Accuracy of Kvaal's radiographic and translucent dentinal root techniques of extracted teeth in Malay adults for dental age estimation

Intan Syakirah Ramli[1], Ummi Solehah Muhd[1], Mohd Yusmiaidil Putera Mohd Yusof [1,2]

[1] Center for Oral and Maxillofacial Diagnostics and Medicine Studies, Faculty of Dentistry, Universiti Teknologi MARA, Sungai Buloh, Selangor, Malaysia
[2] Institute of Pathology, Laboratory and Forensic Medicine (I-PPerForM), Universiti Teknologi MARA, Sungai Buloh, Selangor, Malaysia

Corresponding author:
yusmiaidil@uitm.edu.my

The authors declare that they have no conflict of interest.

KEYWORDS

Dental age estimation, Dentinal root translucency, Kvaal's radiographic method, Bang-Ramm method

J Forensic Odontostomatol
2021. Aug;(39): 2-38:44
ISSN :2219-6749

ABSTRACT

The use of teeth to estimate the age of unknown bodies provides much help especially in skeletal remains with no soft tissues left for identification. However, dental age estimation utilizing degenerative changes in teeth like dentinal translucency is often hampered with large margin of error. This study aims to compare the accuracy of Kvaal's radiographic method (intraoral periapical radiograph) with modified Bang-Ramm dentinal root translucency method in estimating dental age in Malay adults. One-hundred teeth of maxillary and mandibular incisors and canine were collected following dental extraction. Date of birth, date of extraction, gender and ethnicity were documented prior to extraction. All teeth were assessed using two methods of dental age estimation: 1) The equation from Kvaal's radiographic method and 2) Formula from modified Bang-Ramm dentinal root translucency method. The results from the age estimation were compared to the chronological age of the persons from whom the teeth were extracted. The average dental age estimated using both methods significantly correlated with the chronological age for both men and women. Overestimation and underestimation with mean absolute error up to 13 years and 15 years was observed in modified Bang-Ramm and Kvaal, respectively. The estimated age calculated from both methods also showed increasing standard deviation as the patient gets older. From the obtained results it is reasonable to conclude that modified Bang-Ramm method gives better accuracy for dental age estimation in Malay adults.

INTRODUCTION

According to the National Institute of Forensic Medicine Malaysia, hundreds of people die as unknown persons each year. Age assessment is an important forensic procedure in profiling the identity of these unclaimed body remains. The use of teeth to estimate the age of unknown bodies provides much help especially in skeletal remains with no soft tissues left for identification.

Dental development is complete when an individual is reaching the age of 18 to 23 years old. After this stage, dental age estimation can only be relied on degenerative changes that occur especially for early developed teeth such as permanent central incisors of maxilla and mandible. Dentin translucency in root portion is one of the major degenerative changes seen with increasing age. Root translucency develops as the dentinal tubules within a tooth root begin to mineralize from the root

apex toward the crown. [1]{Kinney, 2005 #4}{Kinney, 2005 #4}{Kinney, 2005 #4}{Kinney, 2005 #4}{Kinney, 2005 #4}{Kinney, 2005 #8193}{Kinney, 2005 #8193}{Kinney, 2005 #8193}{Kinney, 2005 #8193}{Kinney, 2005 #8193}{Kinney, 2005 #8193} Many approaches have been suggested for age estimation by means of direct and indirect observation of teeth with the use of microscope or even the science of histology. [2] One of the most simple and reliable of Gustafson's criteria for age estimation is by the measurement of root dentin translucency. [3] It starts in the apical part of root and increases with age in the coronal direction. [4] Following the study by Bang and Ramm [4], modifications had been made by Acharya based on more sample size in Indian population [2]. New linear and quadratic equations to estimate age in adults had been proposed and tested. However, none of the studies utilized Malaysian adults for validation. In addition, the particular change of dentin translucency is least affected by environmental factors and the pathological process [5, 6] and therefore, may provide a concrete dental age estimation marker in estimating the age of an adult. It also shows symmetrical distribution on both sides of jaws. [7, 8]

In 1995, Kvaal et al., developed a radiographic method using intraoral periapical radiograph to estimate dental age in aging individuals using several quantifiable parameters on different monoradicular teeth. [9] Among others, this method involved several simple mathematical equations that can easily be translated to dental age within a short period of time. This conventional method had been considered as the "gold standard" to evaluate the age of a human based on the radiological measurements. [10] The translucency measurements on the other hand, were sensitive to 0.1 mm. However, this method gave a wide range of age estimation corresponding to a specific length of dentin translucency. [11]

The purpose of this study is to compare the accuracy of Kvaal's radiographic method with modified Bang-Ramm dentinal root translucency method in estimating dental age in Malay adults.

