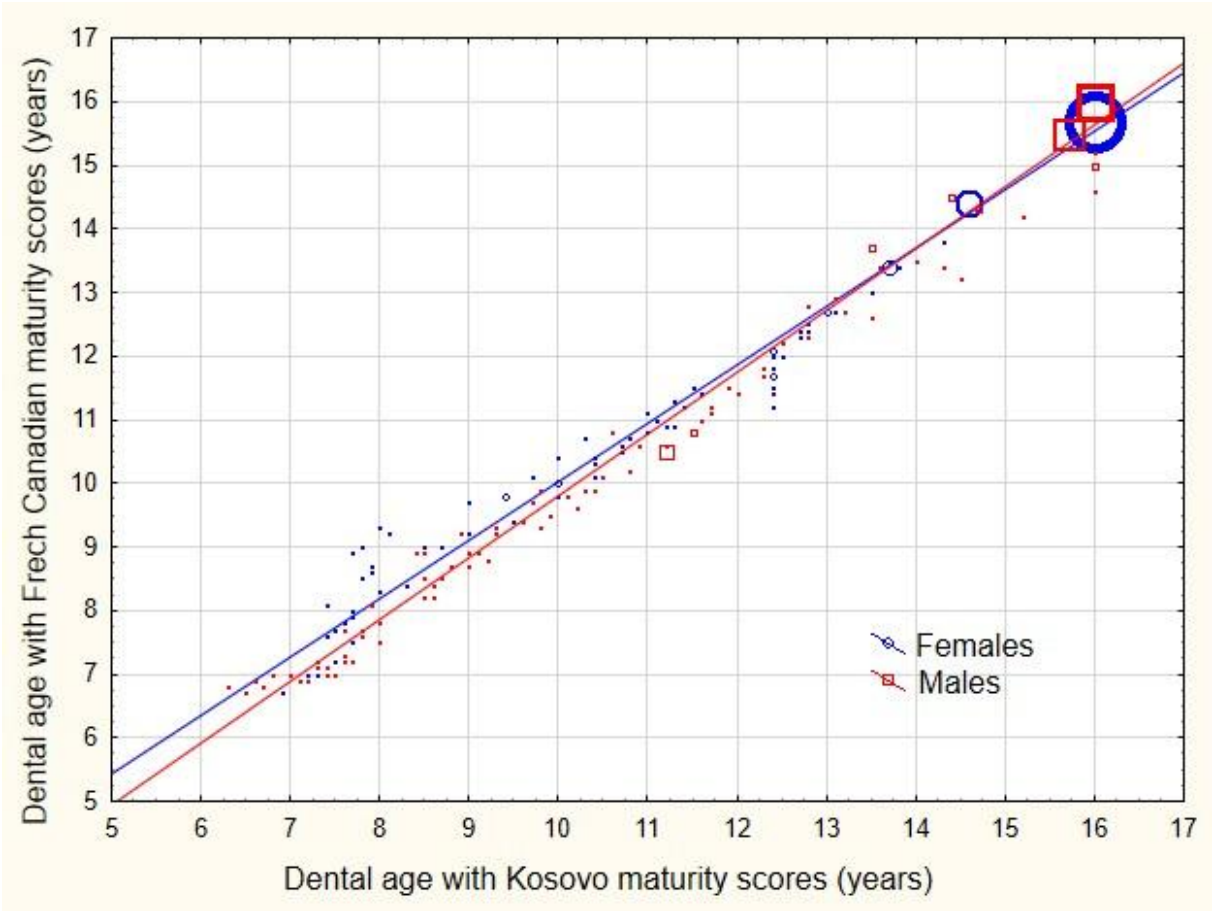

Figure 20. Scatterplot of dental age by the Demirjian's method with maturity scores for a French Canadian population and dental age with maturity scores for a Kosovo population, categorized by gender

4.4 Dental age estimation by Willems' methods

In this chapter, the estimation of the dental age of young people from the Kosovo population was made according to the Willems's method. According to this method, a maturity score was assigned to each of the first seven teeth of the lower jaw, especially of female and male

subjects (OPGs), according to the stage of tooth development, which is shown in Table 6. Their dental age was estimated by the sum of these scores.

The relationship between dental age according to the Willems's method and chronological age was illustrated by scatterplot in Figure 21. Circle size indicates the frequency in the relevant age group.

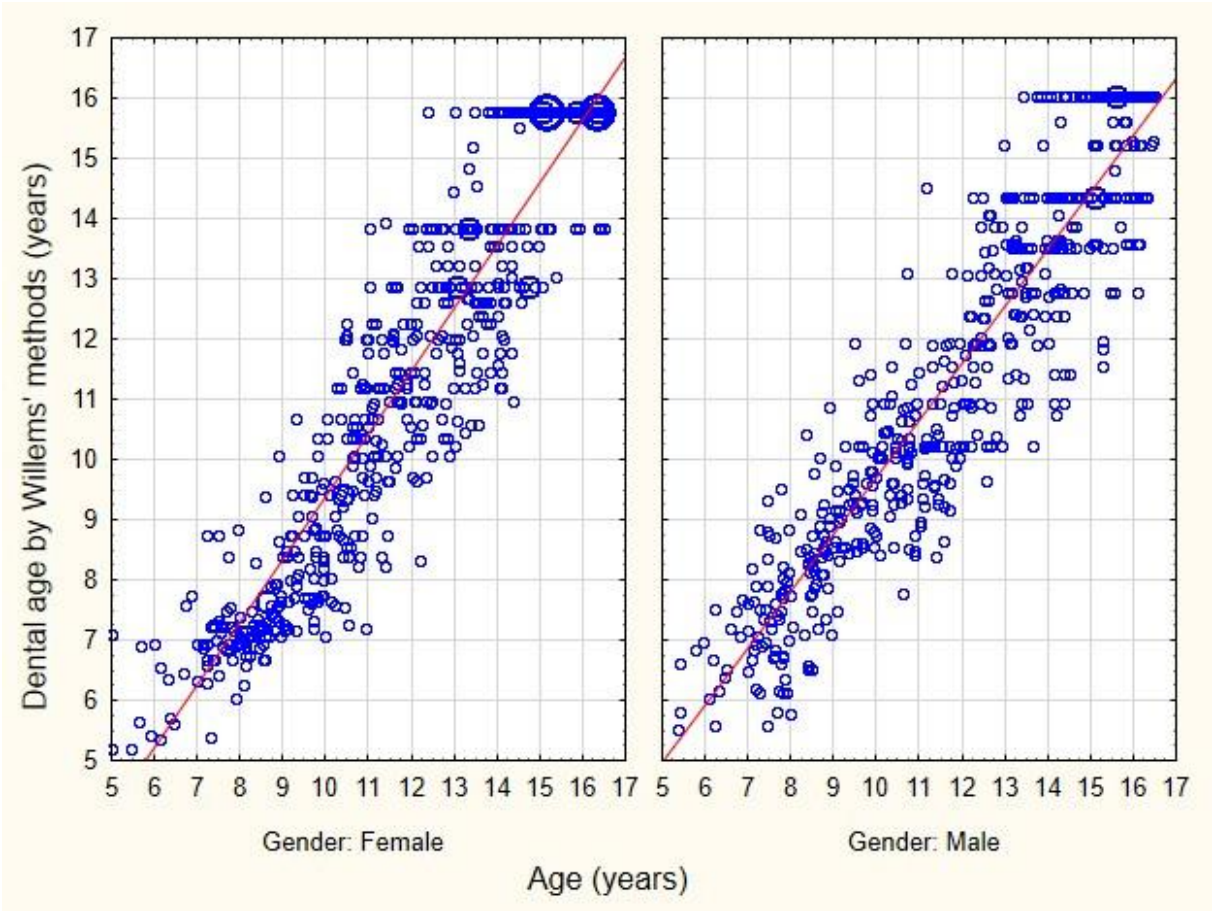

Figure 21. Scatterplots of dental age by the Willems's method by age, according to gender

The Spearman's correlation coefficient of dental age according to the Willems's method with chronological age is 0.930 (n = 563, p <0.001) for girls and 0.923 (n = 543, p <0.001) for boys. Accordingly, the estimation of dental age of a Kosovo sample with maturity scores by the Willems's method shows a high degree of correlation with chronological age for both genders despite noticeable individual deviations (Figure 21).

The distribution of dental age by Willems's method according to the Kolmogorov-Smirnov test does not follow a normal distribution (Kolmogorov-Smirnov Z = 2.508, p <0.001 for girls, Z = 2.163, p <0.001 for boys).

The differences between the genders regarding chronological age and dental age, estimated by the Willems's method, were found only in the 8, 9 and 10 year olds. Since gender comparisons in this research represent secondary goals, only basic parameters of these two key variables of this research (N, Mean, SD) are stated in Table 24. From mean values, it is clear that there is a large degree of correlation of mean values among genders overall years of life and overall.

The coefficients variation is ranged from very low 3.72% to moderate 14.11% for individual age groups. Obviously, a total sample for both genders is significantly higher, about 24%, which is similar to the case of dental age estimation by the Demirjian's method with maturity scores for a French-Canadian population.

Dental age differences obtained by the Willems's method and chronological age are on appearance acceptable normal distributions (Figure 22). According to the results of the Kolmogorov-Smirnov test, the hypothesis on normality of distribution is valid for samples of both genders (Kolmogorov-Smirnov Z = 0.890, p = 0.407 for girls and Z = 1.118, p = 0.164 for the sample of Kolmogorov-Smirnov). For this reason, in subsequent tests, the applied parameter methods will be checked, if necessary, with appropriate boot strap methods that do not require the normality of distribution.

As for the individual deviations of girls, they range from -3.90 to 3.39 years of age, and in boys almost the same, from -3.75 to 3.35 years of age.

Table 24. Summary statistics of chronological age (CA) and dental age (DA) by the Willems's method according to age groups and gender

Age group	Gender	N	CA		DA(W)		
			Mean	SD	Mean	SD	CV (%)
6	Female	15	5.64	0.61	5.89	0.81	13.75
	Male	12	5.86	0.47	6.42	0.61	9.50
7	Female	21	7.20	0.24	7.03	0.76	10.81
	Male	31	7.18	0.27	7.38	0.85	11.52
8	Female	47	8.02	0.29	7.12	0.47	6.60
	Male	49	8.01	0.32	7.57	0.99	13.08
9	Female	51	8.98	0.29	7.94	0.87	10.96
	Male	47	8.97	0.29	8.86	0.91	10.27
10	Female	63	10.01	0.30	9.00	1.27	14.11
	Male	49	10.01	0.29	9.77	0.86	8.80
11	Female	65	10.99	0.27	10.31	1.36	13.19
	Male	58	11.01	0.29	10.17	1.13	11.11
12	Female	61	12.01	0.30	11.71	1.35	11.53
	Male	48	12.01	0.30	11.28	1.28	11.35
13	Female	66	13.04	0.28	12.70	1.34	10.55
	Male	66	13.05	0.31	12.82	1.39	10.84
14	Female	70	14.01	0.27	13.44	1.52	11.31
	Male	64	14.07	0.26	13.69	1.53	11.18
15	Female	52	15.02	0.28	14.95	1.20	8.03
	Male	54	15.00	0.30	14.57	1.32	9.06
16	Female	52	16.08	0.27	15.60	0.58	3.72
	Male	65	15.97	0.29	15.28	0.95	6.22
6-16	Female	563	11.73	2.77	11.73	2.77	23.61
	Male	543	11.83	2.89	11.83	2.89	24.43

CA – chronological age, DA(W) – dental age by Willems' methods, SD – standard deviation, CV – coefficient of variation (%)

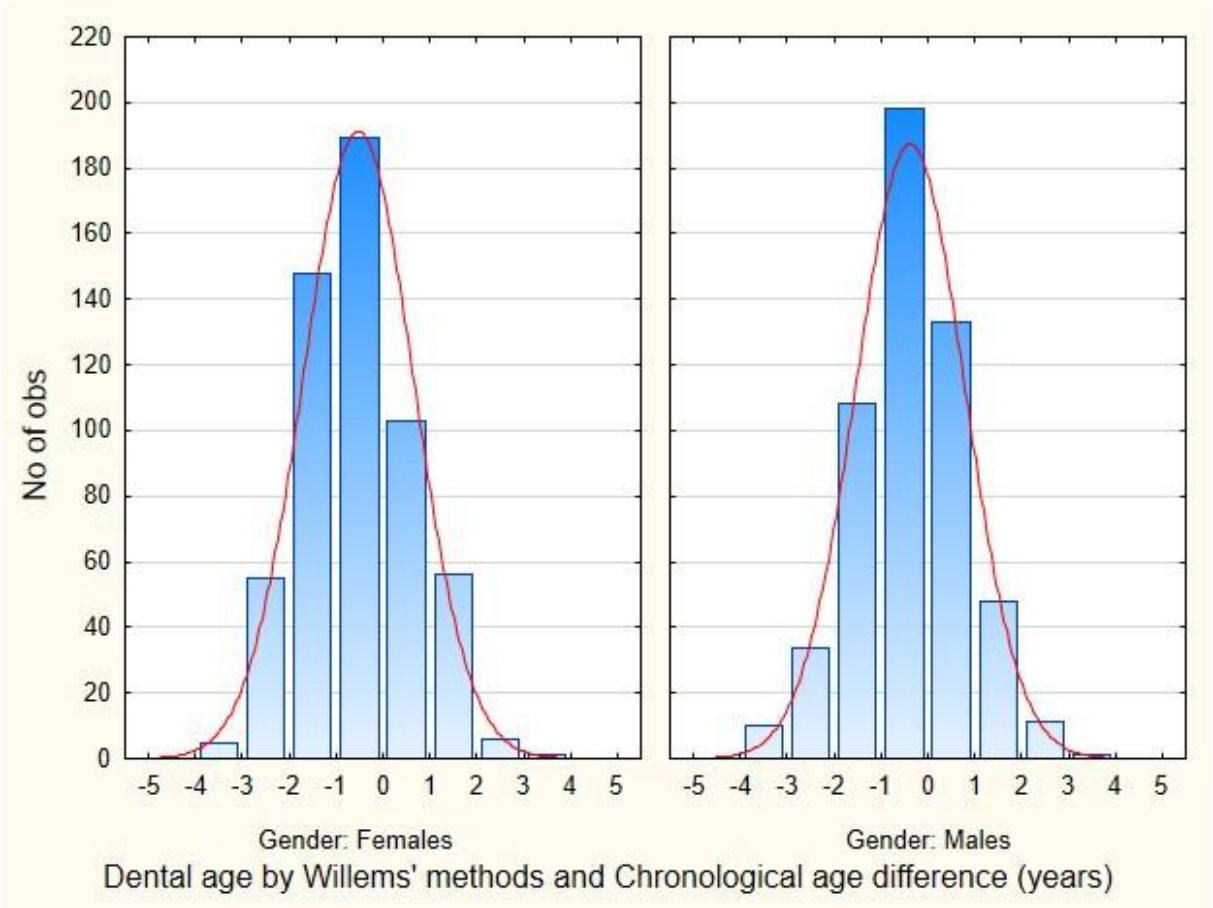

Figure 22. Distribution the difference between dental age by Willems's method and chronological age, according to gender

As can be seen from the data in Table 25, statistically significant differences are found in both genders in the group of 8, 10, 11, 14, 16 year olds. Other statistically significant differences are found in girls in the group of 9 and 13 year olds, and in the group of 6, 12 and 15 year olds boys. These data are illustrated in Figure 23 in which these differences are clearly noticed because the 95% of CIs are completely or almost entirely within the range below or above the line denoting equal values of dental and chronological age (0.0 value highlighted by thick line).

Table 25. Mean age of dental age by the Willems's method and chronological age and difference between age group and gender

Age group	Gender	N	DA(W) – CA						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	T	df	P
6	Female	15	0.25	0.93	-0.27	0.77	1.043	14	0.314
	Male	12	0.56	0.76	0.07	1.04	2.520	11	**0.028**
7	Female	21	-0.18	0.78	-0.53	0.18	-1.037	20	0.312
	Male	31	0.21	0.82	-0.10	0.51	1.391	30	0.174
8	Female	47	-0.90	0.54	-1.06	-0.75	-11.565	46	**<0.001**
	Male	49	-0.44	0.93	-0.71	-0.17	-3.317	48	**0.002**
9	Female	51	-1.03	0.76	-1.25	-0.82	-9.660	50	**<0.001**
	Male	47	-0.12	0.83	-0.36	0.13	-.959	46	0.342
10	Female	63	-1.01	1.16	-1.30	-0.72	-6.926	62	**<0.001**
	Male	49	-0.24	0.83	-0.48	0.00	-2.021	48	**0.049**
11	Female	65	-0.68	1.32	-1.01	-0.35	-4.154	64	**<0.001**
	Male	58	-0.84	1.15	-1.15	-0.54	-5.602	57	**<0.001**
12	Female	61	-0.30	1.34	-0.64	0.04	-1.767	60	0.082
	Male	48	-0.73	1.14	-1.06	-0.40	-4.445	47	**<0.001**
13	Female	66	-0.33	1.31	-0.65	-0.01	-2.045	65	**0.045**
	Male	66	-0.23	1.32	-0.56	0.09	-1.416	65	0.162
14	Female	70	-0.56	1.45	-0.91	-0.22	-3.250	69	**0.002**
	Male	64	-0.39	1.51	-0.76	-0.01	-2.055	63	**0.044**
15	Female	52	-0.07	1.10	-0.38	0.24	-0.469	51	0.641
	Male	54	-0.43	1.30	-0.79	-0.07	-2.425	53	**0.019**
16	Female	52	-0.48	0.68	-0.67	-0.29	-5.056	51	**<0.001**
	Male	65	-0.69	0.95	-0.92	-0.46	-5.873	64	**<0.001**
6-16	Female	563	-0.55	1.17	-0.65	-0.46	-11.160	562	**<0.001**
	Male	543	-0.40	1.16	-0.50	-0.30	-8.083	542	**<0.001**

DA(W) – CA – difference of dental age by Willems' methods and chronological age, SD – standard deviation, 95% CI – confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

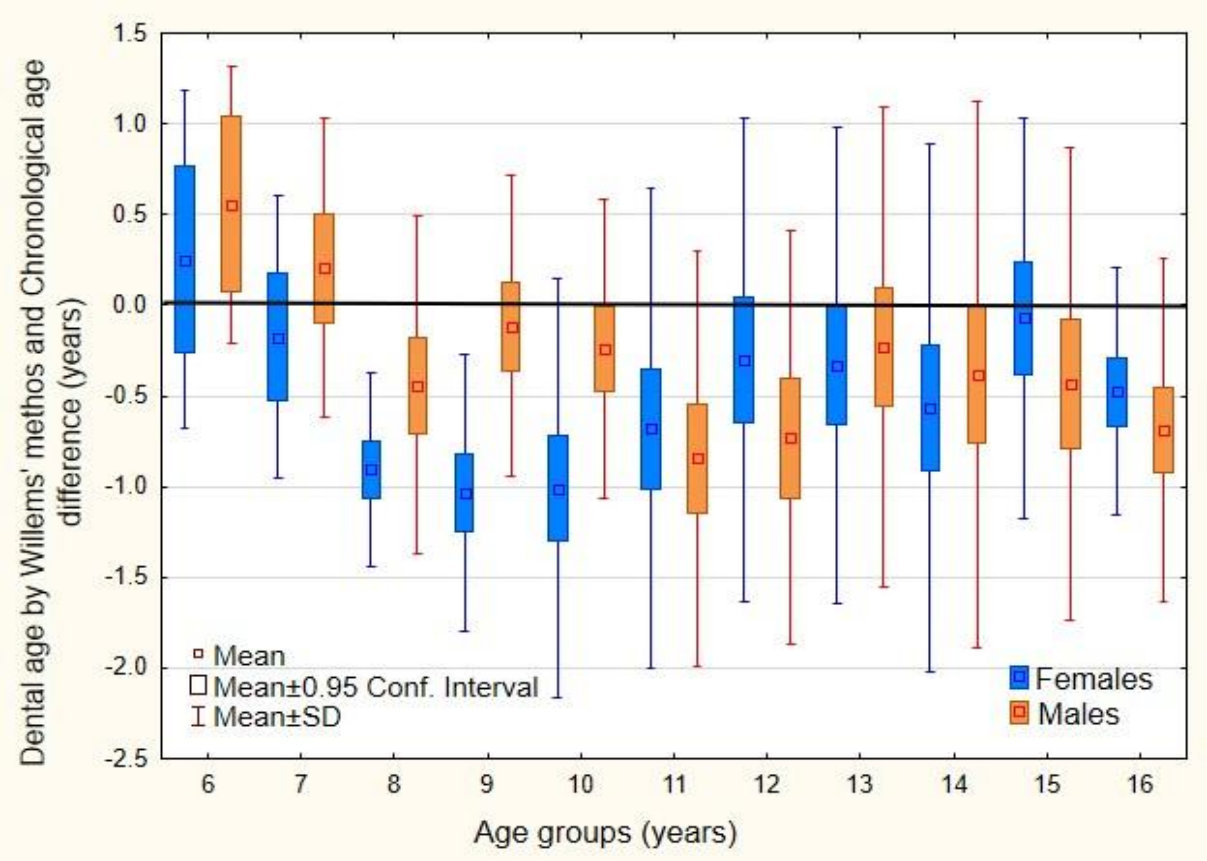

Figure 23. Box plot of the relationship between dental age by the Willems's method and chronological age (DA-CA). Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

A clearer figure of the deviation course from the zero difference is shown in Figure 23. Girls and boys behave somewhat differently, except those in the group of 9 and 10 year olds. However, it is important to point out the fact that dental age of boys estimated by the Willems's method underestimates this age compared to chronological age. As can be seen in the figure, except for the group of 6 and 7 year olds, the difference is below the desirable 0.0 value.

According to t-test results for independent samples, the differences in dental age of girls and boys, listed in Table 25, are statistically significant for age groups of 8 to 10 year olds and the overall sample (Table 26).

The median absolute deviation of dental age estimations from chronological, i.e. deviation, regardless to the gender, the girl or the boy, by the Willems's method is given in Table 27. From the table, it can be seen that the median absolute deviation (the value that divides the

sample in two halves) of dental from chronological age ranges from 0.51 to 1.34 years in girls, while for boys this range is 0.60 to 1.23 years.

Table 26. Gender difference between dental age by the Willems's method and chronological age according to age group

Age group	t statistics		
	t	df	p
6	-0.914	25	0.369
7	-1.677	50	0.100
8	-2.954	94	**0.004**
9	-5.694	96	**<0.001**
10	-3.947	110	**<0.001**
11	0.725	121	0.470
12	1.770	107	0.080
13	-0.435	130	0.664
14	-0.695	132	0.488
15	1.524	104	0.130
16	1.371	115	0.173
6-16	-2.160	1104	**0.031**

p - the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

The frequency of absolute deviation of dental age, estimated by the Willems's method, from chronological age at half-year intervals is shown in Figure 24. It is noticeable that there is a maximum deviation of 0.5 to one year in both genders, and subsequently the frequency drops sharply up to a small number in the age groups of 3.5 and 4 years, which is more pronounced in boys.

Table 27. Mean absolute difference between dental age by the Willems's method and chronological age according to age group and gender

Age group	Gender	N	|DA(W) - CA|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.69	0.65	0.51	0.18	0.92
	Male	12	0.71	0.61	0.57	0.14	1.16
7	Female	21	0.61	0.50	0.56	0.21	0.87
	Male	31	0.66	0.52	0.51	0.25	1.00
8	Female	47	0.97	0.40	1.00	0.69	1.22
	Male	49	0.78	0.67	0.71	0.20	1.14
9	Female	51	1.18	0.50	1.27	0.79	1.55
	Male	47	0.60	0.58	0.41	0.16	0.90
10	Female	63	1.34	0.74	1.34	0.82	1.95
	Male	49	0.69	0.50	0.65	0.25	1.06
11	Female	65	1.16	0.92	1.04	0.41	1.78
	Male	58	1.16	0.82	1.03	0.54	1.75
12	Female	61	1.10	0.81	1.05	0.48	1.50
	Male	48	1.12	0.75	1.10	0.36	1.78
13	Female	66	1.08	0.81	0.82	0.48	1.51
	Male	66	1.08	0.79	0.94	0.39	1.40
14	Female	70	1.33	0.81	1.32	0.77	1.80
	Male	64	1.23	0.95	1.06	0.42	1.84
15	Female	52	0.96	0.53	0.74	0.57	1.23
	Male	54	1.07	0.84	0.87	0.59	1.29
16	Female	52	0.51	0.65	0.33	0.12	0.57
	Male	65	0.84	0.81	0.43	0.25	1.50
6-16	Female	563	1.06	0.75	0.96	0.46	1.51
	Male	543	0.94	0.78	0.77	0.29	1.39

|DA(W) - CA| - dental age by Willems' methods and chronological age absolute difference, SD – standard deviation

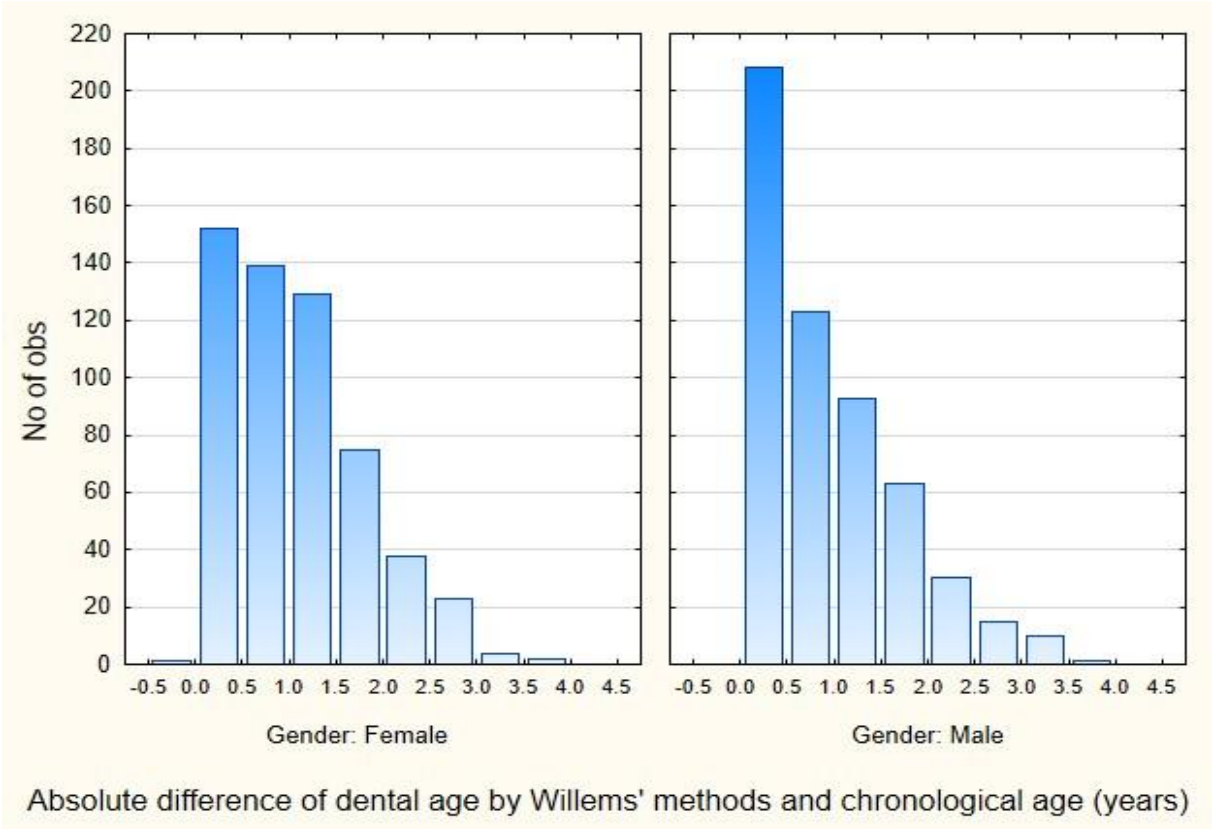

Figure 24. Distribution of mean absolute difference between dental age by the Willems's method and chronological age according to gender

Dental age estimated by the Demirjian's maturity score method for the French Canadian population is statistically significant different from the age estimation by the Willems's method, which can be observed from the t-test results, for the hypothesis that the difference in these estimations is zero for all age groups (Table 28) in both genders. The difference is positive in each age group, meaning that the Demirjian's method overestimates systematically dental age compared to the Willems's method.

The differences, listed in Table 28, are illustrated in Figure 25 with corresponding confident intervals.

A clearer figure of the deviation from the zero difference is shown in Figure 25. Girls and boys, as far as differences are concerned, behave quite differently in almost every age group. However, it is important to point out that dental age estimated by the Willems's method is underestimated in both genders compared to the Demirjian's method with maturity scores for the French Canadian population.

Table 28. Mean age of dental age by the Demirjian's method with dental maturity scores for a French Canadian population and dental age by The Willems's method and difference between age group and gender

Age group	Gender	N	DA(D) – DA(W)						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	df	p
6	Female	15	0.33	0.18	0.23	0.43	6.873	14	**<0.001**
	Male	12	0.61	0.23	0.46	0.75	9.013	11	**<0.001**
7	Female	21	0.33	0.28	0.21	0.46	5.405	20	**<0.001**
	Male	31	0.26	0.27	0.16	0.36	5.314	30	**<0.001**
8	Female	47	0.40	0.22	0.34	0.47	12.675	46	**<0.001**
	Male	49	0.26	0.27	0.18	0.34	6.781	48	**<0.001**
9	Female	51	0.51	0.43	0.39	0.63	8.454	50	**<0.001**
	Male	47	0.20	0.31	0.11	0.29	4.512	46	**<0.001**
10	Female	63	0.67	0.47	0.55	0.79	11.358	62	**<0.001**
	Male	49	0.34	0.35	0.24	0.45	6.899	48	**<0.001**
11	Female	65	0.91	0.51	0.78	1.03	14.277	64	**<0.001**
	Male	58	0.23	0.71	0.04	0.41	2.471	57	**0.016**
12	Female	61	0.90	0.45	0.78	1.01	15.683	60	**<0.001**
	Male	48	0.35	0.89	0.09	0.61	2.734	47	**<0.001**
13	Female	66	0.63	0.57	0.49	0.77	8.971	65	**<0.001**
	Male	66	0.57	0.62	0.42	0.72	7.506	65	**<0.001**
14	Female	70	0.55	0.42	0.45	0.65	10.924	69	**<0.001**
	Male	64	0.69	0.50	0.57	0.82	11.208	63	**<0.001**
15	Female	52	0.37	0.28	0.30	0.45	9.501	51	**<0.001**
	Male	54	0.69	0.60	0.52	0.85	8.376	53	**<0.001**
16	Female	52	0.26	0.16	0.22	0.31	11.579	51	**<0.001**
	Male	65	0.46	0.56	0.32	0.60	6.585	64	**<0.001**
6-16	Female	563	0.58	0.46	0.54	0.62	29.746	562	**<0.001**
	Male	543	0.43	0.58	0.38	0.48	17.431	542	**<0.001**

DA(D) – DA(W) – difference of dental age by Demirjian's methods with maturity score for French Canadian population and dental age by Willems' method, SD – standard deviation, 95% CI – confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

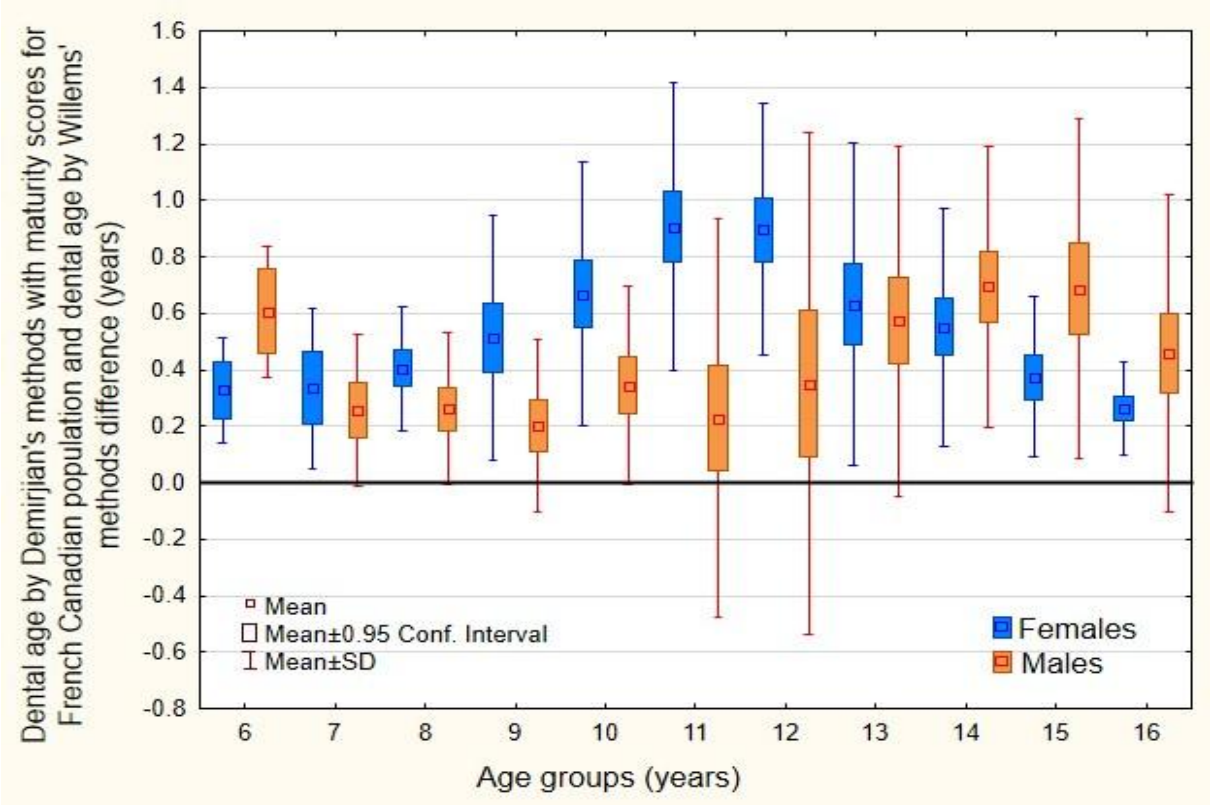

Figure 25. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a French Canadian population and dental age by Willems's method. Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

According to t-test results for independent samples, the differences between two estimations of dental age of girls and boys, listed in Table 29, are statistically significant for almost all age groups and overall except for groups of 7, 13 and 14 year olds.

