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Evaluating legal age of 18 years through observation of third molars using Gambier et al. method in an orthopantomographic sample of subadults from South India

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ABSTRACT

In forensic practice, medicolegal physicians are often tasked with estimating age using dental evidence. This calls for an uncomplicated, reliable, and reproducible method for dental age estimation, enabling physicians to proceed without specific odontological expertise. Among various dental methods, third molar eruption analyses are less complicated and easier to perform. In our study, we explored the effectiveness of Gambier et al.'s scoring system, which examines the eruption of all third molars. We retrospectively analysed 1032 orthopantomograms (528 males and 504 females) of individuals aged between 15 and 24 years. The mean chronological age increased with the progression of stages (1 to 3) and phases (A to D) of the third molar eruption for both sexes. In terms of stages, none showed significant discrimination between minors (<18 years) and adults (>18 years), especially for males. However, Gambier's phase D displayed a relatively high likelihood of being 18 years or older, with an overall 85.9 % of males and 95.7 % of females having all third molars in stage 3 being 18 years or older. While the tested method could be helpful in indicating the completion of the 18th year of life, caution is advised (due to a high percentage of false positives), and it should be used alongside other age assessment methods by experts.

1. Introduction

Evaluating growth and development in children and adolescents for age estimation is common, particularly in civil and criminal proceedings. This need is particularly prominent in cases involving young adult delinquents, young immigrants, and refugees seeking political asylum [1]. Often, individuals may be unaware of their exact age or lack documentation to verify their identity and age. Additionally, some may intentionally falsify documents to misrepresent their age. Regardless of the reasons, age assessments are crucial in ensuring appropriate actions are taken for these individuals [2]. Various maturation indicators, including hard tissues, sexual maturity, and physical characteristics, have been examined for age determination in children and adolescents [3]. Notably, the development and degenerative changes within teeth are widely used for age estimation due to their resilience to systematic influences such as nutritional status, environmental factors, and diseases [4–6].

A wide range of specialists, such as forensic physicians, anthropologists, odontologists, and radiologists, are commonly asked to provide expertise on age assessments for legal purposes. The legal system often

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requires prompt decisions on age assessments, leading to situations where forensic physicians may not have the opportunity to seek specific odontological advice when presented with dental radiographic images [1,7]. Consequently, medico-legal physicians have endeavoured to establish a straightforward and replicable method for assessing dental age or establishing legal age thresholds.

Several dental age estimation methods are available in the literature, with Demirjian's and Cameriere's methods emerging as the most reliable for assessing dental age in children and young adults [8,9]. However, these techniques necessitate the use of panoramic radiographs for age estimation, a procedure that lacks therapeutic benefits. Also, informed consent becomes a concern, particularly if a child feels pressured to agree to a radiograph. Age assessment should only be conducted with the explicit informed consent of the individual. Any decision to decline participation in age assessment should not result in adverse consequences affecting the individual's asylum, immigration, or any other application [10,11]. Moreover, the debate surrounding the potential harm inflicted by radiation exposure raises ethical considerations, with some arguing that it may violate legal principles [12]. Critics also question the justification for exposing individuals to radiation, emphasising the importance of accurate dental mineralisation methods to validate such procedures. However, conflicting results have emerged from evaluations of the accuracy of these methods [13]. Given the intricacies of development and maturation techniques and the need for simple and duplicable approaches, especially in scenarios where swift decisions are required for legal reasons without access to dental expertise, examining a straightforward parameter like the chronological course of third molar eruption becomes a viable alternative.

There are two approaches to determining the eruption of the third molar; through clinical examination [12,14] and/ or assessment of dental X-rays [15,16]. In 2017, Gambier et al. [17] utilised a database from a French University Hospital and introduced a novel method centered on mandibular and maxillary third molar eruption, asserting its user-friendly application in daily clinical settings, particularly for non-odontologically trained physicians. Despite its introduction, this method has not undergone comprehensive examination in diverse populations, warranting exploration due to its potential utility in forensic age estimation, even without specialised training. Hence, the aim of this study is to assess the suitability of Gambier's method in a sample of South Indian sub-adults as a valuable contributor to determining dental age. Based on the findings, our objective is to evaluate the stages and phases of Gambier's method for the assessment of whether an individual has attained 18 years.

