ORIGINAL ARTICLE

Performance analysis of DMF teeth detection using deep learning: A comparative study with clinical examination as quasi experimental study

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ABSTRACT

Introduction: Decayed, missing, and filled teeth (DMF-T) are indicators used to assess the oral health status of an individual or a population. This examination is typically performed manually by dentists or dental therapists. In previous research, researchers have developed a deep learning model as a part of artificial intelligence that can detect DMF-T. Aim of this research was to analyze the comparison of the performance of deep learning with clinical examinations in DMF-T assessment. **Methods:** Experienced dentists conducted clinical examinations on 50 subjects who met the inclusion criteria. Oral clinical photos of the same patients were taken from various aspects, in total 250 images, and further analyzed using a deep learning model. The results of the clinical examination and deep learning were then statistically analyzed using an unpaired t-test to determine whether there were differences between groups. **Results:** The unpaired t-test analysis indicated that there was no significant difference between the result of DMF-T examination by dentist and by DL (P>0.05). Unpaired t-test of this research indicated no significant difference (P = 0.161). The unpaired t-test concluded that t Stat < t Critical two-tail, then who was accepted, which stated that there was no significant difference between the results of the DMF-T examination between two groups. **Conclusion:** The DL model demonstrates good clinical performance in detecting DMF-T.

KEYWORDS

DMF-T, clinical assessment, deep learning, caries detection

INTRODUCTION

Dental caries is the most prevalent disease in the world, especially in Indonesia.[1] Research by the Basic Health Research (RISKESDAS) in 2018 stated that 57.6% of the Indonesian population has oral health problems, with 88% of them experiencing caries and a DMF-T index of 7.1, which is classified as high.[2] The DMF-T index is important not only for assessing the caries status of a population and comparing it with others but also for planning promotive and preventive efforts to reduce caries incidence in a population.[3]

Every five years, the government routinely conducts epidemiological examinations called Basic Health Research (RISKESDAS). The purpose of this examination is to observe the prevalence of diseases or specific events in each Province or District/City in Indonesia. The results will be utilized for planning, monitoring, and evaluating evidence-based health programs.[4] Examination of dental caries status is one of the aspects to be assessed.

Clinical examination (CE) is the gold standard for examination of dental caries.[5] This examination is usually performed by dentists or dental therapists with calculations done manually. Direct visual examination in large populations and widespread regions typically requires substantial human resources and costs.[6]

The current technological advancements have been extensively utilized in various aspects of life, including healthcare. One of the highly popular technological advancements lately is Artificial Intelligence (AI), capable of mimicking human intellectual abilities.[7] Several requirements need to be met to execute this AI, such as structured data and designed algorithms.[8] This can be fulfilled with crucial components that comprise AI like deep learning (DL) models.[9]

DL is an AI method that learns features by constructing multilevel networks like the human brain model, which can recognize, classify, and describe objects in data. The term "deep" indicates the use of deep model approaches, and "learning" indicates that feature learning is its goal.[10] The utilization of technology will reduce the amount of expenses and accelerate the sample collection process, even with a larger sample size. Human resources involved in the examination can also be minimized. This deep learning technology is capable of processing extensive data from start to finish with high accuracy through complex variables, thus considered capable of replacing many resources.[11]

DL has been utilized in the field of dentistry.[12] Research by You et al. stated that the developed AI model can detect plaque on primary teeth.[13] Studies conducted by Lian et al. stated that DL methods can detect and classify the depth of caries lesions from panoramic radiographs.[14] In previous research, we created a DL model that can detect decayed, missing, and filled teeth.[15] In this study, we compared the results of DMF-T examination between CE conducted by dentists and DL. Aim of this research was to analyze the comparison of the performance of deep learning with clinical examinations in DMF-T assessment.

METHODS

This research was analytical research. It involved 50 patients aged 18-45 years who came to the Dental and Oral Polyclinic RSUDZA. Patients who were examined were patients who had never been examined before for this study. Informed consent was given to patients who met the inclusion criteria. After obtaining informed consent from patients, CE was conducted by an experienced dentist of RSUDZA using a probe and mouth mirror.

