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Original Research

Buccolingual root dimension of permanent mandibular canines as a complementary estimator of sex: a pilot study

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ABSTRACT

Objective: To evaluate the potential of the buccolingual dimension of the permanent mandibular canine roots as a sex estimator, using midsagittal cone-beam computed tomography images.

Methods: In this retrospective study, 58 Portuguese patients (27 female and 31 male) aged 18-60 years were assessed. The maximum buccolingual dimension of the cervical root was measured in the midsagittal plane through cone-beam computed tomography images. The Bland-Altman method was applied for the reliability analysis, and a receiver operating characteristics (ROC) curve was obtained for accuracy analysis.

Results: The buccolingual root dimension on the mandibular canine showed statistically significant differences between sexes ($t_{56\ df} = 4.871$; $p<0.0005$). The optimal cut-off to differentiate males from females was 6.64 mm. The area under the curve (AUC) was 83.5% ($p<0.0005$). An overall accuracy of 79% was obtained. The percentage of males correctly estimated was 77.4%, compared to 81.5% of females.

Conclusions: Our data suggest that canines' buccolingual root dimension can serve as a complementary tool for sex estimation in a forensic context. (Rev Port Estomatol Med Dent Cir Maxilofac. 2021;62(4):217-222)

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Dimensão bucolingual da raiz dos caninos mandibulares permanentes como um estimador complementar do sexo: um estudo piloto

Palavras-chave:
Tomografia computorizada de feixe cónico
Antropologia forense
Odontologia forense
Identificação humana
Odontometria

RESUMO

Objetivo: Avaliar o potencial da dimensão buco-lingual das raízes permanentes de caninos mandibulares para a diagnose sexual, utilizando imagens sagitais de tomografia computadorizada de feixe cónico (CBCT).

Métodos: Neste estudo retrospetivo, foram avaliados 58 pacientes portugueses (27 mulheres e 31 homens) com idades entre 18 e 60 anos. A dimensão buco-lingual máxima da parte cervical da raiz foi medida no plano sagital mediano, por meio de imagens de tomografia computadorizada de feixe cónico. O método de Bland-Altman foi aplicado para a análise de confiabilidade, e obtida uma curva receiver operating characteristics (ROC) para a análise de precisão.

Resultados: A dimensão buco-lingual da raiz do canino mandibular apresenta diferenças estatisticamente significativas entre os sexos ($t_{56\ df} = 4{,}871$; $p<0{,}0005$). O ponto de corte ideal para diferenciar entre sexos foi de 6,64 mm. A área sob a curva (AUC) foi de 83,5% ($p<0{,}0005$). Foi obtida uma precisão geral de 79%. O percentual de homens corretamente estimado foi de 77,4%, sendo o valor nas mulheres de 81,5%.

Conclusões: Nossos dados sugerem que a dimensão buco-lingual da raiz canina pode contribuir como uma ferramenta complementar para a estimativa do sexo em um contexto forense. (Rev Port Estomatol Med Dent Cir Maxilofac. 2021;62(4):217-222)

Introduction

Biological profile features, such as age, sex, ancestry, and stature, are key elements in reconstructing human identity. When unidentified remains show an advanced stage of degradation and/or a high degree of destruction, teeth can offer valuable information due to their morphological features and great resistance to extreme environmental conditions.[1,2]

Dental radiographs obtained through conventional x-rays, such as periapical, bitewing, occlusal, and orthopantomogram (OPG), provide two-dimensional (2D) data of the lower face in clinical settings. These 2D images have also been conventionally used for human identification in forensic contexts.[1] Cone-beam computed tomography (CBCT) has started being widely incorporated in dental clinics due to its many advantages and possibilities. This imaging technique can generate three-dimensional (3D) high-resolution oral and maxillofacial images after reconstructing data from axial, sagittal, and coronal planes.[3]

Different forensic odontology groups proposed using 3D image-based techniques by CBCT to obtain more accurate biological profile features, such as age and sex.[4-8] Some of those methods include volumetric and dimensional assessment of the dental crown,[4,5] determination of the pulp cavity volume,[6,7] and volumetric analysis of the pulp/tooth ratio.[8]

