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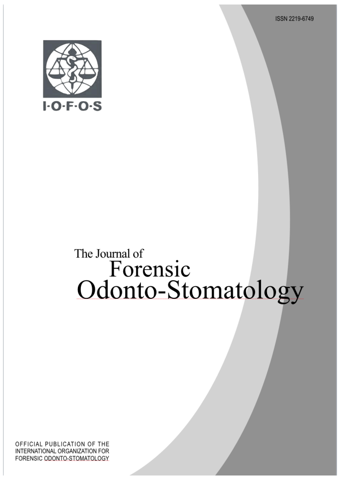

THE JOURNAL OF FORENSIC ODONTO-STOMATOLOGY

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CONTENTS

Application of the Kvaal method with cone beam for the determination of a local formula for the age estimation of adult African melanoderma subject, Côte d'Ivoire

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KEYWORDS

Cone Beam,
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ABSTRACT

Background: Age estimation by invasive dental methods is a destructive, costly and time-consuming approach, whereas, age estimation methods using dental radiographs are simple, non-destructive and provide reliable information. Age estimation by the Kvaal radiographic method has proven to be a reliable method, but possible ethnic variations may limit its uses in other populations. The objective of this study was to reproduce the original Kvaal method with CBCT for the estimation of the age of the adult melano-African subject in Côte d'Ivoire, in order to propose an age estimation formula, specific to our study population, by taking into account the measurements of tooth and pulp ratios.

Methods: A cross-sectional study used 102 radiographic data from a CBCT Planmeca® examination in a private dental clinic in Abidjan. It was data from subjects of at least 18 years of age. Dental measurements in length and width of the entire tooth, root and pulp were performed on maxillary central incisors and the different ratios were calculated according to the Kvaal method. The correlation between age and ratios was also assessed. Age estimated using the Kvaal formula was compared to the chronological age. A linear regression equation was developed using ratios and age predictive factors to evaluate the accuracy of the Kvaal formula.

Results: In all, a total of 102 radiographs of 102 subjects, of whom 55 (53.9%) were females, were analyzed. The median age was 51 years (inter-quartile range [IQR] 41- 58). Using the Kvaal formula, the Standard error of the estimated age was higher in the African melanoderma population compared to the Kvaal population. The new formula derived from that of the Kvaal formula was developed and applied to our study population (Age = 84.7- 114.2 (M) - 29.4 (W - L) gave more than double the standard error of estimated age by Kvaal (26.03).

Conclusion: Our study showed that the measurements made by Kvaal are reproducible with CBCT and there is a correlation between age and the dental parameters studied. However, the age estimation formula determined by Kvaal et al. is not valid for African melanoderma subjects living in Côte d'Ivoire.

INTRODUCTION

Teeth and dentition as a whole are considered as a reliable source for the identification of living or deceased subjects (1,2) and are better predictors of age than bones.(3) As the subject ages, secondary dentine is deposited along the walls of the pulp chamber, leading to a reduction in pulp size.[4] This age-related narrowing phenomenon can be evaluated so as to estimate the age of the subjects, either from sections of the tooth or from dental radiographs. Dental sections require the extraction of teeth and microscopic preparations.[5] The section processes are time-consuming, costly and destructive and cannot be accepted on religious, cultural, scientific and ethical grounds. [6]

The approach to age estimation by dental X-ray techniques therefore remains preferable Age estimation studies involving the analysis of dental radiographs, periapical or panoramic dental radiographs, are relatively simple, non-destructive methods of obtaining information. These are techniques used daily in most dental practices. Unfortunately, these methods are rarely used for age estimation.[6]

In 1995, Kvaal et al. developed a radiographic method based on the study of the relationship between age and size of dental pulp for the age estimation of adult subjects older than 20 years of age.[7] This so-called "Kvaal" technique used a pair of calipers, a stereomicroscope and an ocular microscope to perform different measurements on a retro-alveolar radiographic plate.

Even if the estimation of age using periapical dental radiographs by Kvaal has proved to be a reliable and recommended method by the American Society of Forensic Dentistry, few studies have shown its applicability to other types of radiography. In addition, conventional periapical dental radiographs present two-dimensional images and can therefore lead to overlapping dental structures and biases during measurements.

Currently, age determination studies in forensic dentistry generally use Cone Beam Computed Tomography (CBCT) with three-dimensional acquisitions to locate dental structures without overlapping. With the advent of CBCT, new methods based on volumetric reconstruction and volume-to-pulp ratio, as well as length and width measurements of pulp and tooth, have been proposed for the estimation of adult dental age.[8,9] However, these techniques did not provide a better accuracy compared to the Kvaal method using periapical dental radiographs. The CBCT tool could be used to reproduce the measurements of the original method of Kvaal et al.[10]

Our objective is to reproduce the original Kvaal method with CBCT for the estimation of the age of the adult African melanoderma living in Côte d'Ivoire, in order to propose a new formula for estimating the specific age to our study population, based on measurements of tooth and pulp ratios.

METHODS

Type of study

This is a cross-sectional study with an analytical focus that used radiographic data from CBCT Planmeca® examinations conducted in a private dental practice in Abidjan.

Population and Sample Study

We have used radiographic data taken with CBCT, individuals of both sexes, aged at least 18 years, who consulted the Franchet D'esperey dental practice in Abidjan from 2011 to 2016. The cone beam X-ray should have healthy reference teeth, without coronary and/or root pathology visible on X-ray and teeth with a Smith and Knight Tooth Wear Index (TWI) ≤ 2 before the age of 50 and TWI ≤ 3 after the age of 50, were included.

For the study period, 600 patients were eligible for our study. We randomly selected individuals from the entire study population through a systematic survey with a sampling step. In the case of photographs of individuals who did not meet the above-mentioned inclusion criteria, the next step was selected. The surveys were reviewed every week. The final week, the count gave 102 individuals. In total, a sample of 102 radiographs taken with CBCT, from 102 individuals, was selected from the 600 scans available during the period of study.

Inclusion criteria and choice of reference teeth for dental measurements

The reference teeth used for our study are those proposed by Biuki et al.. They are the upper central incisors, i.e. 11 or 21. [11] These reference teeth must be healthy and free of coronary and/or root pathology visible to the naked eye or on X-ray (no caries, no excessive tooth wear, no dental restoration, no artefacts due to metallic repair materials present in adjacent teeth and no pulp calcification).

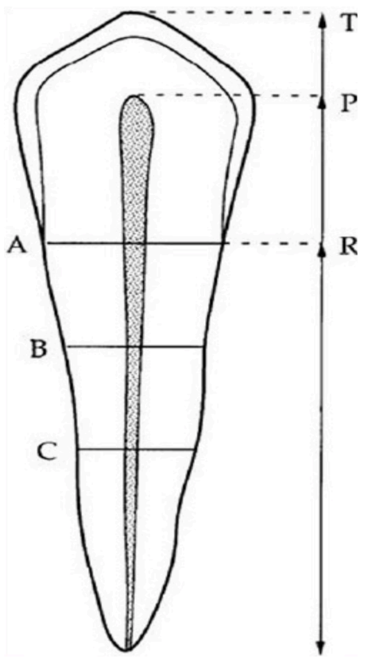
To specify the extent of "excessive tooth wear", we borrowed Smith and Knight's (TWI) dental wear

index.[12] Only teeth with TWI ≤ 2 before age of 50 and TWI ≤ 3 after age of 50 were included.
The presence of the four maxillary incisors is required and the patient should not present any anatomical elements, such as odontoma or impacted tooth that could disturb the study area.

Description of the Kvaal method
Kvaal et al. in 1995 estimated an adult's age based on the relationship between age and dental pulp size from retro-alveolar radiographic images of six types of teeth (incisors, second maxillary premolars, lateral incisors, canines and first mandibular premolars) [7].
They measured the pulp, root and tooth, in particular:
- the length of the tooth
- the length of the root
- the length of the pulp
- the width of the pulp and the width of the root at three levels of the tooth (A, B, C).

To compensate the deformations related to the enlargement and angulation of radiographs, the following 6 ratios were calculated: P = pulp / root length; R = pulp / tooth length; T = tooth / l root length; A = pulp / root width at A level i.e. at the enamel-cementum junction (ECJ); B = pulp / root width at *B* level i.e. halfway between the ECJ and the middle of the root; C = pulp / root width at C level i.e. at the mid-point between the apex and ECJ (figure 1).

Figure 1. Diagram showing the measurements made on the radiographs of each tooth



The mean values M, W and L were also calculated:
M =-mean value of all Ratios excluded ratio T (taken as the first age predictive factor in the study by Kvaal et al.)
W = mean value of the ratios of widths B and C;
L = mean value of the ratios of lengths P and R.
- W - L= the difference between W and L (taken as the second age predictive factor in the study by Kvaal et al.).

In addition, correlation coefficients between age and the calculated ratios and with the different mean values of the ratios were estimated.
Main component analyses were carried out on all ratios with the first component being the mean "M" and the second component being the first component based on the analyses on the different mean of "W" and "L"; these two parameters were determined as the age predictive factors.
Separate regression formulae are given for the six types of teeth of the two jaws and separately for the maxilla and mandible, as well as for each type of tooth. The equations for the six teeth taken as a whole and only for the upper central incisors (chosen as reference teeth for our study) are presented below:
Age = 129.8 - 316.4(M) - 66.8(W-L) with standard error of the estimate (SEE) of 8.6 years; For six types of teeth
Age =110.2 - 201.4(M)-31.3(W-L) with SEE of 9.5 years; for upper central incisors

Data collection
The data were collected on a data collection form by a dentist trained in measurement techniques on digitized CBCT images using Carestream® software. The variables below were collected and/ or measured:
- ✓ Socio-demographic data (age, gender)
- ✓ And we have reproduced all the measurements made by Kvaal (see chapter description of the Kvaal method) on dental radiographs taken with CBCT on two teeth such as the 11 or 21 using Romexis® software.

DATA ANALYSIS

Acquisition and segmentation of images
All CBCT images were acquired and digitized automatically with a Planmeca ProMax® 3D CBCT unit. The data were then imported into semi-automatic segmentation and voxel counting software with a 3D image. Measurements were

taken on sagittal sections, in the antero-posterior axis. Indeed, the sagittal view presents better observations regardless of the tomographic source. The oblique cuts have been chosen to process the image on the screen with the different handling possibilities offered by the software, in order to have a clear image, with a contour that is clearly visible to the operator. Subsequently, the major axis of the tooth was drawn by selecting the measuring instrument that is the ruler on the screen. The long axis is drawn by joining the free edge of the incisor and the apex. Subsequently, the other measurements were made in accordance to the rules of parallelism and perpendicularity

Processing and statistical analysis

The data collected, using DICOM/Carestream, were reported on a data collection sheet and recorded in an entry mask designed under Access. In order to minimize possible biases, including the intra-operator effect, and to ensure the reproducibility of this method, we performed a series of measurements on a sample of 15 radiographs taken by CBCT. The same operator resumed measurements one to two weeks later to ensure that there was no intra-operator variability.

We performed the normality test to verify that the distribution of our sample tended towards a normal distribution. The assumptions of linearity between age and age predictive factors were also verified.

We described qualitative variables by numbers and frequencies and quantitative variables by arithmetic means with their standard deviation or by medians with their inter-quartile range. The comparison of frequencies or percentages was made with the Pearson Chi^2 test (if effective greater than or equal to 5)

In order to determine an age estimation formula, we selected the ratios and the different mean values significantly correlated with age to build an explicative model for age.

The calculated ratios were applied to the age determination formula developed by Kvaal to estimate the age of the subjects. This made it possible to compare the estimated dental age with the recorded chronological age.

Major component analyses were conducted on all reports to determine the predictive factors that significantly influence the age estimation of the subjects in our sample and to propose an age determination formula specific to our study population.

All statistical analyses were performed using Stata Software (StataTM 12.0 College Station, Texas, USA).

RESULTS

Socio-demographic characteristics of the study population

A total of 102 radiographs of 102 subjects were analyzed, 55 (53.9%) of whom were female. The age distribution is presented in Table 1. Among men, the proportion of the 60 - 72 age group was highest (31.9%). Among women, the high proportion of age groups was represented by the 50-59 age group (47.3)..

Table 1. Age distribution according to sex of the survey population, n = 102

Age (years)	Men	Women	Total n = 102
18 – 29	5 (10.7)	7 (12.7)	12 (11.8)
30 – 39	1 (2.1)	7 (12.7)	8 (7.8)
40 – 49	14 (29.8)	11 (20.0)	25 (24.5)
50 – 59	12 (25.5)	26 (47.3)	38 (37.3)
60 – 72	15 (31.9)	4 (7.3)	19 (18.6)
Total	47 (100%)	55 (100%)	102 (100%)

Mean values of the measurements taken

The mean tooth and root lengths measured for the entire sample are 37.99 (± 6.36) mm and 22.13 (± 4.59) mm respectively. In all, there were no significant differences in the mean values obtained between men and women (Table 2).

Determination of age estimation regression equations in years based on dental measurements from the 102 radiographs of the upper central incisors (11/21)

Table 3 showed the correlation coefficient between age and the calculated ratios and the mean of the ratios.

The Pearson correlation test showed that there was a clear negative correlation between the calculated ratios and chronological age. The correlation between age and ratios A, B and the average of ratios M and W was highly significant (Table 3).

Table 2. mean values of dental parameters measured (in mm)

Variables	**Men (n = 47) mean** (SD*)	**Women (n = 55) mean** (SD*)	**Total (n = 100) mean** (SD*)	**P**
Total length of the tooth	38,83 (± 7,27)	37,27 (± 5,43)	37,99 (± 6,36)	0,22
Total length of the root	22,91 (± 5,02)	21,46 (± 4,11)	22,13 (± 4,59)	0,11
Total length of the pulp	28,52 (± 5,99)	27,88 (± 4,42)	28,17 (± 5,18)	0,53
Root width at level A (JAC)	10,67 (± 1,90)	10,58 (± 1,94)	10,62 (± 1,91)	0,81
Root width at level B	9,84 (± 1,84)	9,61 (± 1,41)	9,72 (± 1,61)	0,47
Root width at level C	8,60 (± 1,65)	8,45 (± 1,26)	8,52 (± 1,45)	0,60
Pulp width at level A (JAC)	2,33 (± 0,79)	2,18 (± 0,57)	2,25 (± 0,68)	0,27
Pulp width at level B	2,0 (± 0,56)	1,86 (± 0,46)	1,92 (± 0,51)	0,19
Pulp width at level C	1,70 (± 0,56)	1,56 (± 0,41)	1,62 (± 0,49)	0,13

* Standard deviation

Table 3. Correlation coefficient between age and the calculated ratios and the mean of the ratios

Tooth (11/21)	**r**	**P-value**
P	-0.19	0.05
T	-0.21	0.03
R	-0.01	0.90
A	-0.32	0.001
B	-0.41	0.001
C	- 0.11	0.25
M	-0.28	0.002
W	-0.30	0.003
L	-0.17	0.08
W – L	0.05	0.64

With : r = correlation coefficient; P = pulp / root length; R = pulp / tooth length; T = pulp / root length; A = pulp / root width at level A ; B = pulp / root width at level B ; C = pulp / root width at level C. M = average value of all ratios (excluded ratio T); W = average value of the ratios of widths B and C; L = average value of the ratios of lengths P and R.

Estimation of the age of our study population by applying the Kvaal age estimation formula

According to Kvaal, the formula for estimating a person's dental age from central incisor measurements is as follows: Age = 110.2 - 201.4 (M) - 31.3 (W-L) with a SEE of 9.5 years.

Firstly, the ratios determined in African melanoderma subjects were applied to the formula developed by Kvaal from Norwegian populations. The following formula was obtained: Age = 110.2 - 201.4 (M) - 31.3 (W-L) with a SEE of 22.6 years.

Determination of regression equations of age estimation from our measurements

We determined a new formula, always with the two predictive factors determined by Kvaal as correlated with age in their sample, the regression equation found was as follows: Age = 84.7- 114.2 (M) - 29.4 (W - L) with SEE of 26.03 years. The SEE of 26.03 years) in our African melanoderma population was not acceptable. Indeed, it is more than double that found by age as estimated by Kvaal et al. in the Norwegian population, which was 9.5 years. [7]

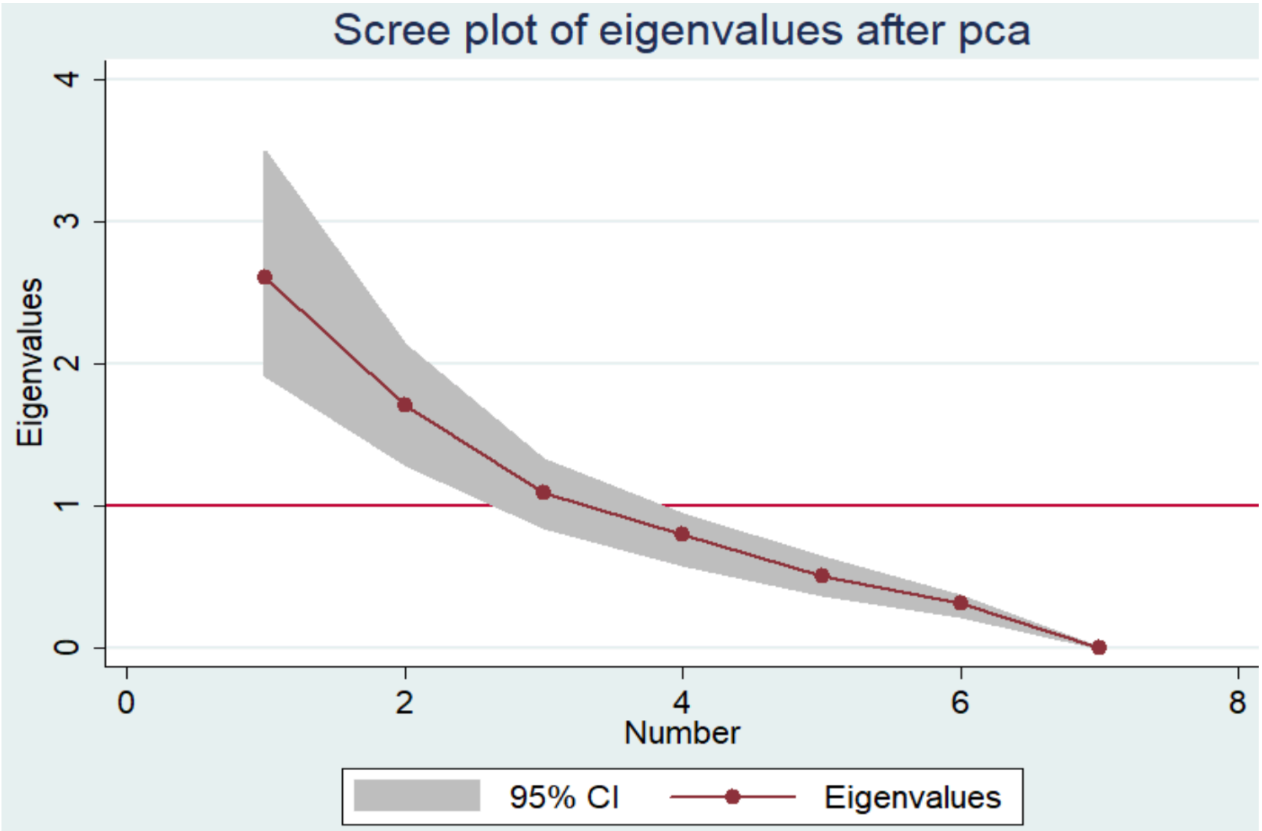
We determined a new equation by including gender as an age predictive factor in our sample. We obtained the following equation:

Age = 87.4 - 117.8 (M) - 34.9 (W - L) - 3.5 (Sex) with a SEE of 26.70 years.

The result shows that gender does not influence the age determination model, with a SEE of 26.70 roughly equal to the SEE of 26.03 found above.

The main component analysis of the data in our study showed that there are three age predictive factors, which explain about 80% of the study design (Figure 2).

Figure 2. Curve showing the main components of our study model: only the first three points (the three predictive factors of age in our study) are above the horizontal level line 1



The first age predictive factor in our sample is the mean of the ratios "A", "B" and "C". That is, the mean of the ratios pulp / root width at level A; pulp / root width at level B and pulp / root width at level C.

The second predictive factor is the mean of the ratios "P" and "T": That is, the mean of the ratios pulp / root length and tooth / root length.

The third age predictive factor we found is the ratio "R" which is the ratio of pulp/ tooth length.

The equation from our three predictive factors was as follows: Age = 70.9 - 105.5 (K) - 11.6 (G) +22.1 (R) with a SEE of 11.77 years. With: K = (A +B + C)/3 (first predictive factor and G = (P + T)/2 (second predictive factor).
With sex as an additional predictive factor, we have the following formula: Age = 70.1 - 114.7 (K) - 9.9 (G) + 30.6 (R) - 3.9 (Sex) with a SEE of 11.62 years.
Gender does not influence our analysis model; it is a negligible predictive factor of age as in the original Kvaal study.
The different equations determined are presented in Table 4

Table 4. The summary of the regression equations found

Parameters	Equations	r²	Standard error of the estimate (years)
Kvaal formula applied to our sample	Age= 110.2 – 201.4 (M) – 31.3 (W-L)		22.6
New equation with the 2 predictive factors of Kvaal	Age = 84.7– 114.2 (M) – 29.4 (W – L)	0.12	26.03
New equation with the 2 predictive factors of Kvaal including sex	Age = 87.4 – 117.8 (M) – 34.9 (W – L) – 3.5 (Sex)	0.14	26.70
New equation with the 3 predictive factors specific to our sample	Age = 70.9 – 105.5 (K) – 11.6 (G) +22.1 (R)	0.15	11.77
New equation with the 3 predictive factors specific to our sample including gender	Age = 70.1 – 114.7 (K) – 9.9 (G) + 30.6 (R) – 3.9 (Sex)	0.17	11.62

With P = pulp/ root length; R = pulp/ tooth length; T = pulp/ root length;
A = pulp/ root width at A; B level = pulp/ of the root width at B; C level = pulp/ root width at the level C.
M = mean values of all ratios (excluded ratio "T" in Kvaal formula only); W = mean value of the ratios of widths B and C; L = mean value of the ratios of lengths P and R.
K = (A+B+C)/3; G = (P+T)/2

DISCUSSION

The aim of this study was to test the Kvaal formula on a melanoderma population and to propose a better formula adapted to the African melanoderma subject.
Our study may have some limitations. Indeed, the dental measurements performed are operator-dependent and can introduce errors. To overcome this bias, the operator was trained in measurement techniques with DICOM and in the handling of CBCT plates with Romexis® software. In addition, the same operator repeated the measurements two weeks later to ensure that the measurements were reproducible.
Another limitation lies in the choice of our sample, which was not representative of all African melanoderma subjects living in Côte d'Ivoire. To minimize this selection bias, we randomly selected the CBCT images for our study.
It appears from this study that the regression formula of Kvaal et al. to estimate the age of the subjects from the pulp/ tooth central incisor measurements is not applicable to African melanoderma subjects living in Côte d'Ivoire. We proposed a formula adapted to our population.
The CBCT made it possible to reproduce the reference radiographic method used by Kvaal et al.. The reconstructions obtained from the CBCT acquisitions are metrically accurate and precise, and do not show any geometric deformation. We had the opportunity to have a CBCT and X-rays from the CBCT for our study.
Several studies have used CBCT to reproduce this method [10,13]. Although this work did not

provide better accuracy compared to the original method, it demonstrated the effectiveness, ease of use of CBCT in the application of the Kvaal method [10,13].

By applying the Kvaal equation for central incisors to our study population, the calculated SEE was 22.6 years. The SEE determined in the Kvaal study in Norwegian subjects was 9.5 years. The age estimated by the Kvaal formula does not match the chronological age in our study sample. The SEE in our study is twice the one found in the study by Kvaal et al.. Variations related to ethnic characteristics and structural variation due to secondary dentine formation in our study population could explain the large differences observed between estimated and actual ages using the Kvaal formula. The difference in measurement tools could be a confounding factor, causing differences in results. A recent study implemented by Babshet et al. highlighted the need for population-specific equations due to differences in ethnic origin [14].

Also, this difference could be explained by the fact that the different age groups in our study are not similar to those of Kvaal. Indeed, the average age in Kvaal's work was 42.6 years and in our study, it was 48.6 years. According to the results of Kvaal's method, it can be applied to all adult populations. Thus, to compensate for measurement errors and errors related to the age difference that Kvaal et al. took the ratios of the different measurements to estimate formulae for age determinations.

By defining our regression formula with the same parameters identified by Kvaal as correlated with age, the predictive factors "M" and "W - L" from dental measurements of our population, the equation (Age = 84.7- 114.2 (M) - 29.4 (W - L)) gave a SEE of 26.03 years. This SEE in our African melanoderma population was not acceptable. Indeed, it is more than double that found by age as estimated by Kvaal et al. in the Norwegian population, which was 9.5 years[7].This lack of agreement between Kvaal's formula and our results can be attributed to the ethnic differences of the study population. In fact, with age, secondary dentine deposits along the wall of the dental pulp chamber, result in a reduction in the size of the pulp cavity. The amount of secondary dentine deposition is influenced by factors such as ethnicity, diet and lifestyle [15]. Indeed, most of the works on age determination using the Kvaal method has always found SEE that are far from those of Kvaal. These SEE ranged from 5.6 to more than 13 [16].

Thus, in 2018, Roh et al. estimated regression equations according to predictive factors determined by Kvaal from upper central incisor measurements on Korean subjects [17]. They found a SEE of 12.19 years.

In 2016, Mittal et al. found, from the measurements of the upper central incisors of Indian subjects, a SEE of 10.09 years different from that of Kvaal and concluded that the applicability of the Kvaal equation was not valid in their study population [18].

In 2014, Patil, et al. found a greater SEE of 12.3 when applying the Kvaal formula from central incisor measurements greater than an Indian population group [19].

In 2007, Meinl et al., as well as Li MJ et al. in 2019 evaluated the use of regression formulae proposed by Kvaal on panoramic radiographs. They showed that the regression formulae do not apply to their sample and conclude that further research is needed [20,21].