The median absolute deviation of dental age estimations by the Demirjian's method for the French Canadian population from estimations by the Willems's method, i.e. deviation regardless to the gender, girls or boys, is given in Table 30. From the table, it can be seen that the median absolute deviation (the value that divides the sample into half) of dental age from chronological age ranges from 0.34 to 0.97 years in girls, while this range is from 0.29 to 0.78 years in boys.

Table 29. Gender difference between dental age by the Demirjian's method with dental maturity scores for a French Canadian population and dental age by Willems's method according to age group

Age group	t statistics		
	t	df	p
6	-3.479	25	**0.002**
7	0.983	50	0.330
8	2.869	94	**0.005**
9	4.054	96	**<0.001**
10	4.042	110	**<0.001**
11	6.142	121	**<0.001**
12	4.171	107	**<0.001**
13	0.581	130	0.562
14	-1.801	132	0.074
15	-3.393	104	**0.001**
16	-2.435	115	**0.016**
6-16	4.756	1104	**<0.001**

p – the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

The frequency of the dental age absolute deviation, estimated by the Demirjian's method with maturity scores for the French Canadian population, from that estimated by the Willems's method at half-year intervals is shown in Fig. 26. It is evident that the maximum deviation is between 0.5 and 1.5 years in both genders, and greater differences are found in negligible numbers in both genders.

Table 30. Mean absolute difference between dental age by the Demirjian's method with maturity scores for a Franch Canadian population and dental age by the Willems's method according to age group and gender

Age group	Gender	N	|DA(D) – DA(W)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.34	0.16	0.31	0.22	0.45
	Male	12	0.61	0.23	0.53	0.48	0.71
7	Female	21	0.37	0.24	0.34	0.22	0.43
	Male	31	0.32	0.19	0.32	0.18	0.45
8	Female	47	0.40	0.22	0.36	0.23	0.53
	Male	49	0.32	0.20	0.29	0.15	0.50
9	Female	51	0.53	0.41	0.42	0.24	0.66
	Male	47	0.29	0.22	0.19	0.14	0.46
10	Female	63	0.70	0.42	0.66	0.37	1.02
	Male	49	0.42	0.25	0.40	0.24	0.56
11	Female	65	0.97	0.37	0.98	0.75	1.24
	Male	58	0.62	0.40	0.56	0.34	0.96
12	Female	61	0.91	0.41	0.83	0.72	1.34
	Male	48	0.78	0.54	0.61	0.45	0.96
13	Female	66	0.75	0.41	0.76	0.41	0.83
	Male	66	0.72	0.44	0.66	0.40	1.17
14	Female	70	0.58	0.38	0.54	0.21	0.82
	Male	64	0.70	0.48	0.72	0.35	1.17
15	Female	52	0.37	0.28	0.21	0.21	0.76
	Male	54	0.71	0.58	0.78	0.03	1.36
16	Female	52	0.26	0.16	0.21	0.21	0.21
	Male	65	0.49	0.53	0.03	0.03	0.81
6-16	Female	563	0.34	0.16	0.31	0.22	0.45
	Male	543	0.61	0.23	0.53	0.48	0.71

\|DA(D) – DA(W)\|- Dental age by Demirjian's methods with French Canadian maturity scores and Dental age by Willems' method absolute difference, SD – Standard deviation

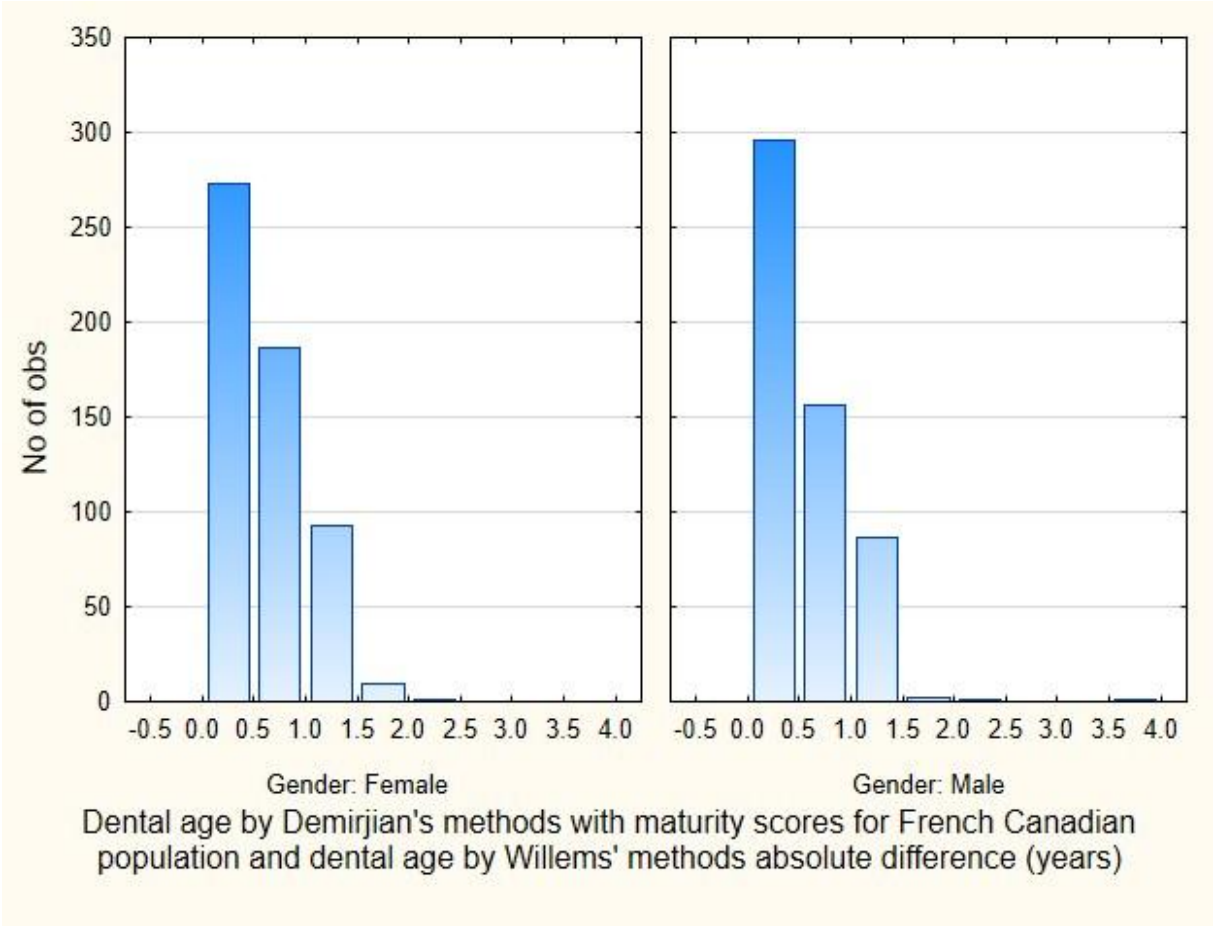

Figure 26. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and dental age by the Willems's method according to gender

As it turns out, there is a statistically significant difference between dental age estimated by the Demirjian's maturity score for a Kosovo sample and the estimation of dental age by the Willems's method as demonstrated by the t-test results for the hypothesis that the difference between these estimations equals zero for all age groups and both genders (Table 31). The difference is positive in almost every age group, meaning that the Demirjian's method almost systematically overestimates dental age compared to the Willems's method, which is similar to the comparison with the Demirjian's method for the French Canadian population.

Table 31. Mean age of dental age by the Demirjian's method with dental maturity scores for a Kosovo population and dental age by the Willems's method and difference between age group and gender

Age group	Gender	N	DA(DK) – DA(W)						
			Mean diff.	SD	95% CI		t statistics		
					Lower	Upper	t	df	P
6	Female	15	0.59	0.44	0.35	0.83	5.204	14	**<0.001**
	Male	12	0.49	0.42	0.22	0.76	4.032	11	**0.002**
7	Female	21	0.40	0.38	0.23	0.58	4.775	20	**<0.001**
	Male	31	0.26	0.37	0.13	0.40	3.976	30	**<0.001**
8	Female	47	0.50	0.46	0.37	0.64	7.509	46	**<0.001**
	Male	49	0.15	0.39	0.04	0.26	2.730	48	**0.009**
9	Female	51	0.93	0.40	0.82	1.04	16.766	50	**<0.001**
	Male	47	0.02	0.31	-0.07	0.11	0.387	46	0.701
10	Female	63	0.85	0.40	0.75	0.95	16.878	62	**<0.001**
	Male	49	-0.01	0.30	-0.09	0.08	-0.192	48	0.849
11	Female	65	0.69	0.44	0.58	0.79	12.674	64	**<0.001**
	Male	58	-0.06	0.40	-0.17	0.04	-1.165	57	0.249
12	Female	61	0.52	0.31	0.45	0.60	13.182	60	**<0.001**
	Male	48	-0.01	0.61	-0.19	0.17	-0.112	47	0.911
13	Female	66	0.32	0.43	0.22	0.43	6.118	65	**<0.001**
	Male	66	0.20	0.65	0.04	0.36	2.432	65	**0.018**
14	Female	70	0.21	0.40	0.12	0.31	4.406	69	**<0.001**
	Male	64	0.44	0.58	0.29	0.58	6.057	63	**<0.001**
15	Female	52	0.09	0.29	0.01	0.17	2.234	51	**0.030**
	Male	54	0.48	0.59	0.32	0.64	6.051	53	**<0.001**
16	Female	52	-0.03	0.19	-0.08	0.03	-1.025	51	0.310
	Male	65	0.21	0.58	0.06	0.35	2.879	64	**0.005**
6-16	Female	563	0.46	0.48	0.42	0.50	22.572	562	**<0.001**
	Male	543	0.18	0.54	0.14	0.23	7.870	542	**<0.001**

DA(DK) – DA(W) – difference of dental age by Demirjian's methods with maturity scores for Kosovo population and dental age by Willems' methods, SD – Standard deviation, 95% CI – Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

These differences are listed in Table 31, and illustrated in Figure 27 with corresponding confident intervals. A clearer figure of the deviation course from the zero difference is shown in Figure 27. As far as differences are unconcerned, girls and boys behave quite differently in almost every age group. However, it is important to point out that in most cases, dental age of both genders estimated by the Willems's method underestimates this age compared to the Demirjian's method with maturity scores for the Kosovo sample. This is particularly

pronounced in groups of 8 to 12 year olds girls, and in the same groups of boys, the estimation of the difference is about zero, and this difference is not statistically significant in the groups of 9 to 12 year olds.

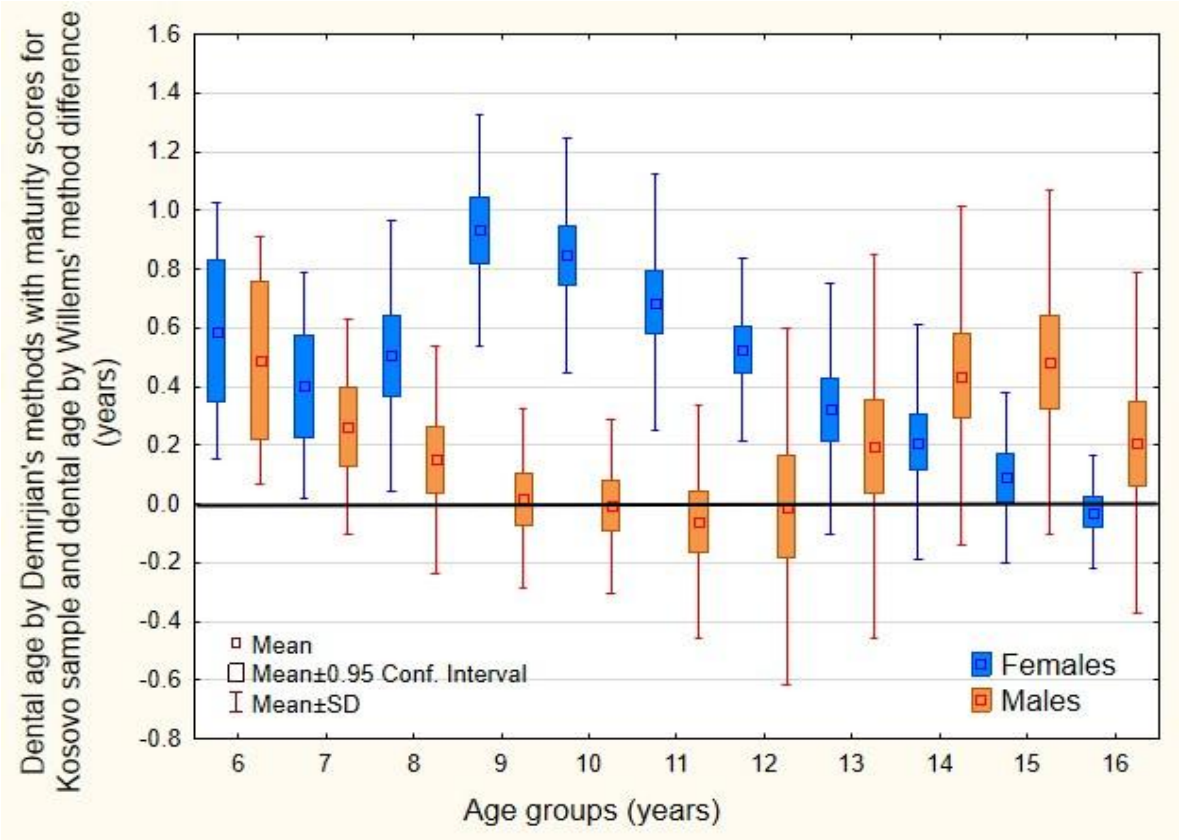

Figure 27. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Willems's method. Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

According to t-test results for independent samples, the difference between the two dental age estimations of girls and boys, listed in Table 32, is statistically significant for almost all age groups and overall, except for groups of 6, 7 and 13 year olds.

Table 32. Gender difference between dental age by the Demirjian's method with dental maturity scores for a Kosovo and dental age by the Willems's method according to age group

Age group	t statistics		
	t	df	p
6	0.584	25	0.564
7	1.327	50	0.191
8	4.094	94	**<0.001**
9	12.700	96	**<0.001**
10	12.535	110	**<0.001**
11	9.875	121	**<0.001**
12	5.963	107	**<0.001**
13	1.304	130	0.195
14	-2.644	132	**0.009**
15	-4.349	104	**<0.001**
16	-2.793	115	**0.006**
6-16	9.056	1104	**<0.001**

p – the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

The median absolute deviation of dental age estimations by the Demirjian's method with maturity scores for a Kosovo sample from dental age estimations by the Willems's method, i.e. deviation regardless to the gender, girls or boys, is shown in Table 33. From Table 33, it can be seen that the median absolute deviation of dental age (value dividing the sample in two halves) from chronological age ranges from 0.14 to 0.93 years in girls, whereas this range is 0.24 to 0.58 years in boys.

Table 33. Mean absolute difference between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Willems's method according to age group and gender

Age group	Gender	N	|DA(DK) – DA(W)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.59	0.44	0.59	0.13	1.02
	Male	12	0.49	0.42	0.38	0.11	0.85
7	Female	21	0.43	0.36	0.22	0.13	0.67
	Male	31	0.33	0.30	0.24	0.12	0.52
8	Female	47	0.53	0.43	0.54	0.13	0.72
	Male	49	0.33	0.24	0.31	0.15	0.40
9	Female	51	0.93	0.40	0.92	0.69	1.26
	Male	47	0.25	0.18	0.21	0.09	0.33
10	Female	63	0.85	0.40	0.87	0.55	1.14
	Male	49	0.24	0.18	0.19	0.14	0.33
11	Female	65	0.72	0.37	0.74	0.52	0.91
	Male	58	0.31	0.26	0.26	0.14	0.36
12	Female	61	0.55	0.27	0.52	0.43	0.76
	Male	48	0.39	0.46	0.26	0.16	0.41
13	Female	66	0.45	0.29	0.52	0.17	0.56
	Male	66	0.55	0.40	0.40	0.23	0.91
14	Female	70	0.34	0.30	0.21	0.09	0.56
	Male	64	0.57	0.44	0.60	0.13	0.92
15	Female	52	0.21	0.21	0.09	0.09	0.52
	Male	54	0.58	0.49	0.66	0.03	1.16
16	Female	52	0.14	0.14	0.09	0.09	0.09
	Male	65	0.39	0.48	0.03	0.03	0.91
6-16	Female	563	0.59	0.44	0.59	0.13	1.02
	Male	543	0.49	0.42	0.38	0.11	0.85

\|DA(DK) – DA(W)\| - Dental age by Demirjian's methods with Kosovo maturity scores and Dental age by Willems' methods absolute difference, SD – Standard deviation

The frequency of the median absolute deviation of dental age, estimated by the Demirjian's method of maturity scores for a Kosovo sample, from estimation of dental age by the Willems's method, at half-year intervals, is shown in Figure 28. It is evident that the maximum deviation is between 0.5 and 1.5 years in both genders, and larger differences are found in negligible numbers in both genders.

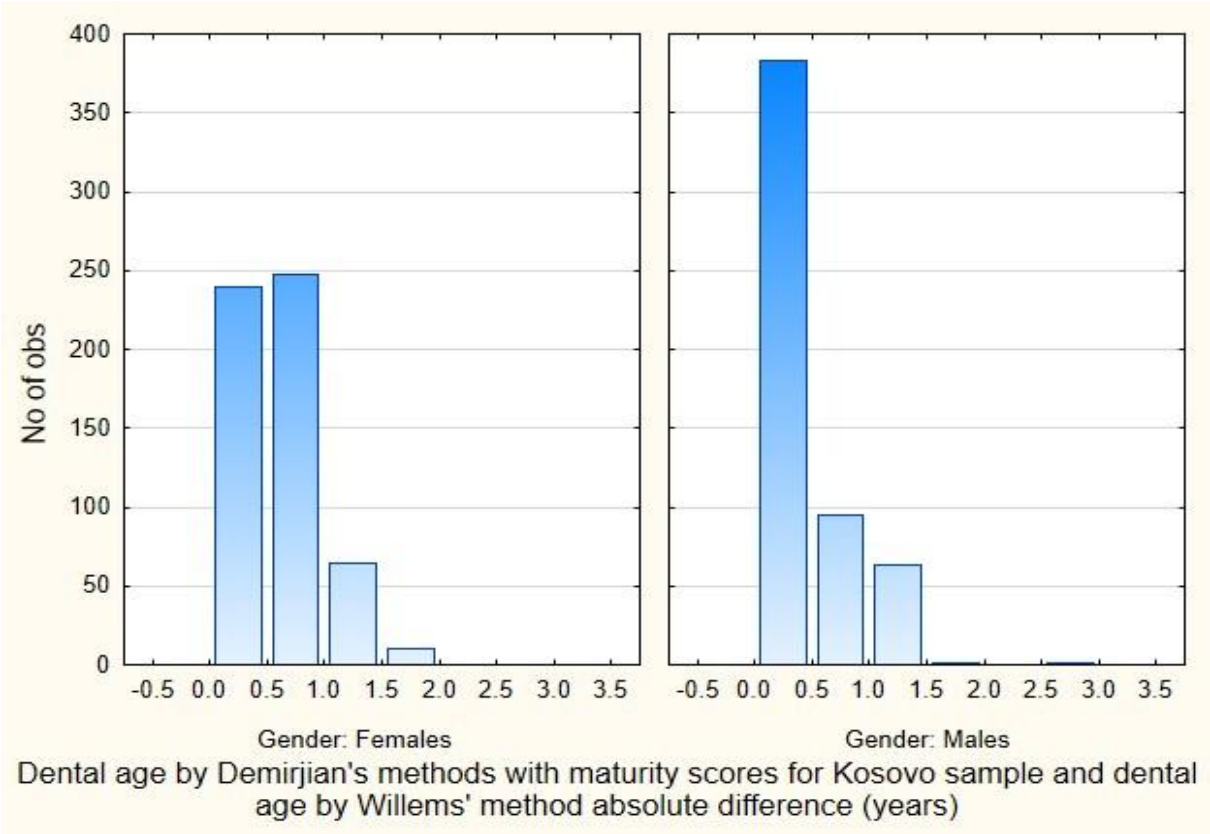

Figure 28. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Willems's method according to gender

The Spearman correlation coefficient of dental age according to the Willems's method and dental age according to the Demirjian's maturity score method for the French Canadian population is 0.992 (n = 563, p <0.001) for girls, and 0.989 for boys (n = 543, p < 0.001). Accordingly, the estimation of dental age by the Willems's method shows a high degree of correlation with the Demirjian's method with maturity scores of the French Canadian population for both genders, despite noticeable individual deviations (Figure 29).

The Spearman correlation coefficient of dental age according to the Willems's method and dental age according to the Demirjian's method, but with maturity scores for a Kosovo sample, is 0.995 for girls (n = 563, p <0.001), and 0.989 for boys (n = 543, p < 0.001). Therefore, the estimation of dental age by the Willems's method also shows a high degree of consistency with the Demirjian's method with maturity scores for a Kosovo sample for both genders, with somewhat more pronounced individual deviations in groups of 10 year olds (Figure 30).

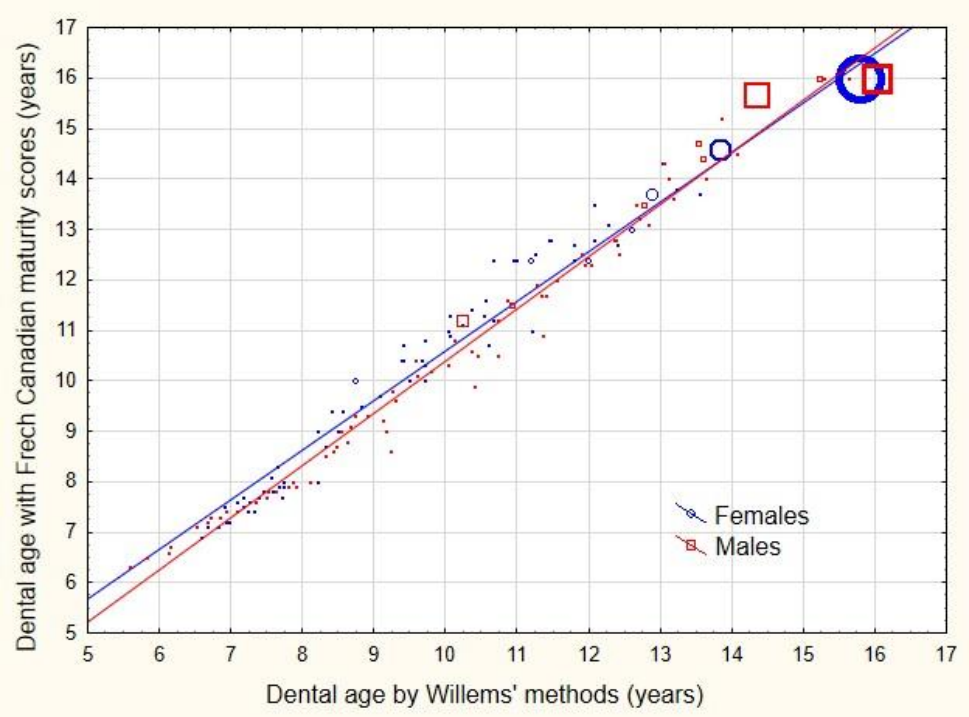

Figure 29. Scatterplot of dental age by the Demirjian's method with maturity scores for a French Canadian and dental age by the Willems's method, according to gender

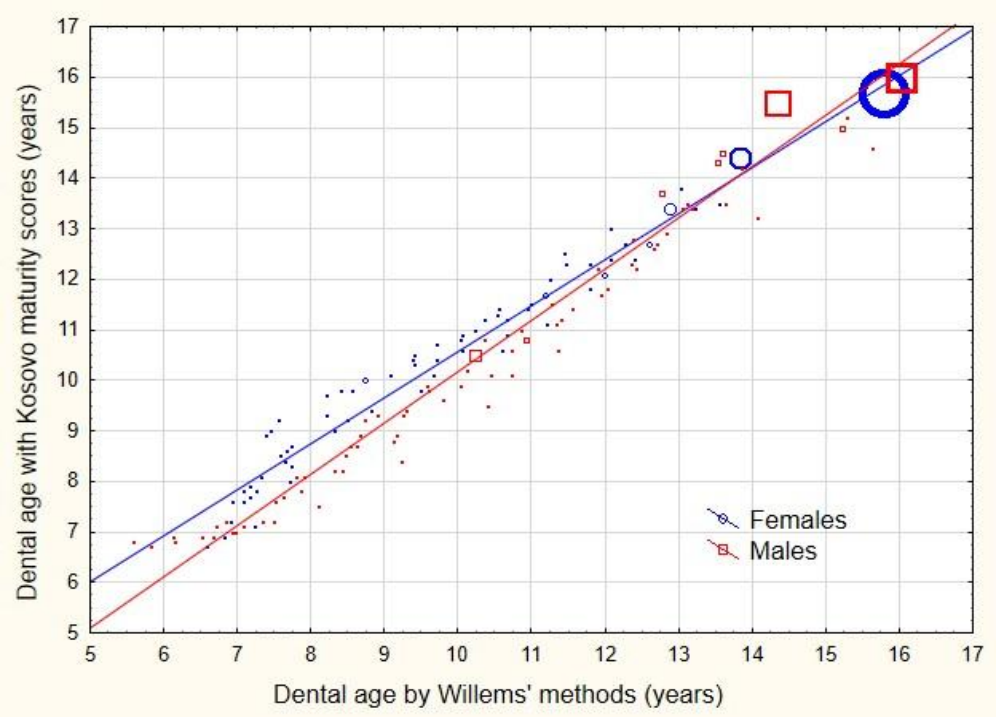

Figure 30. Scatterplot of dental age by the Demirjian's methods with maturity scores for a Kosovo population and dental age by the Willems's method, according to gender

The applied methods of dental age estimation are correlated with each other in a correlation with an exceeding value 0.99. According to the chronological age, the correlations in girls correlate with a value rounded to two decimal places of 0.93, and in boys the value is 0.92.

4.5 Dental age estimation by Cameriere's methods

Dental age estimation by the Cameriere's method refers to chronological age as shown by scatterplot in Figure 31. This figure points to the fact that individual deviations do not differ significantly from those in the Demirjian's method and the Willems's method.

The Spearman correlation coefficient of dental age according to the Cameriere's method with chronological age is 0.894 ($n = 450$, $p < 0.001$) for girls, and it is also 0.894 ($n = 411$, $p < 0.001$) for boys. Therefore, the estimation of dental age of the Kosovo sample by the Cameriere's regression method, which was made on the 8 teeth on the left side of the lower jaw, has shown a high correlation with chronological age for both genders, but with slightly smaller correlation coefficients than those found in the previous methods (Figure 31).

The distribution of dental age according to the Cameriere's method according to the Kolmogorov-Smirnov test does not follow a normal distribution (Kolmogorov-Smirnov $Z=3.477$, $p < 0.001$ for girls, $Z = 3.049$, $p < 0.001$ for boys), which is shown in Figure 31.

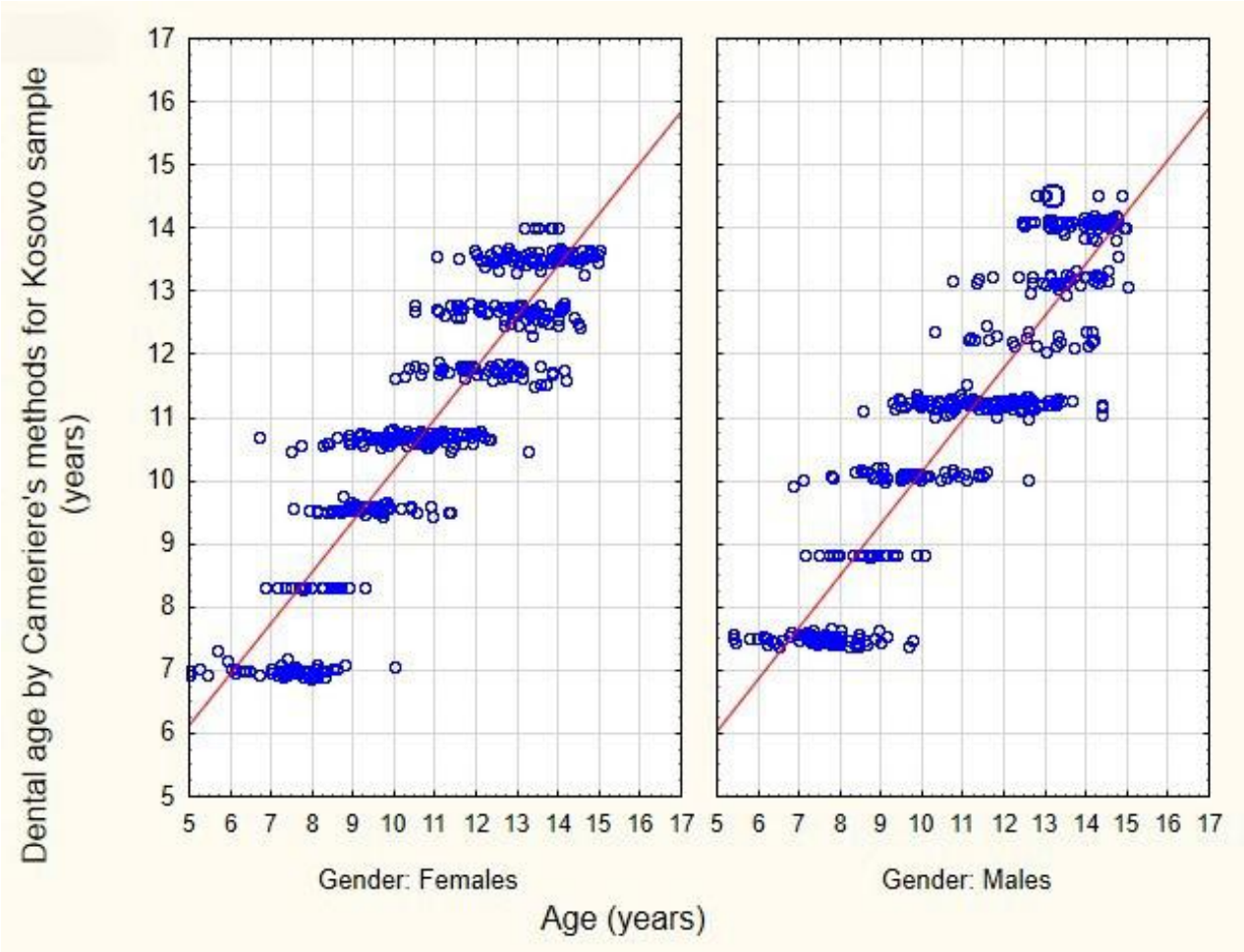

Figure 31. Scatterplots of dental age by the Camerier's method by age, according to gender

Differences between chronological age and dental age, estimated using the Cameriere's method, were found in groups of 6, 11, 12, 14 and 15 year olds. The difference in all these groups is around half a year. Since gender comparisons in this research represent secondary goals, only basic parameters of these two key variables of this study (N, Mean, SD) are listed in Table 34. From the average values themselves, it can be clearly seen that the ratio of average rates between genders overall years of life.

Table 34. Summary statistics of chronological age (CA) and dental age (DA)by the Camerier's method according to age groups and gender

Age group	Gender	N	CA		DA(CK)	
			Mean	SD	Mean	SD
6	Female	14	5.64	0.63	7.03	0.10
	Male	12	5.86	0.47	7.49	0.05
7	Female	20	7.20	0.24	7.61	1.15
	Male	31	7.18	0.27	7.76	0.68
8	Female	47	8.02	0.29	8.02	1.26
	Male	49	8.01	0.32	8.03	0.85
9	Female	51	8.98	0.29	9.48	1.02
	Male	47	8.97	0.29	9.37	1.09
10	Female	63	10.01	0.30	10.47	0.84
	Male	42	9.96	0.28	10.47	1.00
11	Female	65	10.99	0.27	10.88	0.81
	Male	49	11.05	0.29	11.19	0.75
12	Female	59	12.00	0.29	12.07	1.00
	Male	48	12.01	0.30	11.57	0.85
13	Female	64	13.03	0.28	12.81	0.78
	Male	63	13.03	0.31	12.75	1.27
14	Female	54	13.96	0.26	13.04	0.70
	Male	52	14.07	0.26	13.44	0.92
15	Female	13	14.73	0.17	13.47	0.33
	Male	18	14.69	0.16	13.93	0.39
6-15	Female	450	10.87	2.30	10.87	2.08
	Male	411	10.85	2.48	10.85	2.24

CA – Chronological Age, DA(CK) – Dental Age by Cameriere's methods for Kosovo sample, SD – Standard deviation

Dental age differences obtained by the Cameriere's method and chronological age are on appearance acceptable normal distributions (Figure 32). The results of the Kolmogorov-Smirnov test are also shown: the hypothesis about the normality of distribution is confirmed by samples of both genders (Kolmogorov-Smirnov Z = 0.870, p = 0.435 for girls and Kolmogorov-Smirnov Z = 0.721, p = 0.676 for boys). For this reason, further tests will use the applied parametric methods and, if necessary, they will be checked with appropriate boot strap methods that are not sensitive to normality of distribution.

As for the individual deviations of girls, they range from -2.94 to 4.01 years, and they are almost the same for boys, from -3.32 to 3.06 years.