2. Materials and methodology

2.1. Materials

We analysed panoramic radiographs (OPGs) from 1032 individuals (528 males and 504 females) aged 14 to 25 years. These radiographs were captured between 2014 and 2019. The study population primarily consisted of individuals of southern Indian descent hailing from the states of Andhra Pradesh, Telangana, Tamilnadu, Karnataka, and Kerala. These individuals were selected from archived consecutive orthodontic patient records spanning a 6-year period from January 2015 to December 2020. The data exclusively came from private dental practitioners, with a predominant source being orthodontists. These OPGs were primarily taken for orthodontic treatment purposes. Inclusion criteria encompassed high-quality OPGs, featuring all four third molars in intact condition. Exclusion criteria involved OPGs displaying tumors, surgical materials, mandibular or maxillary fractures, gross pathology, history of orthodontic treatment, or signs of infection in the third molar regions. Additionally, OPGs of poor quality that hindered accurate interpretation or unclear radiographs with radiographic distortion, individuals with a history of third molar extraction, those with primary retained third molars, and cases of third molar agenesis were also excluded from the analysis. None of the X-rays were taken exclusively for this research. The outlined investigation protocol received approval from the Ethics Committee of Sechenov First Moscow State Medical University, Moscow, Russia (approval number 24-23 dated 07/12/2023).

2.2. Data management

The numbering of all third molars followed the two-digit system of FDI (Federation Dentaire Internationale, a convention of the World Dental Federation): 18 for the right upper third molar, 28 for the left upper third molar, 38 for the left lower third molar, and 48 for the right lower third molar [18]. All pertinent information, including identification numbers, dates of birth, and radiograph capture dates, was documented in a Microsoft Excel spreadsheet. Prior to analysis, the data was anonymized. Dates of birth and radiological examinations were accessible for all cases. To determine each subject's chronological age (CA), we subtracted the date of the X-rays from their date of birth and then converted the result into decimal ages. The study was carried out under the ethical standards laid down by the Declaration of Helsinki (Finland) and its later amendments [19].

2.3. Methodology- Gambier et al. Staging system

Gambier et al. method is a three-stage scoring system [17]. In stage 1, the follicle is intact, the cusps of the third molar are under the alveolar bone, and the tooth has not erupted. In stage 2, the follicle is disrupted, and the tooth has begun to erupt, indicating that one or more cusps have broken the alveolar bone. In stage 3, the third molar is erupted and reaches the occlusal plane.

In cases where OPGs featured four evaluable third molars, Gambier et al. delineated four phases, which are outlined below: Phase A: All four third molars classified as stage 1; Phase B: At least one third molar classified as stage 2; Phase C: At least one third molar classified as stage 3; and Phase D: All four third molars classified as stage 3.

2.4. Image analysis and Intra-and-Inter-observer assessment

Each OPG was analysed by a forensic odontologist (SBB) with nearly ten years of experience in dental age assessment. The utilisation of unique numbering for each OPG facilitated a randomised and blinded examination process. To evaluate inter-examiner variability, a second examiner (APM) who is specialised in dentistry (public health dentist) and possesses three years of experience in dental age assessment, conducted an additional assessment of the selected OPGs. Additionally, a subset of 100 OPGs was randomly selected for re-evaluation by the first examiner (SBB) after a two-month interval to gauge intra-examiner variability. The findings presented in the study correspond to the initial assessment conducted by the first examiner (SBB).

2.5. Statistical analysis

The data were analysed using IBM SPSS version 29.0 (SPSS Inc., Chicago, IL, USA). Intra- and inter-examiner agreement was determined through Cohen's kappa statistics. The initial analysis involved descriptive analysis, presenting characteristics of each stage and phase in the Gambier et al. third molar eruption. Mean, standard deviation (SD), median, lower and upper quartiles, as well as the range of minimum and maximum age values were reported. A Student *t*-test was conducted to compare mean age based on stages of third molar eruption and to examine intersexual differences. A chi-square test assessed the association between age ($</\geq 18$ years) and phase attainment. Subgroup analysis for the completion of the 18th year of life, considering age and Gambier et al. phases of the third molar eruption, was performed using chi-square with Bonferroni correction to address multiple comparisons between the two age groups and the four phases of the eruption. The

Table 1
Age and Gender distribution of the sample.

Age groups	Males	Females	Total
14–14.9	48	36	84
15–15.9	44	32	76
16–16.9	44	44	88
17–17.9	48	44	92
18–18.9	48	52	100
19–19.9	48	48	96
20–20.9	48	52	100
21–21.9	48	48	96
22–22.9	56	52	108
23–23.9	48	48	96
24–24.9	48	48	96
Total	**528**	**504**	**1032**

significance level was set at 5 % ($p < 0.05$).

3. Results

Table 1 shows the distribution of the overall sample by age and sex. Repeated scoring by the same examiner (intraexaminer) revealed a very high agreement (Cohen's kappa 0.94; 95 % CI of 0.92–0.97), while inter-examiner agreement was 0.92 (95 % CI of 0.89–0.94), respectively.