Landa et al (2009) tested the reproducibility of the method developed by Kvaal et al. and also evaluated the application of the regression formulae of this method. These authors found that the regression formulae applied to their study sample showed values that were far from the real age. Miranda JC's work, in Brazil and Chandan PK, in India, in 2020 gave similar results [22–24].

For all those reasons, Ubelaker et al., in 2008, stipulated that age estimation is more accurate when linear regression equations are used with components specific to a specific population[24].

To support this assertion, we have identified specific factors that had a strong correlation with age, in order to produce a series of new regression equations for estimating the age of the subjects in our study sample.

Thus, three first essential components were identified as having a strong relationship with age in our study population.

The linear regression equation from these three predictive factors, (Age = 70.9 - 105.5 ((A+B+C)/3) - 11.6 ((P+T)/2) +22.1 (R)) with a SEE of 11.77 years, a SEE different from the regression equation found with the Kvaal parameters i.e. the components "M" and "W - L". Some authors have found these two age predictive factors identified by Kvaal valid for their population. Indeed, Mittal et al. in 2016, as well as Patil. et al. in 2014, showed that, in Indian subjects, the factors "M" (average value of all ratios) and "W - L" (difference between "W" and "L") were the best predictors for age estimation.[18,19] But contradictory data exist according to the literature. Roh et al. showed in 2018, that the parameters related to the tooth length of subjects calculated by the original Kvaal method, i.e. the predictive factor "M", showed no significant correlation with the age of the Korean subjects. Only the parameters from the width measurements, i.e. the predictive factors "W - L", showed a good correlation; therefore, a regression equation derived from the width parameters without the length ratios was proposed for the Korean subjects [17]. These same results were found in Mittal's work in 2016, which showed that width ratios are better correlated than length ratios [18].

In order to always determine more relevant predictive factors of the age of our study population, we excluded for the estimation of a new regression equation, the ratio "R" which was our third predictive factor and "C" because their correlation coefficients “r” were not statistically significant. The equation determined with a SEE of 11.77 years was equal to the one found with the three components identified. We can therefore exclude our third main component in determining the age of African melanoma subjects living in Côte d'Ivoire. Nevertheless, SEE is still different from that of Kvaal et al. Another important factor is the influence of gender in the estimates of regression formulae. Each time, we introduced sex to produce the regression equations.

Thus, in the first equation with the two Kvaal predictive factors, namely "M" and "W - L", the introduction of sex gave an equation with a SEE of 26.70 which was substantially equal to that without sex, which was 26.03 years.

In addition, the regression equation with our three predictive factors including gender gave a SEE of 11.62 years, substantially equal to that without sex, which is 11.77 years.

In the last equation excluding our third predictive factor and the ratio "C" and taking into account gender, we had an equation with a SEE of 11.40 years; substantially equal to that without sex, which was 11.77 years.

In summary, gender does not influence the regression equation estimation models in this study. However, the literature reports contradictory data. Indeed, in a meta-analysis conducted in 2017 by Marroquin,[16] five studies tested the effect of gender on the accuracy of the estimated age. Of these, three found that gender does not affect age estimation equation models; however, two studies found that gender played a role in regression equations.[16]

The results of our work are in line with the first observation concerning African melanoderma subjects living in Côte d'Ivoire.

CONCLUSIONS

The Kvaal formula is not suitable for estimating the age of African melanoderma subjects like the one in our sample. This study made it possible to propose a formula more adapted to our population with achievable measurements from CBCT. It is easy to use and offers precision and a non-invasive nature. CBCT remains a powerful tool for investigating the maxillofacial anatomy.

Our perspectives remain oriented towards image analysis methods. Indeed, image analysis and automation systems represent a growing need today. All this can contribute to the implementation of software with programmes to ultimately estimate the age or determine the sex of an individual automatically.

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Application of third molar maturity index for Indonesia minimum legal age of marriage: a pilot study

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KEYWORDS

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ABSTRACT

Background: Child marriage is recognised as a harmful practice. Recently, Indonesia enacted a new law to raise the minimum age of marriage from 16 to 19 years old for women, creating no minimum age difference between males and females. However, this improvement may be detrimental for individuals in remote areas with no legal documentation and the common practices of age falsification to reach the minimum age of marriage. Therefore, implementing an age estimation technique for juveniles is mandatory to reduce the risk of child marriage. Methods: this study used the third molar maturity index (I_{3M}) to distinguish an individual under or over 19 years old. I_{3M} values from 222 digital OPGs aged between 15 to 23.99 years were calculated. The sample was randomly assigned as a training dataset (n = 156) and testing dataset (n = 66). The logistic regression model was created using a 5-fold cross-validation method, and the Youden's Index Value was used to establish the I_{3M} cut-off value. Results: the logistic regression model showed significance in both sex and I_{3M} value for predicting the probability of minimum age of marriage. I_{3M} cut-off values of 0.08 and 0.09 for males and females, respectively, were taken. The accuracy of this test was 80% for both sexes in the testing dataset. Conclusions: the outcome of this pilot study showed a promising result of using I3M as a dental age estimation method to determine whether an individual is over or under 19 years old to comply with the newly enacted legal age of marriage in Indonesia. Future research should be carried out using a balanced age cohort for each sex and a more extensive training sample size to investigate the influence of sex in the cut-off value calculation.

INTRODUCTION

In forensic sciences, determining an individual's age is a vital objective acquired through legal documents, including a medical chart or birth certificate. In the absence of these documents, an individual's chronological age can be estimated through various age-related variables, including teeth. Dental development is highly correlated with chronological age, creating diverse methods to estimate an individual's age.

The practice of dental age estimation has been used in juveniles to determine whether an individual has passed a certain legal age threshold.[1] At this age range, the third molar is the only tooth left to mineralise.[2] Hence, third molar development was commonly used as the main parameter to differentiate between specific age threshold in juveniles.[3, 4]

However, most third molar development techniques have been divided into a finite number of stages,[5, 6] creating a higher error rate if the observed tooth falls between a particular stage.[7] To overcome this limitation, Cameriere et al. researched the Third Molar Maturity Index (I_{3M}) technique, a ratio measurement on orthopantomogram (OPG) images of mandibular third molar and was proven to help distinguish an individual in different legal age thresholds.[8]

In Indonesia, a new law has been enacted to prevent child marriage.[9] It is commonly known that child marriage is a harmful practice.[10] It promotes a higher incidence of sexually transmitted disease,[11] intimate partner violence,[12] and lower economic and educational quality.[13] To prevent this, Indonesia's new law raised the minimum age of marriage from 16 to 19 years old for women, creating no difference between male and female minimum age of marriage. However, applying the new legal age of marriage threshold is difficult for individuals with no legal documents to prove their age.[14] For example, some individuals in rural areas may not have legal documentation or recorded birth date in a medical chart. Consequently, the absence of legal documentation promotes the legal documentation forging to falsify an individual's age to reach the required minimum age of marriage.[15]

Although using the I_{3M} technique or dental age estimation method to determine an individual age threshold is widely used in many countries, dental age estimation is still not commonly used in Indonesian courts. Considering that it is vital to adopt an accurate age estimation method when confronted with a legal age threshold for an individual with no legal documentation and prevent age falsification, a new study in Indonesian law to implement the applicability of the I_{3M} method is needed as there are no studies in determining I_{3M} cut-off value for Indonesian population who are younger or older than 19 years old for both male and female. Therefore, this study aimed to investigate the application of the I_{3M} technique to predict whether an individual is younger (< 19 years old) or older than the minimum age of marriage (≥ 19 years old).

MATERIAL AND METHODS

Sample

In this retrospective observational study, we collected a total of 222 digital OPG images (M = 73, F = 149) from Indonesian children and juveniles between 15 and 23.99 years old from Pramita Laboratory, Semarang, Indonesia. The sample was selected based on the presence and clarity of the lower left mandibular third molar (LL3rdM) without any recorded developmental abnormalities or dental treatment. The anonymity of the sample was preserved while maintaining the information of patient number, sex, date of birth, and date of exposure. Sample age was obtained from the difference between the date of exposure and the date of birth. The required ethical approval was obtained from the institute's ethics committee.

Measurements

Images were imported and enhanced for optimal visualization using Adobe Photoshop CC 2020 software built-in tools. Furthermore, LL3rdM measurement was performed by the first observer (RMB) in conjunction with Cameriere et al. method.[16] The observer was blinded to the actual age of the image during the measurement. Tooth apical ends and length were analysed, and the I_{3M} was defined as follows: if the root development of LL3rdM was complete, the value of $I_{3M} = 0$. I_{3M} was calculated by the sum of total tooth apical ends inner margins ($A_8 = A_{81} + A_{82}$) divided by tooth length (L) from apical ends to the highest point of the crown ($I_{3M} = \frac{A_8}{L}$). If the tooth had not developed a bifurcation, the length between the inner crown margins was considered tooth apical end (A_8) (Figure 1).

Statistical Analysis

Measurements were collated in an Excel file (Microsoft Excel 365) and processed using R.[16] Twenty five images were randomly selected after two weeks and recalculated by RMB and second observer (HE). RMB had over three years of experience, and HE had just been introduced to dental age estimation. Intraclass Correlation Coefficient (ICC) was used to estimate the Intra-Inter-Observer Reliability using the psych package.[17]

The Caret package was used to calculate the *k-fold* cross-validation and the linear model.[18] Consequently, 70 percent of the data were randomly selected (set.seed = 100) and assigned as a training dataset ($n = 156$). The remaining data were used as a testing dataset ($n = 66$). A logistic regression model was created on the dataset using 5-fold cross-validation with dependent variables of $T = 1$ and $T = 0$ for an individual over and under 19 years old, and predictive variables of I_{3M} and sex with $s = 1$ *and* $s = 0$ for male and female, respectively. The model's predictive accuracy was determined using the receiver operating curve (ROC) and the area under the curve (AUC). Furthermore, the optimal cut-off value was established using the highest Youden's index (*J*) value with the cutpointr package.[19]

The cut-off value performance was established in the testing dataset by the terms of accuracy (Eq. 1), Sensitivity (*Se*) or the percentage of the subjects ≥ 19 years old who had I_{3M} < cut-off value, and Specificity (*Sp*) or the percentage of the subjects < 19 years old who had I_{3M} ≥ cut-off value was calculated as follows:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad 1$$

TP (True Positive) represented the results of those who were ≥ 19 years old and had I_{3M} ≤ cut-off value. Alternatively, the results of those who were < 19 years old and had I_{3M} > cut-off value were described as TN (True Negative). FP (False Positive) was the result of those who were < 19 years old and had I_{3M} ≤ cut-off value. Finally, those who were ≥ 19 and had I_{3M} > cut-off value listed as FN (False Negative).

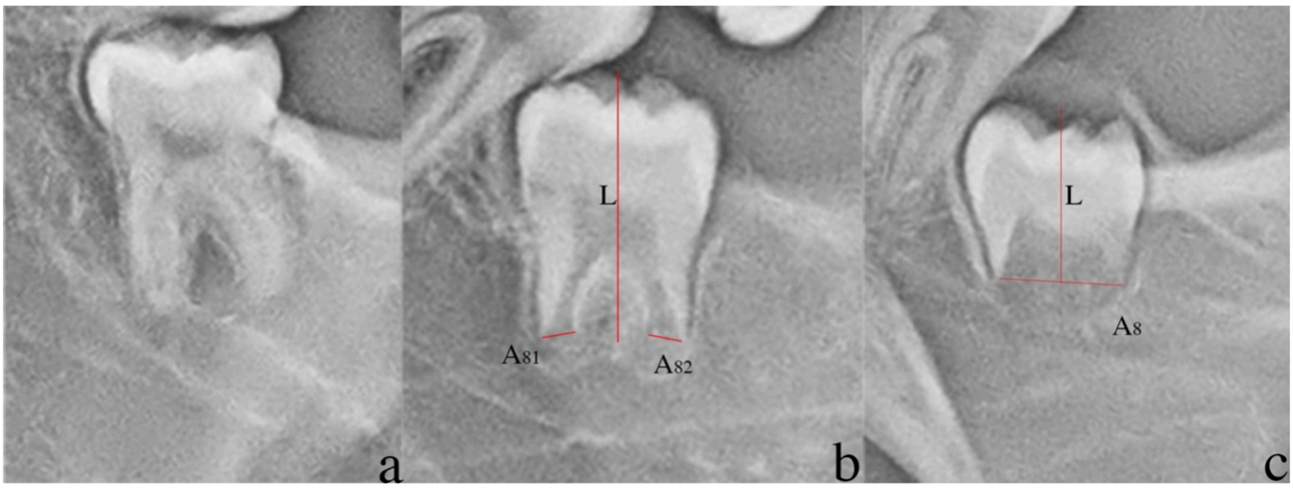
Further evaluation of the model performance was done by calculating the positive predictive value (PPV), negative predictive value (NPV), and positive and negative likelihood ratios (LR +, LR -). PPV and NPV were calculated to examine how many of each positive (≥ 19 years old) and negative (< 19 years old) were correctly classified. LR+ indicated how many TP would be observed per FP. LR- indicated how many FN would be observed per TN.

Bayes post-test probability was calculated (Eq. 2) to help I_{3M} cut-off value distinguished individuals < 19 years old from individuals ≥ 19 years old (i.e., the proportion of individuals with I_{3M} ≤ cut-off value which was ≥ 19 years old):

$$p = \frac{Se \, . \, P_0}{Se \, . \, P_0 + (1 - Sp)(1 - P_0)} \quad 2$$

Where *p* was post-test probability and P_o was the proportion of individuals in the target population who were ≥ 19 years old, given that they were between 15-23.99 years old. P_o was calculated from the data obtained from Statistics Indonesia (Badan Pusat Statistik).[20]

Figure 1. Measurement example of third molar maturity index (I_{3M}). Root development was completed, I3M = 0 (a). The distinct approach was applied when the tooth has developed a bifurcation ($I_{3M} = \frac{A_{81} + A_{82}}{L}$) (b), or not ($I_{3M} = \frac{A_8}{L}$)



RESULTS

Table 1 shows the distribution of the training and testing dataset. Figure 2 shows the I_{3M} value in each sex, with the first value of $I_{3M} = 0$ observed in males and females at the age of 21.5 and 20.3 years old, respectively. Pearson's correlation coefficient between I_{3M} and age was -0.64 ($p < 0.001$). The inter- and intra-rater agreement showed excellent results proving the repeatability of the measurement, with an ICC value of 0.98 and 0.96 for inter- and intra-rater agreement, respectively.[21] The logistic regression model displayed the significance of sex ($p < 0.001$) and I3m ($p < 0.001$) as independent variables for predicting the minimum age of marriage. The model may be written as follows:

$$logit(p) = 2.5401 - 13.4052(I_{3M}) - 1.4954\,(s)$$

The ROC curve is presented in figure 3, with the AUC value of 0.91. As sex became significant as an independent variable, the I_{3M} cut-off value was derived differently for each sex to achieve better accuracy. The I_{3M} for male and female were 0.08 (J = 0.76) and 0.09 (J = 0.76), respectively. The performance of each cut-off value was analysed in the testing dataset with 80% accuracy in both sexes. The female testing dataset achieved better overall performances (*Se*, *Sp*, PPV, NPV, LR+, and LR-) (Table 2-4). Bayes post-test probability showed that the probability of male and female subjects, with $I_{3M} \leq$ the indicated cut-off value for each sex was 19 years old or older, were 0.87 and 0.92, respectively.

Table 1. Age and sex distribution on training and testing dataset

Age (Years)	Male Training Dataset	Female Training Dataset	Total Training Dataset	Male Testing Dataset	Female Testing Dataset	Total Testing Dataset
15-15.99	10	13	23	2	7	9
16-16.99	6	12	18	7	4	11
17-17.99	10	8	18	3	3	6
18-18.99	7	8	15	2	3	5
19-19.99	5	10	15	1	7	8
20-20.99	2	18	20	1	8	9
21-21.99	4	14	18	1	4	5
22-22.99	4	14	18	2	3	5
23-23.99	4	7	11	2	6	8
Total	52	104	156	21	45	66

Figure 2. Box plots showing the relationship between I_{3M} value and chronological age between males and females

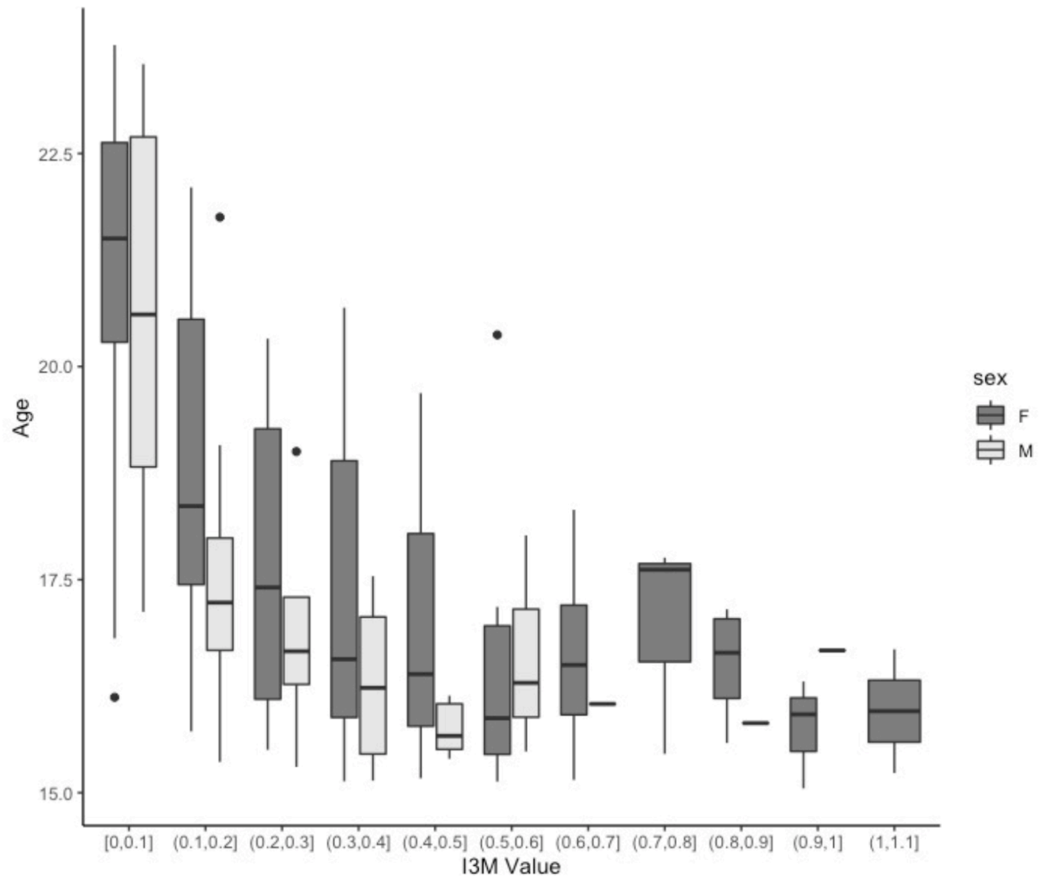


Figure 3. Receiver operating characteristic curve for "19 Years or Older" with an Area Under Curve of 0.91

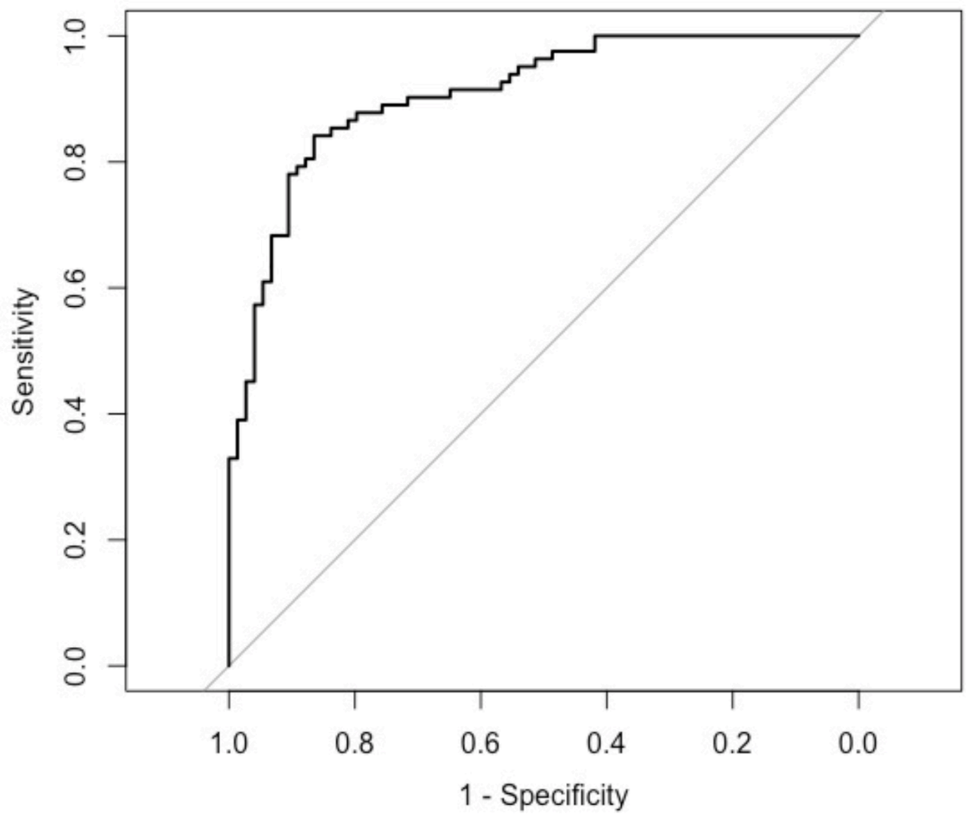


Table 2. Contingency table describing discrimination performance of I_{3M} cut-off value (0.09) on Female testing dataset

Females	Age (years)	
	< 19	≥ 19
Prediction		
I_{3M} > 0.09	16^{TN}	8^{FN}
I_{3M} ≤ 0.09	1^{FP}	20^{TP}

TN = True Negative, FN = False Negative, TP = True Positive, FP = False Positive

Table 3. Contingency table describing discrimination performance of I_{3M} cut-off value (0.08) on Male testing dataset

Males	Age (years)	
	< 19	≥ 19
Prediction		
I_{3M} > 0.08	13^{TN}	3^{FN}
I_{3M} ≤ 0.08	1^{FP}	4^{TP}

TN = True Negative, FN = False Negative, TP = True Positive, FP = False Positive

Table 4. Performance description of each I_{3M} cut-off value in each sex

	Males	Females
Accuracy	0.8	0.8
Se	0.57	0.71
Sp	0.92	0.94
PPV	0.57	0.71
NPV	0.92	0.94
LR+	7.125	11.83
LR-	0.46	0.3
PTP	0.87	0.92

Se = Sensitivity, *Sp* = Specificity, PPV = Positive Predictive Value, NPV = Negative Predictive Value, LR+ = Positive Likelihood Ratio, LR- = Negative Likelihood Ratio, PTP = Bayes' Post-Test Probability

DISCUSSION

The use of I_{3M} to determine the legal age of marriage in the Indonesian population showed an acceptable result in this initial study, where the age threshold is one year old higher than the original study. The original study by Cameriere et al. was conducted to determine the probability of an individual being older or younger than 18 years old with a cut-off value of 0.08.[8] This cut-off value has been tested and validated in many countries with high accuracy.[22] Furthermore, the I_{3M} method also has its versatility in the different legal age thresholds. Balla et al. (2019) applied the I_{3M} method to derive a cut-off value to predict if an individual has reached the age of 16 in the Indian population, resulting in a cut-off value of 0.293 with an accuracy of 88 and 88.7 percent for both males and females.[23] Another cut-off value was also calculated in the Indian population to determine whether an individual has reached the age of 14 in compliance with the child labour laws.[24] Hence, a new cut-off value needs to be calculated for each legal age implementation applied in the respective population.

In this study, our finding suggests that the third molar development in Indonesian juveniles was slower than in other countries. This might be explained by the optimal cut-off value achieved by our study sample to reach 19 years old. I_{3M} has a reverse correlation coefficient with chronological age, meaning that the I_{3M} value will decrease as the individual gets older. Furthermore, Santiago et al. (2018) reported that most of the I_{3M} studies have a high accuracy in using the I_{3M} cut-off value of 0.08 to determine the age of the majority, which is 18 years old.[22] Compared to our study, the I_{3M} values only reached 0.08 and 0.09 at the age of 19 years old, which makes the state of I_{3M} value in Indonesian male juveniles in the age of 19 is equal to 18 years old juveniles in other countries, and even less developed in female. This result is in line with Tangmose et al. (2015), who recommended that genetic differences, including ethnic origin, play a vital role in the third molar development rate.[25] However, a direct comparison with other Indonesian populations or other cut-off values with 19 years old age threshold is not available due to the non-existent data.

The I_{3M} cut-off values were taken differently on each sex. This cut-off value separation was done because sex was a significant independent variable in our model ($p < 0.001$). Furthermore, we observed that deriving the cut-off value equally for both males and females ($I_{3M} = 0.094$) gave an overall lower accuracy (0.79 for both males and females). However, the difference in cut-off value performance between males and females should be used carefully since the training sample was not balanced between the sexes. It is essential to note that multiple studies with balanced samples found that sex was not a significant predictor in their logistic regression model.[23, 26] Consequently, the choice of differentiating I_{3M} cut-off value between a specific group (i.e., sex) should depend on the significant independent variable in the model or achieving a better particular value.

