ORIGINAL ARTICLE

Sensitivity and specificity of DentMA teledentistry in dental caries detection: screening in vulnerable communities

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ABSTRACT

Introduction: Teledentistry offers a practical solution to limited access to dental care by enabling remote screening using smartphone-based technology. Vulnerable populations such as pregnant women, children who rely on parental assistance, and the elderly have a high prevalence of dental caries and often face barriers to routine dental visits due to mobility limitations, time constraints, and dependence on caregivers. These characteristics make them priority targets for teledentistry-based screening. DentMA teledentistry is a smartphone-based application developed by the research team, integrating intraoral photographic capture, deep learning–assisted caries detection, and remote dentist evaluation to support early dental screening. This study aimed to evaluate the sensitivity and specificity of DentMA teledentistry for dental caries screening in vulnerable community populations. **Methods:** This was a prospective study with a cross-sectional design. Intraoral photographs were obtained using a smartphone camera and then uploaded to an Internet of Dental Things (IoDT)-based platform. Intraoral images were reviewed by dental professionals and compared with clinical examinations by co-assistants and dental nurses during activities outside the health center. Photographic assessments carried out by dentists were compared to clinical assessments by co-assistents and dental nurses. Data analysis included sensitivity, specificity, and accuracy, accompanied by Cohen's kappa values >0.60 **Results:** 90 participants were included in this study, consisting of 30 pregnant women, 30 elderly individuals, and 30 children. All photographic views showed high sensitivity of 85.54% (95% CI, 77.0% to 93.1%) and specificity of 86.60% (95% CI, 79.8% to 93.4%) in detecting email-dentin caries and PUFA, with an accuracy of 86.11%. The agreement between the results of clinical examinations and photographic methods (assessed by dentists) was considered strong, with kappa scores ranging from 0.74-0.80. **Conclusion:** Assessment of intraoral photographs using DentMA teledentistry for caries detection demonstrated clinically acceptable accuracy when compared with visual clinical examination, based on sensitivity and specificity values. This strategy has implications for supporting remote dental health services for vulnerable communities (pregnant women, the elderly, and children) without access to healthcare facilities.

KEYWORDS

Teledentistry, sensitivity, specificity, accuracy, dental caries screening

INTRODUCTION

Dental and oral health is an important aspect that requires attention, as it can have a direct impact on overall health.[1] According to the 2023 Indonesian Health Survey (SKI), 56.9% of people have experienced dental caries, and only 11.2% have sought treatment from health workers.[2] Dental caries can be detected

through visits to dentists at health facilities.[3] The size of Indonesia's territory and the inadequate proportion of dentists to the population are other problems related to health service access. Undetected dental disease may be addressed using teledentistry.

Teledentistry is a relatively new term that integrates two fields, namely telecommunications and dentistry.[4,5] Teledentistry provides dental care such as diagnosis, consultation, treatment planning, and facilitates second opinions before undergoing treatment.[6-8] According to research by Jampani, et al.[9] the public can consult and receive education about oral health virtually, which allows them to do it anywhere and anytime at a very affordable cost.

Teledentistry enables rapid and efficient preliminary diagnosis through remote assessment, although direct clinical examination remains the gold standard for dental caries screening.[10] Recent advancements in smartphone-based intraoral photography and asynchronous image evaluation have demonstrated diagnostic performance comparable to conventional chairside examinations, particularly for early caries detection and community-based screening programs.[11]

However, reduced attendance at dental health facilities among high-risk groups—such as children, pregnant women, and the elderly—continues to reflect persistent barriers related to limited mobility, caregiving dependence, and geographic constraints. Teledentistry (especially DentMA teledentistry) allows dentists to assess oral conditions in sufficient detail prior to prescribing medication or recommending further treatment, thereby reducing delays and enabling timely referrals to hospitals or clinics when needed. In addition to being more cost-effective than face-to-face dental care, teledentistry facilitates access to specialist consultations regardless of geographical distance, while maintaining acceptable diagnostic quality.[12]

Despite these advances, evidence remains limited regarding the diagnostic accuracy of teledentistry applications implemented in real-world community settings and applied simultaneously across multiple vulnerable population groups. Therefore, this study addresses this gap by evaluating the sensitivity and specificity of a smartphone-based teledentistry application for dental caries detection among children, pregnant women, and the elderly.