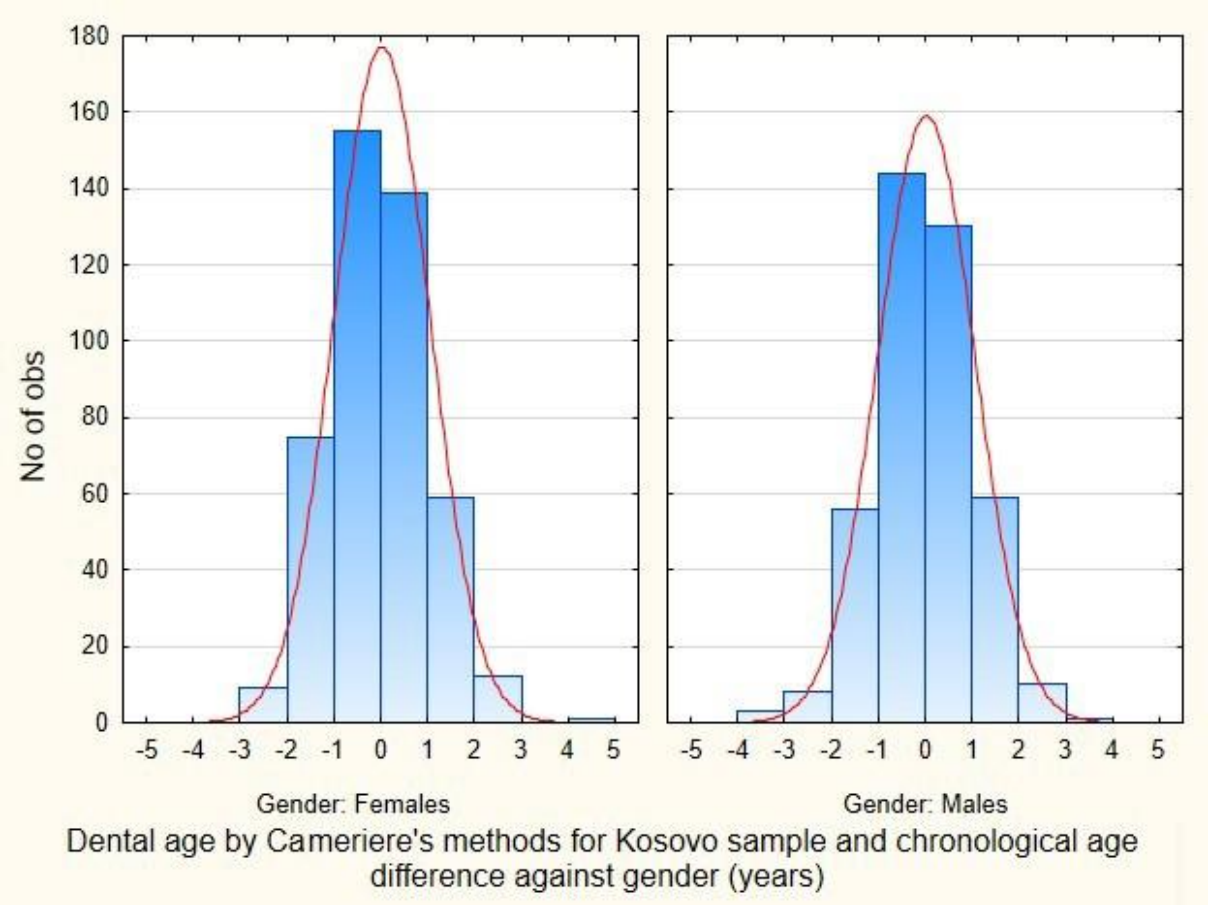

Figure 32. Distribution the difference between dental age by the Camerier's method and chronological age, according to gender

As can be seen from the data in Table 35, statistically significant differences have been found in both genders in the groups of 6, 9, 10, 14 and 15 year olds. Other statistically significant differences have been found in girls in the group of 13 year olds, and in the groups of 7 and 12 year olds boys. These data are illustrated in Figure 33, in which these deviations are clearly notable because the 95% of CIs are completely or almost entirely within the range below or above the line denoting equal values of dental and chronological age (0.0 value highlighted by thick line).

Table 35. Mean age of dental age by the Cameriere's method and chronological age and difference between age group and gender

Age group	Gender	N	DA(CK) – CA						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	df	P
6	Female	14	1.38	0.63	1.02	1.75	8.203	13	**<0.001**
	Male	12	1.63	0.48	1.33	1.94	11.750	11	**<0.001**
7	Female	20	0.41	1.21	-0.16	0.98	1.513	19	0.147
	Male	31	0.58	0.76	0.30	0.86	4.244	30	**<0.001**
8	Female	47	0.00	1.19	-0.35	0.35	-0.015	46	0.988
	Male	49	0.02	0.84	-0.22	0.26	0.145	48	0.886
9	Female	51	0.50	0.90	0.25	0.76	4.004	50	**<0.001**
	Male	47	0.39	1.02	0.09	0.69	2.648	46	**0.011**
10	Female	63	0.46	0.76	0.27	0.65	4.794	62	**<0.001**
	Male	42	0.51	0.92	0.22	0.80	3.571	41	**0.001**
11	Female	65	-0.10	0.79	-0.30	0.09	-1.061	64	0.293
	Male	49	0.13	0.76	-0.09	0.35	1.207	48	0.233
12	Female	59	0.07	0.98	-0.18	0.33	0.559	58	0.578
	Male	48	-0.44	0.81	-0.67	-0.20	-3.758	47	**<0.001**
13	Female	64	-0.22	0.79	-0.41	-0.02	-2.191	63	**0.032**
	Male	63	-0.28	1.18	-0.58	0.02	-1.886	62	0.064
14	Female	54	-0.91	0.69	-1.10	-0.72	-9.661	53	**<0.001**
	Male	52	-0.62	0.96	-0.89	-0.36	-4.702	51	**<0.001**
15	Female	13	-1.26	0.30	-1.44	-1.08	-15.058	12	**<0.001**
	Male	18	-0.76	0.43	-0.97	-0.54	-7.523	17	**<0.001**
6-15	Female	450	0.00	1.01	-0.09	0.09	0.000	449	1.000
	Male	411	0.00	1.03	-0.10	0.10	0.000	410	1.000

DA(CK) – CA – difference of dental age by Cameriere's methods for Kosovo sample and chronological age, SD – Standard deviation, 95% CI – 95% Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

As far as the differences are concerned, girls and boys behave slight similarly to the deviation of zero difference. However, it is important to point out that in the both gender, dental age is overestimated by Cameriere's method, compared with chronological age in the age groups of 6 to 10 year olds, and is underestimated for the age group 12 years.

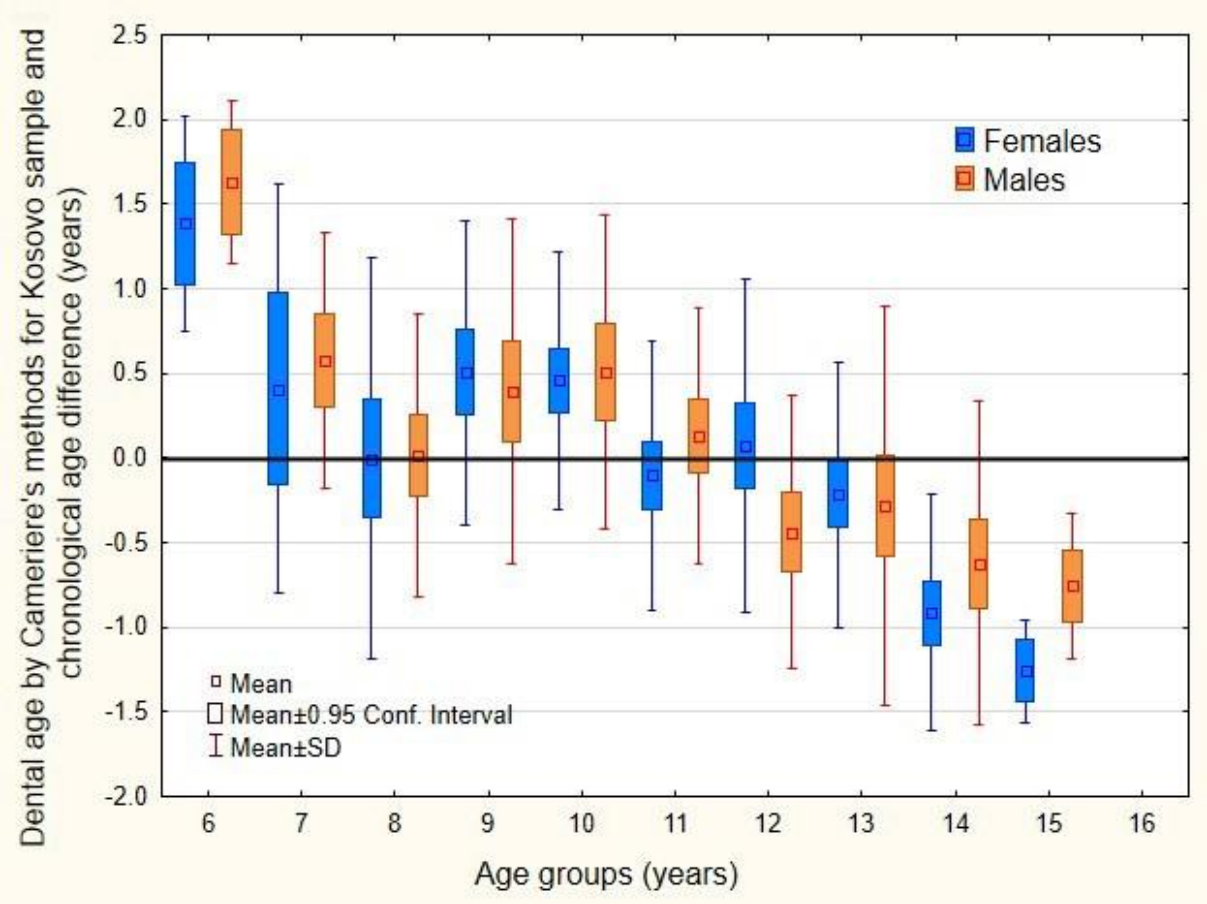

Figure 33. Box plot of the relationship between dental age by the Cameriere's method and chronological age. Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

According to the results of the t-test for independent samples, the differences between dental age of girls and boys evaluated by the Cameriere's method and their chronological age, listed in Table 36, are statistically significant for age groups of 12 and 15 year olds.

The median absolute deviation of dental age estimations by the Cameriere's method from chronological age, i.e. deviation, regardless to the gender, the girl or the boy, is shown in Table 37. From the table, it can be seen that the median absolute deviation (value dividing the sample in two halves) of dental age from chronological age ranges from 0.58 to 1.38 years in girls, while this range is 0.55 to 1.63 years in boys.

Table 36. Gender difference between dental age by the Cameriere's method and chronological age according to age group

Age group	t statistics		
	t	df	p
6	-1.103	24	0.281
7	-0.613	49	0.543
8	-0.095	94	0.925
9	0.566	96	0.573
10	-0.307	103	0.759
11	-1.596	112	0.113
12	2.881	105	**0.005**
13	0.366	125	0.715
14	-1.794	104	0.076
15	-3.630	29	**0.001**
6-15	0.000	859	1.000

p – the probability of the hypothesis that the difference by gender is statistically equal to the independent sample t-test

The frequency of absolute deviation of dental age, estimated by the Cameriere's method, from chronological age at half-year intervals is shown in Figure 34. It is noticeable that there is a maximum deviation of up to 0.5 years in both genders, subsequently the frequency drops to a negligible number in the groups of 3.5 and 4.5 year olds.

Of course, as in previous methods of dental age estimation, a more accurate figure of the deviation course of null differences is shown in Figure 34. As far as the differences are concerned, the girls and the boys behave somewhat similar to the deviation of the zero difference. However, it is important to point out that dental age estimated by the Cameriere's method is overestimated in both genders for the groups of 6 to 10 year olds compared to chronological age, and the age is further underestimated for the groups of 12 year olds.

Table 37. Mean absolute difference between dental age by the Cameriere's method and chronological age according to age group and gender

Age group	Gender	N	|DA(CK) - CA|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	14	1.38	0.63	1.35	0.83	1.91
	Male	12	1.63	0.48	1.49	1.21	2.11
7	Female	20	0.75	1.02	0.39	0.22	0.92
	Male	31	0.58	0.75	0.37	0.11	0.78
8	Female	47	1.01	0.60	1.05	0.55	1.21
	Male	49	0.64	0.53	0.45	0.26	0.95
9	Female	51	0.85	0.57	0.67	0.33	1.40
	Male	47	0.86	0.67	0.90	0.26	1.34
10	Female	63	0.69	0.56	0.65	0.27	0.91
	Male	42	0.86	0.60	0.81	0.43	1.26
11	Female	65	0.58	0.55	0.39	0.16	0.88
	Male	49	0.55	0.53	0.41	0.14	0.67
12	Female	59	0.84	0.50	0.90	0.44	1.22
	Male	48	0.83	0.38	0.82	0.53	1.05
13	Female	64	0.65	0.49	0.61	0.29	0.91
	Male	63	1.03	0.62	1.04	0.46	1.51
14	Female	54	0.93	0.67	0.73	0.39	1.35
	Male	52	0.74	0.87	0.38	0.11	1.04
15	Female	13	1.26	0.30	1.12	1.09	1.35
	Male	18	0.76	0.43	0.58	0.44	0.96
6-16	Female	450	0.81	0.61	0.71	0.32	1.13
	Male	411	0.80	0.65	0.60	0.27	1.19

|DA(CK) - CA|- Dental age by Cameriere's method for Kosovo sample and chronological age absolute difference, SD – Standard deviation

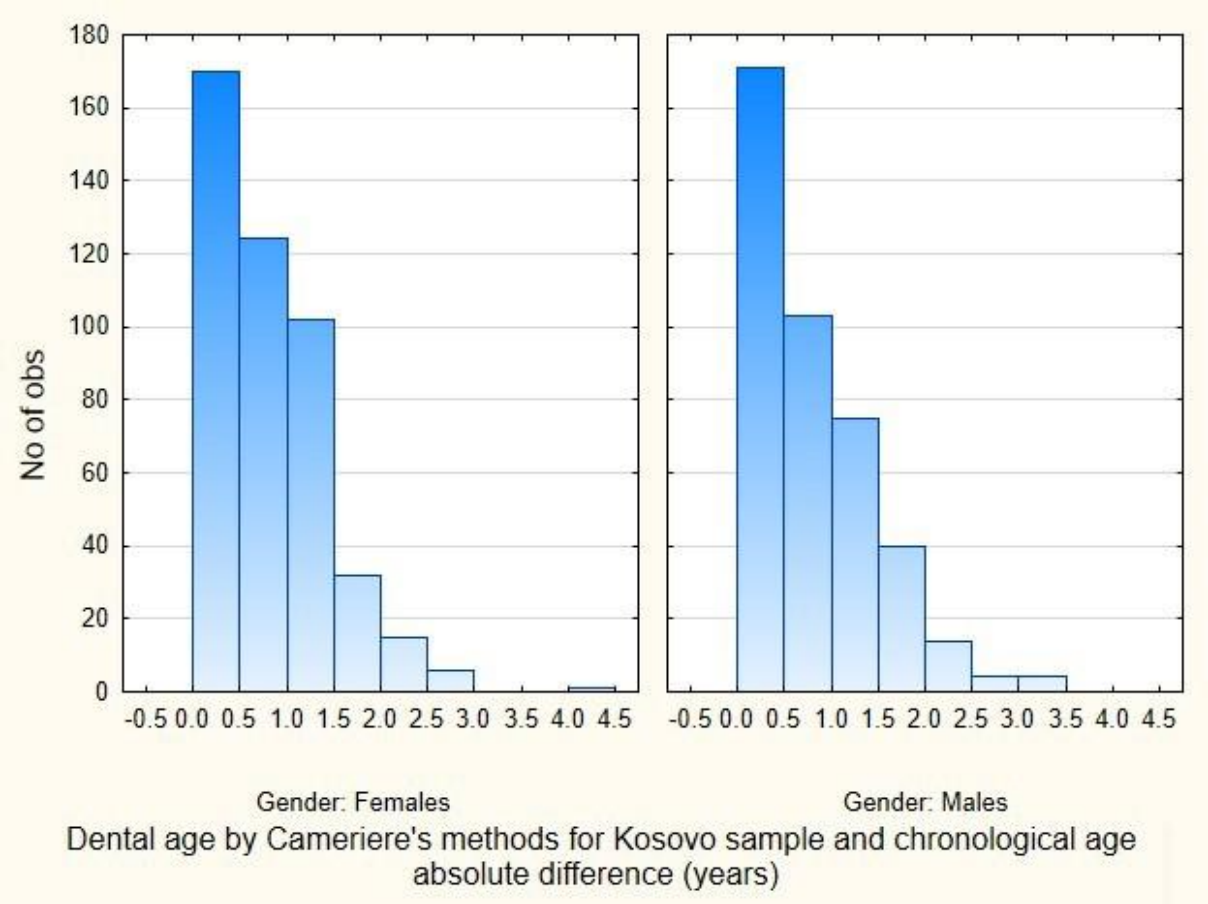

Figure 34. Distribution of mean absolute difference between dental age by the Cameriere's method and chronological age according to gender

4.6 The third molar maturity index in indicating the legal adult age

Dental age estimation was performed according to the method of Cameriere et al. The apical ends of the roots of the left lower third molar of each individual were analysed and the third molar maturity index, I_3M, was defined as follows: if the root development of the third molar is complete, i.e., the apical ends of the roots are completely closed, then $I_3M = 0$, otherwise I_3M is evaluated as the sum of the distances between the inner sides of the two open apices divided by tooth length. Maturity index I_3M is evaluated in an analogous way to the ratio Ai to Li, when I = 6.7, as reported for the other two teeth with two roots in Cameriere et al.(106).

Both impacted and non-impacted third molars were included in this study, provided that their roots were radiographically noticeable. Upper third molars were out of consideration, as they are more variable in their development, are more difficult for visualizing and scoring accurately and so they are rarely used for age estimation objectives. Age distribution gradually decreased as I3M increased in both males and females (Figure 37). The mean age

(standard error) for both groups in each I3M class varied between genders (Table 40) but the differences were not significant ($p > 0.001$).

All analyses of the OPGs were performed by the Ph.D. candidate (JK). The Ph.D. candidate (JK) and another examiner (IG) additionally analysed 50 randomly selected OPGs 2 weeks after the first analysis. The intra-class correlation coefficient was calculated to assess intra-rater and interrater agreement of I3M. The analysis was achieved by using a blind approach, i.e., it was not possible to identify individual's ID, gender, or age. The final sample of 1221 OPGs was randomly divided into a training dataset of 800 OPGs and a test dataset of 421 OPGs, stratified by gender and age groups. A Kosovo-specific logistic prediction model, with the individuals who have attained the age of 18 years and more (E = 1, adults) or under the age of 18 (E = 0, minors) as response variable, and gender (g) and I_3M as predictors, was fitted on the individuals in the training dataset. The receiver operating curve (ROC) was used to determine the cut-off of I3M which was the best in discriminating adults and minors. Also a Youden's index was used that is a single measure of the performance of the dichotomous diagnostic test. The maximum value Youden's index was set as the best performance of the ROC and corresponding cut-off value of I3M was taken for the analysis of the test dataset (107). A distribution of age thru different I_3M classes in a test dataset was evaluated. Possible differences of I3M between genders in a test dataset were evaluated by independent samples t test. To verify the performance of the specific cut-off value of I_3M to discriminate Kosovar adults and minors, a two-by-two contingency table was used to list the results of the selected cases.

The percentage of accurate classification (Acc), sensitivity (Se), or the proportion of the individuals 18 years and older who had $I_3M <$ cut-off and specificity (Sp) or the proportion of individuals younger than 18 who had $I_3M \geq$ cut-off, were also evaluated. The positive predictive value (PPV), negative predictive value (NPV), or the proportions of positive and negative results that are truly positive and truly negative results, respectively were calculated. The positive likelihood ratio (LR+) and negative likelihood ratio (LR−) were additionally calculated to express how many times more or less likely a test result is to be found in adults compared with minor individuals. The post-test probability (p) of fulfilment of 18 years of age or older can help to discriminate between those individuals who are ≥ 18 years and those who are < 18 years. According to Bayes' theorem, the post-test probability may be written as:

$$p = \frac{Se\ x\ \rho\sigma}{Se\ x\ \rho\sigma + \ (1 - Sp)\ x\ (1 - \rho\sigma)}$$

where p is post-test probability and $\rho\sigma$ is the probability that the individual in question is ≥ 18 years, given that he or she is aged between 12 and 23 years, which represented the target population. Probability $\rho\sigma$ was calculated as the proportion of individuals between 18 and 23 years of age who live in the Republic of Kosovo according to demographic data from the 2011 census and those between 12 and 23 years which was assessed from data from the Kosovo Agency of Statistics (ASK) (108). This proportion was considered to be 0.496 for males and 0.493 for females. The threshold of the significance was set at $p < 0.05$.

To measure the performance of the cut-off reported in Cameriere *et al*., the validity of I_3M with the actual sample as the training sample was analyzed. The results are summarized in a 2 x 2 contingency Table (Table 41), shows the numbers of individuals who have I_3M 0.08 and are younger than 18, those with I_3M 0.08 who are over 18, those with $I_3M < 0.08$ who are under 18, and those with I3M < 0.08 who are over 18.

Table 38. Panoramic radiographs from Kosovo, numbers in parenthesis represent samples with closed apices of the left third mandibular molar (I_{3M}=0.00)

Age (years)	Males	Females	Total
12	40	49	89
13	43	36	79
14	47	37	84
15	37	67	104
16	29	81	110
17	47 (4)	85 (2)	132(6)
18	45 (14)	77 (15)	122(29)
19	48 (39)	51 (26)	99(65)
20	50 (49)	53 (39)	103(88)
21	56 (55)	51 (40)	107(95)
22	57 (56)	48 (48)	105(104)
23	44 (44)	43 (43)	87(77)
Total	543 (261)	678 (213)	1221 (474)

Pearson's correlation coefficients for the correlation between I3M and real age were better for males, − 0.817 ($p < 0.001$) than for females, − 0.750 ($p < 0.001$) (Figure 36). The intra-class correlation coefficient for intra-rater agreement was 0.858 (95% CI, 0.786 to 0.906) whereas it was 0.852 (95% CI, 0.779 to 0.903) for the inter-rater agreement.
The results of intra-class correlation coefficient showed a very good repeatability of the variable I_3M.

Logistic regression was performed to assess the impact of I_3M and gender on the discrimination of the individuals into adults and minors. The logistic regression model presented the significance of variable I3M ($p < 0.001$) while gender was not significant ($p = 0.280$). The full model, containing only I3M as a predictor variable, was statistically significant ($p < 0.001$), indicating that model was able to discriminate individuals between adults and minors. The entire model described between 0.496 (Cox and Snell R square) and 0.661 (Nagelkerke R square) of the variance in adult or minor status. The linear logistic model could be recorded as:

$$Logit\ (p) = 1.90 - 14.55 \times I_{3M}$$

ROC analysis was completed on the total training dataset sample because the gender did not significantly contribute to the model. Figure 35, shows the ROC curve of the adult age status, although, the results of Se, Sp, are shown in the Table 39.

Excellent presentation of the discrimination between adults and minors or the maximum Youden index ($J = 0.87$) was for the I_3M value of 0.08. According to Kosovo specific results, was set that an individual was an adult if the cut-off value of I_3M is lower than 0.08 ($I3M < 0.08$), if not, the individual needs to be considered a minor.

Age gradually increased as I_3M decreased, in the test sample, in both males and females Figure 38. In each I_3M class, the mean age varied between genders. The differences were not significant in the older classes, whereas the differences were significant in the younger classes (Table 40).

In females, Acc was 0.909 (95% CI, 0.870 to 0.917), Se was 0.826 (95% CI, 0.787 to 0.834), and Sp was 0.991 (95% CI, 0.953 to 1.00). PPV and NPV were 0.990 (95% CI, 0.943 to

0.999) and 0.852 (95% CI, 0.819 to 0.859). LR+ and LR− were 95.826 (95% CI, 16.69 to 1848.47) and 0.175 (95% CI, 0.166 to 0.223).

The Acc was 0.968 (95% CI, 0.926 to 0.985), in males. The proportion of persons being ≥ 18 years of age whose test was positive or Se was 0.962 (95% CI, 0.925 to 0.978). The proportion of persons being < 18 years of age, test was negative or Sp was 0.976 (95% CI, 0.929 to 0.995). The negative predictive value (NPV) and positive predictive value (NPV) were 0.953 (95% CI, 0.907 to 0.972) and 0.981 (95% CI, 0.942 to 0.996). LR+ and LR− were 40.415 and 0.039.

The Bayes post-test probability was 0.989 (95% CI, 0.926 to 1.000). The only error in selecting minor as adult females was for the 16-year olds, where 96.3% were correctly selected. The greatest error in selecting adult as minor females was for the 18-year olds, where only 55.5% were correctly selected, followed by the 19- and 20- year olds, with 78.9% of correctly selected individuals.

The Bayes post-test probability was 0.975 (95% CI, 0.905 to 1.00). The greatest error in selecting minor as adult males was for the 16-year-old observers, where 90% were correctly selected. The greatest error in selecting adult as minor males was for the 18-year old, where 71.4% were correctly selected (Table 42).

The above mentioned method and below mentioned results are consistent with previous study published by Kelmendi et al. (86).

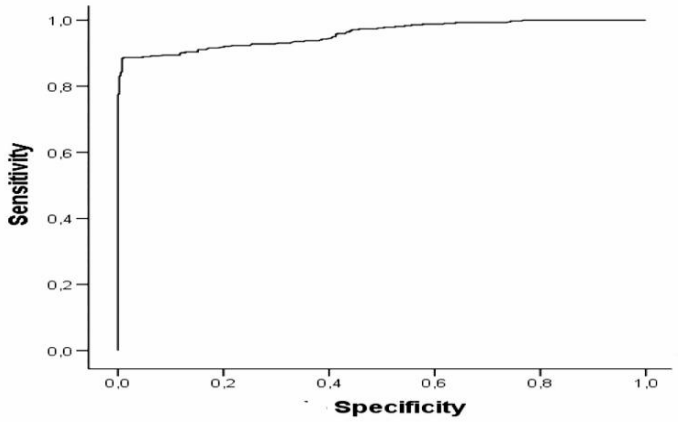

Figure 35. Receiver operating characteristic (ROC) curve for the third molar maturity index for adult age (≥ 18 years) in Kosovars

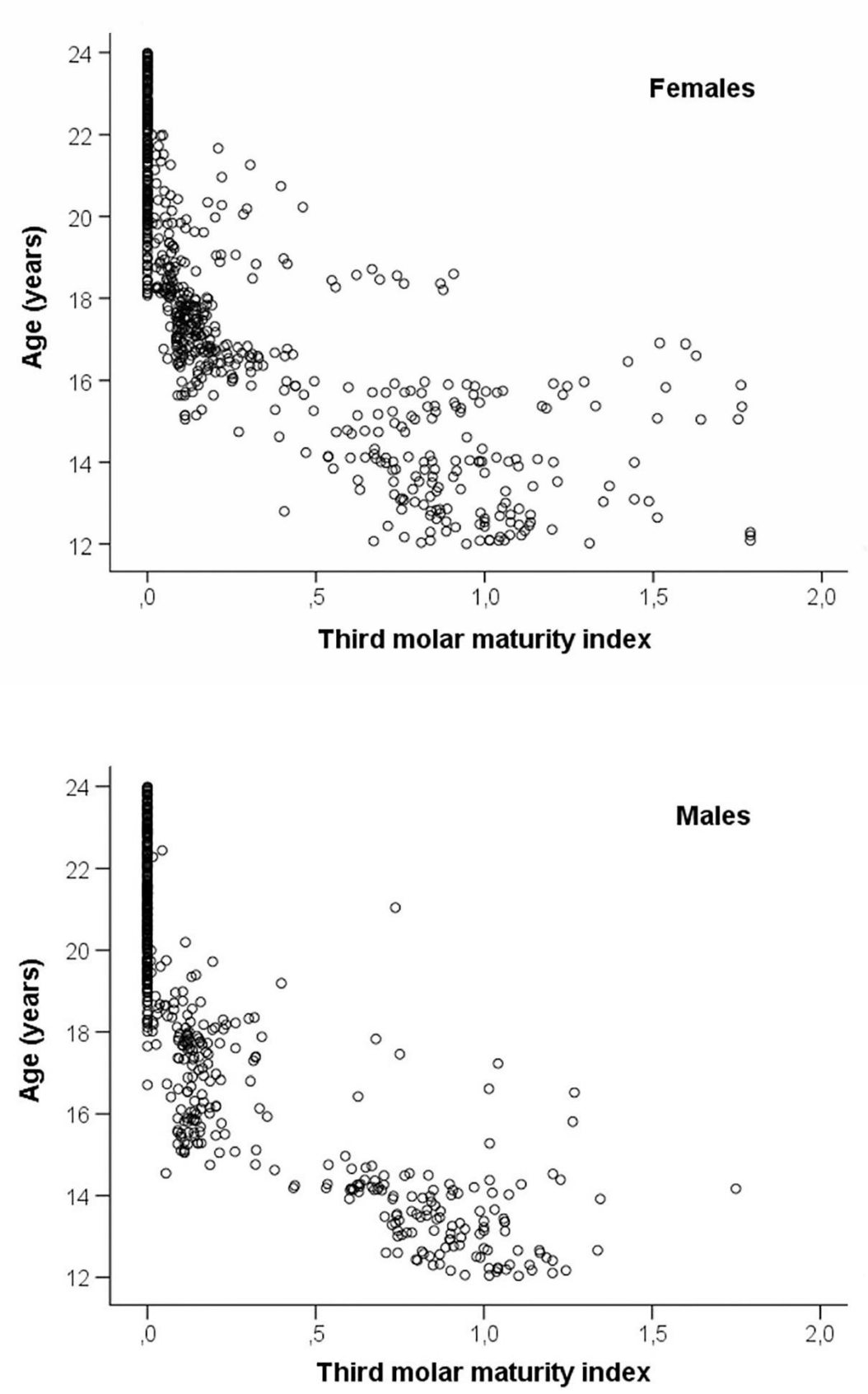

Figure 36. Scatter plot of the relationship between the age and third molar maturity index

Table 39. The quantities from 2-by-2 contingency tables (95% confidence intervall) to test the age of majority in the sample from Kosovo

Quantities	Males	Females
AC	0.937 (95%CI, 0.912 - 0.956)	0.897 (95%CI, 0.873 – 0.913)
Sensitivity	0.937 (95%CI, 0.913 - 0.954)	0.827 (95%CI, 0.802 - 0.844)
Specificity	0.938 (95%CI, 0.910 - 0.959)	0.961 (95%CI, 0.938 - 0.976)
PPV	0.949 (95%CI, 0.926 - 0.967)	0.950 (95%CI, 0.922 - 0.970)
NPV	0.923 (95%CI, 0.895 - 0.944)	0.859 (95%CI, 0.839 - 0.873)
LR+	15.174 (95%CI, 10.112 – 23.429)	20.961 (95%CI, 12.925 – 35.805)
LR-	0.068 (95%CI, 0.0.048 - 0.095)	0.181(95%CI, 0.160 - 0.211)
Bayes PTP	0.938 (95%CI, 0.896 - 0.980)	0.953 (95%CI, 0.916 - 0.990)

AC - accurate classification; J - index; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR+, negative likelihood ratio; Bayes PTP, Bayes post-test probability

The accuracy differed between the gender because the third molar developed the little faster in males in the study sample. Differences between the gender were obvious in Table 38, where it can be seen that after 23 years, all apices were closed in males but in females there were still few third molars that did not have fully formed roots.

From the age of 17, when the first apical closure was noticed in both gender, the number of closed apices followed the increase of age but faster in males than in females. This finding is in correlation with other studies on white populations.

Table 40. Summary statistics of chronological age according to sex and third molar maturity index (I_{3M}) classes

	Males								Females									
I_{3M}	N	Mean	Sd	Min	Q1	Med	Q3	Max	N	Mean	Sd	Min	Q1	Med	Q3	Max	t(df)	P
(0.00,0.04)	278	21.16	1.67	17.57	19.80	21.28	22.57	23.99	239	21.23	1.73	17.02	19.97	21.43	22.60	23.98	0.44 (515)	0.663
(0.04, 0.08)	18	18.53	1.20	16.71	17.83	18.47	18.81	22.43	42	19.05	1.18	16.77	18.14	18.76	19.83	21.98	1.55 (58)	0.126
(0.08, 0.2)	49	17.20	1.14	15.28	16.15	17.39	17.88	20.20	97	17.63	1.07	15.05	17.01	17.56	18.10	20.43	2.19 (144)	0.030
(0.2, 0.4)	37	16.82	1.35	13.92	15.57	16.83	17.97	19.72	100	17.05	1.33	14.62	16.36	16.67	17.31	21.67	0.88 (135)	0.380
(0.4, 0.9)	46	14.99	1.50	13.00	14.15	14.38	16.12	21.04	80	15.86	1.69	12.17	14.83	15.75	16.89	20.23	2.90 (124)	0.004
(0.9, 1.2)	56	13.92	1.21	12.03	12.79	13.99	14.57	17.55	67	13.95	1.27	12.07	12.80	14.01	14.87	17.18	0.13 (121)	0.893
(1.2, 3.4)	59	13.35	1.09	12.04	12.49	13.09	13.92	16.52	53	13.19	1.02	12.01	12.54	13.01	13.60	15.97	0.80 (110)	0.423

Number of individuals (N), mean age within I3M class (Mean), standard deviation of Mean age (Sd), minimum value (Min), 1st quartile (Q1), median (Med), 3rd quartile (Q3) and maximum age (Max), independent samples test (t), degrees of freedom (df), significant if < 0.05 (*)

The research provides the results for the error rating in discriminating adults and minors of each age group for both gender. In males, the inaccuracies were present in participants between 16 and 19 years, and in females between 16 and 20 years. The greatest error rate was found in 18 years' age group in females, where 53% of females of 18 years of age were classified as minors, shown in Table 42.

The Table 41, displays the close association between adult age and positivity on the test (i.e., I3M < 0.08).

Table 41. Contingency table describing discrimination performance of the test for different cut-off values of third molar maturity index I_{3M}

	Males Age		**Total Males**	**Females Age**		**Total Females**
Test	**≥18**	**<18**		**≥18**	**<18**	
I3M< 0.08	281	15	296	267	14	281
I3M ≥ 0.08	19	228	247	56	341	397
Total	300	243	543	323	355	678

However, the overall results for both males and females showed a good proportion of accurately classified individuals or AC, being 0.937 (95% CI, 0.912 - 0.956) in males and 0.897 (95%CI, 0.873 – 0.913) in females, Table 39.

Also, the post-test probability p (the proportion of individuals who are 18 years or older with I3M < 0.08) was 0.95 for females and 0.94 for males. It has been demonstrated good sensitivity and specificity of third molar maturity index and specific cut-off value of I3M. The results were slightly better for males (Se, 0.94; Sp, 0.94) than for females (Se, 0.83; Sp, 0.96).