We present the study result with various performance descriptions in Table 4, most notably the *Se* and *Sp* values. In this context of the study, the *Se* value represents the percentage of subjects over 19 years old and have the I_{3M} below the cut-off value and are therefore correctly specified as an individual who can be married (TP). Thus, a high *Se* value represents a low FP, which classifies an individual under 19 years old and classified as being able to marry. However, the *Se* value in the male samples was lower than the female, which could also be explained by the sex imbalance in our training dataset. On the contrary, the *Sp* value — which represents the percentage of subjects under 19 years old and having I_{3M} above or equal to the cut-off value — was found to be high in both sexes. Moreover, avoiding a higher FP value is commonly done in the field of age estimation.[27]

Our main goal is to help eliminate the practice of child marriage in Indonesia. However, a recent study by Rumble et al. (2018) reported that wealth and education had a significant impact on child marriage ($p < 0.05$).[28] Furthermore, Grijns et al. (2018) reported that the state legal system was creatively interpreted in rural areas and was commonly influenced by religious beliefs.[15] Further studies should address the major drawback of this study by using balanced age cohorts for each sex to calculate the significance of sex in the logistic model and its cut-off value threshold. After all, these findings showed that eliminating child marriage in Indonesia is a complicated matter and using the I_{3M} value to assess dental age can help to assess the individual's biological maturity

CONCLUSIONS

The outcome of this pilot study showed a promising result of using I_{3M} as a dental age estimation method to determine whether an individual was over or under 19 years old to comply with the newly enacted legal age of marriage in Indonesia. The results indicate that future research should be carried out using balanced age cohorts for each sex and a more extensive training sample size to investigate the influence of sex in the cut-off value calculation. In addition, incorporating other testing systems, such as psychological evaluation, can be used further to improve the quality of minimum age of marriage assessment.

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Utility of radiomorphometrics indexes of the mandible for age estimation in adults

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ABSTRACT

Introduction: the mandible undergoes changes in morphology and density related to the aging process. These changes are measured by radiomorphometric indices that allow inferring bone density indirectly. Also, the age estimation process in adults is challenging since the modifications in the anatomical structures are gradual and require long intervals of time to be noticeable. Objective: this study aimed to evaluate the usefulness of radiomoformometric indices of the mandible in age estimation in adults. The sample consisted of 230 digital panoramic radiographs of individuals of both genders (115 men and 115 women), with chronological ages between 20 and 81 years, where radiomorphometric indices were obtained in the premolar region and the mandible ramus, using the software ImageJ. An analysis of variance was conducted considering individuals' gender and age group classification categories with Tukey's post hoc test. Results: a downward trend was observed in means indices values for the older age groups, showing lower values for females. Based on the interaction detected between gender and age groups, multiple regression models were applied to estimate age. These showed a better adjustment for males between 50 and 59 years (R^2=82,85%) and males over 60 (R^2=80,16%). Conclusions: the radiomorphometric indices used in this study allowed to infer age from 50 years onwards in males.

INTRODUCTION

Different methods are used to determine adults` age. Some of them consider the macroscopic, histological, or biochemical characteristics of the teeth, while others study the macroscopic particularities of the bones. [1-4] However, their applicability is compromised by the availability of the anatomical piece being examined and the individual's age. In adulthood, age-related changes are due to the individual´s chronological age (CA) and exogenous factors, such as disease, nutrition, and physical stress.[3] On the other hand, a decrease in the precision of the CA estimation has been demonstrated, which seems to be related to, in the one hadn, the time interval that must elapse for the changes to be observable in the examined structures or tissues, and on the other, the sensitivity of the methods in detecting these changes. Therefore, an error in the CA estimation has been reported in the order of 1.5 to 12 years.[5]

The mandible undergoes modifications during the aging process. Studies have shown that a continuous remodeling of the inferior mandibular cortex occurs with age, which seems to

be influenced by the state of dentition and gender. [6,7] Similarly, it has been observed that mandible density decreases as the individual ages, and that changes in the trabecular pattern apper. [8]
Mandibular bone density has been determined in dental radiographs through linear and angular measurements (morphometric analysis), and, also by densitometric analysis, which can be optical, when obtained in conventional radiographs, or digital, in which case it is expressed in grayscale values.[9] Based on this, some radiomorphometric indices (RI) have been evaluated in relation to their applicability in this task, such as, the the thickness of the inferior mandibular cortex in the premolar area, [6,10,11] the degree of alveolar bone resorption, Panoramic Mandibular Index [12] (PMI), Gonial Index [13] (GI) and the Antegonial Index [14] (AGI).
According to the United Nations High Commissioner for Refugees 79.5 million people were displaced from their country of origin at the end of 2019. Events like persecution, political conflict, human rights violations, and others led them into irregular situations [15] ; for example, not having a valid identification document makes them vulnerable to exploitation or abuse. Hence the need to study the applicability of minimally invasive age estimation methods. The objective of the present work was to evaluate the utility of radiomorphometric indices in the mandible of adult subjects, in order to contribute to the age estimation in medicolegal identification procedures.

MATERIAL AND METHODS

The sample consisted of 230 digital panoramic radiographs of individuals of both genders (115 men and 115 women), with ages between 20 and 81 years (Table 1). The radiographic images were obtained for clinical reasons, so that there was no additional exposure of the subject to ionizing radiation, according to the guidelines of the Declaration of Helsinki [16] for the study in humans. Five age groups were formed for each sex (Group I: 20-29; Group II: 30-39; Group III: 40-49; Group IV: 50-59; Group VI: 60 ≥)

Table 1. Sample distribution according age groups and gender.

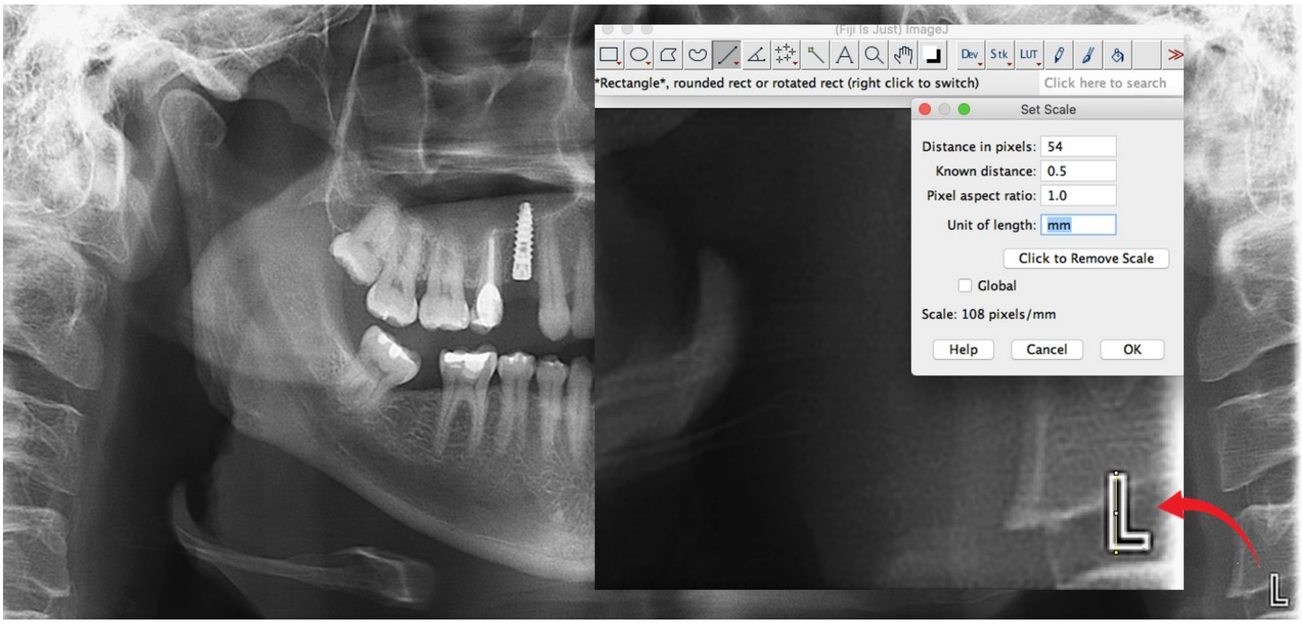
	Gender					
Age groups	Masculine		Femenine		Total	
	N	%	N	%	N	%
20 - 29	16	13,9	16	13,9	32	13,9
30 - 39	14	12,2	16	13,9	30	13,0
40 - 49	16	13,9	16	13,9	32	13,9
50 - 59	27	23,5	26	22,6	53	23,0
60 - +	42	36,5	41	35,7	83	36,1
Total	115	100.0	115	100,0	230	100.0

Image acquisition and analysis

All radiographic images were obtained on a Planmeca Promax direct digital panoramic equipment (SCARA 3, Helsinki, Finland), with the following factors: 54 to 84 kVp, 16 mA and 16 seconds of exposure time. The radiographs were selected according to the following criteria: minimal distortion, no positioning errors and visible mental foramen on both sides of the mandible, and absence of cystic, tumor or trauma-caused bone lesions. These images were initially processed with Romexis 5.0 software (Planmeca, Helsinki, Finland) to improve their contrast, density and sharpnes. Later, they were stored in JPG format with a resolution of 300 dpi for further analysis. Each radiograph was assigned a code to protect the identity of the patient.
Images were analyzed using ImageJ software (https://imagej.net/software/fiji/). Before making the measurements to obtain the RI, the magnification of the radiographic images was corrected, according to the protocol developed

in a previous study, [17] using the software's set scale tool. For this purpose, the radiopaque indicator on the left side of the radiograph was used, assuming a real size of 0.5mm, in such a way that the values obtained were expressed in millimeters for later comparison (Figure 1). All panoramic radiographs were evaluated by a single calibrated observer, who could use the brightness, contrast and magnification resources of the software. Ten percent of the sample was reevaluated 15 days apart to determine intraobserver variability.

Figure 1. Representation of the magnification correction using the ImageJ software set scale tool, through the radiopaque indicator on the left side of the panoramic radiograph.



The following RI were obtained in each radiograph (Figures 2 and 3):

Mandibular height (MH): Distance between the lower border of the inferior cortex of the mandible and the alveolar crest, measured in a perpendicular line to the tangent through the inferior border of the mandible. [11]

H: Distance from the center of the mental foramen to the lower border of the mandibular cortex. [10]

h: Distance from the lower border of the mental foramen to the lower border of the inferior mandibular cortex. [12]

Resorption of the alveolar ridge (RAR: Ratio between MH and the distance from the center of the mental foramen to the lower border of the mandibular cortex (H).[10]

Cortical thickness below the mental foramen (MI): Distance between the superior and inferior border of the cortex, measured on the line drawn for the measurement of MH. [14]

Panoramic mandibular index (PMI): Ratio between the distance from the lower border of the mental foramen to the lower border of the inferior mandibular cortex (h) and MI. [12]

Antegonial index (AGI): Thickness of the inferior mandibular cortex in the antegonial region, measured at the intersection of a tangent that passes through the anterior border of the mandibular ramus and a tangent to the inferior border of the mandible. [14]

Gonial index (GI): Thickness of the inferior cortex measured at the bisector of the gonial angle between a tangent that passes through the lower border of the mandible and another tangential line to the posterior border of the mandibular ramus. [13]

Maximum height of the ramus (MHR): Distance between the points cd (condylion) -tgo (Intersection of the tangents that form the gonial angle) measured on a tangent line to the posterior border of the mandibular ramus. [18]

Gonial angle (GA): Angle between the tangents to the posterior border of the mandibular ramus and the inferior border.[18]

Figure 2. Representation of the tracing and measurement of the radiomorphometric indices studied in the premolar region of the mandible, using ImageJ software, MH: Metal region height; MI: Thickness of the inferior cortex of the mandible; H: Distance from the center of the mental foramen to the inferior border of the inferior cortex; h: Distance from the inferior border of the mental foramen to the inferior border of the inferior cortex.

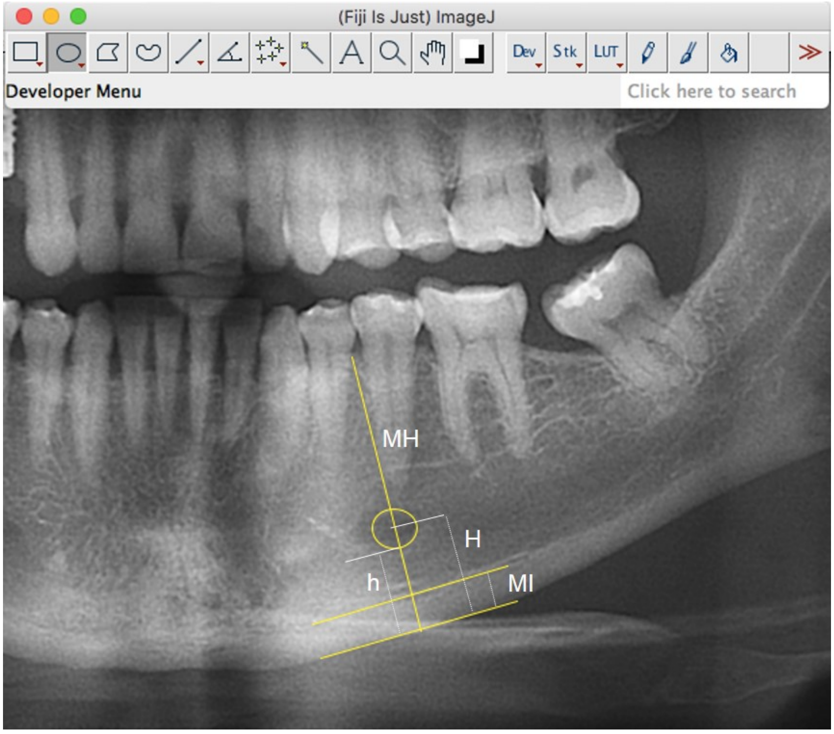
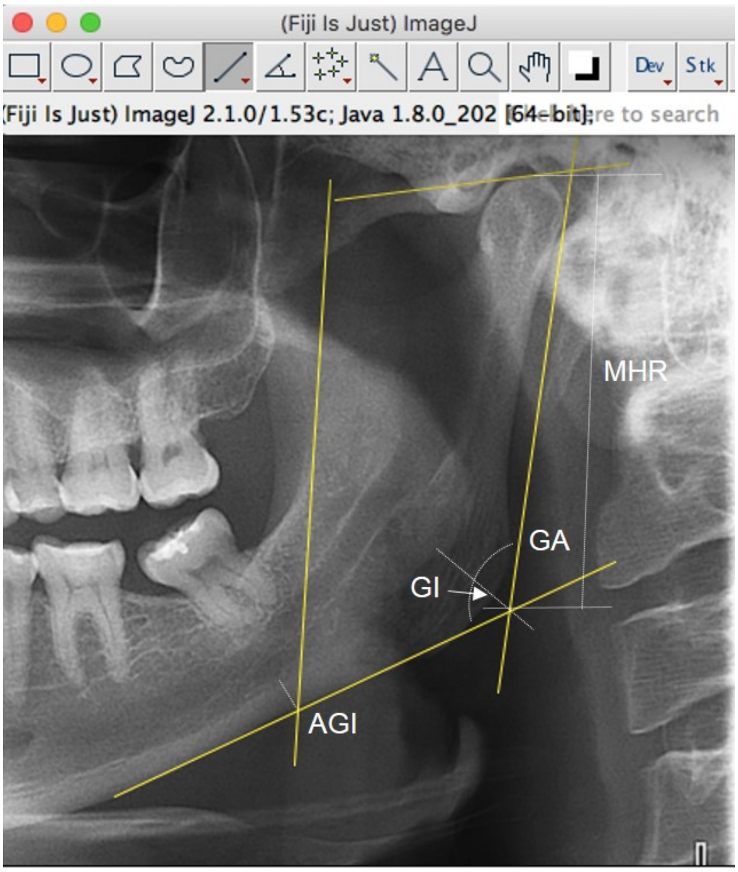


Figure 3. Representation of the tracing and measurement of the antegonial index (AGI), gonial index (GI), gonial angle (GA) and maximum height of the (MHR).



Statistical analysis

The data were processed with MiniTab version 20 software (MiniTabInc., Pennsylvania, USA.) and SPSS version 15 (SPSS Inc., Chicago, USA.). Agreement analysis was calculated via Intraclass Correlation Coefficient (ICC) with a 95% confidence interval. Pearson's correlation coefficient was calculated between the RI determined on both sides of the mandible. Means and standard deviations of the RI were obtained. An analysis of variance (ANOVA) was conducted considering the gender and age group of the individuals as classification categories with Tukey's posthoc test. The gender-age group interaction was analyzed graphically. Multiple linear regression models were built for the quantitative variables considering all individuals classified by gender and age group and gender-age group. The selection of variables was carried out on these regression models using the step-by-step methodology (Stepwise); in addition, the regression models were cross-validated using the folds method with ten folds. The significance level was set at 5%.

RESULTS

The ICC ranged from 0.804 to 0.984 (p = 0.000), which demonstrated the reproducibility of the measurements made. Significant Pearson correlations ((p=0,000) were observed between the values found for the RI on both sides of the mandible: MH (0,893); RAR (0,610); H(0,214); h(0,755); MI (0,696); AGI (0,555); GI (0,563); MHR (0,867); GA (0,942). The mean obtained was used in the different statistical tests.

Table 2 shows the mean and standard deviation for the RI values by gender and age group. In general, the values decrease with age and are lower in female individuals. According to the ANOVA, all variables showed at least one statistically significant effect for gender, age group, or gender-age group interaction. Concerning gender, only the MI and AGI variables did not show statistically significant differences. MH, H, h, RAR, GI, and MHR had a higher mean in males, while, in females, PMI and GA variables were higher. Only H, MI, and AGI variables did not show differences according to age for the age group. MH, AGI, GI, and MHR presented the highest mean in the subjects between 20- 29 years and the lowest mean in older individuals. However, h and RAR showed the opposite behavior. On the other hand, PMI showed the highest average in individuals aged 40 to 49 years and the lowest in individuals over 60 (Table 3).

In the gender-age group interaction (Table 3), MI, PMI, AGI, and GA variables presented statistically significant results. Women showed a higher MI means between 40 and 59 years, and the opposite behavior for the rest of the ages. For PMI, women presented a higher mean between 20 to 29 years and 40 years and older, while for all subjects between 30 to 39 years, the means were homogeneous. For AGI, men showed a higher mean for the ages 30 to 39 years and from 60 years onwards, while the means of women were higher in the remaining age groups. For GA, women had a higher mean up to 59 years, while the means were homogeneous for subjects 60 and over (Figure 4). These results indicate that the regression models could behave differently depending on the gender and age group; in other words, the quality of the estimated models could improve if they are classified by age and gender.

The multiple linear regression models showed a low adjustment coefficient (R^2 = 30.79%) for all individuals. This result was verified by applying a cross-validation (R^2 = 26.02%). For gender, the models showed a better fit for men (R^2 = 45.48%) than for women (R2s = 30.26%). This behavior was maintained for the cross-validations done (R^2 = 38.36%, R^2 = 28.78%, respectively). When analyzing age, the age group 60 years or older showed an adjustment greater than 30% (R2 = 35.78%) and validated in R^2 = 28.40%. For gender and age combined, the models performed better for males between 50-59 years and 60 and over (R^2 = 82.85%, R^2 = 80.16%, respectively). For these two groups, the cross-validations resulted in R^2 = 67.96% and R^2 = 70.69%, respectively. In addition, all the models for men showed adjustment coefficients greater than 30%. On the other hand, for women, although the age groups between 30 and 59 years old showed adjustment coefficients over 40% (Group 30-39: R^2 = 55.32%, Group 40-49: R^2 = 49.71%, Group 50-59: R^2 = 47.27%), their validated adjustment coefficients were low (R^2 = 21.97%, R^2 = 30.43%, R^2 = 22.47%) (Tables 4-7).

Table 2. Mean and standard deviation of the radiomorphometric indices by age group and gender.

RI	Age groups											
	20-29		30-39		40-49		50-59		60≥		Total	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	Sd
MH												
Mas	28.72	3.49	27.19	3.52	28.50	2.13	27.36	2.23	27.21	2.89	27.64	2.88
Fem	26.25	2.54	26.39	2.41	24.99	3.16	23.82	4.84	24.29	1.90	24.85	3.21
RAR												
Mas	2.42	0.30	2.30	0.31	2.39	0.28	2.23	0.23	2.16	0.20	2.26	0.27
Fem	2.57	0.25	2.54	0.24	2.49	0.25	2.24	0.35	2.32	0.24	2.39	0,30
MI												
Mas	3.18	0.38	3.20	0.75	3.28	0.72	2.72	0.67	2.98	0.68	3.01	0,68
Fem	3.00	0.61	2.73	0.66	3.33	0.77	3.12	0.48	2.74	0.72	2.94	0.68
H												
Mas	11.99	1.83	11.86	1.27	12.07	1.40	12.39	1,46	12.70	1.64	12.34	1.56
Fem	10.28	1.31	10.46	1.16	10.06	0.97	10.68	2.15	10.59	1.24	10.48	1.46
h						.						
Mas	10.42	2.08	10.38	1.41	10.29	1.22	10.94	1.58	11.46	1.66	10.90	1.67
Fem	8.72	1.46	8.97	1.22	8.20	0.89	9.26	2.34	9.12	0.82	8.95	1.46
PMI												
Mas	0.31	0.06	0.32	0.09	0.32	0.08	0.26	0.08	0.27	0.09	0.29	0.09
Fem	0.35	0.08	0.31	0.10	0.41	0.11	0,37	0.17	0.30	0.07	0.34	0.11
AGI												
Mas	2.41	0.43	2.42	0.31	2.43	0.49	2.34	0.44	2.13	0.59	2.29	0.50
Fem	2.65	0.61	2.38	0.63	2.66	0.37	2.55	0.48	1.87	0.48	2.31	0.61
GI												
Mas	1.31	0.28	1.39	0.37	1.28	0.40	1.15	0.22	1,25	0.32	1.25	0.32
Fem	1.30	0.37	1.27	0.32	1.18	0.35	1.16	0.28	0,93	0.23	1.12	0.32
MHR												
Mas	65.17	9.05	59.25	4.20	61.82	5.66	60.65	6.83	58,38	4.74	60.44	6.36
Fem	54.17	4.18	54.02	5.95	50.76	3.65	52.56	4.27	51.78	3.52	52.46	4.29
GA												
Mas	124.74	28.88	118.98	4.79	118.18	7.71	120.54	9.08	125.36	7.58	122.40	13.00
Fem	134.26	34.15	124.40	5.51	124.75	8.74	136.04	33.84	134.91	34.55	132.00	29.30

Legend: M: mean; SD: standard deviation; RI: radiomorphometric index; Mas: masculine; Fem: feminine. Group 1: 20-29 years old; Group 2: 30-39 years; Group 3: 40-49 years; Group 4: 50-59 years; Group 5: ≥ 60 years. MH: Mandibular height at the mental foramen; RAR: Degree of resorption of the alveolar ridge; MI: Thickness of the inferior cortex of the mandible; H: Distance from the lower border of the MI to the center of the mental foramen; h: Distance from the inferior border of the MI to the inferior border of the mental foramen; PMI: Panoramic mandibular index; AGI: Antegonial index; GI: Gonial index; MHR: Maximum height of the ramus; GA: Gonial angle.

Table 3. Tukey's homogeneous means and groups of means for the variables classified by age group and gender.

Variable	Class	N	MH	H	h	RAR	MI	PMI	AGI	GI	MHR	GA
Gender	F	115	24.84^{B}	10.47^{B}	9.00^{B}	5.69^{B}	2.97^{A}	0.34^{A}	2.30^{A}	1.07^{B}	52.14^{B}	125.06^{A}
	M	115	27.63^{A}	12.20^{A}	10.75^{A}	6.51^{A}	3.05^{A}	0.29^{B}	2.31^{A}	1.18^{A}	60.37^{A}	121.08^{B}
Age Group	20-29	32	27.38^{A}	11.19^{A}	9.57^{AB}	6.04^{AB}	3.05^{A}	0.33^{AB}	2.47^{A}	1.24^{A}	58.92^{A}	120.99^{A}
	30-39	30	26.77^{AB}	11.09^{A}	9.57^{AB}	6.00^{AB}	2.98^{A}	0.31^{AB}	2.40^{A}	1.25^{A}	56.18^{AB}	122.05^{A}
	40-49	32	26.60^{AB}	10.93^{A}	9.18^{B}	5.81^{B}	3.27^{A}	0.37^{A}	2.51^{A}	1.15^{AB}	56.27^{AB}	121.96^{A}
	50-59	53	25.40^{B}	11.47^{A}	10.08^{A}	6.16^{AB}	2.98^{A}	0.31^{AB}	2.42^{A}	1.14^{AB}	56.74^{AB}	123.50^{A}
	60+	83	25.98^{AB}	11.55^{A}	10.24^{A}	6.24^{A}	2.93^{A}	0.28^{B}	2.05^{B}	1.01^{B}	54.95^{B}	124.40^{A}
Effect	Sex	p	<0.001*	<0.001*	<0.001*	<0.001*	0.448	<0.001*	0.783	0.014*	<0.001*	<0.001*
	Age	p	0.018*	0.114	0.001*	0.007*	0.120	0.001*	<0.001*	<0.001*	0.004*	0.159
	Sex×Age	p	0.346	0.214	0.164	0.074	0.020*	0.035*	0.031*	0.070	0.085	0.008*

Legend: (*) Statistically significant differences at 5%. Means with the same letter in the superscript do not present statistically significant differences according to Tukey's honest significant difference test. MH: Mandibular height at the mental foramen; H: Distance from the lower border of the MI to the center of the mental foramen; h: Distance from the inferior border of the MI to the inferior border of the mental foramen; RAR: Degree of resorption of the alveolar ridge; MI: Thickness of the inferior cortex of the mandible; PMI: Panoramic mandibular index; AGI: Antegonial index; GI: Gonial index; MHR: Maximum height of the ramus; GA: Gonial angle.

Figure 4. Gender-age interaction groups.
Note: Bars represent 95% confidence intervals for the mean.
MI: the thickness of the inferior cortex of the mandible; PMI: Panoramic mandibular Index; AGI: Antegonial index; GA: Gonial angle.

