ORIGINAL ARTICLE

Effectiveness of a Mobile Application 'Gigiku Sihat' in Improving Oral Hygiene of Pre-school Children in Kelantan: A Randomized Control Trial

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ABSTRACT

Introduction: The use of mobile health (mHealth) applications has become an effective approach for enhancing public health. While many oral health-related mobile apps are now available, there is limited information on the efficacy of apps developed locally. This study aimed to assess the impact of the 'Gigiku Sihat' mobile application on improving oral hygiene among pre-school children. **Methods:** This was a non-inferiority, parallel, two-group cluster randomised controlled trial involving 10 KEMAS pre-schools in Tumpat, Kelantan. The pre-schools were randomly assigned to the study group (SG) or control group (CG) using block randomisation. Parents or guardians of children aged 4 to 6 years in the SG received conventional oral health education alongside the 'Gigiku Sihat' app, while the CG only received conventional oral health education. Random assignment was computer-generated, and allocation concealment was maintained until the study's conclusion. Participants, including pre-schools, children, and parents, were unaware of their group allocation until after the baseline data were collected. The primary outcome measure was the Simplified Oral Hygiene Index (OHI-S) at baseline, 6 weeks (Evaluation 1), and 12 weeks (Evaluation 2) after the intervention. Descriptive analysis, repeated measures ANOVA (RM-ANOVA), and independent t-tests were applied, with statistical significance set at $p<0.05$. **Results:** A total of 120 children aged 4 to 6 years and their parents or guardians participated, with 60 parent-child pair in each group. Of these, 115 parent-child pairs completed the study. At baseline, the mean OHI-S scores for SG and CG were 1.3 (95% CI 1.12, 1.48) and 1.2 (95% CI 1.04, 1.36), respectively. At 6 weeks, the SG showed a reduction in OHI-S scores to 1.1 (95% CI 0.94, 1.28), whereas the CG's scores increased to 1.3 (95% CI 1.13, 1.15). At 12 weeks, significant reductions were observed in both groups (SG = 0.6, 95% CI 0.43, 0.71; CG = 0.9, 95% CI 0.76, 1.03; $p<0.05$), with a significantly lower OHI-S score in the SG compared to the CG. **Conclusion:** The combination of the 'Gigiku Sihat' app and conventional oral health education was more effective in improving the oral hygiene of pre-school children at the 12-week evaluation compared to conventional methods alone.
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INTRODUCTION

Dental caries in pre-school children continues to be a major public health concern in both developed and developing nations, affecting a significant proportion of children (1, 2). The American Academy of Paediatric Dentistry (AAPD) defines early childhood caries as the presence of one or more decayed (d) teeth, whether cavitated or non-cavitated, missing (m) due to caries, or filled (f) tooth surfaces in any primary tooth of a child aged 71 months or younger (3). The causes of dental caries are complex, with the main contributing factor being the interaction between bacteria and sugars on the tooth surface (4). Bacteria present in dental plaque metabolise sugars and starches, producing acids that lower the pH level in the mouth. This process leads to continuous mineral loss, weakening, and breakdown of the tooth surface. Consequently, effective plaque control is crucial for the prevention of dental caries (5).

Although dental caries is preventable, recent global reports indicate that oral health has shown little improvement over the past 25 years (6). In Malaysia, national surveys reveal a dental caries prevalence of 71.3% among 5-year-olds and 74.5% among 6-year-olds (7). Additionally, national epidemiological studies conducted in 2005 and 2015 reported that Kelantan had the highest prevalence of dental caries among pre-school children in the country (8). Globally, dental

caries remains a leading cause of childhood morbidity, with studies showing a high prevalence across various countries, particularly in low and middle-income nations, where access to oral health care may be limited (9).

