European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2022, 49 (Suppl), S37–41

e-ISSN : 2757-6744
doi : 10.52037/eads.20222.0020

Article Received : August, 31 2021
Article Accepted : March, 26 2022

CONGRESS PROCEEDING

# Age Estimation Of Adults From Cone Beam Computed Tomography Images

Ezgi Türk *, Özlem Görmez and Derya Yıldırım

Department of Dentomaxillofacial Radiology, Süleyman Demirel University, Isparta, Turkey

*Corresponding Author; ezgiturk2010@hotmail.com

## Abstract

**P**urpose: Age estimation is one of the most important procedures used for identifying an individual in medical, forensic and anthropological studies. Anatomical structures such as teeth, vertebra, cranial structures, pelvis are used in the identification of the individual. Teeth have been frequently used in age estimation methods because they can remain unchanged for a long time and they are less affected by external factors than other body structures. The narrowing of the pulp cavity due to the secondary dentin formation with age is an important criterion that is taken into consideration in dental age estimation of adults. The aim of this study is to estimate age by performing linear measurements of pulp cavity of the maxillary central and canine teeth according to Kvaal's method on cone beam computed tomography (CBCT) images in a sample of Turkish population.
Material and Methods: CBCT images of 74 individuals (37 females, 37 males) aged between 18 and 63 years were evaluated retrospectively. Linear measurements (the length and width measurements of tooth, root and pulp cavity) of 74 maxillary central and 74 canine teeth were performed on pseudo panoramic CBCT sections according to Kvaal's method. The relationship between age and morphological variables was calculated by the Pearson correlation analysis. Multiple linear regression models were established for each tooth to estimate the age.
Results: As a result of the regression equation analysis developed to estimate age from morphological variables, the standard estimation error for maxillary canine teeth= ±10.42, maxillary canine tooth determination coefficient R2= 0.158; the standard estimation error for maxillary central teeth= ±10.65, maxillary central tooth coefficient of determination R2= 0.131; the standard estimation error for both teeth= ±10.18, both teeth coefficient of determination R2= 0.207.
Conclusion: Linear measurements and ratios of pulp cavity of the maxillary central and canine teeth on CBCT images were insufficient to estimate the age according to Kvaal's method in a sample of Turkish population. In future studies, it is recommended to use different radiographic measurements such as larger sample size or pulp area and pulp volume to increase the accuracy of age estimation in adult Turkish individuals.

**Key words**: Age Estimation; Cone Beam Computed Tomography; Forensic Dentistry; Kvaal's Method; Tooth

## Introduction

Biological methods such as fingerprints, tooth comparison, and DNA profiling, radiological methods are the main tools for identifying a person.[1] Age estimation is one of the most important procedures used for identifying an individual in medical, forensic and anthropological studies.[2] The methods that evaluate tooth and bone development are frequently used for age determination. The age of people can be estimated by evaluating structures in different parts of the body such as epiphysis and metaphysis of bones, suture closures of skull bones, costal cartilage, paranasal sinuses and teeth. Teeth have been frequently used in age estimation methods because they can remain unchanged for a long time and they are less affected by external factors than other body structures.[2–4] Therefore, age determination using teeth is one of the most preferred methods of estimating the age of living people and dead bodies.[2] Many methods have been developed for age estimation from teeth. Teeth were generally evaluated morphologically, radiologically, biochemically and histologically.[2,5,6] Administration of methods based on biochemical and histological features of teeth is often difficult due to complex laboratory equipment, long time and tooth extraction requirements.[6] Evaluation of developmental stages in deciduous and permanent teeth makes it easier to determine the age of children and adolescents, but in adults age estimation is more complicated than in younger people due to degenerative changes in teeth such as periodontitis, secondary dentin formation,