A dentist will then examine buccal/labial, lingual/palatal and occlusal aspects of the patient's teeth assisted by a dental therapist to record the results of the examination in an odontogram as shown in Figure 1. Researchers recapitulated the results of the DMF-T examination which were recorded in the odontogram by the dentist in tabular form.

Figure 1. Clinical examination by dentist

A dentist and dental therapist who carried out the dental examination calibrated beforehand to ensure there were no differences in measurements between examiners. Subsequently, clinical oral photos of the same patient were taken in five aspects, such as labial, left and right buccal, and occlusal of upper and lower jaw with the help of a cheek retractor, intraoral mirror and cellphone camera. An example of clinical oral photos taken is shown in Figure 2.

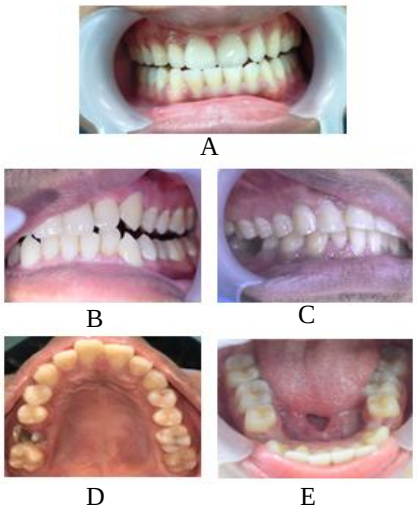

Figure 2. A) Labial aspect; B) Left buccal aspect; C) right buccal aspect; D) occlusal aspect of the upper jaw; E) occlusal aspect of the lower jaw

The clinical oral photos that have been taken were uploaded to Roboflow, which is a computer vision framework. Furthermore, objects within the photos will be detected and annotated. The detection and annotation results are the results of CNN with the YOLO V5 architecture which is part of DL. Objects in the image will automatically be detected and classified as decayed, missing, and filled teeth as shown in Figure 3. We use the YOLO architecture because it can identify objects very quickly, results can be obtained immediately, and has very high accuracy.[16] YOLO can detect multiple objects in a single image.[17]

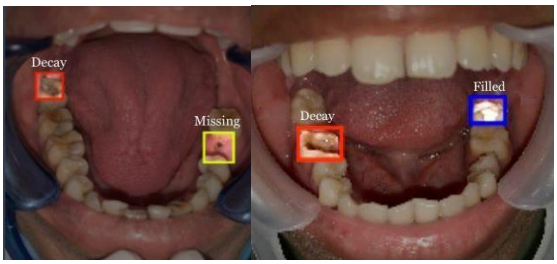

Figure 3. Detection and annotation by deep learning

The researcher then recorded the results of the DL annotation and counted the decayed, missing, and filled teeth manually and summarized them in tabular form. This researcher was not the same person as the dentist who performed the CE to avoid bias. Subsequently, the results of CL and DL were compared and analyzed statistically using unpaired t-test, P value<0.05 was considered statistically different.

RESULTS

The results of the recapitulation of decayed, missing, and filled teeth were summarized and are shown in Table 1. The results of the DMFT examination

conducted by dentists on respondents showed a total of 62 decayed teeth, 121 missing teeth, and 97 filled teeth.

Table 1. Summary of DMF-T Examination by Dentists

D	M	F
62	121	97

The results of DMF-T by DL were also recapitulated and summarized, and are shown in Table 2. Researchers calculated decayed, missing, and filled teeth that were annotated by DL from clinical oral photos. The results of the DMFT examination by DL on the same respondents showed a total of 69 decayed teeth, 92 missing teeth, and 90 filled teeth.

Table 2. Summary of DMF-T Examination by Deep Learning

D	M	F
69	92	90

The results of the DMF-T examination between CL and DL are presented in Table 3. DMF-T values obtained from CE by dentist and DL showed a difference, with a total DMF of 280 by dentist and 251 by DL. The DMF-T index obtained from CE results was 5.6 and 5.02 by DL. This value showed that the two groups had a high DMF-T index based on the World Health Organization (WHO).