Among permanent teeth, mandibular canines are considered those that exhibit the greatest sexual dimorphism and are therefore adopted, by many, as the tooth of choice for sexual estimation studies.[4,6,9,10] From a methodologic point of view, the mandibular canine index appears in the literature as an adequate and easy predictor for sex estimation.[11] However, the mesiodistal width of a mandibular canine crown has recently been suggested as a simpler technique with higher sex prediction accuracy.[10]

Like the rest of the teeth, canines show resilience to extreme physical and chemical conditions observed in circumstances where human identification is challenging, such as mass disasters, crashes, or fires.[12-14] Moreover, they have a long and strong single root inserted in the alveolar bone, which favors its permanence in the oral arch.[15] Nevertheless, a significant impact on teeth can lead to crown fragmentation, causing all metric methods using the canine's crown dimensions to become useless under these circumstances. The development of methods for sex estimation based on teeth roots can therefore be an alternative or complementary tool when other methods are not applicable. Accordingly, this study aims to evaluate the potential of the buccolingual (BL) dimension of the permanent mandibular canine roots as a sex estimator, using sagittal CBCT images.

Material and methods

This retrospective transversal observational study was conducted at a university dental clinic in Portugal. The sample was composed of 58 Portuguese patients (27 female and 31 male) drawn from non-randomly selected patients who attended the dental clinic from January 2019 to January 2020.

The inclusion criteria were: patients aged 18 to 60 years of Portuguese nationality and Portuguese descent presenting at

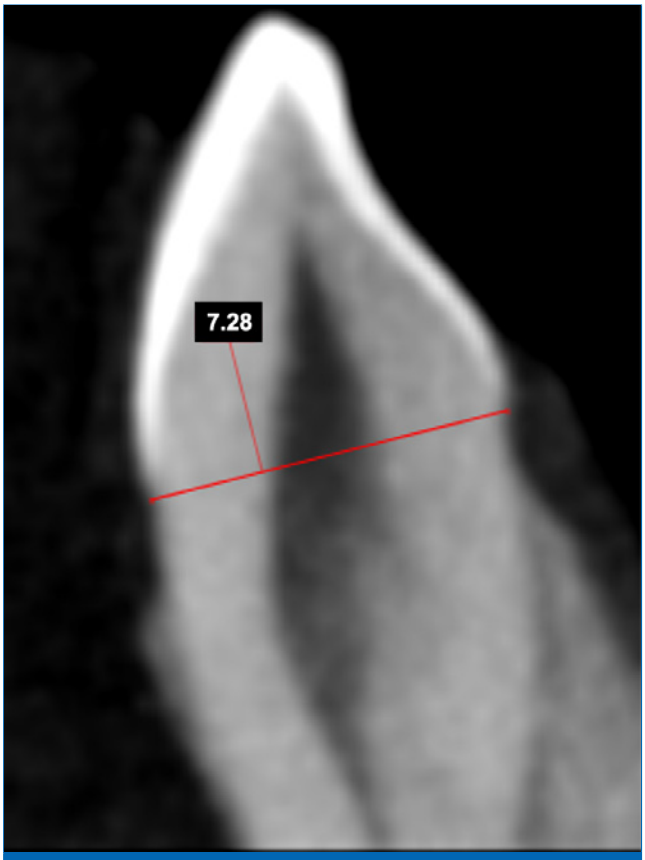

Figura 1. Measurement of the buccolingual root dimension on the cervical margin of a mandibular canine.

least one intact mandibular canine. The exclusion criteria were: patients showing canines with therapeutic, pathological, or physiological root modification affecting the cervical region (such as cervical caries, restorations or sealants, abrasion or attrition injuries, and rotations) and images of canines without a distinctive cementoenamel junction (CEJ). Patients aged over 60 years were excluded to reduce the number of individuals with missing teeth or morphological alterations, frequently associated with advanced age.

This study followed the ethical standards of the responsible committee on human experimentation (institutional and national) and the Helsinki Declaration of 1975, as revised in 2008. The study was approved by the institution's Ethics Committee (Protocol number: 4/CE-IUCS/2020). Written informed consent was obtained from all patients.

The buccolingual (BL) length of the permanent mandibular canine's cervical margin was obtained using CBCT images from the ProMax 3D Plus device (Planmeca, Finland). A voxel size of 0.2 mm and 0.15 mm and the same energy parameters (90 kV and 10 mA) were used. The maximum BL dimension was measured in the midsagittal plane, as shown in Figure 1. On the midsagittal reconstruction, the axial plane that intercepted the most apical extension of the enamel on the buccal or the lingual surface was established as the cervical margin. The Romexis® 3D imaging software was used to draw straight lines from the CEJ (from buccal to lingual) and measure the distances. A single previously calibrated observer performed the measurements three times within a timeframe of 4 days and was blind to previous measurements. In order to consider cases with a single mandibular canine, left or right mandibular canines were used indiscriminately.

