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AI-Powered CNNs Analysis of Mandibular First Pre Molars Radiographic Morphology for Sexual Dimorphism in the South Western Population

Análisis de la Morfología Radiográfica de los Primeros Premolares Mandibulares para el Dimorfismo Sexual en la Población del Suroeste Mediante Redes Neuronales Convolucionales Impulsadas por IA

Zeeshan Qamar[1]; Eisa Alturki[2]; Hamad Almutawtah[2]; Mesfer Alajmi[2] & Sager Al Shatti[2]

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SUMMARY: The first mandibular pre-molars have been considered for sexual dimorphism on their manual morphometric characteristics. Though there is a debate on its reliability for correct predilection of the sexes. The aim of the research was to evaluate the performance of convolutional neural network (CNNs) in distinguishing between males and females based on the radiographic morphology of left mandibular first pre-molars on 2-D images (OPGs). The data was collected from 12,915 patients comprising of 5983 males and 6932 females respectively with an age group of 14-29.99 years. The radiographic data was analyzed by Darwin V7 software trailed by DenseNet121 CNNs was used for identification of males and females across 14-29.99 years of age groups. The performance of the CNNs was measured using the rate of accuracy, confusion matrices and ROC curves. The range for the rate of accuracy was 63.20 % - 73.4 % with mean standard deviation of 68.65 %±3.31 %. The AUC for the ROC curve analysis ranged between 0.63 for 29-29.99 years age group and 0.73 for 18-18.99 years age group. In conclusion it can be suggested that the morphometric analysis of the left mandibular first pre-molars can be used under certain situations where other anatomical characteristic features are unattainable for sexual determination.

KEY WORDS: Artificial intelligence; Convolutional neural networks; Mandibular first pre-molar; Radiology; Sexual dimorphism.

INTRODUCTION

Morphology of the teeth has a substantial role in the field of forensic sciences. Forensic sciences have been utilized for numerous purposes like comparative sex predilection via morphological landmarks of general body features; clinical and non-clinical images of the oral cavity viewing the incisal edges inclinations, analyzing bite marks and odontological age estimation (Rao *et al*., 1989; Schuller-Gotzburg & Suchanek, 2007; Franco *et al*., 2013; Angelakopoulos *et al*., 2017; Franco *et al*., 2022a; Merdietio Boedi *et al*., 2023a; Naidu *et al*., 2022). Determining sex of a deceased individual is a common task at the edge of forensic odontology and anthropology, helping to narrow down lists of missing persons, particularly identification of the victims encountered disaster (Franco *et al*., 2015). Once the sex has been determined, human identification becomes more convenient.

A systematic review analyzing the previous records (1,806), identified studies (53) focusing on sexual dimorphism stating about utilizing the human teeth as a tool (Schwartz & Dean, 2005). Precisely, the canines of the mandibular arch have been studied and reported to have moderate useful applicability (Capitaneanu *et al*., 2017). Additionally it has been recommended as a supplemental tool for identification of sexual dimorphism. In the primates, the sexual dimorphism has been strongly expressed for the canines, lateral incisors, and pre-molars (Rocha *et al*., 2022; Merdietio Boedi *et al*., 2023b). Being located in the field of canine, the mandibular first pre-molars are considered to have an increased value of revealing strong sexual dimorphism. However, researchers have noted that current conventionally employed techniques either have low

[1] Department of O&MFS and Diagnostic Sciences, College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia.
[2] College of Medicine and Dentistry, Riyadh Elm University, Riyadh, Saudi Arabia.

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accuracy or require complex equipment for accurate determination of sexual dimorphism.

Advancement in the technology has led to employ artificial intelligence in healthcare. The use of software Convolutional Neural Networks (CNNs) could be effective in differentiating between males and females from the routine radiographic images (Qamar *et al*., 2020; Franco *et al*., 2022b; Franco *et al*., 2024). This task becomes more challenging when assessing the age and differentiating adolescents from the adults, as they typically have developed pubertal characteristics. The CNNs has been reported to have achieved accuracy rates between 80–83 % for individuals under 15 years of age, and between 84–87 % for those aged 15 to 23 years on validating with the canines. Despite these promising accuracy levels tested on the canines, CNNs require a thorough analysis of all visible teeth in a panoramic radiograph, particularly emphasizing coronal morphology (Franco *et al*., 2022a). The current challenge is to reduce computational demands by selecting more targeted radiographic image sources for sexually dimorphic features, such as focusing on mandibular first pre-molar instead of the entire dentition.