Maintaining good oral hygiene is fundamental to strategies aimed at improving children's oral health (10). Longitudinal research in Scotland has shown that brushing teeth at least once a day helps mitigate the effects of sugar on dental caries in pre-school children who consume large amounts of sugary foods (10). It is advised that children brush their teeth at least twice daily, beginning at an early age (11). Oral hygiene practices are often assessed using self-reports or, more accurately, through debris or plaque indices (12). The accumulation of dental plaque serves as a reliable measure of oral hygiene quality, as it is a key risk factor for early childhood caries (13).

According to a nationwide study, fewer than half (40.1%) of assessed five-year-olds had good oral hygiene, with superior oral hygiene observed among urban children, females, and those attending private pre-schools (7). Primary prevention must begin before the onset of dental caries (14). Numerous oral healthcare programmes for pre-school children have been initiated to provide oral health information and encourage the development of desirable oral health habits. These programmes have been delivered through various means, including games and puppet shows, lectures, verbal tooth brushing instruction, supervised tooth brushing, and the provision of fluoridated toothpaste and toothbrushes (15). When oral health education involves both children and significant others, studies have shown better outcomes (16). Consistent oral hygiene habits in childhood are initiated at home, with the crucial involvement of parents or guardians (17). Brushing supervision is essential due to children's limited dexterity, which makes independent brushing ineffective (18). The Ministry of Health Malaysia recommends brushing supervision for children under the age of six (19). It has also been shown that timely distribution of educational materials to parents or guardians is effective in preventing dental caries (20).

A systematic review by Bromantoro et al. (15) found that traditional oral health education methods involving parents—such as lectures, leaflets, counselling, supervised tooth brushing, and the provision of fluoridated toothpaste—were effective in preventing the development of new caries and gingivitis, as well as in changing oral health behaviours among children. However, traditional approaches face challenges related to participant engagement, logistical issues, workforce efficiency, and cost, particularly for larger populations (21). Given the rapid pace of everyday life and the advantages of affordability, wide reach, flexibility, anonymity, and scalability (21), mobile applications may offer a viable alternative for improving access to oral health education materials for parents or guardians (22, 23). While some studies have explored the effectiveness of mobile applications in improving oral hygiene, particularly among orthodontic patients (24, 25) and pre-school children (26), there is limited information available on interventions that involve parents in improving the oral hygiene of young children (21).

This study is necessary, as little is known about the effectiveness of locally developed mobile applications. The aim of this paper is to determine the effectiveness of a mobile application prototype, "'Gigiku Sihat'," combined with conventional education methods, in improving oral hygiene among children attending KEMAS pre-schools in Tumpat.

METHODS

Study Setting and Design

This study was a non-inferiority, parallel, two-arm, cluster randomised trial conducted from September 2020. It was carried out in KEMAS pre-schools within the Tumpat district of Kelantan. The Kelantan State Community Development Department provided a list of KEMAS pre-schools in Tumpat, based on the number of children enrolled in each age group. Pre-schools with at least four children in each of the 4, 5, and 6-year-old age groups were eligible for inclusion. Out of 34 eligible pre-schools, 10 were randomly selected to participate in the research.

Ethical Statement

Ethical approval for the study was granted by the Human Research Ethics Committee of our institution (USM/JEPeM/19060364). The study was also registered in the National Medical Research Register of the Ministry of Health Malaysia (NMRR-20-2825-57812), with approval obtained from the Ministry of Health Malaysia's Oral Health Programme (KKM-600-56/7/2 Jld.7 (37)). Additionally, approval for field research activities during the COVID-19 pandemic (FR-MCO/1/2020-KK) was secured, in accordance with the Standard Operating Procedure.

Randomisation

Randomisation was performed at the cluster level, with 10 KEMAS pre-schools (clusters) randomly assigned to either the study or control group. To ensure balance between the groups, block randomisation was employed. The allocation of clusters was determined using computer-generated random numbers in SPSS, following the method described by Arifin (2012) (27).

