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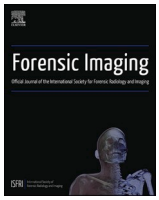

Third molar classification using Gleiser and Hunt system modified by Khöler in Russian adolescents – Age threshold of 14 and 16

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ABSTRACT

Objective: this study tested the applicability of Gleiser and Hunt dental staging system modified by Kohler (GHK) on third molar classification considering the age thresholds of legal interest of 14 and 16 years.
Design: 918 panoramic radiographs of Russian females and males aged between 8 and 23 years were collected. 3M development was classified based on the GHK technique. Ordinal logistic regression was used to test the performance of the technique to separate the Russian individuals as being under or over the age of 14 and 16. Receiver Operating Characteristic (ROC) curves with their respective area under the curve (AUC) were used to quantify the accuracy of the proposed research set up.
Results: AUC was 0.834 (± 0.021) and 0.858 (± 0.016) for separating individuals under of over 14 and 16 respectively (females and males combined).
Conclusion: The staging technique (GHK) had potential applicability to separate Russian adolescents as younger or older than 14 or 16 years. However, future study set ups with narrower age intervals must be designed to challenge the regression approach with a more difficult separation. Whenever applicable, techniques based on other developing permanent teeth (possibly for the age of 14) must be used.

1. Introduction

In Russia, the age of 16 represents the legal threshold for consent with sexual intercourse. The penalties for illegal sexual activity may increase if the victim is younger than 14 [1]. Forensic expertises related to these age limits are challenging because the techniques designed for children – based on crown-root development of the permanent teeth (except third molars) – increase their error over the time, especially due to the scarce teeth with incomplete apex formation [2-4]. By the age of 16, third molars are the only developing teeth [5]. In practice, these teeth may contribute not only to the process of age estimation regarding the ages of legal consent [6], but also throughout the early adulthood as a contribution to the assessment of legal majority [7, 8].

In 1994, Köhler et al. [9] modified a staging system proposed by Gleiser & Hunt [10]. The modified technique (GHK) predicted third molar development within stages of crown, root and apex formation, namely: ½ crown formation (stage 1), ¾ crown formation (stage 2), complete crown formation (stage 3), initial root formation (stage 4), ¼ root formation (stage 5), ½ root formation (stage 6), ¾ root formation (stage 7), complete root formation (stage 8), ½ apex formation (stage 9) and complete apex formation (stage 10). The technique was previously used in several populations worldwide, such as the Belgian one [11], but was never applied in Russian adolescents – scientific gap addressed in the present study.

By knowing the applicability of the technique among Russians, this study might support forensic dental practices not only in the original

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country (with casuistics related to age of consent) but also abroad when it comes to age estimation of undocumented Russians in clandestine migration. Based on the hypothesis that age is correlated with third molar development (and that it can be measured with GHK), this study aims to test the applicability of the GHK to separate Russian individuals under or over the ages of 14 and 16 years.

2. Materials and Methods

Ethical approval was obtained for an observational cross-sectional study (protocol: 5-11, SU). The Strengthening the Reporting of Observational Studies in Epidemiology) guidelines were followed [12].

2.1. Sample and variables

The sample consisted of panoramic radiographs of 551 females (60%) and 367 males (40%). The radiographs were acquired for therapeutic purposes and were retrospectively collected. The inclusion criteria were Russian individuals aged between 8 and 23 years, with available information about date of birth, date of radiographic acquisition and sex. Systemic diseases, visible bone lesions associated with any of the third molars, history of third molar extraction, therapeutic intervention in the third molars and low-quality images were the exclusion criteria. The eligibility criteria led to 918 images (Table 1). The images were imported to a computer (Vaio PCG- 71911X, Sony Corp.™, Minato, Tokyo, Japan). Adobe Photoshop CS6 (Adobe Inc.™, San Jose, CA, USA) was used for image visualization. A single examiner classified each third molar following GHK technique. GHK stages were tested for correlation with the chronological age and sex. The ages related to sexual consent (14 and 16 years) were used as reference to separate individuals under or over 14 and 16. In this context, age groups $<14/16$ years and $\geq 14/16$ years were established.

