Validity and reliability of remote dental screening by different oral health professionals using a store-and-forward telehealth model

M. Estai,*[1] J. Winters,[2] Y. Kanagasingam,[3] J. Shiikha,[1] H. Checker,[1] E. Kruger[1] and M. Tennant[1]

In brief

Suggests that dental practitioners with minimal training have the potential to detect caries from photographs with the same diagnostic accuracy as dentists.

Highlights that store-and-forward telehealth offers a practical and potential cost-saving means to screen for dental caries among asymptomatic populations.

Provides evidence to support the use of MLDPs such as therapists or hygienists to screen for oral diseases and provide treatment plan using telehealth service.

Objective This study was conducted to evaluate the validity and reliability of intraoral photographic assessments by different members of a dental team as a means for dental screening in children. **Methods** The intraoral photographic records of 126 children (2 to 18 years old) were obtained from routine clinical records taken before dental treatment. Intraoral photographs were obtained using a DSLR camera and then uploaded to a cloud-based server using store-and-forward telehealth technology. Images were reviewed by an expert panel to formulate a benchmark screening baseline, to which the screeners' data were compared. The photographic assessments conducted by a mid-level dental practitioner (MLDP) and dentist, were compared to the benchmark expert panel assessment. **Results** The screeners' assessments by means of intraoral photography, when compared to the expert panel assessment had a sensitivity value of 82–89% and specificity value of 97%. The inter-examiner agreement between the expert panel assessment and photographic method (assessed by a dentist and MLDP), was almost perfect, with a kappa score ranging from 0.82 to 0.88. The mean DFT/dft score for the children as determined by the expert panel's review and photographic assessment ranging from 5.41 to 5.79, with mean scores between the two assessment methods not significantly different (P = 0.746). **Conclusion** Our results suggested that oral health professionals (other than dentists) have the potential to screen for caries from intraoral photographs with the same diagnostic accuracy and reliability as dentists. This strategy has implications for supporting the use of MLDPs such as dental therapists or hygienists to screen for oral disease using telehealth.

Introduction

Most dental care services in developed countries are funded privately, with much of it provided on a fee-for-service basis.[1] This is coupled with limited dental insurance and a tendency for the uninsured to be those who are underserved and also experience the majority of the dental diseases.[2] Australia, for example, has one of the healthiest populations in the world but significant healthcare inequalities still exist[3] where patients with high needs have less access to dental care, while patients with the least needs are treated using the most expensive resources.[4] Efficient and effective dental screening has the potential to reduce oral health inequalities and optimise the use of limited resources.[5] Unlike many medical disorders, dental caries is relatively easy to detect in clinical settings or epidemiological studies. Early diagnosis, early intervention, and preventive treatment can prevent or reduce the progress of many dental diseases. This concept is considered the cornerstone of cost-effective delivery of dental care, with the potential to save hundreds of millions of dollars.[6] Therefore, there is a need to shift the oral healthcare system from a cure to care culture.[7]

One of the viable solutions to address unmet oral health needs, is the use of mid-level dental practitioners (MLDPs), specifically dental therapists, to screen for oral diseases,[5,8,9] and where only the more complex patients are referred to dentists, while simple cases are treated by MLDPs. Although the practices of dental therapists have been mostly limited to under-18-year-olds worldwide,[10] dental therapists' scope of clinical practice in some places has been extended to also treat adults.[11] Evidence suggests that dental practitioners with minimal training can successfully screen for oral diseases[9,12] and perform complex dental procedures under the supervision of an off-site mentorship.[13] A recent report on the Alaskan workforce model has provided evidence that employing MLDPs utilising a telehealth system

[1]International Research Collaborative – Oral Health and Equity, Department of Anatomy, Physiology and Human Biology, University of Western Australia, Australia; [2]Dental Department, Princess Margaret Hospital, Australia; [3]Australian eHealth Research Centre, CSIRO, Australia
*Correspondence to: M Estai
Email: abdalla177@gmail.com

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has the potential to address the oral health needs of underserved populations in remote Alaska.[14] This strategy can help in reducing the isolation of local practitioners in remote areas, and allow them to provide treatment under the guidance of a remotely located dental expert.

