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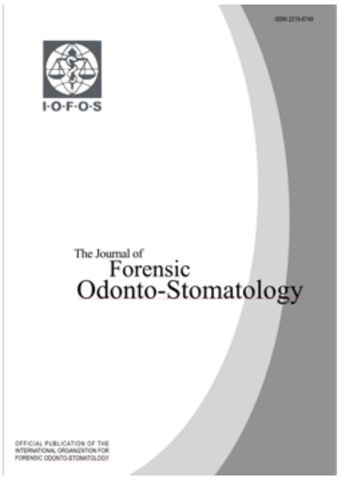

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EDITORIAL

The uniqueness of the human dentition revisited: a logical approach to the current impasse

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Herman Bernitz[1] BChD, MSc, Dip Odont, PhD

[1]*Department of Oral and Maxillofacial Pathology, School of Dentistry, University of Pretoria, South Africa*

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Over the past four decades several authors have tried to prove the uniqueness of the human dentition. The scientific method and its reliability have all been questioned and in general rejected by the broader forensic community. Studies to prove or disprove the uniqueness of the human dentition have been carried out by: Sognnaes et al[1], Rawson et al[2], Kieser et al[3], Bush et al[4], and several others. The mere fact that no one has proved the uniqueness of the human dentition by 2023, confirms that the hypothesis is problematic. Most of the referenced research studies were carried out on study models which disregarded the fact that the dentition is dynamic, ever changing and exposed to outside forces.

To understand the real problem related to the uniqueness of the human dentition several basic principles need to be explained and understood: uniqueness, attrition, Locard's exchange principle and infinity. Uniqueness is defined as the quality of being the only one of its kind and is a state or condition wherein someone or something is unlike anything else in comparison, or is remarkable, or unusual.[5] Dental attrition is the loss of tooth structure or tissue caused by tooth-on-tooth contact during mastication.[6] The signs and symptoms of attrition can include: loss of tooth anatomy resulting in loss of tooth characteristics, including rounding or sharpening of incisal edges, loss of cusps and fracturing of teeth. By implication this means that every time the teeth touch, some form of tooth damage will occur, albeit on a molecular level. Locard's exchange principle states that every contact leaves a trace, and this applies on a macroscopic and microscopic level.[7] By implication every time the teeth touch there is a change in form, albeit on a molecular level. The extent of transfer depends on three variables, namely the intensity of contact, the duration of contact and the nature of the material. Infinity is a mathematical concept which defines a number greater than any assignable quantity or countable number and is designated the symbol ∞.[8]

If one takes all the above principles into context, it becomes clear that the dynamic/living dentition is subject to visual, microscopic and molecular changes every time the upper and lower teeth make contact, creating infinite changes, an infinite number of times. **The human dentition is thus unique for a split second every time the teeth touch**. After every contact we have a unique dentition, different to any on this planet at a molecular level. This uniqueness will only last until the next tooth contact. This process will then be repeated every time the teeth make contact. This process will take place an infinite number of times throughout the individual's life time. The irrelevance of uniqueness is highlighted in an article entitled "Forensics without uniqueness, conclusions without individualization: the new epistemology of forensic identification" written by Cole[9] in which he states "broad consensus in the forensic literature holds that individualization is unachievable and uniqueness is largely irrelevant to supporting claims of individualization."

The time has come to accept the above and adapt the science of forensic odontology to address the challenges of human identification and bite mark analysis in an environment where the uniqueness of the human dentition will remain a theoretical concept.

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Radiographic evaluation of secondary dentin formation in lower premolars for forensic age diagnosis of 18 years in a sample of south Indian adolescents and young adults

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Venkata Chakrapani Kuncha [1], Venkata Soundarya Kolaparthi [2], Rakesh Kumar Raparthi [3], Bhari Jyothi Tadakamadla [4], Santosh Kumar Tadakamadla [4], Sudheer Babu Balla [4]

[1]*Oral Pathology and Microbiology Government Dental College & Hospital India.* [2] *Narayana Dental College India.* [3] *Department of Oral Pathology and Microbiology Panineeya Mahavidyalaya Institute of Dental Sciences India.* [4] *La Trobe Rural Health School - La Trobe University Australia*

Corresponding author: s.balla@latrobe.edu.au

The authors declare that they have no conflict of interest.

KEYWORDS

Dental age estimation, Premolars, Secondary Dentin formation, 18 years, Orthopantomograms.

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ABSTRACT

There has been an increase in the need for alternate methods of dental age assessment, especially for the forensic age diagnosis of the 18th year of life. This is due to the completion of the third molar development before 18 years or the agenesis or therapeutic extractions of the third molars. The present study aimed to verify whether the secondary dentin formation in lower premolars can be used to determine the completion of the 18th year of life in a sample of South Indian adolescents and young adults. For this purpose, 800 orthopantomograms of 400 male and 400 female South Indian subjects aged 14- 22 were evaluated. The characteristics of the secondary dentin formation were determined in all mandibular premolars using the stage classification according to Olze et al (Int J Legal Med 126(4):615-21). The results showed that when stage 3 of secondary dentin formation was reached in the first premolars, the probability of the subject completing the 18th year of life was very high. However, only a few individuals in the studied population were at stage 3. Therefore, proceeding cautiously with this degenerative change in lower premolars is advised due to the higher inter-examiner differences. It is also recommended to use this method in conjunction with other age estimation methods. Further research should investigate other degenerative characteristics in the studied population.

INTRODUCTION

Age estimation of the living and dead people is imperative in forensic and medicolegal practice. Research in this area, especially in living individuals, has become a priority in recent years due to increased refugee migration, juvenile delinquency, and competitive sports.[1-3] In European countries, the age thresholds of legal relevance usually lie between 14 and 21 years.[1] In India, the legally relevant age thresholds are 14 years (child labour), 16 years (age of criminal responsibility), 18 years (age of majority), and 21 years (legal age of marriage). The validation of completing the 18th year of life is of particular importance. From this point of view, numerous researchers have focussed on third molar development to provide proof of completion of the 18th year with a forensically required certainty.[4-7] However, the complete mineralization of third molars before the 18th year, their agenesis or therapeutic extraction in adolescents necessitated the need for alternate methods for age estimation.

Various methods were tested to predict the attainment of the legal age of 18 years as an alternative to third molar development. In 2010, Olze et al. proposed two staging methods based on the radiographic visibility of the root pulp[8] and periodontal ligament[9] on lower third molars. Later the staging method of pulp visibility was tested in lower first and second molars for the prediction of 18 years in the absence of third molars.[10, 11] However, the shape and positional variations of third molars influencing the observations of root pulp or the periodontal ligament visibility has warranted for other dental age estimation methods.[12]

In 1947, Gustafson presented a scientific method for age estimation using degenerative dental changes based on extracted teeth.[13] He studied characteristics of secondary dentin formation, periodontal recession, attrition, dentinal translucency, cemental apposition, and external root resorption and confirmed their correlation with chronological age. Later in 1981, Matsikidis studied these changes and proved they could be evaluated using dental films.[14] In 2010, Olze et al. studied these characteristic features in orthopantomograms (OPGs) and proposed a formula for age estimation based on only four characteristics from Gustafson's criteria.[15] Furthermore, they advised proceeding with caution as the applicability of this method is limited by the quality of the X-ray images. In 2017, Timme et al. suggested that the study of degenerative dental characteristics can be used as evidence to predict the completion of the 18th year of life.[16] In 2019, Hou et al. studied these degenerative changes in Chinese juveniles and young adults. They concluded that their developmental stages could prove the completion of the 18th of life beyond a reasonable doubt.[17] To the best of our knowledge, no investigation of these criteria demonstrating the completion of the 18th year of life in the Indian population has been conducted.

The present study aimed to verify whether the degenerative changes can be used for age estimation in South Indian adolescents and young- adults. To this purpose, the secondary dentin formation in lower premolars was evaluated.

MATERIALS AND METHODS

Materials

The design of this study was a retrospective cross-sectional study of OPGs obtained from the clinical practices of southern India, which comprised five states, i.e., Andhra Pradesh, Telangana, Karnataka, Tamilnadu, and Kerala. Eight hundred OPGs (400 males and 400 females) of South Indian juveniles and young adults aged between 14 and 22 were studied. All the OPGs were made in the period between 2018 and 2022. Total subjects were divided into eight age groups encompassing one year; e.g., 14 years was defined as 14.00 to 14.99 years. Equal distribution of male and female subjects (50 per sex) was ensured in each age group (Table 1). The exclusion criteria for the evaluated premolars followed the recommendations made by Matsikidis that include premolars with caries, filling, crowned tooth or bridged abutment, post and core restoration, root filling, retained root, or premolars undergoing apicoectomy.[14]

Table 1. Age and sex distribution of the total sample

Age group	Male	Female	Total
14-14.9 years	50	50	100
15-15.9 years	50	50	100
16-16.9 years	50	50	100
17-17.9 years	50	50	100
18-18.9 years	50	50	100
19-19.9 years	50	50	100
20-20.9 years	50	50	100
21-21.9 years	50	50	100
Total	**400**	**400**	**800**

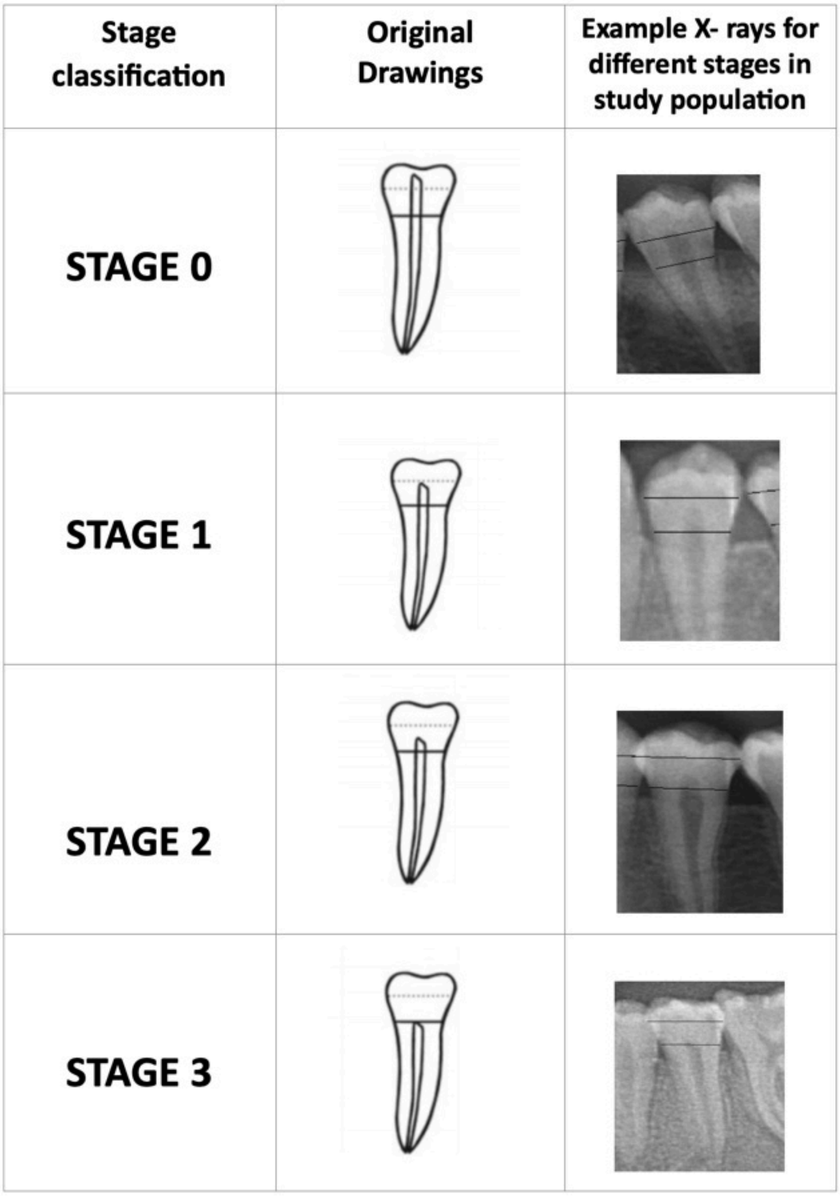
Following the collection, each OPG was provided with a unique identification number (UIN), and the details of the sex and chronological age were entered against each UIN. All the details were entered in a separate Microsoft Excel file. Examiners performing the radiographic analysis were blinded to the information about the sex and age of the subjects.

Method

The characteristics of the secondary dentin formation were determined in all mandibular premolars using the stage classification according to Olze et al.[15] In this classification, four stages were provided to assess the degree of secondary dentin, such as stage 0 (pulp horn reaches above to the above crown equator), stage 1 (pulp horn reaches at maximum to the crown equator), stage 2 (pulp horn exceeds enamel- cementum junction and falls short of the crown equator), and stage 3 (pulp horn reaches at maximum to enamel-cementum junction (Figure 1). In addition, non-evaluable teeth were distinguished between non-presence or due to other reasons such as developing premolars or lack of accessibility.

All the evaluations were performed randomised and blinded. A forensic odontologist with eight years of forensic age assessment experience did all the evaluations. A second examiner, a dentist with no experience in dental age assessment, analysed a few OPGs to study inter-examiner agreements.

Figure 1. Schematic representation of stage classification to determine the degree of secondary formation in mandibular premolars



Statistical analysis

A Microsoft Excel file 2016 (Microsoft Office 2003, Microsoft, Redmond, WA) was used to enter the details of each individual, such as unique identification number, chronological age, sex, and stage classifications of all premolars. Statistical analysis was performed using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL, USA). The significance threshold was set at 5% ($p < 0.05$). Side differences were tested using the Wilcoxon signed rank test. For each stage, the frequencies of the examined teeth, the mean, standard deviation, minimum, maximum, and median, were calculated in both sexes separately. Finally, two-by-two contingency tables were drawn to indicate the performance of the stages of secondary dentin formation for indicating the completion of the 18th year of life.

To assess intra-examiner agreement, 100 OPGs were randomly selected and evaluated for the second time by the first examiner at three months. For the inter-examiner agreement, the same OPGs were reviewed by the second examiner. Cohen's kappa statistics were calculated for intra-and-inter-examiner agreements.

RESULTS

The Cohen's kappa coefficients for the intra-examiner agreement were 0.842 and 0.797 for the first and second premolars. The Cohen's kappa coefficients for the inter-examiner agreement were 0.597 and 0.583 for the first and second premolars, respectively. The output of the Wilcoxon signed-rank test showed that the stage classification did not elicit a statistically significant difference between the right and left sides for both for first premolars ($Z= -2.833$, $p= 0.07$) and second premolars ($Z=-2.167$, $p=0.09$), respectively. From here onwards, the results were presented for the lower left first (#34) and second (#35) premolars.

Table 2 shows the number and percentage of lower premolars which could not be evaluated and, therefore, could not be evaluated for statistical evaluation. The number of missing teeth was provided as well. Depending on the examined tooth, 77.25% to 82.5% of first premolars and 77% to 82.5% of second premolars were evaluable.

Tables 3 and 4 show the descriptive statistics results for each stage of secondary dentin formation for first and second premolars in both sexes. There were no significant differences in the mean age between males and females in different stages for both premolars. Tables 5 and 6 show the results of two-by-two contingency tables describing the discrimination performance of stage 3 of secondary dentin formation to indicate the completion of the 18th year of life.

Table 2. Number and percentage of teeth excluded or missing

Tooth	Sex	Number of cases	Missing teeth	Non-evaluable teeth	Evaluated teeth	Percentage evaluated
34	Male	400	14	77	309	77.25%
	Female	400	10	61	329	82.5%
35	Male	400	14	63	323	80.75%
	Female	400	11	63	326	81.5%
44	Male	400	14	74	312	78%
	Female	400	10	63	327	81.75%
45	Male	400	15	77	308	77%
	Female	400	11	59	330	82.5%

Table 3. Descriptive statistics on the age (in years) of the stages of secondary dentin formation of mandibular premolars in males

Tooth	Stage	N	Mean	SD	Minimum	Maximum	Median
34	0	6	18.73	2.08	16.42	21	18.88
	1	169	18.08	2.18	14.05	21.87	18.02
	2	119	17.95	2.41	14.02	21.65	18.12
	3	15	20.39	1.47	18.2	21.94	21.12
35	0	1	-	-	-	-	-
	1	60	18.57	2.16	14.02	21.63	19.05
	2	216	17.80	2.30	14.08	21.94	17.71
	3	46	19.39	1.82	15.50	21.94	19.44
44	0	6	19.49	1.41	17.61	21	20.01
	1	154	17.99	2.13	14.10	21.75	17.89
	2	129	17.87	2.29	14.02	21.94	18.24
	3	23	20.57	1.11	18.61	21.91	21.08
45	0	1	-	-	-	-	-
	1	41	18.21	2.39	14.02	21.63	19.14
	2	215	18.06	2.29	14.08	21.94	18.06
	3	51	18.50	2.05	15.24	21.94	18.63

Table 4. Descriptive statistics on the age (in years) of the stages of secondary dentin formation of mandibular premolars in females

Tooth	Stage	N	Mean	SD	Minimum	Maximum	Median
34	0	5	18.35	1.54	15.93	20.12	18.48
	1	175	18.26	2.21	14.10	21.94	18.38
	2	139	18.01	2.45	14.02	21.99	18.06
	3	10	20.55	1.01	18.95	21.71	20.96
35	0	0	-	-	-	-	-
	1	40	18.39	2.26	14.14	21.83	18.98
	2	243	17.84	2.23	14.02	21.94	17.84
	3	43	20.03	1.74	14.37	21.99	20.33
44	0	7	18.72	1.35	16.77	20.83	18.48
	1	162	18.15	2.12	14.14	21.99	18.27
	2	122	17.49	2.33	14.02	21.92	17.33
	3	37	20.38	1.21	18.22	21.98	20.45
45	0	0	-	-	-	-	-
	1	50	18.92	2.29	14.14	21.99	19.40
	2	220	17.84	2.24	14.02	21.92	17.7
	3	60	18.94	2.21	14.27	21.98	19.23

Table 5. 2×2 Contingency tables describing discrimination performance of the test on being adult (≥18) or minor (<18) for "stage 3" of secondary dentin formation in lower left first premolars (#34)

Males			
	Age status		**Total**
	<18 years	**≥18 years**	
≤ Stage 2	145^{TP} (100)	149^{FN} (90.8)	294 (95.1)
Stage 3	0^{FP} (0)	15^{TN} (9.2)	15 (4.9)
Total	145 (100)	164 (100)	309 (100)
Females			
	<18 years	**≥18 years**	**Total**
≤ Stage 2	147^{TP} (100)	172^{FN} (94.5)	319 (96.9)
Stage 3	0^{FP} (0)	10^{TN} (5.5)	10 (3.1)
Total	147 (100)	182 (100)	329 (100)

Table 6. 2×2 Contingency tables describing discrimination performance of the test on being adult (≥18) or minor (<18) for "stage 3" of secondary dentin formation in lower left second premolars (#35)

Males			
	Age status		**Total**
	<18 years	**≥18 years**	
≤ Stage 2	141^{TP} (94.6)	136^{FN} (78.1)	277 (85.7)
Stage 3	8^{FP} (5.4)	38^{TN} (21.9)	46 (14.3)
Total	149 (100)	174 (100)	323 (100)
Females			
	<18 years	**≥18 years**	**Total**
≤ Stage 2	145^{TP} (97.9)	138^{FN} (77.5)	283 (86.8)
Stage 3	3^{FP} (2.1)	40^{TN} (22.5)	43 (13.2)
Total	148 (100)	178 (100)	326 (100)

DISCUSSION

Regressive alterations or degenerative changes generally begin immediately after the eruption and continue throughout life.[18-21] Lately, the study of these features has become a subject of interest, especially in the absence of third molars or due to their completed development in subjects younger than 18.[22] In this regard, the authors, in their previous investigations, studied the root pulp visibility in the fully mineralised lower first and second molars for indicating the completion of the 18th year of life in south Indian adolescents and young adults.[10, 11] The accuracy of these methods was reported to be moderate to high, thus warranting the need for other methods or the study of alternate teeth.

The reaction of the pulp dentinal complex in response to various physiological and pathological stimuli results in the formation of secondary dentin. It leads to the reduction of the size of the pulp cavity.[23] This regressive tooth change attracted interest in the forensic literature, and its correlation with age was extensively studied. In 2012, Olze et al.[15] developed a staging system using the conventional OPGs using mandibular premolars as they are predominantly single-rooted teeth. In this study, the authors developed regressive equations using degenerative changes to estimate the living individuals aged between 15 and 40. They recommended using their method for age estimation with the restriction that the quality of OPGs limits the application of the method. In 2017, Timme et al.[16] investigated the validity of Olze et al. stages of regressive changes in 2346 German subjects aged 15 to 70 years. They performed regression analysis and derived regression equations for age estimation. They concluded that this method is inaccurate in older age groups and is applicable and reliable for dental age diagnostics up to 40 years. For the first time in 2019, Hou et al.[17] studied these regressive changes in lower premolars to demonstrate the completion of the 18th year of life. However, no investigations have been reported in the literature studying these regressive changes in the south Indian population. The current study aimed to test whether the degenerative change, i.e., secondary dentin formation in lower premolars, can be used to exclude south Indian individuals under 18 years.

Only one study has explored whether secondary dentin formation in the lower premolars can be used to indicate the completion of 18 years.[17] Hou et al.[17] stated that the respective mean ages for males and females were stage 0: 20.27 and 20.17 years; stage 1: 26.25 and 25.85 years; stage 2: 32.56 and 33 years; and stage 3: 39.19 and 35.55 years, for lower first premolars. For lower second premolars, the minimum age for stage 0 were 19.44 and 18.51 years; stage 1: 24.30 and 24.22 years; stage 2: 31.61 and 15.09 years; and stage 3: 39.28 and 40.05 years, respectively. As in our study, these mean age values are lower than those of the findings of Hou et al.[17], which could be due to the difference in the age range studied, with the upper end of the age extending to 40 years.