How to cite:Turk E, Gormez O, Yildirim D. Age Estimation Of Adults From Cone Beam Computed Tomography Images.EADS. 2022;49(Suppl):S37-41

root resorption and/or tooth erosion.[3,6] Due to the formation of secondary dentin with age, narrowing of the pulp cavity or tooth wear are important criterion that is taken into consideration in dental age estimation of adults.[4] Many radiographic methods based on mathematical measurements and ratios have been suggested for age estimation. Two-dimensional (periapical and panoramic radiography) and three-dimensional (cone beam computed tomography (CBCT), computed tomography (CT), or micro-CT) radiography techniques can be used for age estimation using dental structures. And these methods are noninvasive. Two-dimensional radiographs have limited visualization of dental structures due to distortion and superimposition. These disadvantages are eliminated by the use of three-dimensional radiography techniques and the measurements can be obtained more consistently and accurately. CBCT provides clinicians accurate anatomical information for diagnosis and treatment planning. There are many studies that have used CBCT to measure and calculate ratios such as pulp-tooth linear measurement ratio, pulp-tooth area ratio, pulp volume and pulp-tooth volume ratio to evaluate the relationship between age and secondary dentin deposition.[6] Kvaal et al. developed a method for determining the chronological age of people from measurement ratios by making linear measurements on periapical radiographs of maxillary central, lateral, second premolars and mandibular lateral, canines and first premolars teeth.[7] The aim of this study is to estimate age by performing linear measurements of pulp cavity of the maxillary central and canine teeth according to Kvaal's method on CBCT images in a sample of Turkish population.

## Methods

This study was approved by the Clinical Ethics Committee of Suleyman Demirel University, Faculty of Medicine (approval number 2021/266). Archival CBCT images of patients who were admitted to the Suleyman Demirel University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology between the year 2013 and 2017 were retrospectively screened. CBCT images (Planmeca Promax 3DMid, Helsinki, Finland, 2011; maxilla tomography) of right or left maxillary central incisor and canine tooth of patients over the age of 18 was included in the study. The maxillary central incisor and canine tooth that have good image quality without artifacts, no caries, no dental restorations, no root resorption or apical lesion, no periodontal disease, no previous orthodontic, prosthodontic or endodontic treatment, no developmental and morphological anomalies such as pulp stone and canal calcification were included in the study. Considering these criteria, images of 74 patients (37 female, 37 male) aged between 18 and 63 years were evaluated in this study. Linear measurements of pulp cavity of maxillary central incisor and canine tooth were made on pseudo panoramic CBCT sections using Kvaal's method. The study was performed by a one observer using Romexis software of the CBCT device. Thirty-five percent of the measurements were repeated by the same observer fifteen days after the initial measurements to assess intra-observer consistency. According to Kvaal's method described by Kvaal et al.[7] the following measurements were made on the CBCT pseudo panoramic images of the maxillary central and canine teeth (Figure 1). T: Maximum tooth length/root length P: Pulp length/root length R: Pulp length/maximum tooth length A: Pulp width at the cementoenamel junction/ tooth width at the cementoenamel junction B: Pulp width a in the middle of the distance between the middle of the root and the cementoenamel junction / tooth width in the middle of the distance between the middle of the root and the cementoenamel junction C: Pulp width at the midpoint of the root/ tooth width at the midpoint of the root M (The mean of all ratios): (P+R+A+B+C)/5 W (The mean of width ratios of B and C): (B+C)/2 L (Mean of length ratios): (P+R)/2 The applied method was made to be the same for both teeth. The maxillary central incisor or maxillary canine tooth was determined and the long axis of the tooth was adjusted perpendicular to the horizontal plane in the sagittal section (Figure 2). A panoramic curve was drawn passing through the coronal pulp of the teeth in the axial section and dental measurements performed on the formed pseudo panoramic image (Figure 3). This method provides standardization for the evaluation because the root and crown of the teeth could be observed on the same image at the same plane for each measurement. In addition, standardization was achieved in image resolution without changing the contrast in all images. The relationship between age and morphological variables was calculated by the Pearson correlation analysis. Multiple linear regression models were established for each tooth to estimate the age.