The clinical oral examination has been the primary technique used for dental screening. However, this technique is inappropriate in comparative studies where dental examiners remain non-blinded to certain characteristics of participants.[15] Also, conducting clinical examination in large epidemiological surveys is challenging, as this necessitates huge resources. Seeking approaches that can expedite early detection of dental problems, improve patients' referrals and avoid treatment delay without affecting the accuracy of diagnosis is needed. The growing interest in telehealth services utilising rapidly evolving digital imaging has provided dental providers with alternatives to traditional methods.[16] The use of photographs in dentistry has increased rapidly over recent years and it has become an integral part of routine dental practice.[17] Several studies have examined the use of intraoral photographs in dental epidemiology. Most studies found that telediagnosis of oral diseases based on intraoral photographs can offer a valid and reliable alternative to the traditional oral examination.[15,18–21] Previous studies were focused on the assessment of the feasibility, validity and reliability of the photographic assessment in comparison to a visual examination as the reference standard. However, research reports on comparing the assessment of intraoral photographs by different members of the dental team are limited. Against this background, this study aimed to compare the validity and reliability of the photographic method in the screening for dental caries, between different levels of dental practitioners.

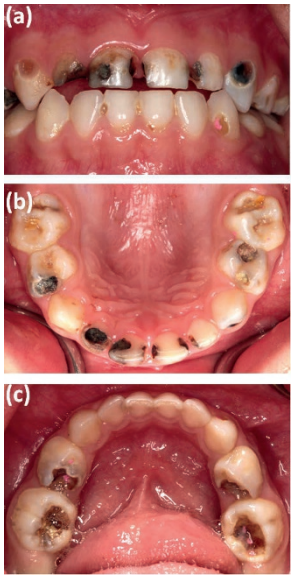

Fig. 1 Intraoral photograph shots showing three views. (a) Anterior view; (b) Upper occlusal view; (c) Lower occlusal view

Methods

Ethical approval for this study was granted by The University of Western Australia Human Research Ethics Committee. This study was a retrospective descriptive study that examined intraoral photographic records of 126 children (2 to 18 years old), who were patients of one author (JW) between the years 2010 and 2014.

Original photograph collection

A digital single-lens reflex (DSLR) camera (Canon EOS 7D, EF 100 mm f2.8 Macro USM Lens, Macro Ring Lite MR-14EX) was used to obtain intraoral photographs from all 126 patients undergoing dental treatment under general anaesthesia. Dental photography was completed pre-operatively by a trainee specialist dental registrar (Paediatric Dentistry). A standard series of three intra-oral photographs per patient was obtained using retractors and intraoral photographic mirrors (anterior, upper occlusal and lower occlusal views), and these were uploaded to a Remote-i server at a later time (Fig. 1). The uploaded images were 1,000-4,000 KB in size and saved as JPEG format to the Remote-i server.

Expert panel review

All intraoral photographs were reviewed by an expert panel to formulate a standard screening baseline, to which the screeners' data could be compared. The panel consisted of three dental practitioners (including authors EK and MT). A dentogram based on the collaborative assessment of the panel was formulated for each patient to reflect the dental status at the time the images were taken. This was at the level of screening, not a comprehensive examination. This was the benchmark against which the other screeners' assessments were tested.

Data assessment

The evaluation of the dental photographs was carried out by two independent, off-site dental practitioners, a MLDP and an internationally-trained dentist (not registrable in the jurisdiction) using a web-based data and image-viewing app built upon the Remote-i system. The Remote-i is a comprehensive data management server that has been widely used as a telehealth platform in various screening programmes.[22] A simple user manual and cover letter were sent to the screeners explaining the study purpose and how to use the system. The system enabled each screener to evaluate photographs independently and insert comments on the predefined oral health assessment form and submit reports or recommendations into the Remote-i server. These independent assessments by dental practitioners created the database used to compare with the benchmark panel assessment and between the screeners. We used a method developed by the WHO based on tooth-by-tooth assessment, which is simple and easy to use in large epidemiological surveys.[23] As the photograph only provides two-dimensional views we could not use the International Caries Detection and Assessment System (ICDAS) (which is based on tooth surface) as the unit of analysis.