Sample Size Determination

Three specific objectives for this study were to compare the dental plaque index scores among 4 to 6-year-old children in Tumpat, Kelantan within the study group,

within the control group, and between both groups after the health education intervention program. The sample size was calculated for each study objective. The sample size for each group was determined using the PS Power and Sample Size Calculation software version 3.1.2 (2014), with an 80% power and a significance level of 0.05. Based on the Simplified Oral Hygiene Index, the sample size for each group was calculated to be 54 (28), with a standard deviation (SD) of the mean difference = 0.31, and δ = 0.24. Since this study is part of a larger investigation, the total sample size was increased to 100 to accommodate the additional objective of evaluating parental knowledge, attitudes, and practices related to nutrition and oral health (SD of mean difference for attitude = 2.482, δ = 1.4) (29). The sample size was further adjusted using standard cluster randomised controlled trial criteria, with the Design Effect (DE) calculated as 1 + (n – 1) ICC, where n represents the average cluster size, and ICC refers to the intra-cluster correlation coefficient. For this study, the average cluster size was 10 (10 research sites), and the DE was 1.09 if the ICC was 0.01 (30). As a result, the adjusted sample size was 109 participants (from a total 10 schools). To account for a 10% dropout rate, the final sample size was set at 120 participants, with 60 in each group. In total, 120 parent-child pairs participated in the research.

Mobile Application Development

The control group received dental education through conventional methods, using face-to-face sessions, pamphlets, video CDs, and practical demonstrations to deliver oral health education, supported by SMS and email reminders. Meanwhile, the study group received combination between conventional methods and the ''Gigiku Sihat'' mobile application, an app specially developed during phase 1 of this study. The ''Gigiku Sihat'' app digitalized the same content from conventional method into an interactive, offline-capable mobile platform with multimedia features and weekly push notifications. Using the Health Belief Model (HBM) as a basis, the app was developed to help user to change their behavior by addressing users' perceptions of risk, benefits, and barriers to practicing good oral health. The development process took place from December 2018 until August 2019, beginning with discussions between the researchers, designers, and development team. The app was developed using the Android platform in Bahasa Melayu, following the Software Development Life Cycle (SDLC) principle.

The development process involved several phases:

Requirement Gathering: The initial phase involved conducting a situational analysis, which included a comprehensive literature review to identify the key oral health issues, the target population, contributing behavioural factors, and relevant stakeholders for the campaign. Following this, the concept for the oral health education intervention was developed. Behaviour modification theories were incorporated, with elements of the Rational Model and the Health Belief Model adapted for the app's design.

Design: The design phase prioritised the creation of an intuitive and user-friendly interface (UI) for the app. A user flow diagram was first developed using Microsoft Word to outline the structure and navigation of the mobile application. The research team initially created a low-fidelity wireframe, which was further refined into high-fidelity wireframes using Adobe XD. Additionally, the app's logo was designed in Adobe Illustrator, and a copyright application was submitted for the mobile application.

Implementation: The app was developed using Android Studio, with Java programming as the primary language. It integrates Google-supported application programming interfaces (APIs), and the app's database was built using Android-SQLite.

Usability Testing: After the initial prototype development, mobile usability tests were conducted. These tests ensured that the app met usability standards and was functional for the target audience. The usability tests focused on user satisfaction and navigational ease. Feedback from participants showed high satisfaction, with the app being easy to navigate and visually appealing. Minor suggestions such as adjustments to button placement and font size were refined to further enhance usability.

Weekly Reminders and Features

The app featured weekly reminders to encourage consistent use, with push notifications alerting parents to important oral health milestones and tips. Other features included a video section, frequently asked questions (FAQs), and an interactive FAQ section tailored to the parents' needs. (Added more details about app features as per reviewer comment). The weekly reminder function helped engage parents and ensured they were reminded to complete tasks related to their child's oral hygiene. Images of the app interface can be included here to provide a visual representation of the features available to the users.

