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Feasibility of oral health evaluation by intraoral digital photography: a pilot study

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Abstract

Objectives: This study investigated the accuracy and duration of intraoral digital photograph examination (IDPE) for evaluating oral health status and explored the feasibility of remote oral health assessment.

Methods: Thirty-one healthy college students underwent evaluations of oral health status via clinical examination (CE) combined with panoramic X-ray assessment at baseline, followed by IDPE 1 month later using photos taken at baseline. Methods for evaluation of gingival health included the Modified Gingival Index (MGI) and Plaque Index (PI). Examinations of caries status included the decayed, missing, and filled teeth and surfaces indexes (DMFT and DMFS indexes, respectively). The duration of each evaluation was also recorded.

Results: There were significant differences in MGI and PI between CE and IDPE. There were no significant differences in DMFT and DMFS indexes between CE and IDPE, and there were positive correlations between CE and IDPE for each of the two indexes (DMFT index: $r=0.56$; DMFS index: $r=0.69$). The IDPE duration was shorter than the CE duration.

Conclusions: The feasibility of caries status assessment via IDPE is promising. Digital oral health evaluation merits further clinical consideration.

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Introduction

Telehealth refers to long-distance clinical care provided through electronic communication, information technology, or other means.[1] With the growing accessibility of the Internet and the widespread use of digital cameras and smartphones, increasing communication between doctors and patients has become readily available;[2] convenient clinical care has also become possible for vulnerable groups or people living in remote areas.[3] Previous studies have shown that remote diagnosis is effective for the diagnosis of oral and maxillofacial diseases.[4,5] Studies by Aziz and Ziccardi and by Carey et al. have demonstrated the application of smartphone technology in telehealth involving oral and maxillofacial surgery.[6,7]

Periodontal disease and caries are the most common diseases that affect human oral health. Notably, periodontal disease is the sixth most common chronic disease worldwide[8,9] and the primary reason for tooth loss among adults.[10] Combined assessments involving clinical examination (CE) and X-ray examination usually require expensive in-person visits for the detection of early-stage oral health problems.[11–13] Thus, there is a need to identify an alternative method (e.g., remote oral health evaluation) that might be convenient for patients and conserve medical resources. Thus far, two studies have shown high sensitivity and specificity for remote caries screening using smartphones.[11,14] However, the accuracy and efficiency of using digital photos for gingival health evaluation have not yet been studied. Therefore, the present study was performed to investigate the accuracy and duration of intraoral digital photograph examination (IDPE) for evaluating oral health status and to explore the feasibility of remote oral health assessment.

Methods

Participants and examiners

This study protocol was approved by the Medical Ethics Committee of the School of Medicine, Xiamen University (project number [for both ethics approval and funding]: 2018X0583). Student volunteers from the University were recruited to undergo oral health assessments. The following inclusion criteria were used: age 18 to 35 years, overall good health (i.e., no severe systemic disease, no mental illness, and no abnormal behavior), and normal visual and auditory functions that allowed cooperation with the dentists. All volunteers provided written informed consent and were permitted to withdraw from the study for any reason at any time during the course of the study. The experiment was conducted in Xiamen Stomatological Hospital and all examinations were performed by two trained dentists from the hospital. Each examiner was accompanied by an assistant who served as a timekeeper and recorder.

Study design

The volunteers were randomly divided into two groups; the volunteers in each group underwent oral examinations by a single trained dentist. Two methods were used to evaluate the oral health status: CE combined with a panoramic X-ray examination at baseline, followed by IDPE 1 month later using photos taken at baseline. To ensure consistency in terms of diagnostic criteria and results, a pre-test was performed before the formal experiments to compare the diagnosis of gingival health and caries between the two dentists. The kappa value between the two dentists was >0.75.

Each CE was performed by the examiner with reference to panoramic X-ray images; an assistant recorded the results and examination duration. After the CE, the examiner used a Canon EOS 90D digital camera (with ring flash and 100-mm macro lens) to take six intraoral digital photos of each volunteer (Figure 1) with aid from assistants in the form of auxiliary tools (e.g., reflectors and retractors). These photos were stored on a computer for subsequent IDPE. One month later, the examiner reviewed these photographs on a computer screen in the order used during the CE; an assistant recorded the results and examination duration.

