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Morphometric Changes in a Sample of Various Age Groups of the Thai Population: A Panoramic Radiographic Study

Weeraya Tantanapornkul[1,*], Sirilawan Tohnak[1], Chutamas Deepho[1], Peerapong Wamasing[1], Praweena Sopapornamorn[2] and Suttipalin Suwannakul[2]

[1]*Department of Oral Diagnosis, Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand*
[2]*Department of Preventive Dentistry, Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand*

Abstract:

Objective: The current investigation was conducted to examine the alterations in oral conditions and panoramic image parameters that occur with age.

Methods: The study sample consisted of 300 male participants and 300 female participants, ranging in age from 10 to 69 years. The age-related changes in intraoral circumstances and morphometric parameters, as observed in panoramic photographs, were explored. A two-way parametric analysis of variance was used to examine the effects of age group and sex. The frequencies and percentages were calculated and compared among groups using the chi-squared test for category variables. A p-value below 0.05 was considered to be statistically significant.

Results: The prevalence of intraoral conditions showed a positive correlation with advancing age. Males exhibited significantly higher crown, root, and tooth lengths in both the upper and lower canines. There was a significant difference between males and females in terms of the pulp area, the pulp-tooth ratio of the upper first molars, and the pulp area of the lower first molars ($p < 0.05$). The study found a substantial correlation between the radiomorphometric parameters and age, with similar trends observed in both males and females.

Conclusion: The findings of our research have the potential to contribute to the evaluation of an individual's age category and offer insights into the patterns of several observable factors on panoramic radiographs.

Keywords: Age estimation, Canine, First molar, Panoramic radiograph, Pulp-to-tooth ratio, Oral condition.

*Address correspondence to this author at the Department of Oral Diagnosis, Faculty of Dentistry, Naresuan University, Phitsanulok, 65000 Thailand; E-mail: weerayat@nu.ac.th

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1. INTRODUCTION

Radiography is an essential, non-invasive approach in forensic dentistry. It is utilized to find evidence that is not manifested during physical examinations [1, 2]. In recent years, the scientific literature has presented various skeletal and dental methodologies aimed at clarifying age. The majority of them incorporate several skeletal age markers. In recent years, there has been a growing interest in dental procedures that can be utilized for the purpose of age estimation. These procedures include adjustments in various anatomical features, such as the pubic symphysis [3], sternal rib ends [4], the auricular surface of the ilium [5], as well as radiographic examinations of the proximal femur and clavicle [6, 7].

Nevertheless, it is common for these skeletal elements to be vulnerable to physiological and metabolic phenomena, often resulting in their non-retrieval or significant degradation that hinders their usefulness in an

osteological analysis. Therefore, it is imperative to assess the validity of more accurate techniques that are less susceptible to the influence of extraneous factors. These factors include the quantity of age-related data present in particular skeletal characteristics, the tactics employed for sampling, and the statistical approaches utilized to construct age estimation methodologies [8-11]. The teeth are considered to be the most resilient anatomical feature within the human body. They exhibit resistance to a wide range of environmental factors, including mechanical, chemical, and thermal impacts. Consequently, they can be employed in diverse research settings and circumstances, particularly when alternative bodily organs are impaired or inaccessible [12]. Age-related changes to the teeth encompass several alterations, such as attrition, periodontal disease, deposition of secondary dentin, translucency of the root, apposition of cementum, resorption of the root, changes in color, and increasing roughness of the root surface. Macroscopic dental changes are commonly seen as a natural aspect of the aging process. Tooth surface loss, tooth loss, and periodontitis are all age-related irreversible processes [1]. Several studies have been undertaken to investigate the identification of an individual's age by examining the secondary changes associated with the aging process. The formation of secondary dentin occurs within the pulp cavity, serving as both an indicator of aging and a reaction to pathological conditions such as dental caries. The process of secondary dentin formation occurs in the pulp chamber, leading to a decrease in its overall volume and dimensions. This phenomenon can be utilized as a means to estimate the age of an individual [13, 14]. Accurate localization of various anatomical features holds significant importance in the field of clinical dentistry, especially in the field of age estimation. A variety of mandibular characteristics, including the mandibular canal and mental foramen, experience alterations over an individual's lifespan that are influenced by factors, such as age, gender, and dental-related factors [15]. The determination of an individual's age group holds significant importance in the context of medical and forensic investigations. The current investigation was conducted with the aim of examining the alterations in oral conditions and panoramic image parameters that occur with advancing age, including canine morphology, mandibular canal (MC), mental foramen (MF) position, and pulp-tooth relationships of the first molars. As far as current information is concerned, the current study has not been examined within the context of Thais. The results of our study have the potential to contribute to the estimation of an individual's age category and offer insights into the patterns of several observable variables on panoramic radiographs.