CNNs have been successfully used in various medical and dental applications, including the detection of diseases and age estimation. The ability of CNNs to recognize subtle morphological differences offers an exciting opportunity to explore their potential in sex determination based on dental radiographs. By focusing on the left mandibular first premolars, this study will contribute to forensic dental science, potentially offering a reliable and less time-consuming alternative for sex estimation, especially in challenging forensic cases. Thus, this study evaluated the performance of convolutional neural network (CNNs) in distinguishing between males and females based on the radiographic morphology of left mandibular first premolars.

MATERIAL AND METHOD

An observational analytical cross-sectional retrospective study was conducted on ethical approval from Riyadh Elm University (FUGRP/2024/369/1161). The samples were selected from an existing oral radiology database of tertiary care hospitals in Saudi Arabia. All images were obtained for diagnostic and therapeutic dental purposes, ensuring that no patient was exposed to radiation for research reasons. The number of subjects included in the study was 12,915 including 5983 male and 6932 females of various age groups as shown in Figure 1.

Inclusion criterion was: i) include the male and female patients with a digital panoramic radiograph (OPG) stored in the database; ii) individuals visited tertiary care dental

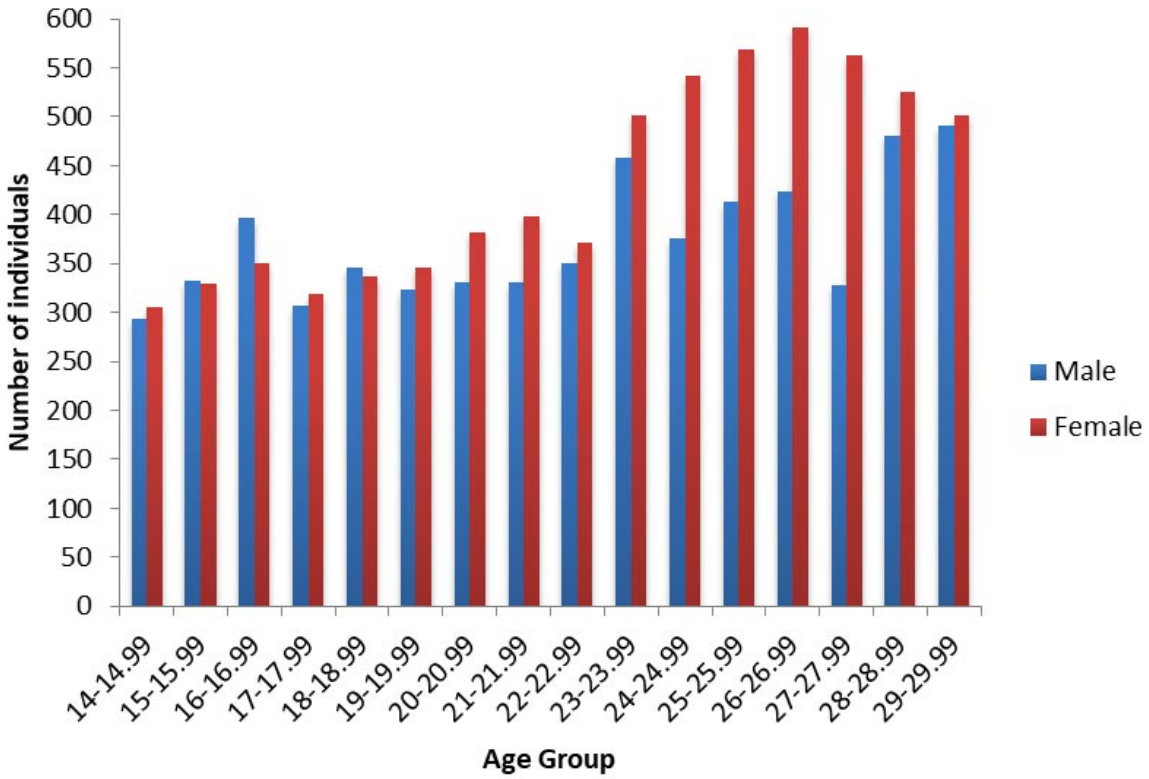

Fig. 1. Number of male and female participants of various age groups

hospital of Riyadh; & iii) aged between 14-29.99 years (Fig. 1). Exclusion criterion was: i) radiographs lacking information about the patient's sex, date of birth, and the date of radiographic acquisition; ii) missing the mandibular left first pre-molar (Fédération Dentaire Internationale, tooth #34); iii) patients with visible bone lesions & iv) radiographs of poor quality. The extent of the first mandibular pre-molar was outlined using the polygonal tool as displayed in Figure 2 and discussed under phase 1.