MATERIAL AND METHODS

A total of one-hundred teeth of maxillary and mandibular incisors and canine were collected following dental extraction of Malay adult population (men/women) in this study. The sample was collected from several private dental clinics in the region. The age range for the individuals was between 24 to 56 years. The age, date of birth, date of extraction, gender, and ethnicity of the patient have been recorded for each sample. Ethics approval was obtained from the Institutional Review Board (600-IRMI (5/1/6)).

The inclusion criteria for the sample selection included sound permanent maxillary and mandibular central incisors, lateral incisors and canine with well-developed root structure, absence from any pathology such as caries, cyst, and inflammation. The exclusion criteria for this study sample included endodontically treated tooth, the tooth with fractured root and the tooth with resorbed root. The extracted teeth were thoroughly cleaned, and soft tissue remnants were removed from the root surface with a scalpel. Teeth were preserved in 10% formalin.

The weighted kappa scores were used to analyze the intra- and inter-observer reliability in reproducing the measurement values based on the out-of-sample participants. The out-of-sample participants were selected based on separate data independent from the main study. Paralleling technique with complementary metal oxide semiconductor (CMOS) digital intra-oral sensor was performed to obtain periapical images in this study. The CMOS sensor (EzSensor, pixel size 35 μm, Vatech, Hwaseong, Korea) coupled to an intraoral x-ray machine (Satelec X-Mind AC/DC, Satelec ACTEON Tuusula, Finland) was used in this study. The images were stored in JPEG format. The periapical was then measured based on maximum tooth length, pulp length and root length according to Kvaal et al., 1995 protocol (Figure 1) on each sample. The radicular portion of each tooth was then divided into levels A (the root and pulp width at enamel-cementum junction), B (root and pulp width are midway between measurement levels A and C), and C (root and pulp width midway between apex and enamel-cementum junction) and the root and the pulp width were measured at each level. Chronologically, levels A and C were first determined followed with level B. The odontometric data was then used to calculate the 'Kvaal dental ratios': the tooth/root length; the pulp/root length; the pulp/tooth length; and the root width/pulp width ratios at the three levels (A, B and C). Age estimation was then calculated based on these ratios.

The same samples were then positioned using the L-shaped scale of the ABFO No. 2 scale on the LED light box to gauge the dentinal root translucency (Figure 2). The teeth were mounted in autopolymerizing acrylic for sectioning by a Leica SP 1600 hard-tissue microtome. The level of dentinal root translucency was measured from the apex and towards coronally for each tooth. Mounted teeth were sectioned longitudinally to 250 µm in the buccolingual plane, as close as possible to the central axis of the tooth. Tooth sections were then placed adjacent to an ABFO No. 2 reference scale on a flat-bed scanner and scanned under a resolution of 600 dpi. Scanned images were imported into Adobe Photoshop Version: 21.2.2 20200807.r.289 image-editing software program for measuring translucency length. [12] The sections were coded to ensure blind assessment of translucency length. All odontometric data was then recorded and substituted in the maximum translucency length for both linear and quadratic equations of modified Bang-Ramm method to attain the estimated dental age.[2]

The estimated age calculated from both methods was further subtracted from the chronological age to identify the error (dental age − chronological age). Based on this standardization, all positive values represented overestimation while negative values exemplified underestimation of the real age. Next, the mean errors and mean absolute errors for every age group were calculated. For calibration purposes, the error was expressed as mean error (ME) to quantify the direction of the error (overestimation or underestimation) and mean absolute error (MAE) to quantify the magnitude of the error. The results were statistically analysed using RStudio version 0.99.893 - © 2009-2016 RStudio, Inc. Boston MA, USA, and Excel 2010 version 14.0.