In forensic age estimation, determining the proof of being over or under the legally defined age limit is essential. This is due to the errors associated with the method and how these errors impact the fate of the assessed person. In this context, the "minimum-age concept" could be applied, which is designed to prevent the erroneous classification of minors as legal adults.[24] The minimum age is derived from the characteristic value, representing the age of the youngest person in the reference population with the ascertained characteristic value. Our study findings showed that stage 3 of secondary dentin formation in the lower first and second premolars could help indicate the completion of the 18th year of life. The minimum age corresponding to the determined stage 3 of secondary dentin formation was 18.2 years in males and 18.95 in females for the first premolar. Since the minimum age for stage 3 in lower first premolars in the population tested is above 18 years, a majority status, i.e., age over 18 years, seems possible. In this scenario, applying the minimum-age concept ensures that the forensic age of the assessed person is never underestimated.

We found that the repeatability was almost perfect while the reproducibility was moderate. Similar findings were reported by Hou et al.[17], where the reproducibility was reported between 0.285 and 0.652 for various regressive changes. The authors in the original study[15] mentioned that the quality of the radiographic images plays a significant role, and OPGs do not display fine anatomical details. It further leads to increased subjectivity and, therefore, observer error.[25] Therefore, observer training and calibration are needed.

To date, there has been limited research addressing the impact of patients' age and gender on the quality of panoramic radiographs. Gelbrich et al. investigated to explore how the image quality of panoramic radiographs is influenced by the age and gender of the patients.[26] Their findings revealed a consistent trend where image quality tended to decrease with the advancing age of patients. Importantly, this decline in image quality was observed regardless of the patient's gender or the specific imaging device used. Furthermore, Gelbrich and colleagues highlighted the significance of radiation levels emitted by the OPG device in relation to image quality. They noted that when radiation levels are reduced, the image quality becomes more susceptible to age-related changes. Additionally, the research by Dannewitz et al.[27] suggested that it is possible to reduce the tube current by approximately 50% without significantly affecting diagnostic accuracy, despite a potential decrease in subjective image quality. It is worth noting that in our present study, we lacked specific information about the OPG devices used. This limitation was due to the retrospective nature of our research. Consequently, it is essential for future investigations to delve into the influence of OPG quality on the methodology employed in our study. One of the limitations of this research is its generalizability. It refers to the extent to which the present study's findings can be applied to a broader context, for example, to other populations. It was observed that the grading was not possible in approximately 20% of the first premolars and 20% second premolars of the total sample. Variations in the premolar position were the main reason while developing teeth was the least for the inability to grade premolars. Another important finding is stage 3 of secondary dentin grading in a very small percentage of individuals. This could be due to the smaller age range (14 to 22 years) selected for this study. Therefore, we recommend extending the upper boundary of the age range up to 40 years to verify whether the stage 3 secondary dentin grading can prove the completion of the 18th year of life beyond a reasonable doubt. Further studies are warranted to investigate other characteristics, i.e., attrition, periodontal recession and cemental apposition in lower premolars for indicating the completion of the 18th year of life.

CONCLUSIONS

Based on the findings, it can be concluded that the grading of second dentin formation in lower premolars is of limited value. Even though the presence of stage 3 in the lower first premolar was helpful in indicating the completion of the 18th year of life, the generalizability of this finding remains a question for multiple reasons. Further studies are warranted to investigate other characteristics, i.e., attrition, periodontal recession and cemental apposition in lower premolars for indicating the completion of the 18th year of life in south Indian adolescents and young adults.

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Accuracy of dental age estimations based on individual teeth and staging system comparisons

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Nada N. AlOtaibi[1,2], Fahad A. Aldawood[1,3], Sakher J. AlQahtani[1]

[1]Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia. [2] Department of Preventive Dental Science, College of Dentistry, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia. [3] Prince Sultan Military Medical City, Riyadh, Saudi Arabia

Corresponding author: nanialotaibi@pnu.edu.sa

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ABSTRACT

Aim**:** To investigate whether a specific tooth or teeth provide the most accurate estimation of chronological age (CA), and determine which of the three staging systems studied represents dental development for an individual tooth.

Method: Data were collected from 400 digital panoramic radiographs of healthy Saudi children aged 6.00–15.99 years. Each permanent tooth on the left side was evaluated to determine its developmental stage and dental age using the methods by Moorrees, Fanning, and Hunt (MFH) (1963), as adapted by Smith (1991), Gleiser and Hunt (1955), and Nicodemo et al. (1974). The accuracy (bias) of each tooth type and stage was assessed in relation to the CA, the teeth and the methods were compared, and the accuracy of age estimation using all teeth and the most accurate tooth in each method were compared.

Results: Regarding staging systems, comparatively, Gleiser and Hunt's method had the lowest bias for the lower first molar (-0.50 ± 1.05 years). Nicodemo et al.'s method had a lower bias for all other mandibular teeth compared to the MFH method.

For individual teeth using the MFH method, the most and least accurate teeth for the combined sexes were the lower central incisor (-0.59 ± 0.77 years) and the lower first molar (-1.54 ± 0.93 years), respectively. No significant difference was found between the biases when using the lower central incisor alone and when using all teeth for the combined sexes.

For individual teeth using Nicodemo et al.'s method, the most and least accurate teeth for combined sexes were the upper central incisor (-0.03 ± 1.01 years) and the lower first molar (-1.08 ± 1.59 years), respectively. A significant difference was found between the biases using the upper central incisor alone and all teeth for the combined sexes, with the upper central incisor exhibiting the lowest bias (P=0.028).

Conclusions: Comparatively, Nicodemo et al.'s method had the lowest bias for all teeth except for the lower first molar, where Gleiser and Hunt's method had the lowest bias. This, however, should not be confused with precision. MFH's staging system was more representative of dental development for an individual tooth.

For combined sexes, the lower central and lateral incisors were the most accurate teeth using the MFH method. The upper central incisor and lower first premolar were the most accurate teeth using Nicodemo et al.'s method. The lower first molar was the least accurate tooth using both methods.

INTRODUCTION

The chronological age (CA) can be estimated by determining the physiological age[1] (also known as biological age), which is based on the degree of maturation of different tissue systems.[2] The dental age (DA) of an individual, determined by the stage of tooth formation, is one index of biological age.[2] DA has many advantages over other indices of biological age. DA determined by tooth formation or mineralization can be used to estimate an individual's age from in utero to approximately 18 or 20 years of age, if a third molar is used.[3] DA is more reliable and genetically controlled than age estimation using skeletal indicators such as cervical vertebrae and wrist bones.[4]

Furthermore, mineralization of tooth crown and root can usually be observed on radiographs, which allows assessment of developmental stages.[5] Many authors have suggested different numbers of radiographic stages in order to quantify the continuous process from the first traces of cusps mineralization until root apex closure, from the three stages by Garn et al. [6] to the 14 stages by Moorrees et al.(MFH).[7] Additionally, only a few authors have calculated the mean age of participants at a particular stage, such as Gleiser and Hunt (1955),[8] (MFH) (1963),[7] as adapted by Smith (1991),[3] and Nicodemo et al. (1974).[9]

Gleiser and Hunt [8] developed a method with 13 stages based on longitudinal data, although it only covered the calcification of the mandibular first molars. The mean age in months at each stage was calculated for both sexes. In 1991, Smith adapted the data from MFH charts to develop tables showing the age at which each tooth reaches each stage and a formula for age estimation.[3] Nicodemo et al.,[9] provided a chronological table of the mineralization of all the permanent teeth using eight developmental stages, with four stages each for the crown and the root. To determine the DA using these methods, the stage of formation of each tooth is defined, and the age corresponding to each stage is read from the tables proposed by the authors. The DA of the child is then calculated as the mean of all tooth formation age estimates. However, this process is complex and time-consuming for clinical practice.

Moreover, examiners should score all developing teeth to obtain maximum information.[5] However, it is unlikely that multiple teeth will yield the same age estimate.[10] Yet, some teeth provide more precise and reliable estimates than others.[10] Few studies have investigated the accuracy of individual teeth and staging systems for age estimation.[11,12] Therefore, this study aimed at investigating whether a specific tooth or teeth provides more accurate estimations of the CA and assessing which staging system is more representative of dental development for an individual tooth.

MATERIALS AND METHODS

Ethical Approval

The Institutional Review Board (E-21-6175) of King Saud University, Riyadh, Saudi Arabia, and the College of Dentistry Research Center (PR 0124) at King Saud University approved this study.

Sample Selection and Size

Data from 400 digital panoramic radiographs of healthy Saudi children aged 6.00–15.99 years were collected in an earlier study.[13] Table 1 describes the data. Each chronological year was assigned to an individual group. A list of all Saudi children (aged 6.00–15.99 years) who had a panoramic radiograph acquired between 2018 and 2021 was obtained from the Information Technology Department of the Dental Clinics at King Saud University (KSU). The inclusion and exclusion criteria were applied to the radiographs in reverse chronological order (from the newest to the oldest) until 400 cases were included. If a patient had multiple radiographs on the file, the oldest (or the latest) one that reflected the selection criteria was included.

The sample size, as calculated in an earlier study,[13] for an effect size of 0.188, based on the Cohen equation and previous studies,[14] at a significance level of 0.05 and statistical power of 0.9, using GPower software,[15] was 40 in each age group, which was subdivided into 20 boys and 20 girls. Therefore, 400 digital panoramic radiographs (200 each from boys and girls) were used. For the current study, the statistical power of teeth was re-calculated to account for the anticipated exclusion of teeth in the final developmental stages and found to be 0.85. The radiographs were initially assessed for the presence of radiographically visible exclusion criteria. The files for patients with acceptable radiographs were then checked for other exclusion criteria. The radiographs were selected by ascending the file numbers until each age group was completed.

Table 1. Demographics of participants (N=400)

Group	Age category	Boys	Girls	Total
1	6.00-6.99	20	20	40
2	7.00-7.99	20	20	40
3	8.00-8.99	20	20	40
4	9.00-9.99	20	20	40
5	10.00-10.99	20	20	40
6	11.00-11.99	20	20	40
7	12.00-12.99	20	20	40
8	13.00-13.99	20	20	40
9	14.00-14.99	20	20	40
10	15.00-15.99	20	20	40
Total		200	200	400

Inclusion Criteria

The participants were included based on the following three main criteria: (1) Saudi patients, (2) children aged 6.00 to 15.99 years, and (3) presence of a panoramic radiograph in the Romexis server of the KSU College of Dentistry.

Exclusion Criteria

The exclusion criteria were as follows: (1) poor quality radiographs: the overlap of structures and presence of artifacts at the region of interest, (2) non-Saudi patients, (3) the presence of any systemic diseases or developmental conditions, (4) abnormal dental development including amelogenesis/dentinogenesis imperfecta, taurodontism, hypodontia, and hyperdontia, (5) presence of gross pathology related to the left side of the jaw or teeth, (6) presence of gross caries and periapical pathosis on the left side of the jaw, (7) presence of large restorations or crowns on the left side of the jaw, (8) early tooth extraction on the left side of the jaw, and (9) known previous orthodontic treatment.

Data Collection

The digital radiographs were analyzed with the naked eye for DA estimation using Planmeca Romexis 3.6.0.R software, available at KSU. Each participant's CA was calculated by subtracting the date of birth registered in the file from the date on which the radiograph was obtained; it was then converted into a decimal system using Eveleth and Tanner's method.[16] Each participant's date of birth was verified by their national identification card preserved in their file. The observer was blinded to the CAs and entered them into a different spreadsheet until all 400 panoramic radiographs were assessed.

Each permanent tooth on the left side was evaluated to determine its developmental stage using the methods by MFH,[7] as adapted by Smith (1991),[3] Gleiser and Hunt,[8] and Nicodemo et al.[9] The codes for the developmental stages of all teeth were transformed tooth-by-tooth into the DA using the sex-appropriate tables provided by the authors. The DA of each participant was then calculated as the mean DA of all teeth combined.

Radiograph viewing conditions were standardized as follows: (1) if image adjustments had been made on the panoramic radiograph prior to data collection, all adjustments were undone; (2) viewing was conducted in a dimly lit room; (3) the zoom level was standardized between the methods; and (4) all age estimation methods were applied using the same contrast and density settings.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows Version 28. The primary observer (N. Alotaibi), who performed all measurements, was trained and calibrated by an expert in the field (S. AlQahtani). To calculate the intra- and inter-examiner values, a 10% random sample of the digital radiographs was selected using random allocation software and re-evaluated after 2 weeks. Cohen's Kappa test was used to verify intra- and inter-observer agreement for all methods.[17]

The final stage of each method (complete apical closure, terminally convergent root canal, and apical end) was omitted from the analysis because it provided the same age estimate for the tooth, although the CA increased.

The accuracy of each tooth type and stage was determined by the mean difference between the DA and the CA (bias). The DA of each tooth type and stage was compared with the CA of each participant. The CA was subtracted from the DA, and a positive result indicated overestimation, whereas a negative result indicated underestimation. Values are presented as means and standard deviations (SDs).

A paired t-test and repeated-measure ANOVA, followed by *post-hoc* analysis, were used to compare the methods in terms of mandibular teeth biases only to facilitate the comparison between the three staging systems. One-way analysis of variance (ANOVA) and *post-hoc* analysis were used to compare the bias among the teeth in the methods by MFH, as adapted by Smith, and Nicodemo et al. for the entire sample. A paired t-test was used to compare the bias using all teeth and the tooth with the least bias for the two methods. The analyses were performed separately for boys and girls, and combined for the tooth type. The biases and SDs for the individual tooth stages were also calculated using each method. Statistical significance was set at $P < 0.05$.

RESULTS

Reliability Test

The intra-examiner Kappa values were 0.88, 1.00, and 0.97 for the MFH, Gleiser and Hunt, and Nicodemo et al. methods, respectively. For inter-examiner agreement, these values were 0.80, 0.87, and 0.73 for the MFH, Gleiser and Hunt, and Nicodemo et al. methods, respectively. These values are "substantial" or "almost perfect."[17]

Accuracy of Staging System and Tooth Type for Individual Teeth:

Accuracy of Staging System for Individual Teeth:

The results of the comparison of the accuracies of the mandibular teeth between the three methods (staging systems) are presented in Table 2. Nicodemo et al.'s method had the lowest bias for all teeth except for the lower first molar, in which Gleiser and Hunt's method had the lowest bias (-0.50 ± 1.05 years). No significant differences were found in the biases of the lower lateral incisors between the MFH and Nicodemo et al.'s methods.

Accuracy of individual teeth:

Using the MFH method, the accuracy of individual teeth showed that the lower central incisor was the most accurate (-0.63 ± 0.73, -0.59 ± 0.77 years), followed by the lower lateral incisor (-0.88 ± 0.89, -0.69 ± 0.92 years), for girls and the combined sexes. For boys, the most accurate tooth was the lower lateral incisor (-0.50 ± 0.91 years), followed by the lower central incisor (-0.56 ± 0.80 years). All teeth underestimated the age, and the least accurate tooth was the lower first molar (-1.54 ± 0.93 years) (Table 3).

The one-way ANOVA revealed a significant difference in bias among the teeth ($P < 0.001$) (Table 3). The *post-hoc* pairwise comparisons, after Bonferroni adjustment, showed that the biases of the lower central incisor in girls and the lower lateral incisor in boys were only statistically significantly different from those of the lower canine (P=0.0020, P=.022, respectively) and lower first molar (P<0.001).

No significant difference was found between the accuracy of age estimation when using the lower central incisor and lower lateral incisor alone and when using all teeth (Table 5).

Using the method by Nicodemo et al., the accuracy of individual teeth showed that the upper central incisor was the most accurate tooth (-0.15 ± 1.09, -0.03 ± 1.01 years), followed by the lower first premolar (-0.17 ± 1.35, -0.06 ± 1.29 years), for boys and the combined sexes. For girls, the most accurate tooth was the lower second premolar (-0.03 ± 1.77 years), followed by the upper first premolar (-0.04 ± 1.02years).

Table 2. A comparison of the accuracies of the mandibular teeth using the MFH, as adapted by Smith; Nicodemo et al.'s; and Gleiser and Hunt's methods expressed by bias (mean difference between dental and chronological ages) in years

Tooth	Method			P- Value *
	MFH	Nicodemo et al.	Gleiser and Hunt	
	Mean (SD)	Mean (SD)	Mean (SD)	
Lower central	-0.59 (0.77)	-0.38 (1.00)		**0.001**
Lower lateral	-0.68 (0.92)	-0.64 (1.15)		0.597
Lower canine	-1.07 (0.93)	-0.08 (1.10)		**<0.001**
Lower first premolar	-0.83 (0.84)	-0.03 (1.25)		**<0.001**
Lower second premolar	-0.77(0.97)	-0.20 (1.79)		**<0.001**
Lower first molar	-1.51 (0.92)	-0.89 (1.30)	-0.50 (1.05)	**<0.001[a]**
Lower second molar	-0.83 (1.01)	-0.64 (1.57)		**<0.001**

* Paired t-test and repeated measures ANOVA. MFH: Moorrees, Fanning and Hunt, SD: Standard deviation.
Bold value means the result is significant p < 0.05. [a]: *Significant different between all the methods.*

Table 3. The accuracy of individual teeth using MFH's method expressed by bias (mean difference between dental and chronological ages) in years

Sex	Tooth	N*	Mean	SD	P.value*
Girls	**Lower central**	**55**	**-0.63**	**0.73**	**<0.001**
	Lower lateral	**72**	**-0.88**	**0.89**	
	Lower canine	114	-1.22	0.81	
	Lower first premolar	138	-0.96	0.76	
	Lower second premolar	165	-0.94	1.05	
	Lower first molar	84	-1.6	0.92	
	Lower second molar	**193**	**-0.88**	**1.05**	
Boys	**Lower central**	**60**	**-0.56**	**0.80**	**<0.001**
	Lower lateral	**75**	**-0.5**	**0.91**	
	Lower canine	129	-0.94	1.02	
	Lower first premolar	146	-0.69	0.88	
	Lower second premolar	174	-0.62	0.87	
	Lower first molar	90	-1.48	0.94	
	Lower second molar	195	-0.78	0.98	
Both	**Lower central**	**115**	**-0.59**	**0.77**	**<0.001**
	Lower lateral	**147**	**-0.69**	**0.92**	
	Lower canine	243	-1.07	0.94	
	Lower first premolar	284	-0.83	0.84	
	Lower second premolar	339	-0.78	0.97	
	Lower first molar	174	-1.54	0.93	
	Lower second molar	388	-0.83	1.01	

* One-way ANOVA test, MFH: Moorrees, Fanning and Hunt,
N: number of teeth (the tooth at the final stage was excluded), SD: Standard deviation.

All teeth underestimated the age, except for the upper central incisor, upper lateral incisor, lower canine, and lower first premolar in girls, in which overestimation was observed. The least accurate tooth was the lower first molar (-1.08 ± 1.59 years) (Table 4).

The one-way ANOVA revealed a significant difference in bias among the teeth ($P < 0.001$) (Table 3). The *post-hoc* pairwise comparisons, after Bonferroni adjustment, showed that the biases of the lower central incisor in girls and the lower lateral incisor in boys were only statistically significantly different from those of the lower canine (P=0.0020, P=.022, respectively) and lower first molar (P<0.001).

No significant difference was found between the accuracy of age estimation when using the lower central incisor and lower lateral incisor alone and when using all teeth (Table 5).

Using the method by Nicodemo et al., the accuracy of individual teeth showed that the upper central incisor was the most accurate tooth (-0.15 ± 1.09, -0.03 ± 1.01 years), followed by the lower first premolar (-0.17 ± 1.35, -0.06 ± 1.29 years), for boys and the combined sexes. For girls, the most accurate tooth was the lower second

premolar (-0.03 ± 1.77 years), followed by the upper first premolar (-0.04 ± 1.02years).
All teeth underestimated the age, except for the upper central incisor, upper lateral incisor, lower canine, and lower first premolar in girls, in which overestimation was observed. The least accurate tooth was the lower first molar (-1.08 ± 1.59 years) (Table 4).

Table 4. The accuracy of individual teeth using Nicodemo et al.'s method expressed by bias (mean difference between dental and chronological ages) in years

Sex	Tooth	N	Mean	SD	P-value *
Girls	Upper central	66	0.09	0.92	**<0.001**
	Upper lateral	79	0.05	0.91	
	Upper canine	138	-0.29	1.41	
	Upper first premolar	**121**	**-0.04**	**1.02**	
	Upper second premolar	146	-0.4	1.28	
	Upper first molar	73	-0.77	1.12	
	Upper second molar	183	-0.39	1.51	
	Lower central	55	-0.25	0.87	
	Lower lateral	72	-0.54	1.09	
	Lower canine	110	0.22	1.09	
	Lower first premolar	138	0.07	1.23	
	Lower second premolar	**163**	**-0.03**	**1.77**	
	Lower first molar	82	-0.85	1.33	
	Lower second molar	192	-0.51	1.58	
Boys	**Upper central**	**69**	**-0.15**	**1.09**	**<0.001**
	Upper lateral	83	-0.21	0.98	
	Upper canine	140	-0.51	1.33	
	Upper first premolar	128	-0.19	1.06	
	Upper second premolar	150	-0.37	1.26	
	Upper first molar	84	-1.08	1.26	
	Upper second molar	187	-0.67	1.51	
	Lower central	60	-0.5	1.1	
	Lower lateral	74	-0.8	1.33	
	Lower canine	126	-0.38	1.14	
	Lower first premolar	**147**	**-0.17**	**1.35**	
	Lower second premolar	175	-0.41	1.84	
	Lower first molar	92	-1.29	1.77	
	Lower second molar	195	-0.77	1.56	

Sex	Tooth	N	Mean	SD	P-value *
Both	**Upper central**	**135**	**-0.03**	**1.01**	**<0.001**
	Upper lateral	162	-0.09	0.95	
	Upper canine	278	-0.4	1.37	
	Upper first premolar	249	-0.11	1.04	
	Upper second premolar	296	-0.39	1.27	
	Upper first molar	157	-0.94	1.2	
	Upper second molar	370	-0.53	1.51	
	Lower central	115	-0.38	1	
	Lower lateral	146	-0.67	1.22	
	Lower canine	236	-0.1	1.15	
	Lower first premolar	**285**	**-0.06**	**1.29**	
	Lower second premolar	338	-0.23	1.82	
	Lower first molar	174	-1.08	1.59	
	Lower second molar	387	-0.64	1.57	

* One-way ANOVA test, N: number of teeth (the tooth at the final stage was excluded),
* SD: Standard deviation

Table 5. A comparison between the accuracy when using all teeth and the most accurate tooth in the MFH method, as adapted by Smith; and Nicodemo et al.'s method, expressed by bias (mean difference between dental and chronological ages) in years

	Bias using	N	Mean bias	SD of bias	Mean difference	SD of the difference	P-value *
MFH method, Boys	All Teeth	72	-0.82	0.59	0.06	0.60	0.389
	Lower Lateral	72	-0.88	0.89			
MFH method, Girls	All Teeth	55	-0.70	0.51	-0.07	0.50	0.278
	Lower Central	55	-0.63	0.73			
MFH method, Both	All Teeth	115	-0.65	0.54	-0.06	0.51	0.200
	Lower Central	115	-0.59	0.77			
Nicodemo et al.'s method, Boys	All teeth	69	-0.06	0.72	0.09	0.56	0.188
	Upper Central	69	-0.15	1.09			
Nicodemo et al.'s method, Girls	All teeth	163	-1.03	1.45	-1.00	0.68	**<0.001**
	Lower Second Premolar	163	-0.03	1.77			
Nicodemo et al.'s method, Both	All teeth	135	0.08	0.65	0.11	0.58	**0.028**
	Upper Central	135	-0.03	1.01			

* Paired t-test, MFH: Moorrees, Fanning and Hunt, SD: Standard deviation. Bold value means the result is significant p <0.05.

