

Comparison of the Cameriere's third molar maturity index and Olze et al.'s stages of radiographic visibility of the root pulp in a Turkish population

Purpose

The purpose of this study was to compare the Cameriere's third molar maturity index and Olze et al.'s stages of radiographic visibility of the root pulp in estimating the age of maturity in the Turkish population. The age of majority, which is legally significant, marks the transition from childhood to adulthood. In Turkey, the age of majority is set at 18 years. As the third molars continue to develop at this age, they can serve as an indicator of dental age.

Materials and Methods

A total of 705 panoramic radiographs obtained from individuals aged 15 to 22 years, including children and adults, were included in this study. The left mandibular third molars were evaluated on panoramic radiographs using Cameriere's third molar maturity index and Olze's method of radiographic root pulp visibility (RPV) stages. Minimum and maximum values were noted for each stage, and a median with upper and lower quartiles, as well as mean and standard deviation were calculated. Sensitivity and specificity values were calculated.

Results

In males, Cameriere's third molar maturity index demonstrated a sensitivity of 0.77% and specificity of 0.96%, while in females, it showed a sensitivity of 0.57% and specificity of 0.92%. Regarding Olze et al.'s stage 0, the sensitivity and specificity values were 0.86% and 0.79% in males, and 0.85% and 0.75% in females, respectively.

Conclusion

Although both methods can be used to distinguish individuals below or above the age of 18, the cut-off value suggested by Cameriere's method resulted in a higher rate of type 2 error (false negativity). Therefore, the method proposed by Olze et al., based on the radiographic visibility of the root pulp, can be employed to differentiate between adults and minors in the Turkish population.

Keywords: Age estimation, radiographic root pulp visibility, legal age, third molar maturity index

Introduction

Age estimation is a critical process conducted in both deceased and living individuals, with applications in civil and criminal law. It plays a vital role in the identification of deceased individuals during forensic investigations. In the case of living individuals, age estimation is necessary for various purposes such as job applications, school admissions, marriages involving minors, asylum and refugee claims, and cases where there is a lack of legitimate identification or proof of legal age. The significance of individual identification has been escalating, driven by the increasing number of refugees and immigrants globally, including in Turkey (1, 2).

Kübra Nur Çakan¹ 

ORCID IDs of the authors: K.N.Ç. 0000-0003-1749-9293

¹Department of Oral and Maxillofacial Radiology, Balıkesir Oral and Dental Health Hospital, Balıkesir, Türkiye

Corresponding Author: Kübra Nur Çakan

E-mail: knurcakan@gmail.com

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Determining the age of unidentified asylum seekers holds importance for both the host country and safeguarding the rights of children (3). Proper processing of asylum claims requires accurate determination of whether individuals are of legal age or not (4). The age of majority marks the transition from childhood to adulthood and holds legal significance (5). While the legal age threshold varies across countries, in Turkey, it is set at 18 years (6).

Numerous radiological dental and skeletal age estimation methods have been documented in the literature. The Study Group on Forensic Age Diagnostics (AGFAD) recommends the use of X-rays and physical examination of teeth and the left hand for age estimation in living individuals (7). Tooth development serves as a parameter for age estimation, but it becomes challenging to accurately estimate age once tooth development is complete (8). The third molars, also known as wisdom teeth, emerge last in the jaw and continue to develop until the age of 22 (9, 10). Consequently, these teeth are utilized to predict whether an individual has reached adulthood (11).

In 2008, Cameriere *et al.* developed a practical method for determining adult age using panoramic radiographs. This method evaluates the relationship between the third molar maturity index (I_{3M}) and age by calculating the ratio of apical width to tooth length. The original study reported a cut-off value of 0.08 for determining adulthood (12). The validity of this value has been tested and confirmed in diverse populations (13-16). In 2010, Olze *et al.* introduced a 4-stage classification based on the radiographic visibility of the root pulp in the lower third molars, specifically in a German population (17). Studies conducted in other populations have validated the suitability of these stages as age markers, particularly in populations with legal age thresholds of 18 and 21 (18-20).

Despite an extensive literature review, we were unable to find a study comparing these two age estimation methods in the Turkish population. Therefore, the objective of this study is to compare Cameriere's third molar maturity index and Olze *et al.*'s stages of radiographic visibility of the root pulp in estimating the age of maturity within the Turkish population.