Tables 2 and Fig. 1 summarise the descriptive statistics of third molars from all four quadrants. The mean age for stage 1 for all third molars ranged from 15.37 to 15.92 years for males and 16.13 to 16.81 years for females. For stage 2, the mean age ranged from 18.52 to 20.41 years for males and 19.57 to 20.33 years for females. For stage 3, the mean age ranged from 20.64 to 20.93 years for males and 21.28 to 21.76 years for females, respectively.

Table 3 indicates no statistically significant differences between males and females for each third molar based on Gambier et al. eruption stages. Nevertheless, significant differences were observed in stage 3 of the upper left third molar (FDI 28) and in stage 2 of the lower right third molar (FDI 48). Furthermore, our study results highlight significant differences in mean age across eruption stages for each third molar and for both sexes, as presented in Table 4.

Table 5 and Fig. 2 shows the descriptive statistics for each phase by sex. There was an increase in the mean chronological age from phase A to phase D seen for both sexes. The mean chronological age of the two sexes varied between males and females for phase A between 15.69 and 15.86 years. For phase B, the mean age ranged between 17.65 and 19.61 years. For phase C, the mean age was between 19.52 and 20.4 years; for phase D, it was between 21.16 and 21.75 years, respectively.

Table 6 outlines the association between age (</≥18 years) and the stage of eruption of all third molars across both sexes. Individuals falling under the stage 1 classification of third molar eruption included 76.5 % to 84 % of males and 72.7 % to 82.1 % of females, all of whom were determined to be younger than 18 years. Conversely, those classified as stage 3 included 65.2 % to 78.9 % of males and 88.9 % to 94.5 % of females who were found to be older than 18 years.

Table 7 illustrates the association between age (</≥18 years) and the phases of eruption for both sexes. In males, phase A was seen in 28.6 % of males and 4.5 % of females who were above 18 years, while phase D was already present in 14.1 % of males and 4.3 % of females who were below 18 years.

Table 2
Descriptive statistics of chronological age according to sex and Gambier et al. eruption stages of all third molars (FDI notation).

Upper right third molar (FDI 18)								
Males								
	n	**Mean**	**SD**	**Min**	**Max**	**Median**	**LQ**	**UQ**
Stage 1	68	15.92	1.35	14.21	18.66	15.57	14.91	16.43
Stage 2	188	19.23	3.08	14.17	23.9	18.9	16.44	23.07
Stage 3	272	20.75	2.87	14.06	24.87	21.5	18.97	22.78
Females								
Stage 1	128	16.69	2.29	14.03	22.65	16.1	14.83	18.13
Stage 2	180	20.14	2.71	15.63	25	20.4	17.69	21.87
Stage 3	196	21.53	2.28	15.29	24.77	22.19	19.49	23.46
Upper left third molar (FDI 28)								
Males								
Stage 1	68	15.92	1.35	14.21	18.66	15.57	14.91	16.43
Stage 2	188	19.23	3.08	14.17	23.9	18.9	16.44	23.07
Stage 3	272	20.75	2.87	14.06	24.87	21.5	18.97	22.78
Females								
Stage 1	132	16.81	2.24	14.03	22.65	16.1	14.98	18.32
Stage 2	152	19.57	2.56	14.8	24.51	19.85	17.26	21.64
Stage 3	220	21.76	2.29	15.29	25	22.45	20.19	23.54
Lower left third molar (FDI 38)								
Males								
Stage 1	100	15.39	1.34	14.06	18.66	15.14	14.26	15.99
Stage 2	124	20.41	3.1	15.01	23.9	20.17	16.98	23.41
Stage 3	304	20.64	2.55	15.01	24.87	20.98	18.53	22.66
Females								
Stage 1	112	16.13	1.66	14.03	19.29	15.62	14.77	17.57
Stage 2	176	20.33	2.59	15.88	25	20.22	18.1	22.3
Stage 3	216	21.28	2.47	15.29	24.77	21.7	19.46	23.44
Lower right third molar (FDI 48)								
Males								
Stage 1	96	15.37	1.37	14.06	18.66	15.02	14.23	16.04
Stage 2	72	18.52	2.14	15.01	20.76	19.91	16.13	20.14
Stage 3	360	20.93	2.63	15.01	24.87	21.53	18.7	23.16
Females								
Stage 1	120	16.19	1.65	14.03	19.29	15.75	14.79	17.68
Stage 2	160	20.08	2.28	16.26	24.51	19.94	17.86	21.81
Stage 3	224	21.55	2.51	15.29	25	22.19	19.66	23.52

Min Minimum age; *Max* Maximum age; *LQ* Lower quartile; *UQ* Upper quartile; *SD* Standard deviation