The statistical analysis was performed using the IBM SPSS Statistics for Windows (V.25.0) software program. The Bland-Altman method was performed with the 2nd and 3rd measurements for reliability analysis (Figure 2). The final BL data corresponded to the average of these two measurements. The assumption of normality was accepted for the Bland-Altman measures (KS; $p > 0.05$). The error between the measures was -0.0024 ± 0.029 mm. The intra-observer error was between -0.0612 mm and 0.0564 mm, with a probability of 95%. The error measurement was lower than the difference between the two groups (males and females), which was 0.77 mm. In order to apply the *t* test for independent samples, the assumption of normality and homogeneity of variances were tested by a

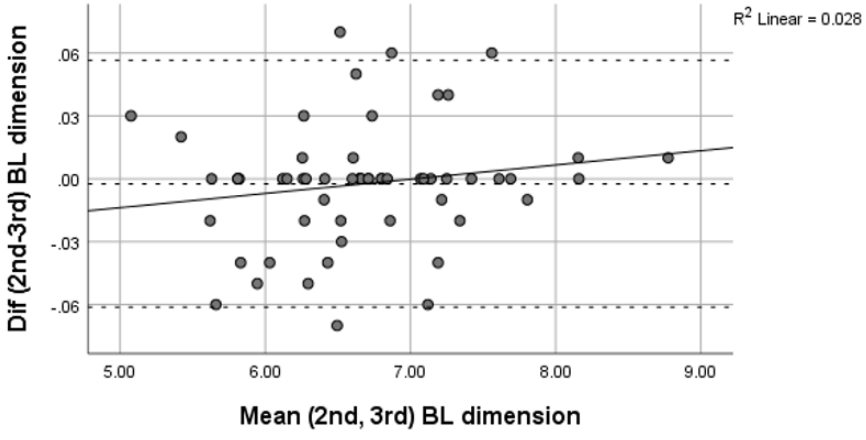

Figura 2. Bland-Altman analysis related to the buccolingual dimension on the 2nd and 3rd measurements (mm) with the mean error and upper and lower limits for a 95% probability.

Kolmogorov-Smirnov test and a Levene's test, respectively. The groups were compared using the *t* test, followed by the accuracy analysis with the receiver operating characteristics (ROC) curve, after calculating the sensitivity and specificity. Then, a cut-off value was obtained discriminating males from females. A statistical significance level of 0.05 was considered.

Results

The male group had an average BL measure (7.03 ± 0.69 mm) higher than the female group (6.26 ± 0.49 mm). The box plot (Figure 3) shows that the measurements taken from a male's mandibular canine are remarkably larger than those of a female. A median of 7.09 mm and an interquartile range of 0.77 mm were obtained for the male sex, and 6.28 mm and 0.78 mm, respectively, for the female sex.

The normality (KS; $p>0.05$) and the homogeneity of the variances (F=2.524; $p>0.12$) were accepted for both populations. The mean difference between sexes in the BL root dimension (0.78±0.16 mm) was statistically significant ($t_{56\ df} = 4.871$; $p<0.0005$).

The ROC curve is presented in Figure 4. The area under the curve (AUC) was 83.5%, and it was statistically significant ($p<0.0005$). For an optimal cut-off of 6.64 mm for the BL root dimension, the overall accuracy was around 79%. The percentage of males correctly classified was 77.4%, whereas for females was 81.5% (Figure 4).