Materials and Methods

Ethical approval

The study protocol received approval from the Ethics Committee for Non-Interventional Clinical Research Studies at the Faculty of Medicine (approval no. 2022/45), and the study was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki.

Study Sample

A total of 910 panoramic radiographs were examined, which included both children and adults ranging from 15 to 22 years of age. These individuals had presented to the Oral and Dental Health Hospital between 2019 and 2022. From this sample, 692 radiographs (Group 1: $n=335$; Group 2: $n=357$) that met the inclusion criteria were included in the study. Group 1 was utilized to test Cameriere's cut-off value

of 0.08, while Group 2 was used to test stage 0 of Olze *et al.*'s radiographic root pulp visibility. The radiographs were obtained using the Castellini X-Radius Trio Plus 2D device, specifically the Castellini Digital Panoramic System from Bologna, Italy. Standardization was achieved as all radiographs were captured by the same dental technician. The inclusion criteria comprised the presence of the right or left mandibular third molar, good quality radiographs, a known age between 15 and 22 years at the time of radiography, and the absence of systemic diseases. Individuals without a third molar, those with malformed third molars, unknown age, systemic diseases, or bone pathologies impacting skeletal and dental development were excluded from the study. Pertinent information including the date of radiographic image acquisition, date of birth, and sex of each subject were recorded. The chronological age of each subject was determined by subtracting the date of birth from the date the radiograph was obtained.

Measurements

The evaluation of the left mandibular third molars on panoramic radiographs involved the application of both Cameriere's third molar maturity index and Olze's method of radiographic root pulp visibility (RPV) stages. To assess these methods, two separate groups were formed from different samples. While the eruption status of the teeth was not considered in Cameriere's method, the RPV method ensured that the roots of the third molars were fully developed and that the apex was closed. To maintain consistency, maxillary third molars were excluded from the study due to the presence of anatomical structures such as the tuber maxilla and maxillary sinus, which hindered their evaluation. The measurements of the radiographic images were performed by the same investigator using Image J (version 1.50n, National Institutes of Health, Bethesda, MD, USA), an image processing software, on a 15.6-inch LED-backlit screen with a resolution of 1920 x 1080 in a semi-dark room. Cameriere's third molar maturity index.

Digital orthopantomographs (OPGs) were analyzed using the Image J software. Lower left permanent third molars (38) were evaluated. On third molars with open apex, the distance between the inner edges of the apex was recorded as A (A_1+A_2) and the length of the tooth as L (Figure 1). The third molar maturity index (I_{3M}) was calculated by dividing the A value by the L value ($I_{3M}=A/L$). In addition, if the root apex of the third molar tooth was complete, then I_{3M} was recorded as 0.0 (12). An $I_{3M}<0.08$ was considered as cut-off value for discriminating minors from adults, in line with Cameriere *et al.*

Radiographic visibility of the root pulp was assessed as described by Olze *et al.* (17) Digital OPGs were classified using the stages of radiographic root pulp visibility. Left lower third molar (38) were used to evaluate root pulp visibility. When the left third molar was not suitable for evaluation, the right lower third molar (48) was used instead. Root pulp visibility was evaluated in four stages (Figure 2):

- Stage 0: The pulp of each root canal is visible along the entire length of the root;
- Stage 1: The pulp of a root canal is not visible from the apex to more than half of the root;

- Stage 2: The pulp of both root canals is not visible along part of the root, or the pulp of one root canal almost the entire length of the root;
- Stage 3: the pulp of each root canal is not visible over almost the entire length of the roots.