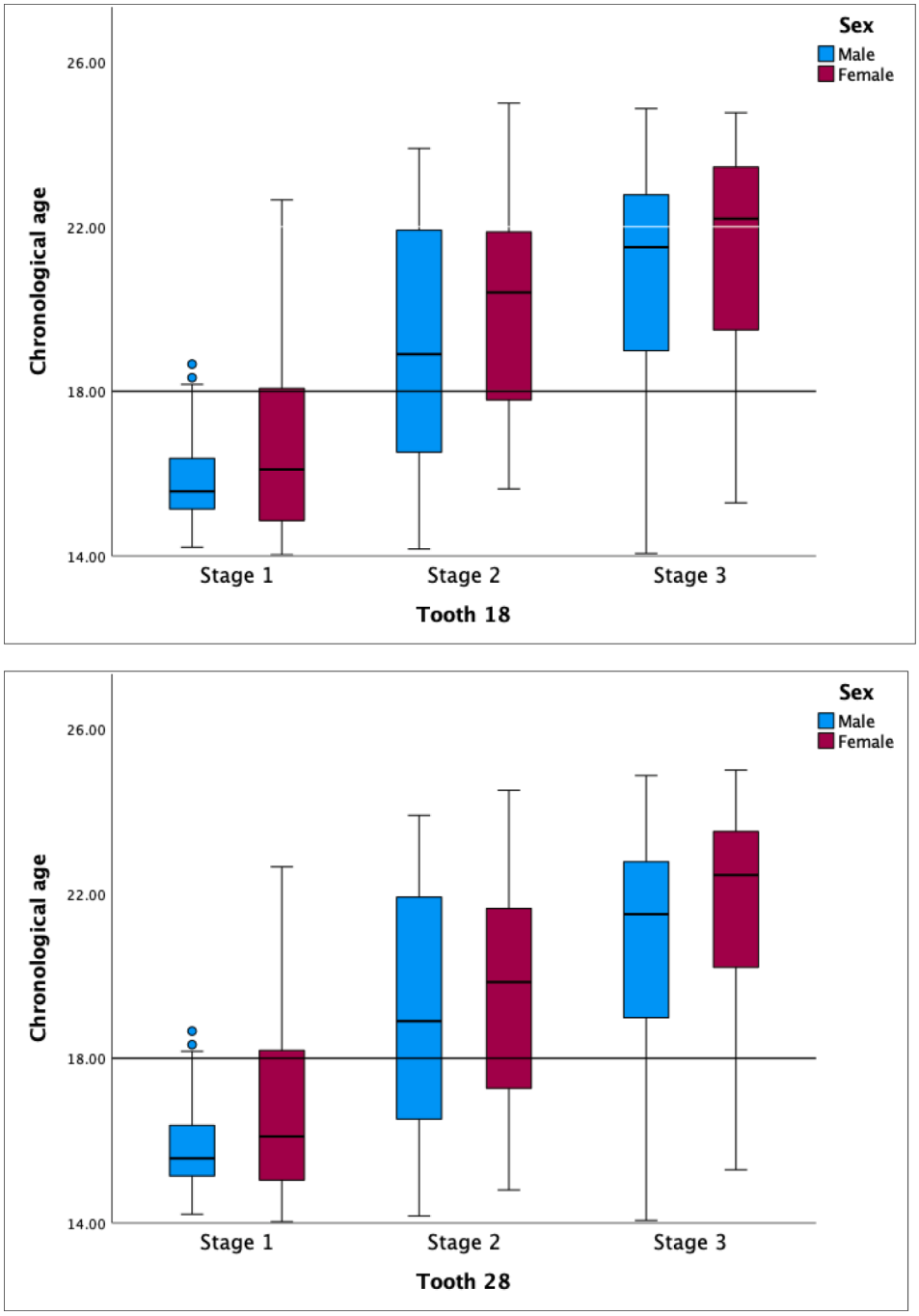

Fig. 1. Box-plot graphical representation of age distribution for each third molar for males and females.

4. Discussion

Research into third molars continues to be a center of attention in medicolegal/ forensic investigations, particularly for dental age estimation, as they are the only teeth that exhibit ongoing development during late adolescence [20]. The assessment of dental age using third molars can be approached through two distinct perspectives: the analysis of third molar development and the evaluation of their eruption stage. In the present investigation, our focus was on evaluating the scoring system recently proposed by Gambier et al. [17] In the initial investigation, the researchers examined a group of 557 French individuals (340 males and 217 females), emphasising the unique characteristics of the scoring system and underscoring its simplicity, characterised by a minimal number of stages. They assert that this scoring system is particularly well-suited for medicolegal physicians who may not possess specialised expertise in forensic odontology. Additionally, the appeal of using the clinical examination of third molars, specifically assessing whether they have reached the occlusal plane, lies in its practicality and the advantage of minimal radiation exposure in non-therapeutic procedures for forensic age estimation.