Table 42. Number and percentage (%) of correct evaluations / total participants in each age group by using the third molar maturity index cut-off value of 0.08 that subjects are 18 years of age and older or younger

Age	Males	Females
12	40 / 40 (100%)	49 / 49 (100%)
13	43 / 43 (100%)	36 / 36 (100%)
14	47 /47 (100%)	37 / 37 (100%)
15	37 / 37 (100%)	67 / 67 (100%)
16	28 / 29 (96.6%)	80 / 81 (98.8%)
17	33 / 47 (70.2%)	72 / 85 (84.7%)
18	32 / 45 (71.1%)	41 / 77 (53.2%)
19	44 / 48 (91.7%)	41 / 51 (80.3%)
20	49 / 50 (98%)	45 / 53 (84.9%)
21	55 / 56 (98.2%	49 / 51 (96.1%)
22	57 / 57 (100%)	48 / 48 (100%)
23	44 / 44 (100%)	43 / 43 (100%)

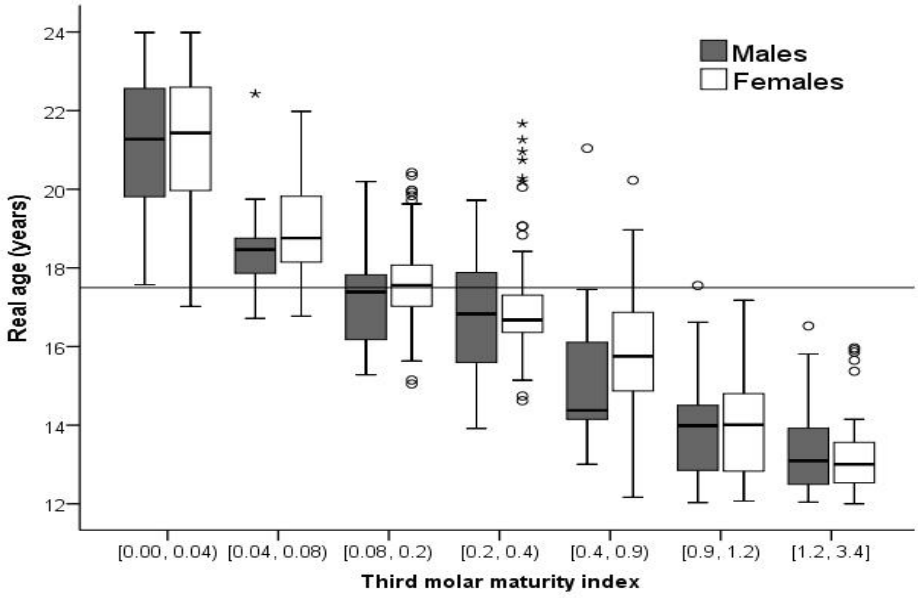

Figure 37. Box-plot of the relationship between real age (years) and the third molar maturity index of sample from Kosovo, box-plot shows median and inter-quartile ranges while whiskers are lines extending from the box to maximum and minimum ages, including outliers

4.7 Dental age estimation in Kosovar population by Moorrees's method

In this chapter, the estimation of dental age of young people from the Kosovo population was carried out using the Moorrees's method (73). According to this method, each of the eight teeth on the left side of the lower jaw was assigned a mean age according to the developmental stages of the crown, root and apex of the tooth, as shown in Table 4 and 5.

After the transformation was carried out, the estimation of the dental age was obtained using the Moorrees's method whose relationship with the crown age is illustrated by scatterplot in Figure 38. Circle size indicates the frequency in the relevant age group. In Figure 38, there is a slightly greater individual deviation compared to the Demirjian and Willems's methods.

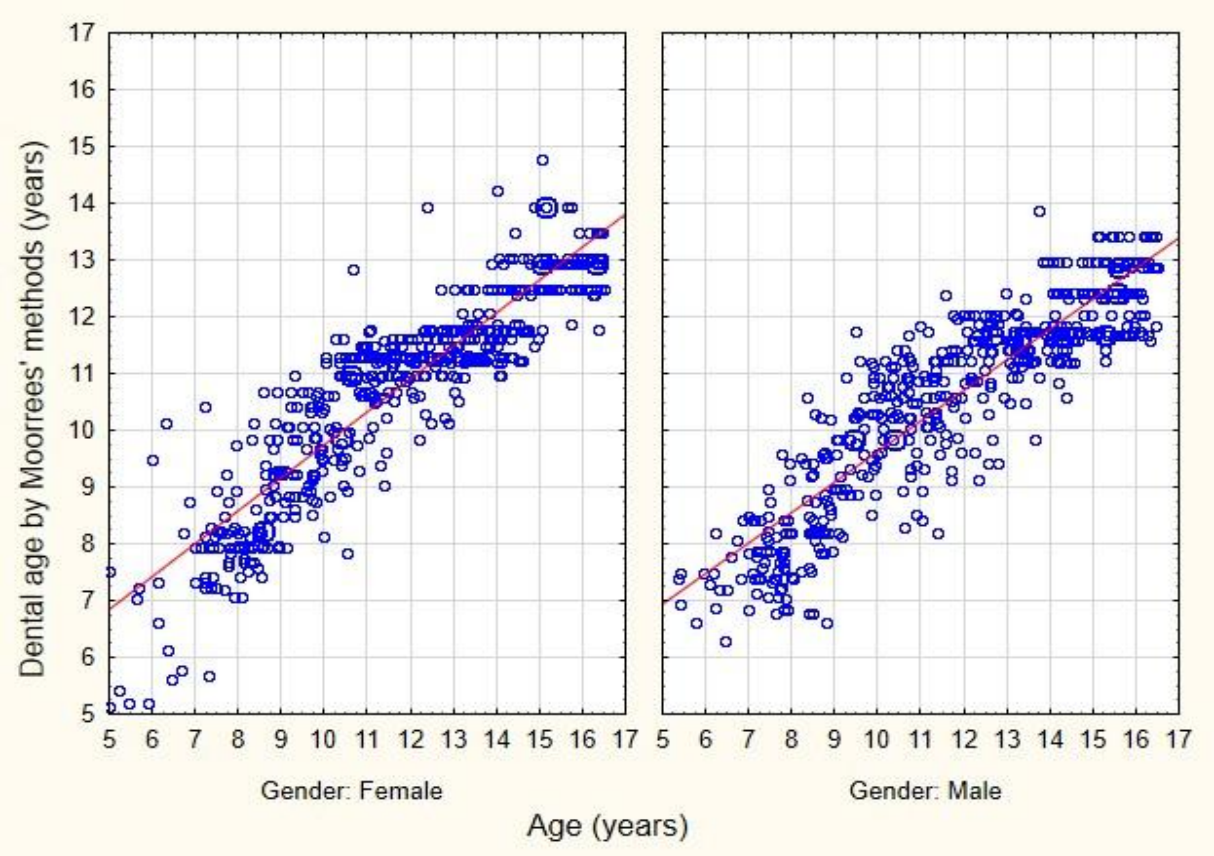

Figure 38. Scatterplots of dental age by the Moorres's method by age, according to gender

The Spearman correlation coefficient of dental age, according to the Moorrees's method, with chronological age is 0.912 (n = 563, p <0.001) for girls and it is 0.899 (n = 543, p <0.001) for boys. Therefore, the estimation of dental age of a Kosovo sample by means of the mean age

of developmental stages of all eight teeth on the lower left side of dentition by the Moorrees's method shows a high degree of correlation with chronological age for both genders despite noticeable individual deviations (Figure 38).

The distribution of dental age by Moorrees's method according to the Kolmogorov-Smirnov test does not follow a normal distribution (Kolmogorov-Smirnov $Z = 3.477$, $p < 0.001$ for girls, $Z = 3.049$, $p < 0.001$ for boys).

The differences between the genders in chronological age and dental age, estimated using the Moorrees's method, were found only in the 11, 15 and 16 year olds. Since gender comparisons in this research represent secondary goals, only the basic parameters of these two key variables are shown in Table 43 (N, Mean, SD). From the average values, it is clear that there is a large degree of agreement of means among the genders overall years of life.

Dental age differences obtained by the Moorrees's method and chronological age are on appearance acceptable normal distributions (Figure 39). According to the results of the Kolmogorov-Smirnov test, the hypothesis on the normality of distribution is relevant to the sample of girls and is irrelevant to that of boys (Kolmogorov-Smirnov $Z = 1.159$, $p = 0.136$ for girls and for the sample of Kolmogorov-Smirnov $Z = 1.376$, $p = 0.045$). For this reason, in subsequent tests, the applied parameter methods were checked with appropriate boot strap methods that are not sensitive to the normality of distribution.

As for the individual deviations of girls, the range is from -4.59 to 3.82 years, and for boys the range is almost the same, from -4.74 to 2.79 years.

Table 43. Summary statistics of chronological age (CA) and dental age (DA) by the Moorrees's method according to age groups and gender

Age group	Gender	N	CA		DA(M)	
			Mean	SD	Mean	SD
6	Female	15	5.64	0.61	6.74	1.49
	Male	12	5.86	0.47	7.24	0.51
7	Female	21	7.20	0.24	7.82	1.00
	Male	31	7.18	0.27	7.88	0.52
8	Female	47	8.02	0.29	8.10	0.64
	Male	49	8.01	0.32	8.00	0.89
9	Female	51	8.98	0.29	9.17	0.90
	Male	47	8.97	0.29	9.07	0.95
10	Female	63	10.01	0.30	10.00	0.85
	Male	49	10.01	0.29	10.23	0.69
11	Female	65	10.99	0.27	10.85	0.78
	Male	58	11.01	0.29	10.37	0.88
12	Female	61	12.01	0.30	11.22	0.53
	Male	48	12.01	0.30	11.02	0.84
13	Female	66	13.04	0.28	11.49	0.48
	Male	66	13.05	0.31	11.40	0.58
14	Female	70	14.01	0.27	11.88	0.66
	Male	64	14.07	0.26	11.77	0.66
15	Female	52	15.02	0.28	12.61	0.71
	Male	54	15.00	0.30	12.19	0.62
16	Female	52	16.08	0.27	12.94	0.43
	Male	65	15.97	0.29	12.59	0.58
6-16	Female	563	11.73	2.77	10.75	1.78
	Male	543	11.83	2.89	10.61	1.73

CA – Chronological Age, DA(M) – Dental Age by Moorrees's methods, SD – Standard deviation

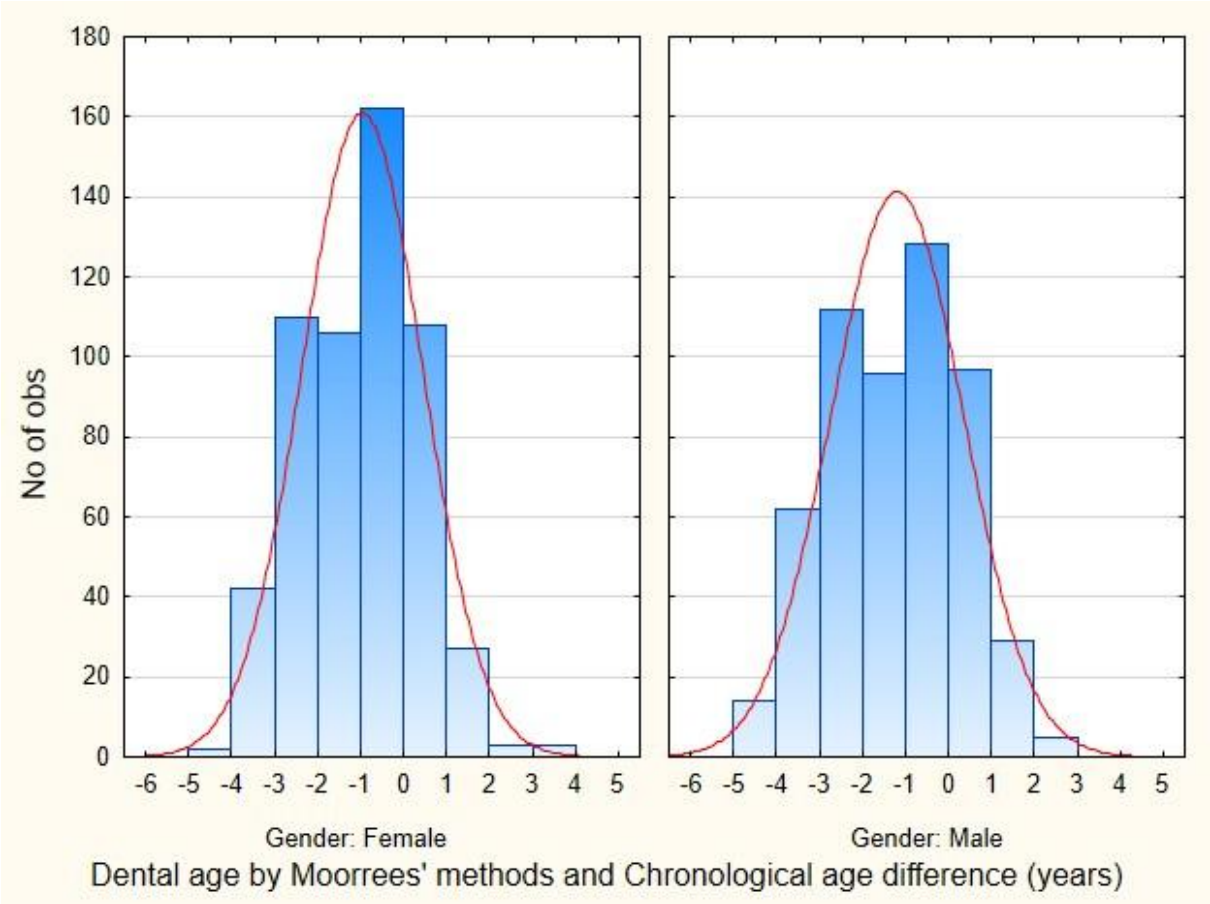

Figure 39. Distribution the difference between dental age by the Moorrees's method and chronological age, according to gender

As can be seen from the data in Table 44, statistically significant differences have been found in both genders in the groups of 6, 7 and 12 to 16 year olds and overall. Other statistically significant differences have been found only in the groups of 10 and 11 year olds, for boys. These data are illustrated in Figure 40 in which these deviations are clearly notable because the 95% of CIs are completely or almost entirely within the range below or above the line denoting equal values of dental and chronological age (0.0 value indicated by a thick line).

Table 44. Mean age of dental age by the Moorrees's method and chronological age and difference between age group and gender

Age group	Gender	N	DA(M) – CA						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	t	df	P
6	Female	15	1.10	1.45	0.30	1.90	2.939	14	0.011
	Male	12	1.38	0.78	0.89	1.88	6.133	11	**<0.001**
7	Female	21	0.61	0.98	0.17	1.06	2.870	20	**0.009**
	Male	31	0.70	0.52	0.51	0.89	7.472	30	**<0.001**
8	Female	47	0.08	0.67	-0.12	0.28	0.803	46	0.426
	Male	49	-0.01	0.81	-0.24	0.23	-0.065	48	0.949
9	Female	51	0.19	0.82	-0.04	0.42	1.652	50	0.105
	Male	47	0.10	0.84	-0.15	0.34	0.773	46	0.443
10	Female	63	-0.02	0.79	-0.22	0.18	-0.174	62	0.863
	Male	49	0.22	0.67	0.03	0.41	2.334	48	0.024
11	Female	65	-0.14	0.82	-0.35	0.06	-1.405	64	0.165
	Male	58	-0.65	0.91	-0.89	-0.41	-5.394	57	**<0.001**
12	Female	61	-0.79	0.57	-0.94	-0.65	-10.939	60	**<0.001**
	Male	48	-0.98	0.83	-1.23	-0.74	-8.228	47	**<0.001**
13	Female	66	-1.54	0.50	-1.66	-1.42	-25.237	65	**<0.001**
	Male	66	-1.65	0.61	-1.80	-1.50	-21.828	65	**<0.001**
14	Female	70	-2.13	0.63	-2.28	-1.98	-28.096	69	**<0.001**
	Male	64	-2.30	0.68	-2.47	-2.13	-27.128	63	**<0.001**
15	Female	52	-2.41	0.66	-2.60	-2.23	-26.191	51	**<0.001**
	Male	54	-2.82	0.58	-2.98	-2.66	-35.540	53	**<0.001**
16	Female	52	-3.14	0.54	-3.29	-2.99	-45.541	51	**<0.001**
	Male	65	-3.38	0.61	-3.53	-3.22	-44.317	64	**<0.001**
6-16	Female	563	-0.99	1.40	-1.10	-0.87	-16.784	562	**<0.001**
	Male	543	-1.21	1.53	-1.34	-1.08	-18.446	542	**<0.001**

DA(M) – CA – difference of dental age by Moorrees's methods and chronological age, SD – Standard deviation, 95% CI – 95% Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

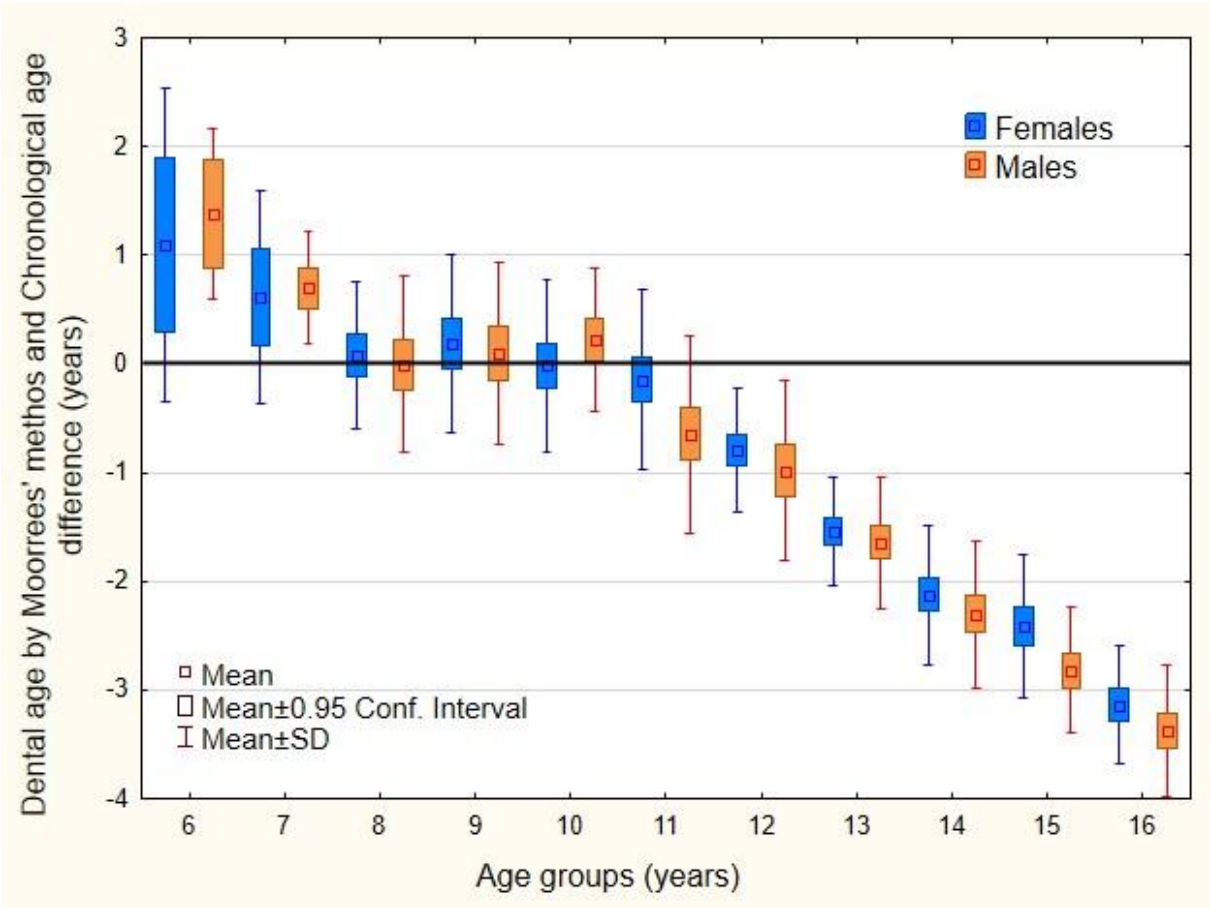

Figure 40. Box plot of the relationship between dental age by the Moorrees's method and chronological age. Box plot shows median and inter-quartile ranges, while whisker are lined extending from box to highest and lowest value, extending outliners

A more accurate figure of the deviation course from the zero difference is shown in Figure 40. Girls and boys behave differently, except for the groups of 11, 15 and 16 year olds. However, it is important to point out that in both genders, dental age estimated by the Moorrees's method underestimates this age compared to the chronological age of groups of 11 year olds, and subsequently in the groups of subjects who are older than 11. As can be seen in Figure 40, the difference is below the desirable 0.0 value except for groups of 6 and 7 year olds.

According to the results of t-test for independent samples, dental age and chronological age differences, as indicated in Table 45, are statistically significant for age groups of 11, 15 and 16 years and the overall sample.

The median absolute deviation of dental age estimation by the Moorrees's method from chronological age, i.e. the deviation regardless to the gender, the girl or the boy, is shown in Table 46. It is apparent from this table, that the median absolute deviation (value that divides the sample in two halves) of dental age from chronological age ranges from 0.50 to 3.14 years in girls, while this range is 0.59 to 3.38 years in boys.

Table 45. Gender difference between dental age by the Moorrees's method and chronological age according to age group

Age group	t statistics		
	t	df	p
6	-0.607	25	0.550
7	-0.411	50	0.683
8	0.565	94	0.573
9	0.562	96	0.576
10	-1.703	110	0.091
11	3.219	121	**0.002**
12	1.423	107	0.158
13	1.082	130	0.281
14	1.531	132	0.128
15	3.325	104	**0.001**
16	2.181	115	**0.031**
6-16	2.576	1104	**0.010**

p – the probability of the difference of the null hypothesis obtained by t-test for one sample

The frequency of the median absolute deviation of dental age, estimated by the Moorrees's method, from chronological age at half-year intervals is shown in Figure 41. It is evident that there is a maximum deviation of 0.5 to one year in both genders, subsequently the frequency drops sharply, evenly over the sample, up to a negligible number in age groups of 4.5 to 5 year olds.

Dental age estimated by the Demirjian's maturity score for the French Canadian population is statistically significantly different from the estimations of dental age using the Moorrees's method as the t-test results show for the hypothesis that the difference in these estimations is zero for almost all age groups (Table 47) in both genders. The difference is positive in each age group from 11 to 16 year olds, meaning that the Demirjian's method overestimates more systematically dental age compared to the Moorrees's method. In groups of 6 to 10 year olds the situation is just the opposite in both genders.

Table 46. Mean absolute difference between dental age by the Moorrees's method and chronological age according to age group and gender

Age group	Gender	N	|DA(M) - CA|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	1.37	1.17	1.21	0.28	1.91
	Male	12	1.41	0.73	1.40	0.87	2.00
7	Female	21	0.87	0.75	0.78	0.30	1.06
	Male	31	0.74	0.46	0.64	0.36	1.20
8	Female	47	0.50	0.45	0.38	0.15	0.70
	Male	49	0.61	0.53	0.51	0.22	0.86
9	Female	51	0.69	0.47	0.60	0.34	0.97
	Male	47	0.65	0.54	0.51	0.28	0.86
10	Female	63	0.69	0.37	0.65	0.44	0.93
	Male	49	0.59	0.38	0.56	0.36	0.81
11	Female	65	0.60	0.57	0.44	0.26	0.66
	Male	58	0.86	0.72	0.71	0.31	1.23
12	Female	61	0.85	0.48	0.76	0.54	1.03
	Male	48	1.05	0.74	0.94	0.44	1.40
13	Female	66	1.54	0.50	1.55	1.22	1.82
	Male	66	1.65	0.61	1.60	1.21	2.04
14	Female	70	2.14	0.61	2.27	1.73	2.51
	Male	64	2.31	0.66	2.40	1.89	2.72
15	Female	52	2.41	0.66	2.48	2.12	2.90
	Male	54	2.82	0.58	2.92	2.34	3.35
16	Female	52	3.14	0.54	3.07	2.87	3.41
	Male	65	3.38	0.61	3.32	2.88	3.82
6-16	Female	563	1.37	1.02	1.08	0.53	2.15
	Male	543	1.58	1.16	1.34	0.57	2.47

|DA(M) - CA| - The absolute differences of dental age by Morrees's methods and chronological age, SD – Standard deviation

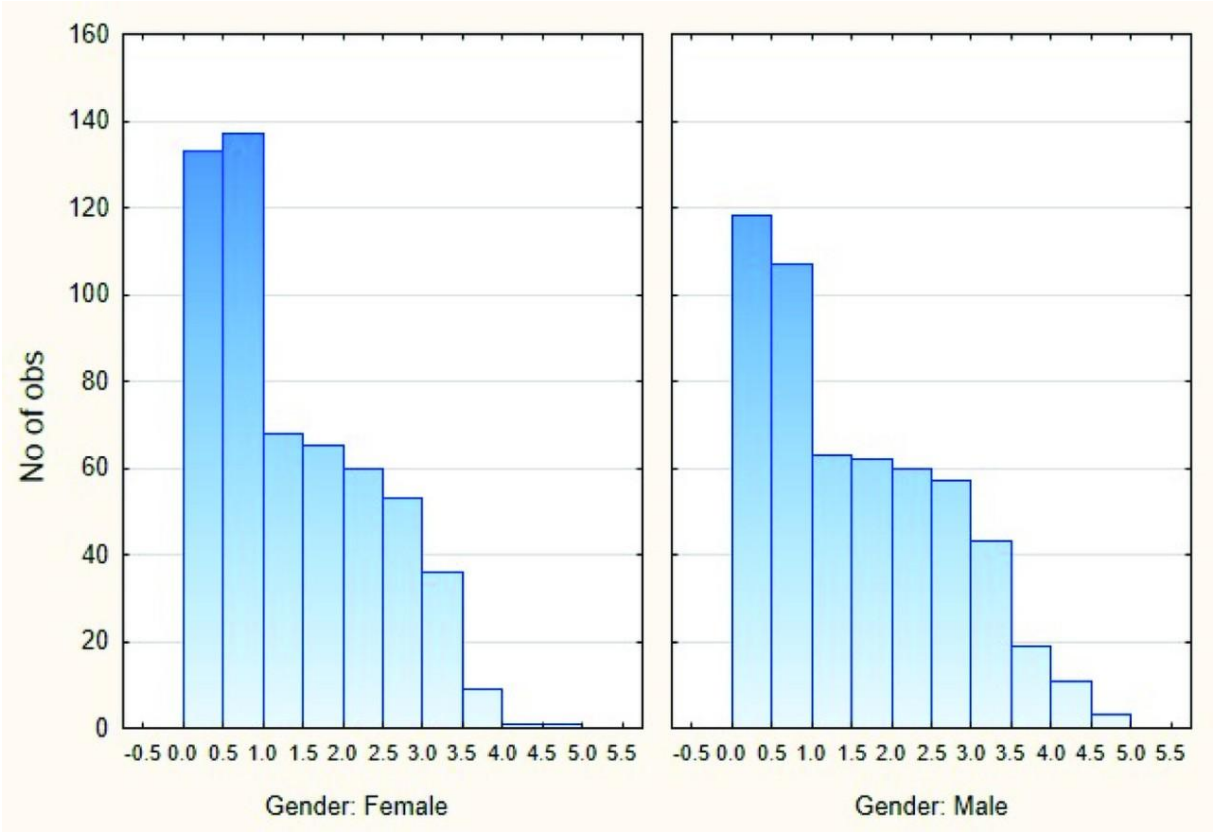

Figure 41. Distribution of mean absolute difference between dental age by the Moorrees's method and chronological age according to gender

The differences, listed in Table 47, are illustrated in Figure 42 with corresponding confident intervals.

A more accurate figure of the deviation course from the zero difference is shown in Figure 42. Girls and boys, as far as differences are concerned, behave quite differently in almost every age group. However, it is important to point out that dental age estimated by the Moorrees's method is underestimated in both genders compared to dental age estimated by the Demirjian's method with maturity scores for the French Canadian population for groups of 11 year olds as well as for groups of subjects older than 11 years with some gender differences.

Table 47. Mean age of dental age by the Demirjian's method with dental maturity scores for a French Canadian population and dental age by the Moorrees's method and difference between age group and gender

Age group	Gender	N	DA(D) – DA(M)						
			Mean	SD	95% CI		t statistics		
					Lower	Upper	T	df	p
6	Female	15	-0.52	1.16	-1.16	0.12	-1.738	14	0.104
	Male	12	-0.22	0.42	-0.49	0.05	-1.789	11	0.101
7	Female	21	-0.45	0.35	-0.62	-0.29	-5.861	20	**<0.001**
	Male	31	-0.23	0.30	-0.35	-0.12	-4.333	30	**<0.001**
8	Female	47	-0.58	0.37	-0.69	-0.47	-10.684	46	**<0.001**
	Male	49	-0.17	0.58	-0.34	-0.01	-2.088	48	0.042
9	Female	51	-0.71	0.64	-0.89	-0.53	-7.928	50	**<0.001**
	Male	47	-0.01	0.59	-0.18	0.17	-0.101	46	0.920
10	Female	63	-0.32	0.83	-0.53	-0.11	-3.094	62	0.003
	Male	49	-0.12	0.68	-0.31	0.08	-1.198	48	0.237
11	Female	65	0.37	1.03	0.11	0.62	2.872	64	0.006
	Male	58	0.03	1.10	-0.26	0.32	0.216	57	0.830
12	Female	61	1.39	0.96	1.14	1.63	11.246	60	**<0.001**
	Male	48	0.61	1.49	0.17	1.04	2.822	47	0.007
13	Female	66	1.84	0.98	1.60	2.08	15.349	65	**<0.001**
	Male	66	1.99	1.33	1.66	2.31	12.161	65	**<0.001**
14	Female	70	2.12	0.90	1.90	2.33	19.677	69	**<0.001**
	Male	64	2.61	1.13	2.33	2.89	18.457	63	**<0.001**
15	Female	52	2.72	0.65	2.54	2.90	30.113	51	**<0.001**
	Male	54	3.07	1.04	2.79	3.36	21.803	53	**<0.001**
16	Female	52	2.93	0.44	2.80	3.05	47.567	51	**<0.001**
	Male	65	3.15	0.54	3.01	3.28	46.819	64	**<0.001**
6-16	Female	563	1.01	1.54	0.89	1.14	15.610	562	**<0.001**
	Male	543	1.24	1.68	1.10	1.39	17.210	542	**<0.001**

DA(D) – DA(M) – The differences of dental age by Demirjian's methods with maturity score for French Canadian population and Dental age by Moorrees's methods difference, SD, Standard deviation, 95% CI, Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

According to the t-test results for independent samples, the two estimations of dental age of girls and boys, listed in Table 48, are statistically significant for almost all age groups and overall, except for the groups of 6, 10, 11 and 13 year olds, which is clearly seen in Figure 42.

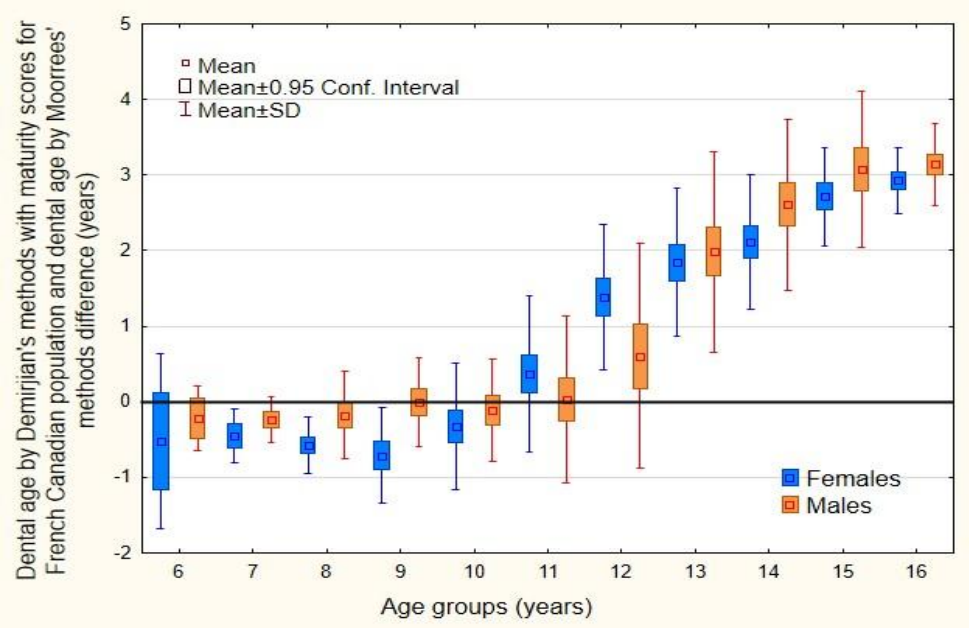

Figure 42. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a French Canadian population and dental age by the Moorrees's method. Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

Table 48. Gender difference between dental age by the Demirjian's method with dental maturity scores for a French Canadian population and dental age by the Moorrees's method according to age group

Age group	t statistics		
	T	df	p
6	-0.857	25	0.399
7	-2.391	50	**0.021**
8	-4.024	94	**<0.001**
9	-5.613	96	**<0.001**
10	-1.423	110	0.157
11	1.750	121	0.083
12	3.318	107	**0.001**
13	-0.713	130	0.477
14	-2.811	132	**0.006**
15	-2.118	104	**0.037**
16	-2.358	115	**0.020**
6-16	-2.367	1104	**0.018**

p - the probability of the hypothesis that the difference by gender is statistically equal to the t-test for independent samples

The median absolute deviation of dental age estimations by the Demirjian's method for the French Canadian population from the estimation of dental age using the Moorrees's method, i.e. deviation regardless to the gender, the girl or the boy, is given in Table 49. From the table, it is apparent that the median absolute deviation (the value dividing the sample in two halves) of dental from chronological age ranges from 0.33 to 3.07 years in girls, whereas this range is 0.28 to 3.27 years in boys.

The frequency of the median absolute deviation of dental age, estimated by the Demirjian's maturity scoring method for the French Canadian population from that estimated by the Moorrees's method at half-year intervals, is shown in Figure 43. It is evident that in both genders, the highest rate of deviation is between 0.5 and one year, especially in boys, and the frequencies of higher rates of deviations gradually decrease in girls up to 4.5 years of age, while the frequency is more pronounced in boys between 3 and 4 years of age.

Dental age estimated by the Demirjian's method with maturity scores for a Kosovo sample statistically differs significantly from the estimation of dental age by the Moorrees's method according to t-test results for the hypothesis that the difference between these estimations is zero for almost all age groups and both genders (Table 50). The difference is negative for all age groups from 6 to 10-11 year olds, subsequently the difference is positive in each following age group, meaning that the Demirjian's method underestimates systematically dental age up to the age of 10, 11 years compared to the Moorrees's method, subsequently it overestimates dental age of the remaining groups.

