THE ACCURACY OF SMARTPHONE IMAGES FOR ORAL HEALTH SCREENING AMONG CHILDREN COMPARED TO CLINICAL EXAMINATION: A PILOT STUDY

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Abstract

The aim of this study was to determine the accuracy of smartphone images for oral health screening among children compared to clinical examination. Children aged 7–12 years old were visually examined by Examiner 1 (E1) for caries status using the International Caries Detection and Assessment System (ICDAS), and carious lesions were classified as enamel or dentin caries, dental plaque assessment using the Debris Index (DI), and gingival health using the Modified Gingival Index (MGI). Following the clinical examination (CE), an iPhone 13 (Apple Corp.) was used to take five images of their teeth for caries detection and one frontal view image of anterior teeth coated with plaque disclosing gel for smartphone image examination (SIE) using the same clinical parameters. The smartphone image examination was conducted independently by Examiner 2 (E2) without any knowledge of the results from the visual clinical examination. The sensitivity of smartphone images to detect enamel and dentin caries was similar at 74% and 72%, respectively, which reflects its ability to correctly identify participants with dental caries. The specificity and positive predictive value (PPV) for dentin caries were both 100%, while the negative predictive value (NPV) was approximately 98%. The positive predictive value and negative predictive value of enamel caries detection were 76.9% and 77.4%, respectively. The inter-rater reliability between the two examinations was calculated using ICC, and the scores for DMFT, DI, and MGI were 0.842, 0.964, and 0.832, respectively. The Wilcoxon signed rank test was used to compare the mean DMFT, DI, and MGI between the visual and image-based examinations with p-values of 0.121, 0.965, and 0.445, respectively (not statistically significant). The findings in this pilot study showed that the mobile teledentistry approach using smartphone images has demonstrated its ability to identify caries, plaque, and gingival status in children with acceptable diagnostic accuracy when compared to visual clinical examination. Smartphone cameras can serve as a reliable and practical alternative in screening for enamel and dentin carious lesions, dental plaque, and gingival status when compared to the visual clinical examination.

Keywords: Decayed, Missing, Filled Teeth Index, Modified Gingival Index, Oral Health, Smartphone, Teledentistry.

Introduction

Oral health is defined as the ability to speak, smile, smell, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, or disease of the craniofacial complex (1). Poor oral health in children can have devastating effects on their well-being, including learning issues, loss of sleep, poor growth, and potential behavioural problems. Diseases related to oral health are significantly linked to lower parental workdays and lower school attendance (2).

Dental caries and periodontal disease are the most common oral diseases in developing countries (3, 4). Both conditions are preventable diseases that share a common causative factor of dental plaque accumulation. In Malaysia, the National Oral Health Plan's 2011-2020 goal of caries-free dentition in 12-year-old schoolchildren is > 70%. However, according to the 2017 National Oral Health Survey of Schoolchildren, only 66.7% were caries-free, even though it shows a slight improvement from the previous national surveys. Meanwhile For periodontal disease, 99.8% of 12-year-old schoolchildren had gingival bleeding in 2017, a drastic decline in periodontal health compared to 2007, when 19.6% of 12-year-old schoolchildren had a healthy periodontal condition (5). These findings show that students' periodontal health has significantly declined, indicating that almost all of them need at least oral hygiene education.

The consequences of oral diseases can be minimised through regular dental screening and early detection of the disease to ensure that children can receive treatment before they acquire serious health consequences (6). Due to barriers encountered by children in getting access to regular dental check-ups, such as long waiting times, a lack of awareness, and time constraints imposed by parents (7), teledentistry has emerged as a substitute for in-person dental examination.

Teledentistry can be described as the remote delivery of dental care, advice, or treatment through the medium of technology instead of face-to-face interaction with the patient (8) and enables patients to reach the dentist at another site, thus saving time and energy. The use of teledentistry in screening dental caries among children is still not widely used in Malaysia, where there is a need for more evidence-based teledentistry practice. Teledentistry in dental screening can be effectively implemented in Malaysia, and there is potential for it to offer services similar to face-to-face screening. However, challenges arise due to limited resources in teledentistry and knowledge or expertise in the domain (9). According to Khokhar et al. (10), while over 60% of dental practitioners acknowledged that teledentistry could improve communication with peers and assist in guiding new patient referrals within dental practices, a significant proportion of practitioners (70-80%) voiced concerns about the accuracy of diagnoses, technical reliability, and privacy associated with it.