2. MATERIALS AND METHODS

The study protocol complied with the Helsinki Declaration and was approved by the university’s ethics committee (IRB no. P1 - 0026/2565). Informed consent was acquired from all participants in the study.

2.1. The Study Population

Using power analysis with a significance level of .05 (alpha error probability), a corresponding confidence level of 95%, and a power of 0.95 (1-beta error probability), we determined the sample size using G*Power. During the study period, we randomly chose 7% of the eligible subjects. The sample comprised 600 individuals, with an equal distribution of 300 males and 300 females, ranging in age from 10 to 69 years. SAGER Guideline was followed in this study. The sample used in this study consisted of Thai individuals. We conducted a comparative analysis of the findings from our study with those from other racial groups. These individuals sought dental treatment at our University Dental Hospital between January 2017 and December 2021. Panoramic digital radiographs were taken to serve several diagnostic purposes. The determination of the chronological age of each participant was achieved by subtracting the date of birth from the date of radiography. Given that a deviation of ± 10 years from the estimated age is deemed permissible in forensic age estimation [16, 17], the participants were categorized into six distinct groups, each comprising 100 individuals: the second decade (ages 10-19), the third decade (ages 20-29), the fourth decade (ages 30-39), the fifth decade (ages 40-49), the sixth decade (ages 50-59), and the seventh decade (ages 60-69). The impact of aging on intraoral conditions and morphometric parameters, specifically focusing on panoramic photographs, were investigated. The study incorporated many participants, wherein panoramic photographs allowed for the visualization of all morphometric characteristics. Specifically, the teeth chosen for analysis were the canines and first molars, which exhibited complete root formation and full eruption. The exclusion criteria encompassed individuals with mixed dentition, systemic conditions that may impact tooth development, eruption, or bone growth, developmental, endocrine, or nutritional disorders, a past medical history of maxillofacial surgery or surgical procedures involving the maxilla or mandible, or temporomandibular disorders.

2.2. Radiographic Evaluation

The study assessed the prevalence of missing teeth, endodontically treated teeth, fixed prostheses, and implant prostheses. The typical number of permanent teeth observed in each participant was 28. All panoramic digital radiographs were assessed by two oral and maxillofacial radiologists who possess over a decade of experience in the assessment of radiographic images. A sample of one hundred panoramic digital radiographs was randomly chosen to assess the level of agreement between examiners, both within and between them, after a one month interval after the initial evaluation. The intraclass correlation (ICC) coefficient was used for this purpose.

2.3. Radiomorphometric Parameters

A panoramic radiograph was utilized to assess six linear and two area measurements. The linear and area measurements were obtained using picture archiving communication system (PACS) software.

2.4. Morphology of the Upper and Lower Canines

The canine crown length (distance from incisal edge to alveolar bone crest) and root length (distance from alveolar bone crest to root apex) were measured. These two measurements were added to be the tooth length of the canine.

2.5. Position of MC

The two points that constitute the most direct path from the crest of the alveolar bone to the lower border of the mandible were identified as being situated precisely at the middle position of the mandibular first molar. A line was drawn to establish a connection between these two points. Then, a tangential line was delineated at the point of intersection between the aforementioned line and the superior border of the MC. The distance from the superior border of MC to the alveolar bone crest was measured as the mandibular bone thickness (MBT) above MC.

2.6. Position of MF

A tangential line was established, running parallel to the inferior border of the mandible. Subsequently, a perpendicular line was made, intersecting the center of the MF. In order to determine the MBT both below and above the MF, measurements were taken of the distance from the center of the MF to the inferior border of the mandible, as well as the alveolar bone crest on a perpendicular line. In order to assess the vertical displacement of the MF in relation to the MBT, the proportion of the MBT situated below the MF was determined by dividing the vertical extent of the MBT below the MF by the total vertical extent of the MBT.

2.7. Relationship of Pulp-tooth in First Molars

The pulp and tooth areas of the maxillary and mandibular first molars were measured using the PACS software. The calculation of the pulp-to-tooth ratio involved determining the ratio between the regions of the pulp and the tooth. A two-way factorial analysis of variance was used to analyze the effects of age group and sex. The frequencies and percentages were computed and compared between groups with the chi-squared test for categorical variables. SPSS statistical software (version 22.0; IBM, Armonk, NY) was used for all statistical analysis. A p-value of less than 0.05 was considered statistically significant (Fig. **1**).

3. RESULTS

The prevalence of intraoral conditions exhibited a positive correlation with advancing age (Table **1**). However, there was no significant difference in the prevalence of these conditions based on sex. Fixed prostheses were not found in the 10s; in addition, implant prostheses were not observed in the 10s and 20s.