Table 3. DMF-T examination

	D	M	F	Total (D+M+F)	DMF-T Index
Clinical Examination (CE)	62	121	97	280	5.6
Deep Learning (DL)	69	92	90	251	5.02

The hypothesis for this research was that Ho stated that the results of the DMF-T examination between CE and DL showed that there were no differences, while He stated that there were differences in the results between CE and DL. The hypothesis chosen in the research was an undirected hypothesis because it could not identify the relationships between groups, so the hypothesis was tested based on two-tail. A P value < 0.05 stated that there was no significant difference between groups, Ho was rejected, and Ha was accepted. The following is a table of statistical analysis results (Table 4).

Table 4. Results of statistical analysis of DMF-T examination

Parameters	Clinical examination (CE)	Deep learning (DL)
Mean	1.730	1.547
SD	1.176	1.190
Variance	1.352	1.351
Observations	159	159
Hypothesized Mean Difference	0	
Df	316	
t Stat	1.406	
P(T<=t) one-tail	0.080	
t Critical one-tail	1.650	
P(T<=t) two-tail	0.161	
t Critical two-tail	1.967	

Based on the results of the table above, the calculated t Stat was 1.406, while the t Critical two-tail value was 1.67. This concluded that the calculated t Stat < t Critical two-tail, then Ho was accepted, which stated that there was no significant difference between the results of the DMF-T examination between the two groups. Unpaired t-test results indicated no significant difference (p= 0.161) between the two groups

DISCUSSION

The DMF-T examination is typically conducted by dentists or dental therapists clinically using standard instruments such as mouth mirrors and probes. DMF-T serves as an indicator to assess the oral health status of both individuals and a population. The oral health status can be determined by assessing the number of teeth that are decayed (D), missing (M), and filled (F).[18] Clinical DMF-T examinations in large populations generally require significant human resources and costs.[6]

The utilization of technology provides an alternative to reduce human resources and costs. DL is one of the rapidly advancing technologies in the fourth industrial revolution. DL can analyze large amounts of data simultaneously with high accuracy; therefore, the implementation of this technology in the field of dentistry is expected to facilitate researchers in collecting extensive data.[11]

Dentistry presents a favorable discipline for employing AI due to its frequent utilization of digital imaging and electronic health records.[19] AI in dentistry is primarily implemented to perform enhanced diagnostic accuracy and efficiency, and CNNs have been proven to correctly detect the presence of caries in approximately 4 out of 5 cases from imaging data.[20,21] Numerous studies consistently highlight the high accuracy, sensitivity, and specificity of DL for caries detection, which usually exceeds 80%.[6]

Currently, there is no research conducted in the field of dentistry regarding DMF-T examinations. In previous research, datasets were processed to develop DL models capable of detecting caries lesions. The previously developed DL model is capable of detecting decayed, missing, and filled teeth with precision values of 93.5%, recall of 83.1%, and mean Average Precision (mAP) of 91.3%. In this study, researchers compared the results of DMF-T examinations between CE conducted by dentists and DL model to assess the performance of the previously developed DL model.

Table 1 shows the results of DMF-T examination by dentist with the number of decayed teeth 62, missing teeth were 121, and filled teeth were 97. For clinical examination, decayed tooth represents cavity in the enamel or cavity extending to the dentin or the pulp, leaving the crown structure intact. Missing is root fragments that are an indication for extraction or edentulous areas left by previous extractions. while filled is the tooth that have been restored with glass ionomer cement or composite resin. No onlay, inlay, crown, or bridge restorations were examined in this study.

