Comparison of Cameriere and Demirjian Methods for Estimating Adulthood in Turkish Population

Cameriere ve Demirjian Metodlarının Türk Popülasyonunda Erişkin Dönemi Tespit Etmesindeki Tanısal Etkinliklerinin Karşılaştırılması

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Abstract

Objective: The current study compares diagnostic performances of Demirjian's mineralization stage (DS) and Cameriere's third molar maturity index (I_{3M}) on estimating adulthood in Turkish individuals and to investigate a more suitable cut-off value in a sample Turkish population.

Materials and Methods: A retrospective study was conducted on a sample of digital panoramic images of 512 healthy individuals aged between 14 and 23 years old. The diagnostic capabilities were tested with receiver operating characteristic (ROC) curves, sensivities, specificity were evaluated and post-test probabilities were calculated with Bayes's theorem.

Results: The areas under the ROC were 0.88 for DS and 0.89 for I_{3M}. The sensitivity and the specifities of H stage were 41.4%, 97.9% for females and 64.3%, 93.4% for males, and $I_{3M}<0.08$ were 46.8%, 97.4% for females and 71.4%, 92.6% for males. The cut-off of the dataset $I_{3M}<0.2$ performed better for females, increasing sensitivity to 73.9%, post-test probability to 80.9% while decreasing specificity to 87.2%.

Conclusion: $I_{3M}<0.2$ performed better for females with higher sensitivity values while lowering the highest specificity values. Concerning legal rights and ethics, $I_{3M}<0.08$ or H stage provide the most accurate and consistent results in adulthood determination in males, whereas in females $I_{3M}<0.08$ and $I_{3M}<0.2$ provide sufficient results when a test with the highest specificity is sought.

Öz

Amaç: Çalışmanın amacı Demirjian diş gelişim basamakları (DS) ile Cameriere üçüncü molar indeksinin (I_{3M}), Türk bireylerin yetişkinlik ile çocukluk dönemlerinin ayırt edilmesindeki tanısal performansını değerlendirmek ve Türk popülasyonu örneklemine daha uygun bir indeks değeri varlığını araştırmaktır.

Gereç ve Yöntemler: Yapılan retrospektif çalışmaya 14-23 yaşları arasında 512 sağlıklı bireyin panoramik radyografileri dahil edildi. Her iki metodun tanısal etkinliği receiver operating characteristic (ROC) eğrisi ile test edildi, duyarlılıklar ve özgüllükleri hesaplandı, test sonrası olasılıklar Bayes testi ile değerlendirildi.

Bulgular: ROC eğrisi altındaki alanlar DS için 0,88 ve $I_{3M}<0,08$ için 0,89 olarak bulundu. Testlerin duyarlılık ve özgüllükleri H basamağı için kadınlarda sırasıyla

%41,4 ve %97,9, erkeklerde sırasıyla %64,3 ve %93,4; I_{3M}<0,08 için kadınlarda sırasıyla %46,8 ve %97,4, erkeklerde sırasıyla %71,4 ve %92,6 olarak gösterildi. Mevcut dataya en uygun indeks değeri olan I_{3M}<0,2 ise kadınlarda testin duyarlılığını %73,9'a, test sonrası olasılığı %80,9'a yükselterek daha etkin bir sonuç ortaya koydu, ancak testin özgüllüğü %87,2'ye düştü.

Sonuç: I_{3M}<0,2 indeks değeri kadınlarda daha yüksek duyarlılığı elde etmiş olsa da en yüksek özgüllük değerlerini düşürmüştür. Yasal haklar ve etik kurallar göz önüne alındığında, erkeklerde I_{3M}<0,08 indeks veya H basamağı, kadınlarda ise I_{3M}<0.08 veya I_{3M}<0,2 indeks değerleri yüksek özgüllükte doğru ve güvenilir sonuçları vermektedir.

Introduction

As worldwide migrations take place, forensic medicine is growing interest in the field of age diagnostics. Age estimation is based on anthropometric measures, signs of sexual maturity, radiological examination of the left hand, and dentition of individuals if the skeletal development is not yet completed (1). Because the skeletal development of the hand and wrist bones are completed around at the ages of 17-18 years, age estimation through radiological examination of the hand is not applicable for early adults. After 17-18 years, when the development of permanent dentition is almost completed, only third molars have the tendency to develop in late adolescence and early adulthood, thus contributing as a reliable method for legal age estimation (2-7).