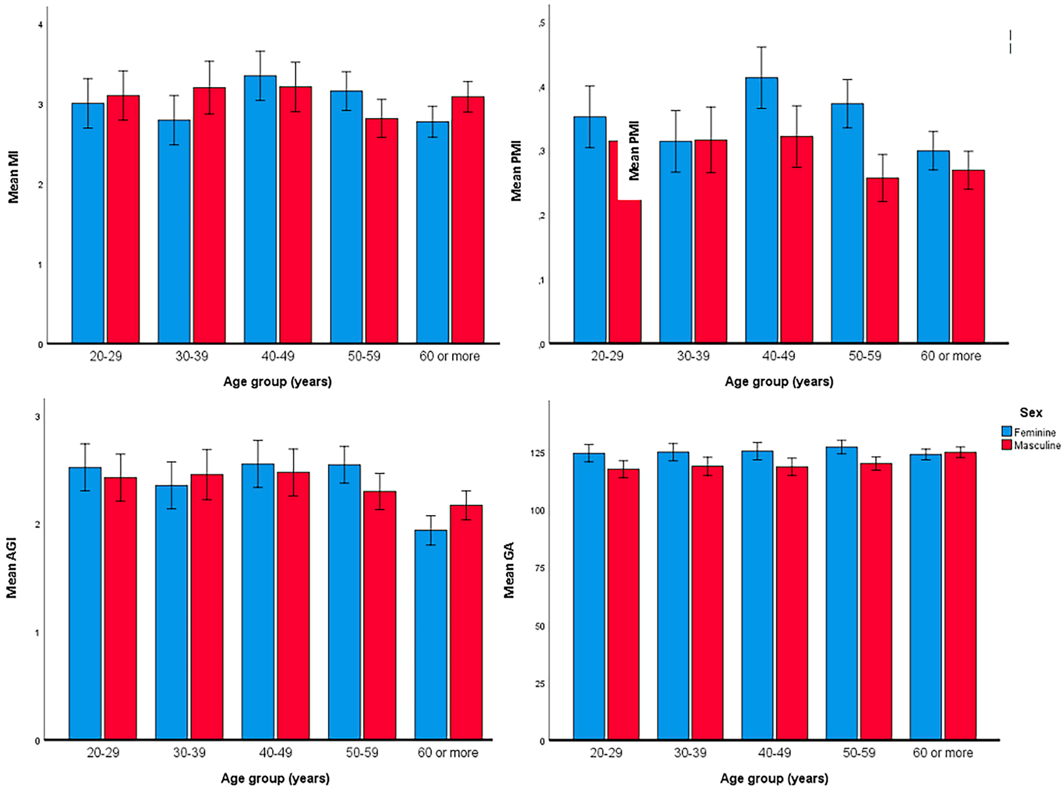


Table 4. Regression models showing the total sample and the individuals classified by gender.

Group	Predictor	Beta	P value	Model statistics
Total	Constant	68.733	<0.001*	$p_{model}<0.001^*$ S=13.84 R^2=30.79% R^2_{adj}=28.60% S_{valid}=14.0595 R^2_{valid}=26.02%
	Gender	3.842	0.082	
	MH	-1.739	<0.001*	
	MI	10.603	<0.001*	
	PMI	-70.738	<0.001*	
	AGI	-9.767	<0.001*	
	GI	-11.859	0.001*	
	GA	0.420	0.001*	
Females	Constat	127.409	<0.001*	$p_{model}<0.001^*$ S=13.87 R^2=32.10% R^2_{adj}=30.26% S_{valid}=13.9598 R^2_{valid}=28.78%
	AGI	-8.695	0.002*	
	GI	-19.437	<0.001*	
	MHR	-0.697	0.029*	
Males	Constant	-17.066	0.533	$p_{model}<0.001^*$ S=12.36 R^2=45.48% R^2_{adj}=41.92% S_{valid}=12.6737 R^2_{valid}=38.36%
	MH	-3.162	<0.001*	
	H	-8.069	0.003*	
	RAR	27.944	<0.001*	
	MI	9.425	<0.001*	
	AGI	-11.529	<0.001*	
	MHR	-0.443	0.068	
	GA	0.798	<0.001*	

Legend: *p˂0.001. R: Pearson's correlation; R^2: Coefficient of determination; S: Standard error; Adj: Adjusted. MH: Mandibular height at the mental foramen; RAR: Degree of resorption of the alveolar ridge; MI: Thickness of the inferior cortex of the mandible; H: Distance from the lower border of the MI to the center of the mental foramen; PMI: Panoramic mandibular index; AGI: Antegonial index; GI: Gonial index; MHR: Maximum height of the ramus; GA: Gonial angle.

Table 5. Regression models by age group.

Age group	Predictor	Beta	P Value	Model statistics
20-29	Constant	30.821	<0.001*	p_{model}=0.052 S=2.82101 R^2=12.06% R^2_{adj}=9.12% S_{valid}=2.89422 R^2_{valid}=1.26%
	AGI	-2.444	0.052	
30-39	Constant	27.277	0.007*	p_{model}=0.043* S=2.27352 R^2=26.55% R^2_{adj}=18.07% S_{valid}=2.37424 R^2_{valid}=7.57%
	Sexo	2.182	0.032*	
	MH	-0.382	0.022*	
	GA	0.125	0.096	
40-49	Constant	26.848	<0.001*	p_{model}=0.014* S=2.61515 R^2=18.54% R^2_{adj}=15.83% S_{valid}=2.7214 R^2_{valid}=5.91%
	GA	0.140	0.014*	
50-59	Constant	32.906	<0.001*	p_{model}=0.001* S=2.55159 R^2=36.66% R^2_{adj}=28.39% S_{valid}=2.71468 R^2_{valid}=17.39%
	Sex	1.507	0.094	
	MI	3.036	0.001*	
	PMI	-9.068	0.025*	
	AGI	-2.462	0.022*	
	GI	-2.909	0.024*	
	GA	0.183	0.001*	
≥ 60	Constante	96.940	<0.001*	p_{model}<0.001* S=5.04112 R^2=39.70% R^2_{adj}=35.78% S_{valid}=5.29084 R^2_{valid}=28.40%
	Sex	4.575	0.036*	
	MH	-0.419	0.118	
	H	-1.871	0.004*	
	AGI	-5.192	<0.001*	
	MHR	0.216	0.125	

Legend: *$p<0.001$. R: Pearson's correlation; R^2: Coefficient of determination; S: Standard error; Adj: Adjusted. MH: Mandibular height at the mental foramen; MI: Thickness of the inferior cortex of the mandible; H: Distance from the lower border of the MI to the center of the mental foramen; PMI: Panoramic mandibular index; AGI: Antegonial index; GI: Gonial index; MHR: Maximum height of the ramus; GA: Gonial angle.

Table 6. Regression models estimated by age group and gender, females.

Age Group	Predictor	Beta	P Value	Model statistics
20-29	Constant	29.225	<0.001*	p_{model}=0.080 S=2.80237 R^2=20.29% R^2_{adj}=14.60% S_{valid}=2.97241 R^2_{valid}=0.00%
	GI	-3.730	0.080	
30-39	Constant	49.140	<0.001*	p_{model}=0.018* S=2.00305 R^2=55.32% R^2_{adj}=44.15% S_{valid}=2.29227 R^2_{valid}=21.97%
	H	0.933	0.126	
	GI	-6.050	0.014*	
	MH	-0.353	0.015*	
40-49	Constant	20.829	0.022*	p_{model}=0.036* S=2.31599 R^2=49.71% R^2_{adj}=37.14% S_{valid}=2.35911 R^2_{valid}=30.43%
	MH	-0.953	0.026*	
	H	4.056	0.005*	
	GI	5.621	0.048*	
50-59	Constant	78.284	<0.001*	p_{model}=0.001* S=2.00374 R^2=47.27% R^2_{adj}=42.68% S_{valid}=2.28519 R^2_{valid}=22.47%
	GI	-4.197	0.010*	
	MHR	-0.391	<0.001*	
≥ 60	Constant	107.415	<0.001*	p_{model}=0.002* S=5.82703 R^2=27.58% R^2_{adj}=23.77% S_{valid}=5.93312 R^2_{valid}=18.99%
	H	-2.372	0.025*	
	AGI	-7.491	0.001*	

Legend: *$p<0.001$. R: Pearson's correlation; R^2: Coefficient of determination; S: Standard error; Adj: Adjusted. MH: mandibular height at the mental foramen; RAR: degree of resorption of the alveolar ridge; MI: thickness of the inferior cortex of the mandible; H: distance from the lower border of the MI to the center of the mental foramen; h: distance from the inferior border of the MI to the inferior border of the mental foramen; PMI: panoramic mandibular index; AGI: antegonial index; GI: gonial index; MHR: maximum height of the ramus; GA: gonial angle.

Table 7. Regression models estimated by age group and gender, males.

Age Group	Predictor	Beta	P Value	Model statistics
20-29	Constant	32.407	<0.001*	p_{model}=0.013* S=2.15466 R^2=57.79% R^2_{adj}=47.24% S_{valid}=2.72914 R^2_{valid}=9.72%
	AGI	-3.875	0.057	
	GI	8.838	0.003*	
	MHR	-0.140	0.106	
30-39	Constant	52.172	<0.001*	p_{model}=0.090 S=1.98177 R^2=35.45% R^2_{adj}=23.72% S_{valid}=2.36466 R^2_{valid}=0.00%
	MH	-0.351	0.064	
	AGI	-3.536	0.084	
40-49	Constant	19.950	0.038*	p_{model}=0.017* S=2.31139 R^2=34.25% R^2_{adj}=29.55% S_{valid}=2.35833 R^2_{valid}=21.77%
	GA	0.198	0.017*	
50-59	Constant	37.357	0.003*	p_{model}<0.001* S=1.57321 R^2=82.85% R^2_{adj}=77.71% S_{valid}=1.85093 R^2_{valid}=67.96%
	H	1.917	<0.001*	
	MI	5.098	<0.001*	
	AGI	-5.804	<0.001*	
	GI	-3.919	0.003*	
	MHR	-0.353	0.002*	
	GA	0.145	0.026*	
≥ 60	Constant	69.029	<0.001*	p_{model}<0.001* S=2.9204 R^2=80.16% R^2_{adj}=76.08% S_{valid}=3.19386 R^2_{valid}=70.69%
	MH	-0.571	0.034*	
	H	-10.661	<0.001*	
	RAR	23.052	<0.001*	
	MI	-6.252	0.005*	
	PMI	57.017	0.007*	
	AGI	-5.098	<0.001*	
	GI	7.471	0.053	

Legend: *p˂0.001. R: Pearson's correlation; R^2: Coefficient of determination; S: Standard error; Adj: Adjusted. MH: Mandibular height at the mental foramen; RAR: Degree of resorption of the alveolar ridge; MI: Thickness of the inferior cortex of the mandible; H: distance from the lower border of the MI to the center of the mental foramen; PMI: Panoramic mandibular index; AGI: Antegonial index; GI: Gonial index; MHR: Maximum height of the ramus; GA: Gonial angle.

DISCUSSION

The mandible undergoes a series of morphological alterations during the individual's life that seem to be influenced by age, sex and the status of the dentition, [19-22] these changes have been studied in dental radiographs. [17,18] Panoramic radiographs are widely used as an initial monitoring tool for the patient, due to its wide coverage of the jaws, easy execution and low radiation dose.[10,23] In this investigation the radiographs were obtained by previous clinical indication, regardless of an "osteoporotic" or "normal" state, hoping to represent an average group of subjects within the selected age range.

In this research, the RI means tended to decrease with age for both genders. However, for women, values were generally lower than men's, and these results have also been reported in previous studies. [6,19,24]They have been attributed to the early onset of the aging process, which begins around 45-50 years for females and is related to the culmination of the menstrual cycle and the drop of sex hormones.[6,19]

Regarding the RI measured in the body and mandibular ramus, the male values for MI, PMI, AGI, GI were lower than those reported in other studies.[19,21,23,24]Women's results for MI and PMI were considered average (≥3.0 and ≥0.33 mm) [6,7,10,17,19,20]; for AGI, the mean value was lower than the standard value (≥3.2 mm). However, it was similar to those indicated by Dutra et al. [6,7] The mean value for GI was lower than the value of ≥1.2 mm, considered standard.[19,24] These results could express discrepancies in the study design, population differences, and subjects with decreased bone density in the study sample.

GA presented a gradual decrease in men with aging. The opposite was observed in women's results, reflecting the conclusions of Damera et al. [25] and Dietrichkeit et al. [26] Due to the morphological changes that the mandible undergoes from birth to adulthood, the obtuse mandible angle of infancy and childhood becomes acute in adults. Nevertheless, as aging progresses, tooth loss leads to obtuse angles because of the muscle forces and bone resorption. [21] Likewise, some studies show that the GA may be related to the size of the mandible: the smaller the ramus, the more obtuse the angle. This point would explain the higher values obtained for females.[26]

The females in the study showed lower MHR values when compared to men's, which reflects other studies [25,27]. In this sense, and according to some studies revised, the height of the ramus fluctuates between 18 and 40 years of age, with a sustained decrease towards the fifth and sixth decades of life, [28]. These results were verified for both genders.

When the regression models were built considering the gender-age group interaction, as the ANOVA indicated, the results obtained were better than the ones obtained calculated separately for these variables. In men, models for the age groups between 50-59 and 60 ≥ years managed to explain 82.85% and 80.16% of the variance between the AC and estimated age, respectively. The models for 30-39, 40-49, and 50-59 age groups showed an adjustment of around 40% in women. In contrast, the model for the group aged 60 ≥ explained 27.58% of the variance, reflecting possibly an osteoporotic condition in the sample rather than age-related changes in the RIs.

Musa et al. [29] found significant differences when separating the subjects into two age groups. Some patients in the groups were under 65 and others over 65. The researchers pointed out that in the middle sixties, the female population was about ten years into the post-menopausal process, and hormonal changes have stimulated bone resorption. The mandible seems to undergo more evident changes from 60 and over, maintaining a relatively stable morphology until 40 years of age. This result could be related to the fact that bone mass constantly increases and peaks at 40 years of age in men and around 30-35 in women. [23] Dutra et al. [6] reported that the MI and GI values decrease abruptly after 60 years of age in both genders, which was indicated by Musa et al. [29] for AGI. Knezovic et al. [24] described that MI, GI, and AGI showed a tendency to decrease with age, showing lower values in women up to 75 years of age when the indices fall abruptly.

In their study, Dietrichkeit et al. [26] assessed the possibility of estimating gender and age in dry mandibles of Brazilian individuals (0-100 years old) considering GA and the MHR values, among other variables. They reported significant differences between gender concerning the studied variables, and they could build logistic regression models to estimate gender with 90% precision. Regarding age, the authors pointed out that only MHR was worthwhile, in contrast to the results of our research, which can be mainly attributed to the studied age range and the selected indices.

From a forensic point of view, the models proposed here could be the starting point to investigate how the morphological characteristics of the mandible contribute to age diagnosis. Future research should consider the influence of the presence or absence of teeth on these indices and how it is related to the estimation of age. Likewise, it is necessary to research whether osteopenia or osteoporosis would affect age diagnosis, particularly in females.

CONCLUSIONS

Estimating age in adults through morphological features of teeth or bones is challenging since the evaluated characteristics often require extended periods to become evident, which decreases the precision in age calculation. This work studied the usefulness of radiomorphometric indices in the mandible for age determination. A decrease in index values was found as age advances, more evident in women. Regression models explained around 80% of the variance between chronological and estimated age in males, from 50 years onwards.

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Facial approximation for identification purposes: soft tissue thickness in a Caucasian population. Sex and age-related variations.

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ABSTRACT

The aim of this study was to collect soft tissue thickness (STT) values of an Italian population from 12 bone landmarks, to improve the facial approximation process for identification purposes. 100 Italian adults (50 males and 50 females), who had undergone head CT for clinical purposes, were analysed in order to expand the database of the Italian population. Average values, standard deviation and range were collected according to gender and age and the obtained values were statistically analysed in order to evaluate any possible significant difference. Only one landmark was statistically significant associated with sex, females showed significantly higher values for para-zygomaxillary. Two landmarks were statistically significant associated with age, upper incisor and pogonion. The obtained results were compared with the existing literature. Such information can be useful in the forensic craniofacial reconstruction process and can facilitate choosing the most suitable STT values according to osteological analysis of the human remains.

INTRODUCTION

Facial approximation is a method that reproduces the facial soft tissue of an individual, considering tissue depth landmarks on the bone surface of the skull. In recent research, this is a useful tool in the forensic investigation of human identification [1-4]. The reproduction of the facial features is conditioned by the soft tissue thickness and the underlying bone surface [5-8] that is sufficiently distinctive and provides a unique facial appearance even by the application of average facial soft tissue thickness [9]. For this purpose, measurements of soft tissue thickness are taken at predefined bone landmarks. In the first studies aimed at establishing facial soft tissue thickness, these values were taken using the needle puncture technique on cadavers [10-16]. Through the development of medical imaging techniques, subsequent studies were conducted on living individuals in order to minimise the error due to the post-mortem changes [17 18]. These studies used different imaging methods for the soft tissue thickness measurements like cephalometric X-ray [18-22], ultrasound [23-27], magnetic resonance [28, 29], and computed tomography/cone beam computed tomography [9, 30-36].

In forensic facial approximation, as landmarks should be located with precision on the bone surface, it is convenient to utilise CT scans [30, 37]. In the literature, many studies are conducted using this technique with sample size ranging from 1 to 500 individuals but generally these samples tend to include

less than 40 individuals on average [2]. Furthermore, many population groups have been investigated but few studies have been conducted on Caucasian populations [9, 15, 32, 37-41] and only two studies [18, 33] on Italian population groups.
The aim of this study was to obtain STT measurements for a large Italian population group according to gender and age, and to compare the results with the existing literature to assess whether there are significance differences in tissue thicknesses that are useful during facial reconstruction procedures.

MATERIAL AND METHODS

Facial soft tissue thicknesses were measured on the head CT scans of 100 Italian adults: 50 males and 50 females, aged between 18 and 98 years. All of them underwent CT scans for clinical reasons not related to this study, so the individuals were not exposed to radiation only for the purpose of this research. As a retrospective study, patient details such as height and weight could not be obtained since not required at the time of the radiological investigation, thus both thin and obese subjects were included in the sample. Our hospital ethics committee was not involved because CT scans were anonymous and only data on age and sex was available; in addition, we did not introduce a new type of intervention on patients. Furthermore, patients with trauma, fractures, malformations or any other congenital or acquired abnormality that could influence the shape of the face or the measurements of the tissue thickness were excluded from the sample.
For this study, 12 osteological landmarks (listed and described in Table 1) were considered and the tissue thickness of each one was measured. These landmarks were selected because of the ease of their localisation on the CT scans and their representativeness of the inter-individual variation and of the facial physiognomy [33].

Table 1. Description of landmarks. *Landmarks defined by Rhine and Campbell [11] †Landmarks defined by Aulsebrook et al. [8]. ‡Landmarks defined by Cavanagh et al. [37]. §Landmarks defined by De Donno et al. [33]

LANDMARK	DEFINITION
Sub-orbital *	Below the orbit, on the lowermost margin of the orbit.
Nasion *	Midpoint of the suture between the frontal and the two nasal bones.
Rhinion *	Anterior tip of the nasal bones, on the internasal suture.
Zygion †	Point on the maximum lateral outer curvature of the zygoma.
Zygomaxillary †	Lowest point on the suture between the zygomatic and maxillary bones.
Para-zygomaxillary §	Point between the horizontal and the oblique/vertical part of the zygomatic bone.
Para-midphiltrum §	The most internal point of the curvature of the maxillary bone in the midline.
Upper incisor ‡	The most anterior point of the maxillary crest in the midline.
Lower incisor ‡	The most anterior point of the mandibular crest in the midline.
Gonion *	The most lateral point on the mandibular angle.
Pogonion [b]	The most anterior projecting point in the midline on the chin.
Menton [d]	The lowest point on the mandible.

Because the head CT scans were focused on the craniofacial region, it was not possible to consider on each CT scan all the landmarks taken into consideration.
Measurements of facial soft tissue thickness were obtained using a Multi Detector row Computed Tomography (MDCT) available at Interdisciplinary Department of Medicine (DIM), Diagnostic Imaging Section, University of Bari, Italy. CT examinations were performed by a 128-row system (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany), using the following acquisition parameters: collimation 160 x 0.5 mm, increment 0.5mm, rotation time 1 s; 120/200-280 kVp/mAs. Automatic dose modulation system was used in all cases (effective dose: <2 mSv).
The obtained data were transferred and analysed on a workstation (HP XW 8600) equipped with image reconstruction software (Vitrea FX 2.1, Vital Images, Minneapolis, MN, USA). In order to take accurate measurements, this tool allows the visualisation of three planes of study: axial, coronal, and sagittal at the same time.
The measurements were taken using an optimal soft tissue window (window width: 350–400 Hounsfield Unit (HU) and window level: 20–60 HU), as follows: first, the landmarks were precisely localised on the skull according to the three planes, then the measurements were taken perpendicular to each landmark, the length of the line projecting from the skeletal to the facial landmark was considered the thickness of the facial soft tissue (Figure 1 and 2). To assess measurement reliability, these steps were repeated by two independent blinded radiologists with 23 and 2 years of experience in CT; any disagreement was resolved by open discussion and consensus.

Figure 1. Coronal, sagittahorizontal slices: example of STT measurements.

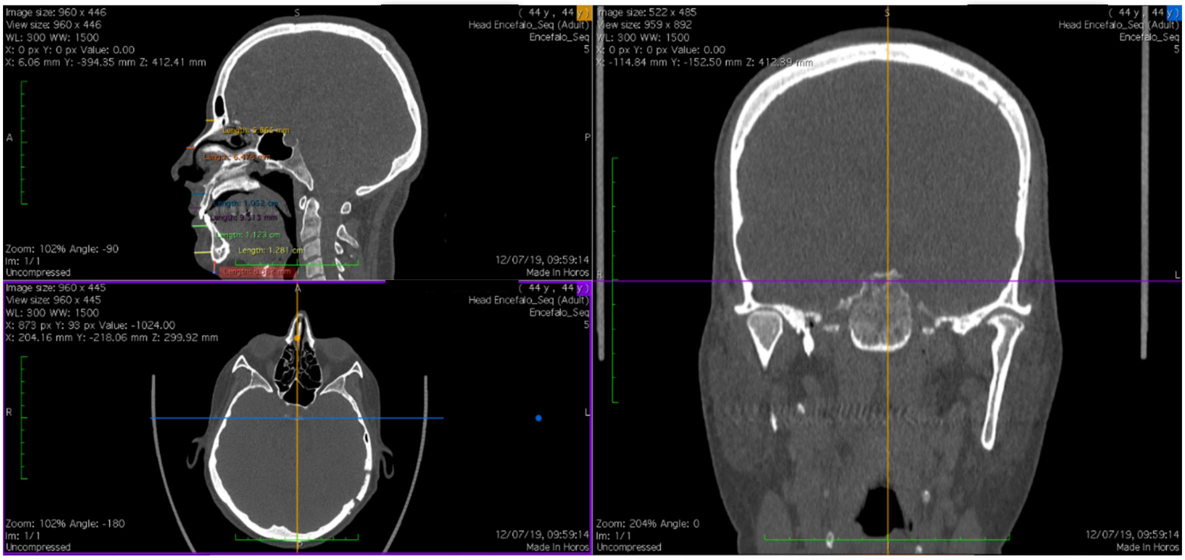

Figure 2. Example of STT measurements.

Data were reported in an Excel database and a statistical analysis was performed using Stata13MP software (StataCorp LLC, College Station, Texas). First, basic descriptive statistics including mean, range (between minimum and maximum), standard deviation, and interquartile range were calculated for each landmark and, in future, these values could be used for facial reconstruction purposes.

The differences between the sexes and the association with age was assessed using Student's t-test and linear regression. All independent variables with a p-value ≤ 0.25 were considered eligible for inclusion into the multivariate analysis. Then, multivariate logistic and linear regression models were used to investigate independent characteristics associated with sex (Model 1) and age (Model 2).

The following independent variables were included in both Models: sub-orbital, nasion, rhinion, zygion, zygomaxillary, para-zygomaxillary, para-midphiltrum, upper incisor, lower incisor, gonion, pogonion, and menton. A stepwise procedure was applied to obtain the final models and the results of the multivariate analysis were expressed in odds ratios (ORs) and 95% confidence intervals (CIs), with a statistically significant level of p-value 0.05.

RESULTS

Table 2 shows the descriptive statistics for the facial soft tissue thickness and the comparisons between males and females. 12 biometric measurements were taken into consideration on 100 head CT scans of Italians adults (50 males and 50 females) aged between 18 and 98 years. The mean age was 58.5 for females and 60.3 for males. Every measurement in this study could not be recorded for each CT scan because some scans included only the upper half of the face. Therefore, measurements had different sample size (N): the sample was complete for sub-orbital, nasion, zygion, and zygomaxillary; for the other landmarks the sample are smaller (rhinion=94; para-zygomaxillary=99; para-midphiltrum=52; upper incisor=48; lower incisor/pogonion/menton=21, and gonion=20). The smallest values were obtained from three landmarks of the upper area of the skull: rhinion, nasion, and zygion; the largest, from para-midphiltrum, upper incisor, and lower incisor that are landmarks of the lower area. The standard deviation (SD) was calculated for each landmark. Lower incisor, upper incisor, and nasion had the lowest values of SD; gonion, sub-orbital, and rhinion the highest; the other landmarks had an intermediate value of SD. So, measurements are strictly similar among them if a low value of SD is obtained. In this study, SD values (minimum value of 1.2, maximum value of 4.1) are satisfactory: considering that all measurements are expressed in millimeters, there is a minimal variability.

Table 2. Comparison of the facial soft tissue thicknesses [mm] between Italian males and Italian females.