There was a significant difference in the bias between the teeth ($P< 0.001$) (Table 4). The *post-hoc* pairwise comparisons, after Bonferroni adjustment, showed that the bias of the lower second premolar in girls was only statistically significantly different from the lower first molar ($P<0.007$). Moreover, a significant difference was also found between the biases when using the lower second premolar alone and all teeth in girls, with the lower second premolar having the lowest bias ($P < 0.001$) (Table 5).
In boys, the upper central incisor was only statistically significantly different from the upper and lower first molar (P=0.004, $P< 0.001$, respectively). However, no significant difference was found between the bias when using the upper central incisor alone and when using all teeth in boys (P=0.188) (Table 5).
For the combined sexes, a significant difference was found between the biases using the upper central incisor alone and that when using all teeth, with the upper central incisor having the lowest bias (P=0.028) (Table 5).

Accuracy of Each Stage for Individual Teeth in Each Method

Using the MFH method,[7] root stages "R$_i$," "R¼ ," "R½ ," "R¾ ," and "A½ " had the highest accuracies ranging from -0.07 ± 1.06 to -0.42±0.85 years. Stage "R¼ " of the lower second molar had the lowest bias (-0.07 ± 1.06 years) (Table 6).
The accuracy of each stage obtained using the Gleiser and Hunt method[8] is listed in Table 7. The lower first molar showed the lowest bias in the following stages: "½ of root completed," "⅔ of root completed," and "¾ of root completed." Of these, the "¾ of root completed" stage had the lowest bias (0.15 ± 0.57 years).
The accuracy of each tooth stage using the Nicodemo et al. method[9] is listed in Table 8. The "full crown," "early root formation," and "1/3 root" stages had the low biases, with the "early root formation" stage having the lowest bias in the upper lateral incisor and upper second molar (0.01 ± 0.43, 0.01 ± 0.99 years, respectively).

Table 6. Bias (mean difference between dental and chronological ages) and SD in years for individual tooth stages using MFH's method

Tooth	Stage	N	Mean	SD
Lower central	R¼	1	-1.57	.
	R½	15	-0.98	0.39
	R¾	25	-0.34	0.50
	R$_C$	44	-0.45	0.74
	A½	29	-0.81	1.00
Lower lateral	R¼	23.00	-1.07	0.57
	R½	18.00	-1.29	0.79
	R 2/3	1.00	-1.03	.
	R¾	48.00	-0.11	0.70
	R$_C$	30.00	-0.73	0.98
	A½	27.00	-0.92	1.03
Lower canine	Cr.$_c$	7.00	-2.39	0.67
	R$_i$	26.00	-1.57	0.55
	R¼	63.00	-1.01	0.70
	R½	52.00	-1.03	0.97
	R¾	57.00	-0.98	1.05
	R$_C$	24.00	-1.17	0.89

Tooth	Stage	N	Mean	SD
	A1/2	14.00	-0.08	0.85
Lower first premolar	Cr¾	1.00	-1.40	.
	$Cr._c$	14.00	-0.99	0.42
	R_i	47.00	-0.78	0.56
	R¼	72.00	-0.86	0.85
	R½	40.00	-0.94	1.05
	R¾	48.00	-0.86	0.86
	R_C	25.00	-1.21	0.77
	A½	37.00	-0.32	0.80
Lower second premolar	Cr¾	15.00	-0.63	0.30
	$Cr._c$	28.00	-0.48	0.62
	R_i	54.00	-0.42	0.85
	R¼	65.00	-0.87	0.87
	R½	34.00	-0.96	1.28
	R¾	62.00	-0.80	1.09
	R_C	44.00	-1.28	0.99
	A½	37.00	-0.61	0.88
Lower first molar	R½	21.00	-1.15	0.45
	R¾	47.00	-1.16	0.68
	R_C	70.00	-2.00	0.97
	A½	36.00	-1.34	0.96
Lower second molar	C_{oc}	1.00	-1.63	.
	Cr½	2.00	-1.26	0.50
	Cr¾	40.00	-0.74	0.46
	$Cr._c$	20.00	-0.82	0.55
	R_i	42.00	-0.64	0.87
	R¼	86.00	-0.07	1.06
	R½	41.00	-0.73	0.90
	R¾	53.00	-1.37	1.02
	R_C	49.00	-1.56	1.03
	A½	54.00	-1.09	0.62

MFH: Moorrees, Fanning and Hunt, N: number of teeth, SD: Standard deviation

Table 7. Bias (mean difference between dental and chronological ages) and SD in years for individual tooth stages using Gleiser and Hunt's method

Stage*	N	Mean	SD
1/2 of root completed	21	-0.28	0.43
2/3 of root completed	4	0.52	0.31
3/4 of root completed	42	0.15	0.57
Root canal terminally divergent	99	-0.86	1.01

N: number of teeth, SD: Standard deviation,
*The stages presented in the table are limited to the age structure of the study sample (the minimum age was 6.00 years).

Table 8. Bias (mean difference between dental and chronological ages) and SD in years for individual tooth stages using Nicodemo et al.'s method

Tooth	Stage	N	Mean	SD
UI$_1$	Early Root Formation	8	-0.62	0.15
	1/3 Root	27	-0.06	0.6
	2/3 Root	100	0.02	1.12
UI$_2$	Full Crown	3	-1.17	0.23
	Early Root Formation	26	0.01	0.43
	1/3 Root	50	0.29	0.78
	2/3 Root	83	-0.31	1.09
UC	Full Crown	13	-0.67	0.3
	Early Root Formation	45	-0.3	0.65
	1/3 Root	69	0.19	1.03
	2/3 Root	151	-0.67	1.62
UPM$_1$	2/3 Crown	7	-0.88	0.22
	Full Crown	51	0.22	0.63
	Early Root Formation	38	0.36	0.74
	1/3 Root	59	0.31	0.92
	2/3 Root	94	-0.7	1.14

Tooth	Stage	N	Mean	SD
LI$_1$	1/3 Root	3	-0.57	0.04
	2/3 Root	112	-0.38	1.02
LI$_2$	Early Root Formation	1	-0.8	.
	1/3 Root	25	-0.14	0.58
	2/3 Root	120	-0.79	1.3
LC	Full Crown	7	-1.61	0.67
	Early Root Formation	30	0.02	0.56
	1/3 Root	66	0.24	0.86
	2/3 Root	133	-0.22	1.31
LPM$_1$	2/3 Crown	1	-1.22	.
	Full Crown	14	0.12	0.36
	Early Root Formation	61	0.45	0.8
	1/3 Root	68	0.85	1.04
	2/3 Root	141	-0.72	1.28
	2/3 Crown	15	-0.3	0.3
	Full Crown	29	0.16	0.65

Tooth	Stage	N	Mean	SD
UPM_2	2/3 Crown	26	-0.28	0.36
	Full Crown	40	0.24	0.6
	Early Root Formation	52	0.37	0.99
	1/3 Root	64	0.07	0.94
	2/3 Root	114	-1.23	1.36
UM_1	Early Root Formation	2	-1.4	0.18
	1/3 Root	4	-0.12	0.13
	2/3 Root	151	-0.95	1.22
UM_2	1/3Crown	1	-1.38	.
	2/3 Crown	51	-0.43	0.49
	Full Crown	81	-0.84	1.05
	Early Root Formation	35	-0.01	0.99
	1/3 Root	47	-0.06	0.96
	2/3 Root	155	-1.58	1.35

Tooth	Stage	N	Mean	SD
LPM_2	Early Root Formation	64	2.06	0.89
	1/3 Root	58	0.52	0.88
	2/3 Root	172	-1.39	1.52
LM_1	1/3 Root	2	-1.14	0.83
	2/3 Root	172	-1.08	1.6
LM_2	R1/4	1	-3.31	.
	1/3Crown	2	-1.54	0.16
	2/3 Crown	43	-0.36	1.33
	Full Crown	50	0.02	0.85
	Early Root Formation	43	0.66	0.99
	1/3 Root	64	0.34	1.01
	2/3 Root	184	-1.51	1.54

UI_1: Upper central, UI_2: Upper lateral, UC: Upper canine, UPM_1: Upper first premolar, UPM_2: Upper second premolar, UM_1: Upper first molar, UM_2: Upper second molar, LI_1: Lower central, LI_2: Lower lateral, LC: Lower canine, LPM_1: Lower first premolar, LPM_2: Lower second premolar, LM_1: Lower first molar, LM_2: Lower second molar, N: number of teeth, SD: Standard deviation.

DISCUSSION

This retrospective cross-sectional study investigated whether specific teeth provide a more accurate estimation of the CA and determined which staging system is more representative of dental development for an individual tooth. The methods by MFH, as adapted by Smith, Gleiser and Hunt, and Nicodemo et al., were chosen because they provide tables with the mean ages of individual teeth in each stage.

Accuracy and precision are both important in DA assessments. *Accuracy*, also called *validity*, is the closeness of a computed value to its true value.[5] *Precision*, also called *reliability*, is the closeness of repeated measurements of the same quantity. [5] It is related to reproducibility and repeatability.[18] A valid age-estimating method with a staging system that is more representative of dental development for an individual tooth is both accurate and precise.

To enable the comparison of the staging systems for the three methods, we used only mandibular teeth, although Nicodemo et al.'s method used the maxillary teeth as well. As expected, compared to other methods, Gleiser and Hunt's method revealed the lowest bias in the mandibular first molar, given that it was limited to this tooth. The biases for all other mandibular teeth were lower in Nicodemo et al.'s method than in the MFH method; the probable reason is that this method involved fewer tooth formation stages, which cover a larger age span, resulting in a more accurate but less precise performance.

Liversidge et al. compared the biases of individual teeth using the Demirjian and Moorrees stages.

They reported poorer tooth performance when using the Moorrees stages (14 stages) than when using the Demirjian stages (eight stages).[12] However, the better accuracy observed in Nicodemo et al.'s method in this study and using Demirjian's stages in the abovementioned study[12] could be misleading.

A staging system with more stages was thought to be more accurate, as the time intervals between stages were smaller. It was also thought that as the number of stages increased, precision decreased.[19] However, this statement may not be completely true. Fewer stages mean that each stage covers a larger span of time, which therefore seems accurate in terms of individual teeth accuracy, but not as a DA estimation method. Nevertheless, more stages occurring over a shorter time span may appear inaccurate regarding individual teeth accuracy; however, they reflect CA better (making it more accurate and precise as a DA estimation method).

This is reflected in the MFH method, as adapted by Smith (14 stages), in which the accuracy in estimating the CA of individual teeth did not differ from that in which all the teeth were used, whereas, in Nicodemo et al.'s method (eight stages), individual teeth performed better in estimating CA than when using all the teeth. This makes MFH, as adapted by Smith, a method with a staging system that is more representative of dental development for an individual tooth.

For individual teeth using the MFH method, as adapted by Smith, the lower central incisor and lower lateral incisor were the most accurate teeth, whereas the first molar was the least accurate. These findings are consistent with those reported by Liversidge et al., in which the lower central and lateral incisors were found to be the most accurate teeth, with a bias of (-0.29 years), while the lower canine and first molar were the least accurate, with biases of (-0.88, and -0.73, respectively).[12]

Stage "R1/4" for the lower second molar, as per the MFH method, had the lowest bias. However, Liversidge et al. found that, based on the MFH method, the early crown stages of the lower second molar, including "Ci," "Cco," and "Coc," had low biases, with the "Coc" stage having the lowest bias (0.06 years).[12] A similar finding was reported by Maber et al., who found that the "Ci" stage of the second molar showed the lowest bias (-0.09 years) using the Haavikko method.[11]

In this study, however, the bias of the "Coc" stage was higher (-1.63 years), which could be attributed to the fact that the minimum age of the patients in the aforementioned studies was 3.00 years, which may explain the high accuracy of the earlier crown development stages of the lower second molars. In comparison, the minimum age included in this study was 6.00 years, which explains why few early stages of the anterior teeth and first permanent molars were available (Tables 6–8).

Furthermore, in agreement with Liversidge et al.,[12,20] the SD of the accuracy of individual tooth stages was related to age. Some early crown stages or stages that occurred near the patient's minimum age had an SD of about 6 months, whereas, for some late root stages, the SD was >1 year.

Regarding testing the accuracy of individual teeth and stages using Nicodemo et al.'s and Gleiser and Hunt's methods, no studies were found; therefore, no comparisons with this study could be made.

Three disadvantages of Nicodemo et al.'s method were observed: 1) acceleration in the final stages as compared with that in other dental development tables, 2) not considering sex-based differences, and 3) a lack of clear description or schematics of the stages.

This study has some limitations. Because Gleiser and Hunt's method used a single tooth, the accuracy of the tooth type was compared using only two methods. It was also not easy to compare the accuracy of the stages for individual teeth in each method because of insufficient data in some of the stages. Future studies involving a comparison that considers the influence of various factors, such as sample size, structure, and distribution of the sample, should be conducted to validate our findings.

CONCLUSIONS

In comparing the staging systems, Nicodemo et al.'s method had the lowest bias for all teeth except for the mandibular first molar, in which Gleiser and Hunt's method had the lowest bias. This, however, should not be confused with precision. MFH's staging system was more representative of dental development for an individual tooth.

Regarding the accuracy of individual teeth, for the combined sexes, the lower central and lateral incisors were the most accurate teeth using the MFH method, while the upper central incisor and lower first premolar were the most accurate teeth using Nicodemo et al.'s method. The lower first molar was the least accurate tooth using both methods.

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Bibliometric analysis of research on dental age estimation

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Sujitha Ponraj [1], Kavitha Ramar [1], Rajakumar Sekar [1], Anand Kasi [1]

[1]*Department of Pediatric and Preventive Dentistry, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology, Potheri, Kattankulathur, Chengalpattu District, Tamil Nadu (India)*

Corresponding author: sonali7695@gmail.com

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KEYWORDS

Dental age estimation, Bibliometric; dentistry, forensic odontology, Citation analysis

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ABSTRACT

Dental age estimation plays a key role in therapeutic, medicolegal, forensic, and anthropological applications. The purpose of this study is to evaluate the research progress on dental age estimation using bibliometric analysis. Data were gathered from Scopus, Web of Science and PubMed. Keyword co-occurrence analysis, collaboration network analysis, and descriptive analysis of bibliographic data were all completed using VOS viewer and Biblioshiny software. There has been an ongoing but gradual rise in research regarding dental age estimation, with notable increase since 2014. The country with the most publications published (205) was India. The year of 2018 (TP = 92) and 2021 (TP = 100) saw a rapid spike in publications and citations, respectively. The Shanghai Jiao Tong University School of Medicine, which has 153 citations, was the most productive institution. Forensic Science International was the journal with the greatest number of publications (73). Author Cameriere had the maximum number of publications (30). The increase in publications associated to collaboration across numerous authors, nations, and institutes serves as evidence of the significant improvement in dental age estimation. This citation analysis allows for the identification of the most relevant and pertinent research fields while providing a view on the development of research in the field of dental age estimation.

INTRODUCTION

Dental age estimation is one of the major parts of forensic dentistry that helps in identification and dental profiling of an individual. [1] The literature acknowledges that various methods exist to determine dental age, which are broadly divided into three types: morphological, biochemical, and radiological methods.[1] Morphological methods rely on the visual examination of dental features, such as tooth mineralization stages, eruption patterns, root formation, and dental crown morphology. Biochemical methods involve the analysis of biological markers within teeth, such as stable isotopes, enamel proteins, or DNA. Radiological methods utilize imaging technologies, such as dental radiographs or cone-beam computed tomography (CBCT), to assess dental development. [2] Every individual has a unique morphology and arrangement of teeth which makes them an identifiable aspect in forensic dentistry. [2] The first publication of information about dental implications in age assessment was a pamphlet called "Teeth A

Test of Age" in 1837, which was presented to the English parliament by dentist Edwin Saunders. [3,4] Due to the fact that teeth start to form in the early stages of embryonic development, this field has undergone substantial research. Additionally, the information offered by the chronology of dental growth is more trustworthy than that from bone development. [5] The consistency and predictability of dental development allow for the establishment of robust age estimation methods based on dental growth stages. These methods involve the examination of specific dental characteristics, such as tooth mineralization, tooth eruption patterns, root formation, and dental crown morphology. By analyzing these features, forensic experts and anthropologists can accurately estimate an individual's age with a higher level of confidence compared to bone development methods. [6] The trustworthiness of dental growth chronology surpasses that of bone development due to the consistent and predictable nature of dental development. Dental age estimation methods provide reliable and valuable information in forensic and anthropological contexts, aiding in accurate age estimation and identification. [6,7,8] These advantages make dental growth chronology a valuable tool in age assessment, underscoring its significance in forensic investigations and anthropological research. [9,10] Due to recent emigration of different population into many countries, dental documentation is becoming more important for surviving persons who lacks appropriate identity documents to attribute a true age for various legal purposes. [11,12] In order to determine the age of children and adults, dental age estimation methods were developed based on the relationship between age and features of the tooth structure. Literature states that there are several methods found to determine the dental age, which are broadly divided into three types namely, morphological, biological and radiological methods. [1]

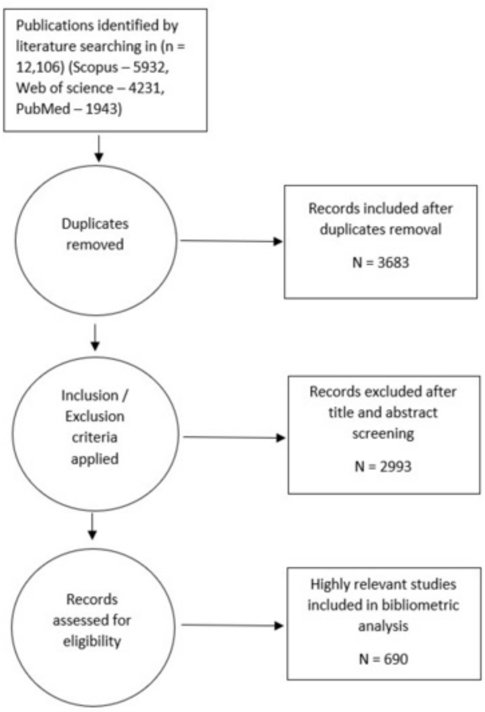
It is possible to weigh the significance of research or a publication by counting the number of citations it receives in the scientific literature. In addition to researchers and publications, the institute where the study was conducted also benefits from the volume of citations. [13] Bibliometric analysis is currently a widely recognised study as it analyses the progress of a particular area of research. In order to emphasize the most important sources, authors, institutions, and nations active in the field, or to portray the current state and research tendencies of a given scientific topic, bibliometric analysis has come to be regarded as a valid method. The key conclusions of this analysis may also aid researchers, academics, and students in characterising scientific findings involving dental age estimation, assessing diagnostic approaches, and identifying crucial subjects and difficulties that may aid in the design of future research.

Despite of these vast literature and various methods in evaluating the dental age, studies on this area brings light on the fact that further research is required to arrive at a concrete result. 14 Forensic odontologist still searches towards the best approach for estimating age. It must be noted that there are numerous dental age estimation techniques that can be employed. Each has advantages and limitations, so it is always best to use a variety of techniques, repeating measurements and computations to ensure the highest level of reproduction. [15] While significant progress has been made in this area, it is acknowledged in the literature that further research is necessary to enhance the accuracy and reliability of dental age estimation techniques. 14 It is important to note that the field of dental age estimation encompasses numerous techniques, each with its own advantages and limitations. 15 Considering the complexity and variability in dental development, it is recommended to employ a combination of techniques, repeating measurements and computations to ensure the highest level of accuracy and reproducibility. So, there is a need to evaluate the progress and the course of scientific literature in this area to bring a clarity. Hence, the aim of this study is to evaluate the research progress on dental age estimation using bibliometric analysis and we further hypothesize that trends on knowledge the results change from time to time.

METHODOLOGY

An extensive literature search was done in the Clarivate Analytics' Web of Science (WoS), Science Citation Index Expanded (SCI-E) section of the Scopus database and PubMed on 9th September 2022 from year 1964 without language exception (Figure 1). The keywords used were "age estimation", "age determination", "dental age", "forensic odontology", "forensic dentistry", "dentistry". All the type of studies pertaining to dental age estimation was included. Studies done with age estimation using methods other than dental structures were excluded. Two reviewers separately inspected the titles and abstracts of all the publications located through the search (SP and AV). The whole texts were analysed in cases when an abstract was insufficient to offer the relevant details. The third reviewer (GS) was consulted, in case of any disagreements regarding the papers. Regarding the publication date or status, no limits were imposed. The following information was retrieved from the papers and reviewed separately by two authors (SP and SS): study characteristics and citation characteristics (journal, title, year of publication, citations, and authors) (study design and the topic addressed). The VOS viewer software (version 1.6.13; Leiden University Center for Science and Technology Studies, Netherlands) and Biblioshiny (Version 4.0) were used for analysis and network visualization of the authors, nations, and keywords were created.