According to the Turkish Institute of Statistics, there has been a 6.5% increase in the Turkish population in the last 5 years, with the population currently nearing 82 million, of which children make up 30% (8). As stated in Article 6 (1c) of the Turkish Criminal Code, any person who has not attained the age of 18 is a minor. Pursuant to Article 31 (3) of the Turkish Criminal Code, children who are between ages 15 and 18 at the time of the crime face imprisonment between 18-24 years if the crime requires heavy life imprisonment, and between 12-15 years if the crime requires life imprisonment. For other crimes, only two-thirds of the sentence is applicable, with imprisonment for each crime to not exceed 12 years (9). The provisions of the Turkish Criminal Code apply normally, without the abovementioned reductions, to persons over 18 years of age. Articles 103 and 104 of the Turkish Criminal Code states that sexually abuse of a child is punishable by 3 to 8 years imprisonment and sexual intercourse without the use of force or threat with a minor who has attained the age of 15 is punishable by 6 months to 2 years imprisonment (10).

It is crucial that an individual is accurately identified as a child or an adult when that person has committed or is suspected of committing a crime. As mentioned above, the type and length of any sanctions to be imposed for crimes committed may vary depending on whether a person is adult. Therefore, the uncertainty of age may result in a potential suspect facing higher or lower criminal sanctions than what would otherwise be applicable. Age determination based on teeth maturation is highly studied in forensic science due to the fact that the degree of dental development is less influenced by systemic factors rather than skeleton, and teeth are the most resistant part of the body in the decomposition process (11). To date, the correlation of third molar development and chronological age was studied in many studies and found effective (4,5,7,12-14); besides, a study by Thevissen et al. (15) conducted on 9 different populations with the same degree of third molar development, found that age was at most 14 months different. Consequently, the importance of population-based studies rises to estimate adulthood. For the determination of age based on the status of tooth formation, Demirjian's method among many other methods stands out to be the best method with its excellent interobserver agreement (3,4,12,13). One other proposed method which stands out for its ease of application is Cameriere's method. Previous studies have discussed the use of Cameriere's third molar maturation index (I_{3M}) which classifies patients with I_{3M} smaller than 0.08 as adults (2,5-7,14). Therefore, the first aim of the study is to compare both methods' sensitivity and specificity on distinguishing adults from minors, and whether there is a more suitable cut-off value for I_{3M} in Turkish population.

Materials and Methods

The retrospective study was approved by the Ethics Committee of İstanbul Okan University (decision number: 101/11, date: 26.12.2018). Power analysis indicated that 512 samples are required for the study (G Power 3.1.9.2). Nine hundred eight digital panoramic images of individuals aged between

14 and 24 years were collected at random from the digital archive of Faculty of Dentistry Department of Dentomaxillofacial Radiology between 2017-2018. The included radiographies belonged patients without any systemic disorders, dental anomalies, pathology present in alveolar bone, and whose left mandibular third molars were present. The included mandibular left third molars were non-decayed, free of periapical pathology and didn't consist of any dental restorations or root canal material. Panoramic radiographies of patients of unknown age or those lacking left mandibular third molars were excluded from the study. Digital panoramic images of 512 individuals were included, of which 306 were females and 206 were males. Images were exported in JPG format. The chronological age for each patient was calculated by subtracting the date of radiography taken from the date of birth (year/month).

Demirjian's mineralization stages (DS) of the tooth development were classified from enamel calcification till apices closure (A-H stages) (16). I_{3M} is calculated as the sum of the distances of open apices $(a_1 + a_2)$ divided by the length of the tooth (l) (Figure 1). When the apices of the tooth are completely closed, $I_{3M}=0$ is recorded. The measurements were done using ImageJ v1.52p and bundled with 64-bit Java for Windows (National Institutes of Health, Bethesda, USA; https://imagej.nih.gov/ij/download.html).

Statistical Analysis

Statistical analysis is done using IBM SPSS v21. Cohen's Kappa score (κ) and intra-class correlation coefficient (ICC) were used for inter and intra-observer reliability. Re-evaluation of randomly selected 100 radiographies were done by first and second observer after two weeks without the knowledge of age and sex of patients.

