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Research Paper

Comparison of the accuracy of two different methods in dental age estimation

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ABSTRACT

Introduction: Age estimation plays a crucial role in forensic medicine, particularly in countries facing significant refugee-related challenges. There are many parameters used for age estimation. The aim of this study is to evaluate the visibility of the pulp and periodontal ligament space in the mandibular third molar using cone beam computed tomography (CBCT) images and to compare the effectiveness of these two methods in chronological age estimation, specifically in assessing the 18–21 age thresholds.

Method: CBCT images of 359 patients (189 females, 170 males), aged between 16 and 29 were analyzed by three independent observers. Patients with a history of trauma and/or surgery in the maxillofacial region, developmental anomalies or pathologies in the mandible, or systemic diseases affecting growth and development were excluded. Additionally, third molars with incomplete root development, developmental or acquired dental anomalies, pulp calcification etc. were excluded from the study. After recording the patients' age and sex, the mandibular third molars were classified according to the Olze (visibility of the root pulp) and Guo classification (visibility of the periodontal ligament) into grades 0, 1, 2, and 3. Each observer re-evaluated the CBCT images of 140 randomly selected patients two weeks later to assess intra-observer reliability.

Results: The simple correlations between Olze and Guo grades were examined regardless of sex, the relationship between both methods and age was found to be significant and positive (Olze vs age $r = 0.493$ and $p < 0.001$, Guo vs age $r = 0.445$ and $p < 0.001$). Additionally, for both the Olze and Guo methods, it was observed that as the grade increased, mean age also increased at a statistically significant level ($p < 0.001$). Olze and Guo's grades changed statistically significantly in the 18 and 21 age thresholds in total ($p < 0.001$). When both methods were evaluated on a grade basis, it was seen that both Olze and Guo grade 0 increased statistically significantly in the under-18 age group, while Olze Grade 1 and Grade 2, and Guo Grade 2 increased statistically significantly in the 18 and over age group ($p < 0.001$). Olze method's cutoff value was found to be > 0, and Guo method's cutoff value was found to be > 1 in distinguishing between those under 18 and over. Both Olze and Guo's methods were found to be more successful in predicting the 18-year-old threshold.

Conclusion: Although they offer a high probability of being accurate, both Olze and Guo classifications do not provide 100 % accuracy in determining the 18 and 21 age thresholds in forensic dental age estimation. However, for both the Olze and Guo methods, the mean age increased as the grade increased. Both the Olze and Guo methods were found to be successful in estimating the 18 and 21 age thresholds.

1. Introduction

Age estimation in forensic medicine is a critical issue in both criminal and civil law.[1] Researchers apply age estimation techniques on corpses in cases of mass disasters, fires, accidents, murders, and infanticide, as well as in situations such as sexual abuse, abduction, marriage, premature birth, child adoption, and the assessment of the age of criminal responsibility in living individuals.[2] The need for accurate identification has recently gained great importance in Turkey, as it has globally, due to the increasing number of refugees.[3] According to the United Nations Convention on the Rights of the Child, an individual under the age of 18 is considered a child.[4] Under the United Nations Declaration of the Rights of the Child, individuals under 18 have special rights and generally cannot be deported to the countries they came from. Consequently, these children are more likely to obtain the right to asylum. Legal regulations concerning age are also in place and enforced in

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Turkey.[5,6]

The age threshold for becoming an adult varies worldwide, ranging from 15 to 21 years old.[7] In China and most European countries, the age of 18 holds legal significance, as individuals over this age are considered adults. However, the age limit of 21 is also important in some European countries.[8] Multiple age thresholds play a role in judicial and administrative procedures; for example, in France, 18 is considered the age of majority.[9] In Turkey, in accordance with the United Nations Convention on the Rights of the Child, every individual under the age of 18 is legally recognized as a child.[5] In Germany, the relevant age thresholds in criminal proceedings are 14, 18, and 21 years old.[10]

There are several methods used in forensic age estimation. These methods are developed by considering physical characteristics such as height and weight, findings related to puberty, mental and spiritual development, and the development of bone and tooth structures.[11] According to the recommendations of the Working Group on Forensic Age Estimation, dental status examination should always be included in age assessments.[12] Radiographic evaluation of teeth is a widely used method for age estimation in individuals under 16 years of age.[13] Since the root tips of all other teeth are closed after the age of 16, the only tooth still in the developmental stage for age estimation may be the third molar. However, considering cases with early root closure, determining the 18-year-old threshold by evaluating the apical development of third molars may not always be accurate.[14]