Statistical analysis

SPSS version 17.0 (IBM Company, Chicago) was used to compute Cohen's kappa to test the inter-examiner reliability for the benchmark panel assessment, and the photographic assessments based on tooth-on-tooth comparisons.[24] Fifteen percent of the intraoral photographs were re-graded to test the intra-examiner agreement, at least, four weeks after the initial scoring of the photographs. The sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) of the photographic method for each examiner were calculated. For this analysis, all teeth were classified as sound or carious. Caries experience, using the DFT/dft (decay, filled teeth) index, were calculated for each case and

Table 1 Demographic characteristic of participants

Characteristics	N (%)
Age	
2-5 years	51 (41%)
6-11 years	56 (44%)
12-18 years	19 (15%)
Gender	
Male	58 (46%)
Female	68 (54%)
Total	**126**

analysed through descriptive statistics. DFT/dft was used instead of DMFT/dmft, as the reasons for missing teeth (exfoliation, caries, other) could not be assessed. Statistical differences between group means were determined by one-way ANOVA. Using the sample size methods devised by Flahault *et al.* where the prevalence of the disease is less than 0.50.[25] With an ideal sensitivity of 95% and a lower 95% confidence limit of 80%, the number of cases with caries required is 50. With dental caries prevalence of 40% (1.5 × 50 = 75), 75 cases are needed without caries. So the total sample size of 125 was required in this study.

Results

The demographic characteristics of the participants are summarised in Table 1. All intraoral photographs were gradable, however, out of 4,032 teeth reviewed, a small proportion of the individual teeth were scored as 'unrated' by the MLDP (142 teeth, 3.5%) and dentist (75 teeth, 1.9%).

Tooth-by-tooth comparisons: The inter-examiner agreement between the benchmark panel assessment and photographic method (assessed by a dentist and MLDP) was almost perfect, with the kappa score ranging from 0.82 to 0.88. The intra-examiner agreement for the photographic assessments for screeners was almost perfect, with the kappa score of 0.82. Across all the screeners and examination methods, the specificity (96% to 97%) was higher than sensitivity (81% to 89%). The level of agreement, sensitivity, specificity, accuracy, positive predictive value and negative predictive value measures for both the benchmark panel and screeners' photographic assessments are presented in Table 2.

The mean DFT/dft score (at the screening level) for the children, as determined by the expert panel was 5.79 (4.30 ± SD), and as determined by the off-site dentist and MLDP was 5.41 (3.94 ± SD) and 5.71 (4.31 ± SD) respectively. The mean DFT/dft was not significantly different between the three assessment groups (P = 0.746). Approximately 90.5% of the children were classified as having caries experience by the expert panel and 88.9% to 90.6% of the children were classified as having caries experience by the screeners (Table 3). The sample also included eight participants with genetic conditions affecting the teeth, such as dentinogenesis imperfecta and amelogenesis imperfecta. All these cases were identified by the expert panel and the screeners.

Discussion

The assessment of two screeners (dentist and MLDP) was compared to the benchmark expert panel. Our results indicate that the assessment of intraoral photographs at a distance maintains a good level of the sensitivity and specificity. Across all examination methods and screeners, specificity values were slightly higher than the recommended threshold, falling outside of the 95% confidence interval around the WHO reference standard. In contrast, sensitivity values were slightly lower than the WHO recommended threshold, except for the dentist, whose sensitivity value was high and met the WHO's reference standard of 0.85-0.90.[23] The higher value for the sensitivity might be explained by the higher likelihood that the dentist scored a tooth as carious when in doubt, in order for it to be subjected to additional investigations.[26] Nevertheless, the MLDP was not significantly different to the dentist or benchmark panel assessments. The high values of the NPV are not of concern given that the low numbers of false negatives reported by all screeners are associated with the high level of agreement across the examiners.[24]