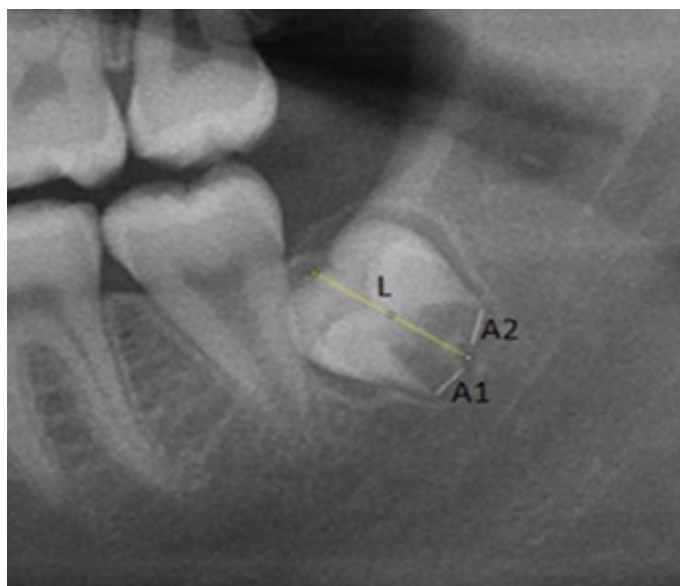


Figure 1. Example of A1, A2 and L measurements on the third molar (Cameriere's third molar maturity index).



Figure 2. Schematic drawings of the radiographic visibility stages of the root pulp of the third molar.

Statistical analysis

SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Variables including name, date of birth, sex, date of radiograph and chronological age were recorded for each subject. Minimum and maximum values were noted for each stage, and a median with upper and lower quartiles, as well as mean and standard deviation were calculated. Sensitivity and specificity values were calculated. Statistical significance level was set at 5% ($p < 0.05$) for all tests.

Results

Age and sex distribution of 692 individuals are shown in Table 1. 335 OPGs were examined to verify the ability of the third molar maturity index to discriminate minors from adults, 357 OPGs to test the performance of Olze *et al.*'s stage 0. Among males, the highest number of subjects was observed among 17-year-olds for both methods. Among females, the highest numbers of subjects were observed in 16-, 18- and 20-year-olds for Cameriere *et al.*'s method, and in 22-year-olds for Olze *et al.*'s method. Table 2 shows descriptive statistics. The third molar maturity index values decreased with increasing age, showing increases in 17- and 21-year-old females and in the 18-year-old females. The median I_{3M} values in males 19 years of age and older were 0.00, indicating a closed apex. Similarly, the median I_{3M} values were 0.00 in women aged 20 years and older. Standard deviations differed between sexes. When the discriminatory performance of Cameriere's third molar maturity index was analyzed, the method showed a sensitivity of 0.77% and a specificity of 0.96% in males. Among females, sensitivity and specificity were 0.57% and 0.92%, respectively (Table 3). Table 4 shows descriptive statistics of chronological age by RPV stage for both males and females. In females and males, stage 0 was first seen at 16 years of age, stage 1 at 17 and 16 years of age, and stage 2 at 17 and 18 years of age, respectively. Additionally, the mean ages were 17.67 years for stage 0, 19.44 years for stage 1, and 20.41 years for stage 2 among males. The mean ages were 18.15, 19.91 and 20.23 years for stage 0, 1 and 2, respectively. In both sexes, the mean age increased as the stage increased. Stages 0 and 1 occur at a

Table 1: Age and sex distribution of the entire sample. Numbers in brackets indicate individuals evaluated to confirm the performance of Olze *et al.*'s root pulp visibility (RPV) stages

Age (years)	Male	Female	Total
15	17	23	40
16	17 (21)	27 (19)	44 (40)
17	22 (31)	20 (23)	42 (54)
18	13 (27)	27 (19)	40 (46)
19	17 (26)	23 (28)	40 (54)
20	18 (26)	27 (26)	45 (52)
21	20 (26)	23 (30)	43 (56)
22	15 (22)	26 (33)	41 (55)
Total	139 (179)	196 (178)	335 (357)

later age in females, while stage 2 occurred at a later age in males. Stage 3 was not observed in both sexes. When the discriminatory performance of the RPV stage 0 to determine whether the individual was over or under 18 years of age was examined, the method showed a sensitivity of 0.86% and a specificity of 0.79% in males. Among females, sensitivity and specificity were 0.85% and 0.78%, respectively (Table 5).

They reported a cut-off value of 0.08, with a specificity of 98% and sensitivity of 70%. However, in your study, the specificity and sensitivity values were lower, with values of 94% and 65%, respectively, compared to Cameriere *et al.*'s findings.