Another radiographic method for age estimation involves investigating the secondary dentin ratio of the existing root.[15] Secondary dentin forms on the pulpal surface of the primary dentin, leading to a gradual decrease in the visibility of the pulp cavity, which can eventually result in the pulp disappearing.[16] There are various stage classifications in the literature to evaluate the visibility of third molar root canals. In 2010, Olze et al.[17] introduced the first staging system. Another method used in age estimation with mandibular third molars is based on the decrease in the visibility of the periodontal ligament space over time.[18] In 2020, Guo et al.[19] proposed a classification based on the visibility of the periodontal ligament. Although several studies suggest that this feature could be used for forensic age assessment, it has not been definitively determined whether the change is purely a radiographic phenomenon or if the periodontal ligament has completely degenerated.[20]

Panoramic imaging, a fast, simple, common, and economical method, is frequently used in studies investigating the root pulp visibility of third molars for forensic age estimation.[21] While panoramic imaging offers many advantages, it also has technical disadvantages such as superposition, magnification, and distortion. These factors may hinder accurate and reliable assessments, especially when imaging dental anomalies such as root dilaceration or positional anomalies in the teeth.[22]

Cone beam computed tomography (CBCT) is a newer imaging method with a low radiation dose that provides submillimeter resolution. Thanks to the detailed, three-dimensional evaluation capabilities of CBCT, subtle changes such as shrinkage in the pulp cavity due to secondary dentin formation can be analyzed more comprehensively.[23]

This study aims to evaluate the visibility of the pulp and periodontal ligament space in mandibular third molars using CBCT images and to compare the usefulness of these two methods in chronological age estimation, particularly in determining the 18- and 21-year-old thresholds.

2. Material and methods

2.1. Ethical approval

This retrospective study was approved by the Local Ethics Committee of the University (Date: September 03, 2024, Decision No: 32), and the study protocol was conducted in accordance with the principles set forth in the Declaration of Helsinki.

2.2. Study design

In this retrospective study, patients who presented to the Department of Oral and Maxillofacial Radiology at the Faculty of Dentistry, Hatay Mustafa Kemal University, between 2021 and 2024, and whose CBCT images were taken for various reasons, were retrospectively examined.

CBCTs from patients aged 16–29 years, with completed root development, and images of optimal diagnostic quality were included in the study. Patients with a history of trauma and/or surgery in the maxillofacial region, developmental anomalies or pathologies in the mandible, or systemic diseases affecting growth and development were excluded. Additionally, third molars with incomplete root development, developmental or acquired dental anomalies, pulp calcification, caries, inflammation, root canal treatment, impacted third molars, or images with artifacts preventing accurate analysis were excluded from the study. The visibility of the root pulp and periodontal ligament space was assessed in the left mandibular third molar; when this tooth met any of the exclusion criteria, the right mandibular third molar was used.

CBCT images from 359 patients (189 females, 170 males) who met the inclusion criteria were selected for the study. After recording the age and sex of the patients, the mandibular third molars were graded according to the Olze and Guo classifications.

In the Olze classification,[17] the visibility of the root pulp in both left and right mandibular third molars were recorded in four grades, as seen in Fig. 1:

- **Grade 0:** The lumen of all root canals is visible up to the root apex.
- **Grade 1:** The lumen of one root canal is completely indistinguishable up to the root apex.
- **Grade 2:** The lumen of two root canals is partially visible up to the root apex, or the lumen of one canal may be invisible for almost its entire length.
- **Grade 3:** The lumen of two root canals is almost invisible along their entire length.

In the Guo classification,[19] the visibility of the periodontal ligament of mandibular third molars with complete root mineralization were recorded in four grades, as shown in Fig. 2:

- **Grade 0:** Periodontal ligament space is visible along the length of all roots.
- **Grade 1:** Periodontal ligament space is not visible from the apex to more than half of one root.
- **Grade 2:** Periodontal ligament space is not visible along almost the entire length of one root or along a part of two roots.
- **Grade 3:** Periodontal ligament space is not visible along almost the entire length of two roots.

2.3. Imaging parameters and display features

All CBCT images were obtained using the same machine (Kavo 3D Op Pro, Biberach, Germany) with a 13 × 15 cm FOV, 380 μm voxel size, and 0.38 mm slice thickness. Images were examined in all sections in the axial, coronal and sagittal planes, including root apices.

