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Age estimation through third molar analysis using the Kullman method among Brazilians

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ABSTRACT

Objective: : this study aimed to estimate age in individuals in a population, creating models for calculating age, the root development table made by Kullman and collaborators in 1992.
Material and methods: : five hundred panoramic radiographs of patients between 15 and 24 years old were used to verify whether there is a relationship between the steps described by Kullman *et al.* and the chronological age. At 17 years old, it was already possible to find lower third molars who completed their development process. A regression model was created to predict age based on the stage of the third molars at the exam.
Results: : the determination coefficients did not exceed 0,46, having a strong tendency to overestimate values.
Conclusion: : the use of the method as mentioned above is not recommended to estimate the age in the studied population, taking into account their peculiarities, such as the variation of years found for the average age calculated for each of the groups and their stages, and it should not be applied alone as a predictor of age.

Introduction

Age estimation plays a fundamental role in different situations and contexts. It is possible to verify the use of different methodologies to estimate chronological age in humans, as in demand created by the growing number of undocumented illegal immigrants seeking asylum or child pornography, increasingly disseminated in media such as the internet[1,2]. Because of its importance to justice and searching for truth, it can be essential to resolve different lawsuits [3].

Dentists usually have easy access to imaging exams, especially radiographs, the main instrument in the investigation of age. They are not invasive exams, generally simple to be accessed and interpreted by a specialist, and easily reproducible in both living and dead individuals [4].

Several aspects can be taken into account to establish a standard of radiographic analysis for the age estimate, according to the age group that is being dealt with, being able to have from analysis of prenatal maxillary bones and the initial mineralization of the central incisors during the sixteenth week of intrauterine life [5] until the development and topography of the third molars, the last teeth to develop in humans [4].

When evaluating a case in which the individual's age is the main problem, one must then look for variables that undergo some differentiation throughout their development and are familiar to people of that age. Therefore, methodologies that focus on the evolution of third molars, a tooth closely related to the transition from adolescence to adulthood, may be relevant in analyzing panoramic radiographs of young adults and the estimation of age[6].

In 1992, Kullman et al. investigated whether the lower third molars can be used to estimate an individual's age. For this purpose, they elaborated a table that classifies these teeth in seven stages of root development and applied this method of classification in 630 panoramic

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radiographs of young people between fifteen and twenty-five years old, finding an accuracy error between ±1.9 to 3.9 years about the average age predicted for the stage of each tooth [7].

One of the advantages attributed to the development stages elaborated by Kullman is that they do not depend on the tooth eruption, so that his technique can be applied [8]. Just as it does not depend on the analysis of adjacent structures, as in the case of Olze et al. (2007) and AlQatahni et al. (2005), responsible for creating the London Atlas of human tooth development and eruption, in which tooth eruption and its position in the occlusal plane are observed along with its maturation [9, 10], the need for this observation can bring some obstacles to the analysis, as in the case of impacted teeth.

Besides, it is also conceivable to see as an advantage that a method has a greater number of stages available for comparison and classification as it increases the chances of the observed element being in an intermediate stage to those who wish to classify it [11]. For example, we can compare the methods of Nolla (1960) and Nicodemo (1969), which are widely applied today and provide only four stages of root development, against the seven studied by Kullman.

Since this method may bring reliable and optimized results, this study aimed to verify if the root development table developed by Kullman can be used to estimate the age of individuals in a Brazilian population through age calculation models, helping the courts solve some of their legal disputes.

Material and methods

A convenience sampling was performed for this study: five hundred panoramic radiographs were randomly selected from the image files of two schools of dentistry to obtain equal numbers of radiographs for each age and in both sexes. The use of the radiographs analyzed in this study was authorized by the Research Ethics Committees of the Dental Schools in the cities of Ribeirão Preto (18746619.0.0000.5440) and Bauru (18746619.0.3002.5417).

There were included in the sample panoramic radiographs with good image quality, from Brazilian patients with known age and sex, between 15 and 24 years old at the time of the exam. These orthopantomogram are single images that show the mandible, maxilla and teeth; the patients were radiographed with the Frankfurt's horizontal line perpendicular to the floor.

