Submitted: 05 July, 2023 Accepted: 03 August, 2023 Published: 03 March, 2024 DOI:10.22514/jocpd.2024.042

ORIGINAL RESEARCH

Journal of Clinical Pediatric Dentistry

Reliability of smartphone images to assess plaque score among preschool children: a pilot study

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Abstract

This study assessed the reliability of smartphone images of plaque-disclosed anterior teeth for evaluating plaque scores among preschool children. Additionally, the reliability of plaque scores recorded from smartphone images of anterior teeth in representing the overall clinical plaque score was also assessed. Fifteen preschool children were recruited for this pilot study. The Simplified Debris Index (DI-S), the debris component of the Simplified Oral Hygiene Index, was used to record the plaque score. A plaque-disclosing tablet was used to disclose the plaque before the plaque score recording. Following that, the image of the anterior teeth (canine to canine) of both the upper and lower arch was captured using the smartphone. Each child had three different DI-S recorded. For the first recording of the overall clinical DI-S, the plaque score was recorded clinically from index teeth 55 (buccal), 51 (labial), 65 (buccal), 71 (labial), 75 (lingual) and 85 (lingual). For the second recording, anterior clinical DI-S, the plaque score was recorded clinically from the labial surfaces of six anterior teeth only (53, 51, 63, 73, 71 and 83). Two weeks later, anterior photographic DI-S (third recording) was done using the smartphone images of the same index teeth used for the second recording. The intra-class correlation coefficient (ICC) was calculated to evaluate the reliability of smartphone images in assessing plaque scores. The results showed high reliability (ICC = 0.987) between anterior clinical and anterior photographic examinations, indicating that smartphone images are highly reliable for evaluating plaque scores. Similarly, high reliability (ICC = 0.981) was also found for comparison between overall clinical DI-S and anterior photographic DI-S, indicating plaque scores recorded from smartphone images of anterior teeth alone can represent the overall clinical plaque score. This study suggests that smartphone images can be a valuable tool for remote screening and monitoring of oral hygiene in preschool children, contributing to better oral health outcomes.

Keywords

Smartphone images; Plaque score; Preschool children

1. 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]. Dental caries and periodontal disease are the most common oral diseases in developing countries [2, 3]. Among children, poor oral health has significant effects on their general health and quality of life, including dental pain and infection, difficulties in eating, sleeping and speaking, missed school time, reduced self-esteem, potential hospitalizations and increased treatment cost and time for parents [4, 5]. Malocclusion can develop following the early loss of primary teeth, and caries in primary teeth often pose an increased risk of caries in permanent teeth [6, 7].

According to the Global Burden of Disease Study, approximately 520 million children globally suffer from primary tooth caries [8]. A systematic review and meta-analysis conducted in 2020 revealed that the worldwide prevalence of dental caries in primary dentition is 46.2%, with a gradual increase from 1995 to 2019 [9]. In Malaysia, the National Oral Health Plan Surveys conducted every ten years (1995, 2005 and 2015) showed only a minimal reduction in caries prevalence among preschool children, from 87.1% in 1995 to 76.2% in 2005 and 71.3% in 2015 [10]. For periodontal disease, 99.8% of 12-year-olds had gingival bleeding in 2017, compared to 19.6% in 2007 [11]. These results indicate a substantial decline in periodontal health among students, implying that almost all of them require at least dental hygiene instruction as treatment.

Microbial dental plaque is a significant contributing factor to dental caries and gingivitis; hence, toothbrushing can be considered the simplest form of plaque control. Effective toothbrushing habits help disrupt this biofilm, thereby aiding

in the prevention of oral diseases [12]. Therefore, regular monitoring of oral hygiene, particularly plaque control, is crucial to reducing caries prevalence.

Traditionally, dental professionals have relied on visual examinations during in-person visits to assess oral hygiene. However, the COVID-19 pandemic and subsequent restrictions on face-to-face interactions have made continuous oral hygiene assessment and monitoring challenging for dental professionals [13]. As a result, there is a growing need for alternative and cost-effective methods to remotely evaluate oral hygiene.