The diagnostic capabilities of the methods to estimate adulthood was tested with receiver operating
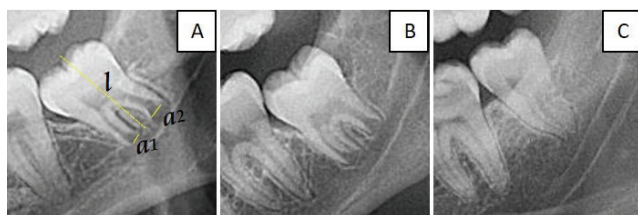

Figure 1. A) Representation for Cameriere's equation; l is the third molar length, a1 and a2 are the open apices distances, B) Third molar at G stage, C) Third molar at H stage

characteristic (ROC) curves. The true positives, was defined as the proportion of correct classification of adults, hence sensitivity; and the true negatives, was defined as test's ability to classify minors, hence specificity of the methods were also evaluated. The sensitivity and specificity of the test were integrated for post-test probability (pp) of individuals attaining legal age (18 years of age or more). Pp is calculated by Bayes's theorem, where p=0 value equals to the present frequency of people who aged between 14-23 years old, and p1 and p2 represents the sensitivity and specificity of the relevant tests. The data was obtained from Turkish Statistical Institute, http://www.turkstat.gov.tr/UstMenu.do?metod=temelist (8).

$$Pp = \frac{(p0*p1)}{(p0*p1)+(1-p2)(1-p0)}$$

Results

The results of κ and ICC for DS were highly consistent as 0.91 and 0.97, while κ and ICC values for I_{3M} were 0.89 and 0.94 respectively.

The ages of patients were not statistically different between groups according to sex. Mandibular third molars which are at B and C stages were too small in number to be taken into account, so the results include information obtained from D stage which corresponds to the time crown formation is completed. Only the ones grouped under H stage and $I_{3M}<0.08$ have statistically higher mean age for females than males (p<0.009) (Table 1).

To test the classification performance of methods to estimate adulthood, the patients who attained the age of 18 and older are classified as adults and the others as minors. The areas under ROC are 0.88 [95% confidence interval (CI), 0.85-0.91] for DS and 0.89 (95% CI, 0.86-0.91) for I_{3M} which indicated quite excellent and compatible performance of the methods (p<0.001).

The best cut-off value from the current data is calculated according to Youden Index J of 0.63 which corresponds to $I_{3M}<0.2$ with a range of 95% CI, ≤0,13-≤0.27. The $I_{3M}<0.2$ cut-off value for I_{3M} had 81.22% sensitivity and 81.87% specificity (p<0.001), positive likelihood ratios and negative likelihood ratios of the several cut-off values are also presented in Table 2. This means that a developed third molar with a maturity

index below 0.2 is more than 4.48 times more likely to be observed in an adult compared to a minor.

The stages of H, G and $I_{3M}<0.08$ and $I_{3M}<0.2$ are evaluated in terms of sensitivity and specificity and the results were summarized in Tables 3 and 4. In females both results presented high specificity values compared to males. In females the specificities of H stage and $I_{3M}<0.08$ were 97.8% and 94.4% whereas in males the results were 93.4% and 92.6% respectively. The sensitivities of H stage and $I_{3M}<0.08$ stayed quite low in females compared to males, being 41.4% and 46.8% respectively. In males the sensitivities of H stage and $I_{3M}<0.08$ were 64.3% and 71.4% respectively. The stages of H and $I_{3M}<0.08$ have high power to identify minors from adults for both sexes. The percentages of correct classification of adults and their post-test probabilities are summarized in Tables 3 and 4.

As the investigated new cut off value of $I_{3M}<0.2$ increased the sensitivity, the problem is that the probability of classifying minors incorrectly, hence the ratio true negatives is decreased from 97.4 to 87.2 for females and from 92.6 to 77.2 for males with respect to $I_{3M}<0.08$.

Discussion

Estimating adulthood is important for medicolegal reasons and the decision of methods on this matter should be consistent and reproducible. To minimize the possible error and have reliable outcomes, combination of methods is recommended since there is no perfect diagnostic test on the determination of legal age. Until now, both methods' reproducibility were studied and compared, and the idea of the present study is to apply both methods to a sample in the Turkish population.