At least one of the lower third molars should be present without pathological evidence. Radiographs that did not have lower third molars or where it was not possible to observe the third molar with sufficient precision because of poor image quality or overlapping structures were excluded along with elements that had extensive lesions. As the eruption of the dental element was not taken into account, impacted teeth or odd dental positions were not excluded from the sample.

Each panoramic radiograph belonged to a patient who underwent examination at one of the schools of dentistry participating in the study or who provided the images through a private orthodontic documentation service at the request of a dentist. They were obtained using extraoral radiography equipment that produces an image in norma frontalis, in which it is possible to observe all the bone structures and other hard tissues of the lower third of the face with the aid of a standard computer monitor that provides these radiographs in image files (.JPEG) that can be opened with Windows Image Viewer® (Microsoft, USA).

Their lower third molars were classified according to the root development scale developed by Kullman. The responsible evaluator was a dental surgeon with a post-graduate degree in forensic dentistry and did not know the identity and age of the radiographs analyzed after the randomization of the images performed by a third person. About twenty-five teeth were analyzed per day and categorized according to their root development according to Table 1 adapted from Kullman's original article.

Data were organized in Microsoft Excel® spreadsheets (Microsoft, USA) and statistically analyzed using R software version 3.6.1 (R Foundation for Statistical Computing) and SPSS version 26.0 (IBM Corporation, USA). An observational cross-sectional study was performed.

Table 1
Classification of the different stages of root development of lower third molars

Ri-R¼ or 1	root development has already started, but less than a quarter of the estimated root length has already developed
R¼-R½ or 2	a quarter or more of the estimated length of the root has already developed but has not reached half of its total length
R½-R¾ or 3	half or more of the estimated length of the root has already developed but has not reached three-quarters of its total length
R¾-Rc or 4	three quarters or more of its root length has already developed but has not yet reached its full length
Rc-Aci or 5	the estimated total root length has already developed, but the closure of its apex has not yet started
Aci-Ac or 6	closure of its root apex has already begun but has not yet reached its end
Ac or 7	apex is entirely closed; root development is complete

To assess intra-rater reliability one hundred radiographs were analyzed and the kappa coefficient level was obtained. The evaluator performed the observation and initial classification of these exams, and after fifteen days, the same images were observed and classified by the same individual. An inter-rater agreement was performed between the evaluator responsible for the study and another expert in legal dentistry considered the gold standard.

Cronbach's alpha coefficient test was applied to compare whether the levels of development of teeth 38 and 48 were similar. A regression model was created to estimate the age of individuals based on the development of their lower third molars at the time of the exam.

Results

The kappa coefficient level for intra-rater reliability was 0.969, and the inter-rater agreement was 0.897. The evaluator was able to reproduce the analysis previously performed on the same sample after the described period and obtain the same classifications obtained in the first observation, thus demonstrating uniformity between both results and the due calibration of the observer.

It was noted that almost half (48,9%) of the elements were in stage 7, while the smallest number was categorized as stage 3. The distribution among the stages of development is seen in Table 2.

Fig. 1 shows the age variation in each development stage, their medians (black line inside the boxes), the first and third quartiles (represented by the gray boxes), upper and lower limits obtained, and outliers.

For both sexes, the levels of development of teeth 38 and 48 were similar: when comparing them in a paired way, there was correspondence between the classifications for both teeth, for each individual, with Cronbach's alpha coefficients of 0.974 in females and 0.891 in males. This analysis implies that, in the absence of one of the teeth, the opposite analog can be used to estimate age.

The analysis of the method for estimating age in the sample generated individual models with coefficients of determination (R^2) that varied from 30.86% to 45.68% for each of the lower molars and both sexes.

The analysis of the Kullman method for age estimation generated adjusted models for the entire sample and the male only. The female could not obtain an adjusted prediction model since when the model is evaluated, one of the teeth does not have a p-value below 0.05, again resulting in a univariate model. For the general sample and the male, it was possible to adjust a model containing the classifications of the two dental elements. For all analyzes, a significance level of 5% was adopted.