In the original study, Gambier et al. [17] asserted that individuals with all third molars in phase D exhibit a relatively high likelihood of being 18 years or older. Our study's outcomes revealed that 85.9 % of males (220 out of 256) and 95.7 % of females (176 out of 184) categorized as phase D were indeed 18 years or older. Conversely, 14.1 % of males and 4.3 % of females with phase D were below 18. These results

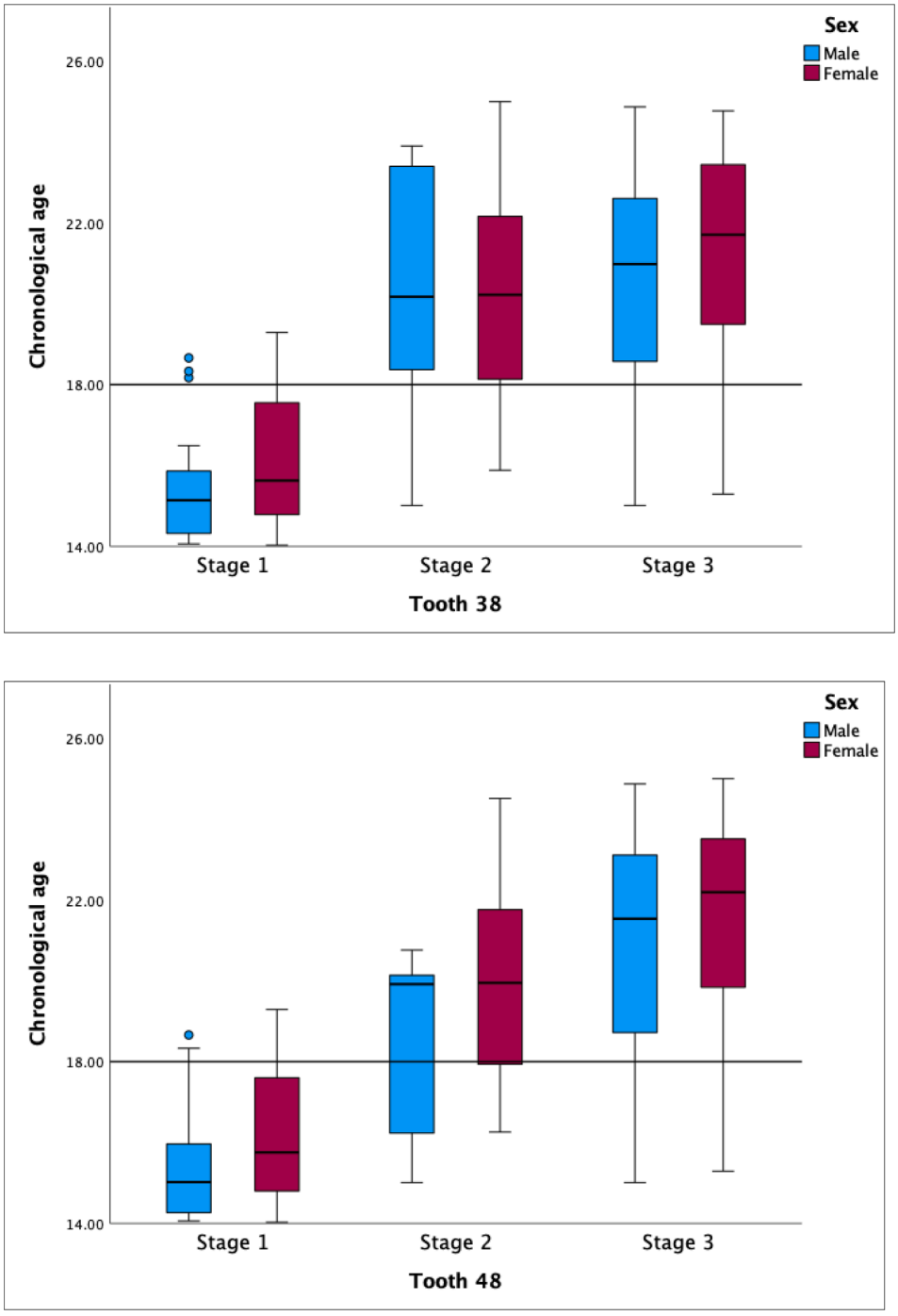

Fig. 1. (*continued*).

align with the observations of Švábová Nee Uhrová P et al. [21], who reported a similar trend on 811 children and young adults of Slovakian origin (472 males and 339 females), noting that 90.30 % of males and 90.59 % of females in phase D were 18 years or older.