The widespread availability of smartphones equipped with high-quality cameras has sparked interest in utilizing smartphone images in dentistry. Numerous studies have explored the use of smartphone images to assess various dental conditions. For example, a pilot study in orthodontics found that smartphone images accurately assessed linear tooth movements [14]. Other studies involving children demonstrated the effectiveness and cost-efficiency of smartphone images for remote dental caries screening, especially during dental service closures due to crises [15–17]. In the field of dental traumatology and oral medicine, studies have concluded that using images captured with smartphones is an effective means of remotely diagnosing traumatic dental injuries and high-risk lesions in the oral cavity [18, 19]. Additionally, the use of smartphone photos to document the oral care status of nursing home residents has also been proven beneficial [20].

Dental plaque detection using photographs by an artificial intelligence (AI) model has been explored and shown promising results [21], while mobile app development to monitor oral hygiene at home has also been reported [22]. However, oral hygiene assessment using smartphone images has been reported scarcely in the literature. A recent study introduced a new tool called the Selfie Dental Plaque Index [23]. This tool utilizes smartphone images of anterior teeth to quantify plaque accumulation. Comparing the Selfie Index with two existing plaque indices, the study found a moderate correlation with the Visible Plaque Index. This suggests that the Selfie Index holds potential as a new tool for quantitative measurements and could be valuable for self-monitoring oral health.

To the best of our knowledge, no available studies have specifically evaluated the use of smartphone images to assess plaque scores among children. Therefore, the objective of this study is to assess the reliability of smartphone images of plaque-disclosed anterior teeth for evaluating plaque scores among preschool children. Additionally, the study aims to determine the reliability of plaque scores recorded from these mobile phone images in representing the overall clinical plaque score.

2. Materials and methods

15 preschool-aged children attending the Faculty of Dentistry, National University of Malaysia, were recruited for this pilot study based on a convenience sampling method. Inclusion criteria were 4–6-year-old cooperative children with all the anterior teeth present. The procedures conducted for the study are shown in Fig. 1.

2.1 Clinical examination

A plaque-disclosing tablet containing 1.36% Erythrosin (Product Dentaires SA, Vevey, Switzerland) was used to disclose the plaque. The children were instructed to chew the disclosing tablet for 30 seconds without swallowing and spit out the excess as per the manufacturer's instructions. A clinical examination to determine the level of dental plaque was carried out by the first author (MV) using the Simplified Debris Index (DI-S), the debris component of the Simplified Oral Hygiene Index [24]. The index was calculated based on the visibility of the disclosing tablet on each tooth surface. Each tooth was scored from zero to three based on the inciso-cervical/occluso-cervical extent of the visible debris on its surface, as noted in Table 1. The DI-S score of each child was recorded as the mean score for the six teeth, ranging from zero to three.

2.2 Smartphone photographs

Following clinical examination, the image of the anterior teeth (canine to canine) of both the upper and lower arch was captured by the first author (MV) using the smartphone (Samsung Galaxy A8+, 12 MP, f/1.7, 26 mm (wide), 1/2.55″, 1.4 μm, dual pixel PDAF, OIS) as shown in Fig. 2. Two separate images were captured, one for the upper anterior teeth and one for the lower anterior teeth. Images captured included the whole labial surfaces of anterior teeth from canine to canine, with clearly visible plaque in the disclosed area. To avoid the first author being influenced by prior knowledge of the participant's clinical DI-S score, all the photographs were stored by another author (EK) in a secured cloud storage system (Google Drive) by creating individual folders for each participant. The first author remained unaware of the sequence of photographs that were stored.

2.3 Assessment of dental plaque

Each child had three different DI-S recorded by the first author. For the first recording of the overall clinical DI-S, the plaque score was recorded clinically from index teeth 55 (buccal), 51 (labial), 65 (buccal), 71 (labial), 75 (lingual) and 85 (lingual). For the second recording, anterior clinical DI-S, the plaque score was recorded clinically from the labial surfaces of six anterior teeth only (53, 51, 63, 73, 71 and 83). The third recording of anterior photographic DI-S using the images captured were used to assess the anterior photographic DI-S. The photographs were randomized, and assessment was done two weeks later to further reduce the possibility of the examiner being influenced by the clinical examination.

