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

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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).

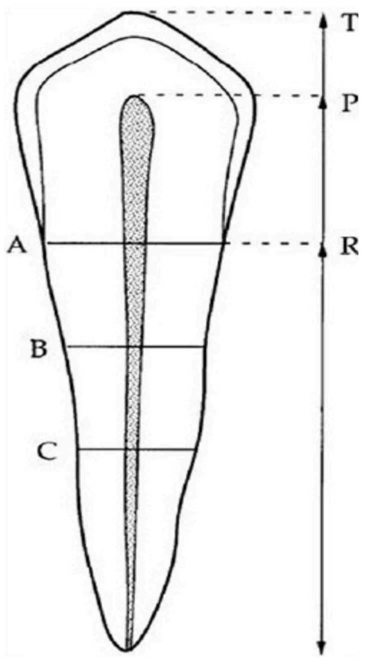
To specify the extent of "excessive tooth wear", we borrowed Smith and Knight's (TWI) dental wear

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)

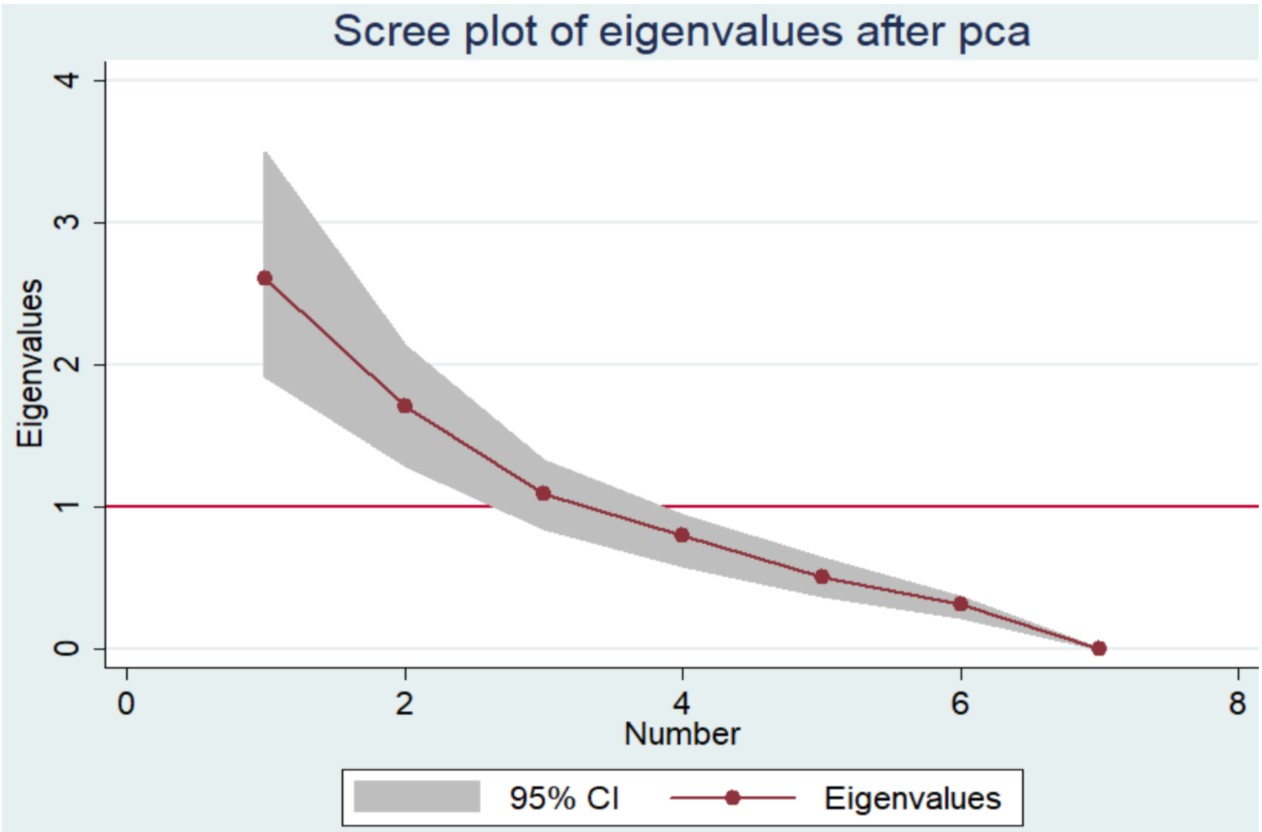
We determined a new equation by including gender as an age predictive factor in our sample. We obtained the following equation:

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**	r^2	**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[25].

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.