Examination parameters

The Modified Gingival Index (MGI)[15] was evaluated in each volunteer as follows: 0 = no inflammation; 1 = mild inflammation (slight changes in gingival color and texture); 2 = mild inflammation of the entire gingiva; 3 = moderate gingival inflammation (moderate bright redness, bright redness, swelling, or proliferation); 4 = severe gingival inflammation (marked redness or hyperplasia, spontaneous bleeding, or ulceration). The MGI of each volunteer was the mean value of all tested teeth.

Figure 1. Digital intraoral photographs taken by professional dentists using cameras with auxiliary tools (reflectors, retractors and air gun). (a) Frontal photograph showing labial surfaces of anterior teeth; (b) right lateral photograph showing buccal surfaces of right posterior teeth; (c) left lateral photograph showing buccal surfaces of left posterior teeth; (d) frontal photograph showing the caries statuses of labial surfaces of lower anterior teeth; (e) maxillary dentition photograph showing palatal and occlusal surfaces of maxillary dentition; (f) mandibular dentition photograph showing lingual and occlusal surfaces of mandibular dentition.

The plaque index (PI)[16] was evaluated in each volunteer as follows: 0 = no plaque; 1 = thin plaque on teeth near the gingival margin, only identified by scratching the side of the probe tip across the teeth; 2 = medium plaque visible to the naked eye in the gingival margin or adjacent teeth; 3 = considerable plaque in the gingival sulcus and/or gingival margin and adjacent teeth. The PI of each volunteer was the mean value of all tested teeth.

The sums of decayed, missing, and filled teeth and surfaces of permanent dentition (DMFT and DMFS indexes) were calculated in accordance with the World Health Organization (WHO) diagnostic standard.[17] The DMFT index was regarded as the sum of the numbers of teeth with caries, teeth lost because of caries, and teeth with filling treatment because of caries. The DMFS index was the sum of the number of tooth surfaces with caries, tooth surfaces lost because of caries, and tooth surfaces with filling treatment because of caries. Both indexes were used to express the caries status of each volunteer.

Intraoral digital photographs comprised an intraoral frontal photograph of maxillary and mandibular occlusion, an intraoral frontal photograph of edge-to-edge dental occlusion, two lateral photographs (left and right), a maxillary dentition photograph, and a mandibular dentition photograph. These photographs were selected for analysis in accordance with the protocol used by Estai et al.[11]

Statistical analysis

SPSS Statistics, version 17.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Intergroup differences were assessed using the Wilcoxon signed-rank test. Spearman correlation coefficients were used to compare results between CE and IDPE. Kappa analysis was performed to assess sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy between CE and IDPE. P values <0.05 were considered to indicate statistical significance.

Results

This study included 31 student volunteers (age range, 18–22 years; mean age, 19.29 years; 48.4% women). The volunteers were divided into two groups (15 and 16 volunteers per group). There were significant differences in MGI and PI between CE and IDPE (both $P<0.01$) (Table 1). There were positive correlations between CE and IDPE in terms of MGI ($P<0.05$), PI ($P<0.01$), and examination duration ($P<0.01$) (Table 1 and Figure 2). The sensitivity, specificity, PPV, NPV, and accuracy of MGI and PI for comparing between CE and IDPE are shown in Table 2.

There were no significant differences in DMFT and DMFS indexes between CE and IDPE, although the examination duration significantly differed between CE and IDPE ($P<0.01$) (Table 3). There were positive correlations between CE and IDPE in

Table 1. Comparison of gingival health status evaluations by CE and IDPE.

Group	CE	IDPE
MGI	0.58±0.56	0.36±0.43**†
PI	0.73±0.62	0.25±0.30**††
Examination duration (s)	234.74±147.73	66.00±30.47**

**$P<0.01$, Wilcoxon signed rank test between groups.
†$P<0.05$, ††$P<0.01$, Spearman's rank correlation coefficient between groups.
CE, clinical examination; IDPE, intraoral digital photograph examination; MGI, Modified Gingival Index; PI, Plaque Index.