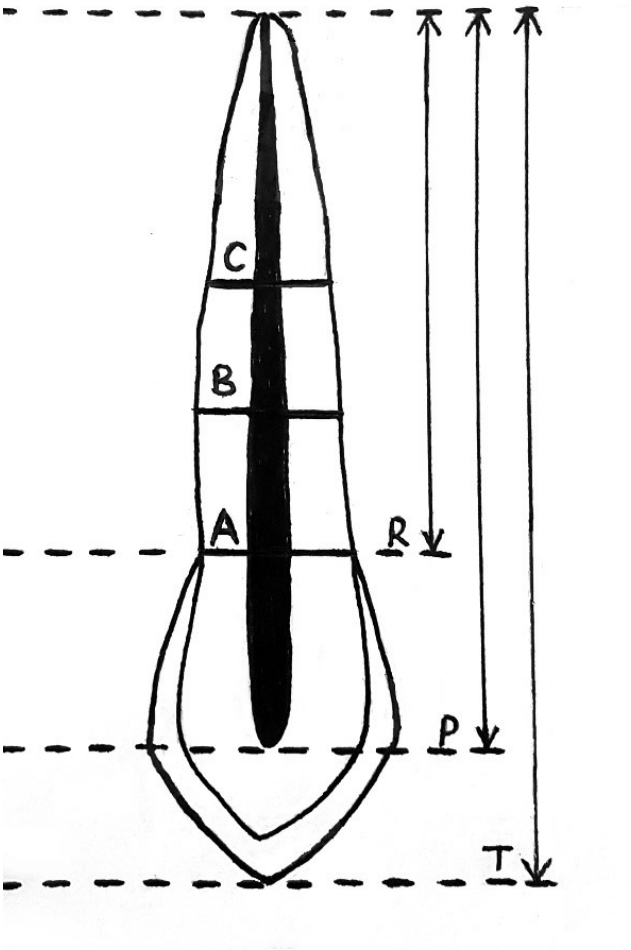


**Figure 1.** Diagram showing the ratios used on the radiographs according to Kvaal et al.[7] T: tooth/root length ratio; P: pulp/root length ratio; R: pulp/tooth length ratio; A: ratio between width of pulp and root at cementoenamel junction; B: ratio between width of pulp and root at midpoint between levels C and A; C: ratio between width of pulp and root at mid-root level

## Results

The correlation between chronological age and measurement ratios of pseudo panoramic CBCT sections according to the Kvaal's method is shown in Table 1. The formula in the created model according to the Kvaal's method is shown below: Age=[24.987-67.473 X Canine (W-L)]-[28.491 X Central Incisor (T)] The multiple regression

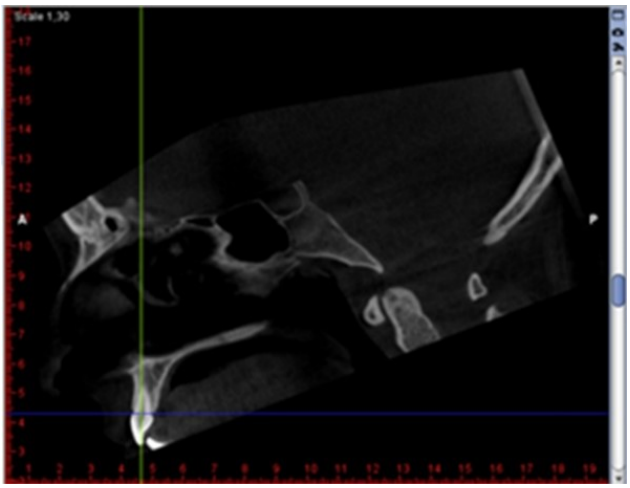

**Figure 2.** Adjusting the long axis of the tooth perpendicular to the horizontal plane in sagittal section at the beginning of the evaluation process.

**Table 1.** Correlation between chronological age and the CBCT image measurement ratios according to Kvaal's method

| Values | Maxillary central incisor tooth<br>Correlation coefficient (r) | Maxillary canine tooth<br>Correlation coefficient (r) |
|---|---|---|
| **M** | -0.173 | -0.217* |
| **W** | -0.126 | -0.342** |
| **L** | 0.154 | 0.175 |
| **P** | 0.035 | 0.082 |
| **R** | 0.242* | 0.250* |
| **A** | -0.209* | -0.119 |
| **B** | -0.088 | -0.292** |
| **C** | -0.253 | -0.298** |
| **W-L** | -0.152 | -0.397** |

P: pulp/root length ratio; R: pulp/tooth length ratio; A: ratio between width of pulp and root at cementoenamel junction; B: ratio between width of pulp and root at midpoint between levels C and A; C: ratio between width of pulp and root at mid-root level; W: mean value of width ratios from levels B and C; L: mean value of the length ratios P and R; M: mean value of all ratios.
* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

analysis that was done in order to estimate age from morphological variables resulted in maxillary canine tooth standard error of estimate=±10.42, the maxillary canine tooth coefficient of determination R2= 0.158; for the maxillary central tooth standard error of estimate=±10.65, coefficient of determination $R^2$ = 0.131; and for the both teeth standard error of estimate=±10.18, coefficient of determination $R^2$ = 0.207. The predictive power of the models was found to be low.