Regarding individual stages, stage 3 signifies the emergence of the third molar to the occlusal plane, a visible occurrence within the oral cavity that physicians can easily identify. Our study findings reveal that among males aged 18 and above, stage 3 was observed in 77.6 % to 81 % of all third molars. Conversely, in females, the results were compelling, with 88.8 % to 96.8 % of all third molars in stage 3 belonging to individuals aged 18 or older. These results diverged from the original study, where the percentage of stage 3 was higher in males than in females. The cause of sexual dimorphism and the considerable variability in the timing of formation, mineralisation, and eruption of third molars remains not fully comprehended. However, in contrast to both studies, Švábová Nee Uhrová P et al. [21] reported that when the left mandibular third molar was classified as stage 3, the probability of being 18 years or older was 86.67 % for males and 85.71 % for females, indicating no significant difference between the sexes.

Švábová Nee Uhrová et al. [21] emphasised the need for future investigations comparing Gambier et al.'s scoring system with alternative methods for third molar eruption. Olze et al. (2008) [16] introduced a four-stage classification system, which was proven valuable in forensic age estimation [22–25]. While we could not directly compare Gambier's method with Olze et al.'s in our study, we referenced another study assessing Olze et al.'s system in a South Indian sample [26]. Their

Table 3
Intersexual differences in mean age by the Gambier et al. stages and quadrant-wise location of the third molars.

Tooth M3	Stage	Males			Females			Sex differences	
		N	Mean	SD	N	Mean	SD	T-statistics	Sig.
18	**1**	68	15.92	1.35	128	16.69	2.29	−1.275	0.209
	2	188	19.23	3.08	180	20.14	2.71	−1.506	0.136
	3	272	20.75	2.87	196	21.53	2.28	−1.568	0.120
28	**1**	68	15.92	1.35	132	16.81	2.24	−1.507	0.138
	2	188	19.23	3.08	152	19.57	2.56	−0.548	0.585
	3	272	20.75	2.87	220	21.76	2.29	−2.111	0.037*
38	**1**	100	15.39	1.34	112	16.13	1.66	−1.759	0.085
	2	124	20.41	3.01	176	20.33	2.59	0.103	0.918
	3	304	20.64	2.55	216	21.28	2.47	−1.436	0.153
48	**1**	96	15.37	1.37	120	16.19	1.65	−1.945	0.057
	2	72	18.52	2.14	160	20.08	2.28	−2.448	0.018*
	3	360	20.93	2.63	224	21.55	2.51	−1.404	0.162

* Statistically significant ($p < 0.05$).

Table 4
Differences in mean age between the Gambier et al. stages according to the sex and quadrant-wise location of the third molars.

Tooth M3	Stage	Males			Comparison of stages		Females			Comparison of stages	
		N	Mean	SD		Sig.	N	Mean	SD		Sig.
18	**1**	68	15.92	1.35	1&2	<0.001*	128	16.69	2.29	1&2	<0.001*
	2	188	19.23	3.08	2&3	0.014*	180	20.14	2.71	2&3	0.019*
	3	272	20.75	2.87	1&3	<0.001*	196	21.53	2.28	1&3	<0.001*
28	**1**	68	15.92	1.35	1&2	<0.001*	132	16.81	2.24	1&2	<0.001*
	2	188	19.23	3.08	2&3	0.014*	152	19.57	2.56	2&3	<0.001*
	3	272	20.75	2.87	1&3	<0.001*	220	21.76	2.29	1&3	<0.001*
38	**1**	100	15.39	1.34	1&2	<0.001*	112	16.13	1.66	1&2	<0.001*
	2	124	20.41	3.01	2&3	0.898	176	20.33	2.59	2&3	0.124
	3	304	20.64	2.55	1&3	<0.001*	216	21.28	2.47	1&3	<0.001*
48	**1**	96	15.37	1.37	1&2	<0.001*	120	16.19	1.65	1&2	<0.001*
	2	72	18.52	2.14	2&3	<0.001*	160	20.08	2.28	2&3	0.006*
	3	360	20.93	2.63	1&3	<0.001*	224	21.55	2.51	1&3	<0.001*

* Statistically significant ($p < 0.05$).

Table 5
Descriptive statistics for each phase by sex.

Males								
	N	Mean	SD	Min	Max	Median	LQ	UQ
Phase A	56	15.86	1.49	14.21	18.66	15.41	14.69	16.91
Phase B	96	17.65	2.44	14.17	20.76	16.71	15.62	20.11
Phase C	120	19.52	3.55	14.06	23.9	18.27	16.55	23.41
Phase D	256	21.16	2.42	15.01	24.87	21.6	19.39	22.85
Females								
Phase A	88	15.69	1.28	14.03	18.6	15.37	14.54	16.34
Phase B	168	19.61	2.44	14.8	24.51	19.5	17.66	21.64
Phase C	64	20.4	3.17	16.04	25	10.76	17.73	22.45
Phase D	184	21.75	2.16	15.29	24.77	22.32	20.22	23.49