Research conducted by Alsharif et al.[13] states that teledentistry may be comparable to face-to-face screening, especially in school-based programs, rural areas and areas with limited access to care, and long-term care facilities. Another positive aspect of teledentistry is that, through online consultation features, it may allow dentists to manage more patients per day.[14]

The DentMA application uses deep learning models. This method has demonstrated increased accuracy and reduced computation times. It documents the teeth and surrounding tissues based on the direction of image capture, and includes close-up images of affected or targeted teeth using the scan feature in the application. The results of the photo display are generally consistent and clear.[15] Through online caries screening and dental examination using this application, doctors and patients can connect efficiently even at a distance.[15,16]

The DentMA teledentistry application is a smartphone-based digital platform developed by the research team that integrates standardized intraoral photographic capture with deep learning–assisted analysis and remote dentist evaluation to support early dental screening. Its ease of use via widely available smartphones has the potential to expand access to dental health services, particularly for populations facing mobility and access barriers, such as the elderly, pregnant women, and children who depend on caregivers.[15]

Despite the increasing adoption of teledentistry, limited empirical evidence is available regarding the diagnostic accuracy of locally developed, application-based teledentistry tools when implemented in real-world community settings and applied simultaneously across multiple vulnerable population groups. This represents a critical gap in validating teledentistry as a reliable screening alternative outside conventional clinical environments.

The novelty of this study lies in evaluating the sensitivity and specificity of DentMA intraoral photographic screening across diverse vulnerable community groups within a community-based context. Accordingly, the aim of this study was to assess the diagnostic accuracy of DentMA teledentistry intraoral photography for dental caries detection among pregnant women, children, and the elderly.

METHODS

A prospective study with a cross-sectional design was conducted from November to December 2023 in the working area of the Meuraxa Public Health Center, Aceh Besar. The number of participants was 90, divided into three groups: 30 pregnant women, 30 elderly individuals, and 30 elementary school children.

This study included three population groups, with a significance level of $\alpha = 0.05$ and statistical power of 80% ($\beta = 0.20$). The minimum sample size was calculated to be 29 participants per group and was rounded up to 30 participants for each group. A total of 90 participants were therefore included. Participants were recruited using consecutive sampling based on predefined inclusion and exclusion criteria. Elementary school children were recruited through the School Dental Health Program (UKGS) at elementary schools located within the working area of the Meuraxa Community Health Center and were not recruited at the Integrated Healthcare Post (Posyandu).

Pregnant women and elderly participants were recruited directly from the Integrated Healthcare Post (Posyandu) within the same community health center area. For the children's group, intraoral photographs were taken by parents or guardians using their Android-based smartphones under guidance provided by the research team. Inclusion criteria for all groups included ownership of an Android-based smartphone with a functioning camera (for children, ownership by parents or guardians) and willingness to participate as indicated by signed informed consent. Exclusion criteria were non-cooperative behavior and absence during the data collection period.

Prior to data collection, participants (or parents/guardians of children) were provided with a standardized video tutorial explaining the correct procedure for capturing intraoral photographs using a smartphone and the DentMA teledentistry application. The tutorial was delivered immediately before the photo-taking session at the study location and reinforced with printed flyers. During data collection, headlamps were provided by the research team to standardize lighting conditions.

Immediately before photographing, participants were instructed to rinse their mouths; for children, parents or guardians cleaned the teeth using moistened cotton or gauze and dried the tooth surfaces with gauze to minimize saliva interference. Intraoral photographs were then captured on-site using participants' smartphones through the DentMA application, following standardized image-taking protocols. To minimize variability and bias related to photo interpretation, examiner calibration was conducted prior to the study using the ICDAS II criteria to ensure consistency in scoring.

Direct clinical dental examinations were performed on the same day as intraoral photo acquisition, immediately after the photographs were taken, by trained co-assistants and dental nurses using standard visual examination procedures. Examiners assessing the intraoral photographs and those conducting the direct clinical examinations were independent of each other. Blinding was implemented such that dentists evaluating the intraoral photographs were not informed of the clinical examination results, and the clinical examiners were unaware of the photographic assessment outcomes.