Figure 1. Flowchart on inclusion of articles



RESULTS

Main information

Table 1 represents the overall description of the scientific literature on dental age estimation. A total number of 690 articles are finally included in this study after careful screening of the articles. The first article published was on 1966. The annual growth rate percentage was about 6.32%. The total number of authors involved are 2260. Among the 690 articles, majority were original article (643) and review article (32).

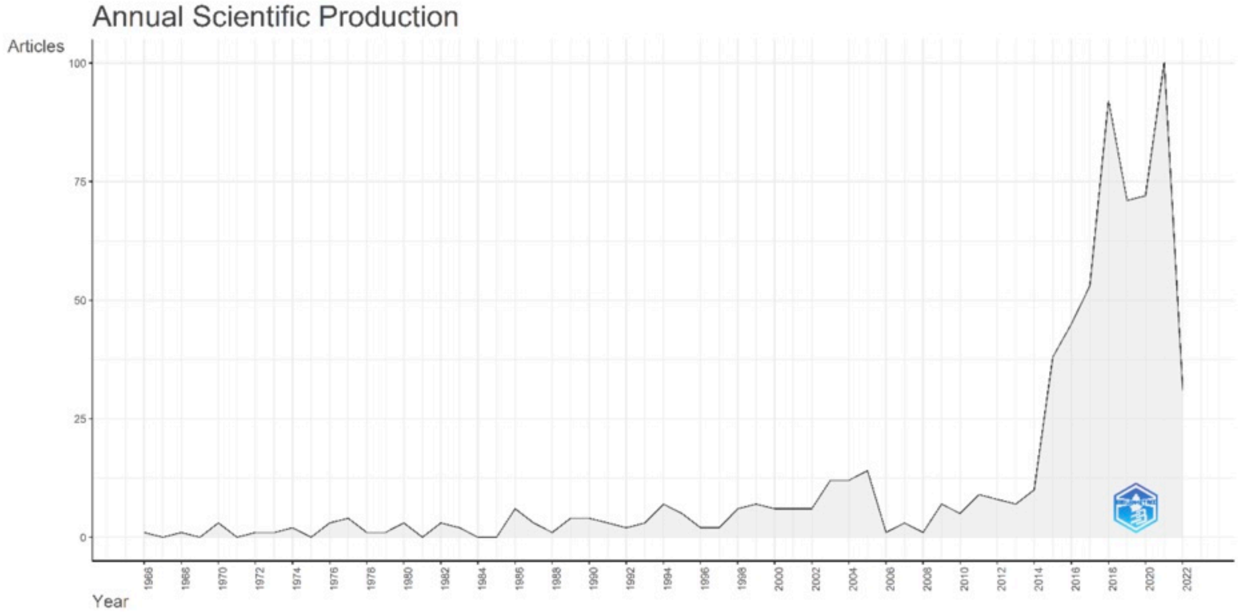
Table 1. Overall description of the scientific literature on dental age estimation

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1966:2022
Sources (Journals, Books, etc)	177
Documents	690
Annual Growth Rate %	6.32
Document Average Age	8.72
Average citations per doc	15.25
References	16996
DOCUMENT CONTENTS	
Keywords Plus (ID)	1389
Author's Keywords (DE)	1033
AUTHORS	
Authors	2260
Authors of single-authored docs	37
AUTHORS COLLABORATION	
Single-authored docs	41
Co-Authors per Doc	4.49
International co-authorships %	20.58
DOCUMENT TYPES	
article	643
book chapter	1
conference paper	4
editorial	1
letter	7
note	2
review	32

Overall growth trends

Figure 2 presents the overall growth trend on dental age estimation. It explains how much this area has developed over the last few decades. Since the first publication was released in 1966, there hasn't been much improvement in the first few years. There have been 87 total publications (TP) in the first 35 years (1966-2000), however the development has been slow and has increased each year. The number of prominent publications began to rise in 2014 and has been steadily rising each year thereafter. The years 2018 (TP = 92) and 2021 (TP = 100), respectively, saw a boom in publications and citations.

Figure 2. Annual scientific production



Citations

Table 2 displays the annual publishing and citation details of dental age estimation research. The mean of Total citation (TC) per article and mean TC per year which started increasing after 1992 with high values seen during 2006, 1992 and 2001. The average citations per document is around 15.25 having totally 16996 references (Table 1).

Table 2. Annual publishing and citation details

Year	N	MeanTC perArt	MeanTC perYear
1966	1	0.00	0.00
1967	0	0.00	0.00
1968	1	24.00	0.44
1969	0	0.00	0.00
1970	3	68.00	1.31
1971	0	0.00	0.00
1972	1	0.00	0.00
1973	1	13.00	0.27
1974	2	18.00	0.38
1975	0	0.00	0.00
1976	3	16.33	0.36
1977	4	3.25	0.07
1978	1	3.00	0.07
1979	1	0.00	0.00
1980	3	34.00	0.81
1981	0	0.00	0.00
1982	3	32.00	0.80
1983	2	0.00	0.00
1984	0	0.00	0.00
1985	0	0.00	0.00
1986	6	69.00	1.92
1987	3	11.00	0.31
1988	1	3.00	0.09
1989	4	5.00	0.15
1990	4	22.50	0.70
1991	3	16.67	0.54
1992	2	119.50	3.98
1993	3	58.33	2.01
1994	7	29.57	1.06
1995	5	91.40	3.39
1996	2	24.00	0.92
1997	2	43.00	1.72
1998	6	60.33	2.51
1999	7	26.00	1.13
2000	6	87.33	3.97
2001	6	99.00	4.71
2002	6	67.67	3.38
2003	12	44.50	2.34
2004	12	71.50	3.97
2005	14	47.79	2.81
2006	1	194.00	12.13

2007	3	54.00	3.60
2008	1	15.00	1.07
2009	7	14.57	1.12
2010	5	25.80	2.15
2011	9	18.67	1.70
2012	8	17.13	1.71
2013	7	4.71	0.52
2014	10	14.70	1.84
2015	38	14.71	2.10
2016	45	12.40	2.07
2017	53	9.13	1.83
2018	92	8.12	2.03
2019	71	5.63	1.88
2020	72	1.82	0.91
2021	100	0.67	0.67
2022	31	0.00	0.00

Leading countries

Table 3 shows the countries with the highest number of publications were India (205), Turkey (41), and Brazil (40). Publications from the India had been cited 685 times with a frequency of 0.162. Despite a lower publication volume as compared to the India, Belgium and Germany led the way in way in citations with a total of 1084 and 1015 citations respectively and a frequency of 0.022 and 0.041 respectively.

Table 3. Top 50 countries with highest number of publications

Country	Articles	SCP	MCP	TC	Freq
INDIA	205	184	21	685	0.162
TURKEY	41	37	4	410	0.059
BRAZIL	40	26	14	383	0.058
CHINA	30	25	5	254	0.043
GERMANY	28	22	6	1015	0.041
UNITED KINGDOM	25	19	6	630	0.036
ITALY	23	18	5	688	0.033
USA	23	15	8	449	0.033
MALAYSIA	17	13	4	116	0.025
SPAIN	17	15	2	399	0.025
AUSTRALIA	15	7	8	230	0.022
BELGIUM	15	10	5	108	0.022
IRAN	15	15	0	87	0.022
JAPAN	15	14	1	323	0.022
FRANCE	12	9	3	447	0.017
INDONESIA	12	8	4	16	0.017
SAUDI	11	10	1	52	0.016
THAILAND	11	10	1	54	0.016
CANADA	10	5	5	443	0.014
CROATIA	10	4	6	144	0.014
FINLAND	9	5	4	141	0.013
NORWAY	7	7	0	462	0.01
POLAND	7	7	0	66	0.01
PORTUGAL	7	5	2	49	0.01
SERBIA	7	5	2	69	0.01
SOUTH AFRICA	7	7	0	54	0.01
KOREA	5	4	1	102	0.007
PAKISTAN	5	5	0	36	0.007
EGYPT	4	2	2	9	0.006
ROMANIA	4	4	0	3	0.006
DENMARK	3	2	1	37	0.004
JORDAN	3	3	0	3	0.004
MALTA	3	0	3	21	0.004
NEPAL	3	1	2	3	0.004
SWEDEN	3	2	1	104	0.004
TUNISIA	3	3	0	17	0.004
ARGENTINA	2	1	1	2	0.003
CHILE	2	0	2	43	0.003
COLOMBIA	2	2	0	2	0.003
HONG KONG	2	0	2	3	0.003
IRAQ	2	2	0	0	0.003
SRI LANKA	2	1	1	9	0.003
SWITZERLAND	2	1	1	15	0.003
BOSNIA	1	1	0	1	0.001
CAMBODIA	1	0	1	0	0.001
CZECH REPUBLIC	1	1	0	0	0.001
GHANA	1	0	1	0	0.001
GREECE	1	1	0	0	0.001
ICELAND	1	1	0	2	0.001
ISRAEL	1	0	1	3	0.001

Leading Institutions

According to Table 4, Shanghai Jiao Tong University School of Medicine had the maximum number of publications in dental age estimation literature. It had a total of 56 publications with a total of 153 citations. The second and third most institution with maximum number of publications is University of Malaya and University of Sao Paulo with a total of 48 and 44 publications with citations of 88 and 43 respectively.

Table 4. Top 50 Institution with highest number of publications

Affiliation	Articles
SHANGHAI JIAO TONG UNIVERSITY SCHOOL OF MEDICINE	56
UNIVERSITY OF MALAYA	48
UNIVERSITY OF SÃO PAULO	44
XI'AN JIAOTONG UNIVERSITY	34
UNIVERSITY OF MACERATA	32
UNIVERSITY OF WESTERN AUSTRALIA	32
KANAGAWA DENTAL COLLEGE	31
MANIPAL COLLEGE OF DENTAL SCIENCES	31
UNIVERSITY HOSPITAL MÜNSTER	31
CHIANG MAI UNIVERSITY	29
KATHOLIEKE UNIVERSITEIT LEUVEN	29
UNIVERSITAS AIRLANGGA	27
UNIVERSITY OF GRANADA	25
GOVERNMENT DENTAL COLLEGE AND HOSPITAL	23
CENTRAL SOUTH UNIVERSITY	22
KING KHALID UNIVERSITY	21
PANINEEYA MAHAVIDYALAYA INSTITUTE OF DENTAL SCIENCES	21
FEDERAL UNIVERSITY OF PARAÍBA	20
UNIVERSITY OF BELGRADE	20
SICHUAN UNIVERSITY	19
UNIVERSITY OF FLORENCE	18
UNIVERSITY OF OSLO	18
ALL INDIA INSTITUTE OF MEDICAL SCIENCES	16
NEW HORIZON DENTAL COLLEGE AND RESEARCH INSTITUTE	16
NOTREPORTED	16
QUEEN MARY UNIVERSITY OF LONDON	16
JSS DENTAL COLLEGE AND HOSPITAL	14
UNIVERSITY OF PRETORIA	14
PEKING UNIVERSITY SCHOOL AND HOSPITAL OF	13
UNIVERSITY OF BRESCIA	13
UNIVERSITY OF JORDAN	13
XI'AN JIAOTONG UNIVERSITY HEALTH SCIENCE CENTER	13
HAMADAN UNIVERSITY OF MEDICAL SCIENCES	12
PANJAB UNIVERSITY	12
THE UNIVERSITY OF WESTERN AUSTRALIA	12
TOKYO MEDICAL AND DENTAL UNIVERSITY	12
UNIVERSITY OF COPENHAGEN	12
UNIVERSITY OF DUNDEE	12
ANKARA UNIVERSITY	11
FACULTY OF DENTAL MEDICINE UNIVERSITAS AIRLANGGA	11
INSTITUTE OF LEGAL MEDICINE	11
INTERNATIONAL MEDICAL UNIVERSITY	11
UNIVERSITY OF BARI	11

UNIVERSITY OF COIMBRA	11
UNIVERSITY OF ZAGREB	11
MCMASTER UNIVERSITY	10
UNIVERSITY OF HELSINKI	10
UNIVERSITY OF INDONESIA	10
ERASMUS UNIVERSITY MEDICAL CENTRE	9
KING'S COLLEGE LONDON DENTAL INSTITUTE	9

Authors

To determine the most productive authors, the data was ranked based on the total number of publications from different authors. Table 5 shows data on authors with the number of their total number of articles and articles fractionalized. An individual author's contributions to a published set of paper are denoted by article fractionalization. Cameriere is the author with maximum number of publications (30) pertaining to dental age estimation. Following that, Liversidge HM (15) and Willems G (15) have the maximum of publications. Cameriere have H index of 38, Willem G has 50 and Galic I has 22.

Table 5. Top 50 authors with highest number of publications

Authors	Articles	Articles Fractionalized
CAMERIERE R[19]	30	5.49
LIVERSIDGE HM[7]	15	6.20
WILLEMS G [22,23]	15	5.15
FRANCO A [25]	12	2.10
NAMBIAR P[26]	12	2.47
SCHMELING A [12]	12	1.94
CHEN T [27]	11	1.44
GALIĆ I [9]	11	1.80
OHTANI S [28]	11	3.97
GUO Y-C [27]	10	1.20
BALLA SB [9]	9	1.16
FERRANTE L[19]	9	1.91
KVAAL SI[21]	9	2.26
OLZE A[12]	9	1.32
ROBERTS G[29]	9	2.23
JAYARAMAN J[29]	8	2.19
JI F[30]	8	1.18
TAO J [30]	8	1.18
ASIF MK[31]	7	1.35
FIEUWS S [32]	7	1.35
JANHOM A [33]	7	1.77
KRUGER E [14]	7	1.56
LUCAS VS [34]	7	1.85
PFEIFFER H [35]	7	1.06
ROBERTS GJ [36]	7	2.14
TENNANT M [14]	7	1.56
THEVISSEN P [32]	7	1.30
BIAZEVIC MGH[37]	6	1.28
CHU G [27]	6	0.89
DE LUCA S [38]	6	0.95
HEGDE S [39]	6	1.75
NYSTRÖM M [40]	6	1.65
SANTIAGO BM [41]	6	0.88
SOLHEIM T [21]	6	2.78
YANG Z [42]	6	0.75
CARDOSO HFV [43]	5	1.39
CINGOLANI M [19]	5	1.31
DIXIT U [39]	5	1.58
DJURIC M [44]	5	0.83
DUANGTO P [33]	5	1.32
IAMAROON A [33]	5	1.32
IBRAHIM N [31]	5	0.90
KARKHANIS S [45]	5	0.90
MÂNICA S [46]	5	1.55
MCDONALD F [34]	5	1.03
PINCHI V [47]	5	0.74
SCHULZ R [48]	5	0.60
SEHRAWAT JS [49]	5	2.53
TIMME M [50]	5	0.88
WANG J [30]	5	0.78

Journals

Table 6 denotes the total of top 50 journals information regarding the total number of articles, H-index, G-index, M-index, Total citation, Publication start year. Forensic Science International had the maximum of 73 publications with H-index of 24, G-index of 46, M-index of 0.558. Its total citation count was 2244 and publications started in year 1980. This is followed by International journal of legal medicine with publications of 62 and journal of forensic sciences with publications of 33.

Table 6. Top 50 journals with highest number of publications

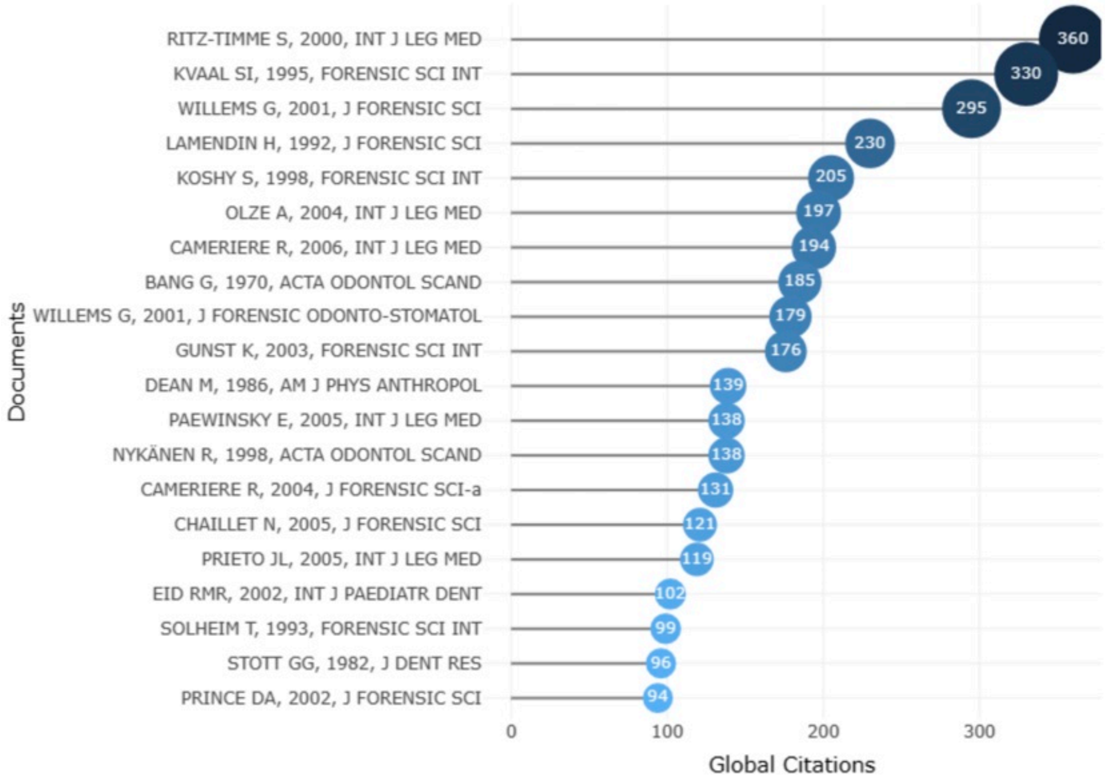
Element	h_index	g_index	m_index	TC	NP	PY_start
FORENSIC SCIENCE INTERNATIONAL	24	46	0.558	2244	73	1980
INTERNATIONAL JOURNAL OF LEGAL MEDICINE	17	40	0.607	1708	62	1995
JOURNAL OF FORENSIC SCIENCES	17	33	0.362	1693	33	1976
JOURNAL OF FORENSIC AND LEGAL MEDICINE	11	18	1.375	346	23	2015
AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY	10	14	0.27	562	14	1986
JOURNAL OF FORENSIC ODONTO-STOMATOLOGY	9	21	0.25	461	27	1987
LEGAL MEDICINE	8	15	0.444	239	26	2005
ACTA ODONTOLOGICA SCANDINAVICA	7	10	0.132	433	10	1970
ARCHIVES OF ORAL BIOLOGY	7	12	0.25	190	12	1995
ANNALS OF HUMAN BIOLOGY	6	8	0.75	122	8	2015
AUSTRALIAN JOURNAL OF FORENSIC SCIENCES	5	5	0.625	59	26	2015
DENTOMAXILLOFACIAL RADIOLOGY	5	5	0.185	73	5	1996
JAPANESE JOURNAL OF LEGAL MEDICINE	5	8	0.088	70	9	1966
AMERICAN JOURNAL OF FORENSIC MEDICINE AND PATHOLOGY	4	6	0.108	57	6	1986
EUROPEAN JOURNAL OF ORTHODONTICS	4	4	0.286	108	4	2009
JOURNAL OF INDIAN SOCIETY OF PEDODONTICS AND PREVENTIVE DENTISTRY	4	7	0.308	58	7	2010
JOURNAL OF ORAL AND MAXILLOFACIAL PATHOLOGY	4	4	0.5	24	5	2015
ORAL SURGERY, ORAL MEDICINE, ORAL PATHOLOGY	4	4	0.073	124	4	1968
BMC ORAL HEALTH	3	4	0.333	55	4	2014
BRAZILIAN ORAL RESEARCH	3	4	0.25	45	4	2011
BRITISH DENTAL JOURNAL	3	3	0.214	85	3	2009
CONTEMPORARY CLINICAL DENTISTRY	3	3	0.333	44	3	2014
DENTAL RESEARCH JOURNAL	3	3	0.375	24	3	2015
FORENSIC SCIENCE, MEDICINE, AND PATHOLOGY	3	5	0.375	30	5	2015
IMAGING SCIENCE IN DENTISTRY	3	6	0.3	37	6	2013
JOURNAL OF INDIAN ACADEMY OF ORAL MEDICINE AND RADIOLOGY	3	5	0.333	30	11	2014
RECHTSMEDIZIN	3	4	0.15	45	4	2003
SAUDI DENTAL JOURNAL	3	4	0.375	26	4	2015

AMERICAN JOURNAL OF HUMAN BIOLOGY	2	4	0.061	37	4	1990
ANNALS OF ANATOMY	2	2	0.286	18	2	2016
ARCHIV FUR KRIMINOLOGIE	2	3	0.1	14	3	2003
BRAZILIAN JOURNAL OF ORAL SCIENCES	2	2	0.154	8	2	2010
CLINICAL ORAL INVESTIGATIONS	2	2	0.667	7	5	2020
COMMUNITY DENTAL HEALTH	2	2	0.091	34	2	2001
DENTAL CLINICS OF NORTH AMERICA	2	2	0.043	7	2	1977
EGYPTIAN JOURNAL OF FORENSIC SCIENCES	2	4	0.286	19	10	2016
EUROPEAN JOURNAL OF ORAL SCIENCES	2	3	0.069	69	3	1994
FA YI XUE ZA ZHI	2	2	0.5	6	2	2019
INTERNATIONAL JOURNAL OF MORPHOLOGY	2	2	0.333	5	3	2017
INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY	2	2	0.095	127	2	2002
JOURNAL OF APPLIED ORAL SCIENCE	2	2	0.125	51	2	2007
JOURNAL OF CLINICAL FORENSIC MEDICINE	2	2	0.083	56	2	1999
JOURNAL OF CONTEMPORARY DENTAL PRACTICE	2	2	0.5	4	3	2019
JOURNAL OF FORENSIC RADIOLOGY AND IMAGING	2	3	0.333	15	4	2017
JOURNAL OF INTERNATIONAL DENTAL AND MEDICAL RESEARCH	2	3	0.333	14	4	2017
MEDICINE AND LAW	2	2	0.067	7	2	1993
MEDICINE, SCIENCE AND THE LAW	2	3	0.063	9	3	1991
MINERVA STOMATOLOGICA	2	2	0.057	26	2	1988
NIGERIAN JOURNAL OF CLINICAL PRACTICE	2	3	0.25	33	3	2015
PESQUISA BRASILEIRA EM ODONTOPEDIATRIA E CLINICA INTEGRADA	2	2	0.286	6	4	2016

Top cited articles

Figure 3 denotes the top 20 cited articles of dental age estimation. The top most cited article is "Age estimation: The state of the art in relation to the specific demands of forensic practise" by Ritz-Timme published in the year 2000 in the International journal of legal medicine. [16] The article is cited for 360 times.