Figure 1. Schematic diagram for odontometric measurement adapted from Kvaal et al., 1995

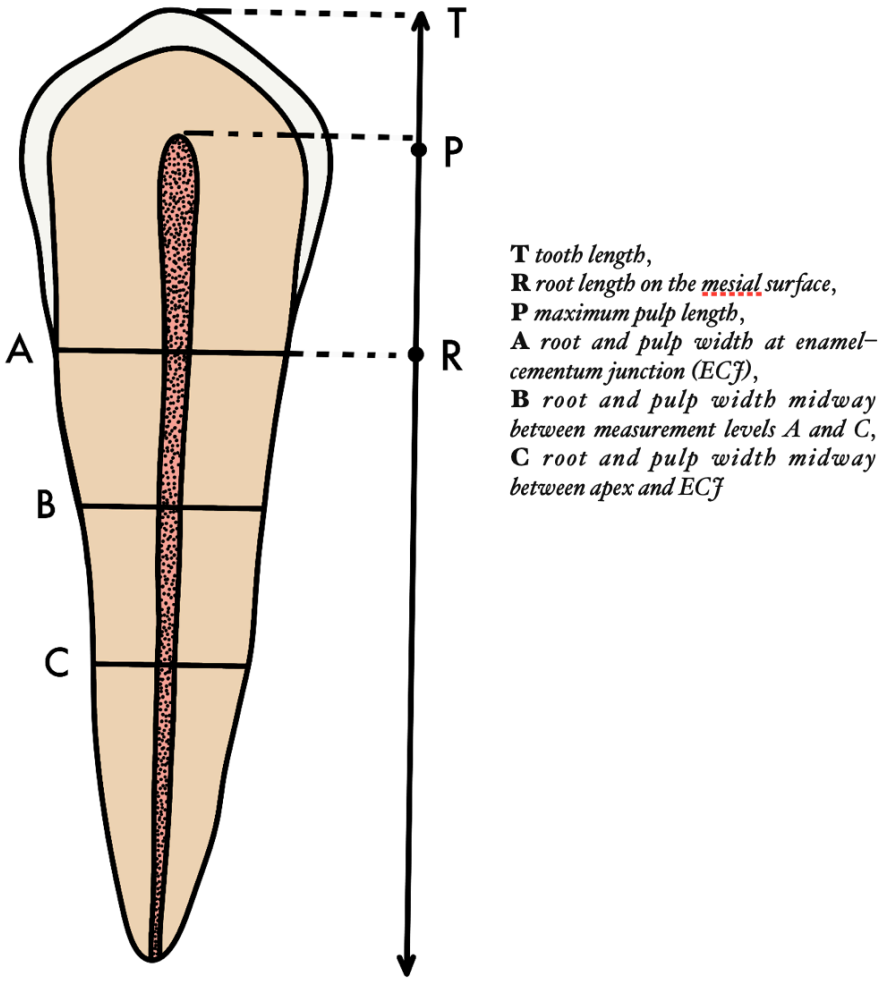
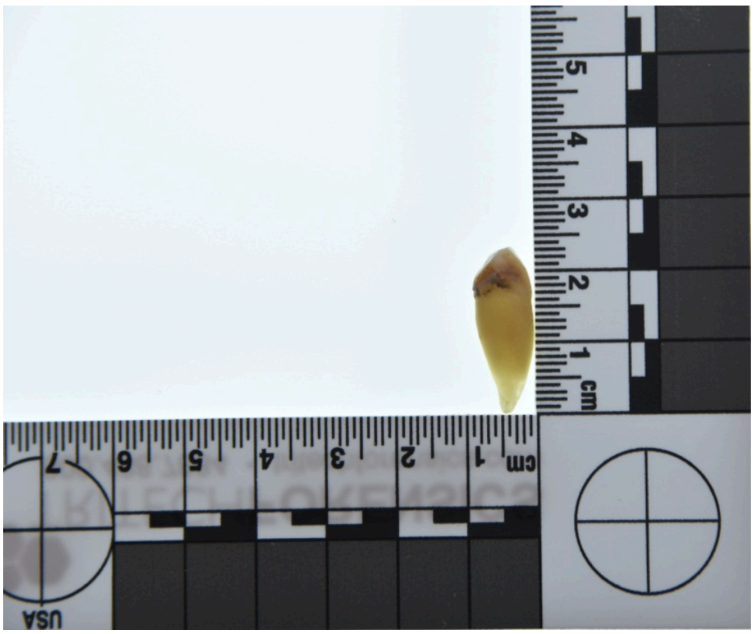


Figure 2. Enhancement of dentinal root translucency via LED light box and ABFO No. 2 scale



RESULTS

The intra- and inter-observer scores for the measurements yielded weighted kappa coefficients of 0.91 and 0.88, respectively. The mean error calculated for estimated age in relation to chronological age and tooth types (central incisor, lateral incisor, and canine) using Kvaal and modified Bang-Ramm methods are shown in Table 1. Generally, for all teeth, Kvaal method displayed positive values that indicated overestimation. In contrast, modified Bang-Ramm for both linear and quadratic equations suggested an underestimation of dental age for all monoradicular teeth. In addition, maxillary lateral incisor exhibited the lowest mean error followed with maxillary central incisor, mandibular central incisor, and maxillary canine for both equations in modified Bang-Ramm. In Kvaal, maxillary lateral incisor showed the lowest mean error followed with mandibular central incisor, maxillary canine, and maxillary central incisor.