Table 49. Mean absolute difference between dental age by the Demirjian's method with maturity scores for a Franch Canadian population and dental age by the Moorrees's method according to age group and gender

Age group	Gender	N	|DA(D) – DA(M)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.77	1.00	0.33	0.13	1.03
	Male	12	0.42	0.19	0.45	0.29	0.58
7	Female	21	0.53	0.21	0.53	0.38	0.64
	Male	31	0.31	0.22	0.28	0.08	0.48
8	Female	47	0.58	0.36	0.53	0.33	0.73
	Male	49	0.45	0.41	0.32	0.12	0.68
9	Female	51	0.81	0.50	0.68	0.43	1.33
	Male	47	0.44	0.39	0.37	0.13	0.63
10	Female	63	0.71	0.53	0.58	0.28	1.03
	Male	49	0.55	0.40	0.47	0.26	0.85
11	Female	65	0.84	0.70	0.72	0.31	1.17
	Male	58	0.87	0.66	0.75	0.37	1.27
12	Female	61	1.49	0.79	1.52	0.88	2.07
	Male	48	1.18	1.08	0.97	0.39	1.58
13	Female	66	1.89	0.89	2.05	1.22	2.47
	Male	66	2.03	1.26	1.84	1.07	2.97
14	Female	70	2.13	0.86	2.02	1.47	2.97
	Male	64	2.61	1.13	2.97	1.73	3.27
15	Female	52	2.72	0.65	2.97	2.07	3.07
	Male	54	3.08	1.03	3.27	2.72	3.67
16	Female	52	2.93	0.44	3.07	2.60	3.07
	Male	65	3.15	0.54	3.12	2.72	3.57
6-16	Female	563	1.51	1.06	1.32	0.58	2.22
	Male	543	1.59	1.36	1.07	0.37	2.97

|DA(D) – DA(M)| - The difference of dental age by Demirjian's methods with French Canadian maturity scores and dental age by Moorrees's methods absolute, SD – Standard deviation

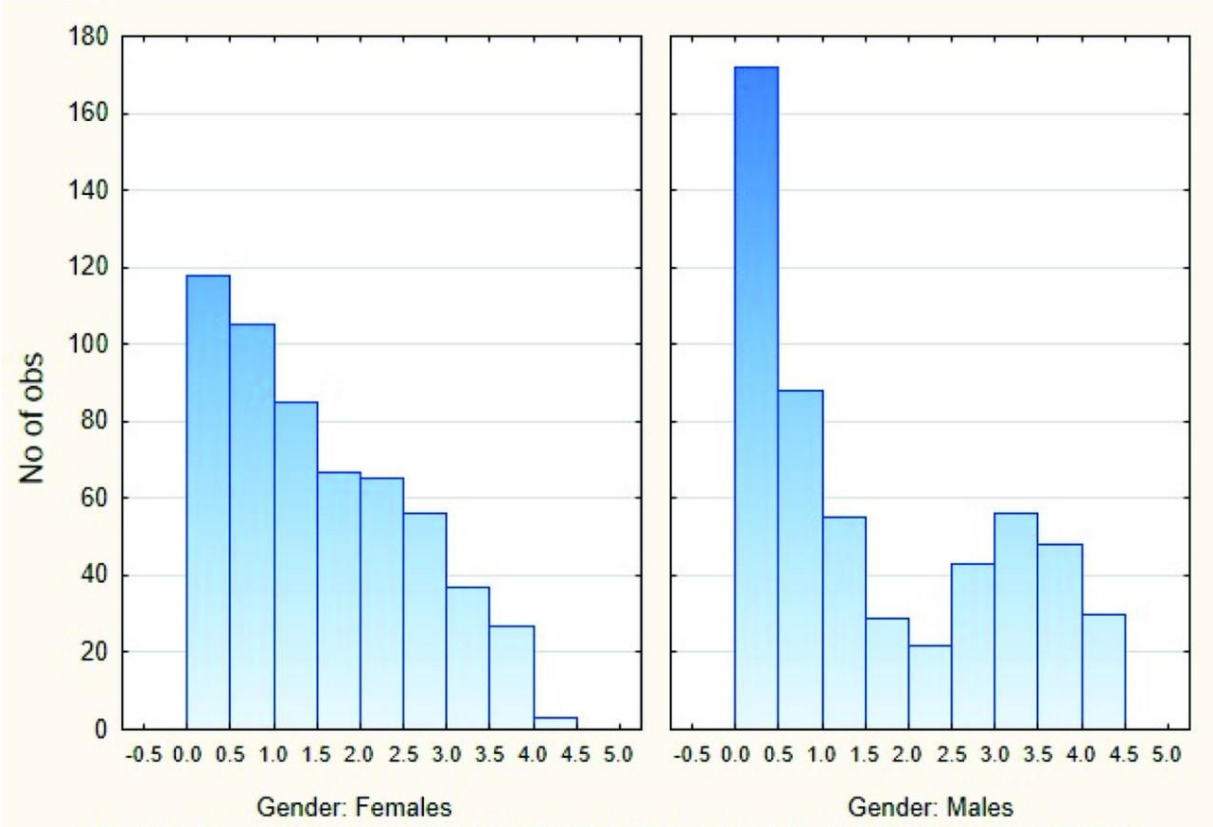

Figure 43. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a French Canadian population and dental age by the Moorrees's method according to gender

The differences, listed in Table 50, are illustrated in Figure 44 with corresponding confident intervals. However, a more accurate figure of the deviation course of the zero difference is shown in Figure 44. Girls and boys, as far as differences are concerned, behave quite differently in almost every age group. However, it is important to point out that in most cases, dental age estimated by the Moorrees's method underestimates this age in both genders compared to the Demirjian's method with maturity scores for a Kosovo sample for young people up to 10 years, subsequently dental age is systematically overestimated as the age of the subjects' increases. These results are quite similar to those relating to the difference between dental age estimated by the Demirjian's method with the French Canadian population and those estimated by the Mooorrees method.

Table 50. Mean age of dental age by the Demirjian's method with dental maturity scores for a Kosovo population and dental age by the Moorrees's method and difference between age group and gender

Age group	Gender	N	DA(DK) – DA(M)						
			Mean diff.	SD	95% CI		t statistics		
					Lower	Upper	t	df	P
6	Female	15	-0.26	1.30	-0.98	0.46	-0.776	14	0.451
	Male	12	-0.33	0.44	-0.61	-0.06	-2.635	11	**0.023**
7	Female	21	-0.39	0.54	-0.63	-0.14	-3.305	20	**0.004**
	Male	31	-0.23	0.40	-0.38	-0.08	-3.206	30	**0.003**
8	Female	47	-0.48	0.49	-0.62	-0.33	-6.645	46	**<0.001**
	Male	49	-0.28	0.58	-0.45	-0.12	-3.411	48	**0.001**
9	Female	51	-0.29	0.57	-0.45	-0.13	-3.609	50	**0.001**
	Male	47	-0.19	0.62	-0.38	-0.01	-2.135	46	**0.038**
10	Female	63	-0.15	0.63	-0.30	0.01	-1.846	62	0.070
	Male	49	-0.47	0.63	-0.65	-0.29	-5.179	48	**<0.001**
11	Female	65	0.15	0.85	-0.06	0.36	1.401	64	0.166
	Male	58	-0.26	0.83	-0.48	-0.04	-2.370	57	**0.021**
12	Female	61	1.02	0.92	0.78	1.25	8.596	60	**<0.001**
	Male	48	0.24	1.35	-0.15	0.64	1.259	47	0.214
13	Female	66	1.53	0.95	1.30	1.77	13.112	65	**<0.001**
	Male	66	1.61	1.36	1.28	1.95	9.633	65	**<0.001**
14	Female	70	1.78	0.94	1.55	2.00	15.729	69	**<0.001**
	Male	64	2.35	1.25	2.04	2.66	15.059	63	**<0.001**
15	Female	52	2.43	0.64	2.25	2.61	27.346	51	**<0.001**
	Male	54	2.87	1.08	2.58	3.17	19.557	53	**<0.001**
16	Female	52	2.64	0.43	2.52	2.75	44.236	51	**<0.001**
	Male	65	2.89	0.68	2.72	3.06	34.326	64	**<0.001**
6-16	Female	563	0.89	1.34	0.78	1.00	15.784	562	**<0.001**
	Male	543	0.99	1.66	0.85	1.13	13.921	542	**<0.001**

DA(DK) – DA(M) – difference of dental age by Demirjian's methods with maturity scores for Kosovo population and dental age by Moorrees's method, SD – Standard deviation, 95% CI – 95% Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

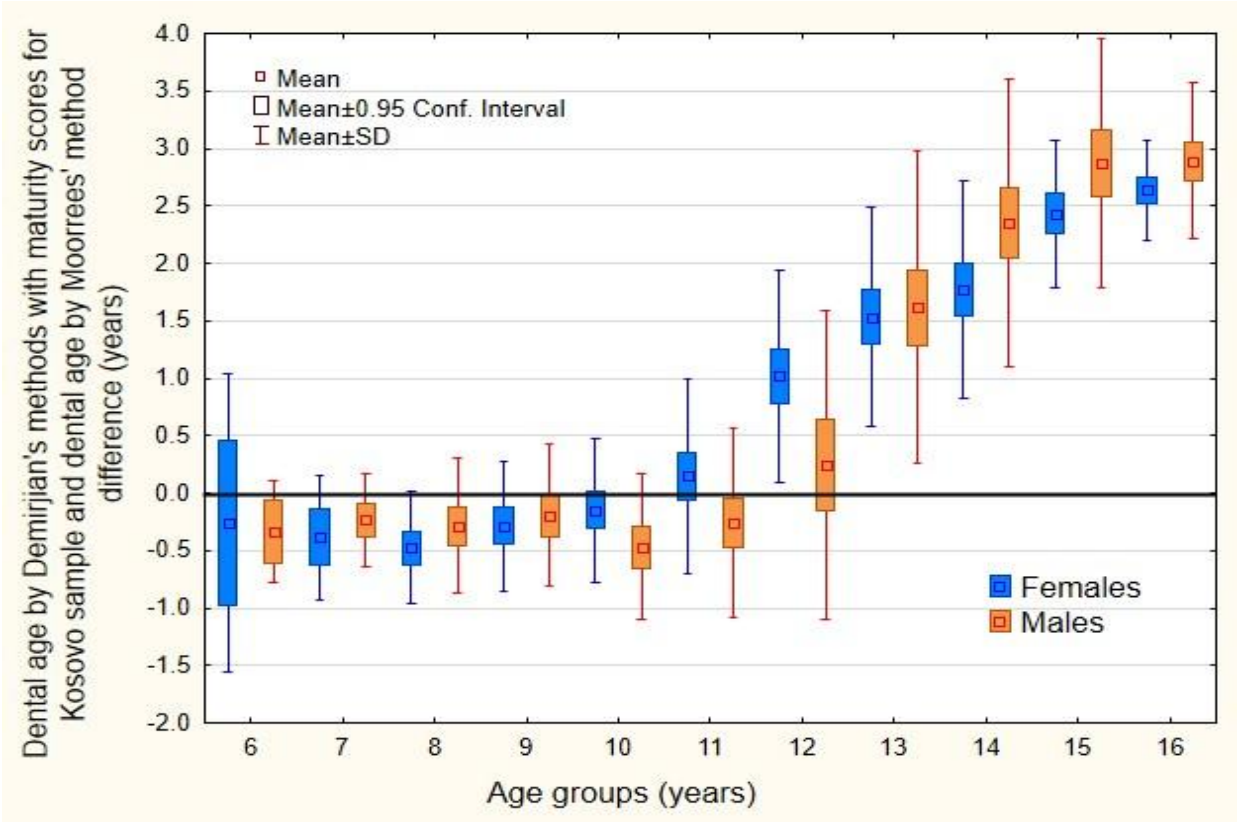

Figure 44. Box plot of the relationship between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Moorrees's method. Box plot shows median and inter-quartile ranges, while whiskers are lined extending from box to highest and lowest value, extending outliners

According to t-test results for independent samples, the difference between the two dental age estimations of girls and boys, listed in Table 51, is statistically significant for almost all age groups of 10 year olds and, also, for those older than 10. Age groups according to gender are not statistically significant for groups of 6 to 9 year olds, which is clearly seen in Figure 44.

Table 51. Gender difference between dental age by the Demirjian's method with dental maturity scores for a Kosovo population and dental age by the Moorrees's method according to age group

Age group	t statistics		
	T	df	p
6	0.189	25	0.852
7	-1.194	50	0.238
8	-1.747	94	0.084
9	-0.788	96	0.433
10	2.691	110	**0.008**
11	2.674	121	**0.009**
12	3.539	107	**0.001**
13	-0.390	130	0.697
14	-3.028	132	**0.003**
15	-2.531	104	**0.013**
16	-2.380	115	**0.019**
6-16	-1.121	1104	0.263

p - the probability of the hypothesis that the difference by gender is statistically equal to the t-test for independent samples

The median absolute deviation of dental age estimations by the Demirjian's method for a Kosovo sample from the estimations of dental age by the Moorrees's method, i.e. deviation regardless to the gender, girls or boys, is listed in Table 57. From this table, it can be seen that the median absolute deviation (value dividing the sample in two halves) of dental age from chronological age ranges from 0.51 to 2.64 years in girls, while this range is 0.41 to 2.89 years for boys.

The frequency of absolute deviation of dental age, estimated by the Demirjian's method with maturity scores for a Kosovo sample from that estimated by the Moorrees's method at half-year intervals is shown in Figure 45. It is evident that both genders are most likely to deviate by 0.5 and one year, and the frequencies of major deviations are unevenly reduced in girls up to 4.0 years of age, whereas they are reduced in 4.5 year olds boys.

Table 52. Mean absolute difference between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Moorrees's method according to age group and gender

Age group	Gender	N	|DA(DK) – DA(M)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.89	0.96	0.67	0.27	1.02
	Male	12	0.50	0.21	0.53	0.37	0.67
7	Female	21	0.60	0.26	0.53	0.40	0.83
	Male	31	0.41	0.22	0.38	0.22	0.58
8	Female	47	0.55	0.41	0.53	0.23	0.73
	Male	49	0.48	0.43	0.37	0.17	0.68
9	Female	51	0.52	0.37	0.43	0.27	0.63
	Male	47	0.52	0.38	0.43	0.18	0.87
10	Female	63	0.51	0.39	0.42	0.22	0.72
	Male	49	0.63	0.47	0.57	0.26	0.93
11	Female	65	0.61	0.60	0.42	0.17	0.82
	Male	58	0.69	0.52	0.50	0.33	0.97
12	Female	61	1.12	0.80	0.97	0.46	1.78
	Male	48	1.01	0.92	0.82	0.35	1.33
13	Female	66	1.58	0.87	1.65	0.82	2.17
	Male	66	1.73	1.21	1.62	0.62	2.57
14	Female	70	1.79	0.91	1.67	1.02	2.67
	Male	64	2.41	1.13	2.65	1.43	3.15
15	Female	52	2.43	0.64	2.67	1.87	2.77
	Male	54	2.89	1.02	3.05	2.52	3.67
16	Female	52	2.64	0.43	2.77	2.32	2.77
	Male	65	2.89	0.68	3.02	2.57	3.47
6-16	Female	563	1.26	1.00	0.92	0.42	1.92
	Male	543	1.47	1.26	0.97	0.42	2.57

\|DA(DK) – DA(M)\| - Dental age by Demirjian's methods with Kosovo maturity scores and dental age by Moorrees's methods absolute difference, SD – Standard deviation

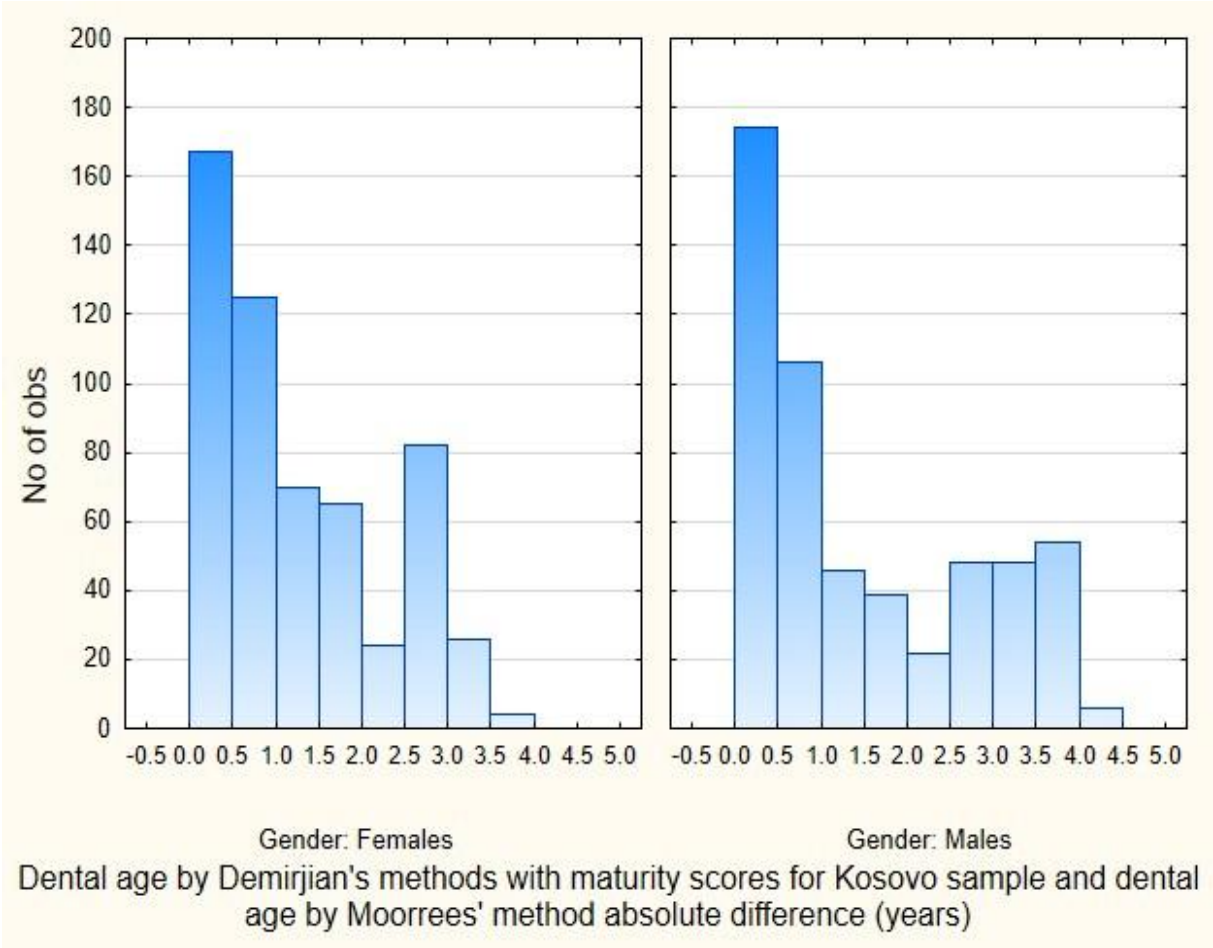

Figure 45. Distribution of mean absolute difference between dental age by the Demirjian's method with maturity scores for a Kosovo population and dental age by the Moorrees's method according to gender

Dental age estimated by the Willems's method significantly differs from that estimated by the Moorrees's method as the t-test results show for the hypothesis that the difference between these estimations equal to zero for almost all age groups and both genders (Table 53). The difference is negative for all age groups of 6 to 11 year olds and then positive in every other age group, meaning that the Willems's method underestimates systematically dental age compared to the Moorrees's method up to 11 year olds and then it overestimates dental age of the remaining age groups.

Table 53. Mean age of dental age by the Willems' method and dental age by the Moorrees's method and difference between age group and gender

Age group	Gender	N	DA(W) – DA(M)						
			Mean diff.	SD	95% CI		t statistics		
					Lower	Upper	t	df	P
6	Female	15	-.85	1.12	-1.47	-.23	-2.925	14	**0.011**
	Male	12	-.82	.58	-1.19	-.46	-4.948	11	**<0.001**
7	Female	21	-.79	.48	-1.01	-.57	-7.457	20	**<0.001**
	Male	31	-.49	.46	-.66	-.32	-5.992	30	**<0.001**
8	Female	47	-.98	.39	-1.10	-.87	-17.112	46	**<0.001**
	Male	49	-.43	.64	-.62	-.25	-4.765	48	**<0.001**
9	Female	51	-1.22	.52	-1.37	-1.07	-16.696	50	**<0.001**
	Male	47	-.21	.54	-.37	-.05	-2.655	46	**0.011**
10	Female	63	-.99	.71	-1.17	-.81	-11.079	62	**<0.001**
	Male	49	-.46	.63	-.64	-.28	-5.116	48	**<0.001**
11	Female	65	-.54	1.04	-.80	-.28	-4.156	64	**<0.001**
	Male	58	-.20	.81	-.41	.02	-1.852	57	0.069
12	Female	61	.49	.98	.24	.74	3.928	60	**<0.001**
	Male	48	.25	1.02	-.04	.55	1.733	47	0.090
13	Female	66	1.21	1.01	.96	1.46	9.767	65	**<0.001**
	Male	66	1.42	1.04	1.16	1.67	11.031	65	**<0.001**
14	Female	70	1.56	1.08	1.31	1.82	12.135	69	**<0.001**
	Male	64	1.92	1.10	1.64	2.19	13.928	63	**<0.001**
15	Female	52	2.34	.84	2.11	2.58	20.069	51	**<0.001**
	Male	54	2.39	1.12	2.08	2.69	15.663	53	**<0.001**
16	Female	52	2.66	.54	2.51	2.81	35.334	51	**<0.001**
	Male	65	2.69	.75	2.50	2.87	28.886	64	**<0.001**
6-16	Female	563	.43	1.61	.30	.57	6.407	562	**<0.001**
	Male	543	.81	1.50	.69	.94	12.596	542	**<0.001**

DA(W) – DA(M) – differences of dental age by Willems' methods and dental age by Moorrees's method, SD – Standard deviation, 95% CI – 95% Confidence interval of the difference, p – probability of difference of the null hypothesis is obtained by one sample t-test

The differences, listed in Table 53, are illustrated in Figure 46 with corresponding confident intervals.

A more accurate figure of the deviation course from the zero difference is shown in Figure 46. Girls and boys, as far as differences are concerned, behave quite differently in most age groups. However, it is important to point out that in most cases, dental age of young boys and girls who were up to 11 years of age estimated by the Moorrees's method is underestimated compared to that estimated by the Willems's method for teenagers up to 11 years. After that, it is progressively overestimated with older age, as quantification of differences shows in Table 53. The differences in estimations of dental age by the Moorrees's method compared to those estimated by the Willems's method behave similarly to the Demirjian's method with the French Canadian sample maturity scores and the maturity scores for a Kosovo sample.

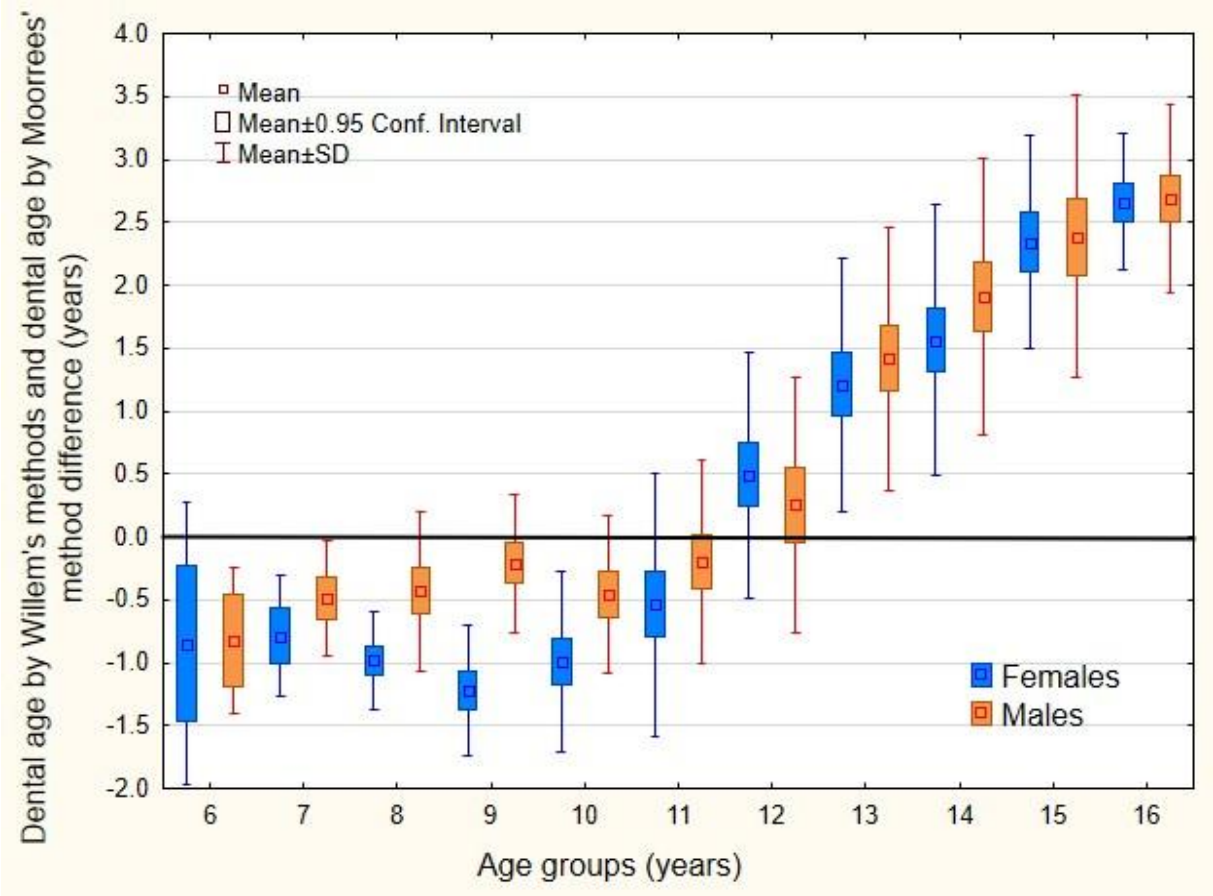

Figure 46. Box plot of the relationship between dental age by the Willems' method and dental age by the Moorrees's method. Box plot shows median and inter-quartile ranges, while whisker are lined extending from box to highest and lowest value, extending outliners

According to t-test results for independent samples, the difference between the two estimations of dental age of girls and boys, listed in Table 54, is statistically significant for 7 to 11 year olds, which is clearly shown in Figure 46.

The median absolute deviation of dental age estimated by the Willems's method from dental age estimated by the Moorrees's method, i.e. deviation regardless to the gender, girls or boys, is shown in Table 55. From this table, it can be seen that the median absolute deviation (value dividing the sample in two halves) of dental from chronological age ranges from 0.85 to 2.66 years in girls, while it ranges from 0.33 to 2.69 years in boys.

Table 54. Gender difference between dental age by the Willems' method and dental age by the Moorrees's method according to age group

Age group	t statistics		
	t	df	p
6	-0.065	25	0.949
7	-2.232	50	**0.030**
8	-5.030	94	**<0.001**
9	-9.363	96	**<0.001**
10	-4.122	110	**<0.001**
11	-2.002	121	**0.048**
12	1.233	107	0.220
13	-1.148	130	0.253
14	-1.866	132	0.064
15	-0.234	104	0.816
16	-0.188	115	0.851
6-16	-4.037	1104	**<0.001**

p - the probability of the hypothesis that the difference by gender is statistically equal to the t-test for independent samples

The median absolute deviation of dental age estimated by the Willems's method from dental age estimated by the Moorrees's method, i.e. deviation regardless to the gender, girls or boys, is shown in Table 55. From this table, it can be seen that the median absolute deviation (value dividing the sample in two halves) of dental from chronological age ranges from 0.85 to 2.66 years in girls, while it ranges from 0.47 to 2.69 years in boys.

Table 55. Mean absolute difference between dental age by the Willems' method and dental age by the Moorrees's method according to age group and gender

Age group	Gender	N	|DA(W) – DA(M)|				
			Mean	SD	Median	Interquartile range	
						Lower	Upper
6	Female	15	0.90	1.08	0.44	0.10	1.39
	Male	12	0.88	0.49	0.84	0.55	1.21
7	Female	21	0.85	0.35	0.91	0.64	1.02
	Male	31	0.58	0.33	0.58	0.33	0.81
8	Female	47	0.98	0.39	0.95	0.80	1.10
	Male	49	0.60	0.48	0.60	0.21	0.81
9	Female	51	1.22	0.52	1.22	0.85	1.57
	Male	47	0.47	0.34	0.34	0.22	0.72
10	Female	63	1.09	0.54	1.07	0.71	1.48
	Male	49	0.61	0.49	0.46	0.22	0.93
11	Female	65	0.89	0.77	0.71	0.41	1.07
	Male	58	0.64	0.53	0.55	0.26	0.99
12	Female	61	0.86	0.68	0.66	0.30	1.43
	Male	48	0.81	0.65	0.68	0.35	1.14
13	Female	66	1.33	0.84	1.36	0.69	1.93
	Male	66	1.52	0.88	1.42	0.87	2.03
14	Female	70	1.59	1.03	1.36	0.82	2.21
	Male	64	1.95	1.03	1.91	1.20	2.61
15	Female	52	2.34	0.84	2.76	1.38	2.86
	Male	54	2.42	1.04	2.61	1.86	3.05
16	Female	52	2.66	0.54	2.86	2.31	2.86
	Male	65	2.69	0.75	2.66	2.23	3.15
6-16	Female	563	1.38	0.93	1.19	0.70	1.93
	Male	543	1.32	1.09	1.00	0.41	1.95

\|DA(W) – DA(M)\| - Dental age by Willems' methods and dental age by Moorrees's methods absolute difference, SD – Standard deviation

The frequency of absolute deviation of dental age, estimated by the Willems's method from that estimated by the Moorrees's method at half-year intervals, is shown in Figure 47. It is evident that the maximum deviation is between 0.5 and one year in both genders, and the frequencies of major deviations are generally reduced in both genders up to 4.5 years.

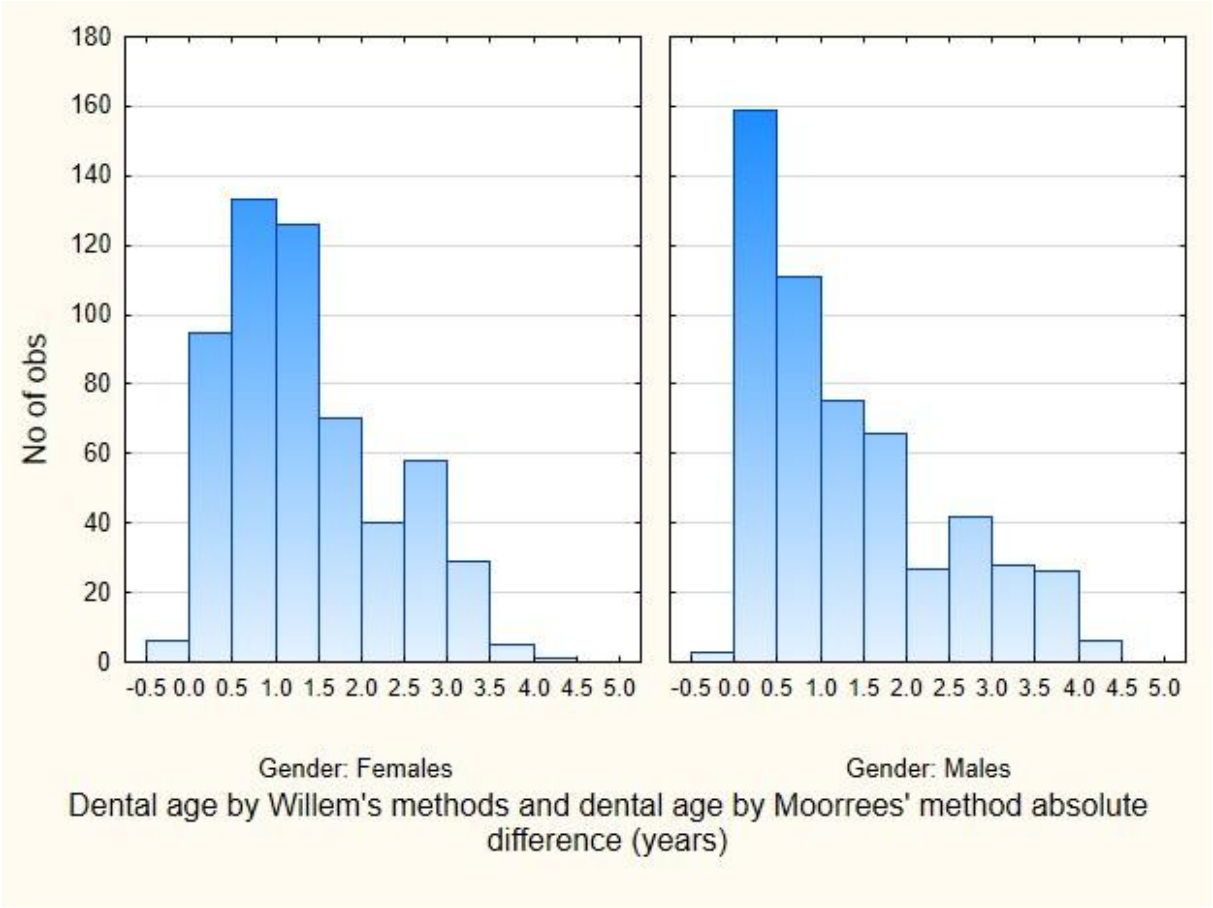

Figure 47. Distribution of mean absolute difference between dental age by the Willems' method and dental age by the Moorrees's method according to gender

The Spearman correlation coefficient of dental age according to the Moorrees's method and dental age according to the Demirjian's maturity score method for the French Canadian population is 0.962 ($n = 563$, $p < 0.001$) for girls, and 0.943 ($n = 543$, $p < 0.001$) for boys. Accordingly, dental age estimated by the Moorrees's method shows a high correlation with the Demirjian's method with maturity scores for the French Canadian population for both genders, despite pronounced individual deviations (Figure 48).