2.2. Examiner agreement

The main examiner revisited 100 images after a month to enable intra-examiner agreement testing. A second examiner was added to enable the inter-examiner agreement – in this process, the same 100 panoramic radiographs were analyzed by the second examiner and compared with the main examiner. The analyses were supervised by a third examiner. Agreement tests were calculated with Weighted Kappa for the upper right (#18), upper left (#28), lower left (#38) and lower right (#48) third molar (Dental coding following the International Dental Federation).

Table 1
Sample distribution based on sex and age

Age	F	M	F+M
8.00-8.99	14	22	36
9.00-9.99	8	18	26
10.00-10.99	29	26	55
11.00-11.99	36	26	62
12.00-12.99	32	32	64
13.00-13.99	36	38	74
14.00-14.99	46	30	76
15.00-15.99	42	20	62
16.00-16.99	44	32	76
17.00-17.99	38	22	60
18.00-18.99	36	18	54
19.00-19.99	32	13	45
20.00-20.99	31	24	55
21.00-21.99	54	19	73
22.00-22.99	51	17	68
23.00-23.99	22	10	32
Total	551	367	918

F: females; M: males

2.3. Statistical analysis

Descriptive statistics were quantified. Bivariate and multivariate inferential analyses were quantified next. Shapiro-Wilk tested the variables for normality. Pearson's Chi-square assessed the association of age and sex within the age groups, and between the quantity third molars between females and males. Spearman's coefficient tested the correlation of stages between third molars (statistical significance at $p < 0.01$). Ordinal logistic regression verified the predictive power of the staging system (GHK) to separate individuals under or over 14 and 16 years. An universal polytomous model (PLUM) was structured [13]. The model was established with proportional-odds and Logit function [14]. Model adjustment and homogeneity of the slopes were also assessed [15]. Receiver operating characteristic (ROC) curves calculated to compare individuals' age with the separation (under or over 14 and 16) predicted by the model. Statistics were performed with SPSS 20.0 software (IBM Corp.™, Armonk, NY, USA) and MedCalc 19.1.3 (MedCalc Software Ltd.™, Ostend, Belgium).

3. Results

Intra-examiner agreement was 0.96, 0.95, 0.96 and 0.96 for #18, 28, 38 and 48, respectively. The same teeth showed inter-examiner agreement of 0.95, 0.96, 0.96 and 0.95, respectively. Shapiro-Wilk revealed lack of normality for stage distribution.

Sample's mean age was 15.69 ± 4.24 years (median: 16 years; IIQ: 12 – 19 years; mean female: 16.3 ± 4.15 years, male: 14.77 ± 4.52 years). A total of 317 (34.5%) individuals were classified in the group <14 years, while 601 (65.5%) were ≥ 14. 455 (49.6%) individuals were aged <16 years and 463 (50.4%) were ≥ 16 (Table 2).

The individuals within the age groups of 14 and 16 (under and over) had statistically significant association of sex and age ($p < 0.001$) (Table 3). The number of available third molars was similar between females and males ($p = 0.865$).

The regression model revealed that tooth #48 was more significant to classify individuals under or over 14 ($p = 0.002$), while for the age threshold of 16, GHK stages for tooth #18 showed statistical significance ($p = 0.027$). The area under the curve reached 0.820 and 0.854, for the separation of Russian females under or over 14 and 16, respectively. For males, the AUC values were 0.855 and 0.866, respectively (Table 4).