Outcome Measures

The primary outcome measure for this study was the Simplified Oral Hygiene Index (OHI-S), which was utilised to evaluate the oral hygiene status of the children (31). A single examiner conducted the assessments, with documentation performed by an assistant. To carry out the examination, a disposable mouth mirror and a torchlight were used while the children were seated in a pre-school chair. The children's teeth were not brushed prior to the examination, although they may have been rinsed.

The criteria for assessing debris, as described by Babaei et al. (32), were applied, with a scoring range from 0 (no

debris) to 3 (debris covering more than two-thirds of the tooth surface). The labial surfaces of teeth 54, 61, 82, and 75 were assessed, and for mixed dentition, the labial surface of tooth 26 and the lingual surface of tooth 46 were also examined. The OHI-S scores were classified as follows: 1.9–3.0 for poor oral hygiene, 0.7–1.8 for fair oral hygiene, and 0.0–0.6 for good oral hygiene (31).

Data Collection and Analysis

A meeting was arranged with the Tumpat KEMAS district officer to plan and discuss the data collection process. The district officer informed the relevant KEMAS pre-schools about the study and briefed the pre-school teachers (referred to as Pemaju Masyarakat) on the data collection procedures. The district officer provided screening forms, which were distributed by the pre-school teachers to the parents or guardians of the children. The parents completed the screening forms and returned them to the district officer, who then handed them over to the researcher. All parents of the selected children were assessed for eligibility based on these forms. The eligibility criteria, including the requirement for parents to own an Android device (smartphone or tablet) and have a comprehension of Bahasa Malaysia, were not disclosed to the pre-schools or parents at the time of the screening.

After the eligibility of parents and children was confirmed, randomisation into the study and control groups took place. A consent package containing study details, a consent form, and a token of appreciation was sent to the selected parents through the Tumpat KEMAS district officer. The signed consent forms were then returned by the parents via the district officer. Once consent was obtained, a baseline face-to-face briefing and oral health education session were held, followed by oral hygiene assessments for both groups, with the study group receiving additional guidance on app navigation. Following the completion of baseline data collection, the intervention was implemented at each pre-school. The first evaluation (Evaluation 1) took place 6 weeks after the intervention, and the second evaluation (Evaluation 2) occurred 12 weeks after the intervention. Tokens of appreciation were given to participants during the follow-up assessments to maintain engagement.

The cluster randomised trial design meant that blinding of participants and study personnel was not possible. Nonetheless, measures were implemented to minimise bias, such as identifying participants before cluster allocation and using random group assignment with allocation concealment.

Statistical Analysis

Data were processed and analysed using IBM SPSS Statistics, version 26. For continuous variables, descriptive statistics including means and standard deviations (SD) were calculated, while frequencies and percentages were computed for categorical variables. At baseline, chi-square tests were employed to compare the demographic characteristics between the groups. To assess changes in the mean OHI-S scores over time within each group, repeated measures ANOVA was applied. Comparisons of the OHI-S scores between groups at baseline, Evaluation 1, and Evaluation 2 were conducted using an independent t-test. The significance threshold was set at $p<0.05$ for all statistical tests.

RESULTS

Sociodemographic Profile

All ten KEMAS pre-schools allocated to the control and study groups were successfully followed up, with 115 (95.8%) of the 120 participants+ initially recruited completing the study. Five pairs of participants were lost to follow-up during the oral hygiene examination at Evaluation 2 due to non-attendance. These dropouts (4.2%) were exclusive from the study group. A follow-up loss rate of less than 5% is generally considered negligible, while a loss exceeding 20% could introduce significant risks to the validity of the study (33). Figure 1 illustrates the flow of clusters and participants through the various stages of the trial, in accordance with the CONSORT guidelines. The number of girls exceeded the number of boys in both the control and study groups. Table I indicates no significant differences between the groups with respect to parents' age, highest level of education, ethnicity, family size, occupation, monthly household income, food expenditure, or main water supply.