The first hundred radiographs were used for observer calibration and were evaluated and discussed under the supervision of a senior dentomaxillofacial radiologist (CAB), who has 10 years of experience. Subsequently, three dentomaxillofacial radiology research assistants (ZEH – with 2 years, MK – with 1 year, and ECE – with 1 year of clinical experience) evaluated all CBCTs by consensus. To assess reliability, 140 randomly selected CBCTs were re-evaluated by all observers (ZEH, MK, ECE) one month later. All data obtained were recorded in a Microsoft Excel file (Microsoft Corp., Redmond, WA, USA). Intra- and inter-observer agreement was assessed using Cohen's kappa test. To standardize the presence and classification of anatomical variations, image contrast, brightness, and zoom settings were adjusted, and the same

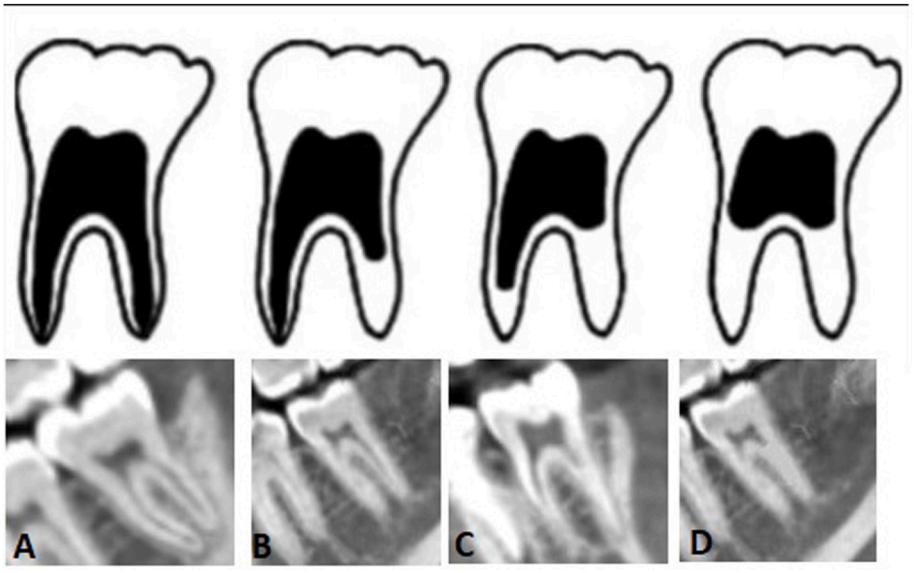


Fig. 1. Root pulp visualization grades as proposed by Olze et al.[17] A. Grade 0, B. Grade 1, C. Grade 2, D. Grade 3.

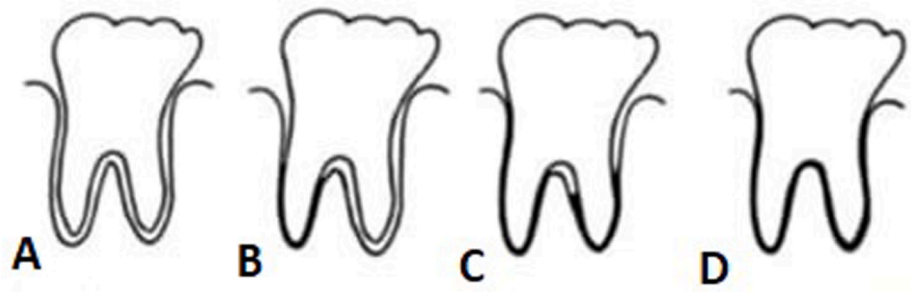


Fig. 2. Schematic drawings and CBCT figures of the grades of radiographic visibility of the periodontal ligament in third molars (adapted from: Guo YC et al.[19]) A. Grade 0, B. Grade 1, C. Grade 2, D. Grade 3.

1.366x768 pixel liquid crystal monitor was used (Dell 14-inch; Dell, Round Rock, Texas, USA).