Table 1 The mean estimated dental age in relation to chronological age by using Kvaal's and modified Bang-Ramm Linear and Quadratic equation methods

Tooth	CA (years old)	Gender	MBR_L (years old)	Error	MBR_Q (years old)	Error	Kvaal (years old)	Error
11/21	40.0	$Male_{(n=11)}$	44.7	4.7	44.3	4.3	53.4	13.4
	41.3	$Female_{(n=14)}$	47.5	6.2	47.1	5.8	54.2	12.9
12/22	42.8	$Male_{(n=12)}$	47.1	4.3	46.7	3.9	46	3.2
	43.2	$Female_{(n=13)}$	48.3	5.1	48.5	5.3	48.6	5.4
33/43	43.3	$Male_{(n=15)}$	52.1	8.8	51.4	8.1	52.3	9.0
	42.8	$Female_{(n=10)}$	53.7	10.9	52.5	9.7	54.0	11.2
31/41	34.0	$Male_{(n=12)}$	39.5	5.5	38.3	4.3	NR	NR
	36.4	$Female_{(n=13)}$	43.6	7.2	42.2	5.8	NR	NR

CA *chronological age*, **MBR_L** *modified Bang-Ramm Linear Equation*, **MBR_Q** *modified Bang-Ramm Quadratic Equation*, **M** *Male*, **F** *Female* **NR** *Not relevant*

Figure 3 exhibited the mean error for estimated age in relation to chronological age based on specific age categories. The mean error for the Kvaal technique in relation to chronological age was overestimated while the mean error for modified Bang-Ramm method for both linear and quadratic equations were underestimated. The highest mean error from the Kvaal method was at the age of 56 years (20 years) while the lowest mean error for the Kvaal method was at the age of 24 years (2.33 years). The highest mean error for linear and quadratic equations from modified Bang-Ramm method was at the age of 24 years, which were -25.33 years and -28.30 years, respectively. On the other hand, the lowest mean error was at the age of 56 years (1.3 years) calculated from the linear formula.

The mean errors generated from the modified Bang-Ramm for both linear and quadratic equation methods exhibited negative values while Kvaal method revealed a positive value (Figure 4). Furthermore, looking into the direction of the dental age estimation, the Kvaal method hinted an overestimation while the modified Bang-Ramm for both linear and quadratic equations suggested an underestimation in regard to the chronological age. Subsequently, the magnitude of the error, as calculated using the mean absolute error, showed the lowest in the modified Bang-Ramm for quadratic equation followed by linear equation and Kvaal methods. This suggests that the modified Bang-Ramm for both linear and quadratic equations method provided more accurate result in age estimation as compared to Kvaal method.

Figure 3 Mean error for estimated age in relation to chronological age based on specific age categories