The DentMA application uses deep learning models, and images were then uploaded to an Internet of Dental Things (IoDT)-based platform, which has demonstrated increased accuracy and reduced computation times. The technique of taking photos followed standardized directional protocols, then included close-

up images of the affected or targeted teeth using the scan feature in the application. The results of the photo display are generally consistent and clear. If the photos were insufficient or unclear, the DentMA application automatically instructs the user to retake the photos.

The DentMA teledentistry application has been developed by Dr. Munifah since 2021, tested (simulated) in the Banda Aceh community, and received intellectual property rights (IPR) number EC00202290700. Furthermore, all the participants' intraoral clinical photographs were collected and sent via email to expert dentists for early detection through screening by observing the intraoral clinical photos and filling out the available odontogram forms.

Primary data were obtained directly during clinical examinations of dental caries in pregnant women, elderly, and elementary school children, as well as screening results from intraoral photos using DentMA teledentistry. Intraoral images were reviewed by dental professionals and compared with clinical examinations by co-assistants and dental nurses during activities outside the health center.

Photographic assessments carried out by dentists were compared to clinical assessments by co-assistants and dental nurses. Intraoral photo analysis at the screening level, using mapping based on a combination of the International Caries Detection And Assessment System (ICDAS) II system and the American Dental Association Caries Classification System, was conducted. This clustering method was also used by Giudice et al.[17] The expert dentists mapped the intraoral photographs.

In this study, suitability was defined as the level of agreement between dental caries detection obtained through DentMA teledentistry intraoral photographic screening and the findings from direct clinical dental examination, which served as the gold standard. Suitability was determined by comparing the presence or absence of dental caries (enamel–dentin caries and PUFA) identified using DentMA with those identified during clinical examination on a tooth-level and participant-level basis.

The validity of each photo screening result against a clinical examination was assessed through diagnostic tests (sensitivity, specificity, and area under the curve). Consistency between the screening tool and the gold standard was evaluated using the Cohen's Kappa coefficient. Kappa values were interpreted according to standard criteria, with values >0.60 indicating substantial agreement.

The formula to determine sensitivity, specificity, and accuracy are as follows: Sensitivity = (True Positives (TP))/(True Positives (TP)+False Negatives (FN)); Specificity = (True Negatives (TN))/(True Negatives (TN)+False Positives (FP)); Accuracy = (TP+TN)/(TP+TN+FP+FN). The formulas for PPV and NPV are Positive Predictive Value=(True Positives (A))/(True Positives (A)+False Positives (B)); Negative Predictive Value=(True Negatives (D))/(True Negatives (D)+False Negatives(C))

RESULTS

This study used primary data obtained from 90 participants, divided into 30 pregnant women, 30 elderly, and 30 elementary school children. Participants who met the inclusion criteria were given informed consent and data were collected through screening results from intraoral photographs using teledentistry, compared to the results of clinical examinations. The results obtained are as follows:

Table 1. Characteristics of the Participants

Item	Children	Pregnant Woman	Elderly
Age			
6-19 years	30		
20-45 years		30	
46-70 years			28
>70 years			2
Sex			
Male	15		9
Female	15	30	21

Table 1 presents the demographic characteristics of the study participants across the three vulnerable groups. The children's group consisted of an equal number of males and females (15 each), with an age range of 6–19 years. Pregnant women participants were all female, with ages ranging from 20 to 45 years. The elderly group was predominantly female, comprising 21 women and 9 men, with ages ranging from 46 to over 70 years.

Table 2. Suitability between DentMA teledentistry screening and Clinical Examination in Vulnerable Groups

Item	Children	Pregnant Woman	Elderly	Overall ($\bar{x}$)
Appropriate	86.6%	76.6%	83.3%	82.2%
Inappropriate	13.3%	23.3%	16.6%	17.8%

Table 2 shows the results of dental caries detection using the DentMA teledentistry application, which demonstrates 82.22% agreement with clinical examination. The results of dental caries screening are almost the same between clinical examinations and teledentistry-based assessments. The appropriate result was highest in children (86.67%), compared to 76.6% in pregnant women and 83.3% in the elderly.