2.4 Statistical analysis

The data obtained from clinical and photographic examinations were inserted and analyzed using Statistical Packages for Social Sciences (SPSS Inc., Chicago, IL, USA) version 26. To evaluate the reliability of smartphone images to assess plaque score, a comparison was made between anterior clinical DI-S and anterior photographic DI-S. To evaluate the reliability of smartphone images of anterior teeth in representing the overall clinical plaque score, a comparison was made between the overall clinical DI-S and the anterior photographic DI-

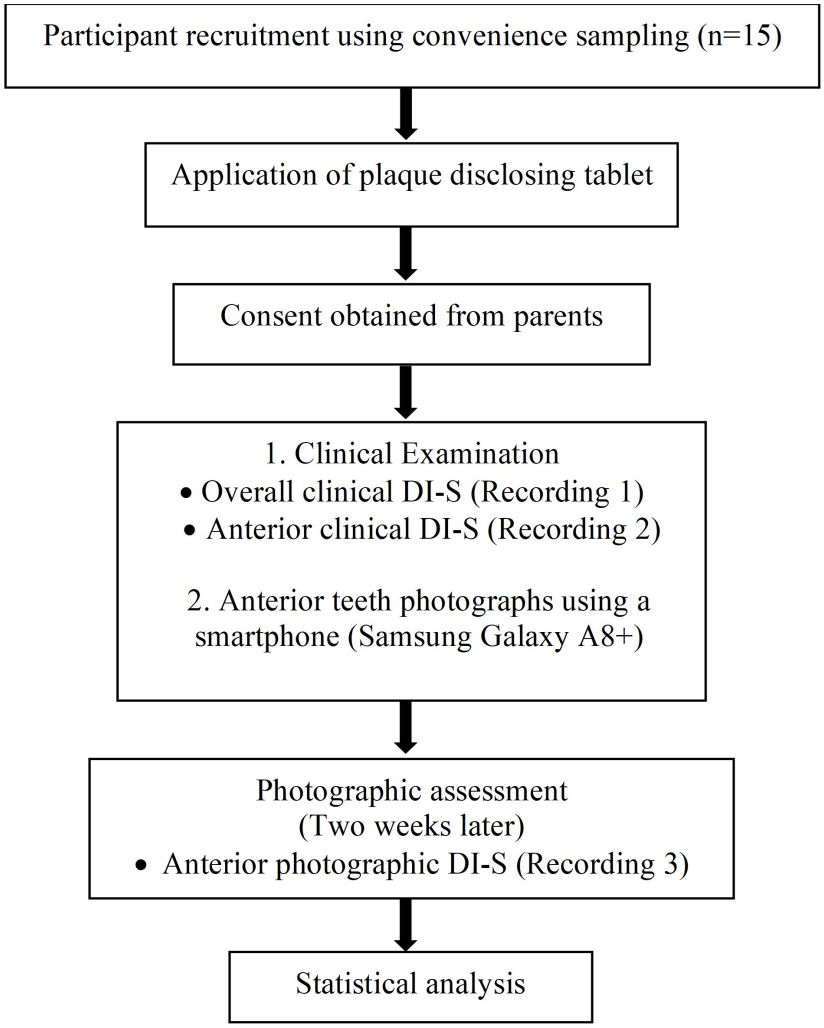

FIGURE 1. Flowchart of the study. DI-S: Simplified Debris Index.

TABLE 1. Debris component of simplified debris index (Greene and Vermillion, 1964).

Score	The extent of visible plaque
0	No debris or stain present
1	Soft debris covering not more than one-third of the tooth surface, or the presence of extrinsic stains without other debris regardless of surface area covered
2	Soft debris covering more than one-third, but not more than two-thirds, of the exposed tooth surface
3	Soft debris covering more than two-thirds of the exposed tooth surface