Landmarks	Males						Females					
	N	Mean	SD	Min	Max	IQ range	N	Mean	SD	Min	Max	IQ range
Sub-orbital	50	8.6	2.8	3.7	17.7	6.8-10	50	7.4	3.0	3.6	14.6	4.9-10.3
Nasion	50	8.3	2.0	4	13.14	7.2-9.3	50	7.3	1.7	3.5	12.8	6.1-8.2
Rhinion	47	4.9	2.9	2.8	19.5	3.7-4.8	47	4.2	1.9	2.4	11	3.2-4.4
Zygion	50	7.6	2.1	4.1	12.5	5.9-9.7	50	8.2	2.6	3.7	16.2	6.4-10
Zygomaxillary	50	8.9	2.4	4	12.6	6.8-11	50	9.5	3.5	4.8	19.8	6.5-11.4
Para-zygomaxillary	49	8.4	1.4	4.9	11.7	7.5-9.3	50	9.5	2.3	4.6	14.8	7.5-11.2
Para-midphiltrum	29	13.4	2.1	7.6	17.9	12.3-14.4	23	12.3	1.6	9.1	15.4	11.2-13.2
Upper incisor	27	10.9	1.9	7.3	14.9	9.7-11.7	21	10.3	1.9	7.8	14.3	9.1-11.8
Lower incisor	12	10.4	1.2	9.2	12.4	9.4-11.6	9	10.5	1.3	8.8	12.9	9.4-11.2
Gonion	11	9.7	3.7	6.4	17.1	7-10.9	9	10.4	4.8	6.3	17.1	7.1-16.3
Pogonion	13	10.3	1.6	7.8	14.1	9.4-10.8	8	9.9	2.5	7.1	14	8.4-11.7
Menton	13	9.6	2.8	5.3	15.6	8.7-11.5	8	9.4	1.3	7.7	12.1	8.8-9.7

N: number of measurements; SD= standard deviation; Min: minimum value; Max: maximum value; IQ range = interquartile range

Sexual differences

All the median values of facial soft tissue thicknesses were larger in males when compared to females except for zygion, zygomaxillary, para-zygomaxillary, lower incisor, and gonion (Table 2). The results of the bivariate analyses were reported in Table 3. The results obtained from the multivariate logistic regression model showed that only one landmark was statistically significant associated with the sex. Females showed significantly higher value of para-zygomaxillary; the other measurements did not present significantly differences between females and males (Table 4).

Age differences

The comparison of the facial STT with the age analyzed by multiple linear regression analysis revealed that STT differed significantly for upper incisor and pogonion (Table 5).

Table 3. Basic descriptive statistics of facial soft tissue thicknesses [mm].

Landmarks	N	Mean	SD	Min	Max	Sex	Age
Sub-orbital	100	8	3	3.6	17.7	**0.0573***	**0.007***
Nasion	100	7.8	1.9	3.5	13.1	**0.0122***	**0.037***
Rhinion	94	4.6	2.4	2.4	19.5	**0.1548***	0.411
Zygion	100	7.9	2.3	3.7	16.2	**0.2150***	**0.136***
Zygomaxilla	100	9.1	3	4	19.8	0.3260	0.427
Para-zygomaxillary	99	8.9	2	4.6	14.8	**0.0094***	0.720
Para-midphiltrum	52	12.9	2	7.6	17.9	**0.0603***	0.574
Upper incisor	48	10.6	1.9	7.3	14.9	0.2686	**0.157***
Lower incisor	21	10.5	1.2	8.8	12.9	0.8284	0.342
Gonion	20	10	4.1	6.3	17.1	0.7056	0.456
Pogonion	21	10.2	2	7.1	14.1	0.6438	**0.018***
Menton	21	9.5	2.3	5.3	15.6	0.8835	**0.212***

*Student's-t test ($p < 0.25$) for statistical differences related to genders and age.
N: number of measurements; SD= standard deviation; Min: minimum value; Max: maximum value.

Table 4. Multivariate analysis results for sex.

Landmark	Odds Ratio	Standard Error	P value	95% Confident interval
Suborbital	1.412714	.2551653	0.056	.991539 - 2.012792
Nasion	1.776511	.5514621	0.064	.9668051 - 3.26435
Rhinion	1.262562	.1799544	0.102	.9548388 - 1.669458
Zygion	.6661141	.1733119	0.118	.4000185 - 1.109219
Parazygomaxillary	**.5408493**	**.1668579**	**0.046**	**.2954414 - .990105**
Para-midphiltrum	1.306336	.2636784	0.186	.8795158 - 1.940289

Table 5. Multivariate analysis results for age.

Landmark	Standard Error	P value	95% Confident interval
Suborbital	1,843026	0,184	-6.494208 – 1.362426
Nasion	3.495582	0.233	-3.107105 – 11.79421
Zygion	3.05681	0.318	-3.355256 – 9.675616
Upper incisor	**1.859748**	**0.019**	**-8.855647 – -.9277276**
Pogonion	**2.52065**	**0.009**	**-12.9089 – -2.163626**

DISCUSSION

Facial approximation is a technique used in forensic anthropology to create a facial appearance based on the skull morphology of an unidentified body. The usefulness of this technique is related to the human ability to identify a known face even if it is not identical with the given one.[42] For this reason, population studies on soft tissue thickness are important to verify the association between facial approximation and biological data (such as race, sex, and age).[18] In this study, data on facial soft tissue thickness measured on 100 CT scans of Italian males and females were collected. The landmarks taken into consideration were the easiest to identify due to correspondence to well-defined anatomical structures.[33] The reduced sample size for some landmarks resulted from the scanning technique used for head CT, in which the primary concern is the lowest possible level of radiation to patients. Nevertheless, this sample represent the largest data set reported in the literature on STTs for an Italian adult population. Because of the lack of information on patients' BMI, along with STTs' mean values, values are reported in common with other studies.[7-9] In this way it is possible to fit the resulting facial approximation to body constitution. For this reason, in Table 1 the ranges of values are reported along with the means and standard deviations, separately for gender groups. This could be an important element in forensic approximation as it is known in the literature that even if the STTs' changing had minimal effect on the facial form, this affected the subjective recognition significantly.[6]

Sexual differences

In this study, all the landmarks were larger in males than in females except for zygion, zygomaxillary, para-zygomaxillary, lower incisor, and gonion. Nevertheless, only para-zygomaxillary was statistically significant associated with the sex. The higher values of males were reported by other authors in different studies [9, 13, 14, 22, 23, 28, 41-43] even if some differences were found.

For example, comparing our data with a population of a different ancestry [22], like an Asian population, the mean values of the present study were higher for the nasal and mental area and lower for the oral area. In addition, they reported lower values in males than in females only for the pogonion landmark.

Comparing our data with other Caucasian populations [9, 41] the mean values of the present study were overall higher for the landmark related to the nasal and orbital area and lower for the oral and zygomatic area. In the Slovak study they reported all the values higher in males than in females, on the contrary, in the present study and in the Czech study some landmarks are higher in females than in males. Furthermore, both Slovak and Czech studies described a gender statistical difference in most of the landmarks in contrast to the present results.

Age differences

Considering different ages, in this study the statistical analysis showed a statistical relevance of STTs for only two landmarks: upper incisor and pogonion. This evidence should be further investigated in future studies with a broader sample in order to assess age differences.

In this case, the comparisons with other Caucasian populations are variable in different studies. The statistical analysis in the Slovak population [41] is completely different compared with the present results: a significant difference was found for other landmarks such as midphiltrum and orbital landmarks. In a Turkish population [39] the differences were found especially for landmarks of the nasal area and even of the oral area, according to the present study and to Wilkinson [5] and De Greef [44] studies. Therefore, the present results revealed that even in the same racial group, the STTs differ from one population to another. For this reason, in the facial approximation process population differences should be taken into consideration and different population data sets of STTs should be considered even for gender and age differences.

CONCLUSIONS

This study aimed to bring a valuable contribution to the European values of STTs for facial approximation, since there were only a few previous data sets on the average soft tissue values for the Italian population. Facial approximation is a valuable tool in the identification process, especially in the early stages and in cases where very little information is available on the identity of the deceased. So, even in the absence of evidence useful for personal identification of skeletal remains, a possible face should be generated taking into account only sex and population data, facial approximation could be successful in the identification process.[9]

Statistical analysis was performed in order to assess the differences considering sex and age of the individuals. Considering sex and age differences, this study provides preliminary data about the impact of sex and ageing on the evaluation of STTs for facial approximation. The statistical results obtained in this study have an ancillary statistical role in the STTs' evaluation, however, more data should be collected in further studies with larger samples. Likewise, there are also population differences comparing the results of the present study with other studies also carried out on a Caucasian population.

The STTs' measurements obtained in this study can be collected with other data sets [18, 33] in a single database for craniofacial reconstruction of an Italian population in forensic cases or in future research studies. We believe that further studies are needed in order to enlarge the population sample, to provide additional information on the variability of STTs according to different variables. This will be useful to calculate a mathematical formula that would quickly calculate mean values for the facial reconstruction process. This could increase the reliability of facial approximation according to specific geographical context and anthropological data.

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Non-accidental head and neck injuries in children and adolescents

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ABSTRACT

Child abuse or maltreatment has been a global problem and research shows that more than half of the cases present with head and neck injuries. This study aimed to propose an online referencing platform for dental professionals to know more about signs of child abuse and neglect (CAN) and how suspicious head and neck injuries might look like in real-life scenarios by proposing a 3D design.

The study was divided into two parts: i) Integrative literature review, ii) Survey. The first part included an integrative literature review to check if there are enough publications by dentists containing real-life images of injuries related to CAN. Using appropriate keywords and searching across four well-known databases 264 publications relevant to CAN were found, of which, only 3 contained real-life images.

Part II of the study included a JISC online survey, consisting of two sections, amongst general dentists, pediatric and forensic dentists. The first section of the survey was about the basic knowledge related to CAN management. A total of 61 dentists from 10 different countries filled the survey, of which 83.1% had seen common head and neck injuries involved in CAN, 61% knew about the dentist's role in reporting such cases, and 66.1% were familiar with local law enforcements to contact. The second section of the survey involved going through real-life scenarios to check the participants understanding of how to tackle a real-life case concluding that only 4-10 participants managed to figure the aspects vital to check before reporting such cases which include a proper detailed history, any previous injuries and their stage of progression, clinical examination of injuries and finally whether the injuries are consistent with the history given.

To conclude, there is insufficient representation of the real-life head and neck injuries for dentists to see related to child abuse. Also, all specialists agreed that they require further training regarding CAN management with real-life examples. To address this, a 3d model of commonly seen head and neck injuries in CAN along with some other tools, was created for training and educational purposes and was embedded in a website https://3datlasofchildabuse.webflow.io/.

INTRODUCTION

Child abuse or maltreatment has been a global problem. In the past, it was noticed that the suspects in most child abuse cases are either parents or other caregivers.[1] There are various reasons which increase the risk of child abuse in a household, these include early age parenting, parents who themselves have been victims of abuse in the past, family problems (which might include divorce, remarriage, single parent), mental disorders, repeated pregnancies, unwanted child, poor education and handicapped children.[2]

According to a record-based analysis done in a children's hospital in Cape Town, South Africa over a span of five years (1992-1996), it was concluded that toddlers were at most risk, and also that intraoral injuries were not quite reported due to examination by medical examiners having insufficient knowledge about intraoral conditions. Based on that, the authors believe that dentists should be consulted for advice on suspicious cases of child abuse and neglect.[3] In 2002, many child deaths happened as a result of this issue and a majority of children were targets of bullying and harassment.[4] Such acts can happen at any place including schools, offices, streets, orphanages, care facilities, etc.[1] The majority of these CAN cases involve injuries in the head and neck region.[1, 5] A research carried out in 2005 by the dental faculty of the University of Glasgow concluded that out of the total 309 cases of child abuse, 59% of the cases reported injuries in the head and neck region.[6] According to another research study, 50% of child abuse cases involved injuries in the head and neck region.[7, 8] Further research stated that out of 4623 cases of trauma admission, 60% had head injuries with a greater risk of leading to death, and 14% were less threatening facial injuries.[9] Often, children who undergo such type of abuse are more prone to denial of dental treatment due to fear of any further leads.[10] According to a study in Japan, since a great percentage of abuse cases involved facial injuries, it was suggested that dentists should be added to the team of child abuse protection in various hospitals.[11] Dentists have a responsibility to report them if recognized.[12]

In the current scenario, keeping in mind the global pandemic (Covid-19), the experts believe that the decrease in the number of reported cases of child abuse may have been due to a decrease in the number of consultations, whereas the actual count could be much more. This can be said for the families which were more abusive before the pandemic. Therefore, during the pandemic, a rise was seen in the suspected cases of child abuse and neglect.[13] Another study found that the number of child abuse cases with major head and neck injuries in the UK during the first month of lockdown, i.e, 23rd March 2020 to 23rd April 2020, has increased quite a lot. Whereas, those with less pronounced injuries might be more.[14]

Dentists should be obliged to identify and report cases that show signs of child abuse and neglect.[2, 15] The dentists carry an important role as they are concerned with the head and neck region.[15] According to a report published by the American academy of pediatrics, it is mandatory for healthcare providers across America to report child abuse and neglect cases to the concerned authorities.[16] A more recent review of 51 jurisdictions across the United State of America concluded that all of them had laws related to dental neglect in children, and dentists who report such cases were protected by law, those who failed to report were sanctioned according to the respective jurisdiction.[17] A literature review of articles related to domestic violence against children concluded that more training is required in this area of dentistry, i.e, forensics, which includes reporting of such cases.[18] Since forensic odontology deals with more legal and criminal aspects of dentistry,[19] the specialists should be sufficiently trained in managing cases of child abuse. Previous research confirms that there is a scarcity of both literature and training on the concerned topic,[1, 4] therefore, more specific training including more realistic approaches along with the addition of child abuse and its management in the curriculum of undergraduate dental courses is required.

To address the above-stated issues, this study aimed to investigate the knowledge of various dentists and forensic dentists about child abuse case management, and based on the findings, provided a solution to the problem.

MATERIAL AND METHODS

This study has been approved by the University of Dundee Schools of Health Sciences and

Dentistry Research Ethics Committee under reference number UOD-SHS-SDEN-TPG-2020-026.
In order to address the aims of this study, the methodology was divided into two sections: an integrative literature review (part I) to investigate the availability of publications containing good-quality images of head and neck injuries in cases of child abuse and neglect and a survey (part II) to understand the knowledge and perspective of various dentists concerning child abuse and neglect, respectively:

Part I: Integrative Literature Review
A Boolean search technique was used with the following search criterion; (*Dentistry* OR *Odontology* OR *dental* OR *dentist*) AND (*Child abuse* OR *child neglect* OR *Child maltreatment* OR *non-accidental injuries*) AND (*Head* OR *Neck*). The databases used included Scopus, Latin American and Caribbean Health Sciences Literature (LILACS), Web of Science, and PubMed. Inclusion criteria for this review included: a) open-source scientific articles published by dentists; b) papers containing good quality images of head and neck injuries related to child abuse; c) scientific papers published from January 1990 till March 2021. Whereas the exclusion criteria included: a) open-source scientific articles not published by dentists; b) papers with no images of head and neck injuries related to child abuse. The Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines were used for this review (20).
The publications selected were then critically analyzed for various parameters for image analysis which included the following: a) the type of image used for publication, whether it was colored or black and white? b) is the image used digital or analog? c) does the publication include a close-up image of the injury or a full-body image of the victim? d) does the publication contain images of intra-oral or extra-oral injury?

Part II: Survey
A survey was designed using Joint Information Systems Committee (JISC) Online Surveys, version 2021, consisting of two sections: first consisting of 1 open-ended and 4 mixed type questions, whereas the second section consisting of 7 open-ended questions.
The first section consisted of questions about the qualification, demographics, and experience with child abuse and neglect cases of the participant. Furthermore, there were questions about law enforcement in their respective locality to refer such cases to and aimed to understand the background knowledge of the participant and his/her experience (if any) regarding cases of child abuse and/or neglect.
The second section consisted of six different clinical scenario-based open-ended questions where the participants were asked whether such scenarios would raise suspicion of a possible child abuse/neglect case. Case scenario 1: a false history given by an accompanying parent/ guardian commonly seen in cases of child physical abuse; Case scenario 2: a possible case of child abuse in form of bite marks; Case scenario 3: a possible case of child dental neglect; Case scenario 4: a child sexual abuse where parents/guardian's history is not consistent with the injuries; and case scenario 5 and 6: knowledge on referring a case to law enforcement authorities. An additional open-ended question was added to know whether the participant would like further training on head and neck injuries in child abuse/neglect cases, and if so, what means of training they would prefer.
The above-mentioned survey was launched from 26th March 2021 till 16th April 2021. An online public link for the survey was sent to official emails of Forensic odontologists from the British association of forensic odontology (BAFO) (n = 30), the American Board of forensic odontology (ABFO) (n = 81), International Organization for Forensic Odonto-Stomatology (IOFOS) (n = 59), Brazilian Association of Forensic Odontology (ABOL) (n = 50 of which 40 were Forensic odontologists while the rest were Pediatric Dentists), and the alumni of University of Dundee (n = 34). Furthermore, it also included dentists from Rehman College of Dentistry (RCD), Peshawar, Pakistan (n = 69). The email addresses of all participants were taken from websites of the respective organizations. All participants were given three weeks to fill the survey. Inclusion and exclusion criteria were summarized in table 1 below.

Table 1. inclusion/exclusion criteria

Inclusion criteria	Exclusion criteria
Forensic odontologists – Diploma, Workshop, Masters, Post Doctorate	Current postgraduate students enrolled in forensic odontology courses
General Dentists – Any other specialty except forensic odontologist and pediatric dentists	Undergraduate students
Pediatric dentists – Diploma, Workshop, Masters or Post Doctorate	

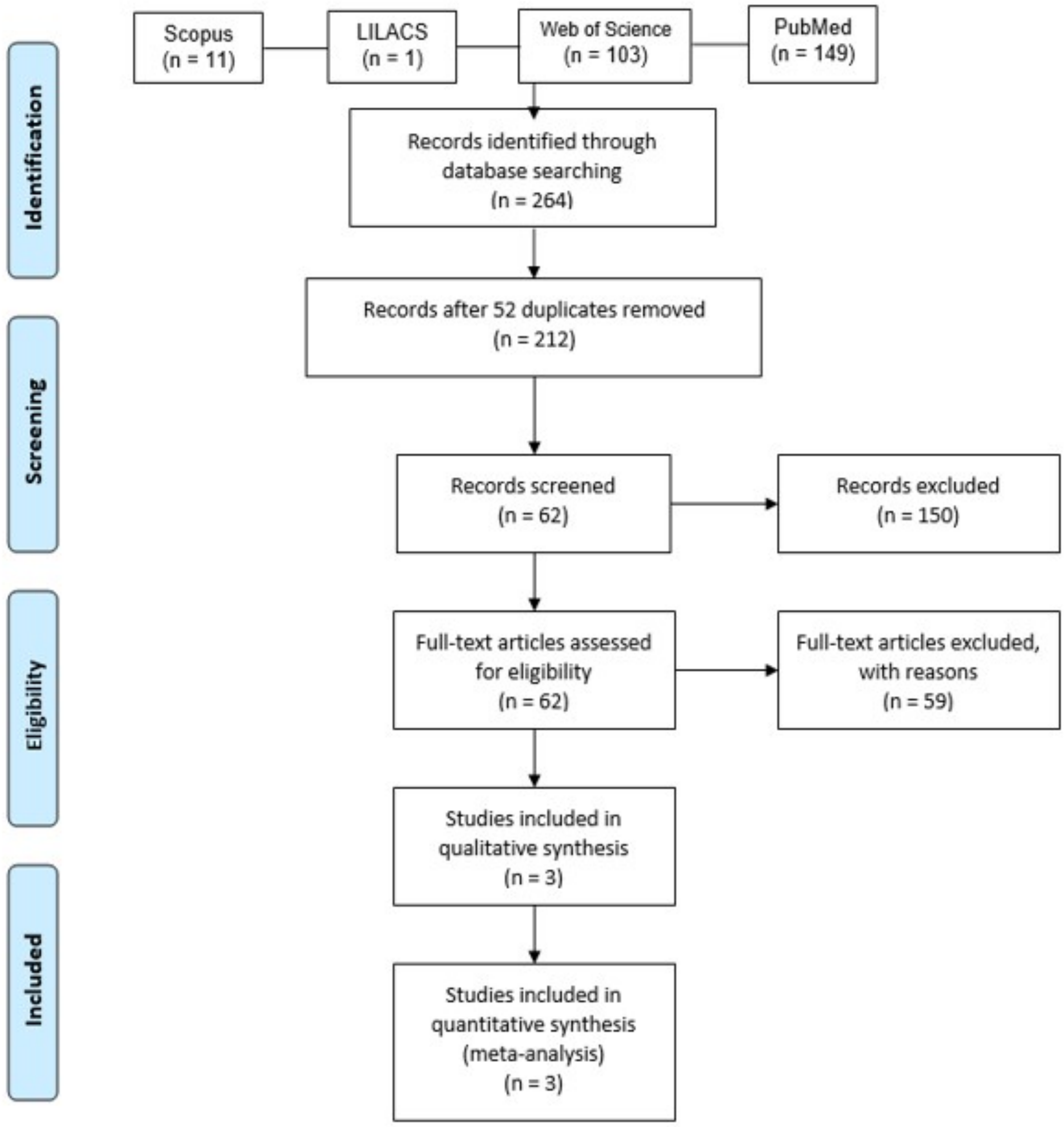
RESULTS

Part I: Integrative literature review
A total of 264 publications were found: LILACS (n=11); Scopus (n=11); Web of Science (n=103); PubMed (n=149); EndNote software was used to search for duplications, only 52 were detected, hence, reducing the total number to 212 publications. The results were further scrutinized based on the inclusion and exclusion criteria and as a result, only 3 publications were found, as shown in table 2 below, published by dental professionals containing real-life images of head and neck injuries in child abuse cases. All the findings are summarized using a PRISMA flow diagram in figure 1.

Table 2. Analysis on literature review findings

Publications	Year	Journal	Author	Black/ White or colored	Digital/ Analog?	Close-up or full body	intra or extra-oral
Dental Treatment Abuse	2014	Journal of clinical and diagnostic research	Paul Chalakkal	Colored	Digital	All close-up intra-oral images	Both
Dentist attitudes and responsibilities concerning child sexual abuse. A review and a case report	2015	Journal of clinical and experimental dentistry	Arturo Garrucho-Rangel	Black and White	Digital	All close-up intra-oral images	Intra-oral
Forensic odontology, part 5. Child abuse issues	2011	British dental journal	Judy Hinchliffe	Colored	Digital	All close-up images of injuries	Extra-oral

Figure 1. Prisma flow diagram



Part II: Survey

The survey link was forwarded to a total of 323 participants. The sample size calculated using an online open-source sample size calculator keeping confidence level 90% with a 10% margin of error for the total participants (n = 323) came out to be n = 56. The survey was filled by 61 participants which contribute to a total response rate of 18.89%. Out of the total sample, the distribution was as follows, general dentists (n = 23, 38.33 %), Pediatric dentists (n = 3, 5%) and Forensic odontologists (n = 34, 56.67%). A country-wise distribution revealed that the participants were from countries including United Kingdom (n = 8), Brazil (n = 22), Pakistan (n = 10), United states of America (n = 7), Malaysia (n = 3), Netherlands (n = 2), India (n = 2), Italy (n = 1), Canada (n = 1) and Spain (n = 1).

83.1% of the participants agreed to have sufficient knowledge of the injuries commonly seen in cases of child abuse and neglect, of which, 45.8% had never assessed a case of child abuse before and only had theoretical knowledge. 15.3% of the participants were unaware of various forms of injuries, whereas 1.7% stated that they do not do child abuse cases in their respective countries of practice. 61% of the participants were confident they knew how to manage cases of suspected child abuse and provided their share of knowledge, whereas 10.2% had no knowledge and 28.8% were not sure how to manage such cases. Further on, participants were asked if they knew of the respective law enforcement in their country to contact in case, they encounter a suspected case of child abuse, and 66.1% said Yes and provided details of the law enforcement agency, whereas 11.9% said No and the remaining 22% were not sure about any law enforcement agencies in their country.

When tested through fictitious scenarios, most of the participants (90%) were confident they could decide on basis of the type of injuries whether a case should be reported or not. The participants' focus was mainly on the type of injuries in question, and they overlooked the fact that in some scenarios, the subject was either a continuing patient (the practice would have had a previous clinical record available) or the injuries were inconsistent with the history being given. The participants wanted to know more about specific details of the injuries such as images and dimensions ignoring the crucial signs which would have helped in differentiating the nature of the injury and perhaps a better diagnosis. The findings from the scenarios are summarized in table 3.

Table 3. Scenario findings

S.No	Scenario	General Dentists	Pediatric Dentists	Forensic Dentists
1	A 10-year-old male patient presents a facial swelling on the right side (as a new patient) and also exhibits various bruises in progressive stages of healing on the right side of his neck. It was tender to touch, and after radiographic examination, you diagnosed a fracture of the mandibular body. The parents claimed that it was due to a fall with an impact on his chin.	None managed to understand the aspects of reporting cases, majority thought it was caused by someone else and they require more information.	None managed to understand the aspects of reporting cases, wanted more information.	Only 4 gave an insight on why it should be reported. The rest wanted more information.
2	A 1.5-year-old female patient was brought to you, on her third visit, presenting multiple round marks on her cheeks. The mother said it happened while the child played with a pencil, and she went to the kitchen for a while.	Wanted more information about injury, 4 provided more specific information. Failed to recognize child neglect.	Wanted more information about the injury. Failed to recognize child neglect.	Wanted more information about the injury, 6 provided more specific information. Failed to recognize child neglect.
3	A 9-year-old girl came to your dental practice (for the first time) accompanied by her mother presenting multiple carious lesions on her anterior teeth. Her mother gave a history of improper diet.	Well equipped with knowledge	Well equipped with knowledge	Well equipped with knowledge
4	A 15-year-old girl came to your practice presenting multiple round bruises with a central hematoma on her neck and a very distinct set of marks with a similar pattern on her left cheek. A linear abrasion mark was also seen on her neck. Her father said she was involved in a local street crime where the perpetrators hit her with the back of the pistol multiple times before they took her belongings and help arrived. What would be your interpretation of the marks?	Focused mainly on bitemark injury, ignored other markers of child abuse.	Focused mainly on bitemark injury, ignored other markers of child abuse.	Focused mainly on bitemark injury, ignored other markers of child abuse. Only 6 managed to identify the markers.

5	An 11-year-old boy came to your department (presenting for the first time) crying continuously and exhibiting severe discomfort. On examination, a hematoma was noted in the left periorbital region and ecchymosis was also noted in the right periorbital region. The parents claimed it originated as a sports injury. What would be your interpretation of the findings?	Wanted to know more about the sport being played, and also thought of a possible physical abuse.	Wanted to know more about the sport being played, and also thought of a possible physical abuse. 2 provided more extensive critique.	Wanted to know more about the sport being played, and also thought of a possible physical abuse. 6 provided more extensive critique.
6	A young female patient aged 11 years old and familiar with the practice presented with multiple crown fractures, an abrasion mark on the left cheek, and a bruise on both upper and lower lips. She is accompanied by her elder sister who claims that she was injured in a road traffic accident. What would be your views and treatment of these features?	Failed to realize patient was familiar to practice. Wanted more information.	Failed to realize patient was familiar to practice. Wanted more information.	Majority failed to realize patient was familiar to practice. Only 4 managed to recognize the age of consent, and the familiarity.