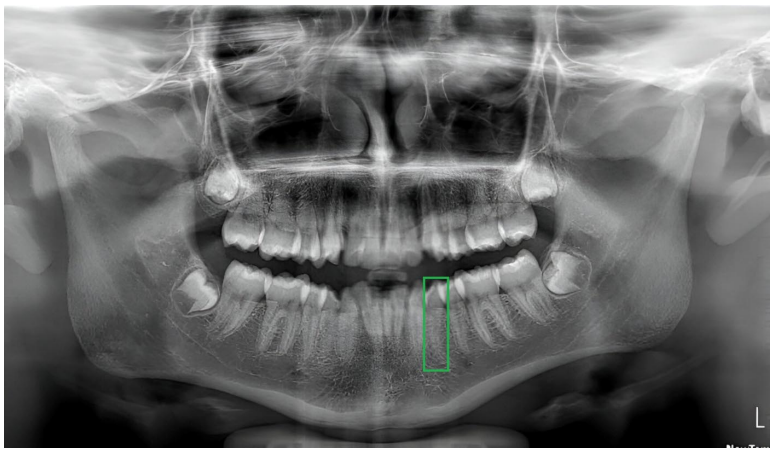

Fig. 2. Orthopantomogram representing left mandibular first pre-molar annotation.

The images were exported into a Huawei Laptop Matebook 13 (China) for annotation and marking of the tooth using a specialized Darwin V7 (Darwin V7 Labs, London, UK) and analyzed as displayed in Figure 3 as phase 1. During the phase 1 image annotation and selection with use of Convolutional Neural Network was done.

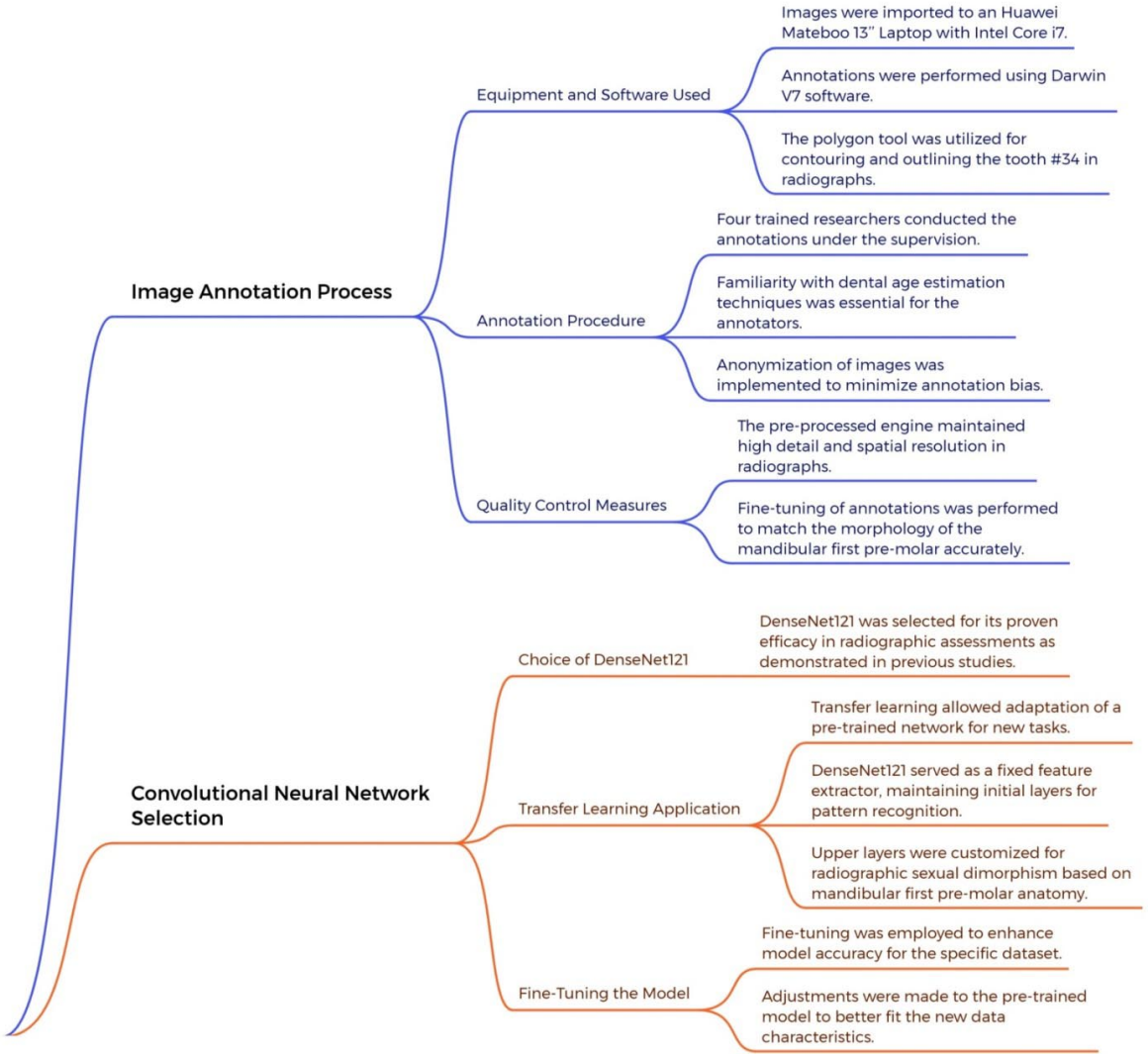

Fig. 3. Phase I for image annotation process and convolutional neural network selection workflow.