Table 3. Sensitivity and specificity of DentMA teledentistry

Teledentistry		Clinical examination		Total
		+	-	
	TRUE	71	13	84
	FALSE	12	84	96
	TOTAL	83	97	180

Sensitivity 85.54% (95% CI, 77% to 93.1%)
Specificity 86.60% (95% CI, 79.8% to 93.4%)
Accuracy 86.11%
Positive Predictive Value 84.52%
Negative Predictive Value 87.50%

Table 3 shows a sensitivity of 85.54%, which means that the DentMA application can detect caries similarly to clinical examinations where both can detect enamel-dentin caries and Pulpal involvement, Ulceration, Fistula, and Abscess (PUFA). The specificity of 86.6% shows that, in addition to being able to detect caries, the DentMA application can also detect healthy teeth, and this is consistent with clinical examinations.

Table 4 shows the sensitivity and specificity estimates with 95% confidence intervals, indicating that the DentMA application demonstrates reliable diagnostic performance in identifying enamel–dentin caries and PUFA lesions. Agreement between intraoral screening using DentMA teledentistry and direct clinical examination was further evaluated using Cohen's Kappa coefficient, which yielded a value of 0.75. This result indicates a substantial level of agreement between the teledentistry-based assessment and the clinical examination.

Table 4. Calculation of 95% confidence intervals of sensitivity and specificity for enamel-dentin caries and PUFA category

Category	Item	Data	Estimation	Sample	SE	95% CI
Enamel-Dentin	Sensitivity	TP = 35, FN = 4, Total = 39	$\frac{35}{39} \approx 0.897$	39	0.048	$0.897 \pm 0.094 \rightarrow (0.803, 0.991)$
	Specificity	TN = 40, FP = 11, Total = 51	$\frac{40}{51} \approx 0.784$	51	0.057	$0.784 \pm 0.112 \rightarrow (0.672, 0.896)$
PUFA	Sensitivity	TP = 36, FN = 8, Total = 44	$\frac{35}{44} \approx 0.8182$	44	0.058	$0.818 \pm 0.114 \rightarrow (0.704, 0.932)$
	Specificity	TN = 44, FP = 2, Total = 46	$\frac{44}{46} \approx 0.9565$	46	0.029	$0.956 \pm 0.057 \rightarrow (0.899, 1.000)$

DISCUSSION

A vital component of the human body, the oral cavity and the tissues that surround it play a significant role in daily bodily functions and people's general well-being.[16] Dental caries is commonly found in patients, and is typically detected when patients visit a dentist at a health facility.[3] However, the number of visits to dentists at primary health facilities is relatively low. This research on smartphone screening involved vulnerable groups that are generally affected by caries.

Based on the data in Table 1, the groups involved consisted of children, pregnant women, and the elderly, with each group consisting of 30 participants. The vulnerable groups divided by gender were dominated by women. The number of children involved in this study was the same between males and females, namely 15 participants each, while in the elderly group, there were 9 men and 21 women. In line with previous research, there is a lack of protection against dental caries during childhood but not during adolescence or adulthood. This shows variation between men and women in accessing or utilizing dental health services.[18]

Based on Table 1, the group of children has an age range of 6-13 years overall, and 30 children had dentin caries and/or PUFA in their oral cavity. This research is supported by Basic Health Research (Riskesdas) data and other studies stating that dental caries is high in children. The results of Hasan's study (2024)[19] found that in children aged 5-9 years, dental caries reached 92.6%, while in children aged 10-14 years it reached 73.4%.[19,20]

The group of pregnant women in the study had an age range of 20–45 years (n = 30), and 27 of the 30 pregnant women had dental caries. The elderly group included 28 participants aged 45–70 years and 2 participants aged over 70 years, all of whom had dental problems. This research is in line with the 2018 Riskesdas data, which show that pregnant women are at risk of developing caries, and study of Tedjosasongko (2019)[21] shows that around 84% of pregnant women have caries.[20,21]