The use of teledentistry has grown exponentially during the COVID-19 pandemic, as the spread of the virus poses a challenge to providing services for patients in dental practices (11). A systematic review by Gurgel-Juarez et al. (12) revealed that teledentistry is effective for dental referrals, treatment planning, and dental treatment monitoring. In the paediatric population, teledentistry has been utilised for the purposes of oral health education and promotion, remote diagnosis and monitoring, and behaviour guidance (13).

Mobile teledentistry is a subset of teledentistry that incorporates cellular phone technology and store-and-forward methods into oral health care services. The features of smartphones with built-in cameras and mobile connectivity can be combined as an effective teledentistry screening tool (14). Some studies on teledentistry have always used Digital Single-lens Reflex (DSLR) cameras or intraoral cameras to assess the accuracy and reliability of photographic methods in oral health screening. However, research on the use of smartphone cameras in epidemiological dental research is still lacking (15). Some studies have explored the feasibility of utilising smartphones for screening oral diseases such as caries (14), oral malignant lesions (15), oral hygiene (16), denture hygiene (17), and aesthetic analysis (18) has shown that images acquired with smartphone cameras can be a reliable tool compared to clinical assessment. However, assessment of gingival health using smartphone images has not yet been explored, especially among children. Smartphones can produce images of equally good quality due to their advancements in technology development. Among children, the feasibility of using smartphone images for caries screening has been studied (14, 19-23); however, the ability of smartphone images to screen for early enamel lesions and more extensive caries has scarcely been explored. Furthermore, to our knowledge, assessment of gingival health using smartphone images has also not yet been widely studied. Therefore, exploring the accuracy of smartphone images for screening of different extents of caries lesions as well as gingival health is crucial, as these features can potentially be a part of comprehensive dental screening through teledentistry. This can be particularly helpful for individuals who have limited access to dental care due to geographic or financial barriers. Additionally, incorporating smartphone technology into dental screening can also improve efficiency and convenience for both patients and dental professionals.

Materials and Methods

Subjects and sampling

Patients aged 7-12 years old undergoing treatment at the Dental Polyclinic Faculty of Dentistry at Universiti Kebangsaan Malaysia and whose parents consented to participate in this study were selected. The inclusion criteria were patients who were between 7 and 12 years old, had overall good health, and were cooperative for dental examinations. Patients who require emergency dental treatment during the visit, have soft or hard tissue abnormalities, swelling, or dental injuries were excluded. Convenient sampling was done by selecting participants who were attending the dental clinic on the selected dates.

Study procedure

Patients who were attending the Dental Polyclinic, Faculty of Dentistry, Universiti Kebangsaan Malaysia, were recruited based on the inclusion and exclusion criteria. Consent was obtained from their parents, and patients were seen in the dental clinics for the research procedure prior to their scheduled treatment session with their respective clinicians. The detailed description of the procedures is discussed below. Two examiners were involved in this study: examiner 1 (E1) conducted the clinical examination (CE) and captured intraoral images with a smartphone camera, and examiner 2 (E2) was involved in the examination of the smartphone images (SIE). The procedures involved in the study are summarised in Figure 1.

Clinical examination (CE)

A clinical examination was conducted with patients on the dental chair and examined under dental light. Teeth were dried with a triple-air syringe prior to the caries assessment, and a visual inspection was conducted. E1 examined each tooth using the International Caries Detection and Assessment System (ICDAS). Teeth with caries on more than one surface—only the surface with the highest ICDAS score—were included in the study. Any tooth that was missing due to caries was also charted. The teeth were also examined for any restorations (temporary, tooth-coloured, or any other type of restoration) on any tooth