Furthermore, on being asked whether or not the participants would like to attain further training in respect of child abuse case management, 92% of the participants agreed that it is required, whereas only 8% believed they have sufficient knowledge about child abuse case management. The participants who agreed wanted more specific training based on management and reporting of such cases with guidance on the recognition of injuries by using examples and real-life images of injuries that may raise suspicion.

DISCUSSION

Based on the findings of this study, there is a need to spread more awareness and research is required in this field for early detection of child abuse which would be vital in terms of reducing the overall child abuse case count, avoiding death and mental traumas, and perhaps the betterment of our society. As evident from previous research, more knowledge about reporting of such cases is required in almost every country, therefore, research on the importance of dental health professionals in detecting early signs of child abuse and reporting was required.[4, 16, 21, 22] By examining various studies, it was concluded that a gap exists in this area regarding injuries in the head and neck region in cases of child abuse and neglect, and according to the authors, there was no specific head and neck injury pattern which may contribute to suspicion about child abuse and neglect cases.[4, 23, 24] This study aims to gather the response of various forensic odontologists, general dentists, and pediatric dentists to cases of possible child abuse that would help understand whether more awareness and education is required. To help decrease the frequency of child abuse and neglect, establishing more law enforcement and perhaps training professionals on how to identify and report such cases in the future is vital.

The survey in this study was distributed via electronic means, which was mainly due to better reach and ease of access to the participants, also in current times of pandemic, it was difficult to think of a paper-based survey and/or interview-based study. According to the first part of the survey, where the participants were asked about their general knowledge regarding the management of child abuse cases in practice, a significant percentage of participants (n = 49, 83%) mentioned being aware of various forms of injuries commonly seen in cases of child abuse and neglect. The results were in line with previous research conducted regarding similar topics which also concluded that the experts had prior knowledge about child abuse in general, whereas they wanted more specific training on how to proceed when one encounters such a case.[11, 25-27] Furthermore, it could be seen that although a large majority of the participants (n = 36, 61%) claimed to have had sufficient knowledge about child abuse case management in general, very few managed to identify the markers of child abuse put in the scenario-based questions in the second part of the survey. The

participants wanted to know more about specific details of the injuries such as images and dimensions ignoring the crucial signs which would have helped in differentiating the nature of the injury and perhaps a better diagnosis. These findings were consistent with previous literature which concluded that dental professionals were aware of injuries which may be a caution sign for child abuse or neglect cases.[25, 28-30]
Apart from that, some signs of child abuse mentioned by W.H.O (World Health Organization) as part of their guidelines for healthcare workers which are related to history taking in suspected cases of child abuse state that the professional should be trained on how to carefully take history keeping in mind the importance of consented history by the victim themselves when they are able to speak and not rely on care-takers history.[31, 32] Markers used in scenarios were collectively taken from various research publications and textbooks, and included the following commonly seen signs which may arise suspicion; i) false or incomplete history given by the parent or accompanying guardian; ii) injuries at various stages of healing; iii) injuries inconsistent with the history; iv) patients attitude towards dentist/healthcare worker.[2, 4, 33, 34]
The primary reason for this discrepancy could be the fear of dental professionals to report due to insufficient training in the respective field of expertise.[26-28, 35] Due to lack of knowledge, dentists often fear not to investigate such cases further, which supports why a majority was unable to identify the actual signs which could link a case to abuse. Dental professionals should also be reminded that they are obligated by law to report cases that arise suspicion of child abuse or neglect as long as their intention is to prevent any further consequence of the crime, they should also be taught that they are protected from prosecution by law for breach in confidentiality for reporting if the intent is to help solve a crime. Apart from fear amongst dental professionals, having no awareness of the importance of history taking in such cases and observation of the physical and mental state of the patient (or victim) is also a shortcoming.[26, 35] In order to identify abuse, one should be sufficiently trained on how to take a proper detailed and consented history, and what signs to look out for in the patients, both physically and mentally. The various methods of managing a child abuse case are also mentioned in the W.H.O guidelines for the management of child maltreatment cases.[31]
At the end of the survey, participants expressed their opinions about further training on child abuse case management, the responses were again consistent with the previous research conducted in concluding that more training was required on this topic in specific areas such as how to proceed if one encounters such case in the clinic. This can also be tallied with previous survey-based research which also concluded that dentists desired more specific training on how to report such cases should one encounter them clinically.[4, 30, 36] Apart from this, some participants (n = 6) also wanted to get more training including real-life scenarios for better understanding, this problem of scarcity of publications and availability of real-life images of head and neck injuries in child abuse cases was also confirmed by the integrative literature review performed as part of this study which resulted in only three publications by dentists containing real-life images of injuries including publications by Chalakkal, P et al, Garrucho-Rangel A et al, and Hinchliffe, J.[34, 37, 38]
According to previous research, it was also evident that dental professionals require more training in child abuse case management [12, 33, 35, 39, 40] which could be in the form of real-life examples as participants from the survey stated as the preferred option. There is information about various forms and nature of injuries commonly seen in suspected cases of child abuse and neglect,[2, 3, 8, 33, 34] but it is rarely accompanied by a pictorial representation of the injuries which might be a reason for difficulties in diagnosing non-accidental injuries amongst professionals. The literature review done as part of this study confirmed the scarcity of pictorial representation of the injuries. For some, learning through visual aids is always better than text solely, such individuals are categorized as visual learners, and with the advancements in technology, we have seen a rise in visual learning, hence, there is a need for a tool that allows visual perspective to the injuries commonly seen in cases of child abuse.
There were certain limitations to the study design as it was conducted during a time of the ongoing pandemic, therefore an online survey was thought to be the best possible option. Portal of invitation for various participants was also via e-mail to all participants and there was limited communication subjected to the response of the

e-mail. These limitations can be overcome by doing a similarly structured study in the future when the scenario related to this current pandemic gets better and there is a resumption of face-to-face learning which will allow a better approach to various dentists and perhaps a better response rate and in turn more specific results.

CONCLUSIONS

This research provides an understanding for dentists to know more about common head and neck injuries in child abuse and neglect cases and to investigate how they might look in realistic situations. According to the qualitative and quantitative analysis of the findings from both the integrative literature review and the survey, it was evident that there is a need for further intervention in the form of training that involves more life-like scenarios to reduce the fear in dentists while reporting cases. They should be told about their rights to report and also that they are exempt from any prosecution for reporting such cases provided it is intended to save a life. The results conclude that although 59% of the dentists are aware of various forms of child abuse and neglect, there is a need for further training using more realistic examples. Additionally, it is essential to increase awareness on how to report suspected cases of child abuse and neglect as evident by 92% of the participants who opted for further training. From the scenarios in the survey, it can be noted that forensic dentists were more well equipped with knowledge related to reporting such cases and signs of child abuse as compared to the pediatric dentists, but since the number of pediatric dentists in this study is not significant, further research can be done to explore the difference in opinions.

To assist with the current lack of pictorial representation, a website was created (https://3datlasofchildabuse.webflow.io/) containing a graphical poster that is suggested for use in clinics and for training purposes which gives a brief account of when, how, and why dentists should report suspected cases of child abuse and neglect. Secondly, in order to focus on the more real-life representation of the head and neck injuries which may commonly be seen by dentists first-hand, a three-dimensional (3D) model is made which constitutes of various injuries, which were confirmed by literature, commonly seen in cases of suspected abuse, and may also be termed as non-accidental injuries, as seen in figure 2 and figure 3 respectively.

Figure 2. Commonly seen extra-oral injuries in child abuse

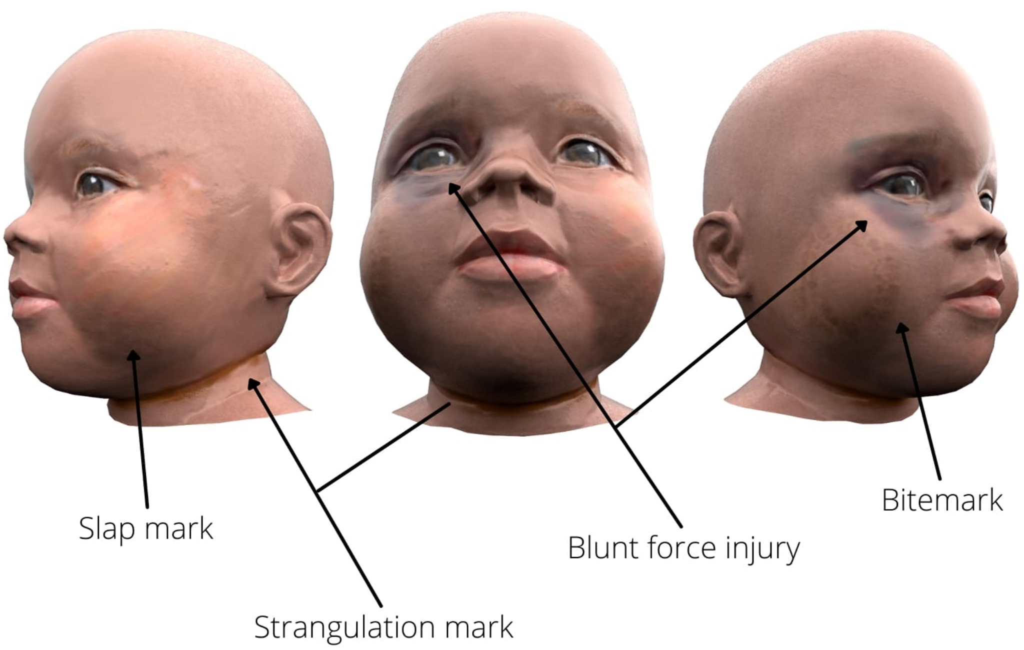
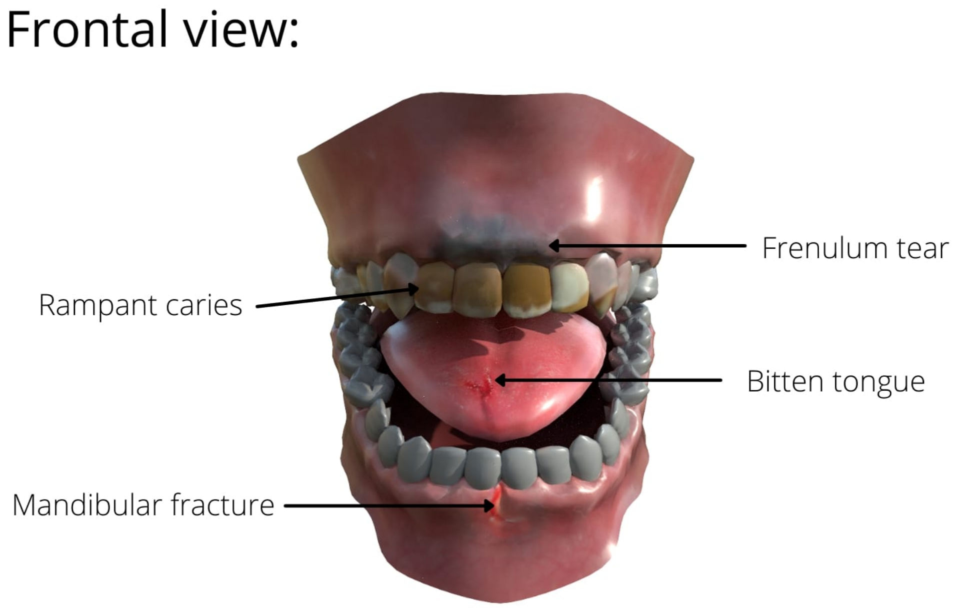
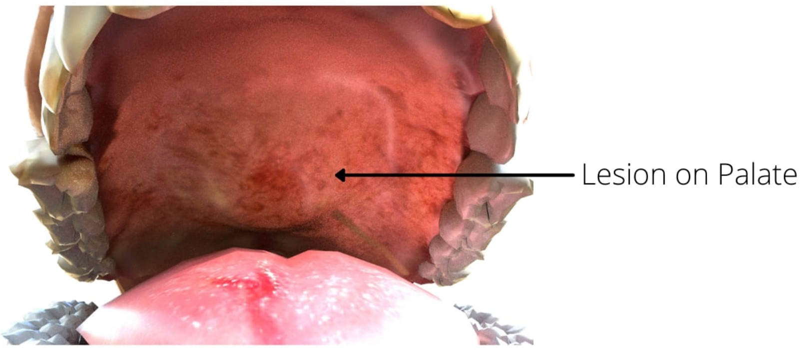


Figure 3. Commonly seen intra-oral injuries in child abuse





Although the model represents real-life injuries, it should not be used as the only mean for reporting purpose, but as a source of approximation of injuries to child abuse cases. Reporting of such cases involves a combination of both detailed history and thorough clinical examination, whereas the model only helps in understanding how certain injuries would look in a more realistic setting. These models will be updated in form of versions to add more features such as being more interactive, representing more injuries and labeling will also be added in the future.

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Role of mandibular anatomical structures in sexual dimorphism in Turkish population: a radiomorphometric CBCT study

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KEYWORDS

Sexual dimorphism,
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ABSTRACT

Sex determination is one of the primary concerns of forensic science. The cranial bones, pelvis, and mandible have been used for determining the sex of specimens. Because the mandible is robust and sexually dimorphic, studies have evaluated its metric and morphological traits.
This study was designed as a retrospective study involving cone beam computed tomography (CBCT) images to assess sexual dimorphism of the mandible in the Turkish population. Total sample group consisted of 176 bimaxillary CBCT scans (71 males and 102 females; ages 19–67 years). Sixteen mandibular parameters were measured using two different software programmes. Measurements were recorded in various planes of three-dimensional (3D) reconstructions of the scans.
All parameters aside from SIMaCD were found to be statistically significant. The highest diagnostic accuracy rate was associated with IMaF, and the overall accuracy rate of the fourteen parameters was found to be 80%.

INTRODUCTION

Sex determination is one of the main concerns of forensic science. Because of the nature of forensic investigations, not all cases retain full body integrity; therefore, sex assessment should be performed on specific anatomical sites that are predominantly bony structures because of bone's durability postmortem.[1] Earlier studies have revealed that the most reliable bone for sex determination is the pelvis. After the pelvis, the cranium was considered to be the second most reliable bony structure for sex determination.[2]
Previous articles have utilized various methods and parameters to determine the sex of a specimen using the cranium. Traditional methods have been mostly based on visual examination of the morphological properties. This has created a major issue because visual examination is based on subjective evaluation.[3] With recent developments in imaging technologies in medicine and forensic science, radiological imaging methods have become universal. These imaging methods, such as CBCT, which provide non-distorted 3D high spatial resolution radiological data, are favourable for sex prediction, especially 3D modalities presenting accurate morphological information.[4–5] In addition to the above mentioned methods, recent studies have shown that artificial intelligence (AI) techniques can provide reliable data for sex estimation.[6] The superiority of AI over other methods is elimination of investigator bias. However, it should be considered that AI

algorithms may also display conflicting results related to human observers.[7] Additionally, to promote this method, forensic scientists must become more familiar with AI. The accessibility limitations of AI algorithms have prevented its widespread use to date.[8]

Thus far, several cranial structures have been found to be scientifically reliable for sex determination. Williams and Rogers conducted a study by visually examining fifty complete or partial adult craniums to determine the sex of the specimens.[9] They evaluated a total of fourteen parameters, including mandibular traits, nasal aperture, and orbital margins, and the overall diagnostic accuracy rate was 96.4%.[9] Uthmann et al. investigated the accuracy rate of the foramen magnum and other cranial measurements for sex identification, revealing 90.7% accuracy for identification of males and 73.3% accuracy for that of females.[10]

The mandible is the most robust bone of the skull and demonstrates sexual dimorphism.[11] Recent articles have recorded forensic and anthropological determinants of sex from mandibular structures.[5,12] Research has been conducted on different ethnic roots and races because skeletal characteristics vary by population.[13,14]

The inferior alveolar canal, which contains the neurovascular bundle, starts with the mandibular foramen at the proximal side of the mandibular ramus and ends with the mental foramen on the anterior side of the mandibular corpus.[15] The position and metrics of the canal differ by population.

The aim of this study was to determine the sex of Turkish dental patients at the Istanbul Medipol University School of Dentistry Dento-Maxillofacial Radiology Department by measuring their mandibular anatomical structures using CBCT images. Our main objective was to establish sex determination through 3D images of the maxillo-mandibular field of view images, which are easily accessible and provide valid parameters that can be measured by dentists, anatomists, and forensic researchers using basic software and CBCT access. Also, by recording linear measurements, the results become more reliable than visual subjective evaluation, which involves no defined parameters.[3]

MATERIAL AND METHODS

This study was designed as a retrospective study involving CBCT images of Turkish dental patients, who presented at Istanbul Medipol University, School of Dentistry, Dento-Maxillofacial Radiology Department. Ethics approval was obtained from Istanbul Medipol University, non-interventional Ethics Committee Number 10840098-772.02-E.60602. The sample group comprised a total of 176 bimaxillary CBCT scans (71 males and 105 females, aged 19–67 years), which were previously taken for various conditions involving impacted teeth, supernumerary teeth, orthodontic consultation, implant surgery planning, pre-orthognathic evaluation, and other possible pathology of the maxilla and mandible. Inclusion criteria were the presence of bilateral mandibular first molars with no periodontal defect. Patients with periodontal disease, acute trauma, Stafne's bone defect, cleft lip and/or palate, or cysts at the relevant sites were excluded.

CBCT scans were obtained using an i-CAT Next Generation (Imaging Sciences, Hatfield, USA) 3D volume scanner at 120 kVp and 20.27 mA for 14.7 seconds. The field of view (FOV) selection included bimaxillary views at 16 cm × 23 cm, and slice thickness was structured at 0.25 mm intervals and isotropic voxels. To measure the parameters, coronal and axial sectioned images were selected. In addition to 2D parameters, measurements were performed on 3D reconstructions of the scans.

Evaluation of the images

Evaluation of the images was performed by two observers who had been trained by a dento-maxillofacial radiology specialist who had 21 years of experience in the field, using Anatomage Vivo Dental software version 5.2 (Anatomage, Inc. California, USA) and i-CAT Next Generation Vision software (Imaging Sciences International, Hatfield, USA).

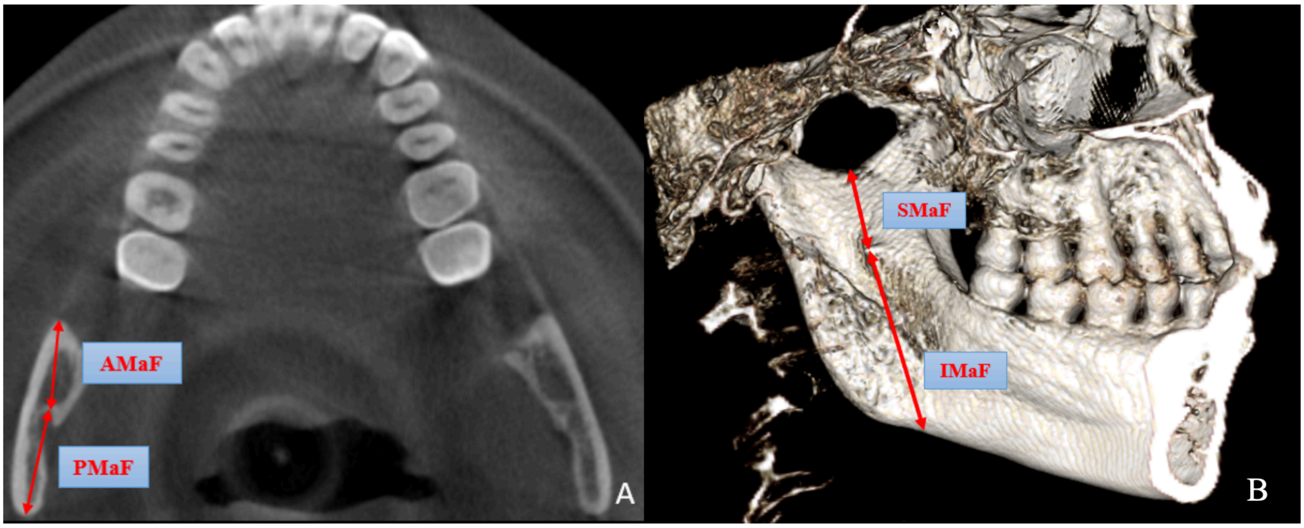
All CBCT images were evaluated in a darkroom by one of the observers. Of the images, 20% (35 cases) were measured by both observers to test the reliability of measurements and assessed with

Interclass Correlation Coefficient. Because a single software programme had not been able to provide both 2D and 3D anatomical measurements, Vision software of the I-CAT Next Generation (Imaging Sciences International, Hatfield, USA) and Anatomage Vivo Dental software version 5.2 (Anatomage, Inc. California, USA) were used on a desktop PC and viewed on a 1920 pixels × 1080 pixels resolution Dell liquid crystal display monitor. Optimal brightness and contrast were set for standardization.

Metric values were measured in millimeters in sagittal and coronal sections using the Anatomage Vivo Dental Software's distance tool. The measurements were made in different coronal and axial orthogonal planes of the scans after selecting the smallest slice thickness of 0.25 mm. Additionally, 3D reconstruction metrics were obtained using the Vision Software. All metrics were selected upon high quality validation and measurability in CBCT images of dental patients. There are many studies in the literature using similar parameters for different ethnic groups to determine sex.[5,16–19]

For horizontal and vertical localization of the mandibular foramen, four metrics were measured in the axial plane, of which the mandibular foramen width was the widest. First, the distance from the most anterior point of the mandibular foramen to the most anterior part of the mandibular ramus was measured and recorded as the anterior mandibular foramen (AMaF). Second, the distance from the most anterior point of the mandibular foramen to the most posterior part of the ramus was measured and recorded as the posterior mandibular foramen (PMaF; Figure 1-A). Third, the distance from the lingula of the mandible to the most inferior point of mandibular notch was measured and recorded as the superior mandibular foramen (SMaF). Fourth, the distance between the lingula of the mandible and the antegonial notch was measured and recorded as the inferior mandibular foramen (IMaF; Figure 1-B).

Figure 1. The position and metrics of the mandibular foramen.



For horizontal and vertical localization of the inferior alveolar canal, four metrics were measured in the coronal plane at the region of the first molar bifurcation. First, the distance from the most superior point of the inferior alveolar canal to the midpoint of the alveolar ridge crest was measured and recorded as the superior inferior alveolar canal (SIAC). Second, the distance from the most inferior point of the inferior alveolar canal to the inferior border of the mandible was measured and recorded as the inferior antegonial alveolar canal (IIAC). Third, the distance from the most lingual point of the inferior alveolar canal to the mandibular lingual cortical plate was measured and recorded as the lingual inferior alveolar canal (LIAC). Fourth, the distance from the most buccal point of the inferior alveolar canal to the mandibular buccal cortical plate was measured and recorded as the buccal inferior alveolar canal (BIAC; Figure 2).

For horizontal and vertical localization of the mental foramen, four metrics were measured in the coronal section, of which the mental foramen was widest. First, the distance from the most superior point of the mental foramen to the midpoint of the alveolar ridge crest was measured and recorded as the superior mental foramen (SMeF). Second, the distance from the most inferior point of the mental foramen to the lowest point of the inferior border of the mandible was measured and recorded as the inferior mental foramen (IMeF; Figure 3-A). Third, the distance from the most anterior point of the mental foramen to the most anterior point of the mentum was measured and recorded as the anterior mental foramen (AMeF). Fourth, the distance from the most posterior point of the mental foramen to the most protruding distal point of the mandibular ramus was measured and recorded as the posterior mental foramen (PMeF; Figure 3-B).

Figure 2. The position and metrics of the mandibular canal.