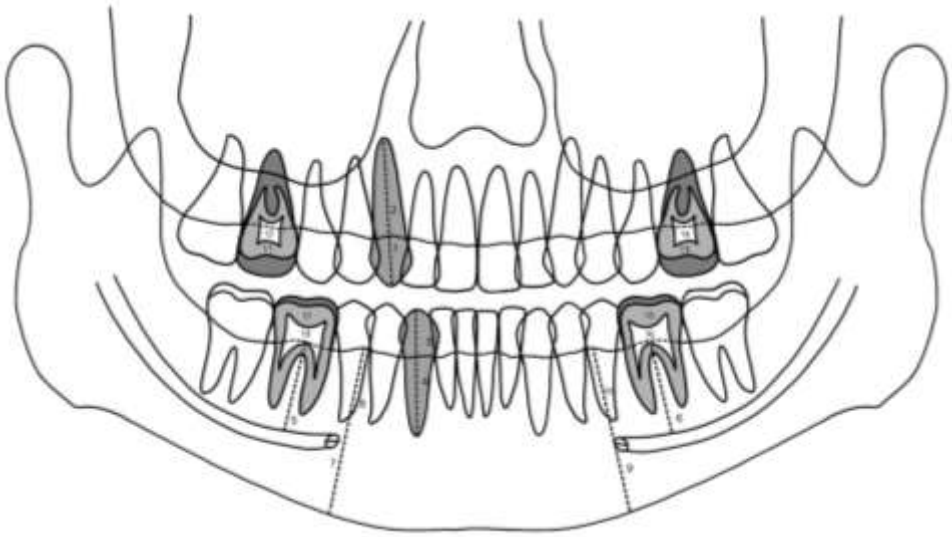

Fig. (1). Measurements of 18 radiomorphometric parameters. Morphology of the upper canine: (1) crown length of the upper right canine, (2) root length of the upper right canine, (3) crown length of the lower right canine, (4) root length of the lower right canine. Position of the mandibular canal: (5) mandibular bone thickness above the right mandibular canal, (6) mandibular bone thickness above the left mandibular canal. Position of the mental foramen; (7) mandibular bone thickness below right mental foramen, (8) mandibular bone thickness above right mental foramen, (9) mandibular bone thickness below left mental foramen, (10) mandibular bone thickness above left mental foramen. Pulp and tooth relationship of the upper and lower first molars; (11) tooth area of upper right first molar, (12) pulp area of upper right first molar, (13) tooth area of upper left first molar, (14) pulp area of upper left first molar, (15) tooth area of lower left first molar, (16) pulp area of lower left first molar, (17) tooth area of lower right first molar, (18) pulp area of lower right first molar (modified from Lee YH *et al*., 2021) [1].

Table 1. Age and intraoral condition of the subjects according to age group.

-	Age Groups (n = 100 for each; male=female=50)						Significance*	
Variable	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**Sex**	**Age groups**
Mean age (Years)	17.14±2.54	22.15±2.32	33.87±2.97	44.51±2.83	54.95±3.08	64.25±2.77	< 0.001*	< 0.001*
Missing teeth	0.05±0.22	0.73±1.05	1.65±2.09	2.44±3.09	6.98±6.71	9.31±7.46	0.699	< 0.001*
Endodontically treated teeth	0.04±0.19	0.07±0.29	0.23±0.55	0.44±0.89	0.58±1.13	1.21±2.11	0.910	< 0.001*
Fixed prostheses	0.00±0.00	0.03±0.12	0.13±0.41	0.59±1.39	0.88±2.04	2.53±5.38	0.275	< 0.001*
Implant prostheses	0.00±0.00	0.00±0.00	0.05±0.24	0.04±0.20	0.12±0.59	1.08±4.18	0.406	0.001*

Note: * Two-way analysis of variance was used to determine significant differences between the group.

Table 2. Radiomorphometric parameters with respect to sex and side.