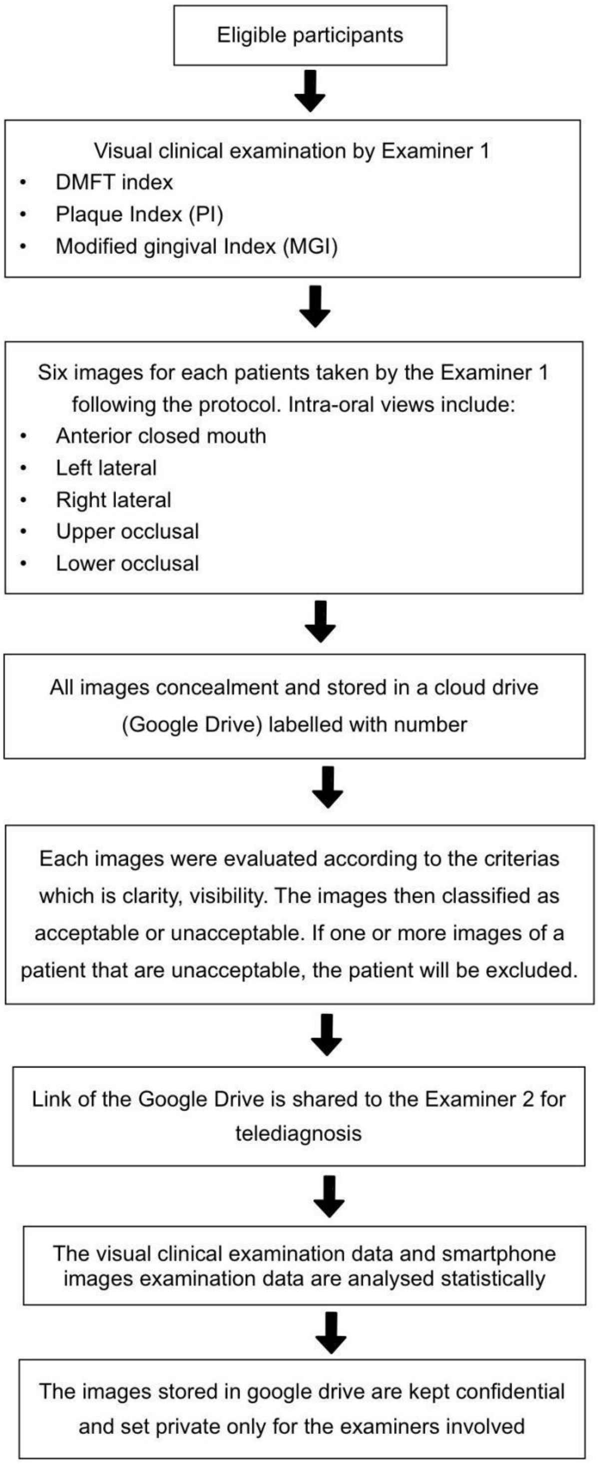

Figure 1: Study flow chart

surfaces. For the dental plaque assessment, twelve teeth, consisting of upper and lower anterior teeth from canine to canine, were evaluated. However, for patients who had exfoliated primary teeth and unerupted permanent teeth, a minimum of eight teeth were included for examination. Plaque disclosing dye (GC Tri Plaque ID Gel) was applied to the examined teeth, and the plaque detected was given a score according to the Debris Index (DI) component of the Oral Hygiene Index (24). The gingival health of the same teeth was examined according to the Modified Gingival Index (MGI) (25). Other soft and hard tissue abnormalities, such as abscesses, sinus tract infections, aphthous ulcers, swellings, and dental injuries, were documented but excluded from the study. For patients who had visibly abundant dental plaque that interfered with the examination of caries, a plaque assessment was conducted first, followed by the removal of plaque using a bur brush and pumice prior to the caries assessment.

Smartphone image capturing

The same examiner (E1) who did the CE captured all the images using a smartphone following the photography protocols. The images were taken using the smartphone model (iPhone 13), with assistance in the form of auxiliary tools (e.g., cheek retractor and intraoral mirror). For caries assessment, five intraoral views were taken (frontal, left lateral, right lateral, upper occlusal and lower occlusal) meanwhile for plaque and gingival assessment, one frontal view was taken. A total of six images were taken for each patient. All images must have visible teeth and any blurry images were repeated until satisfactory quality was obtained. The following criteria were checked for each image; i. clarity of the images; ii. visibility of area of interest. The images were then classified as a) Acceptable and b) Unacceptable. Examples of acceptable images are shown in Figure 2 and 3. The examiner who was responsible for image capturing should follow the photography protocols established to obtain as many teeth as possible (26).

Photography protocol:

1. Patient must sit on the dental chair and follow the instructions of the examiner.
2. Before shooting, auxiliary tools such as an intraoral mirror or a cheek retractor can be used if necessary to capture as many teeth and details as possible. So, the examiner should indicate to the patient how to arrange himself and whether to open, close, pursue lips, and do all the possible movements to obtain the best possible image so that the area of interest is visible.
3. Photos taken with or without camera flash under natural light.
4. At the time of shooting, the camera must be placed at a distance where a clear image can be obtained. More than one attempt is allowed.
5. The images to be taken are:
    a. frontal,
    b. left lateral,
    c. right lateral
    d. upper occlusal
    e. lower occlusal
6. Each participant is recorded numerically, and their images are then saved in a cloud drive (Google Drive, Google) folder labelled with a number for each patient.