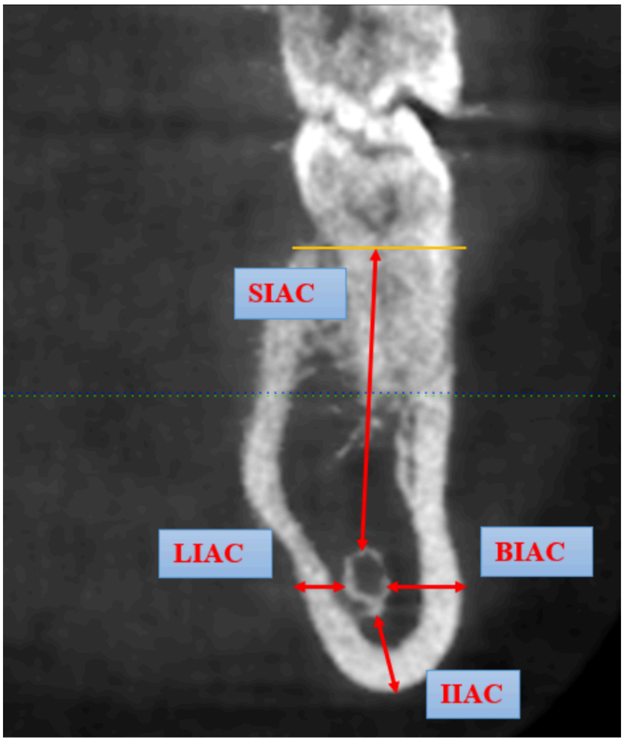
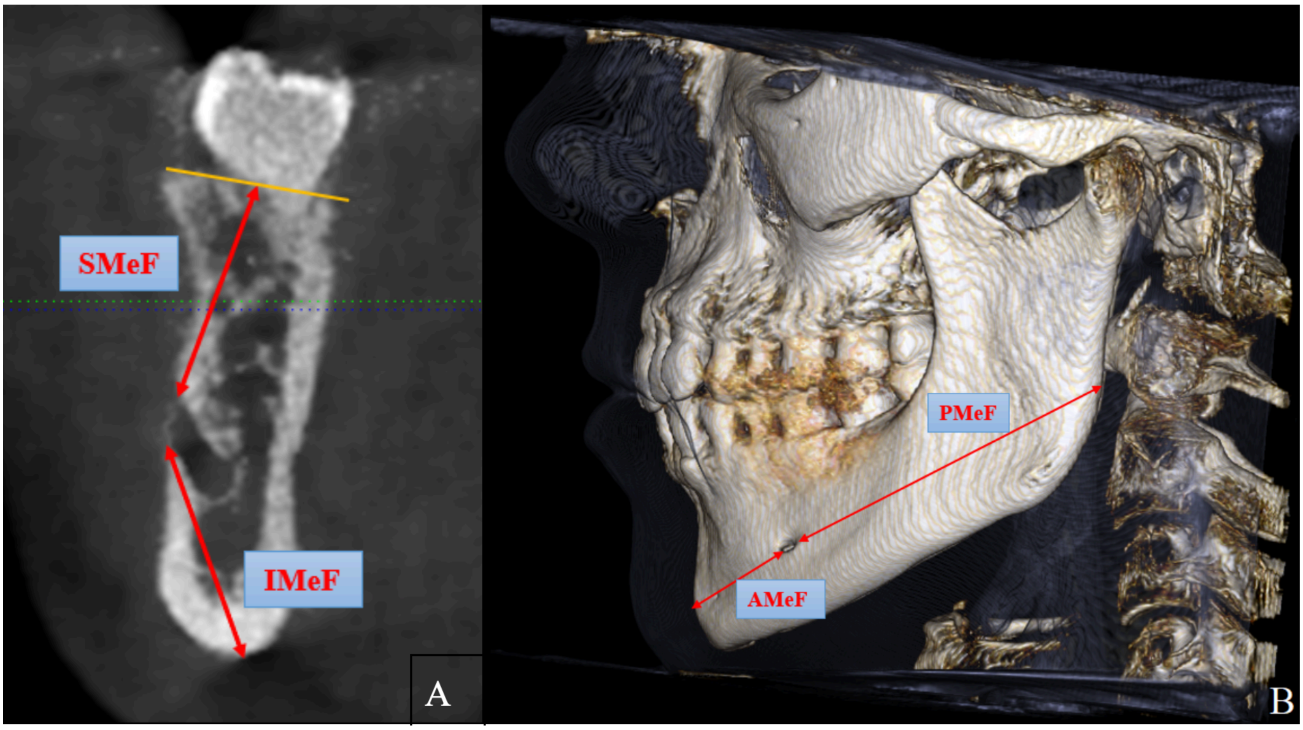


Figure 3. The position and metrics of the mental foramen.



To investigate the difference of intermental distance between the sexes, two measurements were made. In axial section, the linear distance between right and left mental foramen was measured from the most lingual points and recorded as the intermental linear length (ILL; Figure 4-A). The arch distance between the two mental foramina was measured from the labial

side and recorded as the intermental arch distance (IAD; Figure 4-B).
In addition to all these metrics, the inferior alveolar canal diameter was measured in the region of first molar bifurcation. The buccolingual distance was measured from the furthest buccal to lingual points and recorded as the buccolingual mandibular canal diameter (BLMaCD). The superoinferior distance was measured from the farthest superior to inferior point and recorded as the superoinferior mandibular canal diameter (SIMaCD; Figure 5).
The above-mentioned metrics relative to their corresponding software are demonstrated in Table 1.

Fig. 4: The metrics of intermental linear length (A) and intermental arch distance (B).

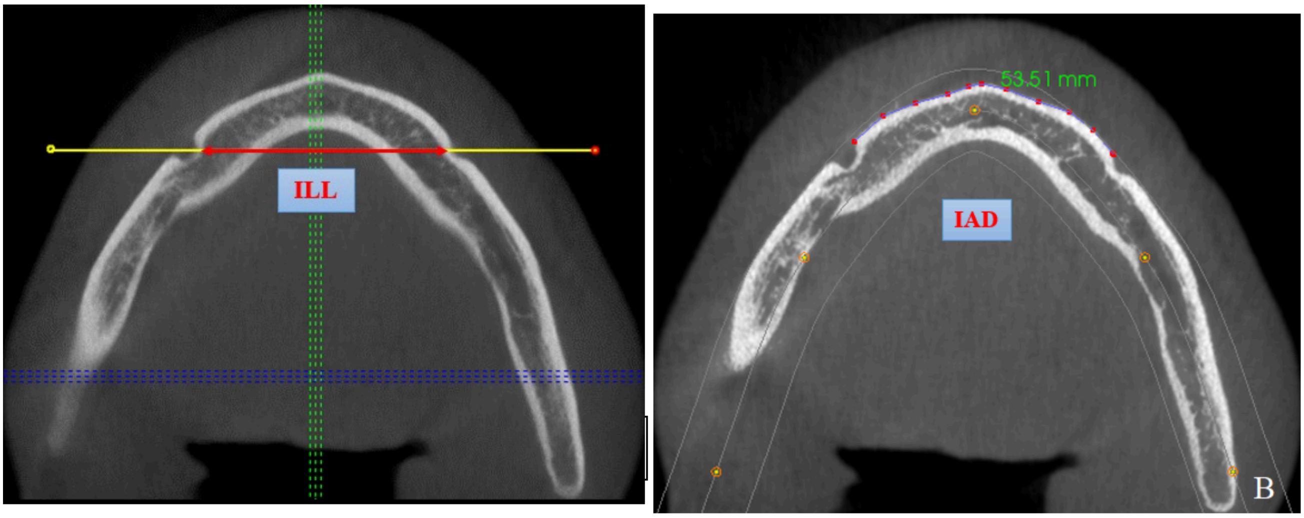


Figure 5. The metrics of mandibular canal diameters.

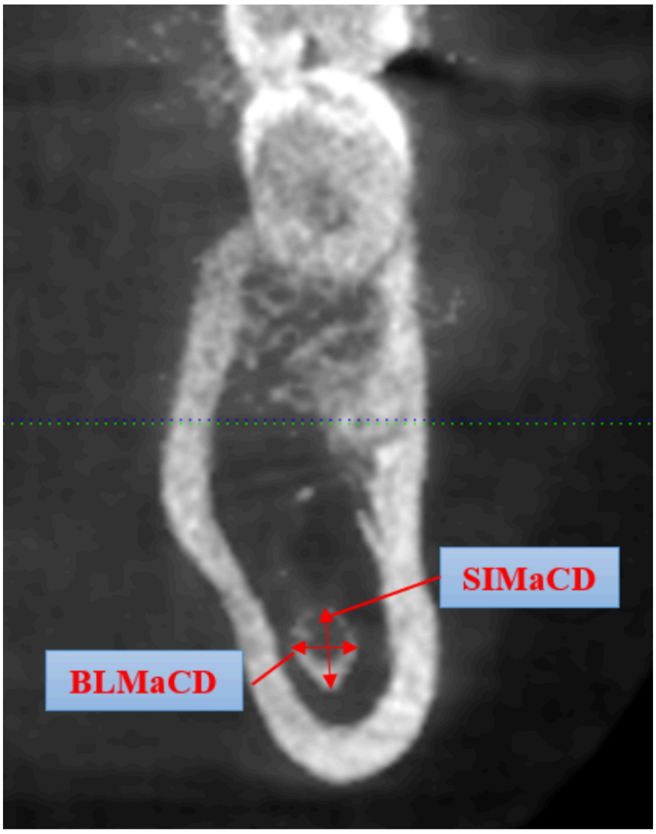


Table 1: Classification of parameters by software and sections.

Vision /I-CAT Next Generation		Anatomage /In-Vivo Dental Software
Axial Section	**Coronal section**	**Measurements on 3D reconstruction and intermental arc distance**
AMaF, PMaF, ILL	SIAC, IIAC, LIAC, BIAC, BLMaCD,SIMaCD, SMeF, IMeF	SMaF, IMaF, AMeF, PMeF, IAD

AMaF: Anterior mandibular foramen, PMaF: Posterior mandibular foramen, SMaF: Superior mandibular foramen, IMaF: Inferior mandibular foramen, SIAC: Superior inferior alveolar canal, IIAC: Inferior inferior alveolar canal, BIAC: Buccal inferior alveolar canal, LIAC: Lingual inferior alveolar canal, SMeF: Superior mental foramen, IMeF: Inferior mental foramen, AMef: Anterior mental foramen, PMef: Posterior mental foramen, ILL: Intermental linear length, IAD: Intermental arc distance, BLMaCD: Buccolingual mandibular canal diameter, SIMaCD: Superoinferior mandibular canal diameter.

STATISTICAL ANALYSIS

To assess the data's normality, the Shapiro–Wilk test was applied to demonstrate the appropriate test for the correlation and comparative analyses. Data that were not normally distributed required the use of the nonparametric Mann–Whitney U test, whereas normally distributed data required the use of the parametric Student's t-test to assess the differences between males and females. A logistic regression model was used to determine which predictors were effective in categorizing male and female mandibles, and the concordance index was calculated. To assess the diagnostic capabilities of the predictors, an optimal cut-off value for each predictor was established according to the Youden index method. The sensitivity, specificity, positive and negative predictive values, and accuracy were also calculated for each predictor. The receiver operating characteristic (ROC) curve and area under the curve (AUC) were calculated, and the AUCs were compared using the DeLong test to determine whether the indicators exhibited statistically significant differences in diagnostic accuracy. A *p*-value of less than 0.05 was defined as statistically significant.

Intraclass correlation coefficients (ICCs) were calculated to determine the inter-observer levels of agreement. Of the data, 20% were measured by both researchers to determine the reliability of measurements.[20] Inter-observer agreement was evaluated using Landis and Koch's scale (< 0, no agreement; 0–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; 0.81–1.00, almost perfect agreement).[21]

RESULTS

The total number of the study sample consisted of 176 individuals ranged between 18–60 years old. Of the 176, 71 (40.3%) were males, and 105 (59.7%) were females.

Of the data calculated by ICC, 20% were measured by both researchers to determine the measurement reliability. Strong and very strong levels of inter-observer agreement were found. When considering all parameters, inter-observer agreement was found to be 0.87. These results indicated high reliability and reproducibility for evaluated measurements (Table 2).

Table 2. Inter-observer reliability as indicated by intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) and *p*-values.

Inter-observer agreement	ICC	95%	*P*	Level of agreement
AMaF	0.98	0.97-0.99	<0.05	Very strong
PMaF	0.98	0.97-0.99	<0.05	Very strong
SMaF	0.98	0.96-0.98	<0.05	Very strong
IMaF	0.98	0.96-0.99	<0.05	Very strong
SIAC	0.98	0.96-0.98	<0.05	Very strong
IIAC	0.97	0.94-0.98	<0.05	Very strong
BIAC	0.95	0.91-0.97	<0.05	Very strong
LIAC	0.92	0.85-0.95	<0.05	Very strong
SMeF	0.98	0.97-0.99	<0.05	Very strong
IMeF	0.97	0.94-0.98	<0.05	Very strong
AmeF	0.98	0.96-0.99	<0.05	Very strong
PMeF	0.99	0.14-0.75	<0.05	Very strong
ILL	0.98	0.97-0.99	<0.05	Very strong
IAD	0.97	0.94-0.98	<0.05	Very strong
BLMaCD	0.89	0.80-0.94	<0.05	Strong
SIMaCD	0.90	0.81-0.94	<0.05	Strong

SD: Standard deviation, AMaF: Anterior mandibular foramen, PMaF: Posterior mandibular foramen, SMaF: Superior mandibular foramen, IMaF: Inferior mandibular foramen, SIAC: Superior inferior alveolar canal, IIAC: Inferior inferior alveolar canal, BIAC: Buccal inferior alveolar canal, LIAC: Lingual inferior alveolar canal, SMeF: Superior mental foramen, IMeF: Inferior mental foramen, AMef: Anterior mental foramen, PMef: Posterior mental foramen, ILL: Intermental linear length, IAD: Intermental arch distance, BLMaCD: Buccolingual mandibular canal diameter, SIMaCD: Superoinferior mandibular canal diameter.

Aside from SMaF, the mean values of all measurements were higher in males than in females. Additionally, all measurements, besides SIMaCD, showed statistically significant differences between males and females. Comparison of mean differences between males and females are shown in Table 3 and illustrated in Figure 6.

Table 3. Descriptive data of all studied linear measurements according to sex.

	MALE				FEMALE				
VARIABLE	MEAN	SD	MEDIAN	RANGE	MEAN	SD	MEDIAN	RANGE	P value
AMaF	16.15	2.60	16	11.54-21.74	15.38	2.13	15.28	10.41-20.70	[1]0.040*
PMaF	18.20	2.20	18.05	14.05-24.45	16.02	2.22	15.82	11.99-24.14	[1]0.000*
SMaF	15.35	2.32	15	10.60-22.70	16.02	2.22	13.80	8.00-22.57	[1]0.002*
IMaF	35.56	6.27	36.40	23.30-48.30	31.88	3.00	32.00	24.40-38.59	[2]0.000*
SIAC	17.30	2.71	17.77	8.53-22.40	15.98	2.51	16.40	7.47-21.26	[1]0.001*
IIAC	7.71	2.30	7.60	2.68-16.77	6.82	1.93	6.60	3.22-14.01	[1]0.006*
BIAC	5.50	1.18	5.26	2.68-8.59	5.12	1.26	4.82	2.88-8.74	[1]0.043*
LIAC	3.40	0.59	3.43	2.00-4.83	3.22	0.54	3.22	2.00-4.35	[1]0.047*
SMeF	14.38	2.49	14.36	7.52-22.97	13.30	1.87	13.24	6.80-16.95	[1]0.001*
IMeF	14.35	1.68	14.49	10.85-19.07	13.55	1.86	13.54	9.81-23.97	[2]0.001*
AMeF	20.53	4.15	19.80	12.80-30.21	19.06	3.62	18.00	13.40-29.30	[1]0.014*
PMeF	63.30	0.74	63.80	61.74-64.72	59.25	0.38	59.40	58.50-60.01	[2]0.000*
ILL	43.83	2.71	44.00	39.05-50.59	42.43	2.68	42.39	33.84-51.70	[1]0.001*
IAD	51.38	3.72	51.39	44.03-62.51	49.71	3.94	49.40	40.97-62.80	[1]0.047*
BLMaCD	3.10	0.65	2.91	2.00-5.20	2.90	0.62	2.83	1.65-4.78	[1]0.005*
SIMaCD	3.23	0.73	3.20	1.77-5.75	3.04	0.64	2.91	1.60-5.40	[1]0.075

[1] Student's t-test; [2] Mann–Whitney U test
SD: Standard deviation *: $p < 0.05$

Correlation analysis was performed to test the relationship between parameters used for logistic regression. According to analysis, IAD and ILL were found highly correlated with each other. To avoid statistical errors, IAD and ILL were excluded from the model.

Logistic regression analysis results showed that the PMaF, IIAC, and IMaF parameters were effective in determining sex. The negative standardized regression coefficient indicated the mandibular landmark of the male sex, and the positive standardized regression coefficient indicated the mandibular landmark of the female sex. According to the logistic regression analysis, sex determination can be achieved with a mean accuracy of 84.1%. Whereas this rate was 76.1% for men, it was 89.5% for women. Application of likelihood analysis to the fourteen variables resulted in the following logistic function formulation:

$$\textit{Logit: } 27.88 - (0.13 \times AMaF) - (0.31 \times PMaF) - (0.05 \times SMaF) - (0.13 \times IMaF) - (0.10 \times SIAC) - (0.25 \times IIAC) - (0.29 \times BIAC) - (0.56 \times LIAC) - (0.14 \times SMeF) - (0.11 \times IMeF) - (0.04 \times AMeF) - (0.06 \times PMeF) - (0.07 \times BLMaCD) - (0.58 \times SIMaCD)$$

The highest diagnostic accuracy using cut-off values among the fourteen parameters disclosed that it was associated primarily with IMaF (76%), followed by PMeF (73%) and PMaF (70%). Additionally, overall prediction of all fourteen parameters revealed that the accuracy rate for the identification of female and male mandibles is 80% (Table 4 and Figure 7). When fourteen parameters were combined, a concordance index of 91% was found.

Figure 6. Mean measurements in males and females. The error bars indicate values of standard deviations.

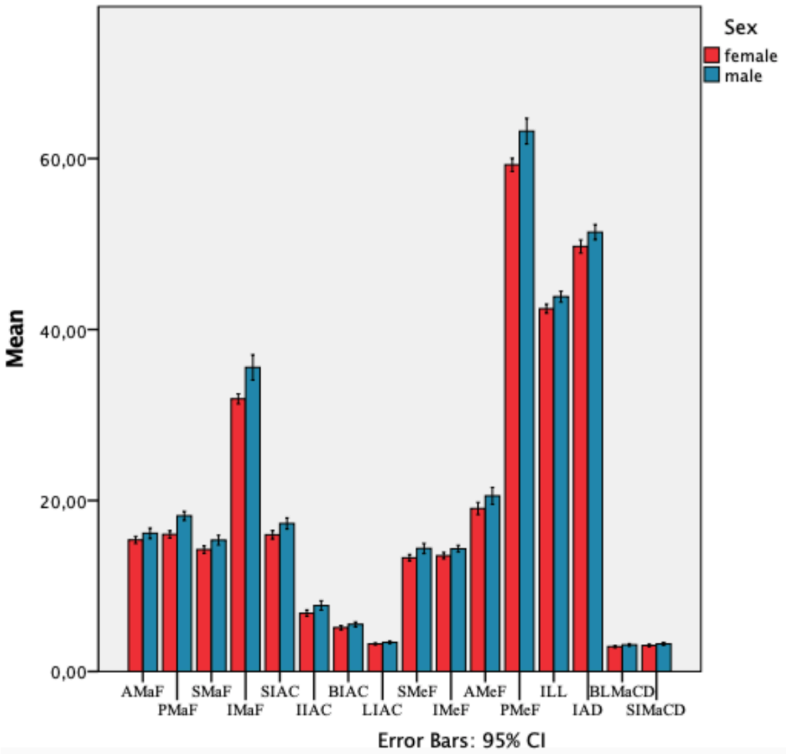
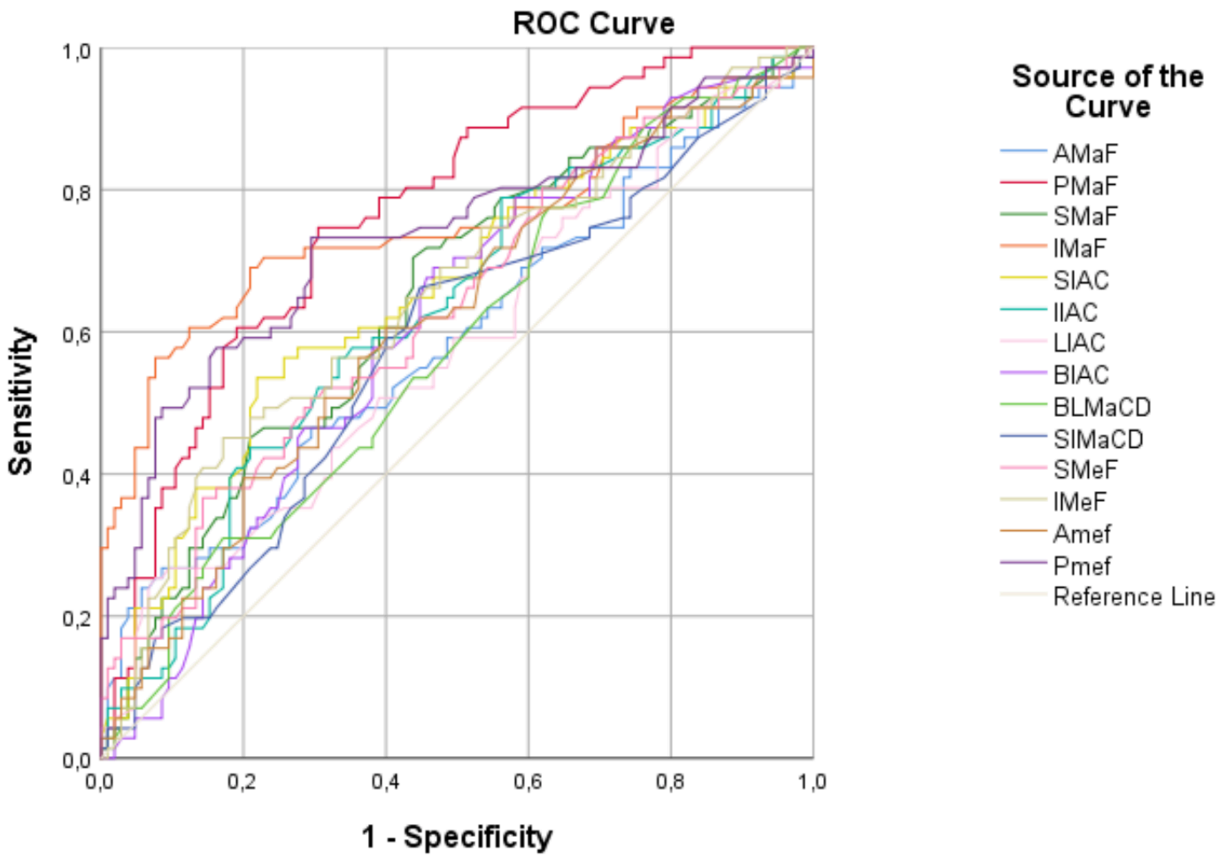


Table 4: Sensitivity, specificity, positive predictive value, and negative predictive value of the fourteen linear measurements selected for sex prediction at the optimal cut-off.

	Cut-off	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy	AUC	95% CI	P
AMaF	18.86	0.24	0.94	0.73	0.64	0.66	0.59	0.50-0,68	0.050
PMaF	20.72	0.52	0.83	0.67	0.72	0.70	0.77	0.70-0,84	0.001
SMaF	18.1	0.29	0.86	0.58	0.64	0.63	0.65	0.56-0.73	0.001
IMaF	38.3	0.59	0.87	0.76	0.76	0.76	0.75	0.67-0.83	0.001
SIAC	21.05	0.34	0.87	0.63	0.66	0.65	0.66	0.57-0.74	0.001
IIAC	11.6	0.18	0.88	0.52	0.62	0.60	0.62	0.54-0.71	0.005
BIAC	6.43	0.13	0.89	0.43	0.60	0.58	0.61	0.53-0.69	0.013
LIAC	3.99	0.17	0.95	0.70	0.63	0.64	0.58	0.49-0.67	0.078
SMeF	16.56	0.30	0.87	0.60	0.65	0.64	0.63	0.55-0.71	0.004
IMeF	15.64	0.28	0.9	0.67	0.65	0.65	0.65	0.57-0.73	0.001
AMeF	27.33	0.23	0.86	0.52	0.62	0.60	0.61	0.53-0.70	0.011

PMeF	68.44	0.51	0.88	0.73	0.72	0.73	0.73	0.65-0.81	0.001
BLMaCD	4.49	0.11	0.90	0.45	0.60	0.59	0.58	0.50-0.67	0.004
SIMaCD	4.73	0.11	0.94	0.57	0.61	0.61	0.58	0.49-0.67	0.078
All	-	75.2	88.4	81.2	84.2	0.80	0.68	-	-

Fig. 7: Receiver operating characteristic curves of the predictors that were included, both individually and combined, in the final logistic regression model
AUC: area under the receiver operating characteristic curve; CI: confidence interval.



DISCUSSION

Human identification is one of the main interests of forensic science. In accordance with this purpose, three important determinants have been studied: age, sex, and stature.[11] Forensic odontologists examine teeth and skull traits to conduct sex estimation. Iscan et al. measured buccolingual dimensions of maxillary and mandibular teeth separately, and the most sexually dimorphic tooth was found to be the canine in both jaws.[22] As a bony structure, the mandible is also regarded as a sexually dimorphic bone by forensic odontologists.[23] Mandibular morphological traits vary by population and race.[14] There are several publications on the mandible that provide forensic databases for different populations. In previous articles, the wide range of metrics that belong to mandibular parameters were significantly higher in males compared to females regardless of the method of measurement.[16,18,24–26] In the current study, aside from SIMaCD, all parameters were found to be statistically significant. Previous articles and the current study showed similar statistical results and studied similar parameters, which are shown in Table 5.[5,16–19]

Table 5: Comparison of the results of different parameters in different studies.

	Saraswathi et al. 50 CBCT (25 females 25 males)	**Gamba et al. Brazilian 160 CBCT (86 females 74 males)**	**Mansımranjıt et al. 73 CBCT (32 females 41 males)**	**Amin Jordanians 270 CBCT (123 females 147 males)**	**Mousa et al. Egyptian 210 CBCT (120 females 90 males)**	**Current study Turkish 176 CBCT (105 females 71 males)**
Parameters in common	AMaF, PMaF, SIAC, IIAC, LIAC, BIAC, SMeF, IMeF	AMaF, PMaF, SIAC, IIAC, LIAC, BIAC, SMeF, IMeF,	SIAC, IIAC, LIAC, BIAC, SMeF, IMeF	AMeF (D3), PMeF (D4), AMaF (D5), PMaF (D6), SMaf (D7), IMaF (D8)	SMeF, IMeF, SIAC, IIAC, BIAC, LIAC, AMaF, PMaF	AMaF, PMaF, SMaF, IMaF, SIAC, IIAC, LIAC, BIAC, SMeF, IMeF, AMeF, PMeF, ILL, IAD, BLMaCD, SIMaCD
Parameters which had statistically significant difference between males and females	AMaF, PMaF, SIAC, IIAC, BIAC	All measurements	SMeF and SIAC	PMeF (D4), PMaF (D6), IMaF (D8)	All of the linear measurements besides BIAC and IIAC	All measurements besides SIMaCD
Accuracy level of parameters	-	-	-	D4 66% D8 57% Total accuracy of 6 predictors is 86.7%	IIAC (73%) IMeF (72%) SIAC, IMeF, and PMaF (65%), LIAC (60%) When the 6 predictors were combined total accuracy is 78%	IMaF (76%), PMeF (73%), PMaf (70%) When the 14 predictors were combined total accuracy is 80%

In this study, the accuracy rate of whole parameters was 80%. The overall measurement outcomes revealed accuracy rates of 78–86.7%, including the present study.[17,19] Although Mousa et al.'s sample size was larger than this study, the number of inspected measurements was higher in this study, and its results revealed similar accuracy rates. According to Mousa et al., the highest accuracy rate was associated with IIAC (73%), followed by IMeF (72%), followed by SIAC, IMeF and PMaF at the same accuracy rate (65%), whereas LIAC (60%) was associated with the lowest accuracy rate.[17] In the current study, IMaF had the highest accuracy rate. Gopal et al. measured SIAC from the occlusal plane of caries and restoration free mandibular first molars.[18] In the current study, the most superior buccal and lingual points of the alveolar crest were preferred for the same measurement to avoid crown height distinctiveness. Additionally, patients with periodontitis were excluded from the study to achieve accurate measurements. Although different reference points were chosen, SIAC showed statistically significant differences in both experiments. Rashid et al. performed similar measurements with the current study using panoramic images.[27] Their measurements corresponded to SMeF, IMeF, SMaF and SMaF+IMaF. SMaF and SMaF+IMaF were found to be the most sexually dimorphic parameters.