Later in phase 2, data augmentation and training, was done using Keras computational framework software to develop a pipeline of radiographic data augmentation layers aimed at reducing over fitting, given the limited number of images in the dataset. The training process employed a stochastic optimization algorithm (SGD), starting with a base learning rate of 1×10^{-3}, which will be gradually reduced to 6×10^{-6} as iterations increased. For the validation process, the k-fold cross-validation method was employed, dividing the dataset into "k" equal-sized subsets. In each round of validation, one subset was used for testing while the remaining (k-1) subsets were used for training. This process was repeated "k" times, with each subset serving as the validation set once as displayed in Figure 4. Figure 5 displays the image and data augmentation parameters maintained for the analysis of the images.

The performance was assessed ROC and AUC. TebsorFlow API and Keras versions 2.5 software were used for evaluation purpose facilitated by Python Version 3.8.10 for algorithm and data management.

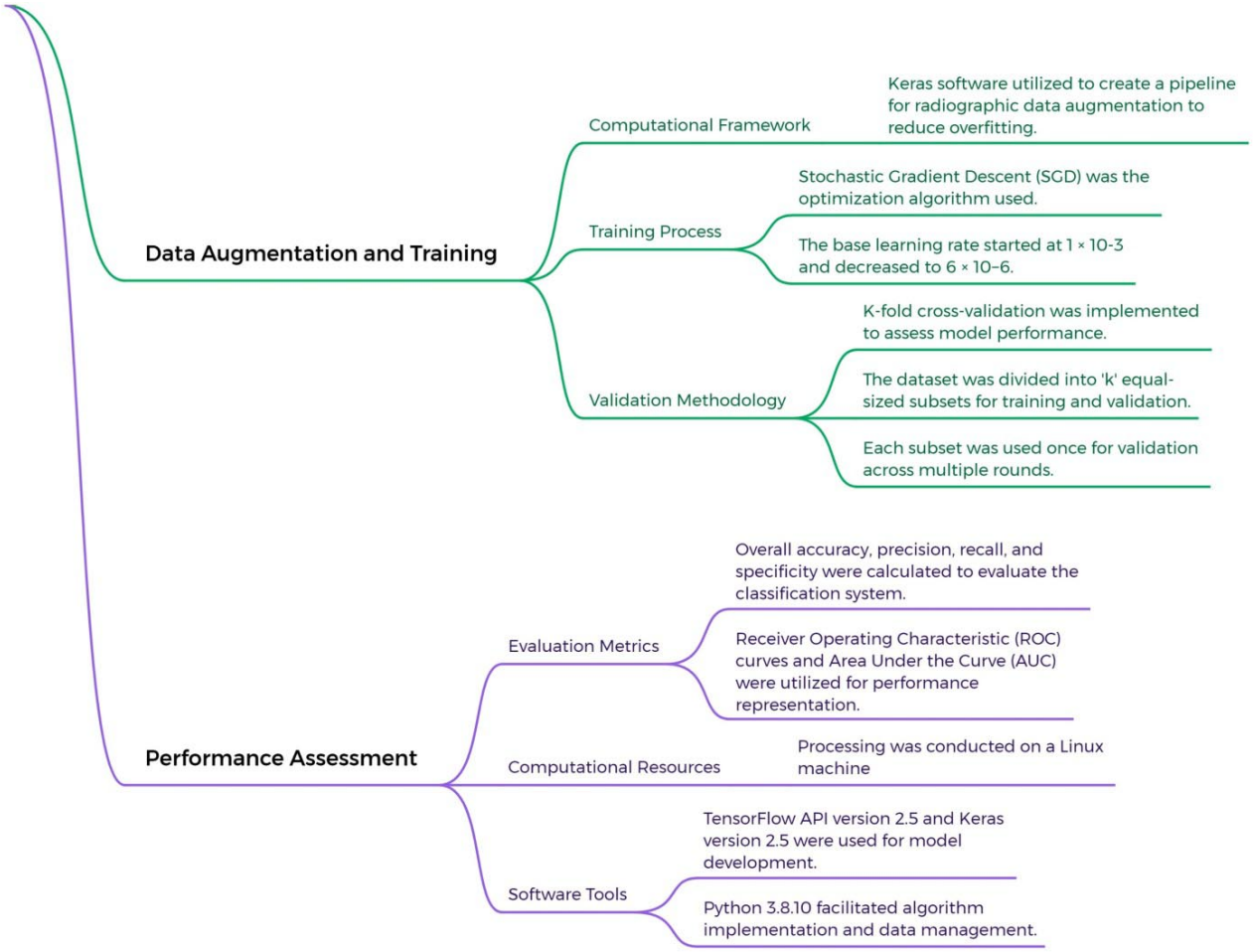

Fig. 4. Phase II for Data augmentation, training, and performance assessment workflow

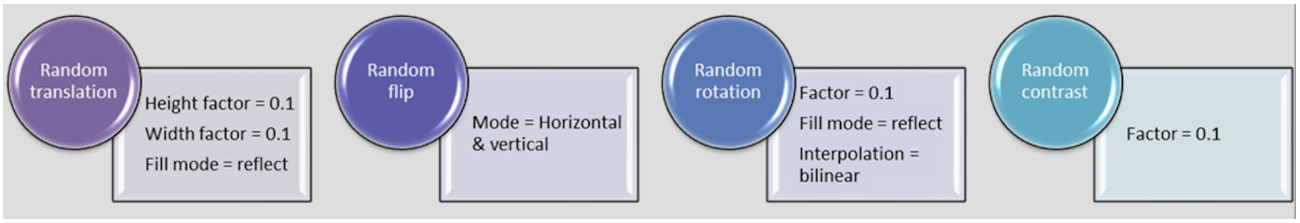

Fig. 5. Image data augmentation layers with their parameters.

RESULTS