Likewise, in the elderly group, it was found that they had many dental and oral problems, especially dental caries. Previous studies have reported that the prevalence of dental caries in the elderly group was 96.8%. This is strengthened by the 2018 Riskesdas data, which reported that the most common diseases in the elderly were non-communicable diseases, including dental and oral problems.[20,21]

The screening results obtained using the DentMA teledentistry application demonstrated an overall agreement of 86.11% with direct clinical examinations across all vulnerable groups, indicating a high level of concordance between the two assessment methods. This finding is consistent with previous studies reporting

strong agreement between smartphone-based teledentistry screening and conventional clinical examinations in community and outreach settings. Previous studies have shown that teledentistry-based caries screening can achieve comparable diagnostic performance to face-to-face examinations, particularly among populations with limited access to dental care.[3,4]

Furthermore, the sensitivity and specificity values observed in this study are in line with earlier reports evaluating photo-based teledentistry applications, which have demonstrated sensitivity ranging from 73% to 89% and specificity between 88% and 96% across pediatric, adult, and geriatric populations. These similarities suggest that DentMA teledentistry performs comparably to established teledentistry approaches and supports its applicability as a reliable screening tool for dental caries detection in vulnerable community settings. ……

Based on Tables 2 and 3, the screening results (assessments) of the DentMA teledentistry application showed a sensitivity of 85.54% and a specificity of 86.6%. This research is in line with the results of Golsanamloo's study (2022)[22] on photo-based teledentistry in 20 pediatric patients at the Tabriz University of Medical Sciences teaching hospital, it was analyzed to have a sensitivity and specificity of 73.22% and 95.8%. There was almost no significant difference between clinical examination and the teledentistry application used in diagnosing caries in children during the COVID-19 pandemic.[22]

The results of Qari's study in 2023, which was conducted on patients over 18 years of age using tele-screening through photos taken independently by the patient, reported sensitivity of 88-89% and specificity of 88-91%, indicating that the results of clinical examinations and teledentistry were highly comparable.[23]

The results of the sensitivity and specificity tests in each study may vary due to the quality of the photos obtained via smartphones, especially in the interproximal and root surface areas, so supporting examinations such as radiography are needed. Another limitation is the lack of color on the enamel and dentin.[22,23] It should be noted that smartphone photographs can provide accurate and clinically meaningful detection of frank caries in the primary and mixed dentitions.[24]

Despite its limitations, teledentistry remains effective in detecting dental caries through early examinations that can be done online. The application of teledentistry is very important and has high value in coastal and urban areas that are underserved by specialist personnel, reducing health service costs and improving the quality of care.[25] Most dentists in developed countries have used Teledentistry as an alternative to detect early dental caries before planning further treatment.[23,26] Teledentistry can also help overcome geographical barriers and travel time in providing clinical care, consultations, and training for dentists or health workers in remote areas and with minimal specialist medical personnel.[10,27]

Smartphone-based technology using DentMA teledentistry is useful in self-dental examinations that can detect cavities through photos, enabling people to detect dental and oral diseases independently.[15,28] This is expected to motivate people to pay more attention to their dental health and seek appropriate treatment to overcome the dental problems they experience.[29] Dental caries detection can be carried out reliably through teledentistry applications. There is an ascending trend in smartphone use in teledentistry applications. Teledentistry serves as a method for early detection in vulnerable communities (school children, pregnant women, elderly) with dental caries and classifies them based on the level of caries risk. This risk assessment can help dental professionals create treatment and prevention strategies to combat dental caries.

The limitation of this research primarily relates to the number of included participants. Despite attempts to address cross-sectional design limitations that are prone to bias, potential confounding factors within the study were not adequately addressed.

CONCLUSION

Online remote examination of intraoral photos using DentMA teledentistry has the potential to be used for dental caries screening, with appropriate diagnostic accuracy and reliability to support community-based screening. The sensitivity and specificity confidence intervals indicate that the DentMA application is reliable in identifying subjects who actually have enamel-dentin and PUFA caries. The implication of this research is its integration into primary care to provide an alternative for remote dental health services for vulnerable communities (pregnant women, elderly, and children) who have difficulty accessing healthcare facilities.

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