Figure 2: Intraoral images taken by E1 using a smartphone camera with auxiliary tools (cheek retractor and intraoral mirror). (a) upper occlusal; (b) right lateral; (c) frontal; (d) left lateral; (e) lower occlusal

Figure 3: Frontal view of labial surfaces of anterior teeth coated with plaque disclosing dye.

7. The link to the Google Drive folder was then shared with the remote examiner (Examiner 2).

Smartphone specification

The camera of the iPhone 13 (Apple Corp.) has a dual 12-megapixel system, including main (f/1.6 aperture) and ultra-wide (f/2.4 aperture) cameras. Its main camera has sensor shift optical image stabilisation as well as auto image stabilisation with 2x optical zoom out and digital zoom up to 5x. The iPhone 13 has a true-tone flash with slow sync, which ensures uniformity of light and provides enough lighting for dark areas. The intraoral images were taken using a single smartphone for all patients.

Smartphone image examination (SIE)

Examiner 2 (E2), who was blinded to the clinical examination, assessed the smartphone images for each patient. The examiner examined the images for caries, dental plaque, and gingival status using the same parameters as the CE.

Storing of smartphone images

Each patient's images were labelled according to the patient's ID, transferred from the smartphone, and stored in individual folders in Google Drive.

Examination parameters

International Caries Detection Assessment System (ICDAS)

All teeth were examined using the International Caries Detection Assessment System (ICDAS). To represent the extent of caries, scores 1-3 were grouped as enamel caries (EC), and scores 4-6 were grouped as dentin caries (DC). Teeth that were restored were scored as F for filled, and missing teeth due to caries were scored as M for missing. Carious teeth scored as (EC) and (DC) were then grouped as D for decayed teeth. The Decayed, Missing, and Filled index (DMFT) was then used to represent the sum of the decayed (D), missing due to caries (M), and (F) filled teeth.

Debris Index

The Oral Hygiene Index (OHI) by Greenspan and John (24) was used. It is a sensitive, simple method for assessing group or individual oral hygiene quantitatively. This index, composed of the debris index (DI) component and score for the labial surface of anterior teeth, was calculated in each patient as follows:

0 = no debris or stain

1 = soft debris covering not more than one-third of the tooth surface

2 = soft debris covering more than one third but not more than two thirds of the tooth surface

3 = soft debris covering more than two-thirds of the tooth surface

Modified Gingival Index

According to a study by Bessa Rebelo et al. (25), the Modified Gingival Index (MGI) devised introduced changes in the criteria of the Gingival Index through a non-invasive approach (no probing) and resetting the rating for mild and moderate inflammation. The gingiva was evaluated in each patient as follows:

0 = normal

1 = mild inflammation or with slight changes in colour and texture but not in all portions of the gingival margin

2 = mild inflammation, such as the preceding criteria, in all portions of gingival marginal or papillary

3 = moderate, bright surface inflammation, erythema, edema, and/or hypertrophy of gingival marginal or papillary

4 = severe inflammation: erythema, edema, and/or gingival hypertrophy of the unit or spontaneous bleeding, papillary congestion, or ulceration.

Calibration of examiners

The calibration of the ICDAS, DI, and MGI for both methods of examination (CE) and (SIE) was done among the examiners involved in this study. E1, who did all the clinical examinations, was calibrated for all the parameters measured in the study using five paediatric patients who attended the Dental Polyclinic in UKM. The caries examination, DI, and MGI score obtained by E1 were then compared to a gold standard examination conducted by a paediatric dental specialist. The intraclass coefficient (ICC) score for DMFT was 0.879, the DI was 0.825, and the MGI was 0.78.

The second examiner (E2), who was involved in the smartphone image examination, was calibrated for all the parameters using ten random images for caries detection, ten random images for MGI, and seven random images for DI, which were also compared to data obtained from another paediatric dental specialist. The ICC score for DMFT was 0.854, the DI was 0.859, and the MGI was 0.858.

Statistical analysis

SPSS Statistics version 28 was used for statistical analysis. For assessing the accuracy of detecting carious lesions, only enamel and dentin caries were used. Filled and missing teeth were excluded from the analysis. Using the examiner's clinical examination as the gold standard, true positive, true negative, false positive, and false negative carious lesions were identified, and sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were analysed. To assess the reliability of the smartphone image examination for DMFT, DI, and MGI, intraclass correlation coefficient (ICC) was used. According to Koo and Li (27), the ICC can be interpreted as follows: < 0.50 = "poor reliability/agreement"; 0.50–0.74 = "moderate reliability/agreement"; 0.75–0,90 = "good reliability/agreement"; > 0.90 = "excellent reliability/agreement". To compare the mean DMFT, DI, and MGI of clinical and smartphone image examinations, a Wilcoxon signed-rank test (22) was used, with a p-value < 0.05 considered statistically significant.

