Medical Principles and Practice

Med Princ Pract , DOI: 10.1159/000527145
Received: January 12, 2022
Accepted: September 14, 2022
Published online: September 27, 2022

A DEEP-LEARNING MODEL FOR IDIOPATHIC OSTEOSCLEROSIS DETECTION ON PANORAMIC RADIOGRAPHS

Yesiltepe S, Bayrakdar IS, Orhan K, Çelik Ö, Bilgir E, Aslan AF, Odabaş A, Costa ALF, Jagtap R

ISSN: 1011-7571 (Print), eISSN: 1423-0151 (Online)
https://www.karger.com/MPP
Medical Principles and Practice

Disclaimer:
Accepted, unedited article not yet assigned to an issue. The statements, opinions and data contained in this publication are solely those of the individual authors and contributors and not of the publisher and the editor(s). The publisher and the editor(s) disclaim responsibility for any injury to persons or property resulting from any ideas, methods, instructions or products referred to the content.

Copyright:
This article is licensed under the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC) (http://www.karger.com/Services/OpenAccessLicense). Usage and distribution for commercial purposes requires written permission.

© 2022 The Author(s). Published by S. Karger AG, Basel

Accepted Manuscript

A Deep-Learning Model for Idiopathic Osteosclerosis Detection on Panoramic Radiographs

Selin Yesiltepe[1], Ibrahim Sevki Bayrakdar[2,3], Kaan Orhan[4,5], Özer Çelik[3,6], Elif Bilgir[2], Ahmet Faruk Aslan[6], Alper Odabaş[6], Andre Luiz Ferreira Costa[7], Rohan Jagtap[8]

[1]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Aydın Adnan Menderes University, Aydın-Turkey;
[2]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Eskisehir Osmangazi University, Eskisehir-Turkey;
[3]Eskisehir Osmangazi University Center of Research and Application for Computer Aided Diagnosis and Treatment in Health, Eskisehir-Turkey;
[4]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ankara University, Ankara-Turkey;
[5]Ankara University Medical Design Application and Research Center (MEDITAM), Ankara, Turkey;
[6]Department of Mathematics and Computer Science, Faculty of Science, Eskisehir Osmangazi University, Eskisehir-Turkey;
[7]Postgraduate Program in Dentistry, Cruzeiro do Sul University (UNICSUL), São Paulo, Brazil;
[8]Division of Oral & Maxillofacial Radiology, Department of Care Planning and Restorative Sciences, University of Mississippi Medical Center School of Dentistry, Jackson, Mississippi, USA

Address for Correspondence:
Selin Yeşiltepe,
Department of Oral and Maxillofacial Radiology,
Faculty of Dentistry, Aydın Adnan Menderes University, Aydın, TURKEY
E-mail: dt_selin@yahoo.com

Running Title: Artificial Intelligence and Idiopathic Osteosclerosis
Keywords: Artificial Intelligence・Deep-learning・Idiopathic Osteosclerosis・Panoramic Radiography・Dentistry

Accepted Manuscript

Highlights of the study

- To best our knowledge, there are no studies examining the performance of artificial intelligence systems in the evaluation of idiopathic osteosclerosis on panoramic radiographs.
- In the present study, sensitivity, precision, and F-measure values were found to be 0.88, 0.83, and 0.86, respectively.
- Deep learning-based artificial intelligence algorithms have the potential to accurately detect idiopathic osteosclerosis on panoramic radiographs.

Abstract
Objective: The purpose of the study was to create an artificial intelligence (AI) system for detecting idiopathic osteosclerosis (IO) on panoramic radiographs for automatic, routine, and simple evaluations. ***Subject and Methods*****:** In this study, a deep learning method was carried out with panoramic radiographs obtained from healthy patients. A total of 493 anonymized panoramic radiographs were used to develop the AI system (CranioCatch, Eskisehir-Turkey) for the detection of IOs. The panoramic radiographs were acquired from the radiology archives of the Department of Oral and Maxillofacial Radiology of the Faculty of Dentistry of Eskisehir Osmangazi University. GoogleNet Inception V2 model implemented with TensorFlow library was used for the detection of IOs. Confusion matrix was used to predict model achievements. ***Results*****:** 50 IOs were detected accurately by the AI model from the 52 test images which had 57 IOs. The sensitivity, precision, and F-measure values were 0.88, 0.83, and 0.86, respectively. ***Conclusion:*** Deep learning-based AI algorithm have the potential to detect IOs accurately on panoramic radiographs. AI systems may reduce the workload of dentists in terms of diagnostic efforts.