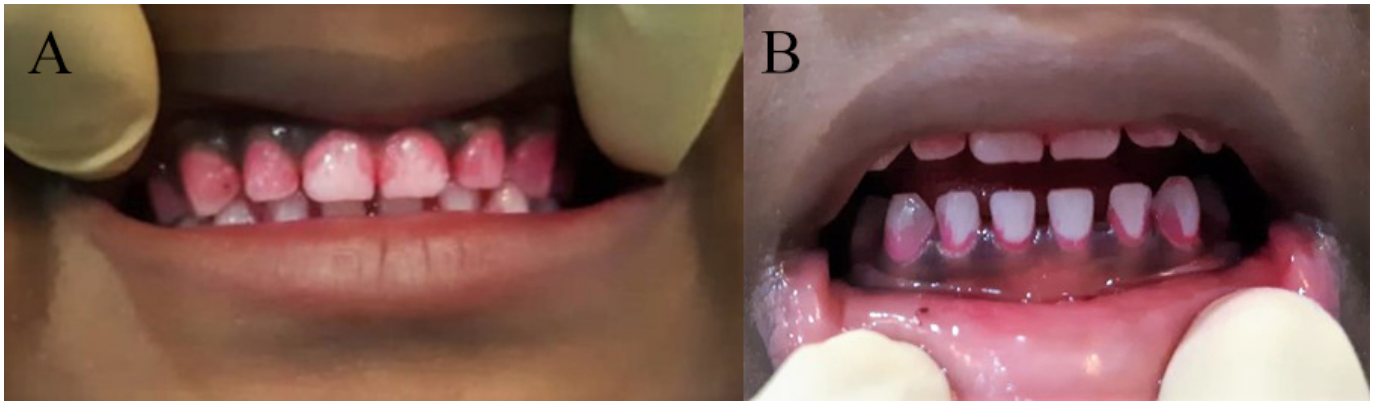

FIGURE 2. Smartphone images showing plaque disclosed anterior teeth. (A) Smartphone image of upper anterior teeth. (B) Smartphone image of lower anterior teeth.

TABLE 2. Clinical and anterior photographic DI-S.

Subject	Mean DI-S score		
	Overall clinical DI-S (Recording 1)	Anterior clinical DI-S (Recording 2)	Anterior photographic DI-S (Recording 3)
P1	1.8	2.0	2.2
P2	1.5	1.7	1.5
P3	2.0	2.0	2.2
P4	0.7	0.3	0.5
P5	0.5	0.3	0.3
P6	2.0	2.2	2.0
P7	2.5	2.3	2.5
P8	1.0	1.0	0.5
P9	1.2	1.2	1.3
P10	2.5	2.7	2.8
P11	2.8	2.8	2.8
P12	1.7	1.8	1.8
P13	1.2	1.0	1.0
P14	2.5	2.5	2.5
P15	2.3	2.3	2.3

DI-S: Simplified Debris Index.

S. The comparison was performed by calculating the intraclass correlation coefficient (ICC). Intervals of confidence of 95% (95% CI) were determined for the estimated intraclass correlation coefficients.

3. Results

In total, 15 preschool children (five girls and ten boys) were examined in this study. A total of 120 tooth surfaces were assessed for plaque score clinically, while a total of 90 tooth surfaces were assessed for plaque score using smartphone images. All the smartphone images were of acceptable quality and yielded adequate diagnostic quality.

The DI-S recordings for clinical and photographic assessment for all 15 participants are shown in Table 2. From the evaluation of the mean DI-S of the fifteen patients, an intraclass correlation coefficient between anterior clinical and anterior photographic examination of 0.987 was noted (Table 3). While for the comparison between DI-S of overall clinical and anterior photographic examination, the ICC ascertained was 0.981 (Table 4). In ideal circumstances, with no measuring errors, ICC equals 1 (ICC = 1). In practice, values greater than 0.9 reflect excellent reliability [25].

TABLE 3. ICC for anterior clinical DI-S and anterior photographic DI-S.

	Intraclass Correlation Coefficient (95% Confident Interval)
Average measure	0.987

TABLE 4. ICC for overall clinical DI-S and anterior photographic DI-S.

	Intraclass Correlation Coefficient (95% Confident Interval)
Average measure	0.981

4. Discussion

The results of this study show that smartphone images of plaque-disclosed anterior teeth are highly reliable for assessing plaque scores, and plaque scores recorded using anterior teeth alone can effectively represent the overall plaque score.