Table 2
Distribution of individuals based on sex and age group, and distribution of quantity and arch position of the available third molars

Variables	n	%
Sex (n = 918)		
Female	551	60
Male	367	40
Age threshold of 14 (n = 918)		
	< 317	34.5
Age threshold of 16 (n= 918)	≥ 601	65.5
	< 455	49.6
	≥ 463	50.4
Available third molars per individual (n = 918)		
1	35	3.8
2	109	11.9
3	113	12.3
4	661	72.0
Quantity of third molar per position (n = 3053)		
#18	783	25.6
#28	800	26.2
#38	729	23.9
#48	741	24.3

N = absolute number of occurrences; % relative number of occurrences; #18: maxillary right third molar; #28: maxillary left third molar; #38: mandibular left third molar; #48 mandibular right third molar.

Table 3
Outcomes for testing the association between individuals' sex and age within the studied age groups of 14 and 16

Age groups	Sex				*p*
	Female		Male		
	N	%	n	%	
14 years					< 0.001*
<	155	28.1	162	44.1	
≥	396	71.9	205	55.9	
16 years	243	44.1	212	57.8	<0.001*
>	308	55.9	155	42.2	
≥					
Total	551	100.0	367	100.0	

Pearson's Chi-square test set with statistical significance of 5%.

Table 4
Outcomes of the ordinal logistic regression model based on its performance to predict the chronological age within each age group, for females and males combined, using GHK stages.

Age group	Predictors	Estimate	SE	Wald	OR	CI 95%	*p*
	GHK stages						
< 14 / ≥ 14 years	#18	0.38	0.25	2.25	1.46	0.89-2.38	0.134
< 16 / ≥ 16 years	#28	0.06	0.27	0.06	1.07	0.63-1.80	0.809
	#38	0.24	0.24	1.02	1.28	0.80-2.05	0.312
	#48	0.77	0.25	9.44	2.15	1.32-3.50	**0.002***
	#18	0.57	0.26	4.87	1.76	1.07-2.91	**0.027***
	#28	0.12	0.26	0.21	1.13	0.67-1.89	0.645
	#38	0.21	0.24	0.82	1.24	0.78-1.97	0.365
	#48	0.38	0.23	2.71	1.46	0.93-2.30	0.100

OR: odds ratio; CI: confidence interval; SE: standard error;
* $p < 0.05$. Age group (< 18 / ≥ 18 years): Model Fitting Information (-2 log-likelihood intercept only = 681.970; -2 log-likelihood intercept and covariates = 158.408); Pseudo R-Square (Cox and Snell = 0.570; Nagelkerke = 0.779; McFadden = 0.642).

Table 5
Outcomes of predictive accuracy for the use of third molar staging according to GHK technique.

Sex	Age	AUC ± SE	Sensitivity	Specificity	PPV	NPV
Females	< 14 / ≥ 14	0.820 ± 0.029	71.84%	91.37%	75.51%	89.75%
	< 16 / ≥ 16	0.854 ± 0.021	80.11%	89.74%	88.17%	82.55%
Males	< 14 / ≥ 14	0.855 ± 0.029	84.29%	87.57%	73.75%	93.08%
	< 16 / ≥ 16	0.866 ± 0.025	86.89%	87.18%	87.60%	86.44%

AUC = area under the curve; SE = standard error; PPV = positive predictive value; NPV = negative predictive value.

Sensitivity, specificity, positive predictive, and negative predictive values were reported in Table 5.

4. Discussion

At first sight, the GHK stages applied to the population of Russian individuals enabled proper classification based on the legal thresholds of 14 and 16 years. These outcomes are possibly explained by the AUC values that ranged above 0.8 for both sexes. Additionally, sensitivity and specificity, and positive/negative predictive values were above 70%. Classifications of AUC rates could interpret these values as, at least, acceptable [16]. From an overview, good performance was expected because most of the third molars were staged 10 among patients aged 19-23 years. This aspect of the sample makes the separation process less challenging. In other words, defining a third molar in stage 10 as being from an individual >14 is easier than defining the same for a third molar staged 5, for instance. In practice, dental age estimation may face straightforward questions from Magistrates, as "Is the victim under 14 or not?" In this context, narrowing the sample to an interval close the age threshold of interest could be interesting to propose a more challenging separation of individuals to the model. On the other hand, this set up could not reflect reality because individuals under dental age estimation have unknown/disputable age. For this reason, this study must be interpreted a preliminary contribution to the field of dental age estimation by showing that, in general, third molars may allocated individuals based on their stage of formation. However, additional parameters may be used to enhance age estimation from third molars.