Invited Manuscript

Introduction
Idiopathic osteosclerosis (IO) is defined as non-expanding radiopaque changes in the trabecular bone which are of various shapes and sizes. Although its etiology is unknown, it may be a result of internal stress and insufficient blood flow to form bone masses in the jaws. This lesion can affect both the maxilla and mandible, but it is frequently observed in the mandibular premolar-molar region. This benign lesion is mostly asymptomatic and generally discovered incidentally on panoramic radiographs taken for routine examination [1].
Panoramic imaging is a specialized tomographic technique used to create a flat representation of the curved surfaces of the jaws. It provides the opportunity to view the entire maxilla, mandible, temporo-mandibular joints, and related structures in a single film. However, interpretation of panoramic radiographic images can sometimes be difficult, especially for inexperienced observers, resulting in overlooked critical diseases [2]. Therefore, in the last two decades, due to the increased availability of digital medical data, increased computing power, and advancement in artificial intelligence, diagnosis with computer aided detection / diagnosis (CAD) systems have been developed and applied to a variety of medical problems [3, 4].
Since 2010, convolutional neural networks (CNNs), the latest core model of artificial neural networks (ANNs) and deep learning in computer vision, have developed rapidly [5, 6]. This approach has been used successfully in medical applications. This rapidly growing new field of research has yielded impressive results in terms of diagnosis and prediction of radiological and pathological analysis [7, 8]. Also, in the field of oral and maxillofacial diagnostic imaging, studies on the application of CNNs in dentistry have shown promising results, but it is still a developing area of research [9, 10].
In this study, we aimed to examine the performance of artificial intelligence (AI) systems in evaluating IO on panoramic radiographs.

Methodology
Study Design

In this retrospective study, we developed automatic IO detection models (CranioCatch, Eskisehir-Turkey) in dental panoramic radiographs using a pre-trained Google Net Inception v2 Faster R-CNN network architecture implemented with TensorFlow library. Eskisehir Osmangazi University Non-Interventional Clinical Research Ethics Committee (Decision date and number: 06.08.2019/14) approved the study protocol. The principles of the Helsinki Declaration were followed in this study.

Radiographic Data Source

Panoramic radiographs taken on patients over the age of 18, regardless of gender differences, were included in the study. Panoramic radiographs were obtained from the radiology archive of the Department of Oral and Maxillofacial Radiology of Eskisehir Osmangazi University School of Dentistry. The data set included 493 anonymized dental panoramic radiographs with IO from March 2018 to March 2019. Panoramic radiographs with artifacts, trauma, jaw pathologies like cyst and tumor etc. were excluded from study group. Panoramic radiographs were acquired on the Planmeca Promax 2D (Planmeca, Helsinki, Finland) with following parameters: 68 kVp, 16 mA, and 13 s.

Ground Truth Annotation

Three oral and maxillofacial (OMF) radiologists (S.Y., I.S.B., E.B) with at least 10 years of experience labeled each tooth on the dental panoramic radiographs using CranioCatch Labeling Tool (Eskisehir, Turkey) and agreed on each label. Polygonal boxes tool was used to annotate all IO on dental panoramic radiographs.

Development of Detection Model

Pre-processing Steps:

493 anonymized panoramic radiographs were used to develop AI algorithm. In the first pre-processing step, panoramic radiographs were divided into 4 equal parts including mandible left, mandible right, maxilla left, maxilla right for shrink to region of interest**.** All images were resized 512 x 256. Images with no IO label were removed. The data set was divided into training group 454 (467 labels), validation group 50 (50 labels) and test group 52 (57 labels).