Figure 3. Top 20 cited articles of dental age estimation



Keywords

Figure 4 represents the top 20 commonly used words in dental age estimation. The top most common word in male is repeated around 761 times, followed by the word female which is repeated around 750 times. Figure 5 represents the word cloud of the most common word used, with the sizes increasing based on the number of times used. The top most common word male is largest in size.

Figure 4. Top 20 commonly used words of dental age estimation

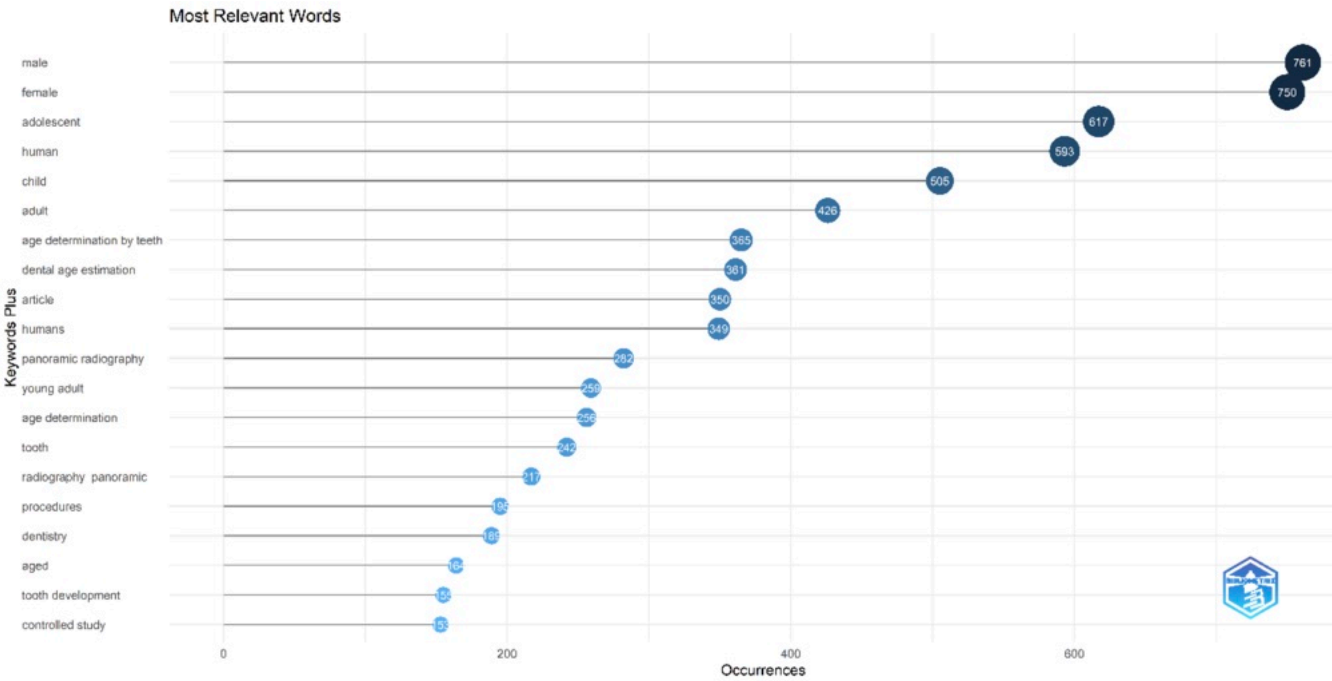


Figure 5. Word cloud of most commonly used words

Thematic evolution and Co-occurrences of keywords

Figure 6 shows the thematic evolution of keywords during three stages of its publication years which are 1966-2000, 2000-2010 and 2010-2022. During the year from 1966 to 2000, forensic odontology followed by tooth development was the most commonly used keywords. In the years between 2000-2010 also forensic odontology was the commonly used followed by age determination. But during the years 2010-2022, age estimation was the most common keywords used. Figure 7 shows the co-occurrences of keywords in which the highest is shown by the keyword "Human" which had 544 occurrences, 209 links with total link strength of 10828. This is followed by the word "Male" which had 450 occurrences, 209 links with total link strength of 9699.

Figure 6. Thematic evolution of keywords

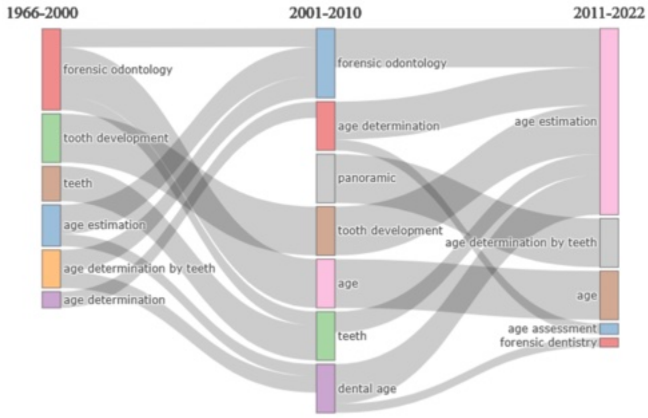
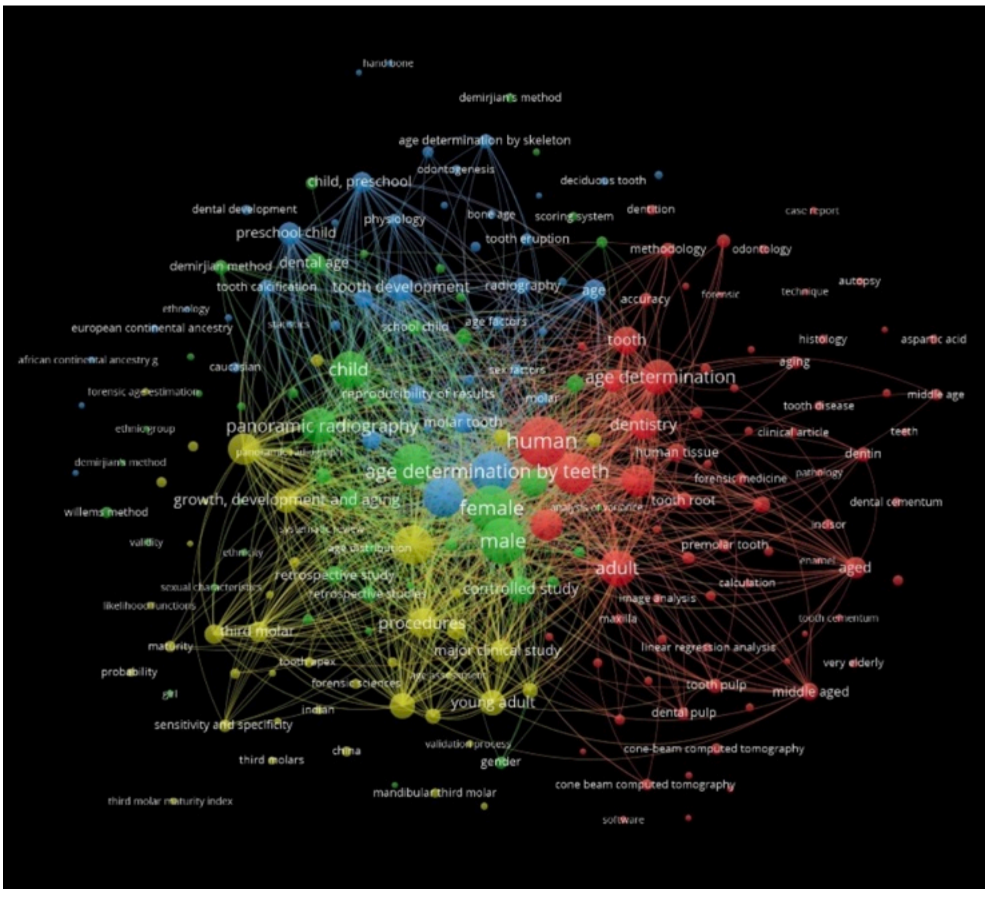


Figure 7. Co-occurrences of keywords

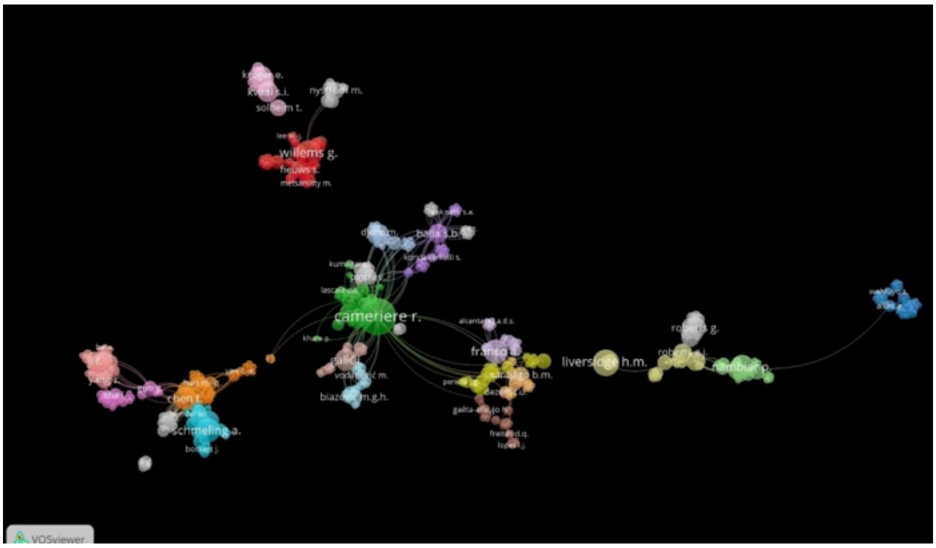


Bibliographic networking

Co-authorship with authors

Figure 8 represents the networking map of co-authorship and authors. Out of all the authors involved only 425 authors showed links with other authors. The connections within each set of authors are denoted by clusters. This map shows a total of 26 clusters all over the world. The Author with the top most number of publications is Cameriere (29) who has 70 links with 115 link strength. It is followed by Liversidge HM (15) and Willems G (15) with 4, 22 links and 8, 37 link strength respectively.

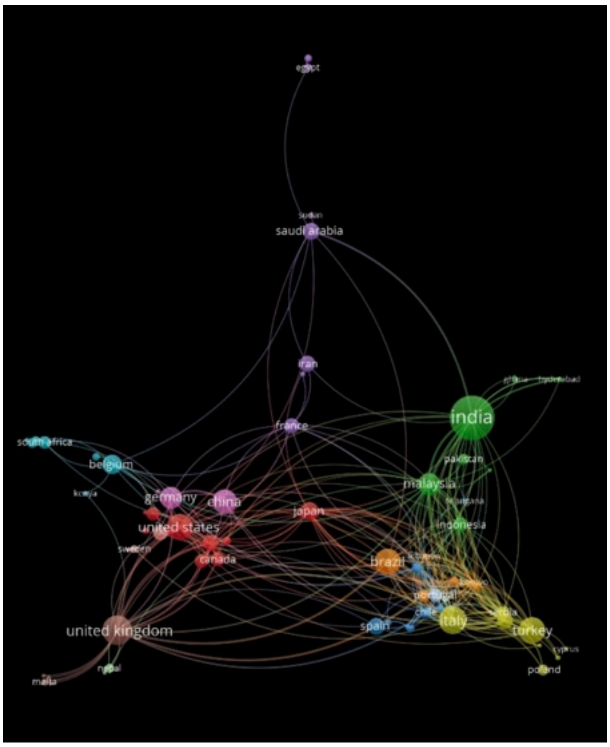
Figure 8. Networking map of co-authorship and authors



Co-authorship with countries

Figure 9 represents the networking map of co-authorship and countries. Out of all the authors involved only 74 countries authors showed links with other countries. This map shows a total of 12 clusters all over the world. The country which has most number of co-authors in publications is India with 135 documents, 30 links and 48 total link strength. This is followed by United Kingdom having 60 documents, 24 links and 60 total link strength.

Figure 9. Networking map of co-authorship and authors



Networking of Citation and Document, author and countries

Figure 10 represents the networking map between citations and document. The paper written by author Ritz-timme in 2000 has a total of 360 citations with 58 citation links. [16] Figure 11 represents the networking map between citations and authors. The author Cameriere has a total of 30 articles with 232 citation links. Figure 12 represents the networking map between citations and countries. The country India has a total of 135 articles with 63 citation links.

Figure 10. Networking map of citation and documents

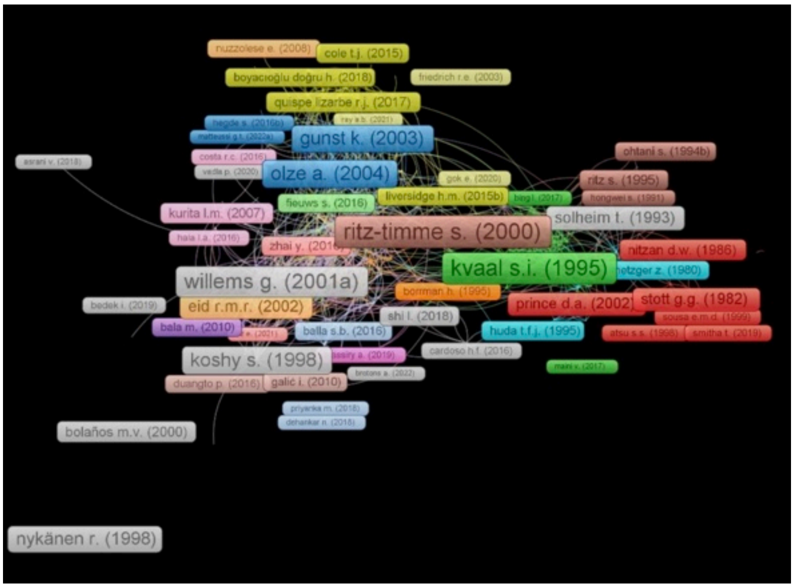


Figure 11. Networking map of citation and authors

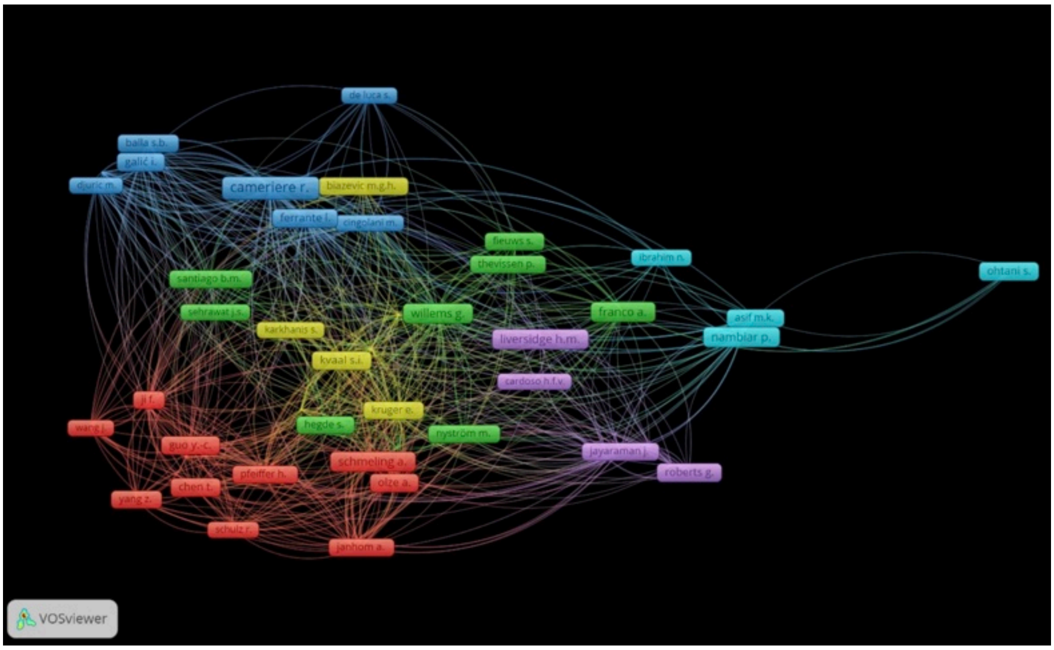


Figure 12. Networking map of citation and countries

Co-citation with References and Sources

Figure 13 shows the networking map of co-citation with cited references for a minimum of 10 times. The document with most citations are "A new system of dental age assessment" by Demirjian in the year 1973[17]. It has been cited for 79 times, with 39 links and 228 total link strength. Figure 14 shows networking map of co-citation with sources. There is a total of three clusters in this map. Forensic Science International was the journal with top most publications and co-citations.

Figure 13. Networking map of co-citation with cited references for a minimum of 10 times

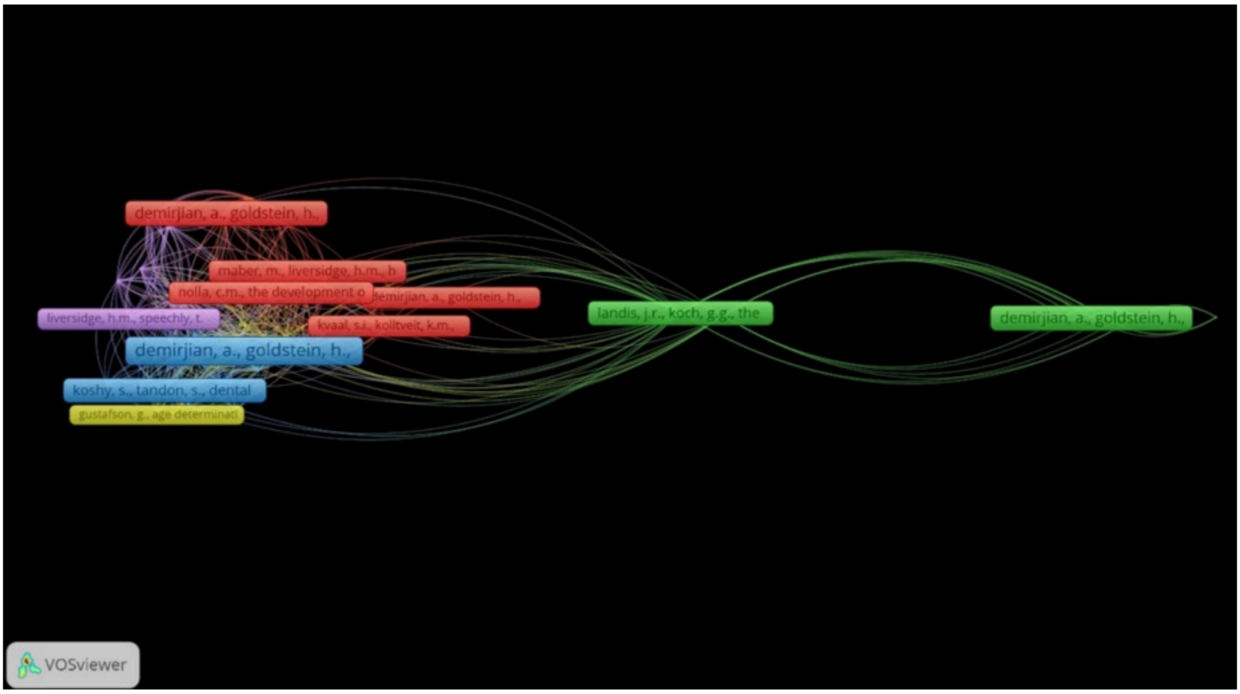
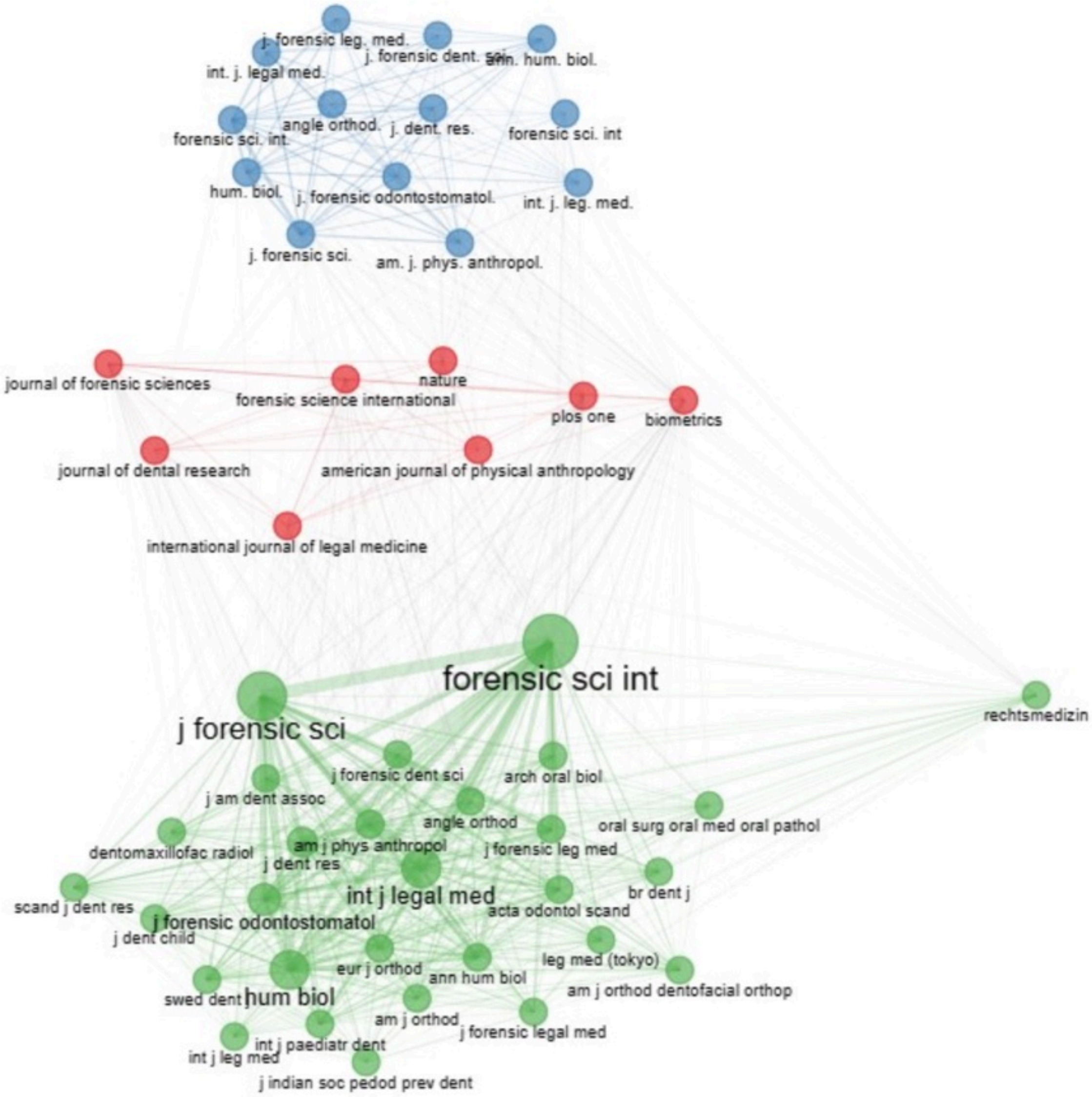


Figure 14. Networking map of co-citation with cited references for a minimum of 10 times



DISCUSSION

The goal of this novel bibliometric analysis was to locate and qualitatively assess the scientific research articles on dental age estimation in the field of forensic sciences. This study was performed using the most commonly used databases worldwide like Scopus, PubMed and Web of science.