A previous study [4], for instance, combined age information from permanent teeth and third molars in age intervals of overlapping dental development – namely 14-15.99 years. The authors observed a decrease in the mean error (difference between chronological and estimated dental age) of the method [4]. The staging systems combined in the study were GHK (for third molars) and Demirjian's et al. [2] – age calculated according to Willems' et al. [17], and the outcomes were only statistically significant for females [4]. This information may be relevant especially regarding the females victims of sexual violence during childhood. Age estimation, in this context, could benefit from combined age estimation techniques, especially because the interval between 14-15.99 includes the legal thresholds of sexual consent addressed in the present study (14 and 16 years). In a recent study, Platt et al. [18] revisited 498 reports of child sexual abuse and detected higher frequency of female victims (75.5%) specifically aged between 10 and 15 years (41.2%). These victims may need dental age estimation to indicate to the Court that a sexual crime affected someone under the age of consent.

By increasing the age threshold of legal interest to 16, the combination of third molars and permanent teeth may not be possible because in most individuals the permanent teeth have complete root formation. Consequently, the methods available for children fails to perform in adolescents [19]. Accordingly, a recent systematic literature review and meta-analysis [20] showed that a method based on developmental stages of permanent teeth had the worst performance exactly among individuals in the age group of 16. In this scenario, third molars remain the sole source of age information and the methods for subadults remain the useful ones [21]. In this case, the present study corroborates the scientific literature that estimates that third molars usually have ½ root formation around the age of 16 [22]. Specifically, tooth #18, for instance, was staged only eight times as ½ root formation in the age group of <14 years, while among individuals aged equal or above 16 it was staged 50 times. In practice, using specific stages as cut-off indicators is not a reliable procedures, especially because third molar have a broad spectrum of variability among persons. Instead, metric cut-offs (continuous data) appear to be proper indicators of age groups as previously pointed out in the scientific literature [23-25].

In this context, the teeth (#48 and #18) pointed out as proper predictors of age for the specific thresholds (14 and 16, respectively)

emerged as interesting data to be considered in future studies. Some of the methods based on metric assessments of teeth proposed the visualization and quantification of developmental information from single third molars, such as teeth #38 [26]. Investigating these methods in comparison with the teeth highlighted by the model of the present study.

These are original findings of the applicability of staging techniques for dental age estimation. Sampling was suboptimal due to heterogeneity of distribution within age intervals, which is justified based on the availability of images – as all the available panoramic radiographs were collected by convenience. The logistic regression does not require normality, but the outcomes must be carefully interpreted because the apparently optimistic predictive values could be more realistic with balanced samples. Future studies in the field should improve the sample distribution in order to allow comparisons between estimated and chronological ages within age intervals of one year.

5. Conclusions

To the best of our knowledge, GHK staging system was applied for the first time in the Russian population. For the first time, the technique was tested based on its performance on distinguishing individuals below or above the age thresholds of legal interest of 14 and 16 years. The thresholds are strongly associated with the Russian legislation behind sexual consent and penalties for those who act illegally. Application of the technique in practice, however, depend on later testing of the regression model in a more challenging sample (also through internal and external validation). At first sight, the performance of the research set up was optimistic, but the inherent sample characteristics rises a flag of caution and suggests the interpretation of these findings as preliminary in a broad scenario.

Declaration of Competing Interest

The authors declare that they have no conflict of interest related to this study.

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