Deep-Convolutional Neural Network (CNN) Architecture

Google Net Inception v2 architecture implemented with TensorFlow library were used for model creation. Inception v2 developed to decrease the confusion of the convolution network. It has three 3×3 convolutions unlike the traditional 5×5 convolutions to enhance computational speed. Thus, using two 3×3 layers in place of 5×5 enhances the performance of architecture. This module allows the convolution network to be wider rather than deeper [11]. **(**Figure 1)

Training

The open-source programming language Python (version 3.6.1; Python Software Foundation, Wilmington, DE, USA) was used to develop AI algorithm. TensorFlow library was used for producing of AI model with GoogleNet Inception V2 network. The training method was applied using computer equipment of Eskisehir Osmangazi University Faculty of Dentistry Dental-AI Laboratory including Dell PowerEdge T640 GPU Calculation Server NVIDIA Tesla with V100 16G Passive GPU (Dell Inc., Texas, USA). The IO detection model with GoogleNet Inception V2 network implemented with TensorFlow library was trained with 200000 epochs. (Figure 2)

Evaluation of Performance of the Model

Model performance was evaluated using the Confusion Matrix. The metrics used to assess the performance of the IO detection model were as follows:

True Positive (TP): The number of accurate detected IO.

False Positive (FP): The number of detected IO even though there was no IO**.**

False Negative (FN): The number of IO were not detected.

The performance metrics of the model were determined according to the formulas using number of TP, FP, and FN, below.

Sensitivity (Recall, True positive rate (TPR): TP / (TP + FN)

Precision (Positive predictive value (PPV)): TP / (TP + FP)

F1 Score: 2TP / (2TP + FP + FN)

Results

Accepted Manuscript

The created AI models (CranioCatch, Eskisehir-Turkey) based on the Deep-CNN method has promising results for IO detection on panoramic radiographs. In the 52 test images, there were 57 IO; 50 IO were detected by AI model, accurately. (Figure 3) 7 IO were not detected. The sensitivity, precision, and F-measure values were 0.88, 0.83, and 0.86, respectively. (Table 1)

Discussion

Osteosclerosis a general term to describe areas of increased bone formation and is usually detected incidentally on radiographs**.** The radiopacity of IO may be similar to other pathologies of the jaw such as condensing osteitis, retained root fragments, hypercementosis, cementoblastoma, impacted teeth, focal cemento-osseous dysplasia, and rarely complex odontomas. Accurate diagnosis is based on bone morphology. There is no enlargement or absence of radiolucent halo or lack of signs. Panoramic radiography is still used clinically as one of the main imaging examinations. IO usually does not require any treatment other than diagnosis. In general, lesions likely persist for years and surgical intervention is not recommended. Periodic follow-up of the lesions is necessary to ensure that the clinical diagnosis is correct [12]. With this, IOs may undergo changes in the young population and have the potential to expand over time. Sclerotic lesions may enlarge or stabilize. Also, IO may cause root resorption, nerve compression, dental impaction, dental displacement, and difficulties in orthodontic movement. It was reported that the dense bone island lesion detected in the adolescent patient may increase in size and density, potentially causing other problems such as increased inclination of adjacent teeth, and the presence of the lesion may complicate any future orthodontic treatment [13]. Marques-Silva et al. [14] claimed that IO may cause changes in tooth position or problems during orthodontic treatment, and they reported a case of tooth resorption caused by IO-induced ectopic eruption course. Mainville et al. [15] reported that external root resorption is present in 10 - 12% of cases of IO which often involves permanent mandibular first molars.

In the literature, there are studies examining the frequency and distribution of IO of the jaws [1, 16, 17]. However, to the best of our knowledge, there are no studies examining the performance of AI systems in the evaluation of IO on panoramic radiographs. The current study aimed to examine the performance of AI systems in evaluating IO on panoramic radiographs.

The use of AI systems for radiographic image interpretation in the healthcare field has ushered in a new era in diagnosis and treatment planning. Diagnostic decisions made by dentists can be sometimes subjective and sometimes wrong. The purpose of radiological AI systems is to create automatic, routine, simple evaluations so that radiologists can read images faster and save time for more complex cases [18]. AI systems allow archive systems where the radiological images of all patients can be regularly reported and stored without the need for extra workload and time. In order to standardize the interpretation of images and provide equal service in diagnostic accuracy, anonymous datasets can be made available and thus helpful in situations where radiological expertise are limited. For this reason, analysis made with AI in panoramic radiographs can facilitate early diagnosis, treatment planning, and archiving of information.

AI has rapidly improved the interpretation of medical and dental images [19] through the application of deep learning models and CNNs [20]. Deep CNN architecture appears to be the most widely used deep learning approach. This is due to the efficient self-learning algorithms and high computational power that provide superior detection, classification and quantization performance based on image data [21]. In the literature, there are studies about detecting vertical root fractures [22], first molar tooth root morphology [23], periapical pathosis [24], mandibular canal detection [25], tooth and tooth numbering [26] using the CNN system.