The mean accuracy with standard deviation of CNNs diagnostic performance was calculated for all the groups collectively including both males and females as 68.65 % ± 3.31 %. The individuals aged between 29-29.99 years had a lowest level of accuracy 63.20 % for *sex* predilection using CNNs. On contrary individuals in 18-18.99 age group interval observed the highest level of accuracy of approximately 73.40 % as shown in Figure 6 and Table I.

The ROC curves and confusion matrices were generated for the set of each individual age group. On evaluating the confusion matrices for the two age groups, the number of males correctly identified was 58 % whereas 68 % of the females were decorously identified for the 29-29.99 years of age group as shown in Figure 7. On contrary the confusion matrices for the 18-18.99 years' age group identified 61 % males and 84 % females correctly (Fig. 7).

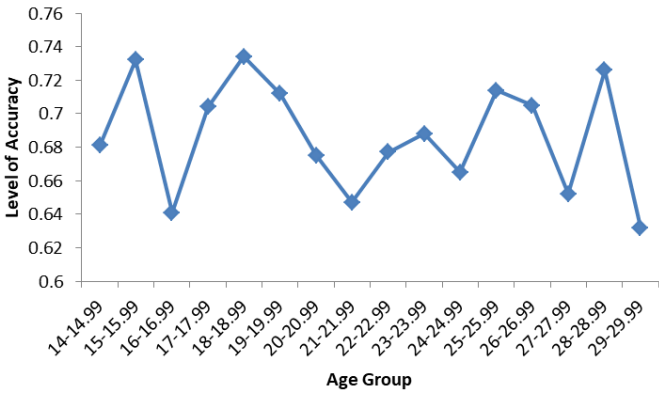

Fig. 6. Level of accuracy for the individual with the age group 14-29.99 respectively.

Table I. Performance metrics quantification for respective age groups based on CNNs classification of sexes; analyzing dental morphology of left mandibular first pre-molars.

Age Groups	Accuracy	Precision	Recall	F1 Score
14-14.99	0.681	0.804	0.498	0.615
15-15.99	0.732	0.661	0.664	0.662
16-16.99	0.641	0.589	0.594	0.591
17-17.99	0.704	0.674	0.735	0.703
18-18.99	0.734	0.672	0.676	0.674
19-19.99	0.712	0.678	0.739	0.707
20-20.99	0.675	0.682	0.619	0.649
21-21.99	0.647	0.721	0.551	0.625
22-22.99	0.677	0.681	0.618	0.648
23-23.99	0.688	0.704	0.73	0.717
24-24.99	0.665	0.669	0.691	0.680
25-25.99	0.714	0.652	0.658	0.655
26-26.99	0.705	0.677	0.729	0.702
27-27.99	0.652	0.596	0.601	0.598
28-28.99	0.726	0.663	0.674	0.668