Results

The final number of participants included in this study was 19. The participants' ages range from 7 to 12 years old, with 6 patients (31.6%) being between 7 and 9 years old and 13 patients (68.4%) being between 9 and 12 years old. Out of 19 patients, 10 (52.6%) were male and 9 (47.37%) were female.

The total number of teeth examined clinically was 442, consisting of 184 primary teeth and 258 permanent teeth. The number of teeth that have caries is 59 (13.3%) for clinical examination and 51 (11.54%) for smartphone image examination. For CE, the percentage of teeth with dentin caries is higher than enamel caries, while for SIE, enamel caries has a higher percentage. For the DI score, the majority of the teeth had a score of 3 for both types of examination (44.8% and 41.3%). The frequency of carious teeth (EC, DC, D), debris index (DI0, DI1, DI2, DI3), and MGI (MG0, MG1, MG2, MG3, MG4) are shown in Table 1.

Table 1: Percentage of teeth with caries, Debrix Index scores, and Modified Gingival Index scores

Caries	N (%) N = 442	
	CE	SIE
Total decayed	59 (13.3)	51 (11.54)
Enamel caries	28 (47.5)	29 (0.07)
Dentin caries	31 (52.5)	22 (0.05)
Filled (F)	30 (6.79)	31(7.01)
Missing (M)	3 (0.68)	0 (0)
Debris Index Score	N (%) N = 217	
	CE	SIE
Debris Index$_1$	26 (12.3)	30 (13.8)
Debris Index$_2$	73 (34.4)	80 (36.7)
Debris Index$_3$	95 (44.8)	90 (41.3)
Total Debris Index (1+2+3)	194 (89.4)	200 (92.2)
Modified Gingival Index	N (%) N = 217	
	CE	SIE
Modified Gingival Index$_1$	24 (11.1)	10 (4.6)
Modified Gingival Index$_2$	5 (2.3)	6 (2.8)
Modified Gingival Index$_3$	3 (1.38)	5 (2.3)
Modified Gingival Index$_4$	0 (0)	0 (0)
Total Modified Gingival Index (1+2+3+4)	32 (14.74)	21 (9.7)

CE=clinical examination, SIE=smartphone images examination

Table 2 shows the accuracy of the SIE for all the parameters examined in this study. The sensitivity of smartphone images in detecting enamel and dentin caries was similar at 74% and 72%, respectively. The specificity and PPV for dentin caries were both 100%, while the NPV was approximately 98%. The PPV and NPV of enamel caries detection were 76.9% and 77.4%, respectively.

Table 2: Caries exposure and gingival status

Parameter	Clinical Examination Mean (SD)	Smartphone Image Examination Mean (SD)	p - value
DMFT	0.253 (0.152)	0.173 (0.132)	0.121
DI	2.114 (0.556)	2.106 (0.523)	0.965
MGI	0.189 (0.302)	0.162 (0.400)	0.445

DMFT=decay, missing, filled teeth, DI=debris index, MGI=modified gingival index, SD=standard deviation
*The mean values were analysed using Wilcoxon rank test

The mean DMFT, DI, and MGI were compared using the Wilcoxon rank test, and the p-value for all the parameters was > 0.05 (Table 3), indicating the mean difference between the two types of examinations is not significant.

Table 3: Accuracy of smartphone image vs clinical examination in assessing carious lesion

CE vs SIE	Caries (%)	
	EC	DC
Sensitivity	74	72
Specificity	98.4	100.0
Positive Predictive Value (PPV)	76.9	100.0
Negative Predictive Value (NPV)	77.4	97.9

CE=clinical examination, EC=enamel caries, DC=dentine caries, SIE=smartphone images examination

To further determine the reliability of the results, the scores for inter-rater reliability between two examinations were calculated using ICC as shown in Table 4. The highest intraclass coefficient score is for the debris index score at 0.964, which gives excellent reliability, while for DMFT and modified gingival scores, it is good and ranges above 0.8 for both scores (Table 4).