Murata et al. [27] showed that deep learning systems can diagnose sinusitis on panoramic radiography at a rate similar to that of radiologists, and their performance is superior to the skills of dentists. In this study, diagnostic performance of the deep-learning system for maxillary sinusitis on panoramic radiographs was high, with an accuracy of 87.5%, sensitivity of 86.7%, specificity of 88.3%, and the area under the curve (AUC) of 0.875. Lee et al. [28] performed dental segmentation on panoramic radiographs and reported that they achieved high success rate in AI performance. This method obtained an F1 score of 0.875 (precision: 0.858, recall: 0.893) and a mean intersection over union (IoU) of 0.877. Ekert et al. [29] investigated the ability of deep CNNs to detect apical lesions on panoramic radiographs. According to the methodology applied in their study, a moderately deep CNN trained on a limited amount of image data showed satisfactory discriminating ability to detect apical lesions in panoramic radiographs. Krois et al. [30] evaluated the success of CNN systems in determining periodontal bone destruction with 1780 panoramic images, reported that the result was similar to that of dentists and that AI systems could reduce the physician's efforts to make periodontal diagnoses. In this study, mean classification accuracy of the CNN was found to be 0.81. Mean sensitivity and specificity were 0.81 and 0.81. The mean

accuracy of the dentists was 0.76. In the present study, sensitivity, precision, and F-measure values were 0.88, 0.83, and 0.86, respectively. Thus, we suggest that AI models based on the deep-CNN method have promising results for the detection of IO on panoramic radiographs. This study is one of a series of studies aimed at using deep learning AI to automate diagnoses in panoramic radiography.

This study has a few limitations. The radiologic dataset included only IO as radiopaque lesions; future studies should eliminate this limitation and expand the use for the network and include other hypersclerotic lesions in the dataset like osteitis, odontomas etc. to propose a network that is of true clinical value. Besides, panoramic images taken from different radiologic equipment with different radiologic parameters should be used for the development of AI models in order to have reliable algorithms for clinical practice. Moreover, differential diagnosis or follow-up of IO was not made in the present study. Further studies can be done with AI regarding the differential diagnosis or follow-up of IO and large datasets.

Conclusion

Deep learning-based AI algorithm have the potential to detect IOs accurately on panoramic radiographs. AI systems may reduce the workload of dentists in terms of diagnostic efforts in the future.

Conflict of Interest: The authors declare that they have no conflict of interest.

Funding: This work was supported by Eskisehir Osmangazi University Scientific Research Projects Coordination Unit under grant number 202045E06.

Ethics Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and in alignment with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Additional informed consent was obtained from all participants included in the study.

Authors' Contributions: Ibrahim Sevki Bayrakdar and Kaan Orhan: literature search and design of the work; Elif Bilgir and Selin Yesiltepe: acquisition of data and writing of the manuscript; Alper Odabaş, Özer Çelik and Ahmet Faruk Aslan: analysis and interpretation of data; Andre Luiz Ferreira and Rohan Jagtap: drafting of manuscript and revisions.

Data Availability Statement: All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

Accepted Manuscript

References

1. Sisman Y, Ertas ET, Ertas H, Sekerci AE. The frequency and distribution of idiopathic osteosclerosis of the jaw. Eur J Dent. 2011; 5(4): 409-14.

2. Nardi C, Calistri L, Grazzini G, Desideri I, Lorini C, Occhipinti M et al. Is Panoramic radiography an accurate imaging technique for the detection of endodontically treated asymptomatic apical periodontitis? J Endod. 2018; 44: 1500–8.

3. Ohashi Y, Ariji Y, Katsumata A, Fujita H, Nakayama M, Fukuda M, et al. Utilization of computer-aided detection system in diagnosing unilateral maxillary sinusitis on panoramic radiographs. Dentomaxillofac Radiol. 2016; 45: 20150419.