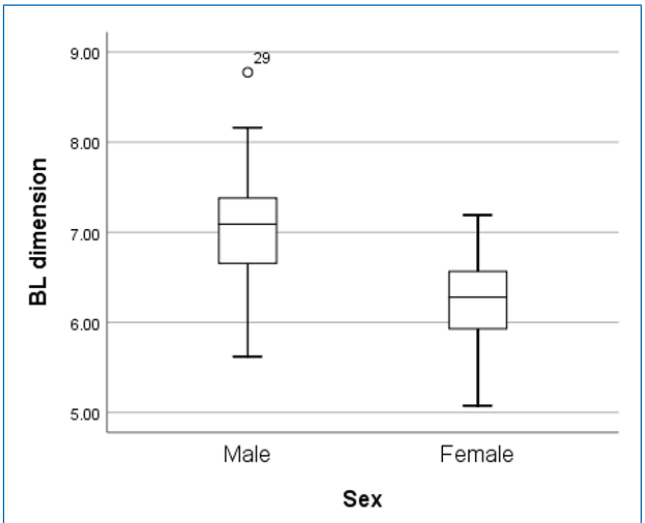

Figura 3. Box plot for buccolingual root dimension by sex.

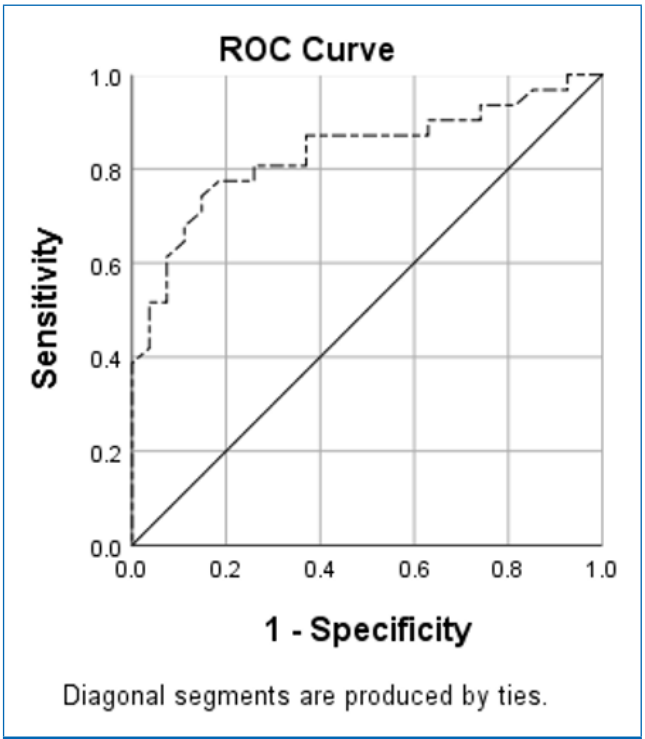

Figura 4. ROC curve for buccolingual root dimension of the mandibular canine.

Discussion

Sex estimation methods are fundamental in the process of human identification, and when sex cannot be determined, the reconstruction of the identity is compromised.[4,16] In the absence of pelvic or skull bones (the gold standards for sex estimation) or when the bone analysis is inconclusive, teeth can be an alternative way to rapidly estimate an individual's sex.[10,17]

The odontometric difference between males and females is generally explained by specific gene expression patterns. Consequently, absolute tooth size and proportions tend to be greater in males.[18] Canines are considered the key teeth for sex estimation, showing the highest sexual dimorphism, followed by premolars, first and second molars, and maxillary incisors.[4,19] Mandibular canines are the preferred teeth of many researchers aiming to develop sex estimation methods based on tooth dimensions. Most of these methods consider mesiodistal crown distance and/or mandibular inter-canine width.[4,9,10,11,20-23] Studies measuring teeth root dimensions for sex estimation are much less frequent, although some anthropological works showed positive results using canine root length or neck dimensions by measuring directly on teeth or through x-ray images.[24-27]

Although canines are very solid teeth, in violent situations such as crash disasters, natural disasters, terrorist attacks, and fires, or simply by prolonged exposure to taphonomic phenomena, teeth crown fragmentation may occur, making methods based on crown measurements impossible. The strong and protected canine root may then serve as an alternative solution. In situations where the dental material is in a deteriorated and fragile state, computed tomography can provide a non-destructive approach and collect not only 3D images but also dental midsagittal planes that are impossible to obtain with conventional x-rays.[28] Yet, its accuracy and real forensic application in dental post-mortem evaluation need to be fully demonstrated.