All experience indicates that distance education will be more than a necessity in the coming period. Especially, ensuring the continuity of service and education is very important in maxillofacial radiology, which is an indispensable branch for the scientific continuity of dentistry. Data obtained as a result of studies showed that distance education still has shortcomings in radiology practical training. Despite some drawbacks, the integration of online learning into radiology education should be utilized rapidly. It is inevitable to change hygiene habits after the pandemic and to make necessary changes in maxillofacial radiology education.

## Discussion

The methods used in age determination are generally radiological, histological, or biochemical. Radiological methods have advantages such as being easy to implement, they are fast, economical and non-invasive.[2,6] Dental age estimation can be made by examining the developmental stages and eruption status of the teeth in individuals whose tooth development is incomplete, and the age-related changes of teeth in individuals whose tooth development is complete.[3] Dental evaluations can be made by considering secondary dentin apposition and narrowing of the pulp cavity in age determination.[2] Kvaal et al.[7] first developed a method on a Norwegian sample for estimating age from measurements of length and width of the pulp cavity and tooth under a stereomicroscope using six tooth groups (mandibular lateral incisors, canines and first premolars and maxillary central and lateral incisors and second premolars) on periapical radiographs. They obtained a high correlation between the rates obtained as a result of the measurements and the age, and they created a regression model to estimate the age of the individuals whose age is unknown. They suggested that the created formula should also be evaluated in different populations. The accuracy of the Kvaal's method has been investigated in various populations in the literature.[2–4,6,8–10] Bosmans et al.[8] (Caucasian individuals), Roh et al.[9] (Korean individuals), Akay et al.[2] (Turkish individuals), Misirlioglu et al.[4] (Turkish individuals), Erbudak et al.[3] (Turkish individuals) and Aydin et al.[6] (Turkish individuals) evaluated the applicability of the Kvaal's method for age estimation in different populations. In our study, we evaluated the applicability of the Kvaal's method in Turkish individuals. In Kvaal's original study, six tooth groups (mandibular lateral incisors, canines and first premolars and maxillary central and lateral incisors and second premolars) were included. In studies using the Kvaal's method, six teeth[2,3,8], four teeth[4] or a single tooth[5,6] were evaluated and regression models were created. We included the maxillary central and canine teeth in our study, since the pulp cavity dimensions are observed more clearly than the teeth with a smaller pulp area and they are generally single-rooted. Many studies have been made on panoramic and periapical radiographs to estimate age according to Kvaal's method and different results have been reported.[2–10] Bosmans et al.[8] tried to estimate age using the Kvaal's method on panoramic radiographs instead of periapical radiographs. According to the reported Kvaal's method, maxillary central, lateral incisor, second bicuspid; and mandibular lateral incisor, cuspid and first bicuspid teeth were selected on the panoramic radiograph. Their results were similar to the study of Kvaal et al.[7] and they stated that there was no significant difference between the application of the original technique on periapical radiographs or panoramic radiographs, especially when measurements were made in all six selected teeth. Misirlioglu et al.[4] found similar results with the original research of Kvaal's method by using digital panoramic radiographs of a Turkish population and found that the pulp width was a better age indicator than the pulp length of maxillary canine teeth. Erbudak et al.[3] also evaluated the correlation between chronological and estimated age using the linear regression models presented by Kvaal et al.[7] and found that pulp cavity measurements on panoramic radiographs were insufficient to precisely estimate the age of Turkish individuals. Roh et al.[9] measured the tooth, root and pulp length and width of six tooth types (maxillary central incisor, lateral incisor, second premolar, mandibular lateral incisor, canine and first premolar) in Korean individuals using the Kvaal's method on digital panoramic radiographs. As a result of their studies, they reported that it would be appropriate to evaluate the width of tooth, root and pulp parameters without the length ratios. Sharma and Srivastava[10] reported that age estimation can be used in their study where they evaluated the applicability of the Kvaal's method to estimate the age of adults using digital periapical radiographs. However, two-dimensional imaging methods have disadvantages such as magnification and distortion to evaluate pulp cavity in three-dimensional imaging. For this reason, the Kvaal's method has also been applied to CBCT images in some studies, and different results have been reported about the applicability of the Kvaal's method to the studied teeth and population in these studies. We also used CBCT images of max-