Table 2 shows the results of DMF-T examination by DL with the number of decayed teeth of 69, missing teeth at 92, and filled teeth at 90. The DL model detected more decayed teeth than CE. This is due to DL's inability to differentiate between remaining root fragments (indicating extraction) and decayed teeth (indicating filling).[22] Teeth that have lost a significant amount of structure can be classified as either carious teeth or missing teeth. Teeth are classified as carious if there is enough remaining crown structure for restoration or if the caries edge extends above the gingival margin. Meanwhile, teeth are classified as missing if restoration cannot be performed due to limited crown structure or if the caries edge is below the gingival margin. Previous research only utilized two-dimensional clinical photos, thus it had not been able to detect the caries edge. Therefore, this deep learning model is still imperfect in determining teeth with indications for extraction or filling. DL still detected remaining root fragments as decayed teeth. DL detected fewer missing teeth due to the previously mentioned issue of root fragments being identified as decayed teeth. The DL method also struggled with detecting missing posterior teeth because of insufficient lighting in the clinical image dataset. Filled teeth were detected by DL and CE at 90 and 97, respectively. The DL values were lower than CE because DL had difficulty distinguishing between healthy teeth and those filled with tooth-colored materials. As a result, DL might misclassify teeth filled with tooth-colored materials as healthy teeth.

Table 3 shows the total results from decayed, missing, and filled teeth categories from both groups, and shows the DMF-T index of each group. The DMF-T index results were calculated by dividing the total DMF-T by the number of samples, namely 50. Both groups show that the DMF-T index results had a high category based on WHO. Based on the results of the statistical analysis, the mean values for CE and DL obtained were 1.730 and 1.547. In other studies, caries were well detected from panoramic photos. but it was only compared types of caries lesions using various types of X-ray images, including intraoral, bitewing, and panoramic photos, with accuracies ranging from 68.0% to 96.1%.[6] Panoramic photos are easier to detect because they use grayscale color to determine brightness levels in the image, making it simpler for analysis and interpretation. On the other hand, clinical photos have additional color parameters such as hue, value, and chroma, which can make them become more complex to analyze and interpret. Additionally, the data used was quite large, thus increasing precision.

In Table 4, P-value<0.05 was considered significantly different. This was in line with previous research which produced an accuracy value of 79.5%. The total DMF-T obtained from the CE results showed a higher value compared to the total obtained by the DL model, namely 280 and 251, respectively. However, based on the statistical analysis, P two-tail was 0.161, indicating no significant difference between the two groups. Nevertheless, these results could still be improved if the accuracy of DL detection increases.

Image enhancement and object classification through preprocessing of oral clinical images to obtain a better dataset can enhance the accuracy of DL in detecting an object. Image enhancement techniques such as segmentation, feature extraction, and contrast improvement before training the dataset will result in precise object classification. Additionally, the quantity and diversity of the dataset will also influence the machine's ability to learn objects more effectively.[23,24]

This research still had some limitations, including a relatively small dataset size of 50 patients and 250 images of the patients. A larger dataset would provide more detailed accuracy regarding DMF-T detection using the DL model. Additionally, the clinical images captured in this examination lacked diversity, with no samples of patients with deep pit-fissures, crown restorations, or dental implants. This limitation made it challenging to assess whether DL could effectively detect such cases as either healthy teeth or teeth with fillings. A well-structured methodological approach was needed for the automatic detection of DMF-T.[25] Various oral clinical images with different surfaces and types of lesions should have been available. This research required support from various parties to enable DL technology to detect DMF-T in various forms of teeth and produce a more effective algorithm.

DL is expected to be developed into an application that facilitates users such as dentists, dental therapists, and other public health workers in detecting DMF-T. The use in the form of an application would undoubtedly be more convenient and time-saving for users. This DL model is also expected to detect dental caries with various depths, such as enamel caries, dentinal caries, and pulpal caries, in both anterior and posterior teeth by incorporating radiographic images.

CONCLUSION

The DL model demonstrated good clinical performance in detecting DMF-T. The research required an increase in the number of subjects for better results. With a large sample, the mean and standard deviation obtained have a high probability of resembling the mean and standard deviation of the population. The implications of this research are significant for both the field of dentistry as well as modern healthcare technology. By introducing a novel dataset and evaluating deep learning models, it is suggested that this research become a foundation for developing advanced diagnostic tools in dentistry.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data supporting reported results can be requested.

Conflicts of Interest: The authors declare no conflict of interest.

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