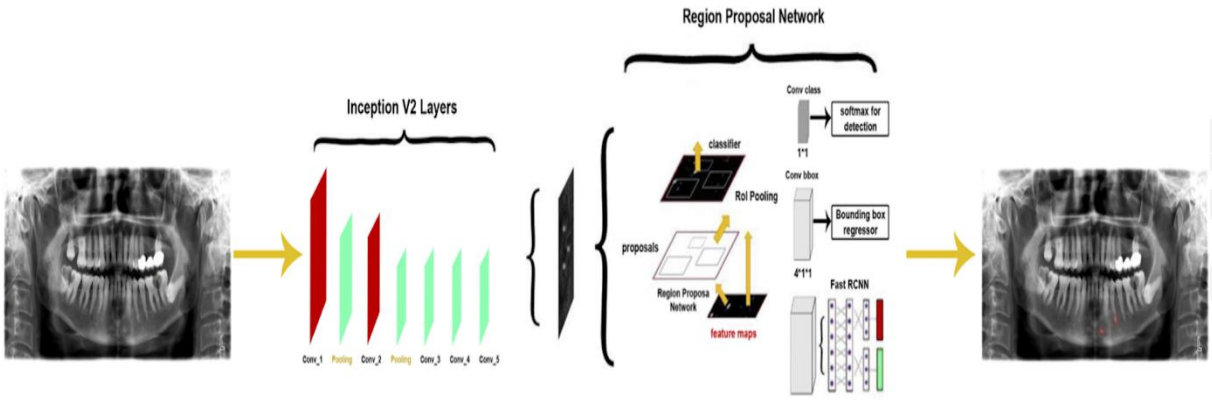
4. Maia PRL, Medeiros AMC, Pereira HSG, Lima KC, Oliveira PT. Presence and associated factors of carotid artery calcification detected by digital panoramic radiography in patients with chronic kidney disease undergoing hemodialysis. Oral Surg Oral Med Oral Pathol Oral Radiol. 2018; 126: 198–204.
5. Song Q, Zhao L, Luo X, Dou X. Using deep learning for classification of lung nodules on computed tomography images. J Healthc Eng. 2017; 1–7.
6. Sklan JE, Plassard AJ, Fabbri D, Landman BA. Toward content-based image retrieval with deep convolutional neural networks. Proc SPIE Int Soc Opt Eng. 2015; 9417.
7. Rezaei M, Yang H, Meinel C. Deep Neural Network with l2-norm Unit for Brain Lesions Detection. In: *International Conference on Neural Information Processing.* 2017; 798–807.
8. Liu J, Wang D, Lu L, Wei Z, Kim L, Turkbey EB, et al. Detection and diagnosis of colitis on computed tomography using deep convolutional neural networks. Med Phys. 2017; 44: 4630–42.
9. Arik Sercan Ö, Ibragimov B, Xing L. Fully automated quantitative cephalometry using convolutional neural networks. J. Med. Imag. 2017; 4: 014501.
10. Miki Y, Muramatsu C, Hayashi T, Zhou X, Hara T, Katsumata A, et al. Classification of teeth in cone-beam CT using deep convolutional neural network. Comput Biol Med. 2017; 80: 24–9.
11. Szegedy C, Vanhoucke V, Ioffe S, Shlens, J, Wojna Z. Rethinking the inception architecture for computer vision. In Proceedings of the IEEE conference on computer vision and pattern recognition. 2016; 2818-2826.
12. Bsoul SA, Alborz S, Terezhalmy GT, Moore WS. Idiopathic osteosclerosis (enostosis, dense bone silands, focal periapical osteopetrosis). *Quintessence Int.* 2004; 35: 590-591.
13. Nakano K, Ogawa T, Sobue S, Ooshima T. Dense bone island: clinical features and possible complications. Int J Paediatr Dent. 2002; 12(6): 433-7.
14. Marques Silva L, Guimaraes AL, Dilascio ML, Castro WH, Gomez RS. A rare complication of idiopathic osteosclerosis. Med Oral Patol Oral Cir Bucal. 2007; 12(3): E233-4.
15. Mainville GN, Lalumière C, Turgeon D, Kauzman A. Asymptomatic, nonexpansile radiopacity of the jaw associated with external root resorption: a diagnostic dilemma. Gen Dent. 2016; 64(1): 32-5.