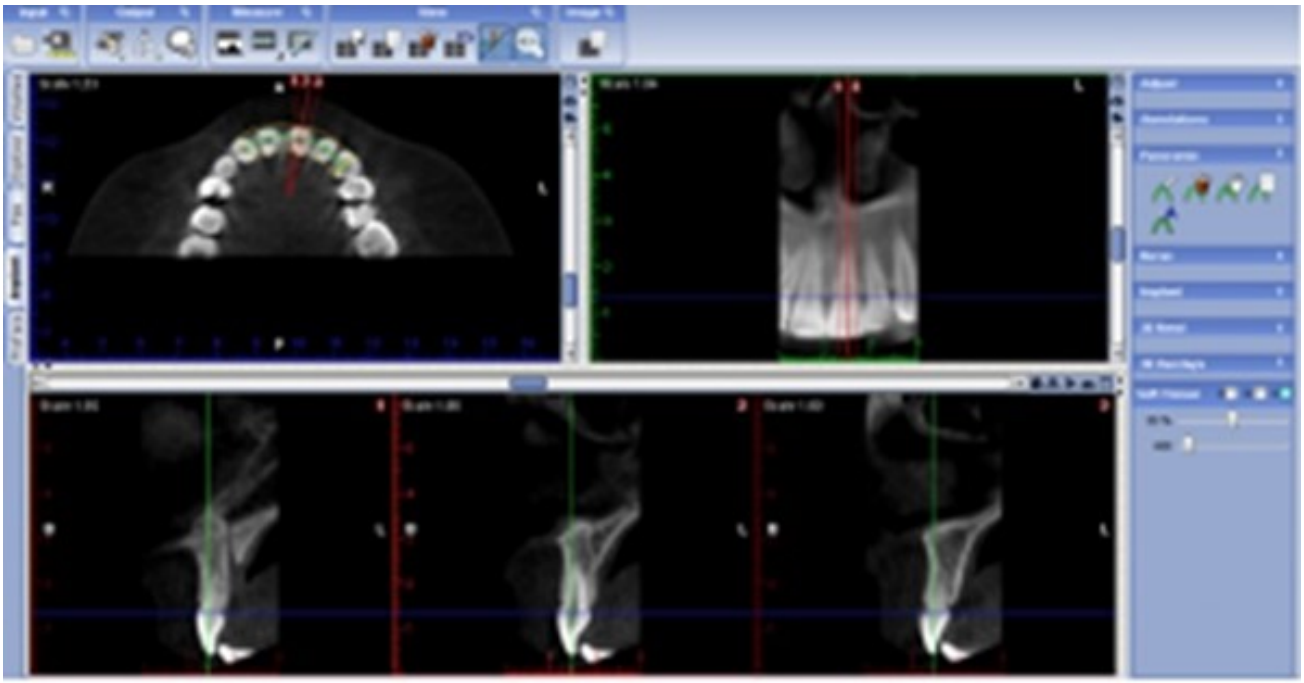

**Figure 3.** Drawing a panoramic curve passing through the coronal pulp of the teeth in the axial section and obtaining a pseudo panoramic image

illary central and maxillary canine teeth in our study. Similar to our study, Adisen et al.[5] performed linear measurements of the pulp cavity of fully erupted maxillary canines in CBCT panoramic sections according to the Kvaal's method in their study. Adisen et al.[5] stated that B and T variables had the highest correlation with the age in linear measurements in the CBCT panoramic section, and they developed a separate regression model using these two variables. In our study, the W-L value was found to have the highest correlation with age in linear measurements in the CBCT panoramic section. The difference of our study results was thought to be due to the size of the population and the difference in the standardization methods of the radiographic images. In a different study CBCT images of 211 single rooted permanent extracted teeth were evaluated. According to Kvaal's method linear measurements and ratios on CBCT images were performed and it was found to be insufficient to estimate the age of the Turkish population.[2] In our study, the Kvaal's method applied on maxillary central incisor and maxillary canine teeth on CBCT images was found to be insufficient to estimate the chronological age in a Turkish subpopulation as Akay et al.[2] reported. Since our study was performed on unextracted teeth, only CBCT pseudo panoramic images were evaluated in order to provide standardization between images in the determination of measurement points. In addition, due to the small number of teeth used in the study, the data obtained as a result of the study may not provide sufficient information about the general Turkish population. The results that differ between these similar studies may be caused by the differences in imaging techniques, preparation of image sections, quality of the image, characteristics of the computer used, and environmental conditions. The difference in the results of the studies was thought to be due to the effects of secondary dentin apposition by many factors such as race, ethnicity and diet. The measurements of tooth length, root length and pulp width used in Kvaal's method is directly affected by the dental attrition and aging of the teeth. Therefore, the evaluated sample size should be increased in order to decrease the impact of external factors causing dental tissue changes like attrition, erosion and pulp cavity narrowing. The differences between study results can also be related to the difference of evaluated population size and the number of the teeth.

