Research Proposal Presentation Transcript

Dental Checkup Assistant Utilizing Deep Convolutional Neural Networks. My name is Mohammad Atieh. I am currently enrolled in the computer science postgraduate diploma program at the University of Essex Online, and I am a practicing dentist and dental educator. This will be my research proposal presentation for the research methods and professional practice course.

1 Significance

A dental check-up visit includes a visual and radiographic examination of teeth. This is followed by documenting the findings of existing teeth conditions on a paper or electronic patient documentation system. This process is called dental charting, which can be done by a dentist or dental assistant and then reviewed by the dentist, open brackets, Ritter et al., comma, 2019, close brackets. This process is time-consuming and prone to overlooked details if not done carefully. So, it will significantly help dentists, save time, and increase the accuracy of the documentation if most of the process is automated and prepared for them for final review and editing.

Several studies discussed the potential use of deep convolutional neural networks (DCNNs) for identifying dental caries or existing teeth conditions on radiographs and intraoral images open brackets, Chen, comma, 2022, semicolon, Bayrakdar, comma, 2022, semicolon, Lee, comma, 2021, semicolon, Antolin et al., comma, 2012, semicolon, Tian et al., comma, 2019, close brackets. However, up to the author's knowledge, no attempt was made to recognize existing teeth conditions from digital 3D models using DCNNs. Moreover, since not all carious lesions are detected visually, the proposed system will combine caries detection

information from radiographs and data gathered from intraoral 3D scans. Another advantage of such a system is acquiring more than one documentation type in one step, saving time and effort. This is represented by creating a 3D model of the patient's teeth and charting simultaneously.

2 Research Questions

So, the first question is: will it be possible to automate most of the dental charting process using information gathered by intraoral scans and radiographs?

The second question is: What is the accuracy of such a protocol?

3 Aims and Objectives

The aim is to investigate the possibility of developing a system that can automate the dental charting process using DCNNs. The objectives of this research are:

1. Combine and modify three previously published protocols to increase the data collected for dental charting purposes.
2. Test the accuracy of this protocol compared to a reference standard composed of two skilled dentists.

4 Hypotheses

The null hypothesis is that the accuracy of the automated charting protocol is at least equal to the accuracy reference standard. The alternative hypothesis is that the accuracy of the automated charting protocol is lower than the reference standard.

5 Key literature

Several attempts are available in the literature for automating caries detection and other existing teeth conditions like fillings, open brackets, Schwendicke et al., comma, 2019. One study explored the use of a group of three static intraoral images to detect and recognize the status of teeth in the dental arch and output them to an electronic patient record (Antolin et al., 2021). The resultant accuracy of their proposed system was around 88%. However, the intraoral image sequence they obtained didn't include the buccal surfaces of posterior teeth, which are opposite to the cheeks, and the lingual surfaces of all teeth, which are opposite to the tongue. In addition, they utilized a series of static images that are not easy to obtain and may not be comfortable for the patient due to the use of lip/cheek retractors and dental photography mirrors. So, using digital 3D models that cover all tooth surfaces would be far more convincing.

On the other hand, malalignment of teeth in the dental arch is another challenge to consider in the recognition and segmentation processes, making them hard to implement in cases of teeth crowding. To overcome that, Tian et al. (2019) proposed a protocol that uses 3D DCNNs to segment and recognize teeth on dental models, resulting in an average recognition accuracy of 92% for two levels of networks.

Regarding caries detection on bitewing radiographs, several studies explored the use of DCNNs for caries detection, reaching an accuracy that is above 80% (Bayrakdar et al., 2022; Chen et al., 2022). However, lower accuracy was reported, too (Lee et al., 2021; Prados-Privado et al., 2020). This shows the importance of having more than one method to augment the process of caries detection.

In addition to caries detection on radiographs, Lee et al. (2021) showed that restorative materials could also be detected using DCNNs like metallic or nonmetallic restoration and gutta-percha. This, again, can augment any automated dental charting process.

6 Methodology

Methodology. After receiving the IRB approval and signing the consent forms for a sample of 30 randomly selected research subjects, an Intraoral scan of the upper dental arches and a complete set of bitewing radiographs will be obtained for each research subject. The intraoral scans will be done using an intraoral scanner (e.g., 3shape TRIOS 5) to construct digital 3D models. The bitewing radiographs will be obtained using a digital intra-oral sensor (e.g., Carestream RVG 6200).

The data gathering will be split into two stages. In the first stage, the resultant datasets will be divided into training and validation datasets (80%) and testing datasets (20%). Three deep convolutional neural networks will be utilized to extract the required information from the datasets in three steps:

Step one: Segmentation and Tooth Classification based on Tian et al. (2019) to recognize and segment individual teeth. In this protocol, a digital 3D model of the patients' teeth will be preprocessed and converted to Sparse Octree models, then subjected to 3D CNNs for segmenting and classifying teeth.

