On the Validation of a New Metric of Extraction Difficulty for Mandibular Third Molars Using Convolutional Neural Network-based Deep Learning

Tsai-Jung Liu[1]*, Chia-Yu Chiu[1], Cheng-Kai Xu[1], Wei-Chih Chen[1], Hsien-An Ni[2], Yu-Wei Wu[3], Jyh-Kwei Chen[4], Jen-Cheng Wang[5], Ya-Fen Wu[6] and Tzer-En Nee[1]

[1]Department of Electronic Engineering, Chang Gung University, Kwei-Shan, Taoyuan, Taiwan, Republic of China.

[2] Department of Technology Application and Human Resource Development, National Taiwan Normal University, Taipei, Taiwan, Republic of China.

[3]ADVANCED SEMICONDUCTOR ENGINEERING INC Chung Li factory.,550, Zhonghua Rd., Sec. 1, Zhongli Dist., Taoyuan City, Taiwan, Republic of China.

[4]Division of Oral and Maxillofacial Surgery, Department of Dentistry, Chang Gung Memorial Hospital Taipei Branch, Taipei, Taiwan, Republic of China.

[5]Department of Computer Science, National Taipei University of Education, Taipei, Taiwan, Republic of China.

[6]Department of Electronic Engineering, Ming Chi University of Technology, Taishan Dist., New Taipei City, Taiwan, Republic of China.

* E-mail: t981130@gmail.com, Tel: +886-3-2118800 ext.5791, Fax: +886-3-2118507

***Abstract*— A new metric of surgical difficulty associated with convolutional neural network (CNN)-based deep learning for the extraction of impacted mandibular third molars has been proposed. Based on the panoramic radiographs, anatomical features were found to influence the difficulty of surgery. Accordingly, the difficulty level was rated on a 10-point scale from 1 to 10, with 1 indicating very easy and 10 indicating very difficult. Resulting from the integrated validation of the proposed metric and Pederson difficulty scoring (PDS) system with CNN models, the improvements of diagnostic accuracy, sensitivity, and specificity were profound for classifying the difficulty of wisdom tooth removal. Furthermore, the evolution of the accuracy and loss functions during the training process along the epochs has also been discussed. The present work suggested that this new metric of surgical difficulty is conducive to making an optimal treatment plan.**

I. Introduction

CNN is a feedforward neural network that excels in processing images and visual recognition tasks. CNN automatically and effectively learns image features through convolutional layers without manual feature extraction.

In recent years, CNN has been widely used in the medical field. In dentistry, CNN is used to detect various conditions, such as caries lesions and periodontal lesions. It can also help to evaluate the difficulty of endodontic treatment, soft tissue analysis, and root morphology of oral cancer patients.

It is important to evaluate the complexity of removing third molars due to potential complications like pain, swelling, and nerve damage. This study aims to introduce a CNN-based deep learning model to predict the difficulty of extracting mandibular third molars using panoramic radiographic images.[1-2]

II. Materials and Methods

Cropping was applied on panoramic dental images to highlight the region of interest (ROI), which was the area surrounding the mandibular third molar. Zero-padding was then employed to adjust the display aspect ratio of the ROI to 1:1. After preprocessing, the dataset was split into 80% for training and 20% for testing the accuracy of the CNN model. An object-detecting model was used to obtain anatomical features, which were set up as the standard for the CNN model. These features included the intersection angle of the long axes of the second and third molars, the extraction space of the third molar (D/F), and the degree of embedding of the entire tooth (J/F). The CNN model was trained by the data in the training set.[3] Furthermore, the CNN model was applied to the data in the testing set to acquire a preoperative evaluation of difficulty and the PDS score prediction.[4-5]

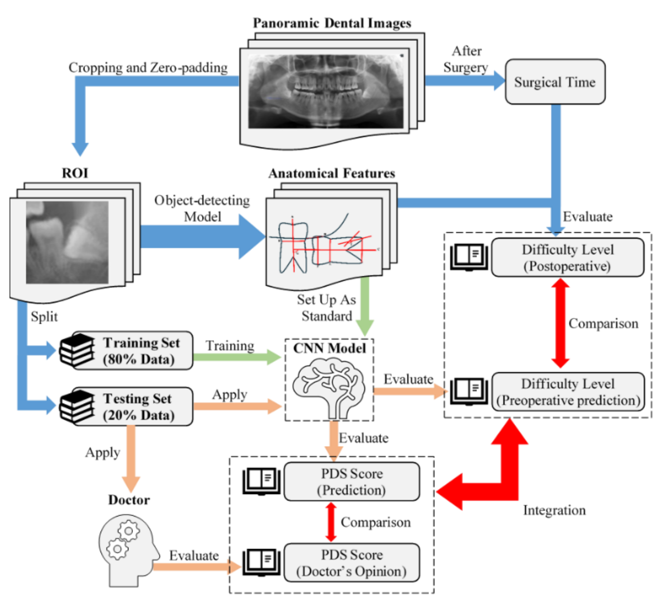

Figure 1 The entire process performed in this study.

III. Results and Discussion

Postoperative surgical difficulty level was evaluated by surgical time and certain influential anatomical features. Meanwhile, the difficulty level was rated on a 10-point scale from 1 to 10, with 1 indicating very easy and 10 indicating very difficult. Figure 2 indicated that the preoperative evaluation of surgical difficulty done by CNN was in line with postoperative ones.