16. Moshfeghi M, Azimi F, Anvari M. Radiologic assessment and frequency of idiopathic osteosclerosis of jawbones: an interpopulation comparison. Acta Radiol. 2014; 55(10): 1239-44.
17. Naser AZ, Roshanzamir N. Prevalence of idiopathic osteosclerosis in an Iranian population. Indian J Dent Res. 2016; 27(5): 544-546.
18. Ozden F, Ozgonenel O, Ozden B, Aydogdu A. Diagnosis of periodontal diseases using different classification algorithms: A preliminary study. Niger J Clin Pract. 2015; 18: 416-421.
19. He K, Zhang X, Ren S, Sun J. Delving deep into rectifiers: Surpassing human-level performance on imagenet classification. Proceedings of the IEEE international conference on computer vision. 2015; p.1026-34.
20. Lakhani P, Sundaram B. Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks. Radiology. 2017; 284: 574-82.
21. Soffer S, Ben-Cohen A, Shimon O, Amitai MM, Greenspan H, Klang E. Convolutional neural networks for radiologic images: a radiologist's guide. Radiology. 2019; 290: 590-606.
22. Fukuda M, Inamoto K, Shibata N et al. Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. Oral Radiol. 2019: 1-7.
23. Hiraiwa T, Ariji Y, Fukuda M et al. A deep-learning artificial intelligence system for assessment of root morphology of the mandibular first molar on panoramic radiography. Dentomaxillofac Radiol. 2019; 48: 20180218.
24. Orhan K, Bayrakdar I, Ezhov M, Kravtsov A, Özyürek T. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. Int Endod J. 2020; 53: 680-689.
25. Fukuda M, Ariji Y, Kise Y et al. Comparison of 3 deep learning neural networks for classifying the relationship between the mandibular third molar and the mandibular canal on panoramic radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol. 2020; 130(3): 336-343.
26. Tuzoff DV, Tuzova LN, Bornstein MM et al. Tooth detection and numbering in panoramic radiographs using convolutional neural networks. Dentomaxillofac Radiol. 2019; 48: 20180051.
27. Murata M, Ariji Y, Ohashi Y, et al. (2018) Deep-learning classification using convolutional neural network for evaluation of maxillary sinusitis on panoramic radiography. Oral Radiol. 2018; 35(3), 301-307.
28. Lee JH, Han SS, Kim YH, Lee C, Kim I. Application of a fully deep convolutional neural network to the automation of tooth segmentation on panoramic radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol. 2020; 129(6): 635-642.