Panoramic tomography (PTG) is a 2D imaging modality used in dental practice. This method has a number of disadvantages compared to 3D imaging modalities such as magnification, elongation, geometric distortion, and superposition.[28–29] Suragimath et al. performed measurements to evaluate sexual dimorphism of the mental foramen using PTG.[30] Unlike Rashid's study, a number of horizontal measurements were included in the current study. Because of distortion and overlapping, horizontal measurements are not dependable on PTG.[28–29] In view of these disadvantages, we utilized CBCT in this study. Because these anthropological and forensic studies are population specific, we examined mandibles specifically belonging to the Turkish population.[31]

In the coronal plane, mandibular canal diameters were measured at the level of the first mandibular molar. BLMaCD demonstrated statistical significance. There has been no up to date article that has assessed mandibular canal diameters in terms of sexual dimorphism; therefore, more research is required to extensively evaluate this topic.

Amin found an accuracy rate of 91.3% for males and 83.8% for females in the Jordanian population.[26] In this study, the accuracy rates for sex determination from mandibular measurements were 89.5% in females and 76.1% in males. These results revealed that female mandibles were correctly identified more frequently than male mandibles.

CONCLUSIONS

The highest diagnostic accuracy rate using cut-off values among the fourteen parameters was primarily associated with IMaF (76%), followed by PMeF (73%) and PMaF (70%). Furthermore, the overall prediction of all fourteen parameters revealed that the accuracy rate for the identification of female and male mandibles is 80%. The accuracy rates of sex determination from mandibular measurements were 89.5% in females and 76.1% in males. In conclusion, these mandibular landmarks showed that they could be used as reliable indicators of sexual dimorphism.

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Use of non-clinical smile images for human identification: a systematic review

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The authors declare that they have no conflict of interest.

KEYWORDS

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Photograph;
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ABSTRACT

Human identification using Forensic Dentistry occurs through comparative analysis of ante-mortem (AM) and post-mortem (PM) data. With the constant improvement of technology, photographs became a common source of AM data. When clinical dental records are not available, images showing the smile can be useful in human identification. The aim of this study was to investigate human identification techniques through the analysis of smile images in the available literature. Studies on human identification through the analysis of smile images were searched in the scientific literature. The search resulted in 4,043 studies. After screening, 14 studies were considered eligible. Eleven were case reports, two were pilot studies and one a technical note. From the eligible studies, in addition to the methodological data, information about the sample, used techniques and results regarding human identification were extracted. Three techniques were detected: direct comparison of morphological characteristics, AM/PM image overlap, and the analysis of smile lines. One or more associated techniques were used for human identification. Authors highlighted as a common limitation of the techniques the quality of the available images, the difficulty in reproducing PM the same images AM, and the eventual image modifications performed by the victim before posting in social media. Advantages included the low-cost aspect of the technique, as well as a potential fast and accurate procedure (depending on the quantity and quality of evidence). In general, studies considered the technique useful and adjuvant for human identification.

INTRODUCTION

Forensic Dentistry is one of the primary methods of identification.[1] The area of investigation is traditionally the oral cavity. In this field, teeth are the main objects of study. Because teeth are considered the most stable and resistant structures in the human body,[2] they provide a good source of information. In skeletal remains, and victims with advanced decomposition or charred, teeth are often the better-preserved structure of the body.[3]

Basically, the forensic exam is performed through the analysis of comparative ante-mortem (AM) and post-mortem (PM) data.[4,5] Traditionally, human identification through dentistry is performed using data from the dental records. Radiographs, clinical forms, dental casts and, more recently, intraoral photographs are examples of data that can be evaluated in the reconciliation phase.[6,7]

With the improvement of technology, smartphones became tools capable of taking self-portraits. The frontal camera is a device that works as a kind of mirror, which allows the user to see and self-evaluate before taking the photograph.[8] The act self-photographic registration become popular in recent years. Worldwide, millions of social media users such as Facebook™, Instagram™ and TikTok™ feed their profiles with images of their faces and their daily activities. The so-called selfies (photographs of the individual taken by him/herself), became more popular. The word "selfie", a reduction of the term "self-portrait photograph", was considered, in 2013, the word of the year by the Oxford dictionary.[4] Taken mainly focusing and framing the face,[9] selfies can be useful in the forensic context. Moreover, in specific cases, casual photographs and videos showing the smile might be the only available data to identify a missing person.

Therefore, the present work aimed to investigate the existing literature on techniques to analyze smile photographs as a comparative method for human identification.

MATERIAL AND METHODS

Study Design

Studies on human identification through smile analysis have been sought in the literature. The nature of the present study was qualitative, consisting of a systematic review. The review was carried out according to the parameters of Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA)[10] and based on Cochrane standards.[11]

Eligibility

The present study was conducted based on the following guiding question: "What is the expert relevance of non-clinical images of the smile for human identification?". To structure this question, the PICO strategy was used, in which P (person) = comparative human identification techniques in Forensic Dentistry; I (intervention) = non-clinical photographs of the smile; C (comparison) = post-mortem dental data and O (outcome) = limitations and advantages of the technique.

Studies human identification cases by smile analysis and studies describing the techniques were included. Literature reviews, letters to the editor, abstracts for conference proceedings and non-scientific articles were excluded, as well as original studies that did not clarify the methodology used.

Variables and sources

Pubmed, Lilacs, Web of Science, Scielo, Scopus, Embase, Open Gray and Open Acess Thesis and Dissertation were the databases used for primary data collection. The terms to be searched were first searched in the Medical Subject Headings (MeSH) and Descriptors in Health Sciences (DeCS) and the Boolean operators "AND" and "OR" were used. The terms were divided into two groups with word variations. The first group included the terms "smile identification", "selfie identification", "smile photography" and "selfie photography". In the second group, the terms "smiling", "human identification", "dental photography", "forensic" and "dental records" were included. The research was carried out on April, 2020, without restriction of year or language of publication of the study.

The studies found in the mentioned databases were imported into Mendeley™ (Mendeley Ltd., London, UK), software used to organize the volume of studies and exclude duplicates. As soon as they were imported into the software, duplicates were automatically deleted. Studies that remained duplicated were deleted manually, after the first filtering.

Selection of studies

The survey of studies was carried out in three phases. In each selection phase, the process was supervised by a second examiner. The first phase was the selection of study titles. Studies that did not have titles related to the objective of this study were excluded. The names of the authors of the studies and the journals in which they were published were not blinded. In the second phase, the study abstracts were read and included or excluded, based on the eligibility criteria. Studies with abstracts with insufficient data were maintained for the next phase. In the third phase, the study was read in its entirety. The studies excluded in this phase had their reasons recorded.

Data extraction

General data were extracted from each study, such as the name of the authors, year, country, and journal of publication. Were registered the number of individuals reported, the type of smile image (selfies, photos or videos), technique used for the analysis, software used for the comparison and the type study (case report, case series, pilot study or technical note).

Risk of bias in the included studies
The Joanna Briggs Institute (JBI) checklist was used as a tool to assess the risk of bias in case reports, case reports in series and cross-sectional observational.[12] Eligible studies were assessed based on the percentage of positive responses to the requirements of the JBI checklists. Studies with less than 50% positive responses to the checklist were considered as high risk of bias. A moderate risk of bias was considered when 50 to 69% of the questions in the checklist were positive and a low risk of bias was considered when more than 70% of the questions in the checklist were positively marked.

RESULTS

Selection of studies
The initial search in the databases, with the terms described, showed 4,053 studies. The studies found in each database, as well as the terms used in the search are described in Table 1. The studies found in the Open Gray and Open Access Thesis and Dissertation databases were not exported, as they were not scientific articles. In the remaining databases, after being exported to the Mendeley™ platform (Mendeley Ltd., London, UK), the studies were automatically checked for duplicates and reduced to 4,028.

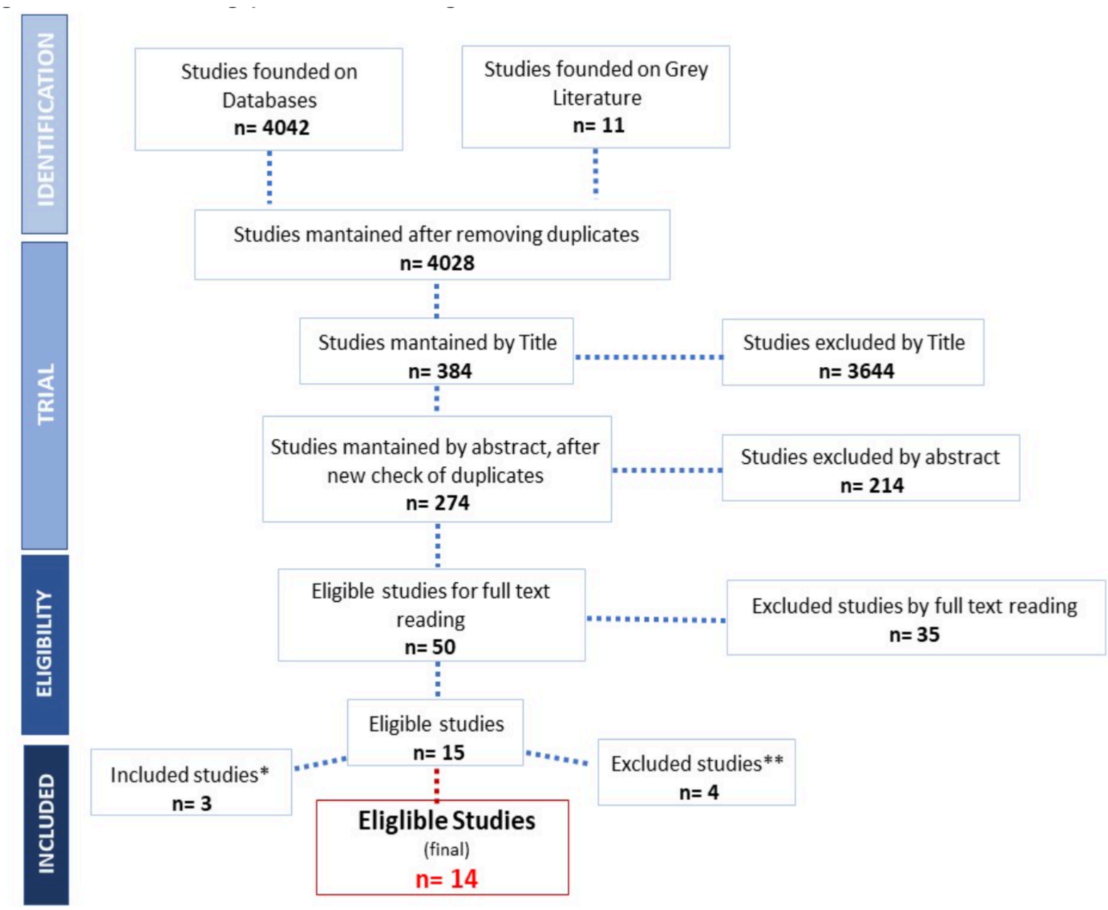
Table 1. Results of studies found using specific terms in the search platforms

Database	Terms	Results
PubMed	((((smile OR smiling OR selfie OR records)) AND (dental OR oral OR teeth OR tooth)) AND (identification OR photography)) AND forensic	484
Lilacs	(records OR photography) AND (smiling OR dental OR oral OR teeth OR tooth) AND (identification OR forensic)	183
Web of Science	ALL=((smile OR selfie OR records OR smiling) AND (dental OR oral OR teeth OR tooth) AND (identification OR photography) AND (forensic))	245
Scielo	(records OR photography) AND (smiling OR dental OR oral OR teeth OR tooth) AND (identification OR forensic)	42
Scopus	ALL ((smile OR selfie OR records OR smiling) AND (dental OR oral OR teeth OR tooth) AND (identification OR photography) AND (forensic)) AND (LIMIT-TO (DOCTYPE , "ar"))	2697
Embase	('smile' OR 'smile'/exp OR smile OR selfie OR 'records' OR 'records'/exp OR records OR 'smiling' OR 'smiling'/exp OR smiling) AND ('dental' OR 'dental'/exp OR dental OR oral OR 'teeth' OR 'teeth'/exp OR teeth OR 'tooth' OR 'tooth'/exp OR tooth) AND ('identification' OR 'identification'/exp OR identification OR 'photography' OR 'photography'/exp OR photography) AND forensic AND [article]/lim AND [embase]/lim	391
Open Grey	(smile OR smiling OR selfie OR records) AND (dental OR oral OR teeth OR tooth) AND (identification OR photography) AND (forensic)	1
Open access theses and dissertations	(smile OR smiling OR selfie OR records) AND (deal OR oral OR teeth OR tooth) AND (identification OR photography) AND (forensic)	10
TOTAL		**4053**

The databases were first organized into directories. The exclusion by reading the title was performed in each folder, removing 3,644 studies in this phase. 384 articles were left for reading the summary in all folders. These were grouped into a single folder and checked for duplicates again. After checking, the number of studies for reading the summary was 274. In this phase, 214 studies were excluded, leaving 50 studies for complete reading. The studies were carefully read and, of these, 35 were excluded because they did not meet the proposed eligibility criteria. Studies that did not use the smile image for human identification, did not describe which identification technique was used or that presented different designs from the one proposed were excluded. At each stage of the filtering process, in case of doubt, the study was continued for the next phase. Thus, 15 eligible studies remained.

Of the remaining 15 studies, four of them were not obtained in full; they were requested from the respective corresponding author, but without success. During the data extraction phase, in the analysis of the references used in the eleven available eligible studies, three more studies that met the eligibility criteria were found and attached. Thus, this systematic review was conducted with fourteen eligible articles (Figure 1).

Figure 1. Screening process for eligible studies



Characteristics of selected studies

The studies were published between the years 1994 and 2019. The most prevalent countries were Brazil (n = 6) and Italy (n = 3), followed by the United States (n = 2), Australia (n = 1), Malaysia (n = 1) and the United Kingdom (n = 1) (Table 2).

Except for study #2,[14] related to a child, all individuals reported were adults.

The studies were developed with volunteers (patients) (n = 3) and with cadavers (n = 11). Most studies were case reports (n = 11), followed by a pilot study (n = 2) and technical note (n = 1).

Except for study #2,[14] all studies used AM photographs for comparative analysis. Of those studies that used photographs, only study #11[21] specified that the photographs used were selfies. Study #2[14] used images captured from a video (frames) filmed by the victim's family.

Three techniques of comparative analysis of AM / PM or simulated data were performed. The techniques were: direct comparative analysis of morphological characteristics, overlapping images and incisal smile line. Three studies used two combined techniques: incisal smile line and image overlay.[5,14,21]

The tools used for comparative analysis were Adobe Photoshop® (n = 8), PowerPoint® (n = 1) and CorelDRAW X71® (n = 1). In four studies, tools were not used or specified, and in study #14[23] a comparative metric formula created for the study was used.

In all studies, the result of the analysis was decisive. In the case reports, the analysis resulted in positive identifications of the individuals. In the pilot and technical note studies, the simulated technique used was considered satisfactory to be used in real cases of human identification. All the methodological data described above, as well as the studies in which they were used, are detailed in Table 3.

Table 2. Eligible studies, selected from the initial search and organized in chronological order of publication in scientific journals

#	Autors	Year	Country	Journal	Title
1	**Phrabhakaran**[13]	1994	Malaysia	Medical Journal of Malaysia	Identification from dental characteristics
2	**Marks et al.**[14]	1997	United States	Forensic Science International	Digital Video Image Capture in Establishing Positive Identification
3	**Whittaker et al.**[15]	1998	United Kingdom	British Journal of Orthodontics	Orthodontic Reconstruction in a Victim of Murder
4	**Al-Amad et al.** [16]	2006	Australia	Journal of Forensic Odonto-Stomatology	Craniofacial identification by computer-mediated superimposition
5	**De Angelis et al.**[17]	2007	Italy	International Journal of Legal Medicine	Dental superimposition: a pilot study for standardising the method
6	**Silva et al.**[6]	*2008*	Brazil	Journal of Forensic Odonto-Stomatology	Forensic odontology identification using smile photograph analysis – case reports
7	**Bollinger et al.**[18]	2009	United States	Journal of Forensic Sciences	GrinLine Identification Using Digital Imaging and Adobe Photoshop
8	**Tinoco et al.**[19]	2010	Brazil	Journal of Forensic Odonto-Stomatology	Dental anomalies and their value in human identification: a case report
9	**Terada et al.**[20]	2011	Brazil	Revista de Odontologia da UNESP	Human identification in forensic dentistry from a photographic record of smile: a case report
10	**Silva et al.**[5]	2015	Brazil	American Journal of Forensic Medical and	Human Identification Through the Analysis of Smile Photographs
11	**Miranda et al.**[21]	2016	Brazil	Forensic Science International	An unusual forensic of human identification: Use of selfie photographs
12	**Silva et al.**[7]	2016	Brazil	Revista Brasileira de Odontologia Legal	Computerized dental delimitation of incisal edges in smile photographs with forensic purposes
13	**Olivieri et al.**[22]	2018	Italy	Forensic Science International	Challenges in the identification of dead migrants in the Mediterranean: the case study of the Lampedusa shipwreck of October 3rd 2013
14	**Santoro et al.**[23]	2019	Italy	Journal of Forensic Odonto-Stomatology	Personal identification through digital photo superimposition of dental profile: a pilot study

* Number assigned to each study found, according to the chronological order of publication in a scientific journal.

Table 3. Methodological data extracted from the eligible studies

*	Sample	Analysis Technic	Image	Tool	Identification	Type of study
1	-Charred body (female) -Charred body (female)	Direct comparison of morphological characteristics in AM / PM images	Non-clinical photographs taken by third parties (provided by the family)	-	Positive	Cases Series
2	Infant skeletal remains (female)	Smile lines and AM / PM image overlay comparing morphological characteristics	Video frames recorded by third parties (provided by the family)	Adobe® Photoshop®	Positive	Case Report
3	Skeletal remains (female)	Overlapping AM / PM images comparing morphological characteristics	Non-clinical photographs taken by third parties (provided by the family)	-	Positive	Case Report
4	Putrified body (male)	Overlapping AM / PM images comparing morphological characteristics	Non-clinical photographs taken by third parties (provided by the family)	Adobe® Photoshop®	Positive	Case Report
5	Pictures, plaster casts and volunteers	Image overlay (provided and simulated) and comparison with your plaster casts	Photographs taken by the authors for the tests	Adobe® Photoshop®	Satisfactory	Pilot Study
6	- Putrified body (male) - Skeletal remains (female) - Charred body (male)	Overlapping AM / PM images comparing morphological characteristics	Non-clinical photographs taken by third parties (provided by the family)	-	Positives	Cases Series
7	Volunteers	Overlapping images (provided and simulated) comparing morphological characteristics	Photographs taken by the authors for the tests	Adobe® Photoshop®	Satisfactory	Technical Note
8	Charred body (female)	Direct comparison of morphological characteristics in AM / PM images	Non-clinical photographs taken by third parties (provided by the family)	Adobe® Photoshop®	Positive	Case Report
9	Skeletal remains (male)	Direct comparison of morphological characteristics in AM / PM images	Non-clinical photographs taken by third parties (provided by the family)	Adobe® Photoshop®	Positive	Case Report
10	Charred body (male)	Smile lines and AM / PM image overlay comparing morphological characteristics	Non-clinical photographs taken by third parties (provided by the family)	Adobe® Photoshop®	Positive	Case Report
11	Charred body (male)	Smile lines and AM / PM image overlay comparing morphological characteristics	Selfies	CorelDR AW X71®	Positive	Case Report

12	Charred and putrefied body (male)	Smile line (lower arch)	Non-clinical photographs taken by third parties (provided by the family)	PowerPoint®	Positive	Case Report
13	Shipwreck (8)	Overlapping AM / PM images comparing morphological characteristics	Non-clinical photographs taken by third parties (provided by the family)	-	Positive	Cases Series
14	Volunteers	Image overlay (simulated)	Photographs taken by the authors for the tests	Adobe® Photoshop®	Satisfactory	Pilot Study

* Number assigned to each study found, in chronological order of publication as shown in table 2. Adobe® Photoshop® (Adobe Inc.™, San Jose, California, USA); CorelDRAW X71® (Corel Corporation™ Ottawa, Ontario, Canada); PowerPoint® (Microsoft Corporation™ Redmond, Washington, USA).

Risk of bias in the included studies

All eligible studies were considered to be at low risk of bias. In the eight case reports, seven of them were rated 100% based on the checklist responses,[5,7,14,16,19-21] while one study had 90% of positive responses.[15] Of the three case series, two of them had 80% of positive responses[6,13] and one obtained 70% of the positive responses.[22] When it comes to the two detected pilot studies, one obtained 100% of the positive responses[23] and one obtained 90% of the positive responses.[17] For the technical note study type, the checklist was used for studies of the case report type; this study obtained 90% positive responses.[18]

DISCUSSION

In human identification, the availability, quantity and quality of AM data is fundamental. Challenging cases, however, include victims with no clinical/dental AM records, such as clandestine migrants,[22,23] victims that never had dental appointments, or victims that were treated by dentists that could not be tracked.[21,24] The analysis of smile photographs emerges as an alternative tool for the process of human identification by forensic odontology.[22]

Depending on the photograph available, the analysis of smile images can be performed in different ways. When the record is of good quality, visualization of the anterior teeth may be sufficient to detect distinctive features of the dentition.[21] In this type of analysis, morphological characteristics are evaluated, such as the shape of the crowns, gingival contours, incisal edges, dental anomalies and distance and alignment between the teeth.[6,21] In the pioneering study proposed by McKenna (1986),[25] 1,000 individuals had their smiles evaluated from photographs. Of these, 76.7% had distinctive dental characteristics that would identify them.

The images posted on users' profile of social media tend to show the best version of the individual. Happiness, in this context, may be expressed through the smile. Eventually, dental features of interest for human identification may be detected.[26] This scenario endorses the importance of forensic odontologists not only during PM data collection and reconciliation, but also during the AM data search analysis.[4]

In summary, the eligible studies detected in this review presented three main methods for evaluating teeth in photographs - direct morphological analysis, image overlap and comparison of smile lines. Each method has advantages and disadvantages and is adopted depending on the case. Direct morphological analysis is performed pairwise between the AM photograph of the victim and the PM examination of the deceased. A direct comparison consists of visualizing dental features simultaneously AM and PM – similarly to the use of an atlas. In general, AM photographs must have quality high enough to enable magnification with pixelization. The direct comparison focuses on exploring an overview of the available AM evidence (that could include distinctive shape and angulation of teeth, for instance).[6] The analysis of details in size and minor morphological features of teeth is hampered in the direct comparison. Image overlap, on the other hand, allows the visualization of the AM and PM data in the same spatial position. In this context, PM photographs reproducing the AM position and photographic frame is necessary. Taking anatomic references between AM and PM images (e.g. canines), computerized superimposition is performed. Normally, the reference points used are based on hard tissue (bones and teeth) because soft tissue is usually damaged or dehydrated PM. A drawback in image overlap is the need of basic knowledge in computer software for image manipulation. Preferably, image overlay-based software packages are preferred. Alternatively, software packages that allow the manipulation of image transparency are used.[18,21] The analysis of smile lines focus on the incisal edges of the anterior teeth and may lead to a more visual representation of the similarities and discrepancies between AM and PM data, but this technique is restricted by the visualization of the anterior teeth on the photograph, image quality, and malalignment of anterior teeth. More evident distinctiveness is found in the deceased that present crowding, while more challenging cases are found within victims that have well-aligned teeth.[5,6] It must be noted that the analysis of the smile line is based on a considerably reduced part of the crowns (incisal edges only) – and, so far, the uniqueness of the anatomy of anterior teeth is disputable in the scientific literature.[27] Hence, these techniques should be used in combination with other means for human identification.[28] Even the different techniques for the analysis of non-clinical photographs can be combined in a single case.[5,6,14,21]

According to Miranda et al. (2016),[21] the smile analysis technique using photographs shows good results. As disadvantages, on the other hand, the authors highlight the limited number of visible teeth, the low quality of the available images and the potential manipulation of the image by the victim while still alive.[6] On limitations of the technique for the analysis of smile lines, Silva et al. (2016)[7] highlight three points that require the attention of the expert: The first is in relation to the quality of the images, in which, in low quality, that can influence the expert to erroneously trace the smile line; Secondly, aesthetic modifications that can "correct" a possibly individualizing characteristic of the victims, such as crowding, fractures and rotations. The third point refers to peri or PM tooth modifications. In cases of charred or body remains, tooth loss and alterations are common, which can impair the analysis of the smile line.

As photographs are two-dimensional images of a three-dimensional structure, PM images should try to reproduce the angulation and characteristics of the AM collection. To this end, experts should strive for AM data collection before the cadaveric examination.[24] It is also important to pay attention to the laterality of the images.[29] Some types of photographs, especially selfies, may be mirrored, creating confusion about the position in which the features appear in each photograph.

Although the existing limitations, the analysis of non-clinical photographs is considered an adjuvant for human identification in the current scientific literature.

CONCLUSIONS

Studies found in the literature on the analysis of non-clinical images for human identification have shown useful application of this technique in practice. The modalities of the technique were considered fast, accurate and low cost, and should be associated with other existing methods with known scientific reliability.

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