The Spearman correlation coefficient of dental age according to the Moorrees's method and dental age according to the Demirjian's method but with maturity scores for a Kosovo sample is 0.962 for girls ($n = 563$, $p < 0.001$) and 0.934 ($n = 543$, $p < 0.001$) for boys. Accordingly, dental age estimated by the Moorrees's method also shows a high degree of correlation with the Demirjian's method with maturity scores for Kosovo sample for both genders (Figure 49).

The Spearman correlation coefficient of dental age according to the Moorrees's method and dental age according to the Willems's method is 0.962 for girls (n = 563, p <0.001) and 0.946 (n = 543, p <0.001) for boys. Accordingly, the evaluation of dental age by the Moorrees's method also shows a high correlation with the Willems's method for both genders (Figure 50).

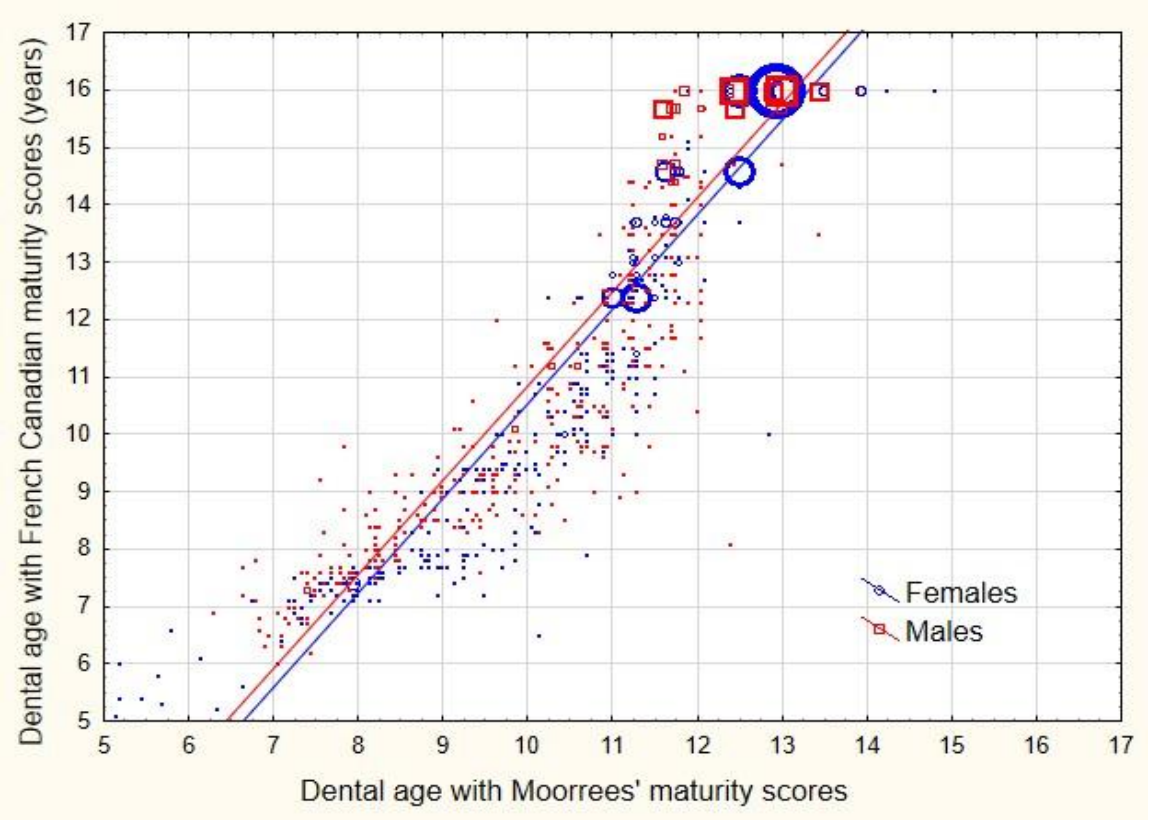

Figure 48. Scatterplot of dental age by Demirjian's methods with maturity scores for French Canadian population related to dental age with Moorrees's maturity scores, according to gender

In Table 56 and Table 57, are shown the main age and standard deviation of each development stages of seven left mandibular teeth and upper incisors, obtained in Kosovo population by Moorrees's method, especially for girls and boys.

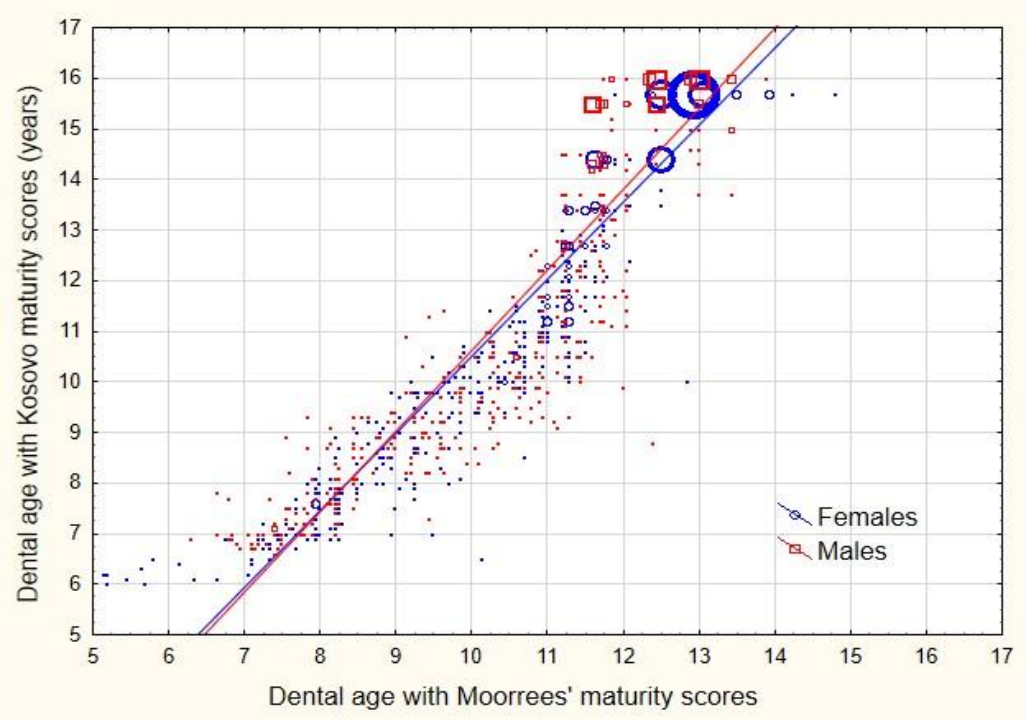

Figure 49. Scatterplot of dental age by Demirjian's methods with maturity scores for a Kosovo population related to dental age with Moorrees's maturity scores, according to gender

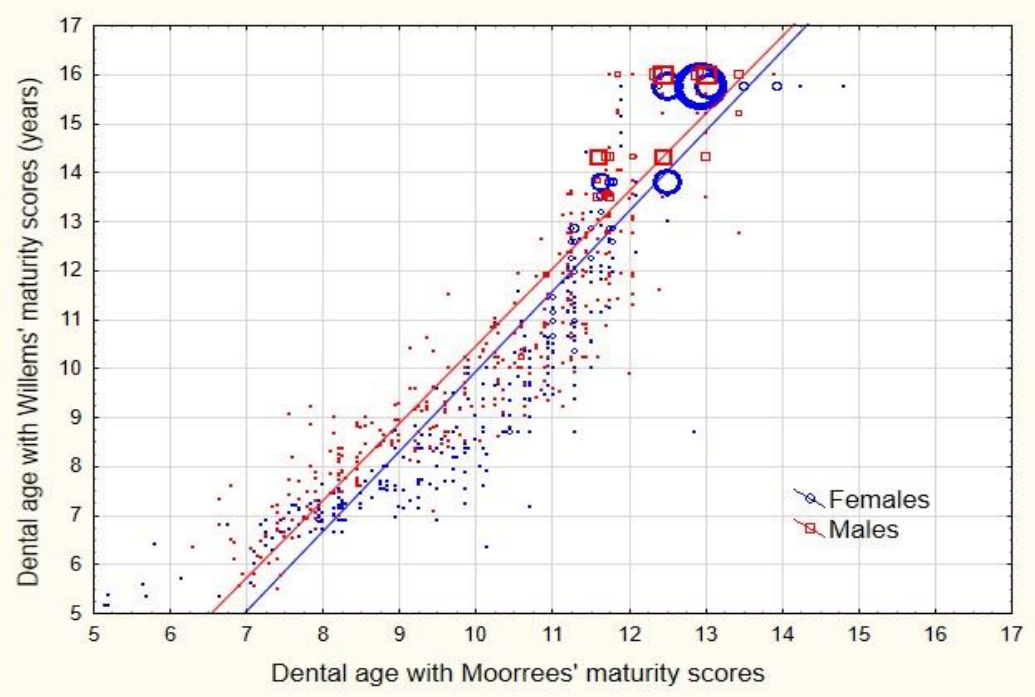

Figure 50. Scatterplot of dental age by Willems' methods related to dental age by the Moorrees's maturity scores, according to gender

Table 56. Mean age of attainment of developmental stages for kosovar girls

STAGE	31		32		33		34		35		36		37		38		21		22		28	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ci														0.00	9.56	1.76					9.46	1.48
Cco														0.86	9.86	1.46					9.74	1.29
Coc														0.63	10.97	1.40					10.66	1.01
Cr½														0.76	11.56	1.26					10.95	0.88
Cr¾									6.35	0.65				1.23	12.52	1.60					11.11	0.83
Crc							6.75	0.50	6.87	1.23			7.02	1.20	13.95	1.71					12.55	0.69
Ri					4.33	0.52	7.06	0.75	7.80	1.47			7.17	1.37	14.38	1.95					13.00	0.00
Cli													7.84	1.61	14.88	1.32						
R¼					6.46	0.84	7.81	1.07	8.39	1.59			9.71	1.00	15.12	1.49	6.10	0.10	6.71	0.58		
R½					8.08	1.18	8.84	0.75	9.57	1.17			9.90	1.18	15.50	1.82	6.20	0.45	7.07	0.76		
R¾			6.80	0.78	8.77	1.12	9.95	1.18	10.52	1.21	6.00	0.00	10.56	1.48	16.76	2.61	6.78	0.52	7.42	0.64		
Rc	6.38	0.50	7.43	1.03	10.54	1.05	10.77	0.90	11.11	0.80	6.25	0.70	12.77	1.70	18.49	2.18	7.58	0.65	7.74	0.45		
A½	7.77	0.73	8.31	1.06	11.42	0.69	11.63	0.66	11.59	0.67	7.27	0.99	13.68	2.70	20.00	1.61	7.71	0.47	8.84	0.52	19.37	1.66
Ac	7.9	0.71	8.78	1.03	12.00	0.00	12.80	0.45	12.86	0.86	8.45	1.40	14.15	2.85	21.82	1.65	8.69	1.26	8.91	0.99		
CRYP															9.34	1.66					9.13	1.76

Table 57. Mean age of attainment of developmental stages for kosovar boys

STAGE	31		32		33		34		35		36		37		38		21		22		28	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ci															9.40	2.28					9.75	1.50
Cco														0.00	10.00	1.55					9.70	1.25
Coc														1.41	10.76	1.88					10.84	0.90
Cr½														0.70	11.12	2.05					10.69	0.74
Cr¾													6.59	0.15	12.03	2.04					10.73	0.83
Crc							6.00	0.00	6.00	0.00			7.01	0.50	12.27	1.61					11.58	0.92
Ri					6.74	0.45	6.69	0.67	6.87	0.71			7.65	0.34	12.91	1.98	6.00	0.00	6.00	0.00	12.67	0.58
Cli													8.31	0.75	13.82	1.89					13.68	0.00
R¼					6.61	0.74	7.27	0.87	8.21	0.72			9.52	0.37	14.10	1.59	6.29	0.49	6.71	0.79		
R½					7.67	0.80	8.42	1.12	8.92	0.95			11.00	1.41	15.26	1.83	6.75	0.75	7.13	0.67		
R¾	6.00	0.00	6.00	0.00	8.47	0.95	9.72	1.10	10.18	1.03			11.76	1.26	17.20	1.76	6.78	0.75	7.58	0.78		
Rc	6.70	0.00	6.30	0.10	10.21	1.13	10.62	1.06	11.03	0.82	6.20	0.74	12.74	1.29	17.68	1.15	7.30	0.96	8.64	0.81		
A½	7.09	0.67	7.35	0.65	11.12	0.88	11.23	0.88	11.56	0.72	7.67	0.80	13.78	1.24	19.85	1.05	8.42	0.56	9.35	0.85	19.55	1.81
Ac	8.35	1.55	9.20	1.40	12.00	0.00	12.83	0.41	13.00	0.00	8.00	0.00	14.76	2.30	21.91	1.41	8.55	1.18	10.05	0.93		
CRYP															9.10	1.46					9.44	1.46

4.8 Comparison of methods for estimating dental age

A fifty randomly selected OPGs were evaluated after two weeks after first evaluation by Ph.D. candidate and another examiner (IG). To compare mean ages of specific tooth stage between gender was used independent-sample T-test and a Mann-Whitney U test was used if any gender listed less than 20 participants within tooth stage (109). To compare the accuracy of different methods, with the null hypothesis that there is no difference between dental age (DA) and chronological age (CA), a paired-samples T-test was used. A Repeated-measures ANOVA in General Linear Model was used to compare DA-CA among all methods. Moreover, was calculated an absolute accuracy of DA-CA or mean absolute error (MAE). Analyses were also done for each gender and age cohort. If the p-value was less than 0.05, than the results were considered statistically significant.

For all four Demirjian's methods, has been slightly found significant differences between the chronological and dental ages, with mean differences between DA and CA, overestimation of DA for both genders was found for Dem1973 (0.28±0.95) shown in Table 58.
The mean CA for boys was 10.51±2.60. The mean of DA was 10.79±2.74. For boys, Dem1973 apart from 6-6.9 and 12-12.9 years' age groups. In all other age groups, no statistically significant differences were observed and the mean of DA was overestimated in all age groups by Dem73 except in 8-8.9 years, with underestimation of 0.01, however, the lower overestimation for DA in the total sample was noted for Dem1976 0.06 years, followed by Dem1973 0.29, the underestimated DA was found by Dem76IN_2 -0.09 and Dem76PM_1 was for -0.17 years, when compared to CA in boys (Table 59).

For girls, the mean of CA was 10.54±2.48years. The mean of DA was 10.81±2.58. Except for 6-6.9 and 10-10.9 years' age groups, in all other age groups no statistically significant differences were observed and DA was overestimated in all age groups except in 8-8.9 and 14-14.99 years' age groups. The highest overestimated DA was by Dem73 for 0.27 y in a total sample compared to CA in girls and the lowest overestimated DA was by Dem76 for 0.12years (Table 60).

The above mentioned method and below mentioned results are consistent with previous study published by Kelmendi et al. (83).

Table 58. Mean age (years) of tooth within stages of panoramic radiographs of 498 males and 524 females from Kosovo

Stage	Tooth n(Mean±SD)						
	31	**32**	**33**	**34**	**35**	**36**	**37**
Males							
A					1()		1(5.69)
B					2(6.08±0.53)		10(7.75±1.38)
C			5(7.61±0.34)	21(6.72±0.83)	49(7.11±0.79)		81(7.33±1.07)
D	1()	6(5.66±0.24)	56(6.81±0.91)	78(7.12±0.98)	76(7.61±1.51)		104(8.61±1.58)
E	14(5.85±0.63)	32(6.51±0.94)	69(7.52±1.11)	97(8.78±1.26)	101(9.32±1.20)	12(5.61±0.20)	101(10.45±1.30)
F	33(7.04±1.42)	59(7.52±1.18)	175(10.16±1.24)	119(10.84±1.08)	130(11.51±1.26)	34(6.76±0.96)	91(12.09±1.15)
G	64(8.19±1.34)	89(8.89±1.11)	103(12.53±1.24)	69(12.22±1.20)	66(12.82±1.17)	121(8.60±1.48)	108(13.69±0.83)
H	386(11.37±2.18)	312(12.04±1.79)	90(13.61±0.91)	114(13.60±0.92)	73(13.75±0.84)	331(11.77±2.01)	2(13.47±1.09)
H†			10.30	10.30	12.04	6,52	
Females							
B			1		4(6.86±1.48)		17(7.10±1.62)
C			7(6.09±0.53)	29(7.01±0.87)	60(7.53±0.87)		81(7.65±1.02)
D	2(5.23±0.33)	2(5.22±0.33)	55(7.38±0.79)	75(7.62±0.98)	69(7.67±1.56)		89(8.43±1.47)
E	7(6.26±0.53)	17(6.22±0.53)	65(7.52±1.08)	81(8.31±1.33)	102(9.48±1.44)	3(5.43±0.56)	102(10.21±1.22)
F	16(6.60±0.67)	41(6.99±0.87)	110(9.48±1.13)	101(10.40±0.87)	98(11.04±1.18)	16(6.23±0.55)	76(11.65±1.02)
G	45(7.28±0.89)	82(8.12±0.97)	133(11.51±1.35)	101(11.74±1.08)	111(12.32±1.13)	104(7.60±1.15)	156(13.24±1.03)
H	454(11.06±2.15)	382(11.65±1.82)	153(13.10±1.06)	137(13.40±0.94)	80(13.71±0.85)	401(11.51±1.89)	3(13.00±0.31)
H†			10.46	10.46	11.57	6.70	12.71

SD, standard deviation; n, number of teeth; †only minimum age was recorded

Table 59. Comparison of chronological age (CA) and dental age (DA) (years) calculated using Demirjian, Moorres' and Willems's methods

Method	Gender	N	CA±SD	DA±SD	(DA-CA)±SD	L*	U*	MAE±SD[b]	t(df)	*P*[a]
Dem1973	**Males**	498	10.51±**2.60**	10.79±**2.74**	0.29±1.02	0.20	0.38	0.82±**0.67**	6.24(497)	<0.001
Dem1976				10.57±**2.59**	0.06±0.91	-0.02	0.14	0.72±**0.56**	1.44(497)	0.151
Dem1976PM_1				10.33±**2.68**	-0.17±1.18	-0.28	-0.07	0.78±**0.59**	-3.31(497)	0.001
Dem1976IN_2,				10.42±**2.62**	-0.09±1.03	-0.18	0.00	0.84±**0.61**	-1.86(497)	0.063
Moorres1963				10.61±**1.73**	-1.21±1.53	-1.08	-1.34	1.58±**1.16**	-18.44(542)	<0.001
Willems2001				10.17±**2.47**	-0.21±0.86	-0.28	-0.13	0.71±**0.53**	-5.38(497)	<0.001
Cameriere2007				10.10±**2.23**	-0.40±1.03	-0.49	-0.31	0.88±**0.68**	-8.73(497)	<0.001
Dem1973	**Females**	524	10.54±**2.48**	10.81±**2.58**	0.27±0.88	0.20	0.35	0.72±**0.58**	7.06(523)	<0.001
Dem1976				10.66±**2.69**	0.12±0.94	0.04	0.20	0.77±**0.56**	2.88(523)	0.004
Dem1976PM_1				10.70±**2.73**	0.16±1.05	0.07	0.25	0.85±**0.62**	3.48(523)	<0.001
Dem1976IN_2,				10.70±**2.80**	0.17±1.08	0.07	0.26	0.88±**0.63**	3.53(523)	<0.001
Moorres1963				10.75±**1.78**	-0.99±1.40	-1.10	-0.87	1.37±**1.02**	-16.78(562)	<0.001
Willems2001				10.17±**2.47**	-0.37±0.83	-0.44	-0.30	0.77±**0.48**	-10.24(523)	<0.001
Cameriere2007				10.28±**2.08**	-0.25±0.96	-0.34	-0.17	0.79±**0.59**	-6.09(523)	<0.001
Dem1973	**Total**	1022	10.52±**2.54**	10.80±**2.66**	0.28±**0.95**	0.22	0.34	0.77±**0.63**	9.35(1021)	<0.001
Dem1976				10.61±**2.64**	0.09±**0.93**	0.03	0.15	0.74±**0.56**	3.08(1021)	0.002
Dem1976PM_1				10.52±**2.54**	0.00±**1.13**	-0.07	0.07	0.82±**0.61**	-0.10()1021	0.918
Dem1976IN_2,				10.57±**2.71**	0.04±**1.06**	-0.02	0.11	0.86±**0.62**	1.30(1021)	0.192
Moorres1963				10.77±**1.75**	-1.10±**1.47**	-1.22	-0.94	1.47±**1.09**	2.57(1104)	0.010
Willems2001				10.23±**2.49**	-0.29±**0.85**	-0.34	-0.24	0.74±**0.50**	-10.99(1021)	<0.001
Cameriere2007				10.20±**2.16**	-0.33±**0.99**	-0.39	-0.27	0.83±**0.64**	-10.50(1021)	<0.001

[a]paired t-test between DA and CA; DA-CA, difference between dental and chronological age; [b]MAE – mean absolute error between dental and chronological age; L, lower interval and U, upper interval of 95% Confidence Interval of DA-CA; SD, standard deviation; df, degrees of freedom

Table 60. A comparisons of chronological age (CA) and dental age (DA) (years) calculated using Cameriere's, Demirjian's and Willems' methods across different age-male

Age groups	N	Method	CA±SD	DA±SD	(DA-CA)±SD	L	U	MAE±SD[b]	t(df)	P[a]
6.0.6.9	32	Dem1973	6.51±0.26	7.48±0.68	0.97±0.64	0.74	1.20	1.04±0.65	8.59(31)	<0.001
		Dem1976		7.27±0.79	0.76±0.73	0.50	1.03	0.84±0.72	5.91(31)	<0.001
		Dem1976PM$_1$		6.67±2.37	0.16±2.28	-0.66	0.98	0.92±0.88	0.40(31)	0.695
		Dem1976IN$_2$,		7.18±0.94	0.67±0.90	0.35	1.00	0.90±0.75	4.25(31)	<0.001
		Moorres1963		7.24±0.51	1.38±0.78	0.89	1.88	1.41±0.73	6.13(11)	<0.001
		Willems2001		7.08±0.88	0.57±0.82	0.27	0.87	0.77±0.71	3.93(31)	<0.001
		Cameriere2007		7.07±0.60	0.56±0.62	0.34	0.79	0.61±0.61	5.18(31)	<0.001
7.0 – 7.9	57	Dem1973	7.56±0.27	7.74±0.71	0.17±0.71	-0.02	0.36	0.52±0.51	1.84(56)	0.071
		Dem1976		7.55±0.82	-0.01±0.81	-0.23	0.21	0.62±0.51	-0.10(56)	0.922
		Dem1976PM$_1$		7.39±1.33	-0.18±1.32	-0.53	0.17	0.70±0.50	-1.02(56)	0.313
		Dem1976IN$_2$,		7.38±0.86	-0.19±0.84	-0.41	0.03	0.69±0.46	-1.69(56)	0.096
		Moorres1963		7.88±0.52	0.70±0.52	0.51	0.89	0.74±0.46	7.47(30)	<0.001
		Willems2001		7.48±0.86	-0.08±0.86	-0.31	0.15	0.66±0.52	-0.72(56)	0.472
		Cameriere2007		7.73±0.82	0.17±0.84	-0.06	0.39	0.64±0.57	1.49(56)	0.142
8.0 – 8.9	49	Dem1973	8.58±0.22	8.57±0.70	-0.01±0.67	-0.20	0.18	0.54±0.40	-0.10(48)	0.920
		Dem1976		8.49±0.72	-0.09±0.69	-0.29	0.11	0.56±0.40	-0.93(48)	0.357
		Dem1976PM$_1$		8.43±0.79	-0.16±0.78	-0.38	0.07	0.63±0.48	-1.41(48)	0.165
		Dem1976IN$_2$,		8.30±0.77	-0.29±0.76	-0.51	-0.07	0.65±0.48	-2.65(48)	0.011
		Moorres1963		8.00±0.89	0.01±0.81	-0.24	0.23	0.61±0.53	- 0.06(48)	0.949
		Willems2001		8.39±0.63	-0.20±0.61	-0.37	-0.02	0.49±0.40	-2.26(48)	0.029
		Cameriere2007		8.27±0.86	-0.31±0.84	-0.55	-0.07	0.73±0.50	-2.58(48)	0.013
9.0 – 9.9	55	Dem1973	9.55±0.31	9.67±0.92	0.11±0.89	-0.13	0.35	0.73±0.52	0.94(54)	0.353
		Dem1976		9.60±0.94	0.05±0.90	-0.19	0.29	0.75±0.50	0.41(54)	0.683
		Dem1976PM$_1$		9.53±0.96	-0.02±0.94	-0.28	0.23	0.76±0.54	-0.19(54)	0.850
		Dem1976IN$_2$,		9.35±1.01	-0.20±0.96	-0.46	0.06	0.82±0.52	-1.56(54)	0.125
		Moorres1963		9.07±0.95	0.10±0.84	-0.15	0.34	0.65±0.54	0.77(46)	0.443
		Willems2001		9.35±0.75	-0.21±0.74	-0.41	0.00	0.63±0.44	-2.05(54)	0.045
		Cameriere2007		9.45±0.88	-0.10±0.80	-0.31	0.12	0.65±0.46	-0.93(54)	0.357
10.0 – 10.9	58	Dem1973	10.51±0.27	10.58±1.05	0.07±1.05	-0.20	0.35	0.77±0.71	0.52(57)	0.604
		Dem1976		10.55±0.97	0.04±0.97	-0.21	0.30	0.74±0.63	0.32(57)	0.750
		Dem1976PM$_1$		10.48±1.00	-0.04±1.01	-0.30	0.23	0.80±0.61	-0.28(57)	0.782
		Dem1976IN$_2$,		10.49±1.11	-0.02±1.04	-0.32	0.28	0.95±0.62	-0.15(57)	0.883
		Moorres1963		10.23±0.69	0.22±0.67	0.03	0.41	0.59±0.38	2.33(48)	0.024
		Willems2001		10.34±0.88	-0.17±0.88	-0.40	0.06	0.66±0.61	-1.49(57)	0.141
		Cameriere2007		10.35±0.75	-0.16±0.79	-0.37	0.05	0.52±0.61	-1.54(57)	0.130
11.0 – 11.9	60	Dem1973	10.49±0.29	11.23±1.00	-0.26±0.97	-0.51	-0.01	0.73±0.69	-206(59)	0.043
		Dem1976		11.20±0.93	-0.29±0.90	-0.53	-0.06	0.71±0.62	-2.53(59)	0.014
		Dem1976PM$_1$		11.04±0.84	-0.45±0.81	-0.66	-0.24	0.71±0.59	-4.34(59)	<0.001
		Dem1976IN$_2$,		10.99±0.96	-0.50±0.91	-0.74	-0.27	0.78±0.68	-4.30(59)	<0.001
		Moorres1963		10.37±0.88	-0.65±0.91	-0.89	-0.41	0.86±0.72	5.39(57)	<0.001
		Willems2001		10.78±0.80	-0.71±0.76	-0.91	-0.52	0.92±0.47	-7.29(59)	<0.001
		Cameriere2007		10.61±0.65	-0.88±0.69	-1.06	-0.71	1.00±0.51	-9.94(59)	<0.001
12.0 – 12.9	54	Dem1973	12.48±0.25	13.13±1.36	0.66±1.25	0.31	1.00	1.07±0.91	3.85(53)	<0.001
		Dem1976		12.80±1.09	0.32±1.00	0.05	0.59	0.86±0.58	2.36(53)	0.022
		Dem1976PM$_1$		12.43±1.04	-0.04±0.97	-0.31	0.22	0.80±0.54	-0.31(53)	0.757
		Dem1976IN$_2$,		12.53±1.20	0.05±1.12	-0.26	0.36	0.89±0.67	0.33(53)	0.740
		Moorres1963		11.02±0.84	-0.98±0.83	-1.23	-0.74	1.05±0.74	-8.22(47)	<0.001
		Willems2001		12.44±1.09	-0.04±0.98	-0.31	0.23	0.83±0.51	-0.30(53)	0.765
		Cameriere2007		11.65±1.24	-0.83±1.13	-1.14	-0.52	1.23±0.66	-5.37(53)	<0.001
13.0-13.9	57	Dem1973	13.41±0.29	13.79±1.23	0.38±1.26	0.04	0.71	1.07±0.74	2.25(56)	0.028
		Dem1976		13.39±0.95	-0.02±0.98	-0.28	0.24	0.80±0.56	-0.13(56)	0.894
		Dem1976PM$_1$		13.08±1.03	-0.33±1.05	-0.61	-0.05	0.93±0.58	-2.37(56)	0.021
		Dem1976IN$_2$,		13.26±1.20	-0.15±1.23	-0.48	0.17	1.11±0.55	-0.94(56)	0.350
		Moorres1963		11.40±0.88	-1.65±0.61	-1.80	-1.50	1.65±0.61	21.82(65)	<0.001
		Willems2001		13.13±0.79	-0.28±0.84	-0.50	-0.06	0.76±0.43	-2.53(56)	0.014
		Cameriere2007		12.53±1.05	-0.88±1.05	-1.16	-0.60	1.07±0.85	-6.32(56)	<0.001
14.0-14.9	55	Dem1973	14.40±0.26	14.84±0.94	0.44±0.89	0.20	0.68	0.84±0.51	3.69(54)	0.001
		Dem1976		14.19±0.72	-0.21±0.69	-0.40	-0.03	0.56±0.44	-2.32(54)	0.024
		Dem1976PM$_1$		13.81±0.67	-0.59±0.63	-0.76	-0.41	0.61±0.61	-6.85(54)	<0.001
		Dem1976IN$_2$,		14.16±0.86	-0.24±0.81	-0.46	-0.02	0.59±0.60	-2.19(54)	0.033
		Moorrees1963		11.77±0.66	-2.30±0.68	-2.47	-2.13	2.31±0.66	-27.12(63)	<0.001
		Willems2001		13.82±0.65	-0.58±0.62	-0.75	-0.41	0.65±0.56	-6.94(54)	<0.001
		Cameriere2007		13.17±0.88	-1.23±0.83	-1.45	-1.00	1.25±0.80	-10.89(54)	<0.001

[a]paired t-test between DA and CA; DA-CA — difference between dental and chronological age; [b]MAE – mean absolute error between dental and chronological age; L — lower interval and U — upper interval of 95% Confidence Interval of DA-CA ; SD — standard deviation; df — degrees of freedom

Table 61. A comparisons of chronological age (CA) and dental age (DA) (years) calculated using Cameriere's, Demirjian's and Willems' methods across different age in -females