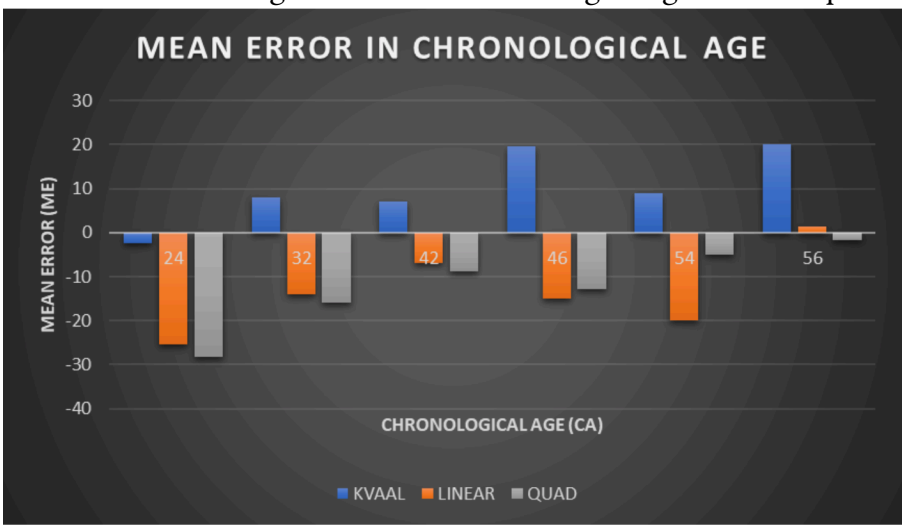
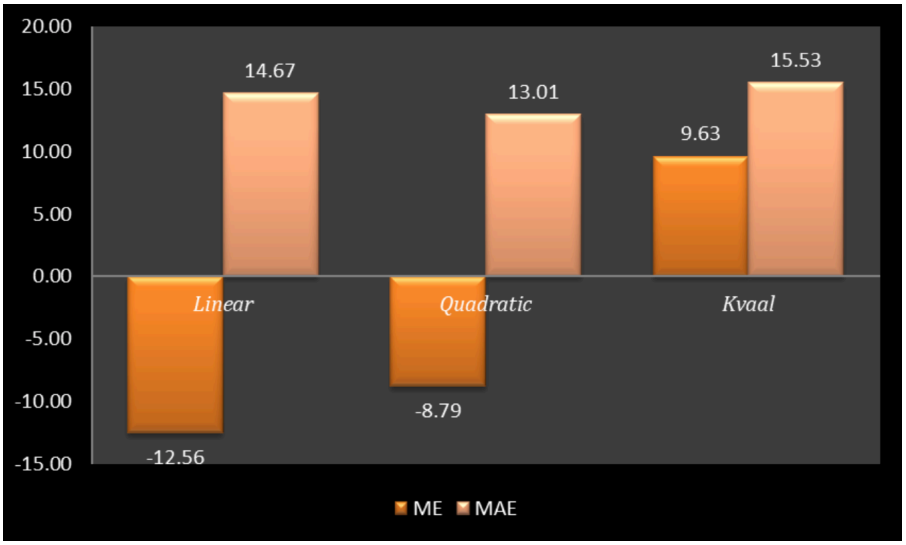


Figure 4 The mean error (ME) and mean absolute error (MAE) values from modified Bang-Ramm for Linear and Quadratic equations and Kvaal method



DISCUSSION

As part of the legal requirement and good clinical practice, the dental age estimation methods must undergo a validation to the specific population prior to being used. This is particularly pertinent to the method developed using a different set of population data. In Malaysia, there have been few studies validating dental age estimation methods using different type of predictors and age category in Malay population. [13-15] Therefore, it is imperative to continuously conduct the research and to look for the improvement on these Kvaal [9] and modified Bang-Ramm methods. [2] Hence, it is crucial to test each method in a specific population, with a large number of samples to identify method's accuracy and precision for that population.

In this study, we found that the modified Bang-Ramm method gave lesser mean absolute error as compared to Kvaal method. Comparisons with other population-specific data is difficult as most studies in literatures utilized the original method of Bang and Ramm. [4] An archeological study performed by Tang et al., 2014 revealed that the average absolute difference between real age and estimated age was 10.7 years and 8.4 years for Spitalfields and All Hallows individuals, respectively, with 58% and 75% estimated within 10 years of known age, and 29% and 33% estimated within five years of known age. [16] The margin of error is comparable to our current study that shows the error ranges from 3.9 years to 10.9 years. It is apparent in our study that the dentinal root translucency is increasing with age. A reason for modified Bang-Ramm methods to have more accurate result could be explained by the fact that those methods have been developed with different regression coefficients for each tooth. In addition, modified Bang-Ramm method extracted only one value which was the length of the dentinal root translucency while Kvaal method comprised of several values extracted from the periapical radiograph which were the ratios of the tooth/root length; the pulp/root length; the pulp/tooth length; and the root width/pulp width ratios at the three levels (A, B and C) and the age estimation were then calculated based on these ratios. The result is better in terms of the mean error. Although the method by Kvaal et al., 1995 was non-destructive, the modified Bang-Ramm method were relatively simple and required less time consumption in calculating the age estimation. This could be an important factor in forensic applications especially during disaster victim identification procedures where time and resources are the uttermost necessity. [16]

One of the advantages of Bang-Ramm method is that it can still be applicable in cases where only root is present. It is well accepted that the amount of translucent dentine increases with age, with an expansion of translucency from the apical portion of tooth to the coronal. The Bang-Ramm method is used in extracted tooth and can be assessed for translucency either in whole or sectioned. From the result, the method underestimated the age, which was contrary to Kvaal method.