2.4. Statistical analysis

Descriptive statistics for the measurements were calculated as mean, standard deviation (SD), number, and percentage frequencies. The Cohen's Kappa test was used for intra-observer agreement and inter-observer agreement. Relationships between categorical characteristics were evaluated using the Pearson Chi-square test. One-Way ANOVA was used to compare sex, Olze, and Guo grades with respect to measured ages, and differing scores were determined using the Scheffe test. The accuracy of sex, Olze, and Guo grades in predicting measured ages was calculated using a multiple linear regression model. Simple relationships between age and scores were assessed using Spearman rank correlation analysis. In addition, after age was grouped as under and over 18 and under and over 21, the estimation accuracy of Guo and Olze grades was evaluated using ROC analysis. Estimation criteria included the area under the ROC curve (AUC), sensitivity (estimation success in patients over 18 or over 21), and specificity (estimation success in patients under 18 or under 21). The predictive success of Olze and Guo's grades was determined by comparing the areas under the ROC curve. Statistical significance was accepted as $p \leq 0.05$. SPSS (ver. 29, SPSS Inc., Chicago, IL, USA) was used for calculations.

3. RESULTS

For the re-evaluation of CBCT images, inter-observer agreement ($k = 0.884$) and intra-observer agreement ($k = 0.842$) were calculated, both indicating good agreement. These values suggest high reproducibility and repeatability.

CBCT images from 359 patients (189 females, 170 males), aged between 16 and 29 years (mean age = 23.2 ± 3.9 years), were evaluated. The sex distribution across all age groups is provided in Table 1. The

Table 1
Sex distribution in all age groups.

AGE	FEMALE n(%)	MALE n(%)
16.0–16.9	12 (6.3)	10 (5.8)
17.0–17.9	8 (4.2)	8 (4.7)
18.0–18.9	13 (6.8)	11 (6.4)
19.0–19.9	13 (6.8)	11 (6.4)
20.0–20.9	15 (7.9)	15 (8.8)
21.0–21.9	16 (8.4)	15 (8.8)
22.0–22.9	13 (6.8)	13 (7.6)
23.0–23.9	19 (10.0)	15 (8.8)
24.0–24.9	13 (6.8)	13 (7.6)
25.0–25.9	14 (7.4)	10 (5.8)
26.0–26.9	14 (7.4)	10 (5.8)
27.0–27.9	12 (6.3)	11 (6.4)
28.0–28.9	12 (6.3)	12 (7.0)
29.0–29.9	15 (7.9)	16 (9.4)
TOTAL	**189**	**170**

distribution of mean ages for Olze and Guo grades, based on sex, is shown in Table 2. The results did not significantly differ between sexes (Olze: p = 0.242, Guo: P = 0.650). On the other hand, when simple correlations between Olze and Guo grades were examined regardless of sex, the relationship between both methods and age was found to be significant and positive (Olze vs age r = 0.493 and p < 0.001, Guo vs age r = 0.445 and p < 0.001). Additionally, for both the Olze and Guo methods, it was observed that as the grade increased, mean age also increased at a statistically significant level (p < 0.001) (Table 2).

The distribution of Olze and Guo grades at age thresholds of 18 and 21 was shown in Table 3. Table 3 shows that both Olze and Guo grades changed statistically significantly in the 18 and 21 age thresholds in total (p < 0.001). When both methods were evaluated on a grade basis, it was seen that both Olze and Guo grade 0 increased statistically significantly in the under-18 age group, while Olze Grade 1 and Grade 2, and Guo Grade 2 increased statistically significantly in the 18 and over age group (p < 0.001) (Table 3). At the 21-year threshold, both Olze and Guo grade 0 showed significant differences by being more frequent in the under 21 years of age, whereas Olze grades 1 and 2 and Guo grade 2 showed significant differences by being more frequent in the 21 and over age group (p < 0.001) (Table 3).

After dividing the groups into two according to age thresholds, the success rates and comparison results of the Olze and Guo grades in age estimation, both for males and females separately and total, are summarized in Table 4. Olze method's cutoff value was found to be > 0, and Guo method's cutoff value was found to be > 1 in distinguishing between those under 18 and over. Both the Olze and Guo methods were found to be more accurate in estimating the 18-year-old threshold than the 21-year-old threshold. However, no significant difference was found between the Olze and Guo methods in terms of their success rates for predicting the age threshold of 18 (Total p = 0.145, p = 0.640 for males and p = 0.116 for females). Similarly, no significant difference was found between the Olze and Guo methods in terms of their success rates for predicting the age threshold of 21 (Total p = 0.333, p = 0.141 for males and p = 0.949 for females). Fig. 3 shows the ROC curves showing the prediction success of the Olze and Guo methods for the 18 and 21 age thresholds for females, males, and in total.

Table 3
Distribution of Olze and Guo grades at age thresholds of 18 and 21.