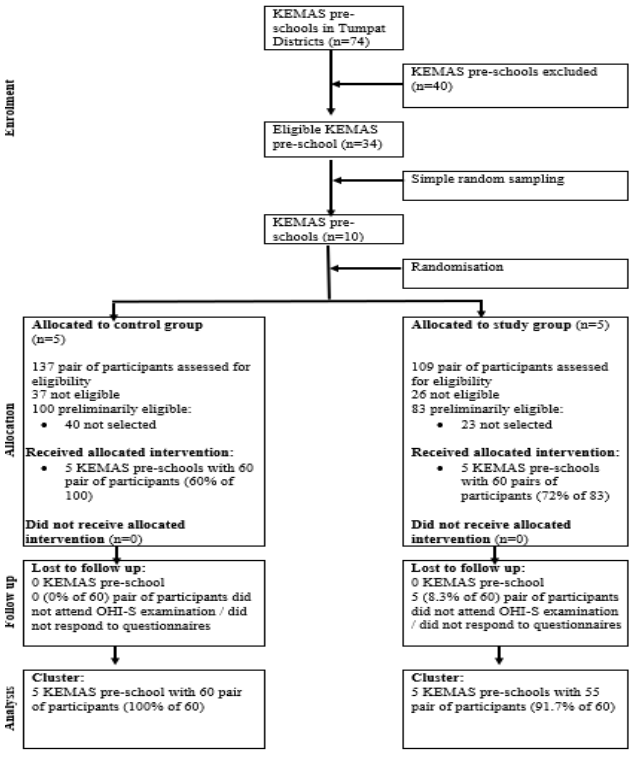

Figure 1: Cluster and participant flow.

Table I: Sociodemographic characteristics of the parents or guardians (n=115).

Variables	Frequency (%)		χ^2 (df)	*P* value
	Control group (n = 60)	Study group (n = 55)		
Age				
< 30	13 (21.7)	10 (18.2)	0.81 (2)	0.667[a]
30-39	31 (51.7)	33 (60.0)		
≥ 40	16 (26.7)	12 (21.8)		
Highest education level				
Secondary education & below	45 (75.0)	40 (72.7)	0.08 (1)	0.782[a]
Post-secondary & Higher	15 (25.0)	15 (27.3)		
Ethnic				
Malay	56 (93.3)	55 (100.0)	-	0.120[b]
Chinese / Siamese	4 (6.7)	0 (0.0)		
Occupation				
Housewife / Not working / Retired	43 (71.7)	37 (67.3)	3.80 (2)	0.150[a]
Self-employed / Employer	8 (13.3)	14 (25.5)		
Employee	9 (15.0)	4 (7.3)		
Family members (including parents)				
< 5 members	22 (36.7)	17 (30.9)	0.78 (2)	0.679[a]
5 – 7 members	32 (53.3)	30 (54.5)		
≥ 8 members	6 (10.0)	8 (14.5)		
Monthly household income (RM)				
< 1,000	23 (38.3)	10 (18.2)	6.79 (3)	0.079[a]
1,000 – 1,999	27 (45.0)	31 (56.4)		
2,000 – 2,999	3 (5.0)	7 (12.7)		
≥ 3,000	7 (11.7)	7 (12.7)		
Monthly food expenditure (RM)				
< 500	13 (21.7)	10 (18.2)	8.38 (5)	0.136[a]
500 – 599	15 (25.0)	8 (14.5)		
600 – 699	6 (10.0)	5 (9.1)		
700 - 799	19 (31.7)	15 (27.3)		
800 – 899	1 (1.7)	7 (12.7)		
≥ 900	6 (10.0)	10 18.2)		
Main water supply				
Well / Tube-well	16 (26.7)	23 (41.8)	2.94 (1)	0.086[a]
Pipe water (Air Kelantan)	44 (73.3)	32 (58.2)		