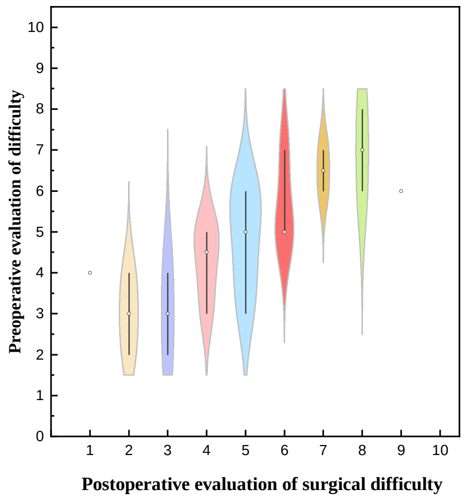

Figure 2 Preoperative evaluation of difficulty by CNN distribution of the postoperative evaluation of surgical difficulty

The CNN-based deep learning model appeared to be able to judge the PDS score of mandibular third molars as well as a doctor did since the predictions made by the CNN model were in line with the doctor's as shown in Figure 3.

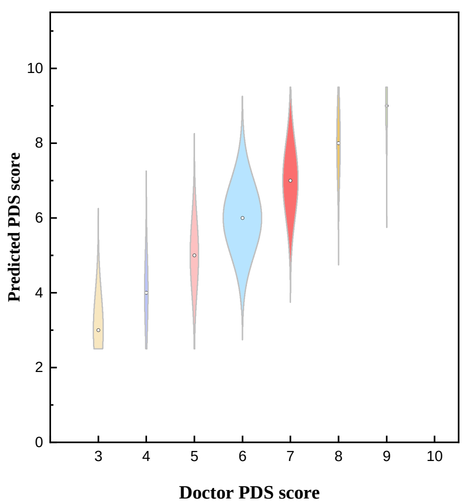

Figure 3 The PDS score predicted by CNN distribution of the PDS score judged by the doctor.

Stochastic gradient descent (SGD) was a common optimization method where the parameters were updated based on the gradient direction. SGD aimed to find the point that minimized the loss function. However, as the loss function decreases, the optimization parameters at the periphery become uneven, which can lead to overfitting and reduced generalization performance. Figure 4 illustrates the learning curve of the CNN deep learning model. Through our analysis, we observed that SGD tends to overfit as the number of epochs increases. The root cause of overfitting is the lack of training data. To address this issue, we plan to gradually increase the amount of training data in the future to reduce the overfitting phenomenon.

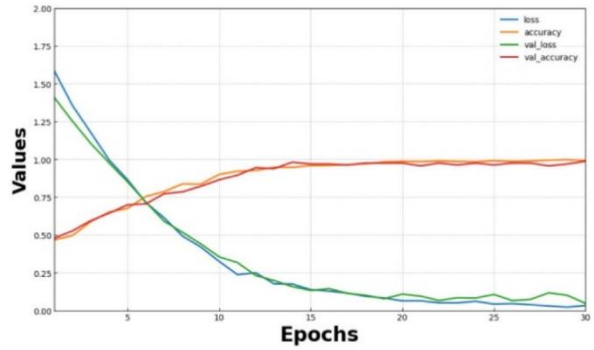

Figure 4 Two-dimensional spatial comparison of the dataset distinguished by operation time.

IV. Conclusion

As far as the preoperative assessment of surgical extraction of the impacted mandibular third molar was concerned, the validated metric of extraction difficulty has been developed profoundly. The difficulty was scored from 1 to 10 - with 1 indicating very easy and 10 representing very difficult. An evaluation of clinical and radiographic diagnosis revealed that certain anatomical features played vital roles in difficulty classifications in oral and maxillofacial surgery practice. Accordingly, the integration of the proposed metric and Pederson difficulty scoring (PDS) system with CNN models appeared to be an improvement. Calculating the accuracy, sensitivity, and specificity associated with the preoperative and postoperative values, the better classification ability of the classification model in this work was also discussed in connection with the most commonly used Pederson index. The present study was intended to shed new light on the influence of artificial intelligence technology in predicting extraction difficulty, potentially aiding dental professionals in medical image assessments, fully automated diagnostics, and successful treatment planning.[6]

References

[1] S.B. Khanagar, A. Al-ehaideb, P.C. Maganur, S. Vishwanathaiah, S. Patil, H.A. Baeshen, and S.C. Sarode, S. Bhandi, "Developments, application, and performance of artificial intelligence in dentistry – A systematic review," in *Journal of Dental Sciences*, vol.16, pp.508-522, Jan. 2021.

[2] N. Ahmed, M.S. Abbasi, F. Zuberi, W Qamar, M.S.B. Halim, A. Maqsood, and M.K. Alam, "Artificial Intelligence Techniques: Analysis, Application, and Outcome in Dentistry—A Systematic Review," in *Hinda wiBioMed Research International*, vol.2021, article 9751564, Jun. 2021.

[3] G. Sammartino, R. Gasparro, G. Marenzi, O. Trosino, M. Mariniello, and F. Riccitiello, "Extraction of mandibular third molars: proposal of a new scale of difficulty," in *British Journal of Oral and Maxillofacial Surgery*, vol.55, pp.952-957, Nov. 2017.

[4] O.M. Gbotolorun, G.T. Arotiba, and A.L. Ladeinde, "Assessment of factors associated with surgical difficulty in impacted mandibular third molar extraction," in *Journal of Oral and Maxillofacial Surgery*, vol.65, pp.1977-1983, Oct. 2007.

[5] D. Torul, H. Akpinar, I.S. Bayrakdar, O. and Celik, K. Orhan, "Prediction of extraction difficulty for impacted maxillary third molars with deep learning approach," in *Journal of Stomatology, Oral and Maxillofacial Surgery*, paper 101817, Mar.2024.

[6] J.Y. Kim, H.S. Yong, K.H. Park, and J.K. Huh, "Modified difficult index adding extremely difficult for fully impacted mandibular third molar extraction," in *J Korean Assoc Oral Maxillofacial Surgery*, vol.45, pp.309-315, Dec.2019.