CBCT is a complex technique that also has some limitations: i) CBCT technicians/operators need to be trained; ii)

measuring precautions need to be taken to avoid poor image quality (beam hardening, image noise, scatter, ring artifacts, motion artifacts), which could result in the exclusion of many images;[29] iii) the CBCT device is expensive and is not available in all dental clinics, legal medicine institutes or scientific police departments. Other limitations in studies like this include pathological or physiological modifications of the teeth (mainly tooth rotation and cervical attrition) that hinder or prevent the image analysis. However, post-mortem computed tomography is being positively evaluated as a complementary method for dental identification purposes nowadays.[30,31] Moreover, the costs of acquiring a device are currently decreasing, and new improvements such as the development of mobile units are being carried out.[32,33] In our view, we are likely to soon witness a widespread use of the CBCT in multiple forensic scenarios.

In this pilot study, we aimed to provide data showing the potential of mandibular canine roots for estimating sex in an adult Portuguese population. A statistically significant difference was found between males and females concerning the cervical BL root dimension of the mandibular canine, and a cut-off was provided. One limitation of this method is the appearance of wear in the cervical region of the canine, more frequent in advanced ages. In these cases, it would not be possible to use the proposed methodology since the original tooth dimension would be altered. Other therapeutic, pathological, or physiological root modifications affecting the cervical region, such as caries, restorations, or rotations, must also be previously checked by the dentist (or trained operator) to avoid misinterpretations. No differences between left and right mandibular canines were found by other authors in a Portuguese population when the mesial-distal dimension of the crown was used as a sex estimator.[10] It would be necessary to confirm whether it is also the case for the cervical BL root dimension.

This pilot study used a small non-random sample; hence, further research in a larger and random population is required to fully validate the usefulness of the proposed method. However, we believe that these preliminary results deserve attention and that this method can contribute in the future as a complementary tool for sex estimation in a forensic context.

Conclusion

The cervical buccolingual root dimension on the mandibular canine showed statistically significant differences between sexes in a Portuguese population sample. This dimension may contribute as a complementary tool for sex estimation, particularly when the canine crown is unavailable. Nevertheless, further studies are needed to validate its application in a forensic context.

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Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed their work center protocols on access to patient data and for its publication.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

Conflict of interest

The authors have no conflicts of interest to declare.

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REFERENCES

1. Adams C, Carabott R, Evans S (eds). Forensic Odontology: An Essential Guide. Wiley-Blackwell, United States. 2014. p. 305.
2. Acharya J, Shrestha R, Shrestha PK, Kanchan T, Krishan K. When Protocols Become Fairy Tales and Gods Remain Buried Under: Excerpts From the Diary of Forensic Experts at Ground Zero During the Mega Quake That Hit Nepal. Am J Forensic Med Pathol. 2017;38:5-8.
3. Jain S, Choudhary K, Nagi R, Shukla S, Kaur N, Grover D. New evolution of cone-beam computed tomography in dentistry: Combining digital technologies. Imaging Sci Dent. 2019;49:179-90.
4. Capitaneanu C, Willems G, Thevissen P. A systematic review of odontological sex estimation methods. J Forensic Odontostomatol. 2017;35:1-19.
5. Manhaes-Caldas D, Oliveira ML, Groppo FC, Haiter-Neto F. Volumetric assessment of the dental crown for sex estimation by means of cone-beam computed tomography. Forensic Sci Int. 2019;303:109920.
6. De Angelis D, Gibelli D, Gaudio D, Noce FC, Guercini N, Varvara G, et al. Sexual dimorphism of canine volume: a pilot study. Leg Med. 2015;17:163-6.
7. Andrade VM, Fontenele R, De Souza AC, De Almeida CA, Vieira AC, Groppo FC, et al. Age and sex estimation based on pulp cavity volume using cone beam computed tomography: development and validation of formulas in a Brazilian sample. Dentomaxillofac Radiol. 2019;48:20190053.
8. Asif M, Nambiar P, Mani S, Ibrahim N, Khan I, Lokman N. Dental age estimation in Malaysian adults based on volumetric analysis of pulp/tooth ratio using CBCT data. Legal Medicine. 2019;36:50-8.