-	Male		Female		Significance	
Parameters	**Left**	**Right**	**Left**	**Right**	**Sex**	**Side**
Upper canine	***(n= 264)***	***(n= 267)***	***(n= 273)***	***(n= 265)***	-	-
Crown length (mm)	8.32±3.56	9.03±3.45	8.45±2.89	8.31±3.24	0.004*	0.887
Root length (mm)	14.04±5.40	13.26±4.23	12.95±4.51	12.38±4.92	0.035*	0.302
Tooth length (mm)	22.12±8.52	22.29±8.21	21.40±7.06	20.69±7.80	0.011*	0.553
Crown-root ratio (%)	61.35±36.61	62.28±28.77	60.98±24.92	61.70±32.25	0.705	0.568
Lower canine	***(n= 278)***	***(n= 283)***	***(n= 288)***	***(n= 288)***	-	-
Crown length (mm)	7.85±2.72	7.96±2.60	7.71±2.07	7.68±2.14	0.131	0.778
Root length (mm)	12.46±4.16	12.60±3.76	11.89±3.06	11.88±3.08	0.002*	0.753
Tooth length (mm)	20.31±6.28	20.56±5.69	19.60±4.48	19.55±4.50	0.005*	0.735
Crown-root ratio (%)	61.25±33.37	61.71±25.69	64.64±25.39	64.57±25.70	0.249	0.484
Upper first molars	***(n= 226)***	***(n= 231)***	***(n= 230)***	***(n= 227)***	-	-
Tooth area (cm^2)	1.03±0.61	1.00±0.82	1.01±0.58	0.91±0.54	0.123	0.097
Pulp area (cm^2)	0.05±0.04	0.05±0.04	0.04±0.03	0.04±0.03	< 0.001*	0.750
Pulp-tooth ratio (%)	3.62±3.08	3.96±3.24	2.99±3.04	3.47±5.14	0.009*	0.057
Lower first molars	(n= 189)	(n= 195)	(n= 198)	(n= 196)	-	-
Tooth area (cm^2)	0.95±0.75	0.91±0.69	0.98±0.72	0.89±0.67	0.974	0.144
Pulp area (cm^2)	0.09±0.10	0.09±0.10	0.08±0.07	0.08±0.07	0.015*	0.928
Pulp-tooth ratio (%)	6.21±9.93	6.12±6.47	5.14±4.50	6.04±9.41	0.204	0.372
Position of mental foramen	***(n= 296)***	***(n= 296)***	***(n= 288)***	***(n= 290)***	-	-
MBT above MF (mm)	16.58±3.40	16.63±3.31	14.43±3.80	14.58±3.40	< 0.001*	< 0.001*
MBT below MF (mm)	13.61±2.56	13.56±2.46	12.50±2.97	12.62±2.74	< 0.001*	0.818
Percent of MBT below MF (%)	44.64±8.02	44.49±7.76	44.76±10.58	45.27±10.28	< 0.001*	< 0.001*
Position of mandibular canal	***(n= 200)***	***(n= 201)***	***(n= 198)***	***(n= 199)***	-	-
MBT above MC at lower first molar (mm)	12.19±8.85	12.00±8.71	11.00±8.09	10.64±7.80	0.008*	0.575

Abbreviations: MBT: mandibular bone thickness; MC: mandibular canal; MF: mental foramen, * Two-way analysis of variance.

3.1. Sex and Side Differences in Radiomorphometric Parameters

Table 2 shows radiomorphometric parameters concerning sex and side, including morphology of the upper and lower canines, position of MC and MF, and pulp-tooth relationship of the upper and lower first molars.

3.2. Morphology of Canines

Males had considerably longer lengths of the upper canine crown, root, and tooth. Nevertheless, there was no significant difference in the crown-to-tooth ratio between males and females. There was no significant difference observed between the sexes in terms of lower canine crown length and crown-to-tooth ratio. However, the root and tooth lengths were significantly greater in females than in males. The significant difference in canine root and tooth lengths and the position of MBT below MF between females and males can be attributed to the combined effects of hormones and diet, which contribute to the craniofacial morphological differences between the sexes. For each sex, the crown-to-root ratio of the upper canine was higher than that of the lower canine in males. In contrast, the ratio of lower canines was higher than that of upper canines in females. However, there were no statistically significant differences between the ratios of the left and right sides.

Table 3. Correlation between age and radiomorphometric parameters.

-	Correlation with Age	
Variable	**Male**	**Female**
Upper canine		
Crown length (mm)	-0.153**	-0.191**
Root length (mm)	-0.390**	-0.372**
Tooth length (mm)	-0.310**	-0.315**
Crown-root ratio (%)	0.027	-0.036
Lower canine		
Crown length (mm)	-0.079	-0.126*
Root length (mm)	-0.279**	-0.322*
Tooth length (mm)	-0.220**	-0.268**
Crown-root ratio (%)	0.076	0.064
Upper first molars		
Tooth area (cm^2)	-0.375**	-0.498**
Pulp area (cm^2)	-0.781**	-0.699**
Pulp-tooth ratio (%)	-0.786**	-0.711**
Lower first molars		
Tooth area (cm^2)	-0.700**	-0.685**
Pulp area (cm^2)	-0.714**	-0.657**
Pulp-tooth ratio (%)	-0.714**	-0.455**
Position of mental foramen		
MBT above MF (mm)	0.078	0.195**
MBT below MF (mm)	0.085	0.182**
Percent of MBT below MF (%)	0.142*	-0.023
Position of mandibular canal		
MBT above MC at lower first molar (mm)	-0.560**	-0.598**

Abbreviations: MBT: mandibular bone thickness; MC: mandibular canal; MF: mental foramen.
Note: * Pearson correlation is significant at 0.05, ** Pearson correlation is significant at 0.01.