Min Minimum age; *Max* Maximum age; *LQ* Lower quartile; *UQ* Upper quartile; *SD* Standard deviation

findings suggested that Olze et al.'s stage D in lower third molars indicated an age of 18 or older, with reported false positives of 13.8 % and 5.4 % in males and females, respectively. In forensic age estimation, it is important to minimize both ethically unacceptable errors (false positives) and technically unacceptable errors (false negatives) [27]. In our study, Gambier's phase D, resulted in false positives of 14.1 % in males and 4.3 % in females. Interestingly, there was no significant difference in false positives between the two methods in the South Indian population. However, Gambier's method requires the evaluation of all four third molars, offering an advantage over Olze et al.'s method, which assesses only a single third molar.

In forensic and medicolegal contexts, minimising errors in age estimation, especially in determining the age threshold of medicolegal interest, is crucial. The introduction of the "minimum-age concept" ensures that forensic age is never overestimated, providing a high level of certainty that the assessed person's age is below the legally relevant limit if the determined minimum age surpasses it [28]. Alternatively, the effectiveness of a specific stage in an age estimation method to determine whether an individual is above or below 18 years can be assessed using the median age of attainment. The median age of attainment represents the age at which half of the children (the median or the 50th percentile) reach or attain that stage [29,30]. This differs from the mean age of attainment, which involves averaging the ages of children at a particular stage. In our study, we observed that the median age for Gambier's phase D was 21.6 for males and 22.32 years for females. Additionally, it was noted that around 86 % of males and 96 % of females who were assigned Gambier's phase D were above 18 years of age. This suggests that Gambier's phase D of the third molar eruption could serve as a useful indicator for the completion of 18 years in the studied sample.

Limitations and future directions of this research

While Gambier's phase D of third molar eruption often denotes the

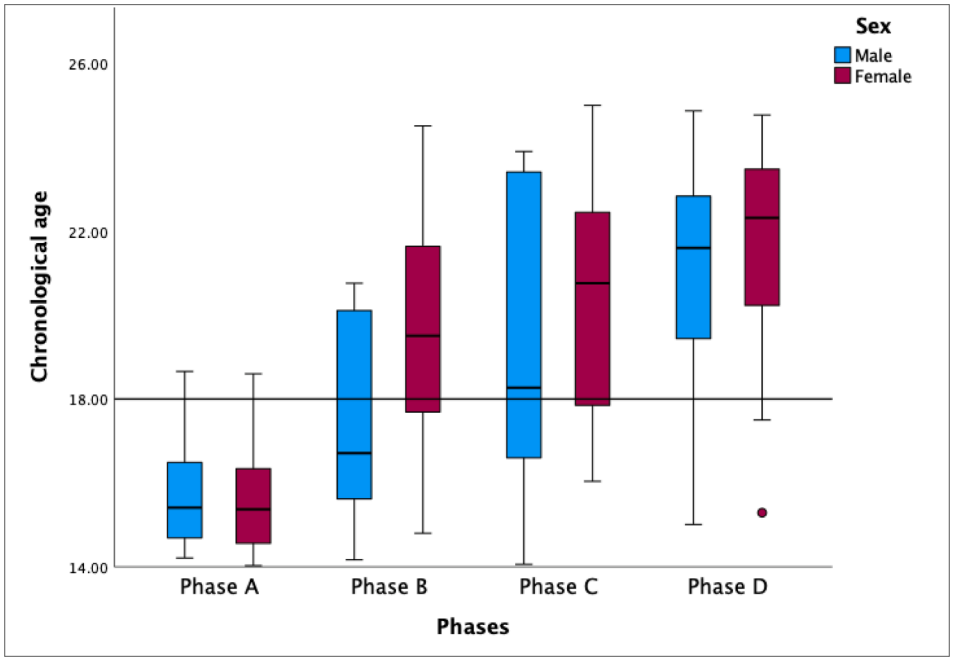

Fig. 2. Age distribution according to phase of all third molars; for males and females.

Table 6
Stage distribution according to age (under or over 18 years) for all third molars in both sexes.