The correction factors and the parameters of the estimate were calculated, and the formulas obtained for estimating the mean age of which group are shown in Tables 3 and 4, in which the abbreviations LLTM (Lower Left Third Molar) and LRTM (Lower Right Third Molar)

Table 2
Total number of teeth classified in each stage and distribution of these numbers between, per tooth and age

Stage	Number of teeth														
	Total	By sex		By teeth		By age									
		Female	Male	38	48	15	16	17	18	19	20	21	22	23	24
1	63	37	26	32	31	41	12	5	2	1	2	0	0	0	0
2	53	36	17	26	27	27	7	7	4	4	0	3	1	0	0
3	50	42	8	26	24	6	14	10	6	5	3	2	2	2	0
4	51	32	19	26	25	7	18	9	4	2	6	1	4	0	0
5	121	54	67	54	67	15	28	21	18	18	10	6	3	2	0
6	170	87	83	82	88	2	15	29	21	23	10	19	15	20	10
7	485	210	275	251	234	0	0	19	45	46	63	69	75	73	89
Total	993	498	495	497	496	98	94	100	100	99	94	100	100	97	99

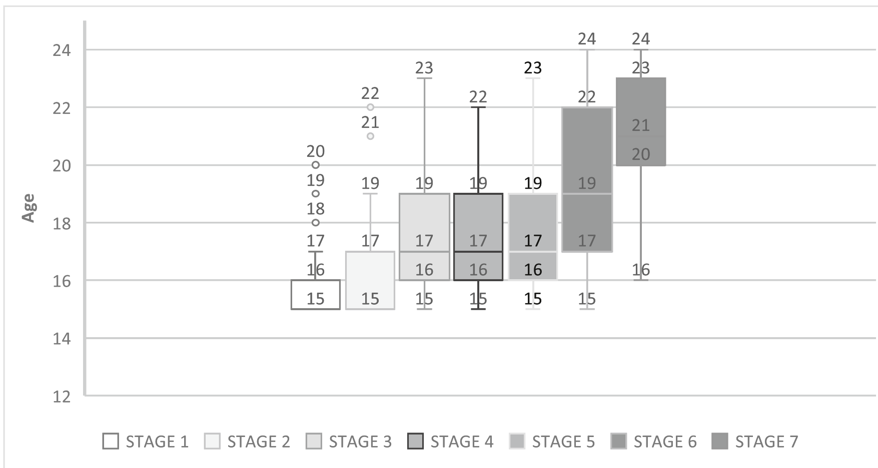

Fig. 1. Age variation found in each of the stages for the sample used in the study.

Table 3
Description of variables used and equations obtained in regression models for age prediction using one tooth (unadjusted models).

Unadjusted Models	Variable	Components	p-value	b	Error	R[2]
Whole sample	**38 (LLTM)**	**Intercept**	<0,001	14,43	2,27	37,68%
		Tooth 38	<0,001	0,91		
		Correction factor	Age = 14,43 + 0,91*LLTM + 2,27			
	48 (LRTM)	**Intercept**	<0,001	14,49	2,28	36,61%
		Tooth 48	<0,001	0,89		
		Correction factor	Age = 14,49 + 0,89*LRTM + 2,28			
Men	**38 (LLTM)**	**Intercept**	<0,001	14,09	2,39	30,86%
		Tooth 38	<0,001	0,91		
		Correction factor	Age = 14,09 + 0,91*LLTM + 2,39			
	48 (LRTM)	**Intercept**	<0,001	14,34	2,39	31,03%
		Tooth 48	<0,001	0,89		
		Correction factor	Age = 14,34 + 0,89*LRTM + 2,39			
Women	**38 (LLTM)**	**Intercept**	<0,001	14,61	2,15	44,21%
		Tooth 38	<0,001	0,93		
		Correction factor	Age = 14,61 + 0,93*LLTM + 2,15			
	48 (LRTM)	**Intercept**	<0,001	14,39	2,12	45,68%
		Tooth 48	<0,001	0,97		
		Correction factor	Age = 14,39 + 0,97*LRTM + 2,12			

b = estimator. R^2 = coefficient of determination. Significance level = 5%.

indicate the stage of development of these teeth.

For the adjusted estimate, the determination coefficients (R^2) varied from 34.08% for males and 39.25% for females. The equation models

Table 4
Description of variables used and equations obtained in regression models for age prediction using both teeth (adjusted models).