Step two: Tooth Status Recognition similar to Antolin et al. (2021) protocol but using a 3D CNN on segmented and classified teeth resulted from the first step.

Step three: Caries Detection using Faster Region-Based Convolutional Neural Network (Faster R-CNN) based on the work of Chen et al. (2022). For this step, preprocessing of bitewings radiographs to segment individual teeth and number them will be necessary as automated segmentation and recognition from bitewing radiographs is a research subject by itself, and will be only practical if included in future research after validating the current protocol.

In the second stage, findings from stage one will be merged using a python code to output a detailed report of the existing conditions of the patient's teeth.

6.1 Reference Standard

Regarding the reference standard for the bitewing radiographs, two skilled dentists will label the carious lesions using LabelMe, an open annotation tool developed by MIT. When a disagreement arises, a third opinion will be sought, and the three must reach a consensus. For simplification, caries will be labeled per tooth and not per surface.

Regarding the reference standard for the clinical tooth status, the same two dentists will perform the examination based on the same criteria to label teeth as carious, filled, or extracted.

6.2 Statistical Analysis

Since there will be a comparison between the automated detection of teeth conditions and a reference standard, a confusion matrix will be utilized, as shown below. Sensitivity(recall), specificity, and accuracy will be then calculated for caries detection, detection of missing teeth, detection of restored teeth, and detection of all tooth conditions. McNemar's test will be used to test the statistical significance between the two methods. The significance level will be set at 0.05.

		Actual			
		Caries	Missed	Restored	All
Predicted	Caries	xxx	xxx	xxx	xxx
	Missed	xxx	xxx	xxx	xxx
	Restored	xxx	xxx	xxx	xxx
	All	xxx	xxx	xxx	xxx

7 Artefacts

The artefact that is expected to be created is a software application using Python programming language that will be able to export detailed information related to the status of each tooth in a spreadsheet format.

8 Timeline of proposed activities

Task	Expected time
Proposal submission and ethical approval	1 month
Research subjects' recruitment and data collection	4 months
Python code	2 months
Training, validating, and testing the neural networks	1 months
Statistical Analysis	2 weeks
Writing	2 months

9 Future Directions

This research proposal discussed the possibility of automating the dental charting process per tooth. However, tooth conditions are charted per surface in the actual dental setting. This proposal could form the basis for expanding this work to apply to tooth surfaces. In addition, more classes of tooth conditions can be included, like tooth wear, developmental defects, and fractures.

Here is the list of references. Please note that no copyrighted images were used in this presentation.

10 References

Antolin, A. M. N., Padilla, D. A. & Reyes, J. M. D. (2021) 'Tooth Condition Classification for Dental Charting Using Convolutional Neural Network and Image Processing'.*2021 6th International Conference on Image, Vision and Computing (ICIVC)*. 174-180.

Bayrakdar, I. S., et al. (2022) Deep-learning approach for caries detection and segmentation on dental bitewing radiographs. *Oral Radiol* 38(4)**:** 468-479.

Chen, X., Guo, J., Ye, J., Zhang, M. & Liang, Y. (2022) Detection of Proximal Caries Lesions on Bitewing Radiographs Using Deep Learning Method. *Caries Res* 56(5-6)**:** 455-463.

Lee, S., et al. (2021) Deep learning for early dental caries detection in bitewing radiographs. *Sci Rep* 11(1)**:** 16807.

Prados-Privado, M., Garcia Villalon, J., Martinez-Martinez, C. H., Ivorra, C. & Prados-Frutos, J. C. (2020) Dental Caries Diagnosis and Detection Using Neural Networks: A Systematic Review. *J Clin Med* 9(11).

Ritter, A. V., Boushell, L. W. & Walter, R. (2019) *Sturdevant's Art and Science of Operative Dentistry*. Elsevier.
Available from: https://www.amazon.com/Sturdevants-Art-Science-Operative-Dentistry-ebook/dp/B078JJLD23/ref=tmm_kin_swatch_0?_encoding=UTF8&qid=&sr= [Accessed 31 March 2023].

Schwendicke, F., Golla, T., Dreher, M. & Krois, J. (2019) Convolutional neural networks for dental image diagnostics: A scoping review. *J Dent* 91(103226.

Tian, S., et al. (2019) Automatic Classification and Segmentation of Teeth on 3D Dental Model Using Hierarchical Deep Learning Networks. *IEEE access* 7(84817-84828.