9. Radlanski RJ, Renz H, Hopfenmuller W. Sexual dimorphism in teeth? Clinical relevance. Clin Oral Investig. 2012;16:395-9.
10. Azevedo A, Pereira ML, Gouveia S, Tavares JN, Caldas IM. Sex estimation using the mandibular canine index components. Forensic Sci Med Pathol. 2019;15:191-7.
11. Rao NG, Rao NN, Pai ML. Kotian MS. Mandibular canine index–a clue for establishing sex identity. Forensic Sci Int. 1989;42:249-54.
12. Goodman NR. Case report: An identification of a burn victim by utilizing recent dental extraction healing sites. Disaster Prevention and Management. 2000;9:8-14.
13. Schuller-Götzburg P, Suchanek J. Forensic odontologists successfully identify tsunami victims in Phuket, Thailand. Forensic Sci Int. 2007;171:204-7.
14. Prajapati G, Sarode SC, Sarode GS, Shelke P, Awan KH, Patil S. Role of forensic odontology in the identification of victims of major mass disasters across the world: A systematic review. PLoS One. 2018;13:e0199791.
15. Scheid RC, Weiss G. Woelfel's Dental Anatomy. 8th edition. Wolters Kluwer, Philadelphia. 2017. p. 504.
16. Krishan K, Chatterjee PM, Kanchan T, Kaur S, Baryah N, Singh RK. A review of sex estimation techniques during examination of skeletal remains in forensic anthropology casework. Forensic Sci Int. 2016;261:165.e1-8.
17. Işcan MY, Steyn M. The Human Skeleton in Forensic Medicine. 3rd Ed. Springfield, IL: Charles C. Thomas. 2013. p. 493.
18. Nagare SP, Chaudhari RS, Birangane RS, Parkarwar PC. Sex determination in forensic identification, a review. J Forensic Dent Sci. 2018;10:61-6.
19. Capitaneanu C, Willems G, Jacobs R, Fieuws S, Thevissen P. Sex estimation based on tooth measurements using panoramic radiographs. Int J Legal Med. 2017;131:813-21.
20. Yadav S, Nagabhushana D, Rao BB, Mamatha GP. Mandibular canine index in establishing sex identity. Indian J Dent Res. 2002;13:143-6.
21. Bakkannavar SM, Monteiro FN, Arun M, Pradeep Kumar G. Mesiodistal width of canines: a tool for sex determination. Med Sci Law. 2012;52:22-6.
22. Rajarathnam BN, David MP, Indira AP. Mandibular canine dimensions as an aid in gender estimation. J Forensic Dent Sci. 2016;8:83-9.
23. Gandhi N, Jain S, Kahlon H, Singh A, Gambhir RS, Gaur A. Significance of mandibular canine index in sexual dimorphism and aid in personal identification in forensic odontology. J Forensic Dent Sci. 2017;9:56-60.
24. Garn SM, Cole PE, Van Alstine WL. Sex discriminatory effectiveness using combinations of root lengths and crown diameters. Am J Phys Anthropol. 1978;50:115-8.
25. Alt KW, Riemensperger B, Vach W, Krekeler G. Zahnwurzellänge und Zahnhalsdurchmesser als Indikatoren zur Geschlechtsbestimmung an menschlichen Zähnen [Tooth root length and tooth neck diameter as indicators in sex determination of human teeth]. Anthropol Anz. 1998;56:131-44.
26. Zorba E, Vanna V, Moraitis K. Sexual dimorphism of root length on a Greek population sample. Homo. 2014;65:143-54.
27. Govindaram D, Bharanidharan R, Ramya R, Rameshkumar A, Priyadharsini N, Rajkumar K. Root Length: As a determinant tool of sexualdimorphism in an ethnic Tamil population. J Forensic Dent Sci. 2018;10:96-100.
28. Nguyen E, Doyle E. Dental Post-mortem Computed Tomography for Disaster Victim Identification: A literature review. Journal of Forensic Radiology and Imaging. 2018;13:5-11.
29. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006;72:75-80.
30. Eliášová H, Dostálová T. 3D Multislice and Cone-beam Computed Tomography Systems for Dental Identification. Prague Med Rep. 2017;118:14-25.
31. Jensen ND, Arge S, Hansen NF, Lynnerup N. Post-mortem computed tomography as part of dental identification – a proposed guideline. Forensic Sci Med Pathol. 2019;15:574-9.
32. Dental Imaging Equipment Market. Future Market Insight. June 2020. Retrieved March 27, 2021, from https://www.futuremarketinsights.com/reports/dental-imaging-equipment-market
33. Sheth NM, De Silva T, Uneri A, Ketcha M, Han R, Vijayan R, Osgood GM, Siewerdsen JH. A mobile isocentric C-arm for intraoperative cone-beam CT: Technical assessment of dose and 3D imaging performance. Med Phys. 2020;47:958-74.