3.3. Pulp-tooth Relationship of the First Molars

The pulp area, the pulp-to-tooth ratio of the upper first molars, and the pulp area of the lower first molars were significantly greater in males. In contrast, the other parameters, including tooth area of the upper and lower first molars and pulp-tooth ratio of the lower first molars, did not differ by sex.

3.4. Position of Mental Foramen and Mandibular Canal

The MBT above and below the MF were greater in males than females. The MBT above MF and percentage of MBT below MF were more significant on the right side. One possible explanation for the substantial positioning of the MBT below the MF on the right side could be the change in the patient's position before the panoramic radiography examination. However, the MBT below MF was not significantly different between the left and right sides. The percentage of MBT below MF was significantly greater in females.

3.5. Pulp-tooth Relationship of the First Molars

The tooth and pulp area and the pulp-tooth ratio of the upper and lower first molars did not differ by side. However, the pulp area of the upper and lower molars and the pulp-to-tooth ratio of the upper molars were greater in males than females.

3.6. Correlation between Age and Radiomorphometric Parameters

The results of the Pearson correlation analysis revealed a significant relationship between the radiomorphometric parameters and age, with the same trends observed in both males and females (Table **3**). There was a negative correlation observed between age and the crown length, root length, and tooth length of both the upper and lower canines in individuals of both sexes. A negative correlation was seen between age and the measurements of tooth area, pulp area, and pulp-to-tooth ratio in the upper and lower first molars, regardless of gender. There were positive correlations between age and the MBT above and below MF in females and the percentage of the MBT above MF in males. Negative correlations were found between age and the MBT above MC at the lower first molar in both sexes.

4. DISCUSSION

The process of age determination holds significant importance in the fields of forensic dentistry and anthropological science, as it facilitates the identification of unidentified individuals with greater ease. Despite the existence of several age estimation methodologies, there is currently no universally applicable method for estimating age across all age groups [18, 19]. The assessment of dental morphological characteristics on radiographic

images is often considered to be a more precise method compared to many other ways of establishing an individual's age. In the current investigation, the authors observed a positive correlation between age and the prevalence of missing and treated teeth, including endodontics, fixed prostheses, and implant prostheses. Our finding was in accordance with the study by Lee *et al*. [1], who analyzed age-related anatomical changes using panoramic radiographs of South Korean subjects. Numerous clinical situations have been observed that have an influence on or exhibit a correlation with post-eruptive changes in dentin, resulting in increased mineralization [20]. Regarding the post-eruptive changes in dentin, the secondary dentin could be identified from tertiary dentin. Secondary dentin is a slower and more intermittent deposition of dentin, which continues throughout life. It results in a reduction of the pulp chamber size. Tertiary dentin is a reparative dentin that is produced in response to adverse external stimuli, *e.g*., advancing caries or tooth breakage. This dentin is characterized by poorly mineralized dead tracts since odontoblasts in the affected region die, and the tubules remain empty [21]. The utilization of implant prostheses can serve as a viable and reliable treatment alternative to conventional restorations, especially in the senior population, where the prevalence of missing teeth has increased [22]. Radiographic assessment of crown-to-root ratios in normal dentition can serve as a valuable point of reference for a range of dental examinations, including prosthetic treatment, orthodontic treatment, and surgical procedures [23]. However, the processes of tooth abrasion, root resorption, malposition, or inclination are known to advance with age, and hence, they may be considered in the method for age estimation.

There were no statistically significant variations observed in the crown-to-root ratios between the upper and lower canines among individuals of both sexes. Ilayaraja *et al*. [18] conducted an analysis of the morphological characteristics of the maxillary canine and mandibular first molar in order to estimate age. This investigation utilized panoramic radiographs from a population residing in South India. There were no statistically significant differences observed between the average chronological age and the average estimated age. On the other hand, Yun *et al*. [23] reported a statistically significant difference in these ratios in mandibular canines. The possibility of the difference in results between ours and Yun *et al*.'s may be the difference in the age variation of subjects. It is well acknowledged that there is a notable disparity in the average lengths of both the crown and the root between males and females. Nevertheless, it should be noted that discrepancies in the crown-to-root ratios based on gender are only observed in a limited number of tooth types. These results indicate the presence of racial disparities, as well as a distinction between the anatomical and clinical crown-to-root ratio [23, 24]. The ratio between the pulp and tooth area decreases gradually as individuals age, indicating a decline in the size of the pulp cavity from the cervical pulp chamber to the root canal apex, which is associated with the aging process. The region of the root pulp located in the coronal third of canines is characterized by a high degree of stability, as it demonstrates minimal morphological variability and is less susceptible to post-developmental changes, such as dental caries. The evaluation of the ratio between the pulp and tooth area offers an indirect means of measuring the deposition of secondary dentin. Secondary dentin is not only surrounded by harder tissues like enamel and cementum but also by primary dentin [16]. Due to the typically close alignment of the root and crown along a vertical plane, the magnification factor does not significantly impact the crown-to-root ratio [25].