29. Ekert T, Krois J, Meinhold L, Elhennawy K, Emara R, Golla T, et al. Deep learning for the radiographic detection of apical lesions. J Endod. 2019; 45: 917-22. e5.
30. Krois J, Ekert T, Meinhold L et al. Deep learning for the radiographic detection of periodontal bone loss. Sci Rep. 2019; 9: 1-6.

Figure Legends
Figure 1. Deep-learning architecture
Figure 2. Steps in the development of idiopathic osteosclerosis detection model
Figure 3. Idiopathic osteosclerosis detection on panoramic radiographs using the AI model (CranioCatch, Eskisehir-Turkey).

Accepted Manuscript

Fig 1



Accepted Manuscript

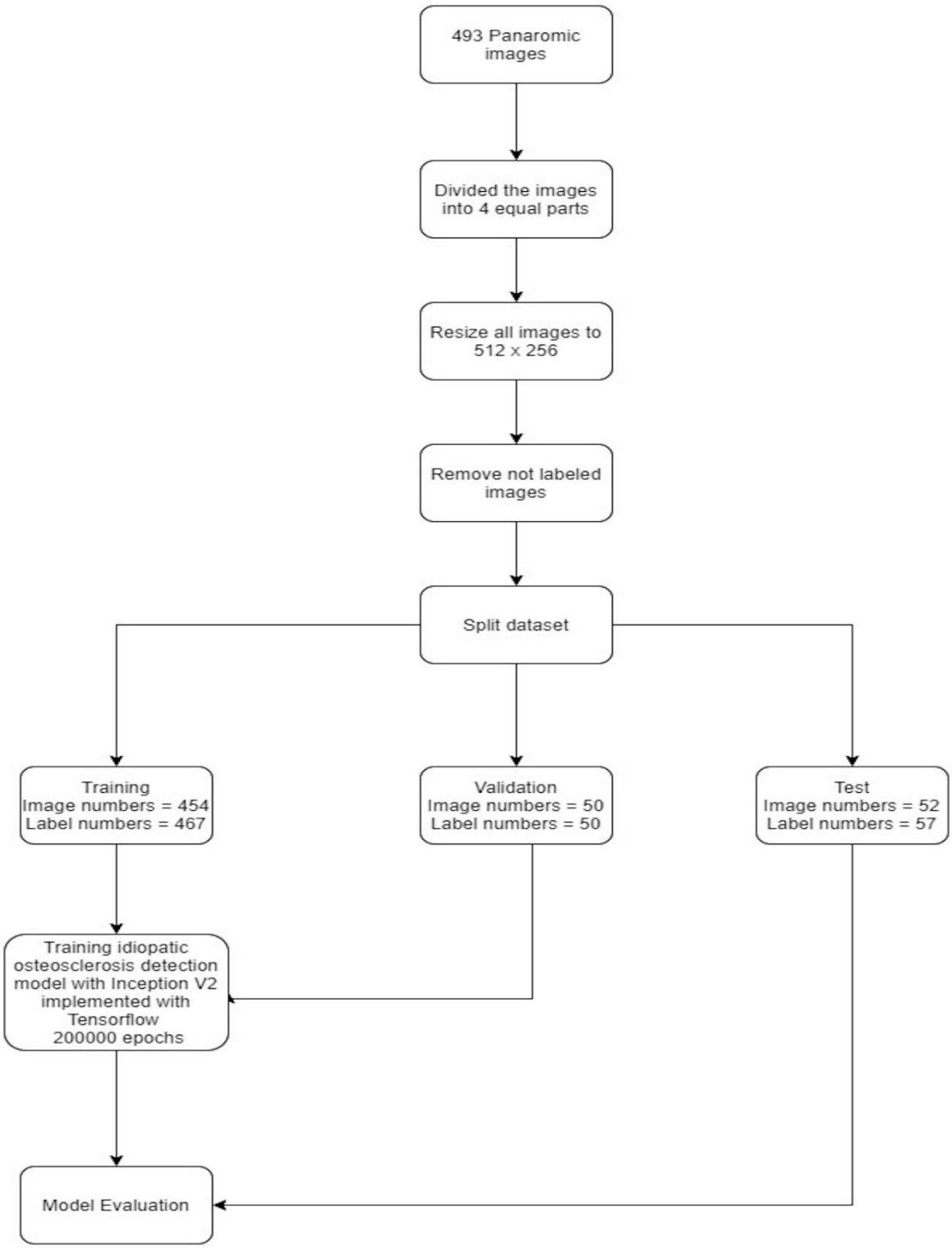

493 Panaromic images
Divided the images into 4 equal parts
Resize all images to 512 x 256
Remove not labeled images
Split dataset
Training
Image numbers = 454
Label numbers = 467
Validation
Image numbers = 50
Label numbers = 50
Test
Image numbers = 52
Label numbers = 57
Training idiopatic osteosclerosis detection model with Inception V2 implemented with Tensorflow
200000 epochs
Model Evaluation

Fig 2

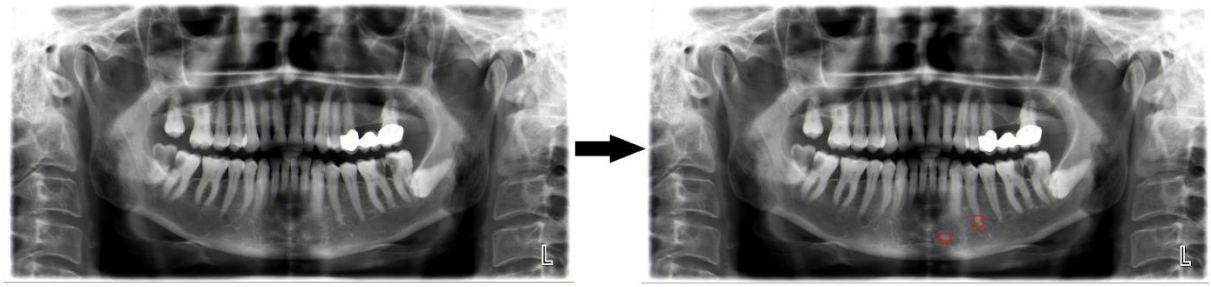


Fig 3

Accepted Manuscript

Table 1. Predictive performance measurement of idiopathic osteosclerosis detection using the AI model (CranioCatch, Eskisehir-Turkey) in test data set.

	True Positive (TP)	False Positive (FP)	False Negative (FN)	Sensitivity	Precision	F1 Score
Idiopathic Osteosclerosis Detection	50	10	7	0.88	0.83	0.86

Accepted Manuscript