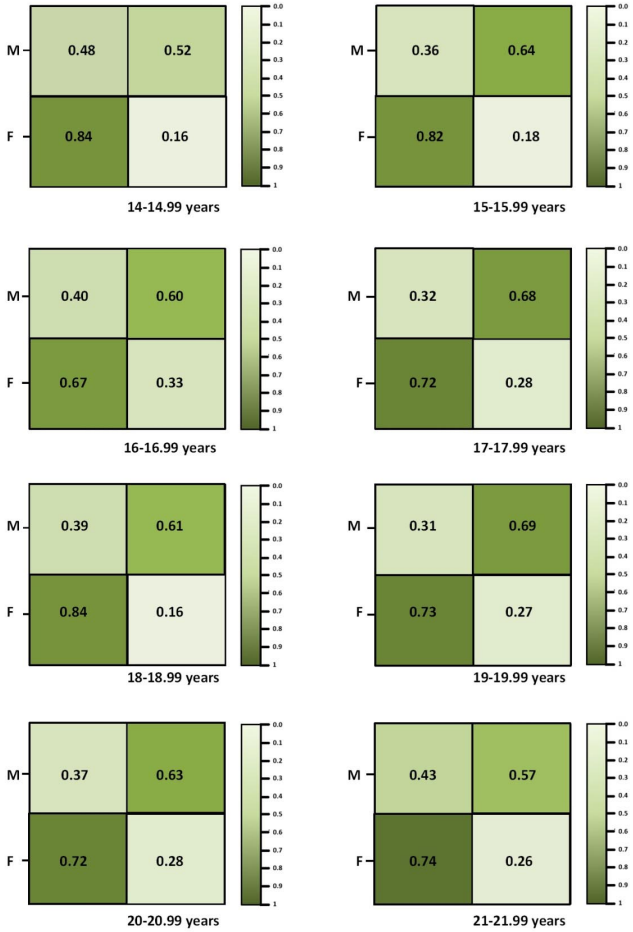

Fig. 7. Confusion matrices of CNNs displaying the potential to identify males and females correctly, for the age group of 14 to 21.99 years.

In general the highest number of females was 84 % currently identified for the 14-14.99 and 18-18.99 years of age groups respectively. But the highest number of male individuals approximately 72 % was of 22-22.99 years of age group correctly identified as mentioned in Figure 8 of confusion matrices. On assessing the lowest percentage, 52 % of male individuals for 14-14.99 years' age group and 64 % of female individuals were identified for 22-22.99 years' age group respectively. The AUC's as well displayed the lowest value for the 29-29.99 year age group of 0.63; whereas, highest for the 18-18.99 year-old age group 0.73 respectively as can be compared in Figures 9 and 10.

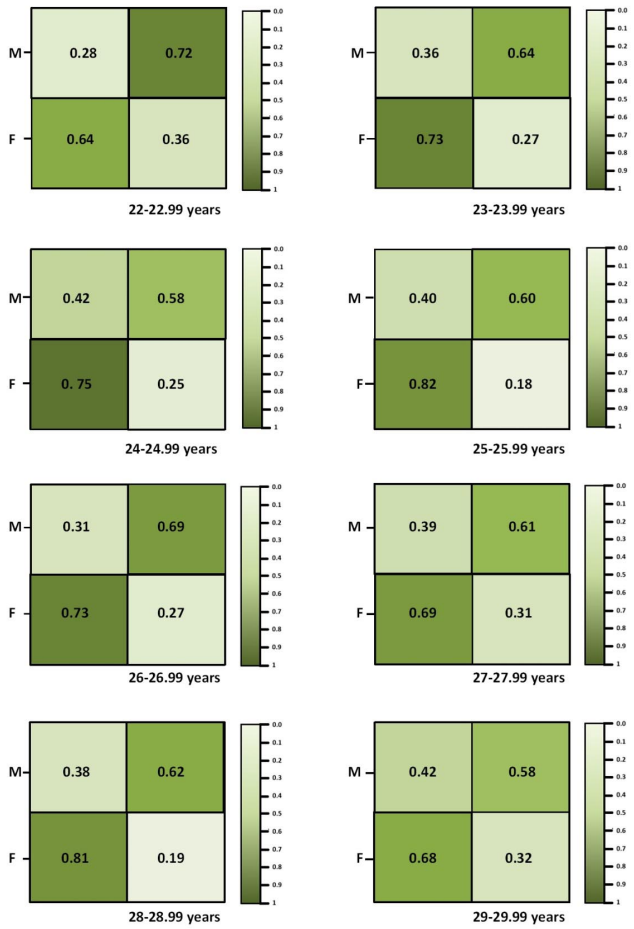

Fig. 8. Confusion matrices of CNNs displaying the potential to identify males and females correctly, for the age group of 22 to 29.99 years.