Age groups	N	Method	CA±SD	DA±SD	(DA-CA)±SD	L	U	MAE±SD[b]	t(df)	P[a]
6.0.6.9	38	Dem1973	6.50±0.28	7.38±0.74	0.88±0.67	0.66	1.10	1.00±0.47	8.15(37)	<0.001
		Dem1976		7.10±0.88	0.60±0.79	0.34	0.86	0.88±0.45	4.65(37)	<0.001
		Dem1976PM$_1$		7.45±0.89	0.95±0.80	0.68	1.21	1.08±0.61	7.28(37)	<0.001
		Dem1976IN$_2$,		7.43±1.22	0.92±1.12	0.56	1.29	1.29±0.57	5.10(37)	<0.001
		Moorrees1963		6.74±1.49	1.10±1.45	0.30	1.90	1.37±1.17	2.93(14)	0.011
		Willems2001		6.91±0.76	0.41±0.69	0.18	0.64	0.68±0.42	3.67(37)	0.001
		Cameriere2007		7.09±0.55	0.59±0.53	0.41	0.76	0.65±0.44	6.83(37)	<0.001
7.0 – 7.9	52	Dem1973	7.58±0.25	7.54±0.78	-0.04±0.80	-0.26	0.18	0.52±0.59	-0.37(51)	0.711
		Dem1976		7.17±0.89	-0.40±0.90	-0.66	-0.15	0.83±0.53	-3.24(51)	0.002
		Dem1976PM$_1$		6.99±0.99	-0.59±0.99	-0.87	-0.31	1.02±0.52	-4.29(51)	<0.001
		Dem1976IN$_2$,		7.02±0.98	-0.56±0.97	-0.83	-0.29	0.95±0.58	-4.19(51)	<0.001
		Moorrees1963		7.82±1.00	0.61±0.98	0.17	1.06	0.37±0.75	2.87(20)	0.009
		Willems2001		7,17±0.63	-0.41±0.65	-0.59	-0.23	0.66±0.39	-4.54(51)	<0.001
		Cameriere2007		7.78±0.95	0.20±0.93	-0.06	0.46	0.70±0.64	1.53(51)	0.133
8.0 – 8.9	57	Dem1973	8.53±0.28	8.25±0.97	-0.27±0.88	-0.51	-0.04	0.76±0.51	-2.35(56)	0.022
		Dem1976		8.10±1.05	-0.42±0.94	-0.67	-0.17	0.87±0.53	-3.41(56)	0.001
		Dem1976PM$_1$		8.13±1.16	-0.39±1.05	-0.67	-0.12	0.92±0.63	-2.83(56)	0.006
		Dem1976IN$_2$,		8.10±1.09	-0.42±0.99	-0.69	-0.16	0.87±0.63	-3.22(56)	0.002
		Moorrees1963		8.10±0.64	0.08±0.67	-0.12	0.28	0.50±0.45	0.80(46)	0.426
		Willems2001		7.88±0.81	-0.65±0.72	-0.84	-0.46	0.88±0.39	-6.85(56)	<0.001
		Cameriere2007		8.63±0.95	0.10±0.83	-0.12	0.32	0.68±0.49	0.94(56)	0.353
9.0 – 9.9	65	Dem1973	9.58±0.28	9.82±0.84	0.24±0.79	0.05	0.44	0.63±0.53	2.49(64)	0.015
		Dem1976		9.73±0.77	0.15±0.72	-0.03	0.33	0.58±0.45	1.66(64)	0.102
		Dem1976PM$_1$		9.61±0.77	0.03±0.74	-0.16	0.21	0.57±0.46	0.30(64)	0.767
		Dem1976IN$_2$,		9.43±0.88	-0.15±0.85	-0.36	0.06	0.71±0.48	-1.40(64)	0.166
		Moorrees1963		9.17±0.90	0.19±0.82	-0.04	0.42	0.69±0.47	1.65(50)	0.105
		Willems2001		9,07±0.60	-0.51±0.57	-0.65	-0.37	0.65±0.41	-7.20(64)	<0.001
		Cameriere2007		9.79±0.76	0.21±0.72	0.03	0.39	0.59±0.46	2.32(64)	0.024
10.0 – 10.9	65	Dem1973	10.58±0.27	11.11±0.92	0.53±0.85	0.32	0.74	0.79±0.62	4.99(64)	<0.001
		Dem1976		10.98±0.93	0.41±0.86	0.19	0.62	0.74±0.59	3.80(64)	<0.001
		Dem1976PM$_1$		11.02±1.08	0.44±1.01	0.19	0.69	0.88±0.66	3.53(64)	0.001
		Dem1976IN$_2$,		11.08±1.07	0.50±0.99	0.25	0.74	0.91±0.62	4.07(64)	<0.001
		Moorrees1963		10.00±0.85	-0.02±0.79	-0.22	0.18	0.69±0.37	-0.17	0.863
		Willems2001		10.27±0.92	-0.31±0.86	-0.52	-0.10	0.77±0.48	-2.92(64)	0.005
		Cameriere2007		10.40±0.66	-0.18±0.64	-0.34	-0.02	0.51±0.42	-2.28(64)	0.026
11.0 – 11.9	64	Dem1973	11.48±0.29	11.86±1.03	0.38±0.93	0.15	0.61	0.74±0.68	3.27(63)	0.002
		Dem1976		11.69±1.06	0.21±0.97	-0.04	0.45	0.76±0.63	1.71(63)	0.092
		Dem1976PM$_1$		11.60±1.16	0.12±1.07	-0.15	0.39	0.86±0.63	0.89(63)	0.378
		Dem1976IN$_2$,		11.65±1.15	0.17±1.07	-0.10	0.44	0.87±0.64	1.28(63)	0.206
		Moorrees1963		10.85±0.78	-0.14±0.82	-0.35	0.06	0.60±0.57	-1.40(64)	0.165
		Willems2001		11.04±1.01	-0.44±0.92	-0.68	-0.21	0.87±0.54	-3.85(63)	<0.001
		Cameriere2007		10.99±0.88	-0.49±0.81	-0.69	-0.29	0.82±0.47	-4.83(63)	<0.001
12.0 – 12.9	63	Dem1973	12.50±0.29	13.02±1.01	0.53±0.98	0.28	0.77	0.90±0.65	4.25(62)	<0.001
		Dem1976		12.87±1.17	0.37±1.14	0.08	0.66	0.96±0.72	2.57(62)	0.013
		Dem1976PM$_1$		12.92±1.33	0.42±1.30	0.09	0.75	1.16±0.71	2.58(62)	0.012
		Dem1976IN$_2$,		12.98±1.34	0.48±1.32	0.15	0.81	1.15±0.78	2.91(62)	0.005
		Moorrees1963		11.22±0.53	-0.79±0.57	-0.94	-0.65	0.85±0.48	10.93(60)	<0.001
		Willems2001		12.36±1.12	-0.14±1.05	-0.40	0.13	0.88±0.58	-1.02(62)	0.311
		Cameriere2007		11.83±0.98	-0.67±0.96	-0.91	-0.43	0.98±0.65	-5.53(62)	<0.001
13.0-13.9	64	Dem1973	13.48±0.30	13.66±0.74	0.18±0.75	-0.1	0.36	0.63±0.44	1.90(63)	0.062
		Dem1976		13.58±0.87	0.10±0.88	-0.12	0.32	0.74±0.47	0.89(63)	0.377
		Dem1976PM$_1$		13.83±0.90	0.35±0.83	0.14	0.56	0.76±0.48	3.39(63)	0.001
		Dem1976IN$_2$,		13.90±0.91	0.42±0.83	0.21	0.63	0.79±0.48	4.03(63)	<0.001
		Moorrees1963		11.49±0.48	1.54±0.50	-1.66	-1.42	1.54±0.50	-25.23(65)	<0.001
		Willems2001		13.00±0.75	-0.48±0.72	-0.66	-0.30	0.72±0.47	-5.27(63)	<0.001
		Cameriere2007		12.68±0.86	-0.80±0.83	-1.01	-0.60	0.89±0.73	-7.75(63)	<0.001
14.0-14.9	44	Dem1973	14.39±0.32	14.29±0.47	-0.10±0.43	-0.23	0.03	0.35±025	-1.54(43)	0.130
		Dem1976		14.36±0.66	-0.03±0.59	-0.21	0.15	0.48±0.33	-0.32(43)	0.750
		Dem1976PM$_1$		14.39±0.56	0.00±0.47	-0.14	0.14	0.35±0.31	0.01(43)	0.989
		Dem1976IN$_2$,		14.50±0.54	0.11±0.45	-0.03	0.24	0.35±0.29	1.55(43)	0.128
		Moorrees1963		11.88±0.66	-2.13±0.63	-2.28	-1.98	2.14±0.61	-28.09(69)	<0.001
		Willems2001		13.54±0.50	-0.85±0.43	-0.98	-0.72	0.85±0.43	-13.12(43)	<0.001
		Cameriere2007		12.99±0.58	-1.40±0.52	-1.55	-1.24	1.40±0.52	-17.87(43)	<0.001

[a]paired t-test between DA and CA; DA-CA — difference between dental and chronological age; [b]MAE – mean absolute error between dental and chronological age; L — lower interval and U — upper interval of 95% Confidence Interval of DA-CA ; SD — standard deviation; df — degrees of freedom

Comparison between the chronological age and dental age, depending on age group and genders by using the four development stages of Demirjian's method

Mean CA for boys was 10.51±2.60. Mean DA was 10.79±2.74. For boys, Dem1973 except in 6-6.9 and 12-12.9 y age groups, in all other age groups no statistically significant differences were observed and mean DA was overestimated in all age groups by Dem73 except in 8-8.99y were underestimation was 0.01, however the lower overestimation for DA in whole sample was noted for Dem1976 0.06y, followed by Dem1973 0.29y, the underestimated DA was found by Dem76IN_2 -0.09 and Dem76PM_1 was for -0.17y, when compared to CA in boys (Table 61).

For girls, mean CA was 10.54±2.48y. Mean DA was 10.81±2.58. Except for 6-6.9 and 10-10.9 y age groups, in all other age groups no statistically significant differences were noted and DA was overestimated in all age groups except in 8-8.9 and 14-14.99 y age groups. The highest overestimated DA was by Dem73 for 0.27 y in total sample compared to CA in girls and the lowest overestimated DA was by Dem76 for 0.12y.

Comparison between the chronological age and dental age, depending on age group and genders by using the Willems' method

Mean CA for boys was 10.51±2.60 y. Mean DA was 10.17±2.47 y. For boys, except in 11-11.99 and 14-14.9y age group, in all other age groups no statistically significant differences were observed and except group ages of 6-6.9 and 11-11.99 mean DA was underestimated in all other age groups, however significant underestimation of -0.21±0.86y was noted in whole sample when compared to CA in boys (Table 60).

For girls, mean CA was 10.54±2.48y. Mean DA was 10.17±2.47. Except for 6-6.9y age groups, in all the age groups, statistically significant differences were observed and mean DA was underestimated in all age groups except for 6-6.9y age group. However, significant underestimation of -0.37±0.83y was observed in total sample of girls (Table 61).

Comparison between the chronological age and dental age, depending on age group and genders by using the Moorrees' method

In males, mean DA was 10.61±1.73 y. For boys, in age groups 8, 9 and 10.9 year olds, no statistically significant differences were observed and except group ages of 6, 7, 9 and 10 year olds mean DA was underestimated in all age groups, however significant underestimation of -1.21±1.53y was noted in whole sample when compared to CA in boys (Table 60).

For girls, mean DA was 10.75±1.78y. Except for 12-12.9 and onwards age groups, in all other age groups, statistically no significant differences were observed and mean DA was underestimated in age groups of 10, 11, 12 and 14 year olds. However, significant underestimation of -0.99±1.40y was observed in total sample of girls.

Comparison between the chronological age and dental age, depending on age group and genders by using the Cameriere's method

In males, mean DA was 10.10±2.23y. For boys, in age groups 8, 9 and 10 year olds, no and except group ages of 6, 7 and 13 year olds, mean DA was underestimated in all other age groups, however significant underestimation of -0.40±1.03y was noted in whole sample when compared to CA in boys.

For girls, mean DA was 10.28±2.08y. Except for 6 to 10.9 year olds, in all other age groups, mean DA were observed underestimation of real age and in age grous of 7 to 10.9 year olds statistically no significant differences was found. However, significant underestimation of -0.25±0.96y was observed in total sample of girls.

Table 62 and Table 63 include the Pearson coefficients of correlation of chronological age and five methods for estimation of dental age of boys and girls. As noted in the tables, the correlations of Pearson correlations are slightly different from the previously mentioned Spearman's correlations (which are documented in the previous chapters) and can therefore be referred to for that reason as well.

In both genders, the correlation coefficients are statistically significant and very high and are about 0.90 and above. Particularly high correlation coefficients are between the Demirjian's method, based on the French Canadian population and the Kosovo sample scores, and the Willems's method. They are 0.99 (Table 62 and Table 63).

Table 62. The Spearman correlation coefficients of chronological age and five methods for estimating dental age for females

Variables		Age	DA(D)	DA(DK)	DA(W)	DA(M)	DA(CK)
CA	r	1.0000	0.9253	0.9272	0.9275	0.9025	0.8979
	n	563	563	563	563	563	450
	p	---	<0.001	<0.001	<0.001	<0.001	<0.001
DA(D)	r	0.9253	1.0000	0.9923	0.9890	0.9443	0.9050
	n	563	563	563	563	563	450
	p	<0.001	---	<0.001	<0.001	<0.001	<0.001
DA(DK)	r	0.9272	0.9923	1.0000	0.9906	0.9417	0.9211
	n	563	563	563	563	563	450
	p	<0.001	<0.001	---	<0.001	<0.001	<0.001
DA(W)	r	0.9275	0.9890	0.9906	1.0000	0.9302	0.9063
	n	563	563	563	563	563	450
	p	<0.001	<0.001	<0.001	---	<0.001	<0.001
DA(M)	r	0.9025	0.9443	0.9417	0.9302	1.0000	0.8723
	n	563	563	563	563	563	450
	p	<0.001	<0.001	<0.001	<0.001	---	<0.001
DA(CK)	r	0.8979	0.9050	0.9211	0.9063	0.8723	1.0000
	n	450	450	450	450	450	450
	p	<0.001	<0.001	<0.001	<0.001	<0.001	---

CA – Chronological age, DA(D) – Dental age by Demirjian's methods with maturity scores for French Canadian population, DA(DK) - Dental age by Demirjian's methods with maturity scores for Kosovo sample, DA(W) – Dental age by Willems' methods', DA(M) – Dental age by Moorrees's methods', DA(CK) - Dental age by Cameriere's methods for Kosovo sample

Table 63. The Spearman correlation coefficients of chronological age and five methods for estimating dental age of males

Variables		Age	DA(D)	DA(DK)	DA(W)	DA(M)	DA(CK)
CA	r	1.0000	0.9152	0.9188	0.9221	0.8985	0.9092
	n	543	543	543	543	543	411
	p	---	<0.001	<0.001	<0.001	<0.001	<0.001
DA(D)	r	0.9152	1.0000	0.9911	0.9834	0.9143	0.8938
	n	543	543	543	543	543	411
	p	<0.001	---	<0.001	<0.001	<0.001	<0.001
DA(DK)	r	0.9188	0.9911	1.0000	0.9846	0.9030	0.9050
	n	543	543	543	543	543	411
	p	<0.001	<0.001	---	<0.001	<0.001	<0.001
DA(W)	r	0.9221	0.9834	0.9846	1.0000	0.9260	0.9112
	n	543	543	543	543	543	411
	p	<0.001	<0.001	<0.001	---	<0.001	<0.001
DA(M)	r	0.8985	0.9143	0.9030	0.9260	1.0000	0.8779
	n	543	543	543	543	543	411
	p	<0.001	<0.001	<0.001	<0.001	---	<0.001
DA(CK)	r	0.9092	0.8938	0.9050	0.9112	0.8779	1.0000
	n	411	411	411	411	411	411
	p	<0.001	<0.001	<0.001	<0.001	<0.001	---

CA – Chronological Age, DA(D) – Dental age by Demirjian's methods with maturity scores for French Canadian population, DA(DK) - Dental age by Demirjian's methods with maturity scores for Kosovo sample, DA(W) – Dental age by Willems' methods', DA(M) – Dental age by Moorrees's methods', DA(CK) - Dental age by Cameriere's methods for Kosovo sample

Coefficients of chronological age correlation and five methods for estimating dental age of boys and girls, illustrated by appropriate scatter plot with appropriate regression lines, are shown in Figures 51 and 52. As can be seen in the figures, dispersion of data about the regression lines is due to the distribution of input data expected. However, in the case between the Demirjian's method based on the French Canadian population and the Kosovo sample scores and the Willems's method, these dispersions are very small in relation to the corresponding regression lines. It is also to be expected in the case of correlation coefficients that are close to one, which points to the fact that estimating dental age by these methods is equally valuable. Also, this is equally valid for both genders.

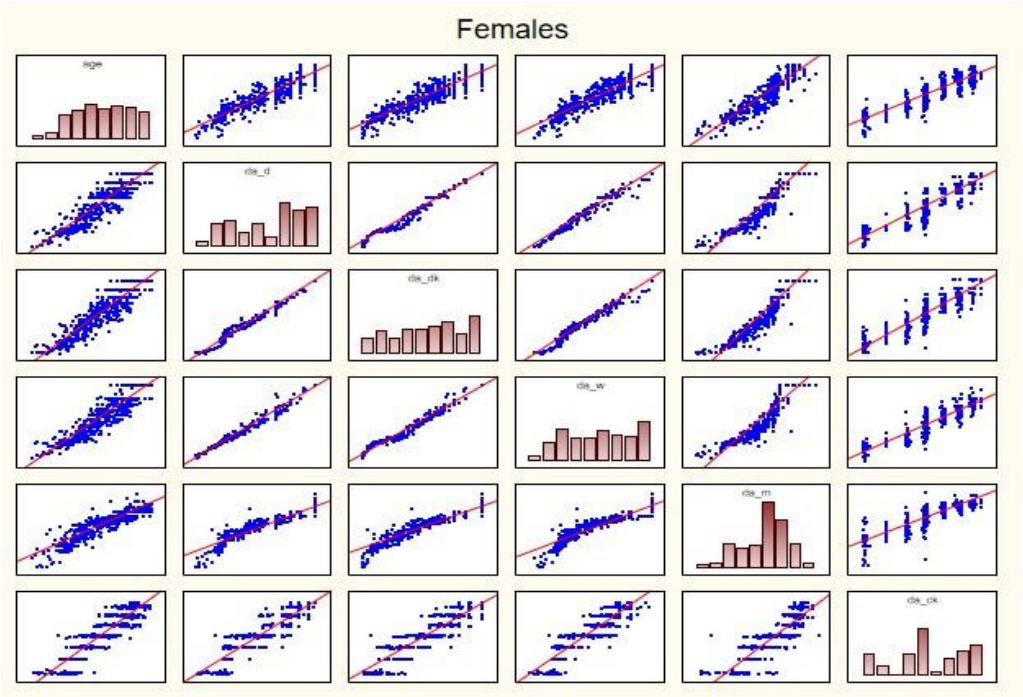

Figure 51. Correlation coefficients of chronological age and five dental age estimation methods for female illustrated with appropriate scatter plots

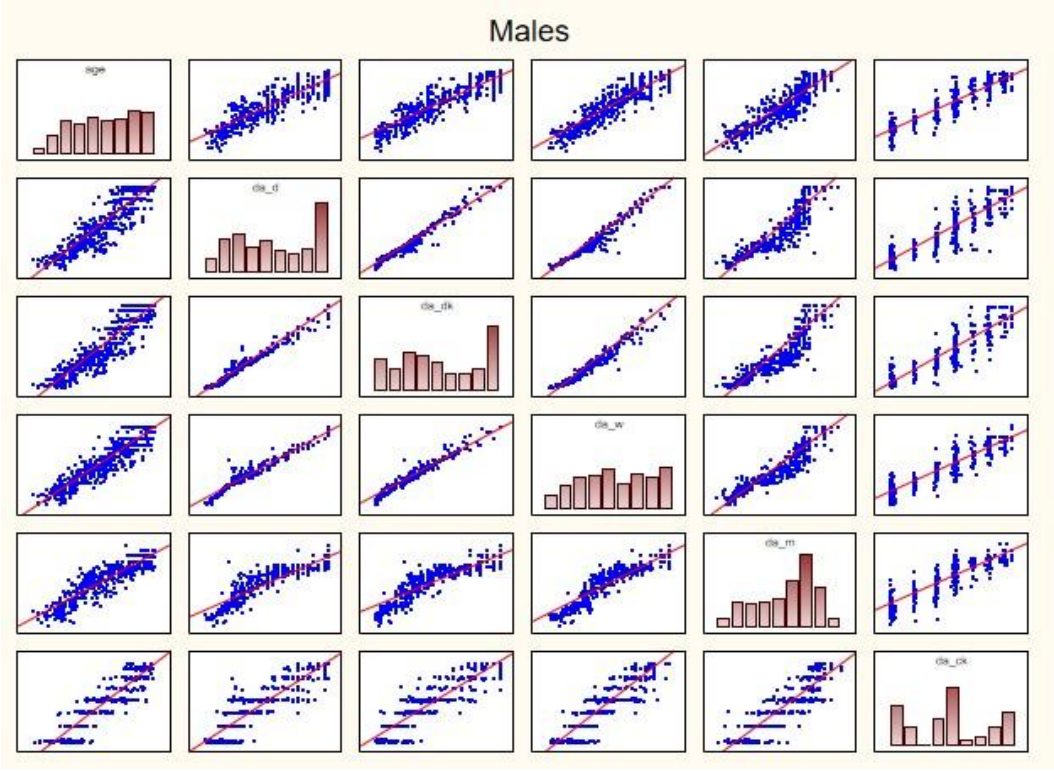

Figure 52. Correlation coefficients of chronological age and five dental age estimation methods for male illustrated with appropriate scatter plots

Figure 53 and Figure 54, show a comparative dental age estimation by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo population (Kosovo model), the Willems' method and the Moorrees/ method by age groups for females (N = 563) and for males (N = 543). As is seen and expected, given correlation of accuracy by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo population and the Willems's method behave similarly by overestimating and/or underestimating chronological age, while the Moorrees's method is not suitable for dental age estimation after age 11.

Figure 55 and Figure 56 show comparative dental age estimation by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo population, the Willems's method, the Moorrees's method and the Cameriere's method for a Kosovo sample by age groups for females = 450) and for males (N = 411) since the Cameriere method was restricted for the age group of 6 to 15 years, due to lack of measurement in some of 1106 OPGs. The figures, show that the Cameriere's method is in agreement with the Demirjian's methods and Willems's method for dental age estimation for Kosovo population.

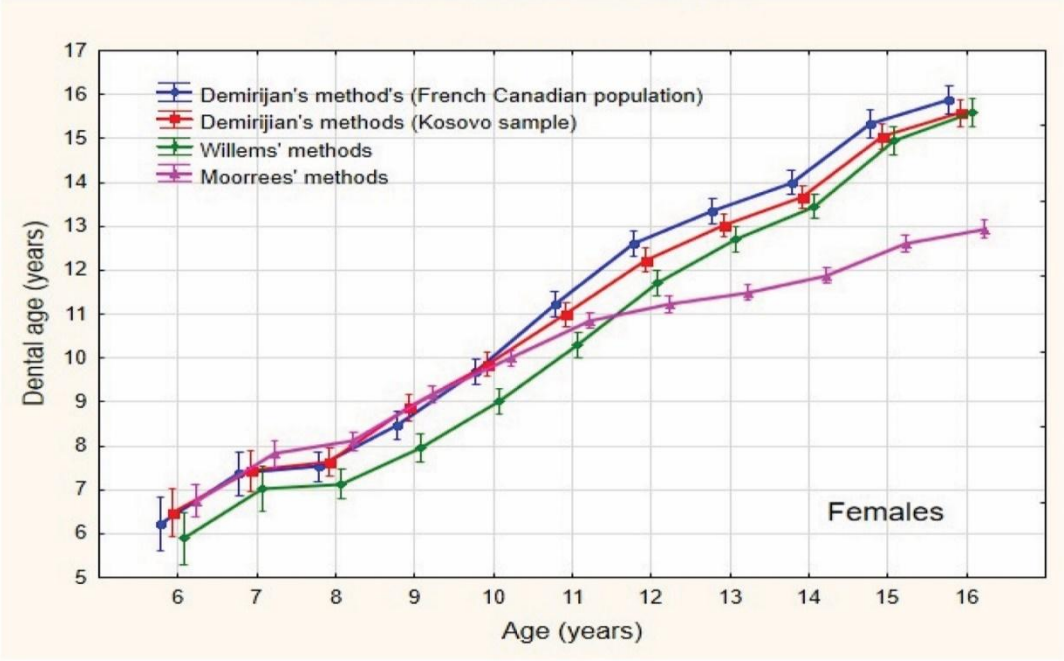

Figure 53. Dental age by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo population, the Willems's method and the Moorrees's method related to age groups for females (N=563)

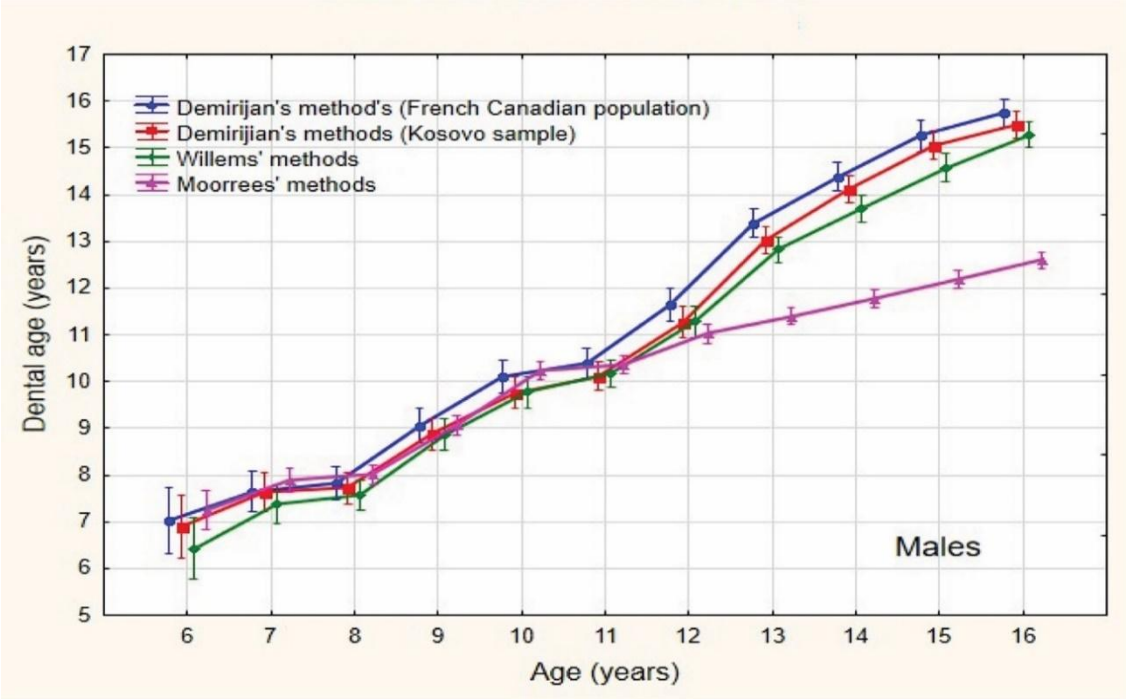

Figure 54. Dental age by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo population, the Willems's method and the Moorrees's method by age groups for males (N=543)

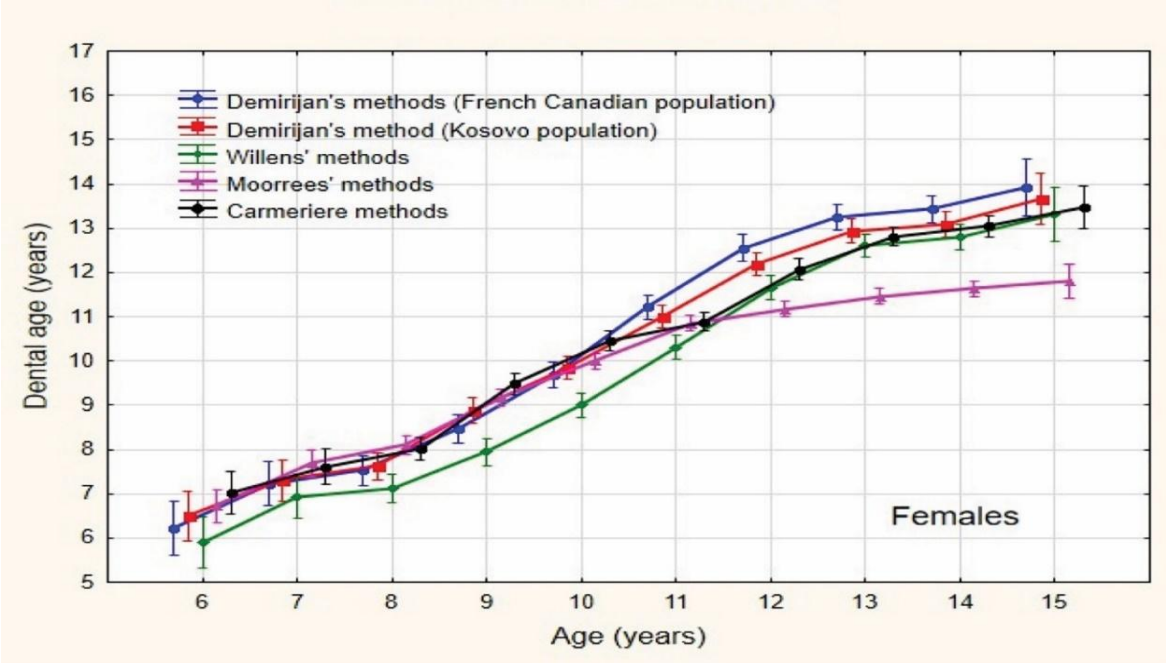

Figure 55. Dental age by Demirjian's methods with maturity scores for French Canadian population, Demirjian's method with maturity scores for Kosovo population, Willems' methods, Moorrees's methods and Cameriere's methods for Kosovo sample related to age groups for females (N=450)

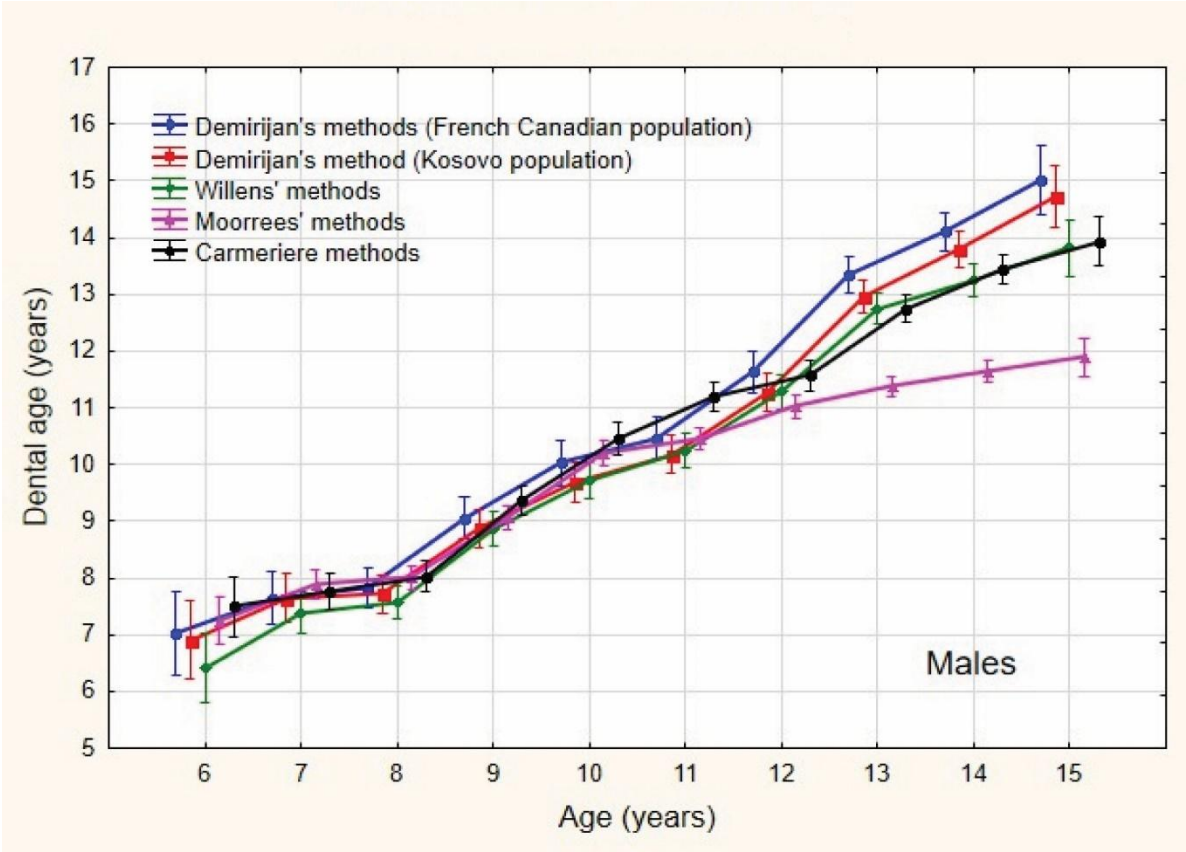

Figure 56. Dental age by the Demirjian's method with maturity scores for a French Canadian population, the Demirjian's method with maturity scores for a Kosovo sample, the Willems's method, the Moorrees's method and the Cameriere's method for a Kosovo sample by age groups for females (N=450)

All previous analyses of dental age including the above mentioned five methods point to the fact that these methods more or less estimate dental age quite well for the Kosovo sample except the Moorrees's method for OPGs over 11 years of age. By comparative representation of average values of all five methods of dental age estimation of a Kosovo sample, the average values of estimations for some age groups, especially for females (N = 563 and N = 450) and males (N = 543 and N =411), which are listed in Table 64 and Table 65.

In this case, the closest approximation of dental age to the average age of the age group (which is not necessarily equal to the group value) is indicated in black and the next nearest value is indicated in red. At the bottom of the table, the first and second places of each method are listed under "hit".

Table 64. Average of dental age estimation between five methods for females by age groups

Age group	Mean age (N=563)	DA(D)	DA(DK)	DA(W)	DA(M)	Mean age (N=450)	DA(CK)
6	5.64	**6.22**	6.48	**5.89**	6.74	5.64	7.03
7	7.20	**7.36**	7.43	**7.03**	7.82	7.20	7.61
8	8.02	7.53	7.63	7.12	**8.10**	8.02	**8.02**
9	8.98	8.46	**8.88**	7.94	**9.17**	8.98	9.48
10	10.01	9.67	**9.85**	9.00	**10.00**	10.01	10.47
11	10.99	11.21	**10.99**	10.31	10.85	10.99	**10.88**
12	12.01	12.61	**12.24**	11.71	11.22	12.00	**12.07**
13	13.04	13.34	**13.03**	12.70	11.49	13.03	**12.81**
14	14.01	**13.99**	**13.65**	13.44	11.88	13.96	13.04
15	15.02	15.32	**15.04**	**14.95**	12.61	14.73	13.47
16	16.08	**15.87**	15.58	**15.60**	12.94		
Hit[a]		**3** + **1**	**4** + **3**	**1** + **2**	**1** + **2**		**2** + **3**

[a] the first two values that are closest to the average value of age group, (D) - Dental age by Demirjian's methods with maturity scores for French Canadian population, DA (DK) - Dental age by Demirjian's methods with maturity scores for Kosovo sample, DA (W) - Dental age by Willems' methods, DA (M) - Dental age by Moorrees's methods, DA (CK) - Dental age by Cameriere's methods for Kosovo sample

Table 65. Average of dental age estimation between five methods for males by age groups

Age group	Mean age (N=543)	DA(D)	DA(DK)	DA(W)	DA(M)	Mean age (N=411)	DA(CK)
6	5.86	7.03	**6.91**	**6.42**	7.24	5.86	7.49
7	7.18	**7.64**	7.65	**7.38**	7.88	7.18	7.76
8	8.01	7.83	7.72	7.57	**8.00**	8.01	**8.03**
9	8.97	**9.06**	8.87	8.86	**9.07**	8.97	9.37
10	10.01	**10.11**	9.76	9.77	**10.23**	9.96	10.47
11	11.01	**10.40**	10.11	10.17	10.37	11.05	**11.19**
12	12.01	**11.63**	11.27	11.28	11.02	12.01	**11.57**
13	13.05	13.39	**13.01**	**12.82**	11.40	13.03	12.75
14	14.07	**14.38**	**14.12**	13.69	11.77	14.07	13.44
15	15.00	**15.26**	**15.06**	14.57	12.19	14.69	13.93
16	15.97	**15.74**	**15.49**	15.28	12.59		
Hit[a]		**4** + **4**	**3** + **2**	**2** + **1**	**1** + **2**		**1** + **2**

[a] the first two values that are closest to the average value of age group, (D) - Dental age by Demirjian's methods with maturity scores for French Canadian population, DA (DK) - Dental age by Demirjian's methods with maturity scores for Kosovo sample, DA (W) - Dental age by Willems' methods, DA (M) - Dental age by Moorrees's methods, DA (CK) - Dental age by Cameriere's methods for Kosovo sample.

5. DISCUSSION

Accuracy and precision are equally important in dental age estimation. Any difference found between the standard population and a sample population can depend on a large number of variables such as precision of the method, age group of the sample structure, sample size, statistical approach and biological variation of individual children (111, 112). A number of previous studies have explored the accuracy of age estimation by the development of teeth. Some researchers used a small sample size or uneven distribution, or they showed their results in a way that makes any comparison difficult.

This research evaluated the accuracy of six age estimation methods based on the development of the mandibular teeth by Demirjian's scoring system. The size of the sample and the distribution of the age, were designated to be representative of the population of Kosovo (69). The accuracy of four Demirjian's methods, based on the French- Canadians, Demirjian's method adopted for Kosovar population, Willems' on Belgian and Cameriere's was also tested in this study. The study presented accuracy as the mean difference between DA and CA or DA-CA and the absolute value of the DA-CA or MAE.

Since 1982, dental radiography, a non-invasive and simple technique used daily in dental practice, has been employed in methods of age estimation (91).