		AGE				TOTAL	p
		<18 age (n = 38)		≥18 age (321)			
		n	%	n	%	n	
OLZE	0	***33$_a$***	***86.8***	160$_b$	49.8	193	***<0.001***
	1	5$_a$	13.2	***101$_b$***	***31.5***	106	
	2	0$_a$	0.0	***55$_b$***	***17.1***	55	
	3	0$_a$	0.0	5$_a$	1.6	5	
GUO	0	***21$_a$***	***55.3***	45$_b$	14.0	66	***<0.001***
	1	16$_a$	42.1	181$_a$	56.4	197	
	2	0$_a$	0.0	***55$_b$***	***17.1***	55	
	3	1$_a$	2.6	40$_a$	12.5	41	
		<21 age (n = 116)		**>=21 age (n = 243)**			
OLZE	0	***92$_a$***	***79.3***	101$_b$	41.6	193	***<0.001***
	1	21$_a$	18.1	***85$_b$***	***35.0***	106	
	2	3$_a$	2.6	***52$_b$***	***21.4***	55	
	3	0$_a$	0.0	5$_a$	2.1	5	
GUO	0	***41$_a$***	***35.3***	25$_b$	10.3	66	***<0.001***
	1	60$_a$	51.7	137$_a$	56.4	197	
	2	7$_a$	6.0	***48$_b$***	***19.8***	55	
	3	8$_a$	6.9	33$_a$	13.6	41	

Statistically significant was indicated in bold and italic (p < 0.001).

4. Discussion

The estimation of an individual's age is crucial in establishing whether they are of legal age. The increasing number of children and young adults with unknown or incorrect birth dates is a current issue in both law and forensic medicine in many countries.[24] In most countries, including Turkey, the 18-year-old threshold is particularly significant due to legal concerns.[21] According to the Turkish Penal Code, a "child" is defined as an individual who has not yet reached the age of 18.[5] This distinction is crucial in determining the legal consequences for crimes committed, especially in cases involving individuals aged 12–15, 16–18, over 18, or over 21. Similarly, the Turkish Civil Code emphasizes the importance of determining whether an individual has reached 18 years of age, as it affects their legal capacity and right to marry.[6]

Several methods for age estimation are described in the literature, including anthropometric measurements, stages of sexual development, and physical examination to detect age-related developmental disorders.[24] According to updated recommendations from the Study Group on Forensic Age Diagnostics (AGFAD), computed tomography of the clavicle ossification is one method used to assess the 18-year-old threshold.[19] Other methods have been developed to estimate chronological age based on tooth development. As tooth development concludes with the mineralization of the third molars, these teeth are often used to estimate age, particularly for determining the 18-year-old threshold.[20] Olze et al.[17] were the first to present age classifications based on the mineralization of mandibular third molars and the stages of root pulp visibility (RPV).[17,18] Guo et al.[19] developed a grading system based on the visibility of the periodontal ligament in mandibular third molars. Solheim[15] proposed examining the secondary dentin ratio in existing roots as a radiographic method for age estimation. He noted that

Table 2
Identifying age means of Olze and Guo Grades based on sex.

SEX		GRADE	N (%)	MEAN(years) ± SD	MIN	MAX	p
Female	Olze Grade	0	111 (58.7)	20.98 ± 3.07	16.1	29.9	***<0.001***
		1	49 (25.9)	22.35 ± 2.46	16.3	29.9	
		2	27 (14.3)	25.91 ± 2.30	19.4	29.9	
		3	2 (1.1)	28.60 ± 1.41	27.1	29.8	
	Guo Grade	0	36 (19.0)	19.87 ± 2.68	16.1	28.3	***<0.001***
		1	107 (56.6)	23.34 ± 3.09	16.2	29.9	
		2	28 (14.8)	25.76 ± 2.65	18.3	29.9	
		3	18 (9.5)	27.44 ± 3.43	17.7	29.9	
Male	Olze Grade	0	82 (48.2)	21.05 ± 3.06	16.1	29.5	***<0.001***
		1	57 (33.5)	24.08 ± 2.58	17.3	29.9	
		2	28 (16.5)	26.88 ± 2.23	19.3	29.9	
		3	3 (1.8)	27.43 ± 2.02	26.1	29.9	
	Guo Grade	0	30 (17.6)	19.97 ± 2.54	16.1	28.4	***<0.001***
		1	90 (52.9)	22.67 ± 3.11	16.3	29.5	
		2	27 (15.9)	25.07 ± 2.58	18.1	29.9	
		3	23 (13.5)	26.62 ± 3.37	18.2	29.9	

Statistically significant values are indicated in bold and italics.