Kvaal on the other hand, shows more time consumptions in terms of the application of different mathematical equation for different type of tooth. [17] The equation depends on several factors such as the type of the tooth, gender, and the particular measurements. In addition, the mean error for each type of the tooth is higher compared to the Bang-Ramm method. However, should the study be conducted with larger sample size, the result for the Kvaal method could have been more accurate.

There are several limitations in this study. First, the sample size could have been larger than a hundred. The reason being, most of the sample that had been collected suffered from missing information on either the date of birth, date of extraction, gender, or ethnicity. Thus, the sample had to be excluded from the study as they were not fulfilling the criteria needed. Some of the teeth had also been excluded due to the presence of caries involving the pulp, tooth with fractured root and tooth with resorbed root. Based on the results, it is reasonable to conclude that modified Bang-Ramm method, especially the quadratic equation, gives better accuracy for dental age estimation in Malay adults as compared to Kvaal method. This can be supported by the smallest value of mean absolute error of 13.01, 14.67 and 15.53 for modified Bang-Ramm quadratic equation, linear equation and Kvaal methods, respectively.

CONCLUSIONS

The accuracy of the modified Bang-Ramm for quadratic equation is superior to linear equation and Kvaal method in estimating the Malay adults. However, in cases where the tooth is discernable, the modified Bang-Ramm for linear equation may be utilized.

REFERENCES

1. Kinney JH, Nalla RK, Pople JA, Breunig TM, Ritchie RO. Age-related transparent root dentin: mineral concentration, crystallite size, and mechanical properties. Biomaterials. 2005 Jun;26(16):3363-76.
2. Acharya AB. Forensic dental age estimation by measuring root dentin translucency area using a new digital technique. J Forensic Sci. 2014;59(3):763-8.
3. Gustafson G. Age determination on teeth. J Am Dent Assoc. 1950 Jul;41(1):45-54.
4. Bang G, Ramm E. Determination of age in humans from root dentin transparency. Acta Odontol Scand. 1970 Mar;28(1):3-35.
5. Nalbandian J, Gonzales F, Sognnaes RF. Sclerotic age changes in root dentin of human teeth as observed by optical, electron, and x-ray microscopy. J Dent Res. 1960;39(3):598-607.
6. Azaz B, Michaeli Y, Nitzan D. Aging of tissues of the roots of nonfunctional human teeth (impacted canines). Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1977 Apr;43(4):572-8.
7. Solheim T. Dental root translucency as an indicator of age. Eur J Oral Sci. 1989;97(3):189-97.
8. Santoro V, Fiandaca C, Roca R, Marini C, De Donno A, Introna F. Validity comparison of three dental methods for age estimation based on tooth root translucency. J Forensic Sci. 2015 Sep;60(5):1310-5.
9. Kvaal SI, Kolltveit KM, Thomsen IO, Solheim T. Age estimation of adults from dental radiographs. Forensic Sci Int. 1995 Jul 28;74(3):175-85.
10. Akay G, Gungor K, Gurcan S. The applicability of Kvaal methods and pulp/tooth volume ratio for age estimation of the Turkish adult population on cone beam computed tomography images. Aust J Forensic Sci. 2017;51(3):251-65.
11. Singh S, Venkatapathy R, Balamurali P, Charles N, Suganya R. Digital approach for measuring dentin translucency in forensic age estimation. J Forensic Dent Sci. 2013;5(1):47-51.
12. Acharya AB. A new digital approach for measuring dentin translucency in forensic age estimation. Am J Forensic Med Pathol. 2010 Jun;31(2):133-7.
13. Ismail AF, Othman A, Mustafa NS, Kashmoola MA, Mustafa BE, Mohd Yusof MYP. Accuracy of different dental age assessment methods to determine chronological age among Malay children. J Phys Conf Ser. 2018 Jun;1028:012102.
14. Mohd Yusof MYP, Wan Mokhtar I, Rajasekharan S, Overholser R, Martens L. Performance of Willem's dental age estimation method in children: A systematic review and meta-analysis. Forensic Sci Int. 2017 Nov;280:245 e1- e10.
15. Mohd Yusof MY, Cauwels R, Martens L. Stages in third molar development and eruption to estimate the 18-year threshold Malay juvenile. Arch Oral Biol. 2015 Oct;60(10):1571-6.
16. Tang N, Antoine D, Hillson S. Application of the Bang and Ramm age at death estimation method to two known-age archaeological assemblages. Am J Phys Anthropol. 2014 Nov;155(3):332-51.
17. 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):208-12.