Adjusted Models	Components	p-value	b	Error	R^2
Whole Sample	**Intercept**	<0,001	14,16	2,24	39,25%
	Tooth 38 (LLTM)	<0,001	0,54		
	Tooth 48 (LRTM)	<0,001	0,42		
	Correction factor	Age = 14,16 + 0,54*LLTM + 0,42*LRTM + 2,24			
Men	**Intercept**	<0,001	13,65	2,33	34,08%
	Tooth 38 (LLTM)	<0,001	0,50		
	Tooth 48 (LRTM)	<0,001	0,49		
	Correction factor	Age = 13,65 + 0,50*LLTM + 0,49*LRTM + 2,33			

b = estimator. R^2 = coefficient of determination. Significance level = 5%.

obtained from this analysis are described in Tables 5 and 6.

The models were applied to the teeth in the sample to observe the success rate of the methodology in the studied population. Then their result was compared with the actual age of the individual in question. The correct response rates (actual age corresponds to the range of years estimated in the equation) in both models are shown in Tables 7 and 8.

Discussion

The application of the root development table elaborated by Kullman to estimate the age among Brazilians through the lower third molars did not bring the desired results in an age estimation method. Applying an equation model to predict the age range to which the individual belonged tends to overestimate results, which can be harmful if applied to legal cases. A qualitative analysis of the data obtained was performed.

When compared to the results obtained by Kullman in 1992, we have

Table 5
Equations found for each of the stages proposed by Kullman in the sample, for both teeth, in unadjusted models.

Group	Tooth	Age Range Minimum age	Maximum age
Whole sample	**38**	Age=14,43 + 0,91*LLTM	Age=14,43 + 0,91*LLTM+4,54
	48	Age=14,49 + 0,89*LRTM	Age=14,49 + 0,89*LRTM + 4,56
Male	**38**	Age=14,09 + 0,91*LLTM	Age=14,09 + 0,91*LLTM + 4,78
	48	Age=14,34 + 0,89*LRTM	Age=14,34 + 0,89*LRTM + 4,78
Female	**38**	Age=14,61 + 0,93*LLTM	Age=14,61 + 0,93*LLTM + 4,30
	48	Age = 14,39 + 0,97*LRTM	Age = 14,39 + 0,97*LRTM + 4,24

Table 6
Equations found for each of the stages proposed by Kullman in the sample in adjusted models.

Group	Age Range Minimum age	Maximum age
Whole sample	Age=14,16 + 0,54*LLTM+ 0,42*LRTM	Age=14,16 + 0,54*LLTM+ 0,42*LRTM + 4,48
Male	Age=13,65 + 0,50*LLTM+ 0,49*LRTM	Age=13,65 + 0,50*LLTM+ 0,49*LRTM + 4,66

Table 7
Rate of correct responses of the models applied to the sample used in the present study.

Unadjusted Models			Adjusted Models
	Tooth 38	Tooth 48	
Male	64%	63,4%	64,9%
Female	59%	59,4%	
Whole sample	65%	66,9%	66,8%

that the Brazilian sample does not benefit from its development table since its R^2 determination indices do not exceed 0.457 (45.7%).

By applying each of the correction factors obtained in the present study to the population of subjects that are part of the sample, it was found that in female cases in unadjusted models, the average correctness rates for age were slightly below 60%. However, significantly higher numbers were not found in the other models applied, not exceeding a correspondence rate greater than 67%. However, these numbers may be inflated, since when comparing the results by age group, it was noted that the highest rates are found from the age of 20, reaching up to 100% correct answers in some cases, against 8% found in younger age groups, such as 17 years old: this situation shows how the application of the method does not produce reliable results in the most crucial age groups for the age estimate.

The high success rate among individuals over twenty years of age can be explained by the fact that, in this age group, third molars are usually more developed, tending to suffer fewer development variations [12]. The exclusion of radiographs with problematic images, which did not fit the inclusion criteria, led to more accurate results in all stages.

Some authors have also studied and suggested a different approach to the classic regression model used here, and which has been used in several age estimation studies [13,14]; some analyses have shown that a Bayesian approach can bring more significant discrimination concerning the fact that the individual is already over 18 years of age, although it does not outperform the more classic approaches to age estimation [15]

Situations that require exact results cannot have a large window of possible responses or high rates of overestimation of age (like Kullman's method in the Brazilian sample), as in the case where an individual had to prove that he had not reached the legal age of majority (eighteen in Brazil). This fact could imply his imprisonment in an ordinary prison in a criminal case, and his civil documents had his birth date wrong. As this case requires precise results, more than one method was used, combining dental analysis through several parameters with carpal bone analysis [16].