Table 4: Reliability of CE and SPE in DMFT, DIS and MGI

	DMFT	Debris Index Score	Modified Gingival Index
ICC (95% CI)	0.842	0.964	0.832

DMFT=decayed, missing, filling teeth, ICC=Intra-class coefficient

Discussion

The aim of this study was to evaluate the accuracy of smartphone images for the screening of caries, dental plaque, and gingival status. Although the smartphone model used in this study is a sophisticated device and can produce images of good quality, six patients had to be dropped from this study due to the unacceptable images. Although a protocol was followed by the examiner who captured the images, many of the images were blurred or could not be all teeth in the mouth, therefore deemed unacceptable. This problem could have been reduced if images were analysed immediately after capture and repeated if necessary. Previous studies (28, 29) included the use of a macro photography setup comprising an interchangeable lens camera coupled to a macro lens and a ring flash. Such integration may be feasible in a clinical setting; however, if the goal is to allow non-dental professionals, such as parents or teachers, to be involved in using smartphones to capture intraoral images of children, minimal equipment is more convenient and feasible. To improve the detection of oral diseases such as caries and gingivitis even from images of suboptimal quality, other more advanced hardware and technologies, such as deep learning and artificial intelligence, may be required.

Children aged 7–12 years were included in this study because a mixed dentition would allow for examination of the parameters for both primary and permanent teeth, although the analysis of the parameters used in this study was not done according to the type of teeth. The caries prevalence in this age group tends to be high, and this is also the age where they are beginning to brush their teeth on their own without parental supervision; therefore, the presence of dental plaque and gingival status is contributed by the patient's ability to brush their teeth.

In our study, the level of oral hygiene of the patient was evaluated through the amount of dental plaque present on the tooth surfaces and the condition of the gingiva. The debris index component of the Oral Hygiene Index (OHI) was used in this study; however, instead of using all the teeth present in the mouth, we only included the labial surfaces of anterior teeth for the determination of the debris index score. Including posterior teeth and lingual surfaces for plaque detection could pose a challenge in terms of the visibility of the teeth on images.

In this study, the reliability of smartphone images to identify early caries lesions and more extensive caries was investigated. The sensitivity and specificity for both types of caries were considered high, indicating the ability of smartphones to correctly identify 74% of enamel caries and 72% of dentin caries. A variable range has been reported by previous studies by Estai et al. (20) (58%–80%) and AlShaya et al. (21) (74.1–89.1%). This could be due to several factors, such as the multiple examiners included in those studies and the different smartphone models that were used. The sensitivity of enamel and dentin caries detection is above 70%, in contrast with a previous study by Kohara et al. (28) which found that the sensitivity of smartphone images in diagnosing initial caries is lower than for moderate and extensive caries. This difference could be because in the current study, teeth scored 1-3 using the ICDAS were classified as enamel caries, while in the previous study, only scores 1 and 2 were classified as initial lesions. The score of 3 refers to the colour changes and presence of enamel breakdown, which is possibly more noticeable in the images. The PPV and NPV values for both enamel and dentin caries are considered high (> 70%), indicating the high likelihood that teeth that are identified as having caries in this study truly have the disease, and teeth that are deemed sound truly do not have the disease. This study has demonstrated that using a smartphone camera to capture photographs can yield acceptable levels of accuracy in caries detection when compared to conventional clinical dental examinations. As evident from the available research (22), numerous teledentistry studies have been introduced to identify caries. A significant portion of these studies required either an intraoral scanner or dental professionals to conduct the index test. To the best of our knowledge, this study represents a pioneering effort as it employed dental students as data collectors and utilised a smartphone camera for data collection purposes. Despite these unconventional approaches, the study yielded promising results.

The mean DMFT, DI, and MGI values were analysed for inter-rater reliability using ICC to analyse the agreement between clinical and smartphone image examinations. The ICC score for all the parameters indicates the high reliability of smartphone images in detecting dental plaque. To our knowledge, studies investigating the reliability of smartphone images in detecting dental plaque are still lacking, with some studies focusing on using intraoral cameras or digital cameras. A study conducted in a nursing home showed high reliability in detecting dental plaque using smartphones (ICC score of 0.84-0.87) (17); however, the index used in the study was the plaque index for long term care. Another study by Azevedo et al. (16) used dental selfies to assess dental plaque and found that there was a moderate correlation between the visual and selfie indexes of dental plaque. Gingival health has also scarcely been investigated in studies using smartphone images as a diagnosis method. Intraoral photographs taken by DSLR cameras were used to screen for gingivitis among patients undergoing orthodontic treatment, and the findings showed that the images were reliable in detecting gingival changes at different periods of orthodontic treatment (30).