Table 4
The success of Olze and Guo's methods in age estimation in males and females.

SEX	Age cutoff	Method	Method Cutoff	AUC	SE	95 % CI	p	Sensitivity	Specificity
Male	18	OLZE	>0	0.713	0.056	0.639–0.780	0.003	55.92	83.32
		GUO	>1	0.741	0.052	0.669–0.805	0.001	32.89	100.0
	21	OLZE	>0	0.744	0.038	0.672–0.808	***<0.001***	66.09	78.18
		GUO	>1	0.677	0.042	0.601–0.747	***<0.001***	37.39	87.27
Female	18	OLZE	>0	0.683	0.056	0.612–0.749	0.007	44.97	90.00
		GUO	>0	0.778	0.045	0.712–0.835	***<0.001***	86.39	65.00
	21	OLZE	>0	0.672	0.040	0.600–0.738	***<0.001***	51.56	80.33
		GUO	>0	0.669	0.040	0.597–0.735	***<0.001***	89.84	37.70
TOTAL	18	OLZE	>0	0.697	0.040	0.647 to 0.744	***<0.001***	50.16	86.89
		GUO	>0	0.759	0.034	0.711 to 0.802	***<0.001***	85.98	55.26
	21	OLZE	>0	0.706	0.028	0.656 to 0.752	***<0.001***	58.44	79.81
		GUO	>1	0.672	0.029	0.621 to 0.721	***<0.001***	89.71	35.34

Statistically significant was indicated as bold and italic.

secondary dentin accumulates with advancing age, leading to the narrowing of the pulp cavity and the eventual disappearance of pulp horns. This study aimed to evaluate the pulp visibility and periodontal ligament space of the mandibular third molar and compare their effectiveness in determining age, particularly the 18–21 age thresholds. In our study, only mandibular third molars with closed apexes were used. This use of only mature (closed apex) third molars have the advantage of indicating the proportions of mature teeth exhibiting the different stages of periodontal ligament visibility. Maxillary molars, due to their location, are adjacent to many anatomical structures. Especially if the maxillary molars extend into the sinus, it is not possible to examine the periodontal ligament space.[17–19] Therefore, in our study, mandibular molar teeth were preferred.

In literature studies, it is suggested that individuals above the 18-year threshold are more likely to fall under Grade 2 or Grade 3 in the Olze classification, with Grade 0 rarely observed beyond this threshold.[21] Gök et al.[1] recorded Grade 0 at the earliest age of 17.2 years, Grade 1 at 19.1 years, Grade 2 at 20.1 years, and Grade 3 at 25.1 years. Olze et al.[17] indicated that all individuals classified in Grades 1, 2, and 3 were at least 21 years old, and those under 18 could easily be excluded. Their study showed that Grade 0 appeared as early as 17.2 years, Grade 1 at 21.0 years, Grade 2 at 22.3 years, and Grade 3 at 25.3 years. In a 2022 study by Günacar et al.,[21] the youngest observed age for Grade 0 was 16.0 years, for Grade 1 it was 18.5 years, for Grade 2 it was 16.3 years, and for Grade 3 it was 32 years. In our study, consistent with the literature, Grade 0 appeared at the earliest age of 16.1 years, while Grades 1, 2, and 3 were first observed at ages 16.3, 19.3, and 26.1 years, respectively.

Guo et al.[19] developed a classification system consisting of four stages based on the radiographic appearance of the periodontal ligaments in mandibular third molars, and stated that the visibility of the periodontal ligament space, finding that the youngest age for Grade 0 was 17.0 years, Grade 1 was 17.5 years, Grade 2 was 21.4 years, and Grade 3 was 23.1 years. A similar study conducted by Sequeira et al.[25] reported the youngest ages for each grade as follows: Grade 0 at 17.0 years, Grade 1 at 18.2 years, Grade 2 at 17.4 years, and Grade 4 at 19.1 years. Similary Sequeira et al.[25] in our study, it was observed that the grades in both Olze and Guo classifications increased with age for both sexes. In another similar study by Lucas et al.[27] evaluated the effect of periodontal ligament visibility on age estimation by classifying it as a percentage. As a result of their study, they stated that there was a significant decrease in periodontal ligament visibility with age. They stated that, the youngest ages for Grades 0, 1, 2, and 3 were recorded as 16.33, 16.17, 18.1, and 18.7 years, respectively. All three studies found a positive correlation between age and the classification grade, with the grade increasing as age increased.[18,25,26] Similarly, in our study, it was observed that there was a decrease in periodontal ligament visibility with increasing age. The youngest ages recorded in our study were as follows: Grade 0 at 16.1 years, Grade 1 at 16.2 years, Grade 2 at 18.1 years, and Grade 3 at 17.7 years.