The sensitivity results in your study were 77% in males and 57% in females, which were lower than those reported in

Table 2: Summary statistics of third molar maturity index in females and males by ages

Age (years)	Males						Females					
	N	Mean	SD	Min	Med	Max	N	Mean	SD	Min	Med	Max
15	17	0.55	0.31	0.19	0.43	1.96	23	0.70	0.29	0.26	0.68	1.29
16	17	0.25	0.19	0.09	0.19	0.86	27	0.41	0.31	0.00	0.27	1.38
17	22	0.35	0.28	0.00	0.25	0.93	20	0.18	0.16	0.00	0.17	0.72
18	13	0.11	0.2	0.00	0.05	0.75	27	0.28	0.25	0.00	0.21	0.97
19	17	0.04	0.06	0.00	0.00	0.18	23	0.16	0.21	0.00	0.10	0.97
20	18	0.02	0.05	0.00	0.00	0.2	27	0.06	0.10	0.00	0.00	0.42
21	20	0.05	0.1	0.00	0.00	0.42	23	0.04	0.06	0.00	0.00	0.21
22	15	0.00	0.00	0.00	0.00	0.00	26	0.01	0.02	0.00	0.00	0.09

Table 3: Contingency table explaining the discriminatory performance of the test in females and males (^a true positive ^b false positive ^c false negative ^d true negative)

Sex		Age (years)		
		≥18	<18	Total
Male	I _{3M} <0.08	64 ^a	2 ^b	66
	I _{3M} ≥0.08	19 ^c	54 ^d	73
	Total	83	56	139
Female	I _{3M} <0.08	72 ^a	5 ^b	77
	I _{3M} ≥0.08	54 ^c	65 ^d	119
	Total	126	70	196

Table 5: Contingency table explaining the discriminatory performance of the test in females and males (^a true positive ^b false positive ^c false negative ^d true negative).

Sex		Age (years)		
		<18	≥18	Total
Male	Stage 0	45 ^a	26 ^b	71
	> Stage 0	7 ^c	101 ^d	108
	Total	52	127	179
Female	Stage 0	36 ^a	29 ^b	65
	> Stage 0	6 ^c	107 ^d	113
	Total	42	136	178

Table 4: Summary statistics of chronological age by root pulp visibility stages in females and males

Sex	Stage	N	Min	Max	Mean	SD
Females	0	65	16	22	18.15	2.08
	1	67	17	22	19.91	1.58
	2	46	17	22	20.23	1.55
Males	0	71	16	22	17.67	1.59
	1	69	16	22	19.44	1.71
	2	39	18	22	20.41	1.40

Discussion

Many methods have been developed for age estimation based on tooth development. The study conducted by Cameriere *et al.* (12) in 2008 introduced a method for age estimation based on the relationship between the third molar maturity index (I_{3M}) and age on panoramic radiographs.

some populations such as the Chinese (87% in males, 77% in females), Colombian (91% in males, 95% in females), French (92% in males, 74% in females), Albanian (94% in males, 75% in females), and Australian (90% in both males and females) populations (21-25). However, the sensitivity values in your study were higher than those observed in the Saudi population (52.3% in males, 51.3% in females) (26). When comparing with Sharma *et al.*'s study in the Indian population, your study showed lower sensitivity in females but higher sensitivity in males (66% in females, 74.7% in males) (27).

On the other hand, the specificity values in your study were higher, with values of 96% in males and 92% in females, compared to other populations such as the French (88% in both males and females), Australian (85% in males, 87% in females), and Indian (83% in males, 79% in females) populations (23, 25, 27). However, the specificity of the female population in your study was lower than that reported in the Chinese (98%), Colombian (93%), Albanian (96%), and Saudi (97%) female populations (21, 22, 24, 26).

In a previous study on the Turkish population, which examined panoramic radiographs of 293 subjects, the speci-

ficity values were 100% in both males and females, and the sensitivity values were 94% in males and 85% in females, which were higher than the values observed in your study (28). It's important to consider that these differences in results may be related to genetic variations both within and across populations (29).