This study has several limitations. Firstly, only one examiner for each method of examination was employed. Including multiple examiners has advantages such as improved reliability and reduced bias; however, since this is a pilot study, a single examiner for each examination method is deemed sufficient. In addition, it is well known that the assessment of caries from images has the limitation of only providing a two-dimensional view, preventing the observation of all tooth surfaces, especially the interproximal surfaces of posterior teeth. It is also known that the photographic method has limitations for detecting caries on root surfaces or non-visible secondary caries. In this study, images were captured from five different angles, enabling the assessment of caries on the buccal, occlusal, and lingual surfaces. Despite the limitations of this study, images captured via smartphone could potentially be a reliable method that can be utilised for screening caries and the oral hygiene status of children. Another limitation is that the handling of children is rather difficult and obtaining a clear picture on the first attempt was a challenge. Also, due to the limited mouth openings of children, the pictures appear out of focus and need to be repeated several times. When using cameras for obtaining intraoral pictures among children, a good level of cooperation is required.

Regarding data protection, smartphones offer a convenient way for patients to connect to the internet and communicate with their dentist. However, when capturing and sharing photos, it is crucial to ensure the secure transmission and storage of these images while safeguarding patient confidentiality, which is a significant concern in telemedicine. The secure flow of data transmission is essential; therefore, transferring and adding patient photos to their records is done carefully and confidentially.

Future recommendations include conducting further studies on larger sample sizes to validate the results and improve the accuracy of smartphone images in detecting dental caries. The feasibility of utilising smartphones for dental screening in non-clinical settings such as at home or schools and by non-dental professionals such as parents and teachers could be explored. Integration of smartphones into comprehensive teledentistry platforms should be explored due to the advantages of accessibility and ease of use of smartphones to enhance application of teledentistry among children.

Conclusion

In conclusion, the study found that smartphone images can be a reliable alternative to clinical examination in screening for enamel and dentin carious lesions, dental plaque, and gingival status. These findings have important clinical implications, making remote dental screening possible and indirectly improving patients' access to dental healthcare professionals. Future recommendations include conducting further studies on larger sample sizes to validate the results and improve the accuracy of smartphone images in detecting dental caries. Additionally, it is important to consider factors such as lighting and camera positioning to optimise the quality of smartphone images for dental examinations. With continued advancements in technology, the use of smartphones in dental examinations may become more widespread, ultimately improving access to dental care for all patients.

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Competing interest

The authors declare that they have no competing interests.

Ethical Clearance

The ethical approval for this study was obtained from the Research Ethics Committee, Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM) (Reference No.: UKM PPI/111/8/JEP-2022-375).

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References

1. FDI World Dental Federation. FDI's definition of oral health. Available at: https://www.fdiworlddental.org. Accessed 16 April 2023.
2. Rowan-Legg, A. Oral health care for children - a call for action. Paediatr Child Health. 2013; 18(1):37–50.
3. Frencken JE, Sharma P, Stenhouse L, Green D, Laverty D, Dietrich T. Global epidemiology of dental caries and severe periodontitis – a comprehensive review. J Clin Periodontol. 2017; 44(18):S94–S105.
4. Riolina A, Hartini S, Suparyati S. Dental and oral health problems in elementary school children: A scoping review. Pediatr Dent J. 2020; 30(2):106–114.
5. Ministry of Health Malaysia. Oral Health Division. National Oral Health Survey of School Children 2017. In Volume II: Oral Health Status of 12-Year-Old School Children. Accessed 12 December 2023.
6. Daniel, S., & Kumar, S. Comparison of dental hygienists and dentists: clinical and teledentistry identification of dental caries in children. Int J Dent Hyg. 2016;15(4):e143–e148.
7. Zotti F, Rosolin L, Simoncelli F, Pappalardo D, Cominziolli A, Zerman, N. Telediagnosis of dental caries: Possible or impossible? A pilot cross-sectional study. Clin Exp Dent Res. 2022;8(6): 1614–1622.
8. Khan SA, Omar H. Teledentistry in practice: literature review. Telemed J E Health. 2013; 19(7):565–567.
9. Mohamed Nazari NS, Wafa SWWSST, Baharuddin NA. Teledentistry in the Malaysian context: Are we there yet? Arch Orofac Sci. 2022; 17(1):9–19
10. Khokhar RA, Ismail WA, Sunny A, Shaikh GM, Ghous S, Ansari M, Zia SH, Arshad S, Alam MK. Awareness regarding Teledentistry among Dental Professionals in Malaysia. BioMed Res Int. 2022; 2022:1-8.
11. Achmad H, Tanumihardja M, Ramadhany YF. Teledentistry As A Solution In Dentistry During The Covid-19 Pandemic Period: A Systematic Review. Int J Pharm Res. 2022; 12(2):272.
12. Gurgel-Juarez N, Torres-Pereira C, Haddad AE, Sheehy L, Finestone H, Mallet K, Wiseman M, Hour K, Flowers HL. Accuracy and effectiveness of teledentistry: a systematic review of systematic reviews. Evid Based Dent. 2022;1–8.