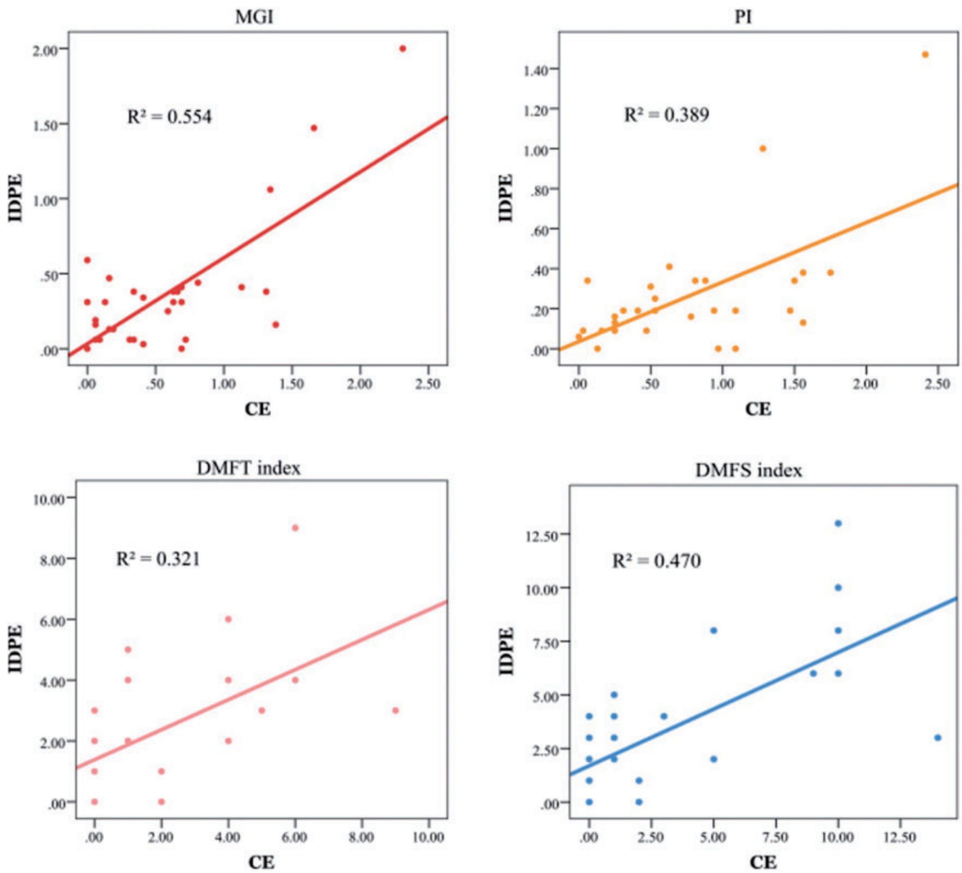

Figure 2. Correlation analyses of oral health status evaluations by CE and IDPE. (a) MGI; (b) PI; (c) DMFT index; (d) DMFS index.
CE, clinical examination; DMFS, decayed, missing, and filled surfaces; DMFT, decayed, missing, and filled teeth; IDPE, intraoral digital photograph examination; MGI, Modified Gingival Index; PI, Plaque Index.

terms of DMFT index ($P<0.01$) and DMFS index ($P<0.01$) (Table 3 and Figure 2). The sensitivity, specificity, PPV, NPV, and accuracy of the DMFT and DMFS indexes for comparing between CE and IDPE are shown in Table 4.

Discussion

Park et al.[18] showed that the use of a photographic method could offer an inexpensive and user-friendly screening alternative to dental examination. The present study investigated oral health status by using

Table 2. Accuracy and reliability measures of gingival health status evaluations using CE and IDPE.

CE versus IDPE	MGI	PI
Sensitivity (%)	67.2	51.9
Specificity (%)	85.2	61.0
PPV (%)	82.7	53.9
NPV (%)	90.7	74.5
Accuracy (%)	90.3	64.5
Kappa statistic (95% CI)	0.50‡	0.10

‡$P<0.001$, kappa analysis between groups
CE, clinical examination; IDPE, intraoral digital photograph examination; MGI, Modified Gingival Index; PI, Plaque Index, PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval.

Table 3. Comparison of the results of dental caries status evaluations by CE and IDPE.