Among the 690 articles that was included, the first article was published in the year 1966 titled "A new method of age estimation in dentistry" by Mukai S in Japanese journal of legal medicine. Evidently, validation studies have augmented the body of relevant scientific literature since the early 2000s. [18] In general, this research examined the performance and application of known techniques in populations that were dissimilar to the original. [18] A new type of study in the dental age estimation literature emerged as a result of the growing number of validation studies[18]. Hence there has been exponential growth happening in the research pertaining to dental age estimation since 2014, with discovery of new techniques in various populations.

The top most cited article with 360 citations is "Age estimation: The state of the art in relation to the specific demands of forensic practise" by Ritz-Timme published in the year 2000 in International journal of legal medicine. This review article describes the credibility of the literature evidence on dental age estimations. The average citations per document is around 15.25% with the high citation values seen during 2006. The primary reason for this increase can be attributed to the article authored by Ritz-Timme, where they presented an innovative and distinctive dental method for age estimation in children using open apices tooth.[19] This pioneering approach garnered significant attention from the scientific community, leading to the higher citation values observed in that specific period.

The study results highlight the fact that India is the country with most number of publications followed by Turkey and Brazil. Research on age estimation is especially important in India because of the country's problematic birth registration laws and child rights concerns. [20] The rights of children without birth certificates and those who have made false age claims must be urgently protected. [20] Though Belgium and Germany have only 15 and 28 articles each, the number of citations is considerably high. Belgium has 1084 citations, which is the highest among the countries, followed by Germany with 1015 citations. This is due to the fact that articles published from Belgium countries got highly cited due to the high novelty of the study and new techniques of dental age estimation.

Among the most productive organisations, Shanghai Jiao Tong University School of Medicine, University of Malaya and University of Sao Paulo have the greater number of publications. These universities belong to China, Malaysia and Brazil respectively. The productivity of a particular university is attributed to the fact that many research groups with a shared area of interest would have existed in the same institution. The analysis of citation data reveals that the most cited papers in the field of dental age estimation originate from Germany and Belgium. Despite the significant impact of these publications, it is important to note that Asian countries dominate the overall research landscape in dental age estimation, with a substantial number of studies originating from research institutions in the Asian region.

Among the journals that published many literature on dental age estimation, Forensic Science International (Elsevier) followed by International Journal of Legal medicine (Springer) and Journal of forensic sciences (Wiley). The highly cited papers by Ritz-timme et al [16], followed by Kvaal et al [21] and Willems et al [22] were published in International Journal of Legal medicine, Forensic Science International and Journal of forensic sciences, respectively. These top three articles are published in England, making a trend that shows the developed country have been significantly contributing to this field of study

The primary themes in dental age estimation research and the dominant patterns in publications on this speciality were also identified in this study. In order to find the pertinent publications about this research area, these keywords can be used in order to narrow their search. Researchers are able to target published research articles with the right terms by employing the analysis of the more often used keywords. The publications chosen for study exhibited a particular trend in the keywords. Typically, keyword co-occurrence networks are built using terms that have been taken directly from publication titles, abstracts, or even author-generated keyword lists. In the same title/abstract or citation context, two keywords are said to co-occur. In addition, the correlation between their separation and keyword similarity is practically inverse. As a result, terms that are more relevant are typically found to be closer to one another. The most frequent used keyword is "male", followed by "female" and "adolescent". The results of the analysis revealed that "forensic odontology" (1966-2010), which has been used continuously since the beginning, and changed to "age estimation" (2010-2022) in the recent years. This symbolises the fact that gender prediction in the age estimation was an important aspect that is growing in this field of research. Gender prediction in age estimation research is gaining importance, with growing recognition of the impact of gender-related dental variations. Incorporating gender information in age estimation models has shown to enhance accuracy and applicability, making it a crucial aspect in the field. Recent studies emphasize gender-specific age estimation techniques, contributing to advancements in forensic and anthropological research.

The goal of the bibliographic coupling study is to show how a single source is used in two different documents. India, Turkey, Brazil, Belgium and Germany were among the top performers and had the most connections when this study was performed for individual nations. Among the documents, the publication by Ritz-timme (2000) [16] and Willems (2000b) [23] had got the most connections. Among the sources, Forensic Science International followed by International journal of legal medicine had the most number of connections. Among the authors, Cameriere, followed by Willem had the greatest number of connections.

Co-citation network analysis of authors is a method for analysing a bibliographic analysis's underlying specialty in a field in terms of the groups of writers who have been referenced collectively in the pertinent literature. Additionally, it provides insights into how authors, who are subject-matter experts, view the connections between published works. [24] Author from Italy, Cameriere, from Belgium, Willems G, from London, Liversidge H have been found as the major contributors in this area of research who have dominated this area of research so far.

The findings of this study show that the nature and size of the collaborating teams in dental age estimation research have varied significantly. An extensive number of publications had many authors, according to the analysis of the authorship pattern and network structure. This may be connected to the regular interactions between several institutions, nations, and scholars to hasten the advancement of this field of study. It's noteworthy that a large percentage of authors had very few publications. It might be due to the fact that the number of publications is influenced by various factors, including the researcher's research productivity, collaborations, research focus, and individual contributions to the scientific community.

Limitations of this study is that there is a slight delay in reflecting the most recent research because bibliometric analysis is based on the published literature. Secondly, not all the databases are included in this study. Thirdly, literature search was done only from 1946, which did not include many landmark key articles on dental age estimation.. Despite its shortcomings, the research on dental age estimation may help future researchers by pointing out potential directions for investigation and revealing research gaps.

The recommended method is represented by a number of scientific organisations, each of which has a unique set of methodological guidelines and evaluation techniques. As a result, comparability, repeatability, and verification are severely constrained. There are currently no standards for age estimation quality assurance that are widely acknowledged. Although performing blind trials would undoubtedly be feasible in the field of age estimate, the crucial tool of external quality control is not used at all. In order to guarantee quality standards and acceptable solutions to the significant legal and societal issue of age estimation in forensic medicine, efforts in these directions are required.

CONCLUSIONS

The overall number of publications on dental age estimation and information about their citation patterns from 1966 to 2022 are both usefully revealed by this bibliometric research. It has demonstrated that there has been a general upward trend in publishing on the subject, with a notable increase in articles after 2014. Additionally, it has identified the top nations and organizations engaged in dental age estimation research as well as associated research trends. Despite the fact that dental age estimation has been widely used for a few decades, notable scientific articles have just recently been made. It is envisaged that this study would enable aspiring and seasoned researchers to envision and create potential future scenarios for interdisciplinary research collaborations on the use of age estimation in dentistry.

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Reverse engineering in forensic investigations: a new approach to bite mark analysis

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Enrica Macorano[1], Federica Mele[1], Mariagrazia Calvano[1], Mirko Leonardelli[1], Stefano Duma[1], Giovanni De Gabriele[1], Maria Grazia Guerra[2], Luigi Maria Galantucci[2], Francesco Introna[1], Valeria Santoro[1]

[1]*Section of Legal Medicine, Interdisciplinary Department of Medicine, Bari University, Italy*
[2]*Department of Mechanics, Mathematics, and Management, Polytechnic of Bari, Italy*

Corresponding author: enricamacorano@gmail.com

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KEYWORDS

Bitemarks analysis, Reverse engineering, Forensic odontology, 3D reconstruction; Personal Identification

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ABSTRACT

The study of bite marks provides crucial elements that contribute towards identifying the biter. In many cases, it assumes importance when bite marks are detected on the body of a victim of violence, but it could also be relevant when the bite marks are seen on food substances at the crime scene. In both circumstances, comparing the bite marks with a suspect's dentition can be decisive in confirming or excluding the culpability.

In this case report, a bun (bread roll) with the sign of a bite was found at the crime scene.

We report a pilot study using 3D reproduction of the bite mark on the bun and dental models of the alleged biter and the victim. A reverse engineering process was used to obtain digital 3D models of the bitten bun and the dental models by taking numerous photographs and stitching them together using a software called Metashape by Agisoft.

The last step was to compare the bitemark to the two dental models, evaluating the spatial distance, the degree of overlap, and the degree of interpenetration. The results confirmed the usefulness of reverse engineering in forensic investigations showing the compatibility between the victim's teeth and the bite mark on the bun.

INTRODUCTION

Forensic odontology is invaluable in cases of unidentified bodies and human remains. [1,2] The uniqueness of the dental formula of each individual and the peculiarities of the dental treatments makes it possible to establish the odontobiography of the deceased that includes age, sex, race/ancestry, general and oral health, habits, profession, diet, and psychological and social status. [3-9]

The most challenging aspect of forensic odontology is investigating bite mark evidence, often seen in daycare centres, sports altercations, sexual assault, and sexual and elderly abuse. The bite marks on a victim's skin or inanimate objects, such as food substances present at the crime scene, are substantial evidence that can lead to the identification of the offender. [6,7]

As for other lesions, also for the bite marks, it is necessary to distinguish different phases of analysis: the first phase consists of the identification of human characteristics of bite marks [10], and then through the analysis of the pattern, it is possible to make a comparison of the bite mark to the dentition of persons of interests. [1,7,10]

Furthermore, the bite marks analysis requires the recording of the dental characteristics of any suspects to carry out the comparison with the lesion observed.

The bite mark and the suspect's dentition could be compared through 2D-3D comparison procedures, using software and experimental models to verify it. [10]

In the case of bites detected on different types of food, numerous comparative studies have been carried out based on the specific characteristics of the food itself. Specific software has also been used in some cases. [1,7]

Similarly, other studies have considered the variability of bite marks on different regions of the human body. [11]

In the comparison procedure between the bite marks and the suspect's dentition, the characteristics studied include the size, shape, and position of the dental elements and any morphological peculiarities useful for identification. [2]

The development of latest generation software allowed 3D acquisition of bite marks detected on food or skin and their comparison with the dental arches of a suspect, providing more precise and detailed information. [12-13]

This study aimed to test the use of a 3D scanning technique by comparing the bite marks found on a piece of bun (bread roll) at the crime scene to the suspect's and the victim's dentition. [14-19]

CASE

A 70-year-old woman was found lying on the floor of her home. At first glance, law enforcement assumed the victim died of natural causes; however, the doctors noticed a suspicious red spot on the deceased's dress in the abdominal region.

The intervention of the medical examiners was then requested, and at least eight stab and cut wounds were found all over the deceased's body. No weapon was found at the crime scene that may have caused the injuries.

During the inspection of the crime scene, the police officers and medical examiners realized that the kitchen table was set for a meal, but it was one element that attracted the attention of those present: on the table, there was a bun divided into two halves, and on one of them a bite mark was suspected (Figure 1).

Figure 1. The bun found on the crime scene with the half closer to the bottom, indicating a possible bite mark

The bun was immediately preserved as evidence to proceed with the subsequent forensic investigations.
The investigation led to a male, an acquaintance of the victim, who, according to circumstantial evidence, could have been the main suspect.
The bite marks on the bun were compared to the dentition of the victim and the suspect to investigate the possible presence of the man at the crime scene.

A forensic odontologist took dental impressions (negative) of the deceased and the suspect and then made dental models (positive) from the impressions.
Among the impressions detected, it was therefore chosen to use only the upper dental arches of the deceased and the suspect (Figure 2-3) as they are more involved in the act of biting and more visible.

Figure 2. Dental arch of the victim. A: Frontal view. B-C: Lateral views. D: Occlusal surface

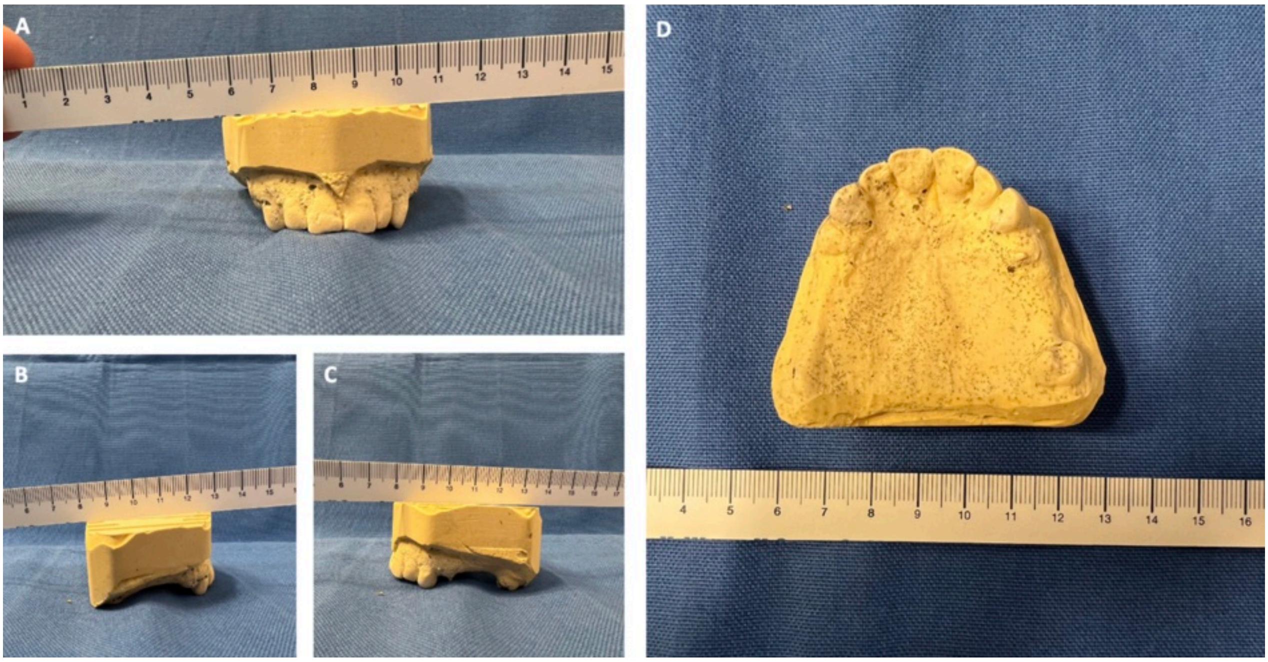
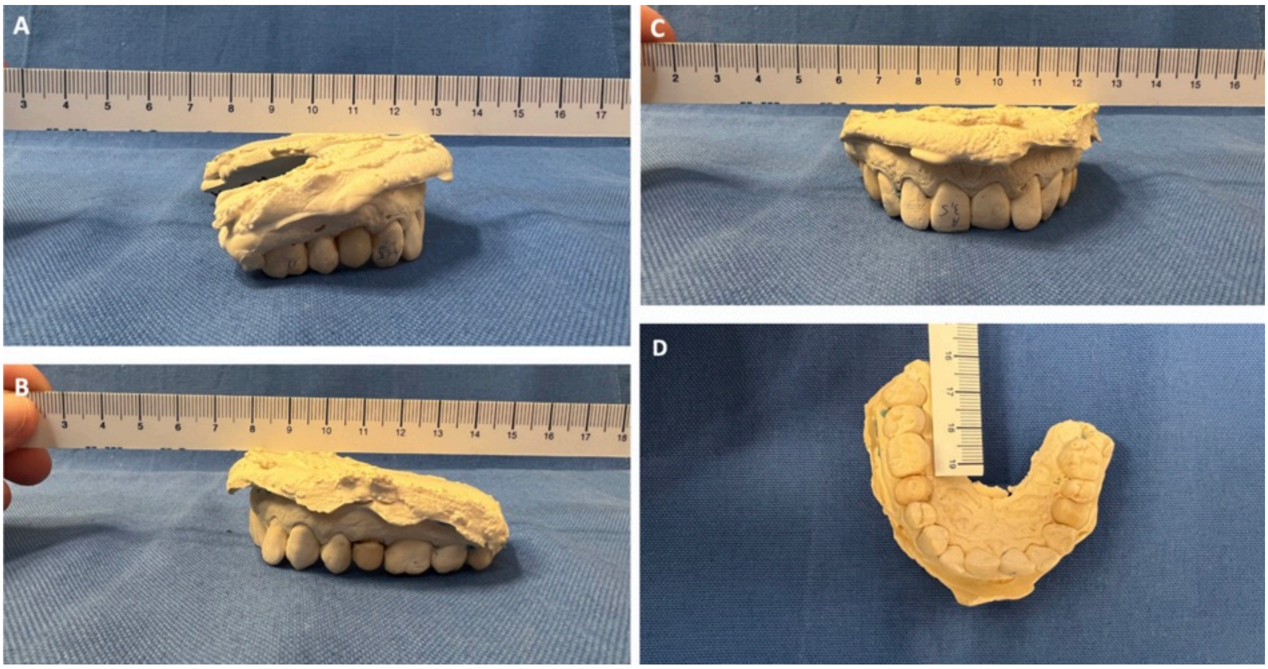


Figure 3. Dental arch of the suspect. A-B: Lateral views. C: Frontal view. D: Occlusal surface



The bun and the dental models of the deceased and the suspect were then analyzed on Polishape 3D' Mechanical Engineering Laboratory to obtain a three-dimensional scan.

MATERIALS AND METHODS

During a murder-scene investigation, a bun with a very evident bite mark was detected (Figure 1). The bun was immediately produced as evidence to proceed with the subsequent forensic investigations.

The bite marks present on the bun were compared to the dentitions of the deceased and of the suspected bite mark perpetrator to confirm the possible presence of the man at the crime scene.

The autopsy of the woman was performed and a forensic odontologist proceeded with the acquisition of the dental impressions of both the deceased and the suspected biter using an alginate impression. The dental casts were made for both impressions (Figure 2-3).

The bun and the dental casts of the dental arches of the woman and the suspect were then analyzed by the "Polishape 3D" Mechanical Engineering Laboratory, Department of Mechanics, Mathematics, and Management, Polytechnic of Bari, Italy, to obtain a three-dimensional scan.

An experimental comparison between bun and bitemarks was attempted through 3D models' creation to avoid food degradation.

In this experimental technique, only the upper arch was used since it is more easily comparable with the bitemark on the bun.

3D reconstruction

Some 3D scanning and additive manufacturing were used to compare the dental models and the bite mark.

A 3D reconstruction of the bun was obtained to be compared with the scan of the woman and with the scan of the offender to verify the degree of overlap and therefore the possible geometric compatibility.

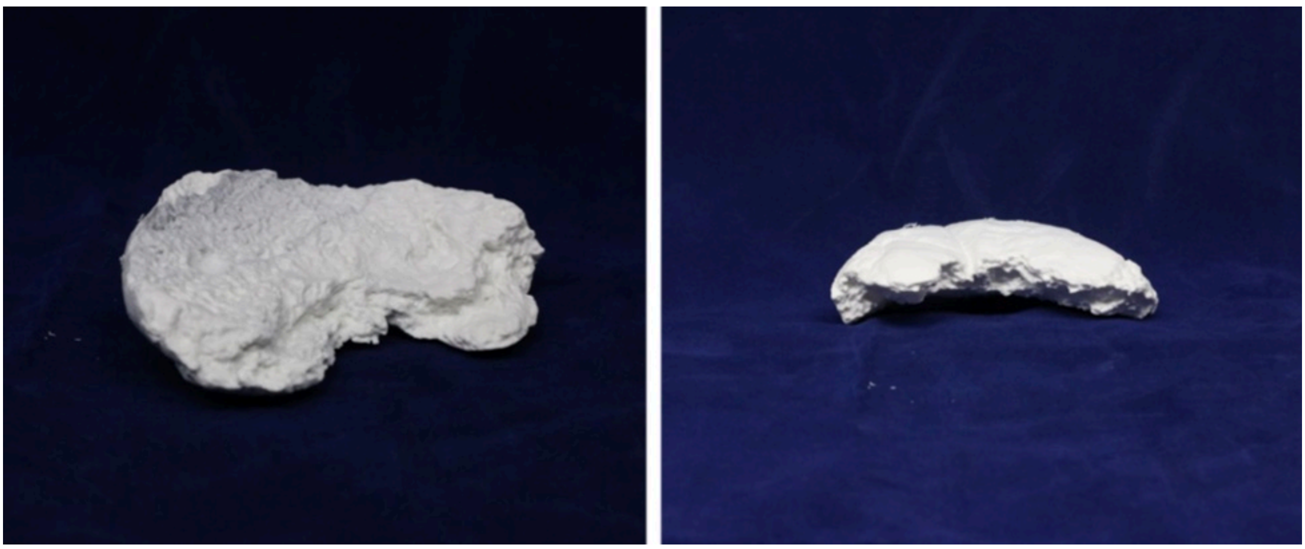
The technique used to obtain the 3D reconstruction is reverse engineering [20] which allows obtaining a 3D model of a physical object starting by taking photographs.