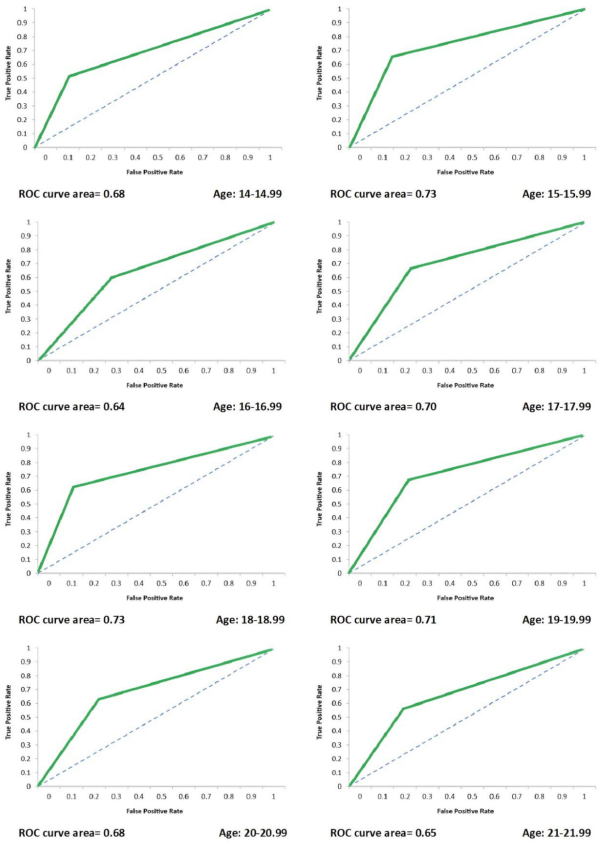

Fig. 9. ROC curves and inherent AUCs' of the performance of CNNs in sexual dimorphism from 14 to 21.99 years.

DISCUSSION

It is thought teeth exhibit traits which could help in sex predilection. The teeth in males are in general larger than the females. *Sex* criteria predilection based on the teeth in particular relies on the size and shape of the teeth. In particular other than size and shape no characteristic odontological feature is observed to be unique in either male or female which could help in sexual dimorphism. Therefore both the morpho-metric and -scopic techniques focus on the dimensions and positioning of the tooth in the respective dental arches. The age group of 14 years onwards was selected as the roots of the mandibular first pre-molars are completed by 13 years of age. The current study was conducted to evaluate the potential of AI in sex predilection using model of CNN on the mandibular first pre-molars. The radiographic dental record (OPGs) of approximately 12915 patients was included in the study comprising of 5983 male and 6932 females with the age group ranging from 14-30 years. The benefit of including the patients of this age group was to minimize the vicissitudes related to the elderly age altering the dental morphology of the mandibular first pre-molars. The CNNs AI software was observed to successfully identify the majority of the females correctly in 14-14.99 and 18-18.99 age groups respectively. On contrary, the 22-22.99 years of age group was observed to be the preeminent for identifying the male patients.

A group of researchers utilized CNN based analysis focusing on the mandibular canines for sexual dimorphism (Franco *et al*., 2022b). They reported that it can be used as a supplemental tool though till date CNN based models encounter challenges in achieving high accuracy (Franco *et al*., 2022b). The researchers selected an age group ranging from 6 years to 23 years. On evaluating the data, they reported slight lower accuracy rates for individuals aged less than 15 years of age of approximately 80-83 % whereas 84-87 % for persons aged between 15-23 years. Whereas the highest level of accuracy in the present study was observed for the 18-18.99 years of age group with 73.40 % slightly lower than that reported by Franco and co-researchers. The study by Franco *et al*. (2022a) displayed higher accuracy levels for in comparison to our study. This could be attributed