Group	CE	IDPE
DMFT index	1.71±2.37	2.23±2.06††
DMFS index	2.84±4.10	3.19±3.17††
Examination duration (s)	109.29±70.80	35.06±24.36**

**$P<0.01$, Wilcoxon signed rank test between groups
††$P<0.01$, Spearman's rank correlation coefficient between groups
CE, clinical examination; DMFS, decayed, missing, and filled surfaces; DMFT, decayed, missing, and filled teeth; IDPE, intraoral digital photograph examination.

Table 4. Accuracy and reliability measures of dental caries status evaluations using CE and IDPE.

CE versus IDPE	DMFT	DMFS
Sensitivity (%)	57.7	48.1
Specificity (%)	95.2	98.6
PPV (%)	43.5	41.8
NPV (%)	97.2	98.9
Accuracy (%)	92.9	97.6
Kappa statistic (95% CI)	0.46‡	0.44‡

‡$P<0.001$, kappa analysis between groups
CE, clinical examination; DMFS, decayed, missing, and filled surfaces; DMFT, decayed, missing, and filled teeth; IDPE, intraoral digital photograph examination; PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval.

digital photographs; these photographs were taken at the time of CE, then reviewed 1 month later to evaluate the feasibility of remote oral health screening. The Ebbinghaus forgetting curve theory indicates that the recall of new information is considerably reduced after 31 days,[19] which suggests that the influence of CE assessments on IDPE assessments was minimized in the present study.

In this study, MGI and PI were used to evaluate gingival health, while the DMFT and DMFS indexes were used to evaluate caries status. We found that digital photos had lower sensitivity and specificity in gingival health examination; moreover, the accuracy of IDPE was higher for evaluating MGI than for evaluating PI. These results might have been because the gingival condition (including color and swelling) and plaque condition were affected by many factors such as the lighting and camera exposure duration, which might have led to clearer photographic assessment of gingival condition, compared with assessment of plaque, although both deviated from the CE findings. Furthermore, important indexes such as changes in gingival tissue, bleeding status, and plaque quantity on the adjacent tooth surface could only be accurately evaluated with a periodontal probe, which could not be used in a photo examination; therefore, IDPE exhibited lower accuracy.

Both the DMFT and DMFS results of IDPE were positively correlated with those of CE. The sensitivity of IDPE was lower for the DMFT and DMFS indexes, but its specificity and accuracy were high. This result was consistent with previous findings that remote diagnosis of caries could be performed using smartphones.[11,14] This might have been because the loss of polish or blackened appearance of dental caries was easily distinguished in photos;[14] moreover, the photos could clearly show changes in the colors of lingual, buccal, and occlusal surfaces. However, interproximal dental caries generally could not be detected through IDPE; therefore, the suitability of remote diagnosis of dental caries should be confirmed by further examinations.

Compared with CE, the duration of IDPE was shorter, which was presumably because the dentists did not require the considerable time communicating with patients that is necessary during CE. This result was consistent with the findings of previous studies in which the remote diagnosis of caries with smartphones exhibited better diagnostic performance, compared with traditional face-to-face clinical screening.[11,14]

In this study, the efficiency of caries status examinations with IDPE was relatively high, which implied that patients might receive a primary evaluation of their caries status if they can properly take intraoral photos with a digital camera at home and transmit these photos to dentists. This remote assessment with intraoral digital photos could facilitate sharing of medical resources, improve convenience for patients, and reduce the effort involved in some stages of clinical assessment. Notably, during periods such as the current coronavirus pandemic, dentists could perform remote preliminary examinations of dental health and avoid exposure to potential infection.

Importantly, although IDPE could shorten the examination duration and may offer a convenient option for patients, it demonstrated low accuracy in terms of gingival health assessment, indicating that remote gingival health assessment may not be feasible thus far. In addition, this study had some limitations. First, only relevant indicators of gingival health and caries were evaluated; the periodontal condition (e.g., attachment loss and pocket depth) and the final caries diagnosis (e.g., caries degree and lesion type) were not comprehensively evaluated. Second, only panoramic radiographs were taken in the present study, which are less accurate than bitewing radiographs in the detection of interproximal caries.[20] Thus, additional studies are needed to confirm our findings.

Conclusion

Within the limitations of the present study, the feasibility of caries status assessment using digital intraoral photos is promising. Digital oral health evaluation merits further clinical attention.

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Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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