The traditional and effective approach to evaluating oral hygiene is through the use of oral hygiene indexes. These indexes typically quantitatively estimate plaque by measuring the covered tooth area or the thickness of the material in the measured area. Since plaque is colorless, staining is often required for visualization before scoring. To assess the reliability of smartphone images in evaluating oral hygiene, it was necessary to compare the index obtained from a photograph with the one obtained clinically. In this study, the Simplified Debris Index (DI-S), which assesses the level of oral hygiene based on the extent of visible plaque on each index tooth surface, was used. This index was suitable for the method employed, as measuring plaque scores using images can only be done using visual inspection.

For this study, we only captured images of the labial surface of anterior teeth. This is because capturing images of posterior teeth using smartphone cameras would not be possible without retractors and mirrors, especially in the lingual or palatal areas. This is even more challenging to perform in children. As remote oral hygiene assessment would require patients/parents

to capture the image, our goal is to create a method that can be easily performed by individuals of all age groups. However, it is arguable whether a plaque score from the anterior teeth alone can accurately assess oral hygiene since plaque accumulation tends to occur more in the lingual and posterior regions. Previous studies have demonstrated that plaque scores recorded from anterior teeth images have high accuracy compared to the total plaque score [23, 26]. However, both studies were conducted among adults, which is why we aimed to assess if similar results could be achieved among children. Therefore, this study is the first to assess the use of smartphone images in evaluating plaque scores among preschool children. Besides the simplicity of the method to capture the required images using a smartphone, the use of a plaque-disclosing tablet also allowed the easy evaluation of plaque scores as the plaque-disclosed area was easily identifiable from the images. Disclosing tablets can be easily used by patients with instructions and can be supplied to them for use during assessments.

Smartphone images are already in use for various purposes in dentistry and have proven beneficial. Similarly, using smartphone images to assess plaque scores can be advantageous for remote oral hygiene assessments. Regular and more frequent monitoring of oral hygiene should allow for improvements in oral hygiene. In Malaysia, the preschool and school oral healthcare program provides dental examination and oral health education for children [27], however, with limited manpower, time constraints, and associated costs, regular school visits may not be possible. Since smartphone images have shown potential for improving oral hygiene, teachers and parents can be trained to capture and share these images with healthcare practitioners to assess and provide feedback on the children's oral hygiene. Furthermore, during the COVID-19 pandemic, restrictions on face-to-face interactions have hindered the continuous conduct of clinical research. This has prompted the development of methods for ongoing research. Multiple clinical trials are being conducted to assess methods that can significantly improve toothbrushing habits among children. The use of smartphone images would allow for the remote assessment of changes in oral hygiene following any home-based intervention. Economic factors [28] and time constraints are often reported as barriers to dental visits [29], so remote dental care may provide opportunities for dental healthcare professionals to regularly monitor their patients.

Overall, the use of smartphone images for plaque score assessment provides a promising avenue for remote oral hygiene evaluation and monitoring. It can benefit school-based oral health programs, continuous research and regular patient care.

5. Conclusions

In conclusion, our study suggests that smartphone images of plaque-disclosed anterior teeth are highly reliable for evaluating plaque scores, and plaque scores recorded using anterior index teeth alone can represent overall oral hygiene status. This suggests that smartphone images of anterior teeth can be a useful tool for remote screening and monitoring of oral hygiene among preschool children.

ABBREVIATIONS

DI-S, Simplified Debris Index; ICC, Intra-class correlation coefficient.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

MV—conducted clinical procedures, performed data collection and analysis and wrote the first draft of the manuscript; FY, HR—assisted in the clinical steps; and AA, EK—revised and edited the manuscript. All authors participated in the study conception and design. All authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee, National University of Malaysia (Ref No: UKM PPI/111/8/JEP-2020-730). Parents of all participating children provided written informed consent before the clinical procedures.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research was funded by a research grant from University Kebangsaan Malaysia (DD-2021-003).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Farinawati Yazid, Haslina Rani, Asma Ashari, Magesh Vijyakumar, Elavarasi Kuppusamy. Reliability of smartphone images to assess plaque score among preschool children: a pilot study. Journal of Clinical Pediatric Dentistry. 2024; 48(2): 143-148. doi: 10.22514/jocpd.2024.042.