Several studies found sexual dimorphism for third molar development in H stage (3-5,7,17). As is the case

Table 1. Summary of DS and I_{3M} according to age and sex						
		Male		**Female**		
		#	Mean age ± SD	#	Mean age ± SD	
DS	D	24	15.04±1.19	56	14.74±1.21	p=0.812
	E	50	15.5±1.15	70	15.07±1.58	p=0.925
	F	40	16.46±1.39	69	16.69±1.71	p=0.641
	G	36	17.66±1.61	55	18.32±1.95	p=0.072
	H	53	19.89±2.08	50	21±1.75	p=0.004*
I_{3M}	$I_{3M}<0.08$	60	19.71±2.05	57	20.67±1.87	p=0.009*
	$0.08 \leq I_{3M}<0.2$	92	18.95±2.21	107	19.44±2.34	p=0.096
	$0.2 \leq I_{3M}<0.3$	116	18.4±2.33	155	18.69±2.47	p=0.321
	$0.3 \leq I_{3M}<0.5$	161	17.74±2.33	216	17.96±2.55	p=0.445
	$0.5 \leq I_{3M}$	45	15.01±1.14	88	14.99±1.18	p=0.893
*Statistically significant differences, I_{3M}: Third molar maturity index, SD: Standard deviation						

Table 2. Sensitivity, specificity, confidence intervals (CI), positive and negative LR of several cut-off points for I_{3M}						
Cut-off value	Sensitivity	95% CI	Specificity	95% CI	LR+	LR-
<0.07	56.35	48.8-63.7	95.47	92.6-97.4	12.44	0.46
<0.08	58.56	51.0-65.8	94.86	91.9-97.0	11.4	0.44
<0.1	62.98	55.5-70	93.05	89.8-95.5	9.06	0.4
<0.15	72.93	65.8-79.3	88.52	84.6-91.7	6.35	0.31
<0.2	81.22	74.8-86.6	81.87	77.3-85.9	4.48	0.23
<0.25	87.29	81.5-91.8	74.32	69.3-78.9	3.4	0.17
<0.3	90.61	85.4-94.4	64.35	58.9-69.5	2.54	0.15
LR+: Positive likelihood ratios, LR-: Negative likelihood ratios, I_{3M}: Third molar maturity index, CI: Confidence interval						

Table 3. Percentage values of sensitivity, specificity, correct classification, and posttest probabilities for females when G and H stages, $I_{3M}<0.08$ and $I_{3M}<0.2$ are used for legal age estimation

	G	H	$I_{3M}<0.08$	$I_{3M}<0.2$
Sensitivity	33.3	41.4	46.8	73.9
Specificity	90.8	97.9	97.4	87.2
Correct classification	64.1	83.5	85.4	82.3
Posttest probability	64.2	70.3	70.8	80.9

I_{3M}: Third molar maturity index

Table 4. Percentage values of sensitivity, specificity, correct classification, and posttest probabilities for males when G and H stages, $I_{3M}<0.08$ and $I_{3M}<0.2$ are used for legal age estimation

	G	H	$I_{3M}<0.08$	$I_{3M}<0.2$
Sensitivity	22.9	64.3	71.4	87.1
Specificity	85.3	93.4	92.6	77.2
Correct classification	69.9	77.4	79.1	80.5
Posttest probability	68.2	68.3	68.5	80.9

I_{3M}: Third molar maturity index

with previous studies, the results of the present study also had statistically significant higher mean ages for females with third molars corresponding H stage and for $I_{3M}<0.08$ than males, supporting earlier third molar maturation in males. Mincer et al. (18) found that 90% of males and 92% of females presenting third molars were at H stage in American children. H stage is stated as a cut-off value for estimation of legal age in Mexican and Colombian populations (12). Cameriere et al. (2) compared the sensitivity and specificities of G, H stages with 0.08 cut-off value for Italian population and concluded that the post-test probabilities of third molars at H stage and has $I_{3M}<0.08$ are both 98%. The sensitivity values of Galić et al.'s (7) study in Croatian individuals on 0.08 cut-off value was significantly high for both sexes, 84% and 91% for females and males respectively higher than the results of the current study. The specificity values of $I_{3M}<0.08$ is quite high being 97.4% for females and 92.6% for males and consistent with the previous studies (5-7,13,14,19,20). Even though the present study's sensitivity and specificity results are comparable to Cameriere et al.'s (2) study, post-test probabilities stayed low being at most 80.9% (2,6,7). The post-test probability of the present study when using H stage or cut-off value of