A technique called close-range photogrammetry [21] that consists of two phases: (i) taking multiple overlapping photographs of the object at varying angles and (ii) using software to stitch the photographs together to create a 3D model of the object was employed.

A Canon (EOS 760D) DSLR (Digital Single Lens Reflex) camera with an EF 50mm f/1.8 II lens and a 12mm extension tube was used for photographing the subjects. This optical configuration was selected to allow a sufficient level of magnification and resolution for a detailed and accurate reconstruction of the object. A total of 72 photographs of the piece of bun with the suspected bite mark were uploaded onto Agisoft Metashape (photogrammetry software) for creating the 3D model.

The resulting model was of 0.01 mm in-plane resolution and 0.03 mm in depth resolution. This resolution made it possible to obtain a sufficiently detailed reconstruction of the bun (Figure 4).

Figure 4. 3D reconstruction of the bun. Views from different planes of spaces



Next was the Additive Manufacturing phase, where the digital 3D reconstructed model of the bun was printed using a 3D printer allowing continuous investigations and comparisons using the 3D model of the bun, even after the degradation of the original evidence.
The 3D printing of the bun was executed with Fused Filament Fabrication (FFF). This process uses a filament of polymeric material extruded through a heated nozzle and deposited on a working platform. The model to be made is thus printed, layer by layer, until it is complete. Here are the technical details of the machine and the material used.

- Printer: Delta WASP 40 70, nozzle diameter 0.4 mm.
- Printing material – White Polylactic Acid (PLA).
- Print layer height (single deposited layer): 0.2 mm.

The same reverse engineering was used to obtain 3D scans of the dentition of the deceased and the offender. For 3D printing the dental models, Digital Light Processing (DLP) was used. This additive manufacturing technique uses a photosensitive resin that photopolymerizes when exposed to ultraviolet radiation. Here are the technical details of the machine and the material used.

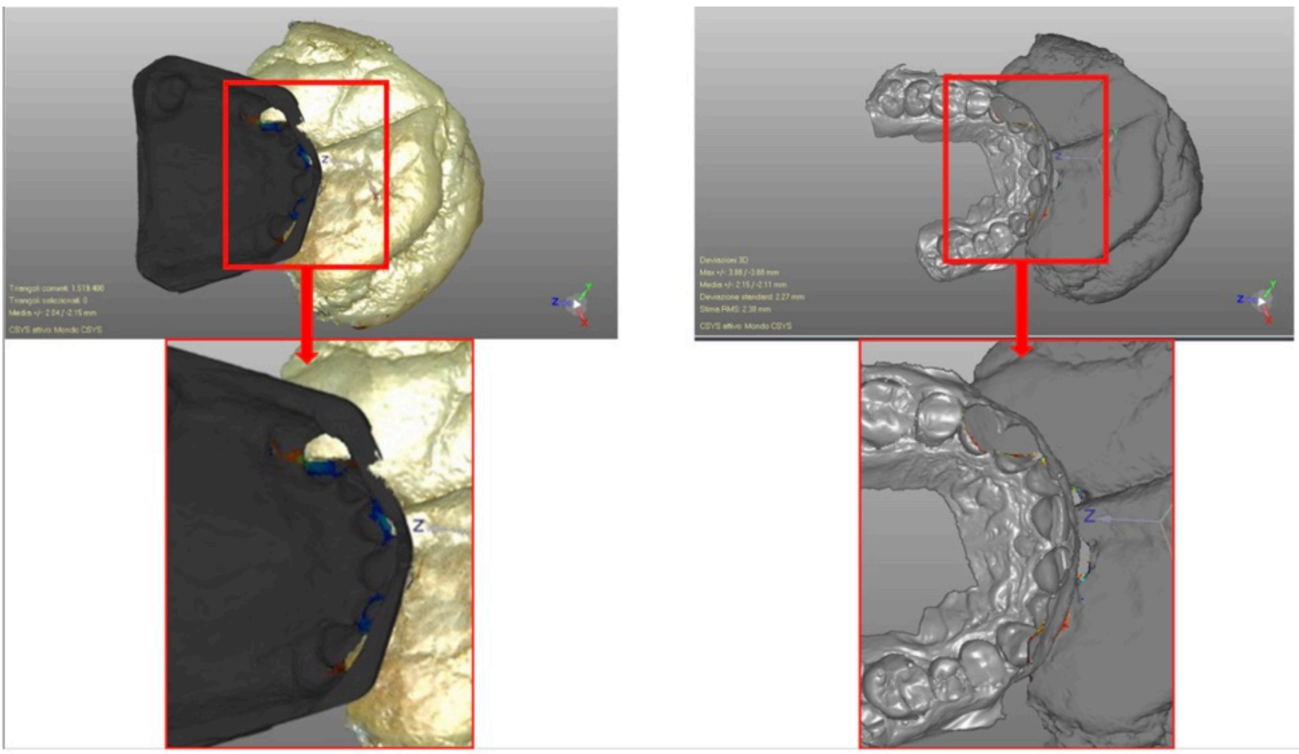
- Anycubic Photon Mono Resin LCD printer.
- Printing material: White Photocentric Hard resin.
- Print layer height (single deposited layer): 0.05 mm.

The bun and the casts of the dental arches of the victim and the suspect were scanned to obtain the virtual model of the pieces of evidence and, therefore, a direct comparison.

Digital comparison

The comparison between the scans of the bun and the dental arches was carried out in two phases: (i) alignment of the scans in correspondence with the bite mark and (ii) comparison of the 3D scans, with the calculation of spatial distances and colourimetric reproduction, to verify the degree of overlap.
The reproductions of the models scanned through additive manufacturing techniques, therefore, allowed a direct comparison between the bun and the dental arches avoiding the use of the original finds (Figure 5).

Figure 5. On the left: a direct comparison between the bun and dental arch of the victim. On the right: a direct comparison between the bun and dental arch of the suspect



RESULTS AND DISCUSSION

From the comparison by overlapping the dental model of the deceased and the 3D model of the bun with the bite mark, it was possible to deduce an objective morphological and dimensional compatibility between the two pieces of evidence, more evident in the medial portion of the evidence and the dental model.

From the comparison with the dental model of the suspect, poor compatibility was found in the medial part, but an excessive interpenetration of the cast on the lateral areas of the bite mark (Figure 6-7).

Figure 6. On the left: colourimetric comparison-intersection between bitemark on the bun and dental arch of the victim, occlusal surface. On the right: colourimetric comparison-intersection between bitemark on the bun and dental arch of the suspect, occlusal surface

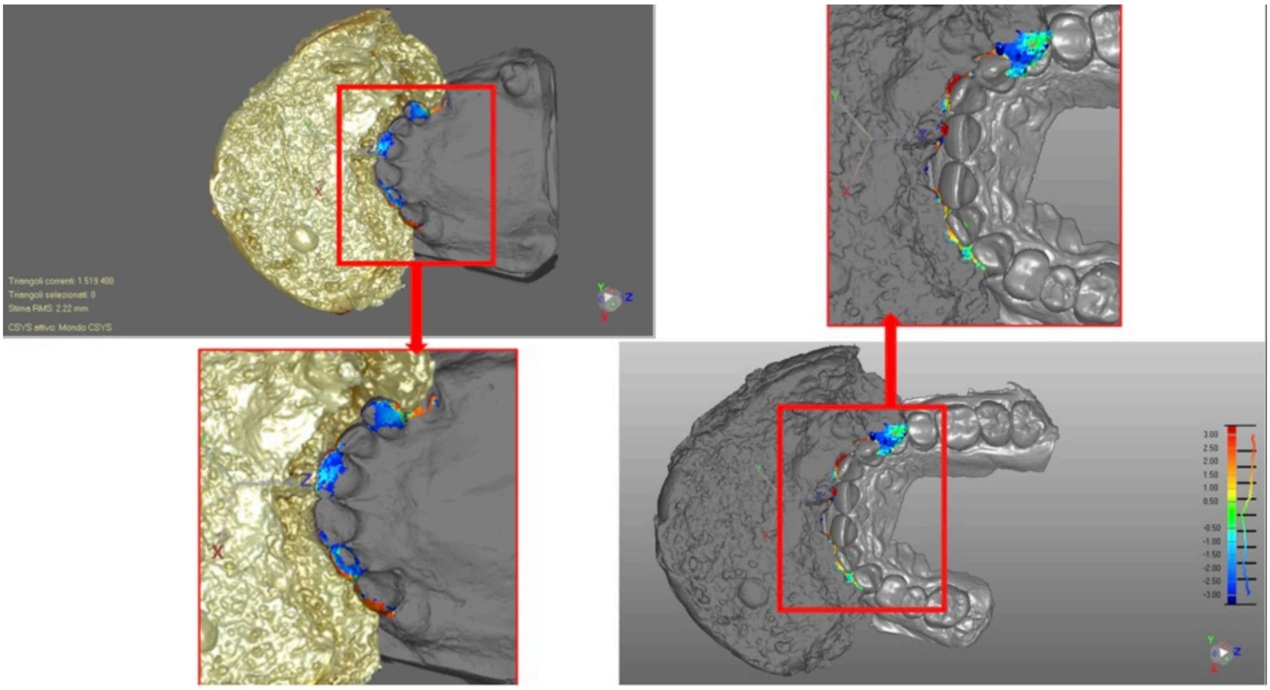
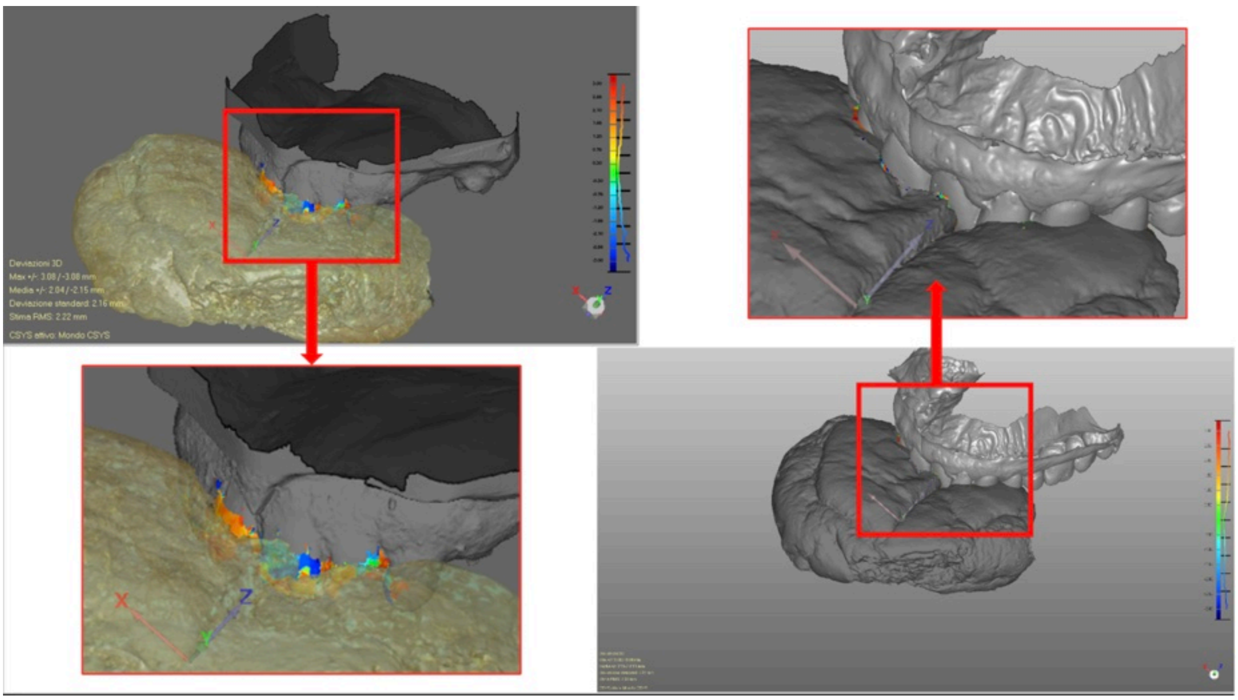


Figure 7. On the left: colourimetric comparison-intersection between bitemark on the bun and dental arch of the victim, axonometric view. On the right: colourimetric comparison-intersection between bitemark on the bun and dental arch of the suspect, axonometric view



However, in the case presented by the authors, reverse engineering techniques adapted to the study of the bitemark detected on the sandwich did not help identify the murderer, since the bitemark belonged to the victim. Furthermore, in this specific murder case, the main suspect confessed after a few days to killing the elderly woman in her home.

However, thanks to the results obtained, we can also consider reverse engineering techniques could be very useful and satisfactory for bit-mark analysis in forensics. The analyses performed seems to be highly sensitive and specific, nevertheless further studies wild broad sample could be performed to validate the technique.

For these reasons, it is helpful to continue the analyses in this field by carrying out multiple comparisons between different foods and bitemarks of different people, to analyze the results.

Our study can therefore be considered a pilot study, which demonstrates that the 3D scanning technique could represent valid support in forensic investigations and personal identification. The high specificity, the objectivity of the analysis and comparison performed using software, and the reproducibility make this technique usable in different areas of personal identification, overcoming the limits of an outdated manual comparison, often conditioned by subjectivity and the operator's expertise.

This technique's most significant advantage is preserving perishable evidence or evidence that may change over time. The 3D reconstruction allows the recreation of a model faithful to the original, kept almost indefinitely in time for any subsequent forensic investigations.

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Dental professional's perspective regarding knowledge, awareness, and attitude towards the importance of charting dental anomalies: a cross-sectional study

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Shruti Gupta [1], Neha Sikka [2], Mala Kamboj [3], Anita Hooda [1], Anju Devi [3], Anjali Narwal [3]

[1] Department of Oral Anatomy, Post Graduate Institute of Dental Sciences, Rohtak, Haryana, India. [2] Department of Dental Materials, Post Graduate Institute of Dental Sciences, Rohtak, Haryana, India. [3] Department of Oral Pathology, Post Graduate Institute of Dental Sciences, Rohtak, Haryana, India.

Corresponding author: guptashruti.82@gmail.com

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KEYWORDS

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ABSTRACT

Objectives: The presence of dental anomalies could play a significant role in the identification of individuals by comparing antemortem and postmortem data. This cross-sectional study aimed to assess the level of knowledge, attitude, and awareness among dental professionals regarding the importance of charting dental anomalies and maintaining dental records.

Methodology: A self-structured questionnaire was e-mailed to dental professionals practicing in India. The responses were recorded, data tabulated, and one-way ANOVA and post hoc tests were applied for analysis. The criterion for significance was $p < .05$.

Results: A total of 406 dental professionals responded to the survey. A significant difference was observed in the mean attitude score of participants towards the importance of charting dental anomalies and maintaining dental records with regard to place of work ($p=.001$), gender ($p=.044$) and educational qualification ($p=.039$). In addition, a statistically significant difference was observed in the mean awareness score of participants with respect to place of work ($p=.033$) and gender ($p=.001$). The major barriers in maintaining dental records were lack of time, adequate knowledge, infrastructure, and financial constraints.

Conclusion: 81.3% and 69.26% study participants had very good awareness and attitude, whereas 71.2% had good knowledge regarding the importance of charting dental anomalies and maintenance of dental records; however, their inaccurate responses in anomaly identification hinted towards the need for proper dental charting and their maintenance to be taught *en masse* and made part of the BDS curriculum.

INTRODUCTION

In the current era, the rise in man-made and natural mass disasters necessitates the accurate identification of an individual's body when it is highly decomposed or intentionally dismembered.[1] Comparison of postmortem with antemortem data plays an important role in establishing an individual's identity.[2] Anything that shows variation from normal becomes a vital part of the identification to distinguish one person from the other.[3] Dental anomalies could be defined as craniofacial abnormalities of position, function, or form of the teeth, bones, and tissues of the jaws and mouth. These anomalies may exist as variations in the normal shape, size, colour, number, identification process. However, very few studies have assessed the knowledge and attitude of dental professionals regarding the importance of charting dental anomalies.[4,5] Thus, this study aimed to assess the level of knowledge, attitude, and awareness among dental professionals regarding the importance of charting dental anomalies and maintaining dental records.

METHODOLOGY

This cross-sectional questionnaire-based survey was conducted among graduate and postgraduate dental professionals practicing in India. Ethical approval was obtained from the institutional ethics committee (PGIDS/BHRC/20/17). The sample size was calculated at 95% confidence level and 5% margin of error with a web-based research advisors sample size calculator, which came out to be 384. A self-structured questionnaire was sent to members of various professional groups via email to assess the knowledge, attitude, and awareness among dental professionals regarding the importance of charting dental anomalies and maintaining dental records. Responses by the participants to the questionnaire were considered as their willingness to participate in the study. The link for the survey was live for a period of five months from January-May 2021, during which 406 participants responded, with a response rate of 62.46%.

The questionnaire was divided into three sections. The first section included questions pertaining to demographics of the responding practitioner. The second section assessed the participant's knowledge regarding how to chart the dental casts. Dental anomalies on casts were fabricated with the help of ivory wax or by modification of teeth on casts, the photographs of which were further modified by Adobe Photoshop CS6 (Adobe Systems Incorporated, California, USA). Two-dimensional photographs of two maxillary and one mandibular permanent dentition casts were included in the questionnaire (Figure 1). Maxillary and mandibular casts that demonstrated the FDI tooth numbering system were also included in the Google forms prior to the dental anomaly charting section for the reference of participants. The third section comprised of questions to assess the awareness and attitude of dental professionals regarding the importance of charting dental anomalies and maintaining dental records as well as barriers encountered in maintaining them (Figure 2). A pilot study was conducted to check the validity of the questionnaire by getting the questionnaire filled by ten dental professionals.