Panoramic radiographs are frequently used for assessment purposes within the field of general dentistry. In the field of forensic research, these tools possess significant worth because of their cost-effectiveness, reproducibility, and ability to be acquired with minimal amounts of radiation exposure. However, panoramic radiographs exhibit lower accuracy compared to periapical radiographs in terms of length measurements, and they also include inherent limitations, including tooth overlap and reduced vision in the lateral portions of the maxilla [26, 27]. The reliability of the horizontal variables in panoramic radiographs was found to be questionable. However, the repeatability of the vertical and angle variables was deemed good, provided that the patient's head was properly positioned in a holder [23]. The observed phenomena are a consequence of the horizontal scanning movement of the panoramic unit, and its characteristics are influenced by various elements, including the distance between the focal plane and the rotational center, as well as the distances between the source-receptor and source-focal plane [25, 28].

A number of researchers have conducted studies to determine the extent to which variations in pulp chamber size and pulp-to-tooth ratio can serve as indications of an individual's age. The application of this age estimation technique exhibits considerable potential in the canines and molars, as observed in panoramic radiography [29-33]. The authors recommended that future studies should examine the impact of race and culture on the parameters. Lee *et al*. [34] investigated the shape and length of the maxillary canine, the position of the MC, the position of the MF, the pulp-to-tooth relationship of the upper and lower first molars, the number of treated teeth and missing teeth, and the presence of periodontitis in Korean participants using digital panoramic radiographs. They examined which factors are the most related to age and whether there are sex differences. The population-specific formula was derived based on regression analysis to estimate age. The results of their study showed higher rates of all factors in males than in females. A negative correlation coefficient indicates that the magnitude of these parameters decreased with age. They also suggested that a new tool could be developed using a generalized linear model to predict age based on dental findings. In addition, studies involving new technologies, such as artificial intelligence, may be necessary to allow the

automatic identification of large amounts of panoramic radiographs [34]. The results of our present study indicated that the MC and MF both migrate upwards towards the alveolar bone crest as age increases. The MC gradually approaches the alveolar border based on the degree of bone resorption. As the relative vertical movement of the MF occurs, it then lies closer to the inferior border of the mandible and moves upwards closer to the alveolar border in old age due to tooth loss and bone resorption [15, 35]. The location and size of the MF both vary with sex and race.[34] Within the field of forensic science, the MF serves as a significant anatomical reference point for the purpose of human remains identification. Numerous forensic anthropological investigations have been undertaken to examine the characteristics pertaining to the shape, size, and location of the MF [36]. Nevertheless, anatomical variations that may occur with respect to the location of the MF and MC should always be taken into account [1]. To the best of our knowledge, this is the first study in Thais. Our findings may aid in the estimation of a person's age group and provide information on the trends of many variables readily detectable on panoramic radiographs.

CONCLUSION

It may be concluded that the intraoral conditions have been found to increase with age. There were sex differences in the size and length of anatomical factors. The radiomorphometric changes evaluated on panoramic radiographs were found to be practical and easy to use. Therefore, a panoramic radiograph is very useful in forensic dentistry and related fields. Additional research could be conducted on different age groups, including children and adolescents who have primary or mixed dentitions. Therefore, it is essential to include other pertinent criteria, including socioeconomic standing, nutritional status, and health status.

AUTHORS' CONTRIBUTIONS

W.T. and S.T.: Study conception and design; C.D. and P.W.: Data collection; W.T., P.W., and S.S.: Analysis and interpretation of results; W.T. and S.T.: Draft manuscript.

LIST OF ABBREVIATIONS

MC = Mandibular canal

MF = Mental foramen

ICC = Intraclass correlation

PACS = Picture archiving communication system

MBT = Mandibular bone thickness

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by Naresuan University's ethics committee, Thailand (IRB no. P1 - 0026/2565).

HUMAN AND ANIMAL RIGHTS

All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent was acquired from all participants in the study.