Using a cut-off value of 0.08 can successfully identify individuals under the age of 18 from those aged 18 or older in both males and females. However, it may lead to more false negatives in females due to the slower development of third molars in women (29). The delay in root development of third molars may result in lower sensitivity in females. Gender differences may contribute to variations in study results. Therefore, even with the same cut-off value, women over 18 years of age with incomplete root development may be misclassified as children. Using a different cut-off value could enhance the discriminatory power of the Cameriere method in females (11).

In our study, when the discriminative power of Olze *et al.*'s RPV stage 0 was tested, the specificity and sensitivity values in females were 78% and 85%, respectively. In males, the corresponding figures were 79% and 86%, respectively. High sensitivity coupled with low specificity values showed that the test itself was better in distinguishing individuals over 18 years of age. In their original study in 2010 involving 1198 individuals, Olze *et al.* (17) reported that stage 0 was first seen in females and males at the ages of 17.2 and 17.6 years, stage 1 at the ages of 21.6 and 22.4 years, and stage 2 at the ages of 24.7 and 22.3 years, respectively. In our study, stage 0 was first seen in females and males at 16 years of age, stage 1 at 17 and 16 years of age, and stage 2 at 17 and 18 years of age, respectively. In contrast to the study by Olze *et al.*, all stages were observed at younger ages in the current study. This may be an indication of closure of root apices at an earlier age in both women and men in the Turkish population. Differential results between the studies can be attributed to the differences in the age range of individuals and characteristics of the populations tested.

In a study by Akkaya *et al.* (2) in 463 individuals aged from 16 to 34 years, stage 0 first occurred at the ages of 16.43 and 16.61 years, stage 1 at 16.93 and 17.91 years, and stage 2 at 18.14 and 18.13 years in women and men, respectively. Our findings are in line with those reported in that study. In 2015, Perez-Mongioli *et al.* (18) conducted a study on 487 individuals between the ages of 17 and 30. In their study, stage 0 was first observed at the ages of 17 and 18.2, stage 1 at the ages of 17.4 and 18.4, and stage 2 at 18.1 and 18.8 years of age, in females and males, respectively. Lucas *et al.* (19) reported similar results in their study of 100 individuals aged between 16 and 26 years. This study reported minimum values that were similar to ours. However, there are also studies which showed higher minimum values (17, 20, 30). Perez-Mongioli *et al.* (18) also estimated the discriminatory power of the test in their study and reported sensitivity results of 79.9% and 80.7% in males and females, respectively. However, the specificity values were 27% in males and 19.6% in females. In our study, both specificity and sensitivity values were higher than those reported by Perez-Mongioli *et al.*

In a 2019 study by Kumar *et al.* (31), the sensitivity and specificity values of the two techniques were compared in 615 individuals aged between 15 and 22 years. In their study,

the cut-off value of 0.08 showed 67% sensitivity and 76% specificity in females. However, Olze *et al.*'s stage 0 showed 72% sensitivity and 91% specificity. In males, the sensitivity and specificity values were 76% and 72% respectively using the cut-off value of 0.08 and 68% and 86% respectively using Olze *et al.*'s stage 0. In comparison to Kumar *et al.*'s study, the cut-off value of 0.08 showed higher specificity and Olze *et al.*'s RPV stage 0 demonstrated higher sensitivity in both females and males in our study.

In a study conducted on 429 third molars, Günacar *et al.* (32) compared the use of the stages of radiographic root pulp visibility in age estimation using OPG and cone beam computed tomography (CBCT). In this study, individuals in the CBCT group had stage 1 and stage 2, while stage 1, 2 and stage 3 were not found in individuals in the OPG group under the age of 18. For OPG in this study, stage 0 first occurred at the ages of 16 years in both genders, stage 1 at 20 and 24 years, stage 2 at 25 and 27 years and stage 3 at 33 and 25 years in women and men, respectively (32). In our study, only the stage 0 age value was similar to this study, the other stages were observed at younger ages. Stage 3 was not present in our study. This may be because stage 3 is seen in advanced ages. Additionally, Günacar *et al.* (32) recommended the use of CBCT for RPV evaluation. This may be due to the 2D nature of OPG, geometric distortion, anatomical noise and superposition of oral structures. RPV evaluation may be incorrect due to the superposition of the external oblique ridge in the third molar region on the pulp tissue in 2D imaging.