From the literature review, it was observed that there were smaller numbers of panoramic radiographs of younger children than those belonging to older children. The reason for that may be that age estimation is performed more commonly by using previous X-rays of children who go to paediatric and orthodontic clinics and this can affect demographic characteristics of such studies. Nowadays, children are maturing earlier than they did at the beginning of this century. Moreover, they are growing faster than their ancestors (113). Dental development does not depend on other maturation phenomena.

Previously, several methods for the determination of dental development from radiographs have been described (114). Most of these are based on a comparison of the radiographic development of teeth with standard diagrams collected from a large number of persons, usually in a distinct of the geographic region (115). The methods for this issue can be applied to living persons. Furthermore, OPGs also provide information regarding the identity of an individual and other age-related features such as enamel attrition, secondary dentine in the pulp, root resorption, cementum annulations, and periodontal recession (116).

The staging of tooth development is an attempt to categorize changes that occur along a continuous path of tooth growth which is an indicator for age estimation. The most commonly used methods are based on tooth development which is divided into developmental stages by using dental radiographs (117). Extra-oral lateral oblique radiographs or cephalographs and intra-oral radiographs are required to view the development of permanent teeth (118). The introduction of dental panoramic tomography in 1954 allowed the visualization of all the permanent teeth at one time, with reduced exposure to radiation (119). These x-ray techniques used in numerous studies on age estimation allowed the estimation of the size of the pulp or changes in the diameter and length of the roots.

Radiological analyses of the development of the third molar can be used for dental age estimation in adolescents (< 24 years of age), after the second molar has been erupted and occlusal integrated (120). The studies of Kullmann and Demirjian, illustrate the third molar development based on panoramic radiographs. The authors looked at either root development and the degree of mineralization (120). These techniques were modified by Mincer and served as the basis for studies by Maber, Garn and Olze, who also looked at third molar development in different ethnic groups and populations followed by Cameriere who has developed the regression formula to asses age by measuring open apices of the mandibular third molar (6).

The youngest (0-4 year olds) groups of children were usually smaller compared to the older ones, while the majority of age groups comprised 5-9 year olds (68, 82, 112). The main reason for that may be that dental caries and malocclusion increase during the teeth development is more common in older children than in younger ones (112). Moreover, radiographic examination is technically sensitive and cannot be easily performed in children under 5 years of age (121).

In this study, 9 to 15-year-olds were the largest groups of children and most of 9-year-olds had complete development and eruptions of the incisors, while their canines and premolars were in the F and G stage of root development, which is in agreement with other studies (112, 122).

Many authors have reported different standards of dental maturation, using different methods, assessed at different populations: Indian, Chinese, Senegalese, Australian, South and south-east African, Saudi, Pakistani, Brazilian and also Europeans (123). Among the most recent groups of populations are: German from south-western Germany, Finnish, Norwegian, Swedish, British, Hungarian from south-western Hungary, Dutch, Danish, Italian, Turkish,

Polish from Central Poland, French from South France, Croatian, Italy, Serbian, Macedonian, those from Bosnia and Herzegovina, and Albanian.

A large number of researchers have published their techniques of assessing dental maturity by tooth formation: Demirjian, Goldstein, Tanner, Glombitza, Nolla, Prahl Andersen and van der Linden and apical opening of root by Roberto Cameriere (67, 87, 124-126). Their techniques employ a scoring system by which they attempt to simplify chronological age estimation and reduce the number of teeth studied to 7 or 4.

The investigation of Demirjian in 1973 resulted in creation of dental maturity scoring system which is easy to use. Besides, it has proved to be the most accurate one and has been employed in a large number of studies worldwide (67, 112). Following the same pattern, this study has adopted this scoring system for Kosovar children. The range of dental age estimation of the Demirjian's method with a maturity score for a Kosovo sample is lower than that for a French-Canadian population, especially in girls (Table 14).

Bagherpour *et al*. studied the stages of dental age development in Iranian children aged 6-13 years, in order to determine the children's age according to Demirjian. The developmental stages of the left mandibular teeth were examined on panoramic radiographs (120).

This research aimed to test the repeatability and accuracy of dental age estimation methods for Kosovar children by determining the mean absolute difference for each gender.

The Demirjian's method has been extensively used in 1999, in British children from Bangladeshi backgrounds and Caucasians. Between the ethnic groups, were found no significant differences. In addition, it was stated that the Demirjian's method could not be applied to British population as it showed overestimation of age (122) in 2005, in another study, this method was applied to Dutch people and was considered to be the most reliable method (127). The original method of Demirjian, was later modified by many authors and one modification was made in 2003 (71). It confirmed that the Demirjian's method was easy to apply and that it can be used in medical legal cases in order to find and determine a person's age (128). In the study of a Turkish population (2007), no gender variations for dental maturity were found if this method was used (129). Also, a study from central Poland obtained similar results. The researchers did not find any gender variations in dental maturity (130). In 1988, in a study of South Indian population, the researchers used the Demirjian's method to estimate a person's age. It can be observed that there was an overestimation by 3

years (131). In 2011, in the study of Indian population, the modified Demirjian's method was used by including the third molar. Reduction in overestimation by 1 year can be observed (132).

A study from 2007, which also used the Demirjian's method, has found a high correlation between chronological age and dental age (133). In the study of a Belgian Caucasian population (2001), the overestimation of chronological age was observed. The adopted scoring system resulted in new age scores and was highly accurate compared with the original method (69). In the study of South Indian population from Mangalore (2014), a positive correlation between chronological age and estimated age was found. However, no statistically significant differences were found between genders (131).

In the most recent studies, the mean absolute difference, which is the difference between dental age and chronological age proportionally aged inside an age interval or inside a proportion of chronological age, is considered to be a measure to quantify the accuracy of the methods (75). In samples with insufficient number of individuals of both genders within a specific age group, the mean age tends to have wider confidence intervals and skewed the mean results (68).

Consequently, in this study, the effectiveness of dental methods was compared in terms of the mean absolute difference between estimated and actual age, and the number of age estimates that were either $<\pm 1$ year considered as accurate from actual age, otherwise $>\pm 2$ years were considered to be inaccurate (134).

Liversidge *et al*., mentioned that in many studies the mean chronological and standard deviations were reported for stages H, whereas in our results, only the minimum age of stages H was recorded for teeth $M_{1,}$ I_1 and stages H for M_2 because of the unsuitability of determination of mean age (122).

The Demirijan's method uses the left side of mandible since studies indicate that the rate of growth is approximately the same on both sides. Several studies have been conducted to determine the accuracy of the Demirijan's method in a specific population. In this study, Demirijan's method overestimated the mean DA by 0.34 years (0.35 years for girls and 0.3 years for boys, ranging from -0.39 to 0.34 years), except for the 10-11-year-old group, which was underestimated by 0.4- to 1.09 years.

These results show that growth in our population occurs earlier than in the French/Canadian population sample studied by Demirjian *et al.* The results of other studies from several countries that used the Demirijan's method also showed an average overestimation in DA ranging from -0.750 to 3.04 years. In this study, the largest discrepancy between dental and chronological ages was observed in the 6 to 6.90 age group.

This result was similar to that of other Turkish studies, namely, Celikoglu *et al.*, Tunç and Koyuturk, and Celik *et al.* Growth prediction uncertainties in younger children may have caused this higher overestimation. The second largest discrepancy between dental and chronological ages in Demirijan's method was in the group of 10 to 11.90 year-old girls in our study. Prepubertal or pubertal growth changes may explain this situation.

Willems *et al.* adopted and simplified the Demirijan's method in Belgian children, and, according to Liversidge, the Willems' method showed more accurate results in estimating DA. For that reason, we used the the Willems' method. In this study, the DA was underestimated 0.34 year (0.44 year for girls and 0.28 year for boys) by the Willems' method; ranged from -0.68 to 0.32 year. DA differences in other studies that were found by authors using the Willems' method was ranged from -0.24 to 0.34 year. Liversidge *et al.* believed that overestimated dental ages in recent studies using Demirijan's method can be partly explained by a positive secular trend in growth and development since 1973. Willems' method showed more accurate results in this study than the Demirijan's method. This result could be explained by the fact that our study was performed 42 years after Demirjian's study and 14 years after Willems' study.This study of dental age estimation in children includes a large sample of children from Kosovo and is the first study which simultaneously compares the four Demirjian's methods for age estimation of children. The mean of age of attainment of some development stages of teeth in children from Kosovo occurred earlier in females compared to males, which is similar to the results obtained by Liversidge *et al.*, Tunc and Koyutürk and Ambarakova *et al*. (68, 75, 135).

Nonetheless, compared to Belgium children described by Liversidge *et al.*, the mean age attainment of tooth development stages, our results were earlier for two stages in advance for I_1, I_2, C and PM_1 tooth, one stages in advance for PM_2 and M_1 tooth and stages A, B for M_2 tooth (75). Comparing to Macedonian children described by Ambarakova *et al.*, the mean age attainment of tooth development stages in our results showed earlier maturation for two stages

in advance for M_2 tooth and one stage in the other teeth, apart from I_2 tooth wherein the results are similar to ours (68). This made us realize that dental maturity in Kosovar children occurs earlier.

By the time when the original method of Demirjian was applied to Belgaum on Karnataka population, the mean difference between dental age and chronological age was minimal (134). In his research, Demirjian has found some key differences between male and female samples. A male sample showed the difference of 0.14 years and female sample showed a minimal difference of 0.04 years. Besides, they showed a significant positive linear correlation. The obtained results are in agreement with the results obtained in our study which was using the Demirjian's method. The results of overestimation of dental age from this research are generally in line with most previous studies but show the smaller difference between DA and CA. The highest overestimation was 0.29±1.02 for males and 0.27 ±0.88 for females. The Demirjian's method has not been improved for sample design, age structure and age range (136). Maturity curves from most published reports are similar to new revised scores for age, while differences occur when sample size per age category is small as well as for the youngest age category. The findings observed in our study, wherein the highest accuracy of Demirjian's methods was confirmed, were in agreement with the Demirjian revised method (Demirjian1976) in younger age-group.

Ozle *et al*. considered the Demirjian system the best method for dental age estimation (103). However, a modified Demirjian's method proposed by Willems has been tested in various geographic population groups and has shown higher accuracy than the Demirjian's method for dental age estimation. While comparing the scores of populations on which these methods for estimation of dental age were based, it was found that dental age of children from Kosovo showed slight overestimation for both genders for 0.28 years compared with French-Canadian children. This study has provided evidence that, in general, the average difference between CA and DA of Kosovar children by using the Demirjian1976PM_1 method was 0.00 years, thus showing that the Demirjian1976PM_1 method was the most accurate method in this context, followed by Demirjian1973 with slight overestimation of 0.28years, Dem1976, Dem1976IN_2.

Therefore, when evaluating the Demirjian system in age estimation, in this study for Kosovar children, all of original Demirjian's methods met the criteria for acceptable range of age difference between estimated and chronological age as was also described by Flood *et al*. and

Chaillet *et al*. in Finnish children (110). Research of Flood *et al*. which included a small sample (n=143) of Western Australian population showed a slight difference compared to our results, thus suggesting that the Demirjian1976PM_1 could be used for testing population in forensic age estimation (110). At the same time, Galić *et al*., recommended this method for Bosnian and Herzegovinian children, Tunc and Koyutürk for Northern Turkish children and Chen *et al*. for Chinese children. However, we strongly believed that Demirjian's methods were adequate for estimation of dental age in Kosovar children (84, 110, 137).

On the other hand, this research that is using Demirjian1976, is in disagreement with some previous studies by Amabakova *et al*., Tunc and Koyutürk, or the study of Cuković *et al*, on Croatian children which showed the overestimation of 0.9 years for males, and 1year for females (68, 135, 138). Having determined their own standards, a large number of these studies compared the results with data of populations other than French-Canadian.

Dental age was determined for the first time by the Willems's method in a Kosovo population. Interestingly, the estimated age is strongly and positively correlated with chronological age.

The Demirjian age estimation method has changed. This study has been conducted by several researches who have observed different performances in different populations. Age estimates revealed that the method of Willems *et al*. (2001) has either overestimated or underestimated years for approximately 0.6 months (7.2 months) or less (75, 139). The performance of the Willems' method in this selected population was compared with other studies. The Willems' method in the selected Kosovar population and underestimation for -0.47y is compared with Belgian children. Different scores are obtained in the research of a Kenyan population, whereas slightly higher scores are obtained for a population of United Arabs Emirates (0.01 years) and British population (0.14 years) (75, 112, 139).

In Malaysia and Macedonia, the score was over 0.45 and 0.42, which is similar to the present population (68, 140). Although the data of the current study show low differences in mean age of -0.47 years, it is statistically significant. There was a significant positive correlation between chronological age and estimated age. In the current study, the Willems's method was better in assessing the age of girls than the age of boys. The same results were obtained in studies which were carried out in Yugoslavia, Brazil, Northern India, Kenya, South India and Malaysia (68, 112, 141-143).

The Willems's method has the ability to estimate the maximum age of group 15-16 years in girls and boys. This occurs when all of the first seven mandibular teeth are in phase H, which means that tooth development was completed. Therefore, the Willems' method should be limited to children whose teeth are still developing in the lower jaw (112). Exclusion of adults with 7 permanent teeth did not affect the statistical significance of overall mean age differences.

The individual 13-16 years age groups showed great changes in mean age differences according to Kihara's research on a Kenyan population (112). This was also recorded by Liversidge *et al*. (2010b), who had to exclude 63% and 89% of 15 and 16 year olds, while using the Willems's method (75). This fact has to be taken into account when scientists intend to carry out age estimation studies using the Willem's method. Authors have to exclude adult individuals from their analyses because they can lead to confusing results, which may lead to increased average age differences. Moreover, it is not possible to determine when maturity is reached because the teeth remain in phase H irrespective of the number of years that have elapsed. It was noted that most published age studies did not mention exclusion of such adults (112). According to this research, Willems' method showed the smallest difference between dental age and chronological age and may be recommended for age estimation if all seven teeth are available. In cases where some of the permanent teeth are missing, alternative methods on four available teeth may be used.

Older individuals may require additional analysis of development of third molars, which continues during the adolescent period. Third molars are associated with a high variability in development, morphology and eruption times (65, 144).

To improve accuracy, dental and skeletal estimation methods were also used simultaneously in some countries. In Austria, unaccompanied juveniles are usually subjected to radiographic examination to determine whether they have a minimum age of 18 years (93). In Germany, the age is assessed by physical examination, panoramic images of the teeth and by hand wrist radiography (145).

Cameriere et al., published a new notion of estimating chronological age in children by measuring the open apices in seven mandibular teeth on radiographs, which gave reliable estimates of age in 455 Italian Caucasian children (87). The reliability of Cameriere's method was evaluated on several sample groups from different nationalities, to find the fact that the original regression model formulated by Cameriere is not always suitable for other countries

as tooth development differed among population related to variation among ethnic groups and regional locations. They were further influence by dietary practice, socioeconomic status, nutritional habits, and lifestyle (82). Few authors therefore modified Cameriere's regression model with newer samples to suit their population and suggested Cameriere's method to be the most accurate method for the population of current decade (87, 104). However, these studies have validated the method and mentioned the need to develop a discreet regression model for the study samples of each country. Thus, in this research has been attempted to formulate a regression model for Kosovar population. The Demirijan's method uses the left side of mandible since studies indicate that the rate of growth is approximately the same on both sides. Several studies have been conducted to determine the accuracy of the Demirijan's method in a specific population. In this study, Demirijan's method overestimated the mean DA by 0.34 years (0.35 years for girls and 0.3 years for boys, ranging from -0.39 to 0.34 years), except for the 10-11-year-old group, which was underestimated by 0.4- to 1.09 years.

These results show that growth in our population occurs earlier than in the French/Canadian population sample studied by Demirjian *et al.* The results of other studies from several countries that used the Demirijan's method also showed an average overestimation in DA ranging from -0.750 to 3.04 years. In this study, the largest discrepancy between dental and chronological ages was observed in the 6 to 6.90 age group.

This result was similar to that of other Turkish studies, namely, Celikoglu *et al.*, Tunç and Koyuturk, and Celik *et al.* Growth prediction uncertainties in younger children may have caused this higher overestimation. The second largest discrepancy between dental and chronological ages in Demirijan's method was in the group of 10 to 11.90 year-old girls in our study. Prepubertal or pubertal growth changes may explain this situation.

Willems *et al.* adopted and simplified the Demirijan's method in Belgian children, and, according to Liversidge, the Willems' method showed more accurate results in estimating DA. For that reason, we used the the Willems' method. In this study, the DA was underestimated 0.34 year (0.44 year for girls and 0.28 year for boys) by the Willems' method; ranged from -0.68 to 0.32 year. DA differences in other studies that were found by authors using the Willems' method was ranged from -0.24 to 0.34 year. Liversidge *et al.* believed that overestimated dental ages in recent studies using Demirijan's method can be partly explained by a positive secular trend in growth and development since 1973. Willems' method showed

more accurate results in this study than the Demirijan's method. This result could be explained by the fact that our study was performed 42 years after Demirjian's study and 14 years after Willems' study. The results obtained from this research are in agreement with other studies showing a negligible number in underestimation and insist on reformulating the original Cameriere's formula to suit the population (82, 84, 85, 87). Further studies are to be conducted to evaluate the applicability of this formula on a larger sample size and to compare the reliability of this model with other methods of age estimation. In forensic science, the acceptable age difference between the DA and CA is reported as ± 1.00 year for children until adolescence. In this study, only in 13, 14-years old age groups that are evaluated by Camerier's method were overestimated by more than one year. According to this criterion, in the present study, Willems' and Demirijan's methods for estimating age are appropriate and recommended for Kosovar children ranging in age from 6 to 14 years old.

A sample of OPGs from Kosovo by I3M has been verified in this research with the purpose of use in legal and criminal procedures. Precisely, I3M could be used to determine if a particular person is a minor or an adult and can further serve for identification of missing persons or unidentified victims.

In this study, which included the training sample from Kosovo, the logistic regression model was used to demonstrate that only the I3M significantly contributed to the discrimination of adults and minors, whereas gender was not statistically significant for this discrimination. Additionally, the ROC curve analysis of the training sample and the maximum value of the Youden index showed that a cut-off value of I3M < 0.08 was the best in discrimination adults from minors.

Our results confirmed the usefulness of the specific cut-off value of I3M < 0.08 to distinguish Kosovar adults from minors in the test sample. The accuracy of classification was better in males (Acc = 0.963) versus females (Acc = 0.909). The 'Se' was better in males (0.962 in males vs. 0.826 in females), whereas the 'Sp' was slightly better for females (0.964 in males vs. 0.991 in females). Our results are better than the results obtained by Cameriere *et al*. in the Italian population (Acc = 0.83; Se = 0.70; and Sp = 0.98). Moreover, our results are within the range of the results of some previous studies on testing of I3M < 0.08 in discriminating adults and minors in various populations (68, 106, 146-155).

In the test sample, the accuracy differed between the genders because the third molars mature at a slightly faster rate in males in a Kosovar sample. The differences between genders are

obvious. They can be found at the age of 17 years, when the first apical closure was noticed in both genders and the number of closed apices followed the increase of age, however, at faster rates faster in males than in females (Table 38). In addition, after 21 years of age, almost all apices of the roots of the third molars were closed in males compared to females whose few roots did not fully completed the development. Generally, the average age of completed mineralization of third molars is near to 23; hence there is no need to evaluate older individuals. These findings are in line with the previous studies from neighboring countries, such as a Serbian study by Zelić *et al*., and a Croatian study by Galić *et al*., or the studies from other continents such as a Botswanan study on black Africans by Cavrić *et al*., South Indian by Balla *et al*., or a Peruvian study by Quispe Lizarbe *et al*. (106, 148, 149, 156). All these studies showed a similar capability of I3M < 0.08 to distinguish adults from minors.

However, in cases where lower third molars are retained, there is the possibility that adults cannot be notable from minors (157). Additionally, in cases where the third molars are angulated, missing, or intentionally extracted, other age estimation methods may be used (145, 158). This study provides the results for the error in discriminating adults and minors in each age group. The inaccuracies were present for the age group of 16–20 years. In discriminating adults and minors, the most significant error was in the age groups close to border age, at 18 and 17 years of age. The highest error rate was found in the 18-year age group in females, where 55.5% of participants were classified as minors. Disqualification from the forensic point of view can be ethically more or less acceptable (159). The Bayes post-test probability p or the proportion of participants, who are 18 year olds or older with I3M < 0.08, was 0.966 for males vs. 0.989 for females. The selection test should have a high specificity to protect minors, which is achieved by the proposed method.

This study on a Kosovar population contributes to the body of evidence from previous studies of verifying the use of the specific cut-off value of I3M for classifying individuals of unknown age as minors or adults. In Kosovo, the legislation system recognizes some other age limits, where the minimum age of criminal and juridical responsibility is 14 years. The Juvenile Justice Code of Kosovo law regulates differences in treating juveniles, adults, and young adults when a person is in several proceedings (160).

The qualifications of responsibility are not uniform in all countries and it must be determined which court has jurisdiction to adjudicate the matter under the special law. The same applies for Kosovo where the Family Law of Kosovo (Law No. 2004/32), in Article 15 under

provision states that “Majority is obtained upon the completion of the eighteenth year of age” (161), whereas under provision it states that “Full capacity to act is attained upon reaching majority or by entering into matrimony prior to this age” (162, 163). However, under Article 16 of the Law, it states that “ due to justifiable reasons, the competent court may allow matrimony for a minor person older than 16 years upon his request, if it concludes that the individual has reached the necessary physical and psychological maturity for exercising his or her marital rights and obligations “(163). According to Article 223 of the abovementioned law, “A person may be destitute of the full or partial capacity to action, if, for example, he or she is not capable of normal judgment or if by his/her actions, he/she gravely endangers his own or others’ rights” (163).

The criminal liability in Kosovo is stipulated under Article 17 of the Criminal Code of the Republic of Kosovo (Law No. 04/ L-082) and it states as follows: 1. A perpetrator of a criminal offense is criminally liable if he or she is mentally competent and has committed the criminal offense intentionally or negligently; 2. A person is criminally liable for the negligent commission of a criminal offense only when this has been explicitly provided for by law; 3. A person is not criminally responsible, if at the time of the commission of a criminal offense, he or she is under the age of fourteen (14) years (164, 165). When it comes to estimating a person’s age, there are numerous techniques, but none of them can be used with high reliability when the person is completing his/her growth (166). However, from a legal point of view, it is important to give information as accurate as possible on whether the person is an adult or a minor (167).

During the identification procedure, the available documents of the person with unidentified age should be analyzed, followed by the physical examination and estimation of the puberty development (149). Some of the countries do not support the use of radiographs for age estimation because an unnecessary radiation exposure should be avoided (168). However, other countries still use the analysis of tooth development, hand wrist bones and clavicles (169).

In contemporary period, forensic and legal medicine experts in Europe are elaborating in many age estimation cases including investigation of unaccompanied minors, asylum seekers and refugees (158, 170). It is witnessing an unprecedented movement of people in large migratory waves, first from the Balkans and now from the countries of the Near East. A large numbers of migrants do not have personal documents (171). Currently, a large number of

emigrant persons and refugees and asylum seekers from the Middle East are passing through Balkan's routes, including Kosovo, to emigrate into high developed European countries such as Germany, Switzerland, France, Italy, the United Kingdom etc. (172).

The number of emigrants and refugees has dramatically raised from 2015 and this number is still rising (172, 173). Furthermore, past wars in the Balkan region, including the last war in Kosovo in 1999, have left many unidentified victims and missing persons (82, 174, 175). In such circumstances, the problem of a forensic expert who is expected to give opinion on a person's age is emphasized. Therefore, a reliable method for determining whether an individual is a minor or an adult is more than needed.

This Kosovar study shows that small differences between populations can be expected even in the same geographical region. These small between-population differences are probably smaller than within-population differences based on differences between individuals (147, 149, 154, 176, 177). Consequently, the results of this research are beneficial for the legal and criminal practice in Kosovo and other countries with Kosovar population. Further research should aim the usefulness of those methods and the specific cut-off of I_3M for different populations (178). Several indicators for age estimation, the developmental stage of a child have been developed for a specific biological system, particularly indicators for sexual and somatic maturity, skeletal age, and dental age (127).

It has been observed for the Moorees's method, in which panoramic radiographs were utilized, that female development was ahead of male development, and that root formation stages showed variation compared with crown formation stages. These findings are related to other studies (179-181). The mean age in the results of the present study was more than a year ahead for almost a third compared with that of the Moorrees's method. Consequently, age estimation of Kosovar children, using maturity data from Moorrees *et al*., is likely to underestimate age considerably. The mean age was adapted for estimating age by adding half the interval to the next stage, with the exception of "apex closed" stage, because once that the tooth apex matures, it can no longer be used to estimate age using this method.

The variation in the timing of individual tooth maturation is large for most stages of tooth formation and it increases with age. Standard deviation for most stages was from just less than a year to just over 2 years. No ethnic differences in mean ages were observed. The proportion of children in some molar stages is plotted against age. The obtained data show a wide age range for these stages. The steep slope of the line for "crown complete" of the first permanent

molar reflects a small age range, while the range for “apex half closed” for the third permanent molar is from 15 to 20 years. Most comparisons of mean age were not significantly different between males and females. Exceptions were the latter half of root stages of the canine, apex closure of the first molar and apical stages of the third molar. Of these, the mean age of females was ahead compared with that of males except for third molar stages.

The dentist needs to remain familiar with recently published studies and consider the use of larger population studies because they are statistically more accurate. More importantly, the dentist must understand the effects of potential ancestral admix on the calculated results in forensic dental age estimation.

There are special conditions, such as prosecution of an undocumented juvenile immigrant, that require an age estimate and the probability of the individual attaining an age other than 18. Sometimes, the legal demand such as the age of an individual at the time of crime is needed. It should be determined with great accuracy. Such questions can be answered after the mean estimated age and standard deviation from the individual’s appropriate population-specific study had been calculated. The probability that the individual has attained any given age can be determined by utilizing the mathematical continuous distribution function for a normal distribution curve (65).

Physical growth often deviates from chronological age but corresponds well with skeletal age which represents the relative degree of bone maturation. Among all growth indicators, dental age has the weakest correlation with overall somatic development (182-184).

In general, a positive correlation between dental age and chronological age has been found. Correlations between dental, skeletal and chronological age are relevant to orthodontics, pediatric dentistry and forensic medicine. These correlations are an important addition to patient records (charting, radiographs, study models) since they provide basic knowledge on dental development and can be used for further therapeutic decisions (44, 55, 182).

Such knowledge as the knowledge about dental age can be useful in making decisions about primary teeth extractions, also, in making decisions on timing of orthodontic treatment. In patients with delayed dentition, orthodontic therapy may begin at a later stage, resulting in shorter treatment duration and more stable results (182, 185).

6. CONCLUSION

The research study was set out to estimate dental age using Demirjian's, Williems', Cameriere's dhe Moorres' method in children and adolescents attending the University Dentistry Clinical Centre of Kosova. It was observed that the mineralization of the permanent dentition from upper jaw (21, 22 and 28) and all teeth of lower jaw of the left side by using aforementioned methods resulted in statistically significant overestimation or underestimation of the age but the estimated dental age were positively correlated to the chronological age. The mean age attainment of tooth developmental stages in Kosova's children and adolescent occurred earlier in females than males. There existed different patterns of tooth maturity in children of the same age group. However, a slight underestimation was found for both genders compared with Willems' method. The methods performed better in estimating the age for the girls as compared to boys who were significantly overestimated. Majority of the subjects had their age estimated within one year of their actual age. Also, was found the tendency to overestimate the age of the younger children as compared to the older ones. Maturity scores for a Kosovo sample and the Willems's methods behave similarly by overestimating and / or underestimating the chronological age, while the Moorrees's method is not suitable for dental evaluation after age 11.

The dental maturity for children attending UDCCK was also assessed. It was found out that there was slight statistical difference between the tooth maturity for girls and boys in most of the maturity stages. All current dental evaluations that have been analysed, outlined the fact that Demirjian's, Willems' and Cameriere's methods assess dental age for a Kosovo sample in a better manner than the Moorrees's method.

In the course of this research, maturity scores to dental age have been converted for Kosovar girls and boys. In this study, the mean age of attainment of developmental stages according to the Demirjian's and Moorrees's model for permanent dentition were used to evaluate the radiographs of Kosovar girls and boys.

All third molars have already completed their root development by the age of 18 years. Since mineralization is completed by the age of 23 years, there is no need to evaluate older individuals.

This research also confirmed the usefulness of specific cut-off value of I3M < 0.08 to distinguish Kosovar adults from minors in the test sample. The accuracy of classification was better in males compared with females. Third molars mature at a slightly faster rate in males in the sample of Kosovar children and young adults. Furthermore, it can be observed that after

21.91 years, almost all apices of the roots of third molars were closed in males, unlike females who still had few roots that were not fully formed.

All these studies showed similar capability of I3M < 0.08 to distinguish minors from adults. However, it was difficult to tell the difference between adults and minors in cases where the mandibular third molars were retained in a severely resorbed mandible.

This study provides data for the error in distinguishing adults from minors in each age group. The inaccuracies were present in participants between 16 and 20 years of age. The most significant error in distinguishing adults from minors was in the age groups close to border age, at 18 and 17 years of age.

A sample of Kosovar population contributes to the body of evidence from previous studies which are verifying the use of the specific cut-off value of I3M for classifying individuals of unknown age as minors or adults. Basically, the same population should be evaluated by other scientific methods in order to obtain an optimal accuracy.

6.1 Study limitation and recommendation

Some information and details related to day, month and year of the person's actual date of birth were missing in some of the patients' files; hence it was not possible to determine their chronological age. Subsequently those OPGs were excluded from the research. In consequence, this can significantly limit research studies that involve a large sample size. Also, the substantiation of patients' dates of birth through birth certificates was not involved in this study. Hence, the date of birth from the patient's file was used, which was recorded as told by the parent or guardian in the course of filling in the consent form in Radiology Unit in UDCCK. Any inaccurate recording of this important information may contribute to disparity between the OPG and age cohorts resulting into inaccurate outliers. Since this study is retrospective, the patients were not examined and their general development and health status were unknown. On the other hand, the OPGs with anomalies, lesions, tumours or traumas were excluded.

No research related to age estimation was conducted in Kosovo before. The results of this study may be used in clinical scientific disciplines such as orthodontics, pediatrics as well as in forensic and anthropological sciences. Furthermore, this study may contribute to some

situations in which age estimation is required such as investigations into asylum seekers of unknown age, young people accused of criminal activities, and convicted criminals whose age is claimed to be less than specific cut-off value prior to sentencing, such as the age of majority.

The dentist needs to remain familiar with recently published studies and consider the use of larger population studies because they are statistically more accurate. More importantly, the dentist must understand the effects of potential ancestral admix on the calculated results in forensic dental age estimation.

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8. CURRICULLUM VITAE

Jeta Kelmendi was born on January 7th 1987 in Prishtina, Kosova. She has graduated at the Faculty of Medicine, Department of Dentistry, University of Prishtina "Hasan Prishtina", Republic of Kosova in 2012 with an average grade of 9.40, attaining the title Doctor of Dental Medicine. In 2018 she has finished her specialization in Orthodontics, attaining e title Specialist of Orthodontics. Since 2012, she has been working in the private clinic in Prishtina, also working as Teaching Assistant in preclinical course - Human Tooth Anatomy and Morphology and Cariesology, in Faculty of Medicine, Department of Dentistry, University of Prishtina "Hasan Prishtina", Republic of Kosova. Since 2012, she started working voluntary as dental editor in publishing house Alb-Med, translating and adopting the professional books in Albanian language. In October 2013 she has started her PhD studies at the School of Dental Medicine, University of Zagreb, Croatia. In June 2017, she applied and was accepted in the course " Identification of dead people after accidents with the use of Interpol Computer program" in Longyearbyen, Svalbard. She was in the organizing committee of several dental conferences, over and above she has actively participated in numerous international scientific conferences local and aboard and is author and co-author of several scientific posters and papers, in relevant international journals.

8.1 List of published scientific articles

Scientific articles:

Web of science

1. **Kelmendi J**, Cameriere R, Koçani F, Galić I, Mehmeti B, Vodanović M. The third molar maturity index in indicating the legal adult age in Kosovar population. International journal of legal medicine. 2017 Dec 16:1-9 **(Q1)**
2. **Kelmendi J**, Vodanović M, Koçani F, Bimbashi V, Mehmeti B, Galić I. Dental age Estimation Using Four Demirjian's, Chaillet's and Wiillems' Methods in Kosovar Children. Legal Medicine. 2018 Apr 24 **(Q2)**
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Scopus:

4. Kamberi B, Koçani F, Begzati A, **Kelmendi J**, Ilijazi D, Berisha N, Kqiku L. Prevalence of dental caries in Kosovar adult population. Int J Dent.2016;2016 **(Q1)**
5. Vodanović M, Galić I, **Kelmendi J,** Chalas R. Occupational health HAZARDS in contemporary dentistry – a review. Medical Sciences, 44(2017) : 25-41 **(Q4)**
6. Mehmeti B, Azizi B, **Kelmendi J**, Ilijazi-Shahiqi D, Alar Z, Anic-Milosevic S. Shear bond strength of orthodontic brackets bonded to zirconium crowns. Acta Stomatol Croat. 2017 Jun; 51(2): 99–105 **(Q4)**
7. Mehmeti B, Haliti F, Azizi B, **Kelmendi J**, Ilijazi-Shahiqi D, Jakovljevic S, Anic-Milosevic S. Influence of different orthodontic brackets and chemical preparations of ceramic crown on shear bond strength. Australasian Medical Journal.2018;11(2):156-161

Abstracts published in international journals:

1. Azizi B, Budimir A, Mehmeti B, **Kelmendi J**, Gabric D. The effect of antimicrobial photodynamic therapy (aPDT) and light-activated disinfection (LAD) on contamined titanium and zirconia implants - in vitro study. Acta stomatol Croat.2017;51(4):350-365

2. Mehmeti B, Azizi B, **Kelmendi J**, Ilijazi-Shahiqi D, Jakovljevic S, Anic-Milosevic S. Ceramic surface evaluation with SEM after SBS testings of orthodontic brackets. Acta stomatol Croat.2017;51(3):258

3. Mehmeti B, Alar Z, Sakoman M, Azizi B, **Kelmendi J**, Ilijazi-Shahiqi D, Anic-Milosevic S. Comparison of shear bond strength of metal and ceramic orthodontic brackets bonded to zirconium crowns. Acta stomatol Croat.2017;51(2):171

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