Our results also showed that there was a positive correlation between age and the Olze and Guo methods, meaning that there was a decrease in pulp visibility with increasing age. Especially, it was seen that both Olze and Guo Grade 0 increased statistically significantly in the under-18 and under-21 age groups, while Olze Grade 1 and Grade 2, and Guo grade 2 increased statistically significantly in the 18- and 21-over age groups. Additionally, our study found that both the Olze and Guo methods were more accurate in estimating the age threshold of 18 than the age threshold of 21. However, no significant difference was found between the Olze and Guo methods in terms of their success rates in estimating the age thresholds of 18 and 21. This suggests that the method used to determine the age thresholds of 18 and 21 is irrelevant. However, both methods have higher sensitivity in detecting the age of 18. Despite high detection rates, this result may vary in different populations, different age ranges, and different imaging techniques used.

Dental radiographs are commonly used for age estimation by assessing the stages of mineralization, the formation of root and crown structures, eruption, and the intermingling of primary and permanent dentition[24] Panoramic radiography, a fast, simple, and cost-effective imaging method, is widely used in studies investigating the pulpal visibility of third molars for forensic age estimation.[1] However, panoramic radiography has limitations, such as its 2D nature, the superimposition of anatomical structures, and geometric distortion, which can complicate the evaluation process. In contrast, CBCT offers superior spatial resolution and 3D imaging, enabling clear visualization of the roots of third molars without magnification, distortion, and anatomic superposition. Additionally, CBCT allows for the examination of bucco-lingual inclination and root positioning within the alveolar bone.[24] However, the use of ionizing radiation for imaging has always had implications for radiation protection for medical personnel, the public and patients. It has always been advocated that the principle of "as low as reasonably achievable" should be followed and that doses should be kept as low as reasonably practicable, taking into account social factors. In addition, The European Academy of Dentomaxillofacial Radiology added that doses should be reduced as much as possible, especially in children and young adults, and unnecessary radiological examinations should be avoided.[27] Gunacar et al.[21] compared the effectiveness of panoramic radiography and CBCT in imaging Olze classification and concluded that CBCT provided superior images of the mandibular third molar pulp. Due to these advantages, CBCT was the preferred method in our study.

Although various methods for age estimation exist, there is a lack of studies comparing these methods directly. In our study, efforts were made to balance the number of patients in different age groups and the female-male ratio as closely as possible, reducing potential statistical errors due to these variables. Gunacar et al.[21] used data collected by a single observer and noted that evaluations by multiple observers would lead to more reliable results. In our study, data were scanned twice by three different observers to minimize error and improve accuracy. We believe our study will contribute to the literature in this regard.