When the two methods were compared in our study, Cameriere's method ($I_{3M} < 0.08$) showed lower sensitivity in females and males compared to Olze *et al.*'s stage 0. Moreover, Olze *et al.*'s stage 0 showed higher specificity in for both sexes than the cut-off value of Cameriere. It is important to decide whether an individual is a minor or adult in order to hold them accountable for their actions and to protect the rights of children (15). Incorrectly identifying a minor as an adult or identifying an adult as a minor will result in the individual not being properly punished (33). For this reason, age estimation methods should be simple and minimize errors (34, 35).

In this study, a cut-off value of 0.08 by Cameriere *et al.* successfully discriminated individuals under 18 years of age; however, it should be noted that it causes a high rate of false negatives. Olze *et al.*'s stage 0, on the other hand, is successful in distinguishing individuals over the age of 18 but may cause a high rate of false positives.

Conclusion

There was no significant difference observed in the sensitivity and specificity results between Cameriere's and Olze's methods. Both methods can effectively differentiate individuals below or above the age of 18. However, Cameriere's method, with its proposed cut-off value, showed a higher rate of type 2 error (false negativity). Despite this, it is considered more acceptable. Therefore, the method proposed by Olze *et al.*, based on the radiographic visibility of the root pulp, can be employed to differentiate between adults and minors in the Turkish population. It is recommended to further validate this method through studies with larger sample sizes. Additionally, considering the limitations of the two-di-

mensional imaging technique (OPG), the option of employing cone-beam computed tomography (CBCT) should be considered to enhance the accuracy of these methods.

Türkçe özet: Cameriere'nin üçüncü molar olgunluk indeksi ile Olze ve ark.'nın kök pulpasının radyografik görünürlük aşamalarının Türk popülasyonunda karşılaştırılması. Amaç: Reşit olma yaşı, bireyin çocukluktan yetişkinliğe geçiş yaşı olup, hukuki öneme sahiptir. Türkiye'de reşit olma yaşı 18'dir. Yasal yetişkinlik yaşı olan 18 yaşında halen gelişmekte olan üçüncü azı dişleri diş yaşını tahmin etmek için kullanılabilir. Bu çalışmanın amacı, Türk popülasyonunda olgunluk yaşını tahmin etmek için Cameriere'nin üçüncü molar olgunluk indeksini ve Olze ve ark.'nın kök pulpasının radyografik görünürlük aşamalarını karşılaştırmaktır. Ge-reç ve Yöntem: Bu çalışma, 15-22 yaş arası çocuk ve yetişkin hastalardan alınan 705 panoramik radyografi üzerinde yapılmıştır. Bulgular: Cameriere üçüncü molar olgunluk indeksi erkeklerde %0,77 duyarlılık ve %0,96 özgüllük, kadınlarda %0,57 duyarlılık ve %0,92 özgüllük gösterdi. Olze ve ark.'nın evre 0'nin duyarlılık ve özgüllük sonuçları erkeklerde sırasıyla %0,86 ve %0,79, kadınlarda %0,85 ve %0,75 olarak bulundu. Sonuç: Her iki yöntem de 18 yaş altı ve üstü bireyleri ayırt etmek için uygulanabilir de, Cameriere tarafından önerilen cut-off değeri daha yüksek oranda tip 2 hata (yanlış negatiflik) üretmiştir. Bu nedenle, Olze ve ark.'nın kök pulpasının radyografik görünürlüğü yöntemi, Türk popülasyonunda yetişkinler ve küçükler arasında ayırım yapmak için kullanılabilir. Anahtar Kelimeler: yaş tahmini, radyografik kök pulpası görünürlüğü, yasal yaş, üçüncü molar olgunluk indeksi

Ethics Committee Approval: The study protocol was approved by the Ethics Committee for Non-Interventional Clinical Research Studies at Faculty of Medicine (approval no. 2022/45).

Informed Consent: Participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: KNC participated in designing the study, participated in generating the data for the study, participated in gathering the data for the study, participated in the analysis of the data, wrote the majority of the original draft of the paper, participated in writing the paper, has had access to all of the raw data of the study, has reviewed the pertinent raw data on which the results and conclusions of this study are based, have approved the final version of this paper, guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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