The age range in years found by Kullman in the original research in each of the stages was approximated to that found here, which ranged between 0.96 and 5.15 years (mean ± 3.1), against 1.9 and 3.9 years (mean ± 2) shown in their original study. The age range found for each stage of application of the models was 4.5 years; between the youngest and the oldest age found, there is an interval of more than four years in all cases; this is not a high value, but it is not a desirable value when talking about age estimation in court cases, for example.

No teeth analyzed had reached the final stage at 15 or 16 years of age. By age 17, one-fifth of the elements of that age had already finished their development. After 20 years old, all lower third molars were past the initial stage of root development (the root began its growth process but did not reach the first quarter of its estimated total length). This number is equivalent to 6.5% of teeth belonging to minors that belong to the sample. Before completing 24 years, approximately 40% of the roots would have reached the apex closure.

The minimum age of 17 years for full maturation of third molars found in this analysis coincides with data found in another study carried out in a similar population in 2012 when applying the methodology developed by Demirjian, who prepared a table with eight stages of maturation evolution for the observed tooth [17].

The Third Molar Maturation Index developed by Cameriere et al. (2008) was applied to panoramic radiographs of patients from a radiology clinic in northeastern Brazil in 2019 to assess its performance as an age estimator and predictor of legal age, and it was possible to verify a high accuracy of the method (80.8%) and absence of significant differences in the development of third molars between the sexes, but with better results among men [18].

In 2018, Brazilian third molars were also tested for age estimation using the methods of Nolla (1960), Dermijian (1973), and Nicodemo,

Table 8
Rate of correct responses by age of the models applied to the sample used in the present study.

Unadjusted Models							Adjusted Models	
	Whole sample		Male		Female		Whole Sample	Male
Real age (in Years)	Tooth 38	Tooth 48	Tooth 38	Tooth 48	Tooth 38	Tooth 48		
15	41,7%	41,7%	58,3%	33,3%	43,5%	47,8%	46,9%	60%
16	16%	22%	28%	28%	16%	16%	22%	28%
17	24%	20%	8%	8%	48%	40%	24%	8%
18	32,7%	36%	16%	20%	32%	24%	32%	16%
19	48%	59,2%	32%	45,8%	32%	44%	49%	37,5%
20	94%	98%	100%	100%	92%	40%	100%	100%
21	94%	96%	100%	100%	100%	96%	96%	100%
22	98%	92%	100%	100%	100%	88%	100%	100%
23	96%	95,9%	100%	100%	100%	96%	96%	100%
24	98%	100%	100%	100%	100%	100%	100%	100%

Moraes and Médici Filho (1974), which, despite bringing good results, showed a tendency of males to finish the development of this tooth faster when compared to females, in addition to the possible influence of factors such as location and socioeconomic status of the individual on teeth maturation [14].

It is clear the need for validation and use of correction factors for the application of age estimation methodologies in different populations, as well as for the dental element to be used in the investigation since studies comparing the development of third molars in different populations show that there are differences in the speed of maturation of these dental elements in different countries [19,20]

There is no consensus on what values are necessary to obtain in the application statistics of a methodology so that it is validated and accepted as a standard, and it is not possible to determine when an error rate is unacceptable. One should seek to increase the quality of the developed techniques, assessing the applicability of the method in a specific population and adequate statistical evaluation, seeking to reduce biases and possible errors, paying attention to possible influencing factors [21]. When it comes to observation methods, it is recommended that the evaluator apply more than one estimation technique validated in the population in question and may even combine techniques from Forensic Anthropology with Dentistry to obtain more accurate results [11,22]

Conclusion

Despite bringing a correlation between age and stage of root development of third molars, the Kullman method, when applied to the Brazilian population, does not provide reliable numbers of correct results in age prediction; in spite of it, the method can be used as an auxiliary in estimating the age group, thus helping to solve various legal problems.

Declaration of Competing Interest

None.

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None

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