REFERENCES

1. Adams CMT. A Pathologist's Guide to Forensic Odontology Identification. In: Rutty GN, editor. Essentials of Autopsy Practice . Springer London; 2013 [cited 2017]. p. 135–49. Available from: http://link.springer.com.gate2.inist.fr/chapter/10.1007/978-0-85729-519-4_6
2. Meinl A, Huber CD, Tangl S, Gruber GM, Teschler-Nicola M, Watzek G. Comparison of the validity of three dental methods for the estimation of age at death. Forensic Sci Int. 2008;178(2–3):96–105.
3. Reppien K, Sejrsen B, Lynnerup N. Evaluation of post-mortem estimated dental age versus real age: a retrospective 21-year survey. Forensic Sci Int. 2006;159 Suppl 1:S84-88.
4. Kvaal S, Solheim T. A non-destructive dental method for age estimation. J Forensic Odontostomatol. 1994;12(1):6–11.
5. Paewinsky E, Pfeiffer H, Brinkmann B. Quantification of secondary dentine formation from orthopantomograms--a contribution to forensic age

estimation methods in adults. Int J Legal Med. 2005;119(1):27–30.
6. Vandevoort FM, Bergmans L, Van Cleynenbreugel J, Bielen DJ, Lambrechts P, Wevers M, et al. Age calculation using X-ray microfocus computed tomographical scanning of teeth: a pilot study. J Forensic Sci. 2004;49(4):787–90.
7. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int. 1995;74(3):175–85.
8. Pinchi V, Pradella F, Buti J, Baldinotti C, Focardi M, Norelli G-A. A new age estimation procedure based on the 3D CBCT study of the pulp cavity and hard tissues of the teeth for forensic purposes: A pilot study. J Forensic Leg Med. 2015; 36:150–7.
9. Ge Z, Ma R, Li G, Zhang J, Ma X. Age estimation based on pulp chamber volume of first molars from cone-beam computed tomography images. Forensic Sci Int. 2015; 253:133. e1-7.
10. Marroquin Penaloza TY, Karkhanis S, Kvaal SI, Nurul F, Kanagasingam S, Franklin D, et al. Application of the Kvaal method for adult dental age estimation using Cone Beam Computed Tomography (CBCT). J Forensic Leg Med. 2016; 44:178–82.
11. Biuki N, Razi T, Faramarzi M. Relationship between pulp-tooth volume ratios and chronological age in different anterior teeth on CBCT. J Clin Exp Dent. 2017;9(5): e688–93.
12. Smith BG, Knight JK. An index for measuring the wear of teeth. Br Dent J. 1984;156(12):435–8.
13. Jagannathan N, Neelakantan P, Thiruvengadam C, Ramani P, Premkumar P, Natesan A, et al. Age estimation in an Indian population using pulp/tooth volume ratio of mandibular canines obtained from cone beam computed tomography. J Forensic Odontostomatol. 2011;29(1):1–6.
14. Bosmans N, Ann P, Aly M, Willems G. The application of Kvaal's dental age calculation technique on panoramic dental radiographs. Forensic Sci Int. 2005;153(2–3):208–12.
15. Marroquin TY, Karkhanis S, Kvaal SI, Vasudavan S, Kruger E, Tennant M. Age estimation in adults by dental imaging assessment systematic review. Forensic Sci Int. 2017; 275:203–11.
16. Roh B-Y, Lee W-J, Ryu J-W, Ahn J-M, Yoon C-L, Lee S-S. The application of the Kvaal method to estimate the age of live Korean subjects using digital panoramic radiographs. Int J Legal Med. 2018;132(4):1161–6.
17. Mittal S, Nagendrareddy SG, Sharma ML, Agnihotri P, Chaudhary S, Dhillon M. Age estimation based on Kvaal's technique using digital panoramic radiographs. J Forensic Dent Sci. 2016;8(2):115.
18. Patil SK, Mohankumar KP, Donoghue M. Estimation of age by Kvaal's technique in sample Indian population to establish the need for local Indian-based formulae. J Forensic Dent Sci. 2014;6(3):166–70.
19. Meinl A, Tangl S, Pernicka E, Fenes C, Watzek G. On the applicability of secondary dentin formation to radiological age estimation in young adults. J Forensic Sci. 2007;52(2):438–41.
20. Li M-J, Chu G, Han M-Q, Chen T, Zhou H, Guo Y-C. Application of the Kvaal method for age estimation using digital panoramic radiography of Chinese individuals. Forensic Sci Int. 2019; 301:76–81.
21. Landa MI, Garamendi PM, Botella MC, Alemán I. Application of the method of Kvaal et al. to digital orthopantomograms. Int J Legal Med. 2009;123(2):123–8.
22. Miranda JC de, Azevedo A de CS, Rocha M, Michel-Crosato E, Biazevic MGH. Age estimation in Brazilian adults by Kvaal's and Cameriere's methods. Braz Oral Res. 2020;34:e051.
23. Chandan PK, Arora KS, Das M, Kaur P, Mohaptra S, Pareek S. Assessment of validity and reliability of Kvaal's method for age estimation among a population sample - A retrospective study. Indian J Dent Res Off Publ Indian Soc Dent Res. 2020;31(2):186–90.
24. Ubelaker DH, Parra RC. Application of three dental methods of adult age estimation from intact single rooted teeth to a Peruvian sample. J Forensic Sci. 2008;53(3):608–11.