Males					Females			
Age Classification	**Upper right third molar (#18)**							
	Stage 1	**Stage 2**	**Stage 3**	**Total**	**Stage 1**	**Stage 2**	**Stage 3**	**Total**
<18 years	52 (76.5)	80 (42.6)	52 (34.8)	184 (34.8)	96 (75)	48 (26.7)	12 (6.1)	156 (31)
>/=18 years	16 (23.5)	108 (57.4)	220 (65.2)	344 (65.2)	32 (25)	132 (73.3)	184 (93.9)	348 (69)
Total	68 (100)	188 (100)	272 (100)	528 (100)	128 (100)	180 (100)	196 (100)	504 (100)
	Upper left third molar (#28)							
	Stage 1	**Stage 2**	**Stage 3**	**Total**	**Stage 1**	**Stage 2**	**Stage 3**	**Total**
<18 years	52 (76.5)	80 (42.6)	52 (34.8)	184 (34.8)	96 (72.7)	48 (31.6)	12 (5.5)	156 (31)
>/=18 years	16 (23.5)	108 (57.4)	220 (65.2)	344 (65.2)	36 (27.3)	104 (68.4)	208 (94.5)	348 (69)
Total	68 (100)	188 (100)	272 (100)	528 (100)	132 (100)	152 (100)	220 (100)	504 (100)
	Lower left third molar (#38)							
	Stage 1	**Stage 2**	**Stage 3**	**Total**	**Stage 1**	**Stage 2**	**Stage 3**	**Total**
<18 years	84 (84)	32 (25.8)	68 (22.4)	184 (34.8)	92 (82.1)	40 (22.7)	24 (11.1)	156 (31)
>/=18 years	16 (16)	92 (74.2)	236 (77.6)	344 (65.2)	20 (17.9)	136 (77.3)	192 (88.9)	348 (69)
Total	100 (100)	124 (100)	304 (100)	528 (100)	112 (100)	176 (100)	216 (100)	504 (100)
	Lower right third molar (#48)							
	Stage 1	**Stage 2**	**Stage 3**	**Total**	**Stage 1**	**Stage 2**	**Stage 3**	**Total**
<18 years	80 (83.3)	28 (38.9)	76 (21.1)	184 (34.8)	96 (80)	40 (25)	20 (8.9)	156 (31)
>/=18 years	16 (16.7)	44 (61.1)	284 (78.9)	344 (65.2)	24 (20)	120 (75)	204 (91.1)	348 (69)
Total	96 (100)	72 (100)	360 (100)	528 (100)	120 (100)	160 (100)	224 (100)	504 (100)

completion of the 18th year of life in our sample, caution is warranted due to both strengths and limitations of the method. Despite a sizable sample size and high agreement among the examiners, we excluded impacted third molars, a significant limitation given the reported high impaction rates in the South Indian population [26,31,32]. Furthermore, the retrospective nature precluded clinical intraoral examination assessment, emphasising the need to validate hypotheses and minimise unnecessary radiation exposure to juveniles. Future research should further validate our findings and explore the effectiveness of Gambier et al. stages across diverse populations, comparing them with alternative methods to refine age estimation techniques.

5. Conclusion

Our study results enable the prediction of the completion of the 18th year of life within the examined South Indian population. However, it's crucial to note that individual stages of the scoring system alone may not suffice to signify the attainment of adulthood. Instead, when focusing on Gambier's phase D of third molar eruption (where all four third molars are categorised as stage 3, indicating full eruption and reaching the occlusal plane), 85.9 % of males and 95.7 % of females in our study were classified as 18 years or older. While our study did not establish the Gambier et al. scoring system as superior to another third molar eruption method, it is noteworthy for its ease of use in everyday clinical situations, even for physicians without forensic odontology expertise. It can complement other methods, although it is not recommended as the sole method due to a higher risk of misclassification (false positives).

Table 7
Number of individuals for each phase by age classification (</≥18 years) in both sexes.

Males	<18 years (%)	≥18 years (%)	p- value. (Chi-square)
Phase A	40 (71.4)	16 (28.6)	0.009*
Phase B	52 (54.2)	44 (45.8)	0.111
Phase C	56 (46.7)	64 (53.3)	0.484
Phase D	36 (14.1)	220 (85.9)	0.000*
Females			
Phase A	84 (94.5)	4 (4.5)	0.000*
Phase B	48 (28.6)	120 (71.4)	0.689
Phase C	16 (25)	48 (75)	0.548
Phase D	8 (4.3)	176 (95.7)	0.000*

*Statistically significant ($p < 0.05$)
Note: p values in the chi-square analysis were adjusted with Bonferroni correction.

CRediT authorship contribution statement

Subramanyeswara Swamy Chinni: Conceptualization, Data curation, Methodology. **Waheeda Shahnaz:** Data curation, Methodology, Writing – original draft. **Sowmya Akkanapally:** Data curation, Methodology, Writing – original draft. **Rehana Sultana:** Investigation, Formal Analysis, Writing – review & editing. **Asa Priyanka Mula** Investigation, Formal Analysis, Writing – review & editing. **Sudheer B. Balla:** Conceptualization, Investigation, Formal Analysis, Writing – original draft, Writing – review & editing, Supervision. **Galina Zolotenkova:** Supervision. **Nikolaos Angelakopoulos:** Writing – review & editing, Supervision.

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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