Our findings demonstrated a substantial to almost perfect inter-examiner agreement for both screeners (dentist *versus* MLDP) and against the benchmark expert panel. The intra-examiner reliability for the photographic assessment was also high, suggesting that screeners were consistent in the way they identify caries from photographs. Although the MLDP had a marginally lower level of agreement in comparison to the benchmark panel, the MLDP had a slightly higher mean DFT/dft score compared to the dentist, suggesting that the MLDP has a lower threshold of identifying lesions as carious on photographs. The results of a recent study in which intraoral photographs were used to screen for caries *in vivo* that compared photographic assessments with a visual oral examination suggests that the photographic method can be a valid and reliable way of screening for caries[19,20] and it can be used in large epidemiological studies with some degree of confidence.[15] Our findings are also consistent with other studies evaluating the efficacy of dental screening by different members of the dental team *in vivo*, which indicated that MLDPs are capable of screening for caries to a similar standard as dentists.[8,9,27,28]

The quality of photographs and the capability to grade correctly are important factors when evaluating the feasibility of telediagnosis of oral diseases.[29] The DSLR camera used in this study produces images of 18 megapixels and is considered adequate for producing

Table 3 Proportion of children with caries-experienced and mean DFT/dft score at the level of screening

	Caries experience (%)	Mean DFT/dft (±SD)
Benchmark panel	90.50%	5.79 (4.30 ± SD)*
MLDP	88.90%	5.71 (4.31 ± SD)*
Dentist	90.60%	5.41 (3.94 ± SD)*

*The level of significance between the dentist, MLDP and benchmark panel assessments is (P = 0.746).
MLDP = Mid-level dental practitioner

Table 2 Accuracy and inter-examiner reliability of photographic assessment calculated on the basis of tooth-on-tooth comparisons

	Sensitivity (%)	Specificity (%)	Accuracy	PPV	NPP	Kappa (95% CI)
Benchmark panel *vs* MLDP	82%	97%	94%	91%	94%	0.82 (0.79–0.85)
Benchmark panel *vs* Dentist	89%	97%	96%	92%	97%	0.88 (0.86–0.90)
Dentist *vs* MLDP	81%	96%	93%	88%	94%	0.80 (0.77–0.83)

Positive predictive value (PPV), negative predictive value (NPV)
MLDP = Mid-level dental practitioner

high-quality images, even in low-light situations, or at high magnification. However, in some cases, there was uncertainty about the loss of detailed diagnostic information due to the presence of saliva, blood or debris, particularly for the posterior permanent teeth. The difficulty in detecting carious lesions and differentiating them from staining or dark artefacts could explain why some teeth were scored as 'unrated' by the screeners. These limitations could contribute to the lower sensitivity in the posterior permanent teeth compared to other parts of the dentition. This reflects previous studies which have found variations in the inter-examiner reliability in detecting caries in posterior teeth largely due to the morphology of the fissures and staining.[30,31]

The use of photographic methods in large-scale epidemiological studies is considered feasible. Photographic assessment utilising store-and-forward telehealth technology has been used widely to screen for diseases.[32] The photographic method has the potential to facilitate the archiving of photographic records which can facilitate remote assessment of photographs in research studies that may need blinding.[15] This strategy also has implications for prioritising new patient appointments, and facilitating patient referrals to a dental consultant, thus reducing waiting lists and travel, and delays in diagnosis and associated treatment.[33] Healthcare professionals (nurse) or non-licensed healthcare professionals (teacher) could obtain intra-oral photographs from children for a later assessment by an off-site dentist.[12,15,34] The use of dental practitioners with limited training like MLDPs can offer a practical and potential cost-saving means to screen for dental diseases using photographic methods, among populations with high levels of need, who have limited access to oral care.[35]

Conclusion

The sample in this study was enriched with dental caries; these sorts of cases are those that you want strong assurance will be picked up urgently in a screening programme. This study suggests that different members of the dental team, with minimal additional training, have the potential to detect caries from web-based presented photographs with a comparable diagnostic accuracy and reliability to dental experts. This approach offers the potential to free up economic and human resources as well as support the use of MLDPs to screen for oral diseases and increase the capacity to care for those who have no access to oral care because of distance or social exclusion. In the future, pattern recognition and artificial intelligence algorithms could be used to detect caries from the photographs without human intervention. However, at present, this technology is still under development. Further testing of the effectiveness of different oral health professionals to screen for caries and other important oral conditions is needed.

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