Figure 1. Pictures of casts incorporated in the questionnaire for charting task with labelled anomalies included in the charting

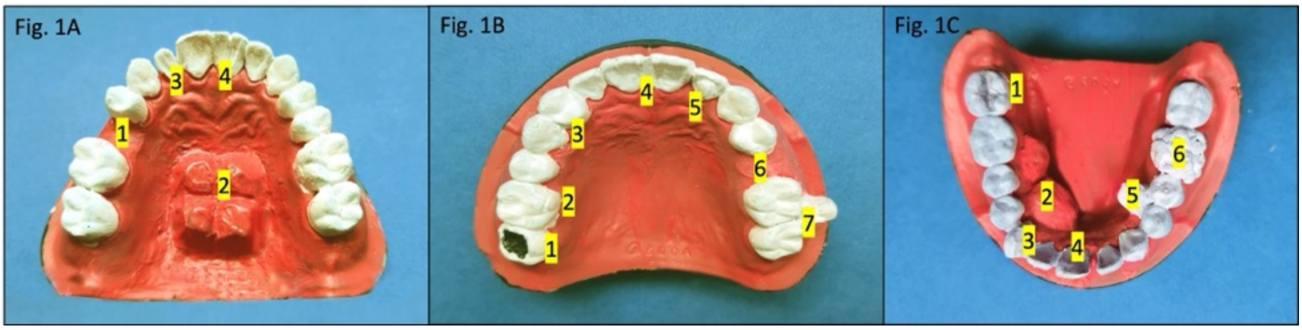
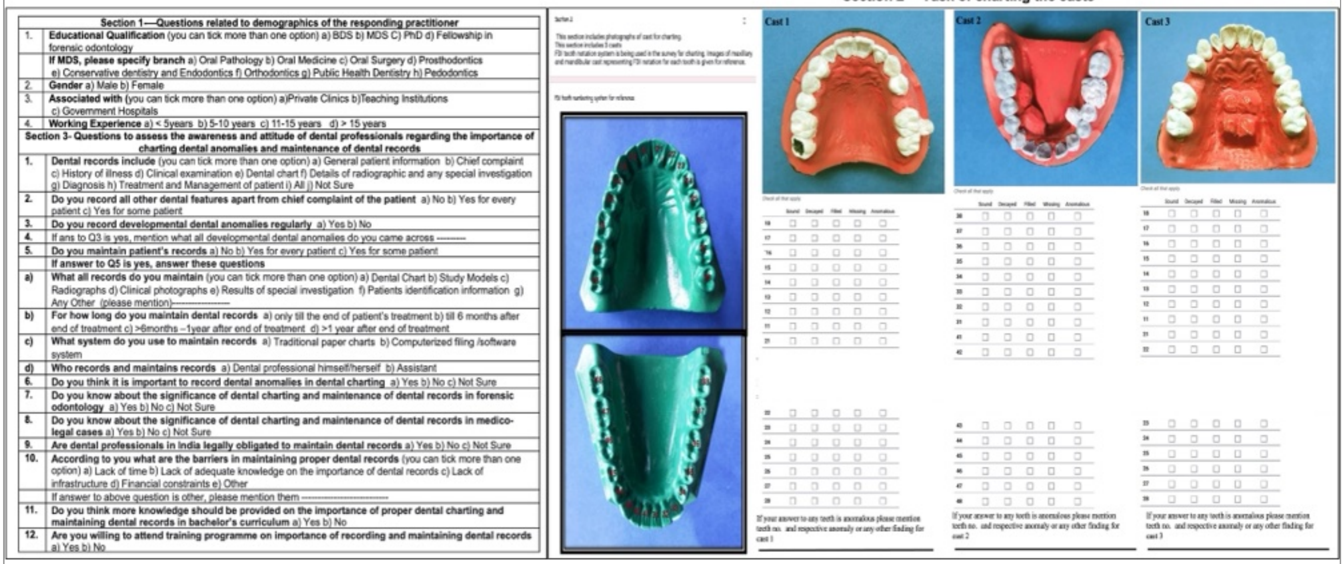


Fig 1A: 1- Missing tooth; 2-Torus Palatinus; 3-Peg Lateral; 4-Gemination
Fig 1B: 1- Grossly decayed tooth; 2-Cusp of Carabelli; 3- Transposition between canine and first premolar; 4-Mesiodens; 5-Talon's cusp; 6-Missing tooth; 7- Paramolar
Fig 1C: 1- Filling; 2- Torus mandibularis; 3- Rotated Canine; 4- Fusion between two central incisors; 5-Parapremolar; 6-Mulberry molar

Figure 2. Self-structured Questionnaire used in the study

Section 2--- Task of charting the casts



Section 1—Questions related to demographics of the responding practitioner	
1.	**Educational Qualification** (you can tick more than one option) a) BDS b) MDS C) PhD d) Fellowship in forensic odontology
	If MDS, please specify branch a) Oral Pathology b) Oral Medicine c) Oral Surgery d) Prosthodontics e) Conservative dentistry and Endodontics f) Orthodontics g) Public Health Dentistry h) Pedodontics
2.	**Gender** a) Male b) Female
3.	**Associated with** (you can tick more than one option) a)Private Clinics b)Teaching Institutions c) Government Hospitals
4.	**Working Experience** a) < 5years b) 5-10 years c) 11-15 years d) > 15 years
Section 3- Questions to assess the awareness and attitude of dental professionals regarding the importance of charting dental anomalies and maintenance of dental records	
1.	**Dental records include** (you can tick more than one option) a) General patient information b) Chief complaint c) History of illness d) Clinical examination e) Dental chart f) Details of radiographic and any special investigation g) Diagnosis h) Treatment and Management of patient i) All j) Not Sure
2.	**Do you record all other dental features apart from chief complaint of the patient** a) No b) Yes for every patient c) Yes for some patient
3.	**Do you record developmental dental anomalies regularly** a) Yes b) No
4.	If ans to Q3 is yes, mention what all developmental dental anomalies do you came across ---------
5.	**Do you maintain patient's records** a) No b) Yes for every patient c) Yes for some patient
	If answer to Q5 is yes, answer these questions
a)	**What all records do you maintain** (you can tick more than one option) a) Dental Chart b) Study Models c) Radiographs d) Clinical photographs e) Results of special investigation f) Patients identification information g) Any Other (please mention)------------------
b)	**For how long do you maintain dental records** a) only till the end of patient's treatment b) till 6 months after end of treatment c) >6months –1year after end of treatment d) >1 year after end of treatment
c)	**What system do you use to maintain records** a) Traditional paper charts b) Computerized filing /software system
d)	**Who records and maintains records** a) Dental professional himself/herself b) Assistant
6.	**Do you think it is important to record dental anomalies in dental charting** a) Yes b) No c) Not Sure
7.	**Do you know about the significance of dental charting and maintenance of dental records in forensic odontology** a) Yes b) No c) Not Sure
8.	**Do you know about the significance of dental charting and maintenance of dental records in medico-legal cases** a) Yes b) No c) Not Sure
9.	**Are dental professionals in India legally obligated to maintain dental records** a) Yes b) No c) Not Sure
10.	**According to you what are the barriers in maintaining proper dental records** (you can tick more than one option) a) Lack of time b) Lack of adequate knowledge on the importance of dental records c) Lack of infrastructure d) Financial constraints e) Other
	If answer to above question is other, please mention them --------------------------
11.	**Do you think more knowledge should be provided on the importance of proper dental charting and maintaining dental records in bachelor's curriculum** a) Yes b) No
12.	**Are you willing to attend training programme on importance of recording and maintaining dental records** a) Yes b) No

Each correct answer was awarded one, and the wrong was awarded zero marks. For questions that included, not sure as a third option, average marks were awarded when required. Based on the scores obtained by the participants, knowledge, awareness, and attitude were graded as poor (0-25%), fair (26-50%), good (51-75%) and very good (76-100%).[6]

The responses obtained were tabulated, and the percentage frequency distribution for responses to each question was computed. The data obtained were subjected to statistical analysis. Parametric data was expressed as mean and standard deviation (SD). One-way ANOVA and post hoc test (Tukey HSD) were used for analysis. The criterion for significance was $p < .05$.

RESULTS

In the present study, four hundred and six participants responded to the survey, the demographic details of whom are depicted in Table 1.

Among females, the mean knowledge, awareness and attitude score±SD were 36.59±5.40,10.28±2.07 and 4.17±1.00 respectively while in males it was 36.42±4.60, 9.45±2.58 and 3.93±1.30 respectively. A significant difference was observed in the mean awareness (p=.001) and attitude (p=.044) between males and females; however, the mean knowledge score was not significant (p=.757).

With regard to place of work, a significant difference was observed in mean attitude (p=.001) and awareness (p=.033), however no difference was observed in the mean knowledge score (p=.061) of participants (Table 2). The post hoc test for multiple comparisons revealed that the mean awareness score was significantly different (p=.018) among participants working in teaching institutions alone and working in both teaching institutions and private clinics. The mean attitude score of dental professionals working in both teaching institutions and government hospitals was significantly different than those working in private clinics (p=.028), both teaching institutions and private clinics (p=.031) and teaching institutions alone (p=.001).

With respect to educational qualification, a significant difference was observed in the mean attitude score (p=.039) of participants, whereas no significant difference was observed in the mean knowledge (p=.216) and awareness (p=.447) (Table 3). The post hoc test revealed a significant difference between mean attitude score of BDS and MDS participants (p=.033).

No significant difference was observed in the mean knowledge (p=.148), awareness (p=.411) and attitude (p=.219) score of participants with respect to work experience (Table 4).

With regard to the specialities of the MDS participants, no significant difference was observed in the mean knowledge (p=.081) and awareness score (p=.686), however, a significant difference was found in the mean attitude score ($p < .001$) of participants. The post hoc test revealed a significant difference between the mean attitude score of participants from the Conservative dentistry and Endodontics branch versus Orthodontics (p=.015), Pedodontics (p=.001) and Prosthodontics (p=.029).

The majority of participants in our study had good knowledge (289), followed by very good (110) and fair (7) knowledge, while none had poor knowledge. 330 (81.3%) participants had very good awareness followed by good (36), fair (30), and poor (10) awareness. 281 (69.2%) participants had very good attitude followed by good (82), fair (30), and poor (13) towards charting dental anomalies and maintenance of proper dental records.

Table 1. Demographic details of the study participants

Variables		**Frequency N(%)**
Gender	Males	121(29.8%)
	Females	285 (70.2%)
	Total	406(100%)
Educational Qualification	BDS	73(18.0%)
	MDS	326(80.3%)
	PhD	3(0.7%)
	BDS/MDS with fellowship in forensic odontology	4 (1.0%)
	Total	406 (100%)
Place of work	Teaching Institutions	195(48.0%)
	Private Clinics	77(19.0%)
	Both Private Clinics and Teaching Institutions	45 (11.1%)
	Government Hospitals	70 (17.2%)
	Both Teaching Institutions and Government Hospitals	19 (4.7%)
	Total	406 (100%)
Working Experience	< 5years	227(55.9%)
	5-10 years	102 (25.1%)
	11-15 years	40(9.9%)
	> 15 years	37(9.1%)
	Total	406 (100%)
Speciality of MDS	Conservative dentistry and Endodontics	33 (9.93%)
	Periodontics	41 (12.35%)
	Oral Pathology	47 (14.16%)
	Pedodontics	30 (9.04%)
	Oral Medicine	25 (7.53%)
	Prosthodontics	66 (19.88%)
	Public Health Dentistry	23 (6.93%)
	Oral Surgery	28 (8.43%)
	Orthodontics	39 (11.75%)

N-Number of Subjects

Table 2. Association of Knowledge, Awareness, Attitude score with place of work

Place of Work		N	Mean ± SD	Range		F-value	p-value
				Minimum	Maximum		
Knowledge Score	Teaching Institutions	195	36.43 ± 5.04	23.5	53.0	2.271	.061
	Private Clinics	77	36.62 ± 4.90	18.5	47.0		
	Both Private Clinics and Teaching Institutions	45	36.61 ± 4.27	28.5	45.5		
	Government Hospitals	70	35.82 ± 5.57	14.0	46.5		
	Both Teaching Institutions and Government Hospital	19	39.79 ± 7.10	27.0	53.0		
	Total	406	36.54 ± 5.17	14.0	53.0		
Awareness Score	Teaching Institutions	195	10.27± 2.00	1.5	12.0	2.650	.033 (S)
	Private Clinics	77	9.81± 2.42	3.0	12.0		
	Both Private Clinics and Teaching Institutions	45	9.12 ± 2.79	1.5	12.0		
	Government Hospitals	70	10.16 ± 2.19	1.5	12.0		
	Both Teaching Institutions and Government Hospitals	19	10.18±2.66	1.5	12.0		
	Total	406	10.03 ± 2.26	1.5	12.0		
Attitude Score	Teaching Institutions	195	4.27 ± .97	0.0	5.0	5.019	.001 (S)
	Private Clinics	77	4.05 ± 1.07	0.0	5.0		
	Both Private Clinics and Teaching Institutions	45	4.10 ± 1.26	0.0	5.0		
	Government Hospitals	70	3.88 ± 1.24	0.0	5.0		
	Both Teaching Institutions and Government Hospitals	19	3.24 ± 1.19	0.0	5.0		
	Total	406	4.10 ± 1.10	0.0	5.0		

ANOVA
N-Number of Subjects, S-Significant, SD-Standard Deviation

Table 3. Association of Knowledge, Awareness, Attitude score with place of work

Educational Qualification		N	Mean± SD	Range		F-value	p-value
				Minimum	Maximum		
Knowledge Score	BDS	73	35.41± 4.96	18.5	46.0	1.492	.216
	MDS	326	36.80 ± 5.20	14.0	53.0		
	PhD	3	37.17 ± 5.20	33.0	43.0		
	BDS/MDS with fellowship in forensic odontology	4	35.63 ± 5.81	27.5	40.5		
	Total	406	36.54 ± 5.17	14.0	53.0		

Awareness Score	BDS	73	9.75 ± 2.43	1.5	12.0	.888	.447
	MDS	326	10.09 ± 2.24	1.5	12.0		
	PhD	3	9.50 ± 2.18	7	11.0		
	BDS/MDS with fellowship in forensic odontology	4	11.25 ± .29	11.0	11.5		
	Total	406	10.03 ± 2.26	1.5	12.0		
Attitude Score	BDS	73	3.78 ± 1.27	0.0	5.0	2.812	.039(**S**)
	MDS	326	4.17 ± 1.05	0.0	5.0		
	PhD	3	3.50 ± 2.18	1.0	5.0		
	BDS/MDS with fellowship in forensic odontology	4	4.25 ± .500	4.0	5.0		
	Total	406	4.10 ± 1.10	0.0	5.0		

ANOVA
N-Number of Subjects, S-Significant, SD- Standard Deviation

Table 4. Association of Knowledge, Awareness, Attitude score with place of work

Work Experience		**N**	**Mean ± SD**	**Range**		**F-Value**	**p-value**
				Minimum	**Maximum**		
Knowledge Score	<5years	227	36.10± 4.91	18.5	47.0	1.791	.148
	5-10 years	102	36.95± 5.71	14.0	53.0		
	11-15 years	40	37.98± 4.54	29.5	48.0		
	>15 years	37	36.53± 5.65	26.0	53.0		
	Total	406	36.54± 5.17	14.0	53.0		
Awareness Score	<5years	227	10.07 ± 2.17	1.5	12.0	.961	.411
	5-10 years	102	9.77 ± 2.61	1.5	12.0		
	11-15 years	40	10.46 ± 1.95	4.0	12.0		
	>15 years	37	10.08 ± 2.10	2.0	12.0		
	Total	406	10.03 ± 2.26	1.5	12.0		
Attitude Score	<5years	227	4.14 ± 1.09	0.0	5.0	1.482	.219
	5-10 years	102	3.93± 1.23	0.0	5.0		
	11-15 years	40	4.31 ± .81	2.0	5.0		
	>15 years	37	4.01 ± 1.06	1.0	5.0		
	Total	406	4.10 ± 1.10	0.0	5.0		

ANOVA
N-Number of Subjects, SD-Standard Deviation

DISCUSSION

Dental charting, information on dental anomalies and proper record maintenance plays a key role in determining an individual's identity by comparing ante and post mortem records.[7] A task of dental charting was included in the study to assess the knowledge of participants regarding dental anomalies. Decayed 17 was recognised by 300 participants, whereas filled 47 was correctly acknowledged by only 138 participants. The third molar was missing bilaterally in all casts; however, 58.74% of participants incorrectly reported it as sound, decayed, filled or anomalous. In addition, 31.16% of the participants wrongly charted missing 25 and 15 as sound, decayed, filled, and anomalous. A higher wrong response rate by the participants may be attributed to the lack of attention by the dental professionals during the charting process.

Paramolar and parapremolar were correctly identified and named by 102 and 26 participants, respectively. However, 14 and 93 participants labelled them as supernumerary tooth. Specific terminologies, if used routinely, would be more helpful for accurate identification and comparison of records in the future. Mesiodens between teeth 11 and 21 was identified by thirteen participants only whereas twenty-one and six participants reported it as filling and fusion, respectively. The identification of mesiodens by a fewer participants could be attributed to the presence of only occlusal view of the cast in the questionnaire.

The most common anomalies of shape identified were gemination (62) followed by talons cusp (20) and fusion (18). Twenty-three participants identified fusion as macrodontia. In the study by JayaKumar et al.[5], the talons cusp on 32 and 41 teeth was identified by 5.9% and 9.9% participants respectively. The lower identification of anomalies of shape in our study could be either due to lack of attention and ignorance of the participants, or the two-dimensional pictorial representation of the casts. A prominent cusp of Carabelli was evident on maxillary first molar in one of our casts, which was not reported during charting by any participant. The cusp of Carabelli has forensic, ethnic and anthropological importance because its prevalence varies among different population.[8]

Rotation of 43 was identified by eleven (2.71%) participants only, whereas transposition between 13 and 14 was identified by sixty (14.78%) participants. In the study by JayaKumar et al.[5], rotated 32, 35, and 42 were reported by 6.9%, 36.6% and 46.5% of participants, respectively, whereas transposition was accurately identified by 5.9% of participants.

Mulberry molar was identified by 104 participants in the present study. The peg lateral was identified by 145 participants; however, 28 reported it as microdontia. Torus palatinus and mandibularis were recognised by 207 and 185 participants, respectively, whereas13 participants identified them as swelling or exostosis.

In the current study, 346 (85.2%) participants believed that it was important to record dental anomalies in dental charting and 298 (73.4%) affirmed that they regularly recorded developmental dental anomalies (Figure 3A and 3B). In the studies by Rahman et al.[9] and Sarode et al.[10], 90.2% and 89% of participants affirmed that they recorded common dental anomalies, respectively, whereas in a study by Tomar et al.[11], only 40% of the practitioners record developmental anomalies. Two hundred ninety-six (72.9%) and 83 (20.4%) dental professionals in our study reported that they recorded all other dental features apart from the chief complaint for every and some patients respectively (Figure 3C). In the study by JayaKumar et al.[5], 88% of participants confirmed that they recorded features that were not included in the patient's chief complaint and did not require treatment. However, findings of the dental charting task contraindicate the affirmation by participants that they regularly record all features other than chief complaint and developmental anomalies, which was in corroboration with the observations by JayaKumar et al.[5]

The dental record is an official legal document owned by the dental professional that mentions all diagnostic information, history of present illness, clinical examination, treatment done, prognosis and all patient-related communications that occurred in the dental office.[10,12] In our study, 376 participants thought that details of radiographic and any special investigation was the main component of dental records followed by dental chart (373), general patient information (370), clinical examination (361), chief complaint (357), history of illness (353), diagnosis (344) and management of patient (339). However, 15 participants were not sure about the components of the dental record.

Figure 3. Frequency of Responses to Questions

In our study, 274 (67.5%) and 104 (25.6%) participants stated that they maintained dental records for every patient and some patients, respectively, while 28(6.9%) did not maintain any records (Figure 3D) which was in accordance with Sarode et al.[10] who also reported that 6% of practitioners did not maintain any dental records. In addition, 88% and 73.2% of the participants of different studies stated that they maintained dental records regularly.[5,9] According to the participants of our study, radiograph was the most commonly maintained record (328), followed by clinical photographs (297), results of special investigations (240), study models (228), patients identification information (224), dental chart (189) and others (17). Others included treatment done, previous treatment records, consent of patient, pedigree analysis, case history, factors related to periodontal status of patient, and diagnosis. In a study by JayaKumar et al.[5], radiographs were mostly maintained in the dental record, followed by dental charts, casts and photographs. Tomar et al.[11] reported that there was 100% maintenance of some records such as patient's details, medical history, and clinical findings, whereas very few participants maintained the treatment log.

Of the 378 participants who maintained records in the present study, 242 (64.02%) used traditional paper charts, whereas 136 (35.98%) used a computerized filing/software system to maintain the records. In a study by Astekar et al.[13], 53% used pre-printed forms, 26% software and 21% used both software and pre-printed forms., while Sarode et al.[10] reported that 11% of participants who maintained records using a computer software program, whereas 83% and 6% recorded them manually using pre-printed forms and blank pages, respectively. McAndrew et al.[14] compared hand- and computer-generated methods of record keeping and observed that computer-generated notes had a higher compliance rate with the set parameters and could make defence easier and more efficient in litigation cases and clinical audits. In our study, 269 (71.2%) dental professionals-maintained records themselves, whereas 109 (28.8%) reported that assistants-maintained records for them. The importance of maintaining records by dental professionals could be emphasised as there is a higher probability of errors if records are maintained by an assistant.

There are no clear-cut guidelines or laws regarding the duration for which records must be retained but it is recommended that depending on the type of records, they should be retained for 5-15 years or more.[12] The majority of participants in our study-maintained records for

>1 year after the end of treatment (191) followed by >6 months – 1 year after the end of treatment (82), till 6 months after the end of treatment (66) and only until the end of patient's treatment (39). In Sarode et al.'s study[10], 50% of participants maintained dental records for weeks to few years (2 weeks to 1.5 years) whereas 50% preserved them permanently. In the study by Preethi et al.[15], 93% practitioners maintained dental records for less than seven years. In addition, 39.9% of the participants of Rahman et al.'s[9] study was aware of the period for which dental records should be maintained.

Dental records are not only vital for forensic investigations, but are also required for court evidence, dental insurances and could be employed for teaching and research purpose.[15-16] 302 (74.4%) and 356 (87.7%) participants knew about the significance of dental charting and maintenance of dental records in forensic odontology and medico-legal cases, respectively, (Figure 3B) which was in association with the findings of Preethi et al.[15] where 17% participants did not know about the significance of dental record maintenance in identifying deceased and crime suspects. 97% participants in the study by Jayakumar et al.[5] considered maintenance of dental records to be forensically or medico-legally important. Dental record maintenance is a legal obligation in the American and European countries, but in developing countries like India, rules are still ambiguous.[9-10] Two hundred thirty-three (57.4%) participants of the present study believed that dental professionals in India are legally obligated to maintain dental records, whereas 127 (31.3%) were not sure about it (Figure 3B). However, all participants (100%) of the study by Astekar et al.[13] believed that in India, the maintenance of records is not legally mandatory.

The majority of participants in the current study reported that lack of time (288) was the major barrier in maintaining dental records, followed by lack of adequate knowledge on the importance of dental records (208), lack of infrastructure (164), financial constraints (103) and others (19). Other factors included lack of interest, cumbersome tasks, lack of manpower, ignorance of medical practitioners, and lack of patient co-operation. Study by Al-Azri et al.[17] on Australian dentists reported increased workload, lack of time, storage space, experience, refresher courses or CPD lectures and lack of computer facilities as the main barriers. With the advent of the digital era, many barriers could be overcome as digital scans could be very useful for identification, forensic, legal, and rehabilitation purpose.[18-19]

Almost all, 380 (93.6%) participants believed that more knowledge should be provided on the importance of proper dental charting and maintaining dental records in the bachelor's curriculum and 321 (79.1%) were willing to attend a training programme on the importance of recording and maintaining dental records.

The significant difference between the mean attitude score of BDS and MDS participants in our study indicated that participants became more consistent in maintaining records during their postgraduate course as they were required to maintain records for evaluation and submission of reports during their MDS degree. Furthermore, a significant difference with regard to place of work indicated that practitioners associated with teaching institutions or government hospitals had slightly more awareness and positive attitude towards charting dental anomalies and maintaining dental records as they have to appear before court as professional experts and were more used to observing dental anomalies in institutions. However, dental professionals in private practice usually have less time and infrastructure to maintain proper records for longer periods of time.

One of the major limitations of this study was the two-dimensional picture of casts depicting the anomalies only from the occlusal view. Also, the anomalies were fabricated by modifying the casts, so the results could vary if book pictures were used instead. However, anomalies in patients do not always present with the same clinical presentation. Another limitation of this study was that most participants were associated with institutions and had MDS as their educational qualification.

CONCLUSIONS

The majority of participants in the present study had very good awareness and attitude towards the importance of charting dental anomalies and maintenance of dental records; however, their knowledge score and inaccurate findings in dental charting opposed the fact. Incorrect or partially correct dental records are not useful in forensic investigations as well as legal evidence. Our study points towards the need of training the students during their bachelor's curriculum regarding importance of dental charting and proper maintenance of dental records with further enhancement through various CDE programmes/workshops.

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