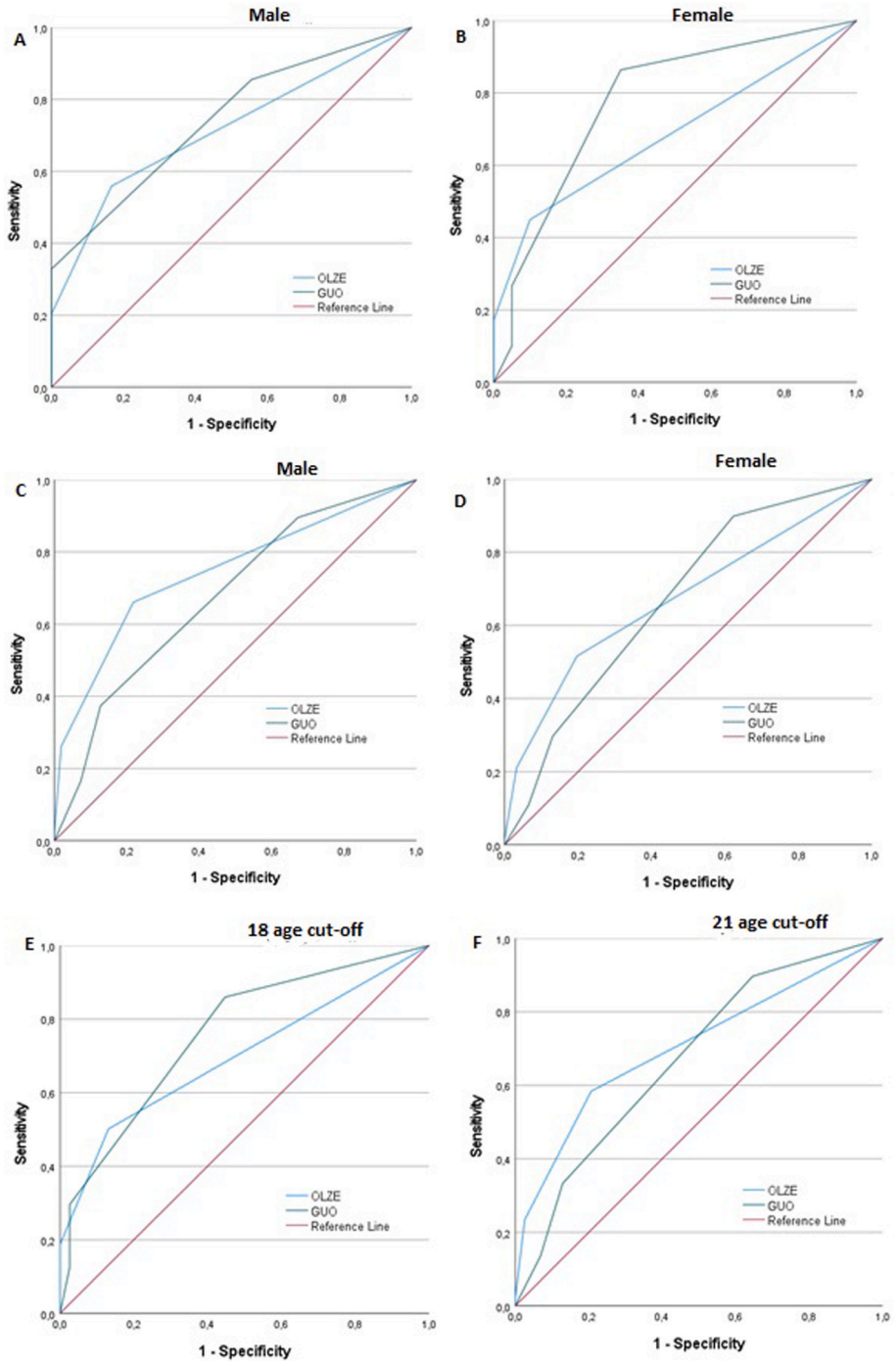


Fig. 3. ROC curves showing the predictive success of the Olze and Guo methods. A. and B. The success of the Olze and Guo methods in distinguishing the 18-year-old threshold for males and females. C. and D. The success of the Olze and Guo methods in distinguishing the 21-year-old threshold for males and females. E. and F. The success of the Olze and Guo methods in distinguishing the 18 and 21-year-old thresholds, regardless of sex.

However, some limitations exist in this study. Firstly, although such methods can be used when age estimation is required for undocumented individuals, their clinical practicality is questionable. Another potential issue is the formation of tertiary dentin in teeth that are in occlusion, due to the stimulating effects of post-eruption changes such as functional wear. Although teeth with advanced attrition or restorative treatments were excluded, minor wear might still be missed radiologically and clinically, potentially being misinterpreted as secondary dentin. Furthermore, histological examination, which would definitively confirm dentin types, is not feasible for age estimation in living individuals, as it requires tooth extraction. Finally, the study is conducted on a population from a specific region. A multicenter study encompassing different regions of the country, with a larger number of patients in each age group, is likely to yield more generalizable results.

5. Conclusion

1. Both the Olze and Guo methods showed an increase in mean age as the grade increased. Both methods were found to be more accurate in estimating the 18-year-old threshold. However, both methods were found to be useable for determining the 18 and 21-year-old thresholds. However, while both classifications provide high accuracy in

determining the 18 and 21-year-old thresholds for age estimation in forensic dentistry, they do not provide 100 % accuracy. Therefore, additional methods and classifications specific to specific populations should be developed to increase sensitivity.
2. The imaging of the third molar root pulp and periodontal ligament space demonstrates clear changes with advancing age. These changes can be used as important indicators in the forensic estimation of age.

Ethical approval

This study was approved by the Ethical Committee of the Hatay Mustafa Kemal University (decision date:September 03, 2024, decision number:32).

Author contributions

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

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