0.08 is 70% for females and 68% for males. Moreover, correct classification of females and males were low as 85.4% and 79.1% respectively for $I_{3M}<0.08$. The results of Cavrić et al.'s (5) study in black African population contradicted the results of the present study, their study showed only 10% incorrect classification with 94% pp. Another study on the French population tested $I_{3M}<0.08$ on the assessment of the adulthood and found lower specificities 88.8%, 88.4% with higher post-test probabilities 87.9%, 89.9% for females and males respectively when compared with the results of the present study (21).

The study of Gulsahi et al. (14) discussed the utility of 0.08 cut-off value in a sample of Turkish individuals. The results of their study had 94.6% and 85.9% sensitivities for females and males respectively with 100% specificity. From the ethical perspective, the results were consistent with the desired outcomes. In other words, the test's capability to distinguish minors and preserving their legal rights is 100%. The results of the current study revealed 46.8% sensitivity and 97.4% specificity for females and 71.4% sensitivity and 92.6% specificity for males. A recent study conducted on Turkish individuals had high specificity values being 96.2%, 94.9% with substantially lower sensitivity values being 55.4% and 75% for females and males, respectively (22). The variance of sensitivity values might be due to the influx of immigration, the increase of population, and the parallel increase of inaccurate civil registration in rural areas in recent years.

Another cut-off value was obtained from the dataset of the present study. When the new cut-off value, $I_{3M}<0.2$, was considered for legal age estimation, the sensitivity of the new value rises from 46.8% to 73.9% for females and 71.4% to 87.2% for males while specificity decreases from 97.4% to 87.2% for females and 92.6% to 77.2% for males. The post-test probabilities of $I_{3M}<0.2$ were increased for both sexes with respect to the results of $I_{3M}<0.08$. From the statistical perspective when ethics were not considered, a new cut-off value 0.2 may be used practically. Akkaya and Yilanci's (22) study also reported a better cut-off value for Turkish individuals being $I_{3M}<0.19$ for females which was very close to the cut-off value of the current study. The results suggest that newly identified cut-off value might produce more accurate discrimination. Here lies the dilemma of the current study that in expense of 27% decrease

in false negatives, could 10% decrease of specificity be ignored in females with the cut off I_{3M}<0.2 with respect to I_{3M}<0.08. Even though the desired values of sensitivity and specificity are obtained from the new cut-off value, ethical considerations of legal purposes determine its utility. Still, the aim is solely based on legal purposes and the 0.2 cut-off value has 12.8% and 22.8% chances of classifying minors as adults for females and males respectively. Such high chances of misclassification can easily violate minors' legal rights in the Turkish population.

Every year more and more migration occurs and Turkey with its strategic place being a bridge between middle-east and Europe becomes a suitable place for refugees and immigrants to settle. Therefore, the profile of the population changes slightly each year and up-to-date population-based studies are important for contributing new evidence and information for forensic science.

Conclusion

For age estimation, the methods should have high specificity to decrease the number of false classifications of minors as adults and protect their legal rights. The cut-off I_{3M}<0.2 seemed to increase the test performance with respect to sensitivity and post-test probability, while decreasing specificity values. Therefore, I_{3M}<0.08 and H stage might still be recommended for adulthood estimation for Turkish males, but for Turkish females, based on ethical and legal considerations I_{3M}<0.08 and I_{3M}<0.2 provide respectively the best and sufficient results.

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Ethics

Ethics Committee Approval: The retrospective study was approved by the Ethics Committee of İstanbul Okan University (decision number: 101/11, date: 26.12.2018).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept: B.A., E.F., Design: B.A., C.B., Data Collection or Processing: B.A., M.Ş., G.K., Analysis or Interpretation: B.A., M.Ş., C.B., E.F., Literature Search: B.A., M.Ş., C.B., G.K., Writing: B.A., M.Ş., C.B., E.F.

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