STANDARDS OF REPORTING

SAGER guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

[1] Lee YH, Auh QS, Chun YH, An JS. Age-related radiomorphometric changes on panoramic radiographs. Clin Exp Dent Res 2021; 7(4): 539-51. http://dx.doi.org/10.1002/cre2.375 PMID: 33305888

[2] Sharma P, Gupta N, Saxena S. Experimental studies of forensic odontology to aid in the identification process. J Forensic Dent Sci 2010; 2(2): 69-76. http://dx.doi.org/10.4103/0975-1475.81285 PMID: 21731343

[3] Chiba F, Makino Y, Motomura A, *et al*. Age estimation by quantitative features of pubic symphysis using multidetector computed tomography. Int J Legal Med 2014; 128(4): 667-73. http://dx.doi.org/10.1007/s00414-014-1010-4 PMID: 24789356

[4] Loth SR. Age assessment of the Spitalfields cemetery population by rib phase analysis. Am J Hum Biol 1995; 7(4): 465-71. http://dx.doi.org/10.1002/ajhb.1310070408 PMID: 28557099

[5] Nishi K, Tsurumoto T, Okamoto K, *et al*. Three-dimensional morphological analysis of the human sacroiliac joint: influences on the degenerative changes of the auricular surfaces. J Anat 2018; 232(2): 238-49. http://dx.doi.org/10.1111/joa.12765 PMID: 29277920

[6] Ford JM, Kumm TR, Decker SJ. An analysis of Hounsfield Unit values and volumetrics from computerized tomography of the proximal femur for sex and age estimation. J Forensic Sci 2020; 65(2): 591-6. http://dx.doi.org/10.1111/1556-4029.14216 PMID: 31670845

[7] Toutin R, Bilfeld MF, Raspaud C, *et al*. Contribution of the use of clavicle bone density in age estimation. Int J Legal Med 2022; 136(4): 1017-25. http://dx.doi.org/10.1007/s00414-021-02741-6 PMID: 34988616

[8] Gelbrich B, Gelbrich G, Lessig R. Does the quality of dental images depend on patient's age and sex? - Explanations from the forensic sciences. J Forensic Odontostomatol 2009; 27(1): 2-11. PMID: 22717952

[9] Igarashi Y, Uesu K, Wakebe T, Kanazawa E. New method for estimation of adult skeletal age at death from the morphology of the auricular surface of the ilium. Am J Phys Anthropol 2005; 128(2): 324-39. http://dx.doi.org/10.1002/ajpa.20081 PMID: 15810005