13. Sharma H, Suprabha BS, Rao A. Teledentistry and its applications in paediatric dentistry: A literature review. Pediatr Dent J. 2021; 31(3):203–215.
14. Estai M, Kanagasingam Y, Huang B, Shiikha J, Kruger E, Bunt S, Tennant M. Comparison of a Smartphone-Based Photographic Method with Face-to-Face Caries Assessment: A Mobile Teledentistry Model. Telemed J E Health. 2017; 23(5):435–440
15. Karthikayan R, Sukumaran A, Diwakar MP, Raj V. Accuracy of smartphone based photography in screening for potentially malignant lesions among a rural population in Tamil Nadu: A cross-sectional study. Digit Med. 2019; 5(2):56.
16. Azevedo CL, Henriques PS, Pannuti CM, Michel-Crosato E. Selfie Dental Plaque Index: A New Tool for Dental Plaque Assessment. J Clini Exp Dent. 2022; 14(11):e926–e931.
17. Bleiel D, Rott T, Scharfenberg I, Wicht MJ, Barbe AG. Use of smartphone photos to document the oral care status of nursing home residents. Gerodontology. 2023; 40(2):244–250.
18. Lazar R, Culic B, Gasparik C, Lazar C, & Dudea D. Evaluation of smartphone dental photography in aesthetic analysis. British Dental Journal. 2021; 1-8.
19. Duong DL, Kabir MH, Kuo RF. Automated caries detection with smartphone color photography using machine learning. Health Inform J. 2021; 27(2):1-17.
20. Estai M, Kanagasingam Y, Mehdizadeh M, Vignarajan J, Norman R, Huang B, Spallek H, Irving M, Arora A, Kruger E, Tennant M. Mobile photographic screening for dental caries in children: Diagnostic performance compared to unaided visual dental examination. J Public Health Dent. 2022; 82(2):166–175.
21. AlShaya MS, Assery MK, Pani SC. Reliability of mobile phone teledentistry in dental diagnosis and treatment planning in mixed dentition. J Telemed Telecare. 2020; 26(1-2):45–52.
22. AlShaya M, Farsi D, Farsi N, Farsi N. The accuracy of teledentistry in caries detection in children - A diagnostic study. Digital health. 2022; 8:1-14.
23. Guo S, Chen Y, Mallineni SK, Huang S, Liu B, Zhang S, Lu C. Feasibility of oral health evaluation by intraoral digital photography: a pilot study. J Int Med Res. 2021; 49(2):1-8.
24. Greene JG, & Vermillion JR. The simplified oral hygiene index. The Journal of the American Dental Association. 1964; 68(1), 7-13.
25. Bessa Rebelo MA, de Queiroz AC. Gingival Indices: State of Art. Gingival Diseases – Their Aetiology, Prevention and Treatment. 1st edition. London, United Kingdom: InTech Open Limited. 2011.
26. Zotti F, Rosolin L, Simoncelli F, Pappalardo D, Cominziolli A, Zerman N. Telediagnosis of dental caries: Possible or impossible? A pilot cross-sectional study. Clin Exp Dent Res. 2022; 8(6):1614–1622.
27. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med. 2016; 15(2):155–163.
28. Kohara EK, Abdala CG, Novaes TF, Braga MM, Haddad AE, Mendes FM. Is it feasible to use smartphone images to perform telediagnosis of different stages of occlusal caries lesions? PloS One. 2018; 13(9):1-12.
29. Morosini I deA, de Oliveira DC, Ferreira F deM, Fraiz FC, Torres-Pereira CC. Performance of distant diagnosis of dental caries by teledentistry in juvenile offenders. Telemed J E Health. 2014; 20(6):584–589.
30. 30. Kim HN, Kim K, Lee Y. Intra-Oral Photograph Analysis for Gingivitis Screening in Orthodontic Patients. Int J Environ Res Public Health. 2023; 20(3705):1-12.