[a]Pearson chi-square test; [b]Fisher's exact test

Changes in OHI-S Score in the Study Group

A significant reduction in the OHI-S score was observed in the study group ($p<0.05$), with a large effect size (0.50). Table II shows that a post hoc test, applying Bonferroni correction, identified significant differences between baseline and Evaluation 1, baseline and Evaluation 2, as well as between Evaluation 1 and Evaluation 2. At baseline, 60.0% of pre-school children in the study group had fair oral hygiene, which increased to 63.6% at Evaluation 1. However, by Evaluation 2, the majority (60.0%) of children in the study group demonstrated good oral hygiene. At baseline, only 8 pre-school children had good oral hygiene, but this number increased to 15 at Evaluation 1 and further rose to 33 by Evaluation 2.

Table II. Pairwise comparison of oral hygiene of pre-school children within control and study group

Variables	Time		Mean difference (95% CI)	*p* value
Within Study group (n=55)				
OHI-S scores				
	Baseline	Evaluation 1	0.2 (0.04, 0.34)	**0.011**
	Baseline	Evaluation 2	0.7 (0.53, 0.93)	**<0.05**
	Evaluation 1	Evaluation 2	0.5 (0.36, 0.73)	**<0.05**
Within control group (n=60)				
OHI-S scores				
	Baseline	Evaluation 1	-0.1 (-0.41, 0.13)	0.614
	Baseline	Evaluation 2	0.3 (0.13, 0.48)	**<0.05**
	Evaluation 1	Evaluation 2	0.4 (0.20, 0.69)	**<0.05**

Post hoc test using Bonferroni correction.

Changes in OHI-S Score in the Control Group

In the control group, the OHI-S score also showed significant improvement ($p<0.05$), although with a smaller effect size (0.16). Table II indicates that a post hoc test with Bonferroni correction revealed significant differences between baseline and Evaluation 2, as well as between Evaluation 1 and Evaluation 2.

At baseline, 73.3% of pre-school children in the control group had fair oral hygiene, which slightly decreased to 75.0% at Evaluation 1. By Evaluation 2, the percentage of children with fair oral hygiene reduced to 65.0%. Only 8 and 9 pre-school children had good oral hygiene at baseline and Evaluation 1, respectively. However, this number increased to 19 by Evaluation 2. Table III outlines the changes in dental plaque index scores among 4 to 6-year-old children in Tumpat, Kelantan, in both the study and control groups, before and after the oral health education intervention.

Table III: Oral hygiene scores of pre-school children in study and control group before and after health education intervention program.

Oral hygiene (OH)	Mean (95% CI)			F statistic (df)	ES	*p value*
	Baseline	Evaluation 1	Evaluation 2			
Within study group (n=55)						
OHI-S scores	1.3 (1.12, 1.48)	1.1 (0.94, 1.28)	0.6 (0.43, 0.71)	53.12 (2)	0.496	<0.05
Within control group (n-60)						
OHI-S scores	1.2 (1.04, 1.36)	1.3 (1.13, 1.15)	0.9 (0.76, 1.03)	11.51 (1.688)	0.163	<0.05

Repeated measures ANOVA.
ES = Effect size

Changes in OHI-S Score between the Study and Control Group

As illustrated in Table IV, the study group showed a significantly lower mean OHI-S score at Evaluation 2 compared to the control group. Even at Evaluation 1, the study group had a slightly lower mean OHI-S score than the control group, although the difference was not statistically significant.

Table IV. Oral hygiene of pre-school children between study and control group.

Variables	Mean (SD)		Mean difference (95% CI)	t statistic (df)	p value
	Control group (n=60)	Study group (n=55)			
OHI-S score					
Baseline	1.2 (0.61)	1.3 (0.67)	-0.1 (-0.34, 0.14)	-0.85 (113)	0.400
Evaluation 1	1.3 (0.82)	1.1 (0.64)	0.2 (-0.04, 0.50)	1.67 (113)	0.098
Evaluation 2	0.9 (0.51)	0.6 (0.52)	0.3 (0.13, 0.51)	3.38 (113)	0.001

Independent t-test.