[10] Landa MI, Garamendi PM, Botella MC, Alemán I. Application of the method of Kvaal *et al*. to digital orthopantomograms. Int J Legal Med 2009; 123(2): 123-8. http://dx.doi.org/10.1007/s00414-008-0268-9 PMID: 18663460
[11] Roksandic M, Vlak D, Schillaci MA, Voicu D. Technical note: Applicability of tooth cementum annulation to an archaeological population. Am J Phys Anthropol 2009; 140(3): 583-8. http://dx.doi.org/10.1002/ajpa.21136 PMID: 19639640
[12] Zelic K, Pavlovic S, Mijucic J, Djuric M, Djonic D. Applicability of pulp/tooth ratio method for age estimation. Forensic Sci Med Pathol 2020; 16(1): 43-8. http://dx.doi.org/10.1007/s12024-019-00200-8 PMID: 32048137
[13] Juneja M, Devi YBK, Rakesh N, Juneja S. Age estimation using pulp/tooth area ratio in maxillary canines-A digital image analysis. J Forensic Dent Sci 2014; 6(3): 160-5. http://dx.doi.org/10.4103/0975-1475.137047 PMID: 25177137
[14] Panchbhai AS. Dental radiographic indicators, a key to age estimation. Dentomaxillofac Radiol 2011; 40(4): 199-212. http://dx.doi.org/10.1259/dmfr/19478385 PMID: 21493876
[15] Bhardwaj D, Kumar JS, Mohan V. Radiographic evaluation of mandible to predict the gender and age. J Clin Diagn Res 2014; 8(10): ZC66-9. http://dx.doi.org/10.7860/JCDR/2014/9497.5045 PMID: 25478451
[16] Cameriere R, Ferrante L, Belcastro MG, Bonfiglioli B, Rastelli E, Cingolani M. Age estimation by pulp/tooth ratio in canines by peri-apical X-rays. J Forensic Sci 2007; 52(1): 166-70. http://dx.doi.org/10.1111/j.1556-4029.2006.00336.x PMID: 17209930
[17] Mathew D, Rajesh S, Koshi E, Priya L, Nair A, Mohan A. Adult forensic age estimation using mandibular first molar radiographs: A novel technique. J Forensic Dent Sci 2013; 5(1): 56-9. http://dx.doi.org/10.4103/0975-1475.114552 PMID: 23960417
[18] Ilayaraja V, Ganapathy N, Jisha G, Keerthipriyadharshini T, Maheswaran T, Yoithapprabhunath TR. Digitized morphometric analysis using maxillary canine and mandibular first molar for age estimation in south Indian population. Open Dent J 2018; 12(1): 762-9. http://dx.doi.org/10.2174/1745017901814010762 PMID: 30369986
[19] Mohammed RB, Koganti R, Kalyan SV, Tircouveluri S, Singh JR, Srinivasulu E. Digital radiographic evaluation of mandibular third molar for age estimation in young adults and adolescents of South Indian population using modified Demirjian's method. J Forensic Dent Sci 2014; 6(3): 191-6. http://dx.doi.org/10.4103/0975-1475.137068 PMID: 25177143
[20] Mjör IA. Dentin permeability: the basis for understanding pulp reactions and adhesive technology. Braz Dent J 2009; 20(1): 3-16. http://dx.doi.org/10.1590/S0103-64402009000100001 PMID: 19466224
[21] Elsevier Complete Anatomy Articles, Tooth (mandibular first molar). 2024. Available from: https://www.elsevier.com/resources/anatomy/tooth-mandibular-firstmolar/microanatomy/dentin/15558
[22] Ranjan R, Gowd MS, Shankar T, Singh A. Prosthetic consideration in implant-supported prosthesis: A review of literature. J Int Soc Prev Community Dent 2017; 7(7) (Suppl. 1): 1. http://dx.doi.org/10.4103/jispcd.JISPCD_149_17 PMID: 28713760
[23] Yun HJ, Jeong JS, Pang NS, Kwon IK, Jung BY. Radiographic assessment of clinical root-crown ratios of permanent teeth in a healthy Korean population. J Adv Prosthodont 2014; 6(3): 171-6. http://dx.doi.org/10.4047/jap.2014.6.3.171 PMID: 25006380
[24] Wang J, Rousso C, Christensen BI, *et al*. Ethnic differences in the root to crown ratios of the permanent dentition. Orthod Craniofac Res 2019; 22(2): 99-104. http://dx.doi.org/10.1111/ocr.12288 PMID: 30650237
[25] Laster WS, Ludlow JB, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy and prediction of asymmetry in panoramic radiographic images. Dentomaxillofac Radiol 2005; 34(6): 343-9. http://dx.doi.org/10.1259/dmfr/28020783 PMID: 16227476
[26] Devlin H, Yuan J. Object position and image magnification in dental panoramic radiography: a theoretical analysis. Dentomaxillofac Radiol 2013; 42(1): 29951683. http://dx.doi.org/10.1259/dmfr/29951683 PMID: 22933529
[27] Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: Mandibular linear dimensions and angles. Am J Orthod Dentofacial Orthop 1986; 90(1): 45-51. http://dx.doi.org/10.1016/0889-5406(86)90026-0 PMID: 3460346
[28] Yim J, Ryu D, Lee B, Kwon Y. Analysis of digitalized panorama and cone beam computed tomographic image distortion for the diagnosis of dental implant surgery. J Craniofac Surg 2011; 22(2): 669-73. http://dx.doi.org/10.1097/SCS.0b013e31820745a7 PMID: 21415634
[29] Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms?a contribution to forensic age estimation methods in adults. Int J Legal Med 2005; 119(1): 27-30. http://dx.doi.org/10.1007/s00414-004-0492-x PMID: 15538610
[30] Cameriere R, Brogi G, Ferrante L, *et al*. Reliability in age determination by pulp/tooth ratio in upper canines in skeletal remains. J Forensic Sci 2006; 51(4): 861-4. http://dx.doi.org/10.1111/j.1556-4029.2006.00159.x PMID: 16882230
[31] Cameriere R, Ferrante L, Cingolani M. Precision and reliability of pulp/tooth area ratio (RA) of second molar as indicator of adult age. J Forensic Sci 2004; 49(6): JFS2004125-. http://dx.doi.org/10.1520/JFS2004125 PMID: 15568706
[32] Kim S, Lee YH, Noh YK, Park FC, Auh QS. Age-group determination of living individuals using first molar images based on artificial intelligence. Sci Rep 2021; 11(1): 1073. http://dx.doi.org/10.1038/s41598-020-80182-8 PMID: 33441753
[33] Bardal R, Soltani M. Age estimation by pulp/tooth area and width ratios in panoramic images of upper and lower canines among the Iranian population. Braz Dent Sci 2021; 24(4) http://dx.doi.org/10.14295/bds.2021.v24i4.2466
[34] Lee YH, An JS. Age estimation with panoramic radiomorphometric parameters using generalized linear models. J Oral Med Pain 2021; 46(2): 21-32. http://dx.doi.org/10.14476/jomp.2021.46.2.21
[35] Kanchan T, Krishan K. Mental foramen in prediction of age. J Clin Diagn Res 2015; 9(6): GJ01. http://dx.doi.org/10.7860/JCDR/2015/13023.6083 PMID: 26266138
[36] Apinhasmit W, Methathrathip D, Chompoopong S, Sangvichien S. Mental foramen in Thais: an anatomical variation related to gender and side. Surg Radiol Anat 2006; 28(5): 529-33. http://dx.doi.org/10.1007/s00276-006-0119-7 PMID: 16642278