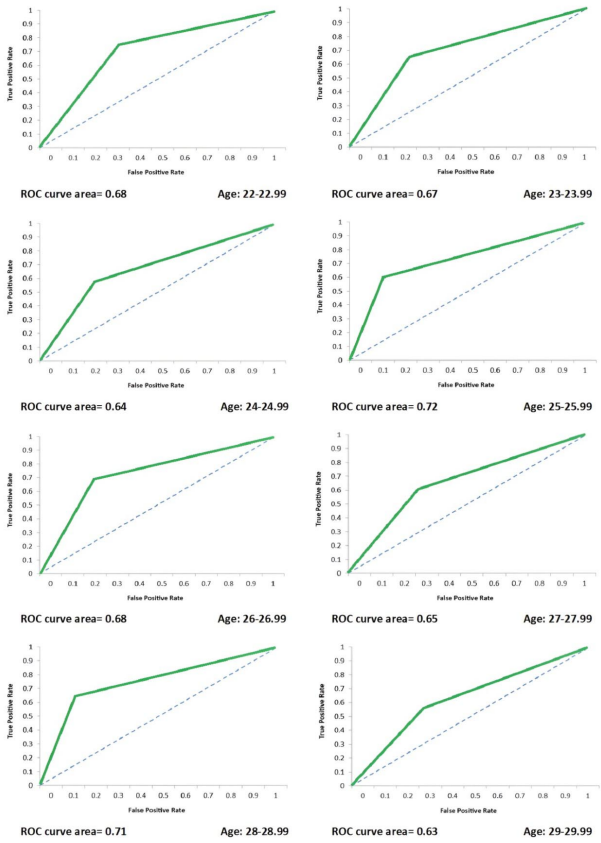

Fig. 10. ROC curves and inherent AUCs' of the performance of CNNs in sexual dimorphism from 22 to 29.99 years.

to the difference in the type of tooth included for CNNs model (mandibular-canine vs -first pre-molar; or/and type of data set; or/and model architecture.

Furthermore, on comparing the traditional techniques for morphometric measurements employed by Schwartz & Dean (2005), the CNNs have displayed a significant technological progression. The researchers identified the dimensions of the teeth have potential role for sexual dimorphism but with certain limitations in conducting it manually. Therefore the approach in current study of utilizing a technique driven by AI for morphometric analysis has reduced the dependency on manual process providing automated solutions in the field of forensic dentistry.

In general the CNNs in particular for females in 14-18.99 years of age group have shown strength that mandibular first pre-molars are a reliable indicator for sexual dimorphism.

Utilizing Al software in particular CNNs have a significant promising future in the study of forensic odontology (Hemalatha *et al*., 2023). The potential of AI software to predict the sex utilizing 2D images hypothetically reduce the time duration in the investigations related to forensic odontology in particular during catastrophic circumstances (Balan *et al*., 2022). Though, the study also has highlighted the need of further refinement of CNN models. In particular enhancing the accuracy of CNN models for certain ages and its further computational optimization, can increase its capability for sexual dimorphism. In general this model outperformed and reduced the computational demands by focusing of the certain features of left first mandibular pre-molar.

In conclusion, the findings suggest that the AI software, CNNs model can be used to analyze the mandibular first pre-molars of left side as a reliable marker for sexual dimorphism in South Western population. However, further extensive research using CNN models is needed in order to enhance and refine the accuracy for the individuals of all the ages which can contribute towards efficient and consistent scientific investigations.

QAMAR, Z.; ALTURKI, E.; ALMUTAWTAH, H.; ALAJMI, M. & AL SHATTI, S. Análisis de la morfología radiográfica de los primeros premolares mandibulares para el dimorfismo sexual en la población del suroeste mediante redes neuronales convolucionales impulsadas por IA. *Int. J. Morphol., 43(2)*:365-372, 2025.

RESUMEN: Se ha considerado el dimorfismo sexual de los primeros premolares mandibulares en función de sus características morfométricas manuales. Sin embargo, existe un debate sobre su fiabilidad para la correcta predilección de los sexos. El objetivo de esta investigación fue evaluar el rendimiento de las redes neuronales convolucionales (CNN) para distinguir entre hombres y mujeres en función de la morfología radiográfica de los primeros premolares mandibulares izquierdos en imágenes 2D (OPG). Los datos se recopilaron de 12.915 pacientes que comprendían 5.983 hombres y 6.932 mujeres respectivamente con un grupo de edad de 14-29,99 años. Los datos radiográficos fueron analizados por el software Darwin V7 seguido por DenseNet121, CNNs fueron utilizados para la identificación de hombres y mujeres en grupos de edad de 14-29,99 años. El rendimiento de las CNN se midió utilizando la tasa de precisión, matrices de confusión y curvas ROC. El rango para la tasa de precisión fue de 63,20 % - 73,4 % con una desviación estándar media de 68,65 % ± 3,31 %. El AUC para el análisis de la curva ROC varió entre 0,63 para el grupo de edad de 29-29,99 años y 0,73 para el grupo de edad de 18-18,99 años. En conclusión, se puede sugerir que el análisis morfométrico de los primeros premolares mandibulares izquierdos puede utilizarse en determinadas situaciones en las que no es posible obtener otras características anatómicas para la determinación sexual.

PALABRAS CLAVE: Inteligencia artificial; Redes neuronales convolucionales; Primer premolar mandibular; Radiología; Dimorfismo sexual.

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Corresponding author:
Dr. Zeeshan Qamar
Department of OMFS and Diagnostic Sciences
College of Medicine and Dentistry
Riyadh Elm University
Riyadh
SAUDI ARABIA

E-mail: zeeshan.qamar@ymail.com