DISCUSSION

This study aimed to assess the Simplified Oral Hygiene Index (OHI-S) scores of pre-school children before and after the intervention. At baseline, the mean OHI-S score for the study group was 1.3 (95% CI 1.12, 1.48), and for the control group, it was 1.2 (95% CI 1.04, 1.36). In comparison to the findings of Sahiti et al. (29), the mean OHI-S score in this study was higher. This difference may be attributed to the fact that Sahiti et al.'s study sample was from a non-government institution, whereas this study's participants were from government-run pre-schools. Supporting this, Bennadi et al. (36) reported that children in government-run preschools generally had higher plaque scores than those attending private preschools. Children from higher socioeconomic backgrounds, whose parents are more likely to be well-educated and concerned about oral hygiene, tend to enrol in private schools (34).

In contrast, the mean OHI-S score in this study was lower than those reported in previous studies on pre-school children in rural Nigeria, India, and Egypt (36, 37, 38), where higher levels of dental plaque were attributed to limited access to oral health education, lower socioeconomic status, and insufficient resources for oral hygiene. Studies in Nigeria, India, and Egypt have highlighted the challenges of inadequate preventive care and education, leading to poorer oral health outcomes. However, our study, conducted in a government-run pre-school system, showed lower OHI-S scores, likely due to the targeted oral health education interventions and the innovative use of the 'Gigiku Sihat' mobile application, which empowered both parents and children to engage in improving oral hygiene. This combination of traditional education and technology likely improved adherence to oral hygiene practices, resulting in better outcomes compared to regions with fewer resources.

Moreover, Razeghi et al. (39) explored the impact of health promotion interventions on preventing early childhood caries in children aged 2 to 5 years receiving dental treatment under general anaesthesia. While their study found significant improvements in oral health outcomes, the population and intervention type differ from those in the present study, which focused on a mobile health application aimed at improving oral hygiene in pre-school children. Several studies have reported on oral health indicators similar to those examined in this study, albeit with different focuses. For example, Aliohani et al. (40) reviewed the management of early childhood caries, while Perazzo et al. (41) explored oral health-related quality of life in pre-school children. While these studies indicated higher levels of dental issues, including early childhood caries and cariogenic risk, their findings are not directly comparable to our results due to differences in study designs and populations. Nonetheless, these studies underscore the importance of addressing oral health challenges in young children and provide valuable context for the ongoing discussion on improving oral hygiene practices, especially in under-served populations. Additionally, the mean OHI-S score for the control group in this study aligned with that found by Shitsuka et al. (42) in children with tooth erosion.

In this research, the OHI-S score for the control group, which received conventional oral health education, showed a significant reduction. Nomair et al. (43) observed no significant change in OHI-S scores following a 6-month period of conventional oral health education. This discrepancy could be due to the difference in the duration of follow-up, as Nomair et al.'s study involved a 6-month follow-up, whereas this study had a 3-month period for the final assessment. A systematic review and meta-analysis by Stein et al. (44) found that conventional oral health education was effective in reducing plaque accumulation over a shorter duration.

For the study group, which received both conventional oral health education and the 'Gigiku Sihat' mobile application, the OHI-S score showed a significant reduction with a large effect size across the evaluation period. However, there are few studies that have used the OHI-S to measure oral hygiene in mobile application interventions, which limits direct comparisons. Three randomised controlled trials demonstrated significant reductions in dental plaque between baseline and 4-week (24), 6-week (25), and 6-month (45) follow-ups. However, after 9 months, the decrease in dental plaque was no longer statistically significant (45). This suggests that while mobile app interventions show promising early results, their long-term effectiveness requires further investigation. The relatively short follow-up period (12 weeks) in this study is a limitation, and longer-term studies would be valuable in providing more robust evidence for the efficacy of mobile apps like 'Gigiku Sihat'.