## Conclusion

Linear measurements and ratios of pulp cavity of the maxillary central and canine tooth on CBCT images were insufficient to estimate the age according to Kvaal's method in a sample of Turkish population. In future studies, it is recommended to use different radiographic measurements on CBCT images with a larger sample size to increase the accuracy of age estimation in adult individuals.

None

## Author Contributions

O.G. and D.Y. conceived of the presented idea. D.Y., O.G., E.T. developed the theory and performed the computations. E.T. and O.G. verified the analytical methods. D.Y. and O.G. encouraged E.T. to investigate and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

## Conflict of Interest

Authors declare that they have no conflict of interest.

## Authors' ORCID(s)

E.T. 0000-0001-9811-7677
O.G. 0000-0001-9516-6625
D.Y. 0000-0003-3125-1358

## References

1. Demiralp KO, Kursun Cakmak S, Aksoy S, Bayrak S, Orhan K, Demir P. Assessment of paranasal sinus parameters according to ancient skulls' gender and age by using cone-beam computed tomography. Folia Morphol (Warsz). 2019;78(2):344–350. doi:10.5603/FM.a2018.0089.
2. Akay G, Gungor K, Gurcan S. The applicability of Kvaal meth-

ods and pulp/tooth volume ratio for age estimation of the Turkish adult population on cone beam computed tomography images. Australian Journal of Forensic Sciences. 2019;51(3):251–265. Available from: https://doi.org/10.1080/00450618.2017.1356872. doi:10.1080/00450618.2017.1356872.

3. Erbudak H, Ozbek M, Uysal S, Karabulut E. Application of Kvaal et al.'s age estimation method to panoramic radiographs from Turkish individuals. Forensic Sci Int. 2012;219(1-3):141–6. doi:10.1016/j.forsciint.2011.12.012.
4. Misirlioglu M, Nalcaci R, Adisen MZ, Yilmaz S, Yorubulut S. Age estimation using maxillary canine pulp/tooth area ratio, with an application of Kvaal's methods on digital orthopantomographs in a Turkish sample. Australian Journal of Forensic Sciences. 2014;46(1):27–38. Available from: https://doi.org/10.1080/00450618.2013.784357. doi:10.1080/00450618.2013.784357.
5. Adisen MZ, Keles A, Yorubulut S, Nalcaci R. Age estimation by measuring maxillary canine pulp/tooth volume ratio on cone beam CT images with two different voxel sizes. Australian Journal of Forensic Sciences. 2020;52(1):71–82. Available from: https://doi.org/10.1080/00450618.2018.1474947. doi:10.1080/00450618.2018.1474947.
6. Uğur Aydın Z, Bayrak S. Relationship Between Pulp Tooth Area Ratio and Chronological Age Using Cone-beam Computed Tomography Images. J Forensic Sci. 2019;64(4):1096–1099. doi:10.1111/1556-4029.13986.
7. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int. 1995;74(3):175–85. Available from: https://www.ncbi.nlm.nih.gov/pubmed/7557754https://www.sciencedirect.com/science/article/pii/037907389501760G?via%3Dihub. doi:10.1016/0379-0738(95)01760-g.
8. 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. Available from: https://www.ncbi.nlm.nih.gov/pubmed/16139112. doi:10.1016/j.forsciint.2004.08.017.
9. Roh BY, Lee WJ, Ryu JW, Ahn JM, Yoon CL, Lee SS. 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):1161–1166. doi:10.1007/s00414-017-1762-8.
10. Sharma R, Srivastava A. Radiographic evaluation of dental age of adults using Kvaal's method. J Forensic Dent Sci. 2010;2(1):22–6. doi:10.4103/0974-2948.71053.