Despite this limitation, the findings from this study and recent randomised controlled trials conducted over the past five years suggest that mobile application interventions are effective in reducing dental plaque, with positive results that have been sustained for up to six months. We anticipate that additional data will emerge as the focus shifts towards preventing oral diseases, especially with the increased use of technology during the COVID-19 pandemic. This highlights the importance of a future review of the evidence on mobile phone interventions for oral health, particularly those aimed at reducing dental plaque, to further substantiate the current findings.

At baseline, the majority of pre-school children in the study (60.0%) and control (73.3%) groups exhibited fair oral hygiene. However, by the final evaluation, the majority of children in the study group demonstrated good oral hygiene (60.0%), while in the control group, most children continued to have fair oral hygiene (65.0%). This result is significant because it aligns with previous studies that have shown that poor oral hygiene is linked to a higher prevalence of early childhood caries. For example, in Nigeria, poor oral hygiene was associated with a greater incidence of early childhood caries (36). The absence of good oral hygiene is often indicative of insufficient oral care practices (46). The results of this study are particularly important as they demonstrate the potential of mobile health interventions, such as the 'Gigiku Sihat' app, to improve oral hygiene habits, especially among children from low socioeconomic backgrounds, who are typically at a higher risk of oral health issues.

Furthermore, this research confirmed the effectiveness of the 'Gigiku Sihat' mobile application in improving oral hygiene among pre-school children. The study group exhibited a significantly lower mean OHI-S score compared to the control group. Consistent with the current study, other randomised controlled trials have reported a significant reduction in dental plaque (24, 25, 43). Many mobile interventions for improving oral hygiene tend to focus on children rather than parents and often include gamification elements to engage young users (47, 48). However, no comparisons could be made with studies incorporating gamification, as it was not part of the present study. Future research could explore whether combining active reminder systems with gamification could result in even greater improvements in oral hygiene outcomes.

Notably, as with this study, previous research has highlighted the use of active reminder systems to promote oral hygiene, particularly among orthodontic patients. Mohammed et al. (49) found that active reminder systems were effective in reducing dental plaque both in the short and long term, based on a systematic review and meta-analysis. Thus, it is plausible that the push notifications in 'Gigiku Sihat', functioning as an active reminder system, contributed to the positive results observed in this study. Future updates to the 'Gigiku Sihat' app could incorporate real-time monitoring and analysis features, using sensors to enhance oral hygiene. Technological advancements such as sensor-equipped toothbrushes have shown promise in reducing dental plaque over time, with studies demonstrating a significant improvement with electric toothbrushes between 6 and 12 weeks (50). Integrating such technologies into the 'Gigiku Sihat' app could increase user engagement and improve oral hygiene outcomes.

Overall, the findings suggest that the OHI-S scores in both the study and control groups significantly decreased. While the majority of pre-school children in the study group had good oral hygiene during the final assessment, the control group still showed fair oral hygiene. The comparison between the two groups provides strong evidence that the 'Gigiku Sihat' mobile application, when combined with conventional oral health education, significantly improves the oral hygiene of pre-school children, with sustained effects at the 12-week evaluation.

This study was conducted in KEMAS pre-schools, which are government-run institutions where oral hygiene levels are generally lower compared to private pre-schools. Furthermore, most participants came from low socioeconomic backgrounds, which are known to be more vulnerable to dental caries. These findings are especially significant for underprivileged populations, demonstrating that mobile health interventions like 'Gigiku Sihat' can bridge the gap in oral health education and outcomes for those with limited access to dental care. However, the study also has a limitation. The study was conducted in 12-week duration, therefore the long-term effectiveness of the 'Gigiku Sihat' intervention on oral hygiene remains uncertain. Future studies should

consider longer follow-up periods to assess the lasting impact of such interventions.

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